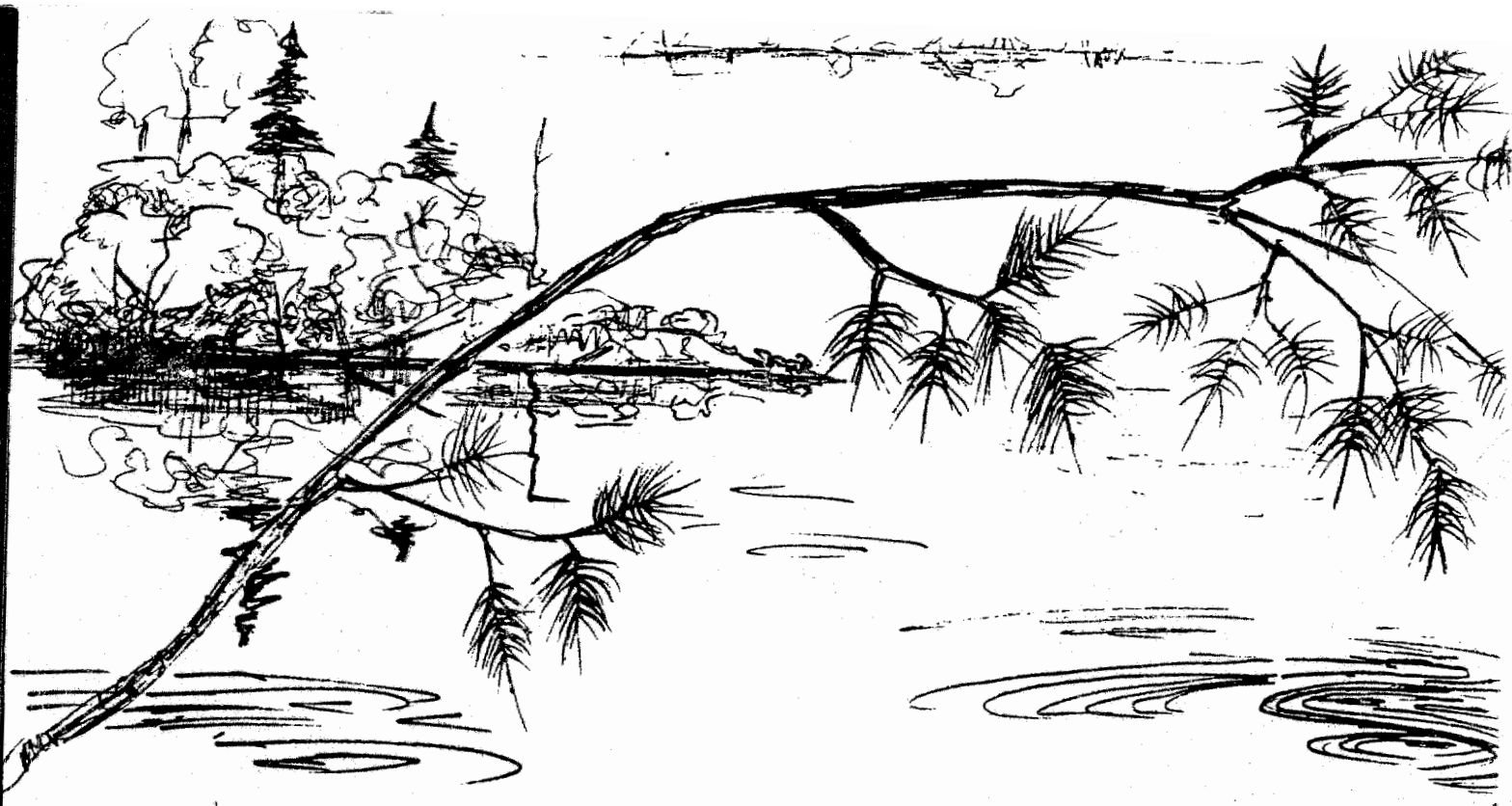

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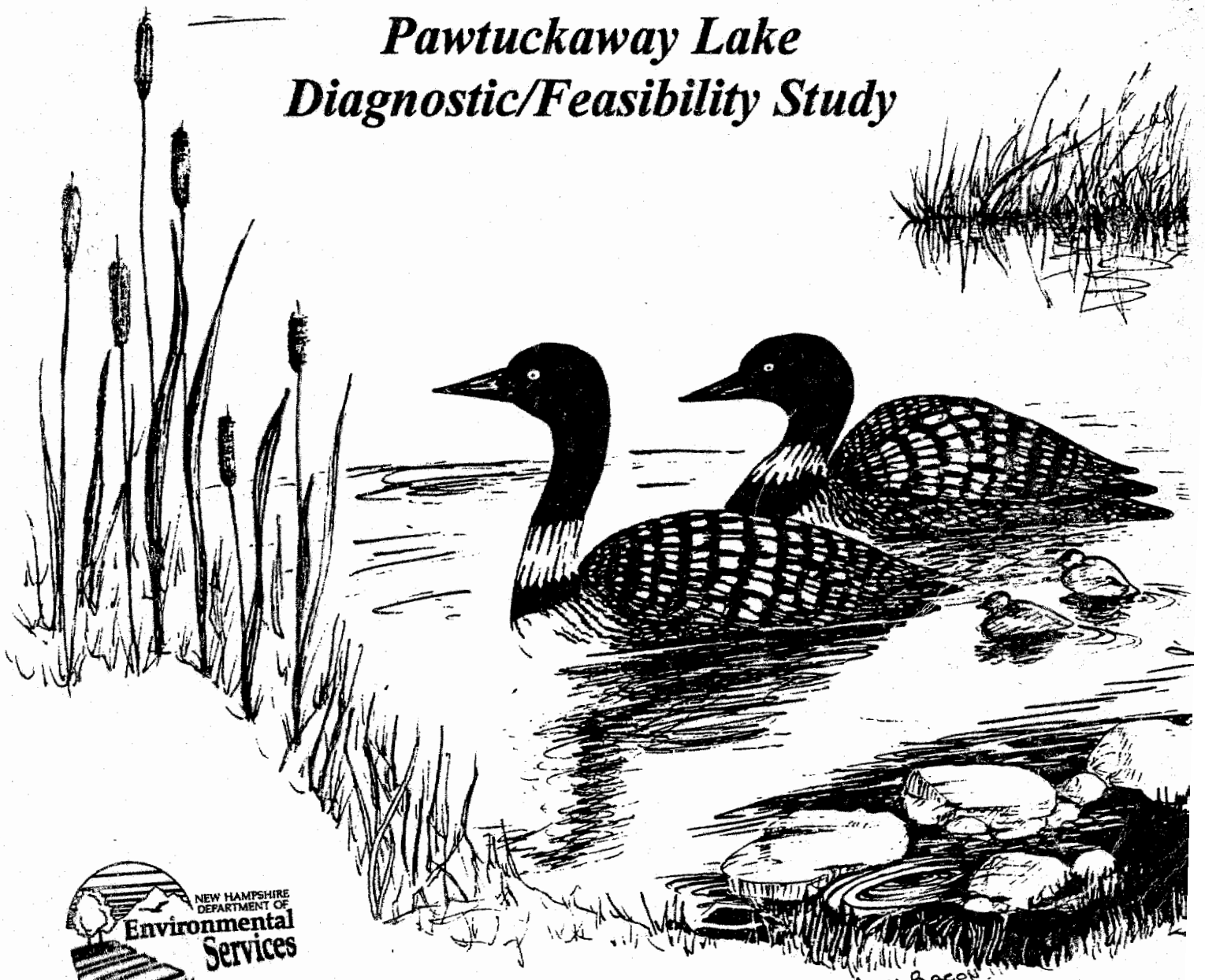

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Environmental Services

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NHDES-WSPCD-95-2

Pawtuckaway Lake Diagnostic/Feasibility Study

Final Report
June 1995

New Hampshire Department of Environmental Services
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June 15, 1995

Mr. Warren K. Howard, Program Manager
US Environmental Protection Agency
Region I
John F. Kennedy Federal Building
Boston, Massachusetts 02203

Dear Mr. Howard:

Transmitted herewith is the Phase I Diagnostic/Feasibility Study for Pawtuckaway Lake, Nottingham, New Hampshire. This report was prepared, in part, under the Clean Water Act, through a Section 314 Environmental Protection Agency grant. This report culminates over 14 months of lake, groundwater and tributary monitoring, watershed evaluation and sediment characterization. Hydrologic and phosphorus budgets were constructed for each sub-watershed area of the lake. Once again, this study reflects the importance and the value of the Clean Lakes Program in its efforts to protect and restore our nation's lakes.

This project produced a wealth of knowledge of the physical, biological and chemical aspects of Pawtuckaway Lake. Based on biological and chemical assessments and lake modeling techniques employed, the trophic status of Pawtuckaway Lake is borderline oligotrophic/ mesotrophic. The hydrologic and nutrient budget sections were important in defining sources of water and phosphorus to the lake.

The feasibility section provides an overview and recommendations for watershed management, lake protection and possible lake restoration scenarios. This section focuses on decreasing non-point sources of phosphorus to Pawtuckaway Lake. Recommendations include utilizing Best Management Practices to decrease the phosphorus load to the lake from stormwater runoff, groundwater seepage and inflowing tributaries. The feasibility study also focuses attention on problems such as hypolimentic anoxia and internal phosphorus loading to the lake. Possible restoration techniques are discussed that could reduce in-lake sources of phosphorus. Lastly, the feasibility section provides a project implementation schedule that includes obtaining Section 319 money to initiate the Phase II Implementation Program.

Respectfully submitted,

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ABSTRACT

The Pawtuckaway Lake Diagnostic/Feasibility Study presents more than fourteen months of limnological data and discusses spatial and temporal water quality trends. The diagnostic data was used to determine feasible and cost-effective means for watershed management and possible lake restoration.

The Pawtuckaway Lake Clean Lakes Study accomplished each of the objectives defined in the work plan. The following tasks were completed during the study and research phases of this project:

1. Identified the historical and existing water quality of Pawtuckaway Lake;
2. Identified the water quality of Pawtuckaway Lake's inflowing tributaries and two outlets;
3. Developed hydrological and phosphorus budget for Pawtuckaway Lake;
4. Documented several sources of phosphorus to the lake;
5. Identified the importance of the lake's sediments to supply internal phosphorus loading to the lake;
6. Compared several trophic models that classified Pawtuckaway Lake;
7. Reviewed many non-point sources of phosphorus to the lake;
8. Developed a feasible, cost-effective plan of actions for watershed management.
9. Recommended non-point source Best Management Practices that will help protect the lake for future generations;
10. Reviewed current lake restoration techniques and researched the feasibility of each method's potential for restoration success; and
11. Developed a time table in which each recommendation may be achieved.

The results and recommendations of the Pawtuckaway Lake Diagnostic/Feasibility Study provide a basis for lake protection through watershed management. The use of lake restoration techniques is not necessary at this time but is reviewed for possible use if the lake quality deteriorates.

Although this project was successful in accomplishing its goals, only upon the implementation of a watershed management program, which incudes phosphorus reduction, will this project be considered a complete success. Project coordinators must now obtain the necessary funds to implement the project's recommendations. The town, the lake association and the many volunteers continue to be involved in any efforts to protect Pawtuckaway Lake.

ACKNOWLEDGEMENTS

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The authors are appreciative of the work by George Hastings and Katie Bramley in preparing various land use maps with GIS technology.

Members of the Citizen Advisory Committee (CAC), are thanked for their participation in the study, and for their concern and dedication in the protection of Pawtuckaway Lake. Special thanks also to Marge Carlson and Linda Pandolfi from the town offices in Nottingham who were also very helpful and courteous in providing information and allowing us access to the town property at Drowns Dam to sample the outlet.

Additional thanks go to Jeff Boucher and the personnel at Pawtuckaway State Park for providing field assistance and providing unlimited access to tributaries within park boundaries. The lake front property owners on Pawtuckaway Lake are also acknowledged for allowing us to install seepage meters in front of their homes, and/or providing access to their property to sample tributaries or resident wells.

Special thanks to the Pawtuckaway Lake Improvement Association for their complete support of this study and their ongoing commitment to protecting Pawtuckaway Lake. Particular thanks go to Celeste Schmitt, June Phillips, Dale Clunie, Dave Finn, Jon White, Jon Crowell,

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GLOSSARY OF TERMS

ACID PRECIPITATION: Precipitation having a lower than normal pH (higher acidity) resulting from the oxidation of sulfur and nitrogen oxides, present in the atmosphere, into sulfuric and nitric acid.

A.N.C.: Acid Neutralization Capacity, also known as alkalinity. Refers to the quantity and kinds of compounds present which shift the pH to the alkaline or basic side of neutrality.

ANOXIC: Lack of oxygen (also, anaerobic)

BATHYMETRIC CHART: A map depicting the depth contours of a lake bottom.

BENTHIC: Referring to bottom zones or bottom-dwelling forms.

BIOMASS: The weight of all living material in a given area at a given time.

DIMICTIC: Lakes that circulate freely twice a year in the spring and in the fall. They are directly stratified in the summer and inversely stratified in the winter.

EPILIMNION: The upper, well circulated, warm layer of a thermally stratified lake.

EUTROPHIC: Nutrient rich waters, generally characterized by high levels of biological production.

FLUSHING RATE: The number of times a volume of water equal to the lake volume passes through the lake in a given year.

HYDROLOGIC BUDGET: A compilation of the total water inputs and outputs to and from a lake.

HYPOLIMNION: The deep, cold, relatively undisturbed bottom waters of a thermally stratified lake.

LIMITING NUTRIENT: An essential substance for plant growth which is present in the environment in the least amount relative to the needs of the plant.

LOADING: The amount of a substance that is added to a lake during a specified time period.

MESOTROPHIC: Waters containing an intermediate level of nutrients and biological production.

METALIMNION: The middle layer of water in a thermally stratified lake, between the epilimnion and hypolimnion, where the decrease in temperature with depth is at its greatest.

NUTRIENTS: Inorganic substances required by plants to manufacture food by photosynthesis. Phosphorus is the nutrient that usually limits the amount of plant growth in New Hampshire lakes.

OLIGOTROPHIC: Nutrient poor waters, generally characterized by low biological production.

OSGOOD INDEX: A useful estimate of the probability that deep mixing events will occur in a lake during summer stratification, bringing phosphorus from the metalimnion and upper hypolimnion to surface waters.

PHOSPHORUS MODEL: A mathematical equation that predicts the in-lake phosphorus concentration, based on the phosphorus inputs and various morphologic and hydrologic characteristics. It is used to predict the effect of changes in phosphorus inputs on the lake's water quality.

PHOTIC ZONE: The depth of lake water that receives sufficient sunlight to permit photosynthesis.

PHYTOPLANKTON: Microscopic plant life that float within or on top of lake water.

PLANIMETER: An instrument used to measure the area of any plane surface by tracing the boundary of the area.

POLYMICTIC: Lakes with frequent or continuous circulation.

PRIMARY PRODUCTIVITY: The rate of producing organic matter from inorganic substances by photosynthesis.

PRODUCTION: The weight of new organic matter formed over a period of time plus any losses during that time.

RUNOFF: Precipitation that enters surface waters from overland flow and from groundwater.

THERMAL STRATIFICATION: Horizontal layers of water, arranged from top to bottom in order of increasing density due to differences in temperature.

THERMOCLINE: The point of maximum temperature decrease with depth in a thermally stratified lake. Diagramatically, it is where the temperature profile curve switches from concave upward to concave downward.

TROPHIC STATE: The nutritive state of a lake or, more specifically, the level of the plant nutrient phosphorus. It is often described, however, in terms of the biological production in the lake.

WATERSHED: The total area draining into a lake, including the area of the lake itself. Also called drainage basin.

WET POND: Also known as retention pond. Basin designed to collect stormwater runoff and remove sediment, B.O.D., organic nutrients and trace metals. May be planted with aquatic macrophytes to remove soluable nutrients.

EXECUTIVE SUMMARY

A. INTRODUCTION

The Pawtuckaway Lake study began in October of 1991 as a result of a Clean Lakes Program grant.

The lake's watershed is located in the Town of Nottingham in the southeastern portion of the State of New Hampshire.

The goals of the diagnostic study were to determine the phosphorus inputs to Pawtuckaway Lake and to identify the problem areas of significant phosphorus loading.

The goals of the feasibility section were to evaluate watershed Best Management Practices that would reduce the supply of phosphorus to the lake and to identify possible lake restoration techniques that may be used if the lake quality deteriorated. The feasibility section also discusses the most feasible, cost effective methods for implementation.

B. STUDY APPROACH

Prior to recommendations being made for protective and restorative measures, a fuller understanding of such processes as lake flushing rates, groundwater influences, watershed utilization, sediment characteristics and nutrient sources had to be achieved. To this end, biologists began an intensive study to document the physical, chemical and biological processes of Pawtuckaway Lake. Refer to the glossary for aid in understanding the technical terms.

1. Physical, Chemical, and Biological Monitoring

Measurements of water chemistry, plankton populations, chlorophyll-a and transparency were recorded. An inventory of macrophytic growth was documented. Detailed maps and an evaluation of the lake's littoral areas were completed. Sediment cores were extracted and analyzed for specific metals and phosphorus. Land use, topographical ground cover, and soils maps for the watershed were prepared.

2. Hydrologic Budget

The hydrologic budget for the gaging period (December 1991 through November 1992) quantified all significant sources of flow into Pawtuckaway Lake by gaging tributaries and outlets, estimating direct surface runoff, measuring precipitation and evaporation, and estimating groundwater seepage rates. Tributaries were the greatest inflowing component to Pawtuckaway Lake, contributing 74.5 percent of the hydrologic budget. The subwatershed areas of Back Creek B, Mountain Cove Brook and Round Pond Brook comprise 65 percent of the watershed area and contributed 77 percent of the tributary inflow. Direct precipitation represented 11.1 percent of the total water budget of Pawtuckaway Lake. Direct runoff to the lake from the surrounding shoreland accounted for 9.4 percent of the budget. Groundwater seepage contributed the remaining 5.0 percent of the inflowing water to the lake.

Direct outflow or discharge from the two controlled outlet structures represented 91.1 percent of the outflow budget for the sample year. Evaporation accounted for 4.8 percent of the outflow. Water recharge into the groundwater was estimated to be only 4.1 percent of the total discharge from the lake.

3. Nutrient Budget

Phosphorus loading, the primary factor limiting plankton growth, was determined through water quality sampling and analysis of many of the sources quantified in the hydrologic budget. Groundwater, atmospheric and direct runoff inputs were estimated. Phosphorus loading to Pawtuckaway Lake from nearshore septic systems was determined by direct measurement of

groundwater phosphorus. The quantities of water column and sediment phosphorus concentrations were calculated, and a nutrient budget was prepared for the study year.

One of the most important goals of this study was to quantify the various avenues of phosphorus inputs to Pawtuckaway Lake. Chapter VIII discusses the annual phosphorus budgets for the lake.

The greatest single contributors of phosphorus to Pawtuckaway Lake were the tributaries which contributed 47 percent of the external phosphorus load. Other monitored sources included septic leachate/groundwater seepage (21%), direct runoff (22%) and atmospheric (14%). Much of the tributary phosphorus contributions were from three stations, Back Creek B which contributed 33 percent of the tributary phosphorus load, and Mountain Cove Brook which added 24 percent of the phosphorus load and Round Pond Brook which accounted for 16 percent of the total tributary phosphorus load to the lake..

4. Lake Modeling

The determination of the trophic state of a lake involves a comparison of the actual total phosphorus loading to the lake with the maximum loadings that the lake can tolerate before excessive algal and macrophyte growth occurs and transparency diminishes. A trophic state model is a mathematical relationship which, by incorporating such factors as phosphorus loading and hydraulic retention time, allows a lake to be classified as oligotrophic, mesotrophic, or eutrophic. Four different classification methods were utilized and their results are compared for this study. The trophic models classify Pawtuckaway Lake in the oligotrophic/mesotrophic state.

C. STUDY RESULTS

Pawtuckaway Lake is a typical dimictic lake exhibiting thermal stratification into three layers during the summer months and mixing completely during the spring and fall overturns each year. During the summer months, the hypolimnion exhibited anoxic or very low dissolved oxygen conditions which frequently existed from 7.0 meters to the bottom depth of 15.3 meters. Total

phosphorus concentrations were elevated in the hypolimnion and increased as the summer progressed, indicating internal phosphorus loading.

In-lake phosphorus concentrations at Pawtuckaway Lake ranged from a mean study year minimum of 12.0 µg/L in the epilmnion of the South Station to a maximum of 21.8 µg/L in the hypolimnion of the North Station. Maximum in-lake total phosphorus concentrations were measured in the hypolimnion of the North Station.

Study year mean phosphorus concentrations for the Pawtuckaway Lake tributaries ranged from 10.2 µg/L in Fernalds Brook B to 74.7 µg/L in Fernalds Brook A. Maximum seasonal phosphorus concentrations were recorded in Fernalds Brook A during the winter, spring, summer and fall with concentrations of 73.2 µg/L, 89.8 µg/L 86.3 µg/L and 53.0 µg/L respectively.

In-lake phytoplankton densities at Pawtuckaway lake ranged from 376 to 1495 units/mL in the North Station and from 441 to 2043 units/mL in the South Station. The populations were typically dominated by Cryptophyceae, Bacillariophyceae (Diatoms), and Cyanobacteria (Blue-Greens). The rotifers Kellicottia and Keratella co-dominated the zooplankton community during the study period at Pawtuckaway Lake.

Mean monthly in-lake chlorophyll-a concentrations ranged from 2.44 mg/m^3 in October to 10.46 mg/m^3 in April at the North Station. Chlorophyll-a concentrations at the South Station ranged from 2.42 mg/m^3 in October to 6.34 mg/m^3 in April. The mean chlorophyll-a concentrations for the study period at the North and South Stations of Pawtuckaway Lake were 4.46 mg/m^3 and 3.96 mg/m^3 respectively.

Mean monthly transparencies ranged from 2.0 m in April to 5.2 m in September at the North Station and from 3.0 m in April to 5.6 m in September at the South Station. The mean transparencies for the Study period at the North and South Stations were 3.6 m and 4.4 m respectively.

During the study period, Burnhams Marsh Outlet (North) had the lowest median specific conductance value (27.60 µmhos/cm) and Fernalds Brook A had the highest median specific conductance value of 155.45 µmhos/cm. Study year and seasonal median values for conductance in White Grove Brook and Fernalds Brook A were in excess of 100.00 µmhos/cm.

CHAPTER I INTRODUCTION

Lakes are important resources in New Hampshire. They provide enjoyment in fishing, swimming, and boating, and they enhance the beauty of the natural environment. Their value for tourism amounts to many millions of dollars each year. The recreation and tourism industry in New Hampshire plays a vital role in many communities and in the state economy. However, the increased intensity of use of these water bodies has resulted in the aesthetic degradation of many lakes throughout the state. The same people that were attracted to these lakes and ponds because they were clean, clear and tranquil are now complaining of diminished quality as well as overdevelopment.

To accommodate this growth in lake use, lake and watershed management has become increasingly important in the last twenty years. Limnologists are now trying to educate the public on the importance of lake preservation before the resource is destroyed and it becomes necessary to spend thousands of dollars on lake restoration. Recently, a limnology course for school-aged children was developed and is currently being used nationally in hopes that more lakes will be protected by future generations.

The Pawtuckaway Lake Study began in October of 1991 and was partially funded by a Section 314, Clean Lakes Program grant. The project afforded limnologists the opportunity to study and to better understand the ecology of Pawtuckaway Lake and to examine the watershed and land-use properties that have an effect upon the lake.

The Pawtuckaway Lake watershed encompasses an area of approximately 11,851 acres and contains a major lake, numerous small ponds, extensive wetland areas and an extensive system of tributaries. The majority of drainage in the watershed is channeled to Pawtuckaway Lake by Back Creek and Mountain Brook, both of which consist of extensive drainage configurations branching throughout the watershed. Approximately 74% (8,767 acres) of the watershed lies within the southeastern portion of the Town of Nottingham, New Hampshire. The remaining 26% (3,083 acres) of the watershed area occupies an eastern section of Deerfield, New Hampshire.

A priority list developed by the Department of Environmental Services ranked Pawtuckaway

Lake as moderate for lake restoration and preservation. The facts that Pawtuckaway Lake had shown a decrease in water quality, had a state park operated by the Department of Resources and Economic Development (DRED), and had a strong lake association weighed heavily upon the choice of Pawtuckaway Lake for Phase I consideration.

The historic water quality trends reflected decreasing hypolimnetic oxygen, increasing chlorophyll-a and a planktonic succession from diatoms to blue-greens. The lake has an unencumbered public access, a popular state park that offers seasonal camping, and supports heavy usage. Because of the recreational assets Pawtuckaway Lake offers to people throughout New England and its close proximity to the states largest population center, lake protection becomes an important issue. Both shoreland owners and transient users have a large stake in protecting Pawtuckaway Lake.

The goal of this study was to determine the sources of these stresses. To achieve this end, hydrologic and nutrient budgets for the lake were determined and problem areas in the watershed were delineated.

The goal of the feasibility section was to describe some of the methods available to both improve the lake and protect it from further degradation. The implementation of these recommendations will be dependent upon the initiative of state and local government, the citizens of Nottingham, and the shoreland and critical watershed property owners of Pawtuckaway Lake. Cooperation will be a key element in establishing the implementation goals. A strong working relationship among the Pawtuckaway Lake Association, the Department of Environmental Services and Pawtuckaway State Park was developed during the diagnostic/feasibility study year. This relationship will act as a catalyst in achieving the water quality goals for Pawtuckaway Lake.

CHAPTER II HISTORICAL DATA

A. HISTORICAL DEVELOPMENT AND EARLY USES

The earliest inhabitants in the Pawtuckaway Lake region were various small Indian groups living in the Nottingham area. These Indians all belonged to the Penacook Confederacy, a part of the larger Algonquin Division which covered Northeastern America.

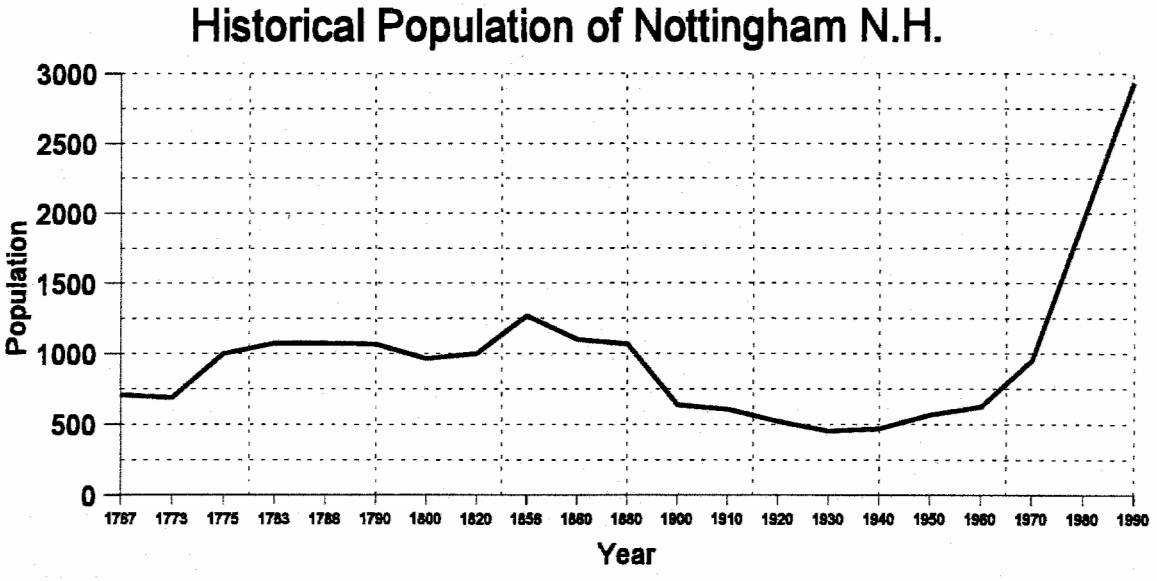
Pawtuckaway is the Indian name for "Place of the big buck". There is evidence that a few scattered Indian families lived near the Pawtuckaway shoreline based on relics found when the state park visitors center was built, including a mortar and pestle used in the grinding of corn (Anon, undated).

The actual founders or proprietors of Nottingham were granted a charter for a town in 1722. Settlers arrived sometime in 1727. After the town built a church and blockhouse, the proprietors gave appropriations for roads and sawmills. One of the earliest saw/grist mills was located near Dolloffs' Dam at the southern end of Pawtuckaway Lake. The land was rugged, inhospitable and made very poor farmland. The Indians called this area the "land of sticks and stones" (Anon, undated).

Around 1790, a few families settled in the more remote areas. Today we see remnants of their struggle in the graveyards and cellar holes scattered throughout the mountainous Pawtuckaway watershed. A small schoolhouse was built soon after settlement began. Other services were found in Raymond or Nottingham, both long journeys over rough roads.

The mountain community started to become a less desirable place to live after the Civil War due to the harshness of the land to farm, with the good land in the Midwest opening up and transportation to get there. However, in the late 1800's Nottingham population figures surged as a result of the appearance of sawmills and gristmills and an abundance of water power in the area. Actual population data is presented in Figure II-1.

Figure II-1



Around 1825, the Newmarket Manufacturing Company, a textile mill, purchased a large tract of land and the rights to water power in the Pawtuckaway area. The company completed construction on two dams around 1836, forming two artificial ponds; Dolloff Pond and Pawtuckaway Pond, flooding a total of 802 acres (Crompton, undated). The dam at the south end was called Dolloff Dam and the one to the north was called Drowns. A dike had to be built at what is now the entrance to Seamans Point to control flooding or runoff onto private property. The two ponds contained 35 islands (some of which are floating islands). The largest of the group being Big Island, with its 500 acres (Crompton, undated).

During the year 1915, a forest fire lookout tower was erected by the state on South Pawtuckaway Mountain in Nottingham to protect the rich forest lands. This mountain was then part of the George W. Goodrich farm and together with the other two peaks was considered ideal for a state reservation. The state first acquired other lands in 1923 and additional mountain land was purchased in 1924 to form the 918 acre Pawtuckaway Reservation (NHDRED, undated).

In 1934, the Newmarket Manufacturing company was moved to Lowell, Mass. in a process of consolidation. The lake and surrounding property was used by the New Hampshire Electric Company until the power produced no longer met the needs of the region. Eventually the Water Resources Board accepted the property for the benefit of future users.

In late 1939, a few of the campers on the lake got together to talk over the subject of water drawdown in the pond. Some of the suggestions were to drawdown Pawtuckaway early one year and Mendums Pond the next (Mendums Pond in North Nottingham and Barrington was another pond the Electric Company used for water supply), holding back the water as much as possible during July and August (Crompton, undated). In 1940, another meeting was called. Some of the people present felt something could be done to improve the conditions on the pond and the result was the establishment of the Pawtuckaway Lake Association.

There was little water in the pond, to speak of during the months of July and August and into late Fall. You could not navigate to the lower pond because there was merely a stream of water to the dam. Water level was the topic at almost every association meeting.

In 1950, a solution to the water level issue was found when the Water Resources Board and Electric Company signed an agreement of restrictions of operations at the pond (Crompton, undated). In 1955, just five years after the agreement, the electric company offered their holdings to the state (minus some acreage which was sold privately). The high water level of the pond question came up again when Francis C. Moore of the Water Resource Board called on camp owners to mark ballots as to the height of water they desired. After the ballots were counted, a level of 25 feet at Dolloff Dam was agreed upon which indicates full capacity to this day (Crompton, undated).

The increased water level resulted in the formation of one large waterbody. In 1958 and 1959, a request was made to the state that the names of Dolloff Pond and Pawtuckaway Pond be changed to Pawtuckaway Lake. The request was granted and in the same year the association was incorporated and entitled the "Pawtuckaway Lake Improvement Association".

In 1961, land between the western lakefront property and Pawtuckaway Reservation was acquired to form a multi-purpose recreational park. Development began in 1966. Today this 670 acre property lies adjacent to the 4831 acre western shoreline of Pawtuckaway Lake, creating 5500 acres of recreational land adjacent to the 1,180 acre lake (NHDRED, 1985). Seasonal camping, swimming, boating and fishing as well as year-round trail use make Pawtuckaway an attractive area which is reflected in the attendance figures of approximately 150,000 visitors for each of the past two years. The presence of the state park has acted as a buffer for development within the watershed. The park encompasses 47% of the watershed and has limited the amount

of residential development along the shoreline that has engulfed a large percentage of other lakes in southern New Hampshire.

The existing first and second tier development at Pawtuckaway Lake is concentrated along the southern and eastern shorelines. Existing shoreline dwellings traditionally of a seasonal nature are being winterized at an increasing rate and the majority of recently built shorefront homes are being built as year-round units.

In 1988, the Pawtuckaway Lake Improvement Association began participating in the New Hampshire Volunteer Lake Assessment Program. The association has compiled lake and tributary water quality data over the past seven years and has also evolved into an integral facet for the protection and preservation of the lake through the association's various activities and public outreach programs.

Pawtuckaway Lake today is host to several seasonal fishing tournaments, an increasing year-round residential population and various recreational activities offered through the state park. Dolloff and Drowns dams are maintained and operated by the NHDES Water Resources Division, which regulates the annual fall drawdown of seven feet to accommodate spring runoff volumes.

While there has been a sizeable amount of urban growth along Routes 152 and 4 as well as around Pawtuckaway Lake, Nottingham remains largely rural in character with much of the land in forests and fields. Most of the development has been primarily new single-family homes, although many former homesteads have been restored and are now occupied. Of these new residences, a large portion of them have been seasonal second homes constructed around the lake. The only significant commercial developments exist along Route 4 and at Nottingham Center. Approximately 20% of the land in Nottingham presently exists as state parks and forests which are extensively used for multiple-use conservation and recreation. Industrial development has not occurred in Nottingham at the present time. Relatively little land area is used for agriculture because of the rugged terrain and stony soils.

However, the Fernald family dairy farm in Nottingham Square is currently under operation and serves as a reminder of the Pawtuckaway Region's rural character.

B. USES AND ACCESS POINTS

Pawtuckaway Lake and the surrounding area support heavy recreational usage.

Pawtuckaway State Park offers 5500 acres of recreational land situated along the western shoreline of Pawtuckaway Lake. This year, over 150,000 visitors enjoyed the year-round trail use and seasonal activities making Pawtuckaway one of the more popular state parks in New Hampshire. Seasonal camping is very popular and sites are available on an 89-unit mainland campground or an 80-unit island campground. Hiking, picnicking, mountain biking, fishing and boating are popular during the warmer months. Ice fishing, snowmobiling, cross-country skiing and hunting are popular during the winter months.

Rock climbing is popular on the cliffs in the valley below North Mountain which also contains one of the largest glacial boulder fields in the world. The park has a large swimming beach just south of the Burnhams' Marsh wildlife management area. Canoe and paddle-boat rentals are available and the park also maintains a boat launch on Horse Island.

An unencumbered public boat launch is located at the northern end of the lake in the Bay of Fundy Natural Area. Several bass tournaments are launched from this site during the summer. The Town of Nottingham owns and operates a beach for its residents in the Drowns Dam area. Residents can enjoy swimming, fishing and picnicking.

Cabin rentals are available throughout the shorefront community. The Pawtuckaway Lake Improvement Association also organizes various annual lake activities, including an annual fourth of July boat parade, sailboat races, and an island/shoreline clean-up day.

C. HISTORICAL WATER QUALITY

1. Water Quality Surveys

Pawtuckaway Lake surveys were completed by New Hampshire Fish and Game in 1937 and 1947. In 1937, Pawtuckaway Lake was reported to have light brown water, transparency to 11 feet (3.3 meters), epilimnetic pH of 6.4, and a bottom dissolved oxygen of 2.0 mg/L at a depth of 33 feet (10.0 meters). The 1947 data shows a transparency of 10 feet (3.0 meters), a surface pH of 6.6 and a bottom dissolved oxygen of 3.9 mg/L at 40 feet (12.2 meters). Bottom composition of the lake was estimated to be 80% muck, 10% rock, 5% gravel and 5% sand. Both emergent and submergent vegetation was recorded as abundant. Recommendations were made to continue with a warm water fish management policy. Fish and Game survey data is presented

in Appendix II-1.

During the summer of 1971, an intensive study was made of (1) lake water quality as affected by park usage, and (2) the attitudes of private water-oriented landowners toward the park. This study, conducted by the Water Resources Research Center at the University of New Hampshire, Durham, was undertaken to determine the effect of Pawtuckaway State Park on the quality of the environment. Analysis of the water quality data indicated two major findings. First, the levels of the water quality indices were within the boundaries acceptable for recreational (or higher) use. Second, the level of park use or attendance had minimal effects on the water quality indices.

The attitudinal survey indicated that the majority of the respondents favored the park and its users; that is, most felt that the park had not created any marked deterioration in the quality of the environment. Rather, most felt that the park was an asset, in that it had kept a large tract of land from being privately developed and helped to improve and maintain real property values (Chauncey, et al. 1972).

The results of both the water quality analysis and the attitudinal survey indicated that the establishment of Pawtuckaway State Park had not had an adverse effect on the quality of the immediate environment.

A limnological survey conducted by the Department of Environmental Services on August 14, 1979 recorded a transparency of 4.0 meters and a chlorophyll-a of 3.51 µg/L. Vegetation was described as common and an observation noted clumps of Oscillatoria in abundance near the Dolloff Dam area. The hypolimnion had 30% dissolved oxygen (D.O.) saturation with 3.5 mg/L of oxygen at a depth of 8.5 meters. The mid-hypolimnetic total phosphorus value measured 7.0 µg/L. Utilizing the 1979 survey results and the State of New Hampshire Trophic Classification Scheme, Pawtuckaway Lake was classified as oligotrophic (NHSWPCC, 1981).

A second limnological survey conducted by NHDES on July 25, 1989 recorded a transparency of 3.6 meters and an increased chlorophyll-a value of 5.28 µg/L. Vascular plant abundance was described as scattered to common with a common to abundant growth on the northern and western shorelines. The hypolimnetic oxygen value in 1989 was 0.6 ppm, compared to 3.5 ppm in 1979. However, the hypolimnetic sample depth was 6.8 meters greater in 1989. The 1989 mid-hypolimnetic total phosphorus value measured 14 µg/L. Using the trophic classification scheme again in 1989, Pawtuckaway Lake was classified as mesotrophic. However,

based upon the limnological data presented in both the 1979 and 1989 surveys, Pawtuckaway Lake can be considered a borderline oligotrophic/mesotrophic lake. Two more trophic points in 1979, or two less trophic points in 1989, would have changed the classification in either direction. Historical NHDES water quality surveys are located in Appendix II-2.

2. Volunteer Monitoring Program

The Pawtuckaway Lake Improvement Association (PLIA), has participated in the New Hampshire Volunteer Lake Assessment Program (NHVLAP) since 1988. Volunteer monitors collect water quality samples from the lake and several tributaries within the Pawtuckaway Lake watershed. Sampling equipment and bottles are provided by the New Hampshire Department of Environmental Services Limnology Center. Volunteer monitors are trained on an annual basis in order to ensure that proper Standard Methods field sampling techniques and protocols are followed.

All samples collected by volunteer monitors at Pawtuckaway Lake are returned to the Limnology Center in Concord, NH for analysis. The Limnology Center is inspected by the Environmental Protection Agency and utilizes EPA quality assurance and quality control protocols.

Data collected through the NHVLAP in 1988,1989,1990 and 1991 at Pawtuckaway Lake can be used in data interpretation and is valuable in determining historical lake quality trends for this study. Historical NHVLAP data for Pawtuckaway Lake is presented in Appendix II-3.

a. pH and Acid Neutralizing Capacity (ANC). Historical values in tributary pH data ranged from a low of 3.70 in Mountain Brook (#4) during 1991 to a high of 7.30 in Fernalds Brook A (#8) in 1990. The lowest true mean pH observed between 1988 and 1991 was 5.07 in Fundy Brook. The Fundy Brook subwatershed is dominated by wetland areas which tend to be naturally acidic due to the break-down of organic materials. The decomposition of tannins and lignins within wetlands creates acidic conditions and results in a low tributary pH value.

The highest true mean pH was 6.96 recorded in 1990 at Back Creek A (#12). In the majority of streams, the true mean pH values averaged at or near 6.5 which is to be expected from tributary samples collected during the summer months. The observed high and low values

were well within expected values and show relatively little impact from acid rain deposition.

Acid Neutralizing Capacity analysis are not performed on tributary sample for the New Hampshire Volunteer Lake Assessment Program.

Samples were collected and analyzed for pH from Pawtuckaway Lake at all three layers during the months when the lake is thermally stratified. Values from 1988 through 1991 ranged from a low of 5.90 in the hypolimnion to a high of 7.70 in the epilimnion. The highest true mean pH was 6.82 in the epilimnion. This is a common occurrence in many lakes due to the abundant biological activities within the photic zone, causing the pH to rise. The lowest true mean pH was recorded in 1988 in the hypolimnion with a pH of 5.93. Generally, pH values in the hypolimnion are lower than upper water layers due to the lack of planktonic photosynthesis.

Acid Neutralizing Capacity values recorded in the epilimnion from 1988 through 1991 ranged from a low of 3.50 mg/L as $CaCO_3$ in 1991 to a high of 4.70 mg/L in 1990. These values are below the state ANC mean of 6.5 for New Hampshire lakes and ponds and reflects the naturally poor buffering capacity of this regions underlying geology. Also, the three year average pH of rainfall from 1988 to 1991 was 4.15 which compromises the buffering capacity and influenced lower ANC values.

b. Specific Conductance. Conductivity values in the tributaries at Pawtuckaway Lake ranged from a low of 26.5 µmhos/cm in Round Pond Brook (#14) to a high of 2030.0 µmhos/cm in Fernalds Brook A (#8) during the monitoring seasons. The high conductivity values in Fernalds Brook A can be attributed to the agricultural runoff within the subwatershed. All samples collected from Whites Grove Brook (7) over the four year period had conductivity values greater than 100 µmhos/cm.

The mean conductivity values for Pawtuckaway Lake ranged from 42.4 to 50.4 µmhos/cm in the water column. This data is lower than the New Hampshire state mean of 56.0 µmhos/cm for lakes and ponds.

c. Apparent Color. Mean color values for the tributaries ranged from a low of 15 cpu's measured in Loon Cove Brook A (#3) to a high of 153 cpu's in Fundy Brook (#13). From 1988 to 1991, Fundy Brook and Back Creek B (#11) had mean apparent color values of 123 and 110 cpu's respectively. Both tributaries have watersheds dominated by wetland complexes which

naturally increase apparent color values due to processes of decomposition.

Mean in-lake apparent color values were 24 cpu's in the epilimnion, 26 cpu's in the metalimnion, and 43 cpu's in the hypolimnion. These values are typical of water described as lightly tea-colored.

d. Total Phosphorus. The highest mean total phosphorus concentrations in tributaries from 1988 to 1991 were observed in Fernalds Brook A (143 µg/L) and in Fundy Brook (91 µg/L). The lowest mean concentration was recorded at the Dolloff Dam outlet (5 µg/L). The remainder of the means ranged between 13 µg/L and 78 µg/L. Overall values ranged from a maximum of 207 µg/L in Fernalds Brook A to a minimum of 4 µg/L in Fernalds Brook B. Agricultural areas within the Fernalds Brook A watershed contribute to the elevated phosphorus concentrations in the brook.

In-lake phosphorus concentrations at Pawtuckaway Lake ranged from 6 to 17 µg/L (mean of 10 µg/L) in the epilimnion, from 7 to 23 µg/L (mean of 15 µg/L) in the metalimnion and from 5 to 51 µg/L (mean of 18 µg/L) in the hypolimnion from 1988 to 1991. The mean in-lake phosphorus concentrations for this period are considered to be average for New Hampshire lakes and ponds (11-20 µg/L).

e. Chlorophyll-a and Transparency. Chlorophyll-a data collected through the New Hampshire Volunteer Lake Assessment Program at Pawtuckaway Lake from 1988 to 1991 indicated a maximum chlorophyll-a concentration of 5.69 µg/L in 1989. The minimum chlorophyll-a value of 2.72 µg/L was recorded during the summer of 1990. Chlorophyll-a concentrations for the four year period were well below the 7.27 µg/L mean for lakes and ponds in New Hampshire which is compiled from over 500 lakes. The maximum chlorophyll-a value in 1989 corresponded with the lowest transparency recorded during the four year period of 3.1 meters. The maximum transparency recorded was 4.0 meters in 1988. The four year mean transparency had a depth of 3.5 meters which is just below the mean of 3.8 meters for New Hampshire lakes and ponds.

f. Phytoplankton. The net phytoplankton community was sampled in July of each year from 1988 to 1991 at Pawtuckaway Lake. In 1988, the phytoplankton community was dominated

by the Chlorophyceae, green colonial phytoplankton and the Bacillariophyceae or diatoms. Sphaerocystis (green) had a relative species abundance of 41% and Asterionella (diatom) accounted for 40% of the community abundance in 1988. The 1989 phytoplankton community was comprised of Coelosphaerium (blue-green), Sphaerocystis (green), and Microcystis (blue-green). Relative percent abundances for these species were 36%, 32% and 28% respectively. The 1990 phytoplankton sample was dominated by the blue-green (Cyanobacteria), Chroococus, with a relative percent abundance of 66%. The diatom Asterionella, and the green phytoplankton Staurastrum were the dominant species in 1991, with abundances of 37% and 15% respectively. Many of the species found in Pawtuckaway Lake from 1988 to 1991 are commonly associated with nuisance algae blooms and eutrophic conditions. However, the low epilimnetic total phosphorus values and the four year chlorophyll-a mean of 3.56 µg/L indicate borderline oligotrophic/mesotrophic conditions with little evidence of nuisance algae blooms.

g. Temperature and Dissolved Oxygen. Pawtuckaway Lake exhibited the typical stratification for a north temperate lake during the summers of 1988 through 1991. By mid to late July, the surface waters were approximately 20°C warmer than the bottom waters.

Pawtuckaway Lake experiences a depletion of oxygen in the bottom waters which frequently occurs in the summer in many lakes. Pawtuckaway Lake had less than 5.0 mg/L of dissolved oxygen in the water column from a depth of 5.0 meters to the bottom (14.0 meters), from 1988 to 1991. The bottom dissolved oxygen value was less than 1.0 mg/L for all four years.

3. Complaints and Aquatic Nuisances

Several complaints and inquiries have been received because of blue-green algae blooms. In August of 1978 and 1979, severe algae blooms caused by Oscillatoria were reported. Pawtuckaway Lake has never been chemically treated for nuisance algal growth.

Fishkills were reported in 1985 and 1992. However, these fishkills were not isolated to Pawtuckaway Lake. Several southern New Hampshire lakes experienced similar fishkills during these years and were attributed to spawning stress or heat stress or a combination of both factors. The lake has not been stocked by the Fish and Game Department since 1958 and recent concerns have been raised as to the possibility that the lake is deteriorating as a fishery. In 1992, the

Pawtuckaway Lake Fisheries Committee was formed to monitor the impact of fishing on the lake and to educate the public about responsible fishing practices.

Historically, the subject of drawdown and lake level has been the source of many complaints and inquiries from the citizens at Pawtuckaway Lake. However, the drawdown procedures at Pawtuckaway Lake date back to 1950 and has received general acceptance through the years.

D. DRAWDOWN PROCEDURES

The drawdown and current mode of operation at Pawtuckaway Lake is documented in an agreement dated August 14, 1950 between the New Hampshire Electric Company and the New Hampshire Water Resource Board. The practice may have preceded that date and has remained essentially unchanged since that date. The practice of fall drawdown is implemented for multiple public purposes. The gradual release of stored water through the fall increases flow in the Lamprey River with attendant enhancement of riverine quality and presumably the fishery. This drawdown also allows shorefront property owners to clean their frontage and perform improvements to docks, walls and beaches.

Through the winter months, the lowered lake level keeps the ice away from shorefront structures and provides storage for high runoff from occasional winter rains on frozen ground and the spring thaw. The winter operation also allows the lake level to fluctuate, thereby moderating stream flow peaks downstream. The ratio of watershed size to lake surface area is such that one inch of runoff will raise the lake sixteen inches. It is evident that the lake may rise significantly from runoff events.

The drawdown and subsequent freezing of the exposed bottom acts as a natural aquatic weed control method. Secondly, stored up nutrients such as phosphorus which can stimulate algae blooms, will be flushed out of the lake system.

The drawdown operation at Pawtuckaway has received general acceptance through the years. The potential exists to modify the operation, however, should it be in the public interest, both generally and specifically with respect to the property owners.

E. FISHERIES

A netting investigation conducted by the New Hampshire Fish and Game Department in 1957 indicated an overall excellent bass, bullhead, and white perch fishery. A good predator population of small and largemouth bass and chain pickerel were present along with an adequate forage of golden shiners, yellow perch, pumpkinseed sunfish and white suckers.

In 1963, an electro-fishing investigation indicated an excellent predator population, particularly largemouth bass, with ample forage fish available. Based on this investigation, it was said that the fish population in this lake was as good or better than most lakes.

Numerous complaints from anglers on Pawtuckaway Lake resulted in another investigation in 1971 by the New Hampshire Fish and Game Department. Contrary to the favorable findings of past years, this sampling indicated a poor fishery and a definite decline in predator species abundance. Considering the size of Pawtuckaway Lake (1,180 acres) and the level of effort (3 nights of electroshocking), the catch in 1971 was extremely small, especially for smallmouth and largemouth bass and brown bullheads. The sizes of species caught were significantly smaller than previous studies as well. The decline in fisheries quality was attributed to a considerable increase in shorefront development, angling pressures and motor boat activity (Miller, 1994).

In 1976, survey findings further documented a declining trend in smallmouth bass with a corresponding increase in largemouth bass populations. An attempt to stock smallmouth bass in 1977 failed to alter what was perceived to be a naturally developing imbalance.

A follow-up survey conducted in 1979 produced only a few small-sized largemouth bass. Smallmouth bass were not sampled during this study period but were presumed to be present. The lakes remaining fisheries appear to have remained essentially unchanged for over the twenty year period that data is available. Brown bullheads were still providing an excellent fishery for anglers. Other species sampled in 1979 included chain pickerel, yellow perch, golden shiners, common sunfish, common white suckers, chubsuckers and eels (Miller, 1994).

In 1989, a three day fyke netting investigation produced low numbers of smallmouth and largemouth bass in the sample. The remaining fisheries in Pawtuckaway Lake had very similar characteristics to the 1979 survey. Species sampled in 1989 included chain pickerel, yellow perch, golden shiners, common sunfish, and common white suckers. White perch were present

in good numbers as well as brown bullheads which continue to provide a stable fishery for anglers.

A fyke netting investigation was conducted in 1993 in response to further angler complaints and inquiries from lake residents concerned with the declining fishery in Pawtuckaway Lake. Results from this survey indicated a problem with the baitfish population in the lake. Baitfish sampled were large in size and no longer served as forage for predator species. This scenario is creating an imbalance in the fisheries community structure.

The annual seven-foot drawdown of the lake may be one factor contributing to this problem. The drawdown consolidates fish into localized basins and prevents juvenile gamefish from populating rocky habitats essential for protection from predators. Pressures associated with the approximately fifteen annual bass tournaments may also be contributing to the imbalance in the fisheries population.

Anadromous alewives were stocked at Pawtuckaway Lake in the spring of 1994 in an effort to take pressure off the golden shiner population. The alewives will also provide an abundance of forage for the existing game fish species. Alewives will exit the lake in the fall and return to the ocean for the winter months. This process of stocking will continue until a revised recommendation can be made regarding the fisheries management at Pawtuckaway Lake for the future (Miller, 1994).

F. VASCULAR PLANTS

The Biology Bureau of the New Hampshire Department of Environmental Services, as part of the lake and pond inventory program, constructed an aquatic plant distribution and abundance map for Pawtuckaway Lake in 1979 and again in 1989. Appendix II-4 presents the results of both macrophyte surveys. The aquatic plant survey conducted in August, 1979 determined that Vallisneria americana (tape grass) and Sparganium (bur reed) dominated the macrophyte community. Eriocaulon septangulare (pipewort), Nuphar (yellow water lily), and Potamogeton (pondweed) were found in significant abundances throughout the entire shoreline. The overall abundance was considered to be common with plants found along much of the shoreline and abundant in the Fundy Bay area. However, plants were not considered to be a problem for navigation in the main body of the lake.

A second aquatic macrophyte community survey was conducted in July, 1989. The overall macrophyte community abundance was classified as scattered-common with plants found around most of the shoreline but not considered a problem or nuisance for swimming and navigation. Sparganium (bur reed), Utricularia (bladderwort), Eleoccharis (spike rush) and Nuphar (yellow water lily) dominated the macrophyte community during the 1989 survey. The reduction in number of aquatic macrophytes documented in 1989 and the subsequent change in overall abundance from the 1979 survey is directly related to the fact that the 1979 survey was compiled in the middle of August which is the peak of the aquatic vegetation growing season. The 1989 survey was conducted in July before the macrophyte community at Pawtuckaway Lake reaches maximum abundance.

CHAPTER III WATERSHED CHARACTERISTICS

A. GENERAL HYDROLOGY AND TOPOGRAPHY

1. Topography

The Pawtuckaway Lake watershed encompasses an area of approximately 11,851 acres and contains a major lake, numerous small ponds, extensive wetland areas and an extensive system of tributaries. The majority of drainage in the watershed is channeled to Pawtuckaway Lake by Back Creek and Mountain Brook both of which consist of extensive drainage configurations branching throughout the watershed. Approximately 74% (8,767 acres) of the watershed lies within the southeastern portion of the Town of Nottingham, New Hampshire. The remaining 26% (3,083 acres) of the watershed area occupies an eastern section of Deerfield, New Hampshire.

The watershed is characterized by rapidly fluctuating terrain, which contains a mixture of steep slopes and mountainous terrain. Heavily forested rolling hills are interrupted by pastures and hayfields to break up the monotony of the extensive forests.

In the southwestern section of the watershed, the forest floor is littered with abundant glacial boulders deposited by the retreat of the glaciers. Elevations range from about 200 feet to 1,000 feet above sea level throughout most of the watershed. Elevations over 600 feet are not uncommon, especially in the Pawtuckaway Mountains region. Mt. Pawtuckaway, the highest point in the watershed, is 1,011 feet.

The watershed is dominated by the Pawtuckaway Mountains in the west and by Pawtuckaway Lake in the south. Pawtuckaway State Park encompasses approximately 46% of the total watershed area and contains the steep slopes of the Pawtuckaway Mountains, and a mixture of heavily forested terrain and vast expanses of wetlands. Back Creek is the most extensive tributary system entering Pawtuckaway Lake. Origins for the drainage pattern extend

to the northern tip of the watershed as well as the western border and meander through the rolling hills and extensive wetland areas before discharging into the lake. Figure III-I delineates watershed boundaries and illustrates prominent topographical features within the Pawtuckaway Lake watershed.

2. Hydrology

The Pawtuckaway Lake watershed is characterized by an extensive system of tributaries and wetland complexes. Eleven tributaries discharge into Pawtuckaway Lake in addition to the discharge over both spillways from Burnhams Marsh which act as inflowing components to the lake. Direct runoff and groundwater seepage also contribute to the inflowing hydrologic component at Pawtuckaway Lake.

Discharge from Pawtuckaway Lake is regulated through Drowns Dam located in Fundy Bay and Dolloff Dam located in the southeastern cove of the lake. Discharge over the spillway at Drowns Dam flows north to a confluence with the North River. Water discharged over Dolloff Dam forms the Pawtuckaway River. Both the North River and Pawtuckaway River eventually empty into the Lamprey River in Epping, NH.

B. CLIMATE

Pawtuckaway Lake is located in the Town of Nottingham, which lies in Rockingham County, New Hampshire, approximately 23 miles east of Concord, New Hampshire at coordinates 43°05'00" North and 71°09'00" West.

The climate of the region is characterized by moderately warm summers, cold, snowy winters, and ample rainfall. The weather is occasionally influenced by the Atlantic Ocean which is about 25 miles to the east. However, the prevailing winds are from the west, thus the climate is more influenced by air masses moving in from the interior rather than the air moving landward from the ocean. Daily temperatures can be quite variable because of changing weather patterns that alternately transport warmer air from a southerly direction and colder air from a northerly direction.

The total annual precipitation for the study area is about 54 inches, including the water

PAWTUCKAWAY LAKE: BASE MAP FEATURES

- Primary Road
- Secondary Road
- Trail or Other
- Town Boundary
- Transmission Line
- Stream or Shoreline
- Intermittent Stream
- Subwatershed Boundary
- Watershed Boundary
- Surface Water

Data sources:
Watershed boundaries compiled and digitized at 1:24,000 by NH Department of Environmental Services.
Roads, hydrography, boundaries and pipeline features from 1:24,000-scale USGS Digital Line Graph (DLG) data.

This map was produced by the NH DES GIS Program, May 1994.

N

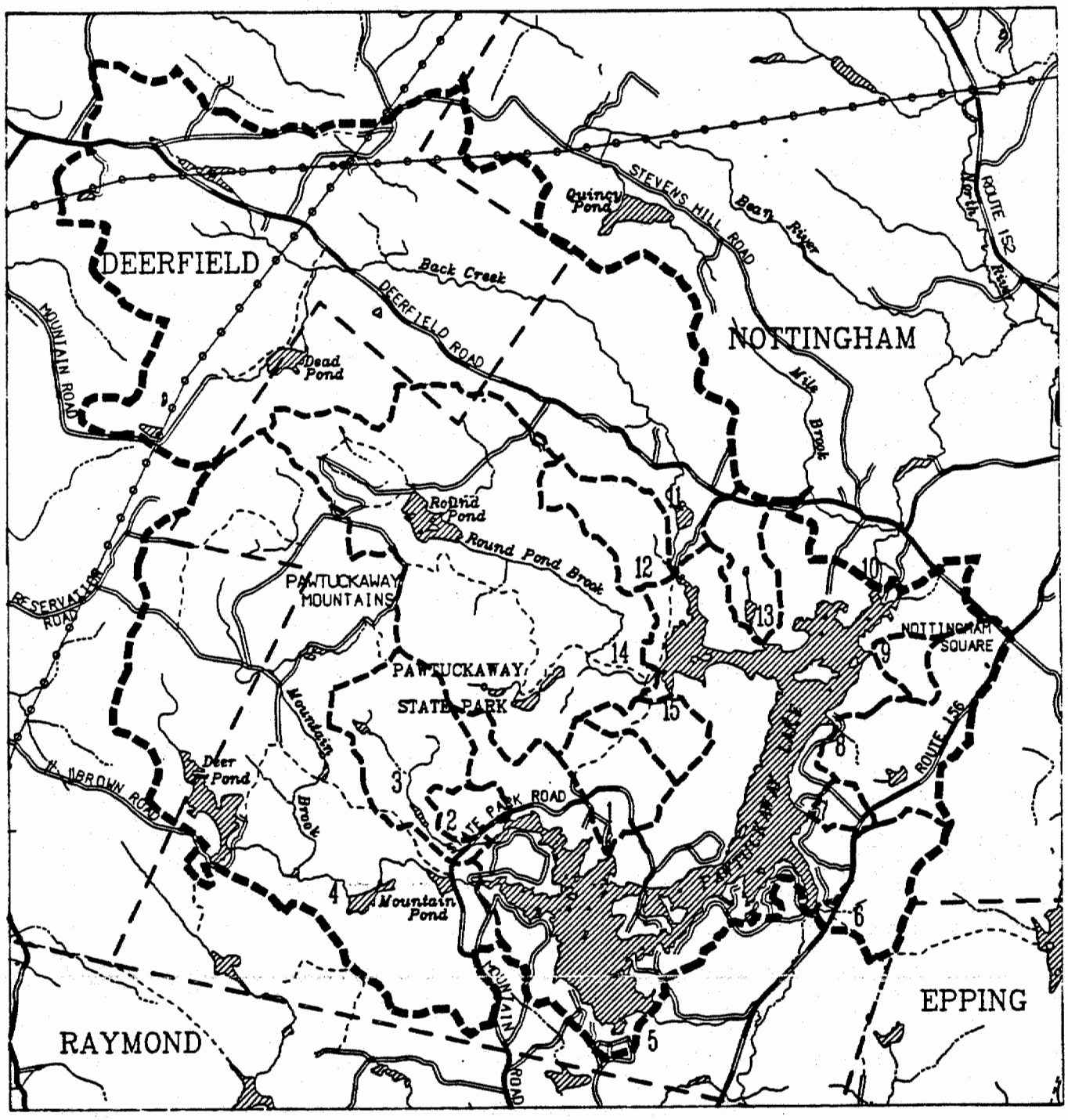


Figure III-1: Pawtuckaway Lake Base Map

equivalent of snow. Generally, snow is present from mid-December to the end of March. Precipitation in this region is acidic.

C. GEOLOGY

About 355 million years ago, most of central and southeastern New Hampshire lay under a great inland sea. Glacial scouring and erosion attacked and gradually lowered and removed the highland mass during hundreds of millions of years. Streams flowing westward from the highland carried vast amounts of sand and mud into the inland sea overlying New Hampshire. The sea received sediments until all the rocks of sedimentary origin in the Pawtuckaway quadrangle were deposited (Fig. III-2A). By this time a great sheet of sand and mud more than 20,000 feet thick had accumulated in the sea.

Approximately 300 million years ago, the land began to rise and the great inland sea retreated from this part of New Hampshire, never to return. The sediments laid down in the sea became dry land and were exposed to the forces of erosion. Before erosion could do much to the newly exposed land, the tremendous forces of continental drift exerted against our eastern shore caused the horizontal sediments to buckle and fold (Fig. III-2B). The severe pressure of folding caused massive recrystallization among the sediments composed of mud, muddy sand and limy mud. These muds were recrystallized to mica schist, garnet schist, staurolite schist, sillimanite schist, quartzite and actinolite granulite (Freedman, 1980).

As the sedimentary rocks folded, magma rose from the depths of the earth and intruded into the folds and fractures. This intrusion produced a black, coarse-grained, granite-like rock (Fig. III-2C). This type of rock can be observed throughout Pawtuckaway State Park. The last phase of the New Hampshire magma series consisted of the injection of pegmatite dikes composed of quartz, feldspar and mica. As the magma cooled slowly, large crystals of quartz, mica and feldspar formed (Freedman, 1980). Locally, rare minerals such as tourmaline, beryl and uranium are present in small quantities. Quartz veins are also very abundant in the Pawtuckaway Lake region.

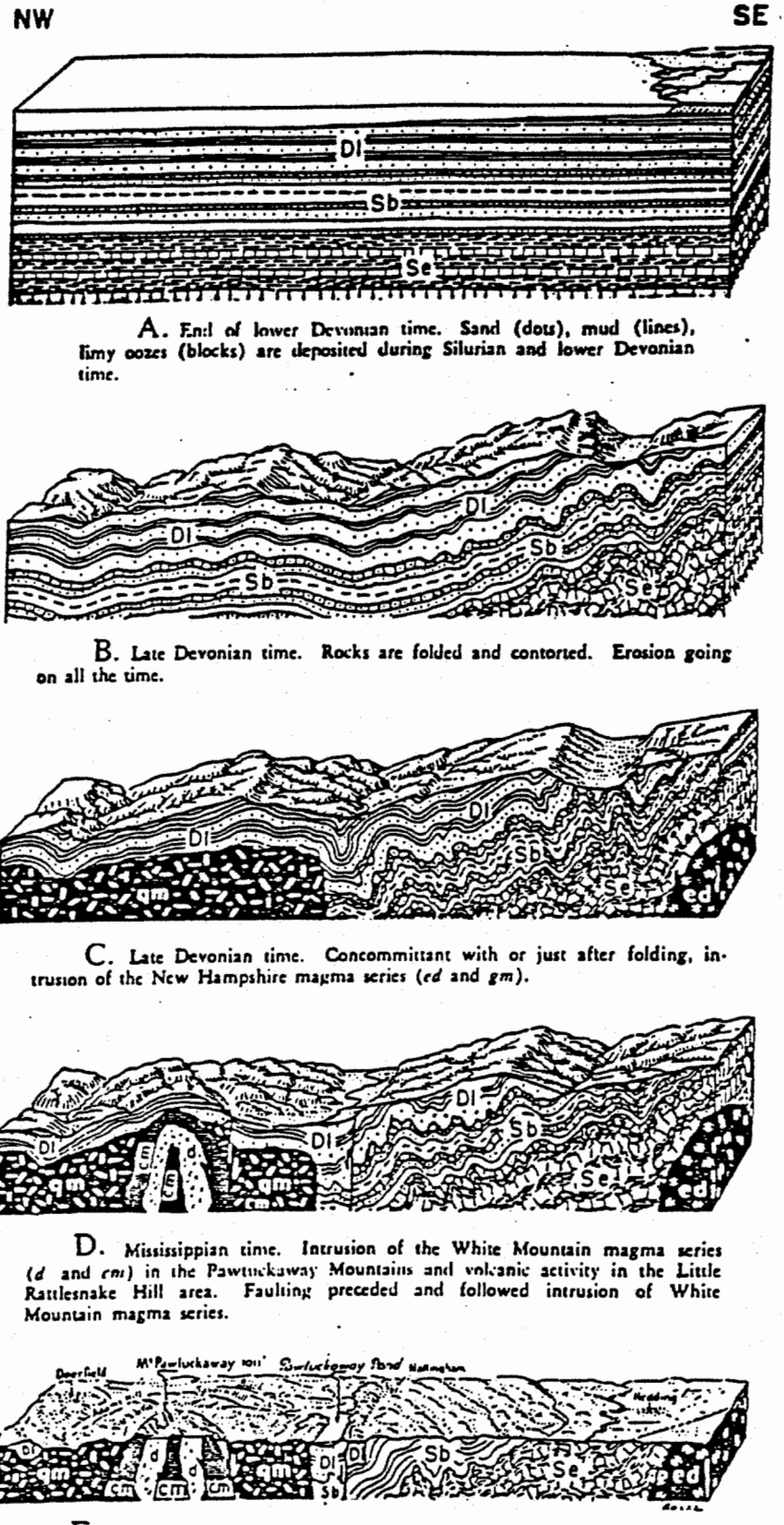
Approximately 275 million years ago, another body of magma rose up from deep in the earth and forced aside the heated plastic rock of the New Hampshire magma series. The new consolidation of magma, referred to as the White Mountain Series, formed gabbro and diorites

which make up the interior valleys of the Pawtuckaway Mountains (Fig. III-2D). Forces in the earth developed a circular fracture around the solid rock, and more magma of a different composition rose to fill the fracture. This magma eventually cooled and formed a coarse-grained monzonite, which now makes up the outer circle of the Pawtuckaway Mountains in what is called a ring-dike.

All during the folding of the rocks and during the successive magma intrusions, erosion continued to carve the rocks. Over a span of about 300 million years, miles of overlying sediments were removed to expose the igneous rocks formed by the successive intrusions of magma. However, the elevation of the surface was at no time, higher than it is today. As erosion cut down the surface, the land slowly rose to maintain a balance deep within the earth (Freedman, 1980).

About 2 million years ago, a solid mass of ice over a mile thick swept down over New Hampshire. This continental glacier originated in Labrador and Canada and approached the Pawtuckaway Lake region from the northwest. Evidence for the direction of travel is evident by scratches and grooves on rock surfaces made by the advancing glacier as it slid over them and by the shape of the hills carved by the glacier. The great weight of the ice caused it to push soil off bedrock and ice and melt-water into cracks in the newly exposed rock. The forward motion of the glacier scraped at mountain faces and plucked out blocks of rock surrounded by ice. When the glacier started to melt and the ice front to retreat, about 30,000 years ago, huge boulders and glacial outwash were deposited throughout the region. Most of the Pawtuckaway region today is covered with a variable thickness of till and glacial outwash. The irregularly distributed till and outwash dammed many of the pre-glacial streams and formed the numerous lakes, ponds, swamps and extensive drainage patterns that characterize this region.

Today, the Pawtuckaway Mountain area, within Pawtuckaway State Park, is probably the most interesting part of the entire region. The state park boasts one of the largest aggregations of glacial boulders in the world. These boulders are light-gray, coarse-grained monzonite which were plucked from the ring-dike that constitutes the Pawtuckaway Mountains. The large, sheer cliffs that rise above the boulders and valley floor resulted from the faulting created by internal pressure along a weak area. The eastern half of Pawtuckaway Lake is perched upon bedrock composed of gray phyllites, quartzite and mica-schists of the Littleton formation. The western portion of the lake covers bedrock composed of light-gray to dark-gray quartz monzonite. Figure



A. End of lower Devonian time. Sand (dots), mud (lines), limy oozes (blocks) are deposited during Silurian and lower Devonian time.

B. Late Devonian time. Rocks are folded and contorted. Erosion going on all the time.

C. Late Devonian time. Concommittant with or just after folding, intrusion of the New Hampshire magma series (*ed* and *gm*).

D. Mississippian time. Intrusion of the White Mountain magma series (*d* and *cm*) in the Pawtuckaway Mountains and volcanic activity in the Little Rattlesnake Hill area. Faulting preceded and followed intrusion of White Mountain magma series.

E. Present. Region eroded to present topography.

(A-E) Series of diagrams to illustrate the story of the rocks of the Mt. Pawtuckaway quadrangle. The cross sections are imaginary trenches several miles deep cut across the Mt. Pawtuckaway quadrangle at successive stages in its development. Se = Eliot formation; Sb = Berwick formation; Dl = Littleton formation; ed = Exeter diorite and qm = quartz monzonite, both belonging to the New Hampshire magma series; d = diorite and cm = coarse-grained monzonite, both belonging to White Mountain magma series.

Figure III-2(A-E): Historical Geology of the Pawtuckaway Lake Region. Reprinted from DRED 1980.

III-2(A-E), shows the historical geology of the Pawtuckaway Lakes region.

D. SOILS

1. Pawtuckaway Lake Watershed Soils

The Pawtuckaway Lake watershed is comprised of soils developed largely from glacial till and glacial outwash. Glacial till consists of the mixed materials deposited by glaciers with little or no sorting by water. The advance and retreat of the glacial ice sheet picked up rocks and ground them into particles the size of sand, silt or clay. Some fragments of rock were not ground into fine particles but were carried along by the ice sheet and deposited as unsorted mixed materials when the glacier melted. This activity gave rise to the many bedrock outcrops and stones found throughout the soil profile.

The soils in the region are characterized by a surface organic mat, one to two inches thick, composed of partly decomposed leaves and needles which lies two to three feet above bedrock. The bedrock in the region is derived from granite, gneiss, granodiorite, phyllite, syenite, and schist.

The watershed is characterized as having very poorly drained to somewhat excessively drained soils on glacial till, with gently rolling to extremely sloped topography. The composition of soils in the Pawtuckaway Lake watershed includes 23 separate soil classifications. The dominant soil composition includes Chatfield-Hollis-Canton complex, Canton series (bouldery), Greenwood and Ossipee (ponded), Canton series (stony) and Hollis-Rock outcropping- Chatfield complex, in the ratio of 40.3%, 18.3%, 5.0%, 5.0% and 4.5% respectively (NHDES GIS Program, 1994).

Chatfield-Hollis-Canton complex soils (stony) are found evenly distributed throughout the watershed and are present along the southern and southwestern shoreline adjacent to Pawtuckaway Lake. This soil-complex is characterized by deep, moderately deep and shallow, well drained to somewhat excessively drained soils on uplands. Formation of this complex was derived from glacial till composed mainly of schist, gneiss, and granite. These soils are commonly found on knobby hills and ridges that in most places have a northeast orientation. Soils in this complex are poorly suited to producing crops and forage because of surface stones

and outcroppings of bedrock. These conditions also limit the feasibility of urban development. The limitation of depth to bedrock makes the siting of septic systems and buildings important from both economic and construction standpoints. However, extensive urban development has occurred on these soils immediately adjacent to Pawtuckaway Lake on the southern and southwestern shoreline despite the bedrock limitations and erodibility hazards from slopes ranging from 0 to 60%. The majority of this soil complex within the watershed remains wooded. Appendix III-1 presents the soils adjacent to Pawtuckaway Lake.

The Canton series (bouldery) soils are well drained and commonly found on uplands. Believed to have formed in a sandy loam mantle underlain by sandy glacial till derived mainly from granite and gneiss, these soils are evenly distributed throughout the watershed. Parcels of this soil type frequently exhibit a 0 to 35% slope on the backslopes of ridges, knolls and hills. Boulders and stones cover more than 3% of the soil surface and deposits of this soil type are often long and narrow with the long axis oriented north to south. This soil is poorly suited for agricultural purposes because of boulders and surface stones. This factor also places limitations on urban development due to problems with siting septic systems, roads and buildings. Canton bouldery soils are best suited as woodlands and the majority of deposits within the watershed remain wooded or designated for recreational purposes in Pawtuckaway State Park.

Greenwood and Ossipee soils (ponded) underlie the vast numbers of wetland complexes within the watershed. These soils are characterized as very deep, very poorly drained soils formed from organic accumulations and are underlain by loamy sediments on uplands. This soil type typically contains a dark reddish brown mucky peat surface layer about 12 inches thick with 0 to 2% slopes. Since standing water is present throughout most of the growing season, agriculture and urban development are not feasible practices. Most areas of these soils are not utilized, but some areas are managed as wildlife habitats such as the Burnhams Marsh Wildlife Management area within Pawtuckaway State Park. Most of these soils are classified as wetlands within the watershed. A large extent of the Back Creek B subwatershed is composed of these soils.

The moderately steep soils of the Canton (stony), complex are characterized as deep well-drained stony soils, derived from fine sandy loam underlain by gravelly glacial till derived mainly from granite and gneiss. Commonly found on shoulders and backslopes of hills, areas are long and narrow or irregular in shape with stones covering .01 to 3.0% of the soil surface. Although this soil is poorly suited for urban development, entire parcels have been completely subdivided

along the eastern shoreline of Pawtuckaway Lake. Slopes in these areas range from 0 to greater than 35% with extensive areas of imported fill in order to level building sites and septic systems. This soil is poorly suited for agricultural purposes due to the abundance of surface stones and steep slopes. Most areas within the watershed are used for woodlands.

The Hollis-Rock Outcrop-Chatfield soil complex is described as a shallow to moderately deep, well drained to somewhat excessively drained soil complex commonly found on uplands and at the base of backslopes. This complex also exhibits exposures of bare hard bedrock, consisting of unweathered volcanic and metamorphic coarse-grained monzonite which is found in the ring-dome of the Pawtuckaway Mountains. Slopes in this region range from 0 to 90° which eliminates the possibilities of agricultural practices or urban development from occurring. These outcrop soils formed from a thin mantle of glacial till derived mainly from schist, gneiss and granite. Outcroppings of this particular complex are localized in the Pawtuckaway Mountain region of the watershed. The exposed ledges and ridges of this region are visible from Pawtuckaway Lake when viewed in a northwesterly direction.

The dominant soil types in the Pawtuckaway Lake watershed are best suited for forestry and have little agricultural value. Agriculture has declined gradually since about 1850 and farmland is still being abandoned and allowed to grow up in forest. Forests cover more than 72% of the watershed and the small number of pastures tend to be rocky, poorly drained and susceptible to erosion on steep slopes. The region possesses good productivity for forestry practices and good wildlife habitats both in wetlands and wooded areas. A soils map for the Pawtuckaway Lake watershed is presented in Appendix III-1.

2. Soil Limitations for Septic Systems

Septic systems typically consist of a septic tank connected to a leach field. The septic tank provides primary treatment by trapping solid organic waste. The liquid wastewater exits into the leach field where it is filtered and drained into the soil. The soil filters this partially treated sewage which eventually drains into the groundwater table or into rivers and lakes that may be nearby.

Table III-1
Soil Limitations for Septic Systems in the Pawtuckaway Lake Watershed

Limitation	Acres	Percentage
Ponding / Poor Filter	6.8	.1
Variable	22.8	.2
Ponding / Percs Slowly	281.5	2.4
Wetness / Poor Filter	301.3	2.5
Percs Slowly	514.3	4.3
Flooding / Depth to Rock	529.1	4.5
Moderate	592.3	5.0
Wetness / Percs Slowly	831.7	7.0
Water	898.3	7.6
Ponding Subsides	905.0	7.6
Poor Filter	2,193.8	18.5
Depth to Rock	4,774.8	40.3

Key: Variable- Limitations need to be determined as these areas consist of land covered by streets, parking lots, and buildings intermingled with soil inclusions that make up less than 45% of the map unit.

Moderate- Soil properties or site features are not favorable for the indicated use and special planning design, or maintenance is needed to overcome or minimize limitation.

Severe- Soil properties or site features are so unfavorable or so difficult to overcome that special design, significant increases in construction costs, and possibly increased maintenance are required. .

Septic systems can be effective in removing organic matter, bacteria and nutrients if properly designed and maintained. They only work, however, if the proper site conditions exist. Soils play a key role in treating wastewater; however, tightly bound or poorly drained soil types such as clays are not effective filters. Gravel is also a poor filter because wastewater drains too rapidly.

Figures III-3 and III-4 depict soil limitations for individual septic system design criteria in the Pawtuckaway Lake watershed and in the area adjacent to the lake respectively. These soil limitation maps help local planners zone their towns for future growth. Knowing what areas are best for septic systems minimizes the potential for water pollution problems in the future.

Tables III-1, III-2, and III-3 itemize the various soil limitation areas by total acreage and percentage of the entire watershed, within a one mile buffer of the lake and within a half-mile

PAWTUCKAWAY LAKE WATERSHED: SOIL LIMITATIONS FOR SEPTIC SYSTEMS

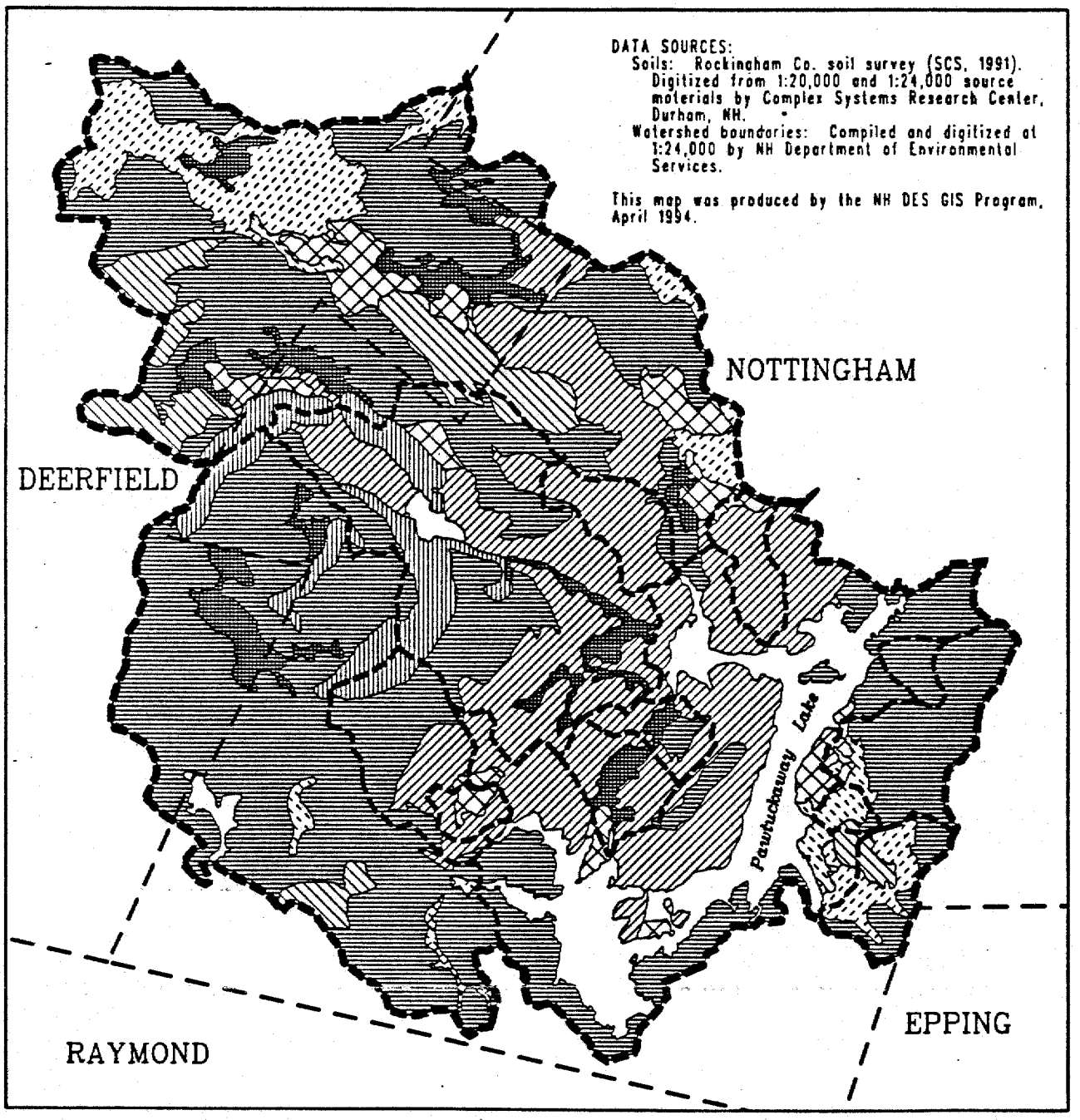


Figure III-3: Soil Limitations for Septic Systems in the Pawtuckaway Lake Watershed

SOIL LIMITATIONS FOR SEPTIC SYSTEMS ADJACENT TO PAWTUCKAWAY LAKE

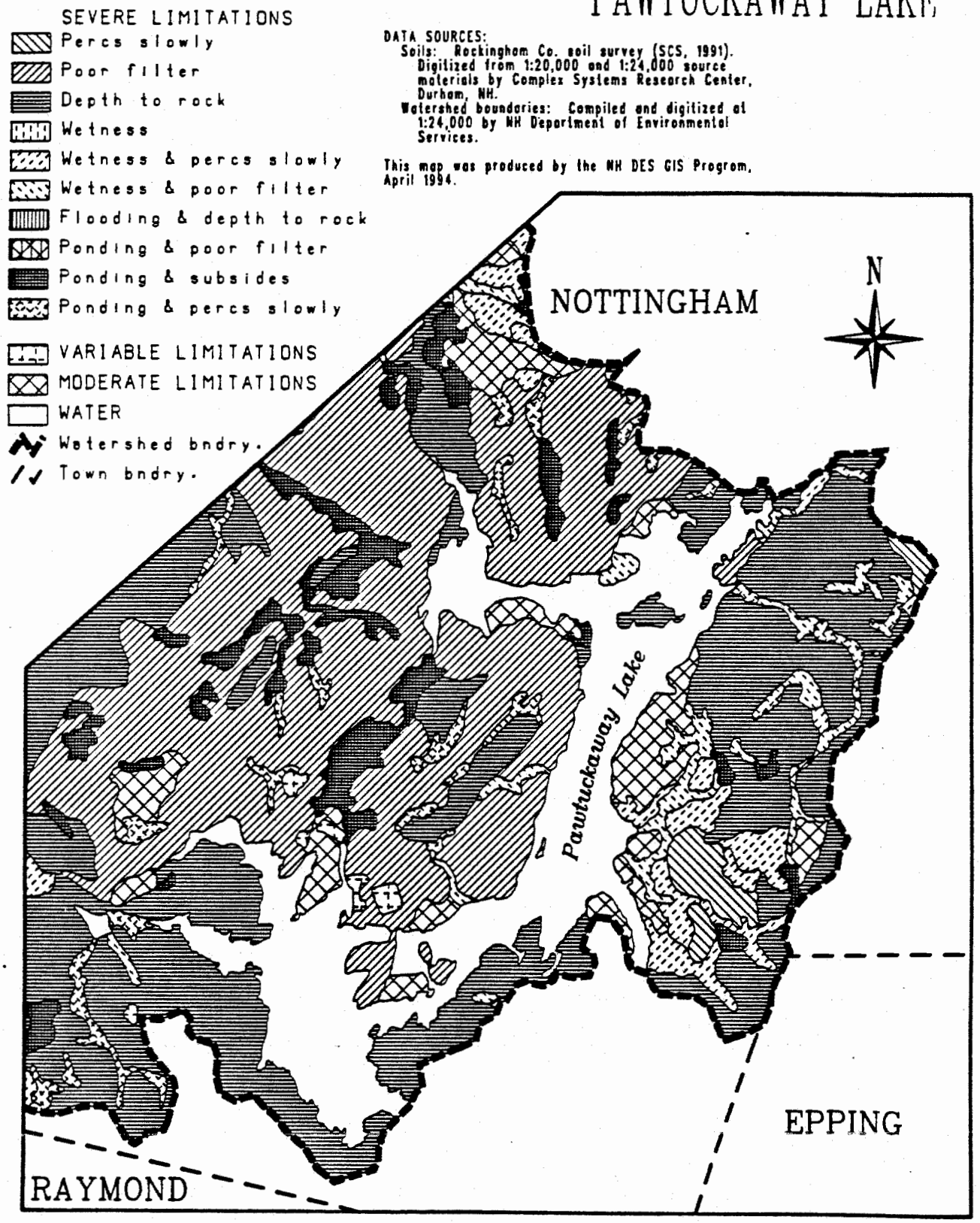


Figure III-4: Soil Limitations for Septic Systems Adjacent to Pawtuckaway Lake

buffer of the lake respectively. Approximately 87% of the soils within the Pawtuckaway Lake watershed have severe limitations for septic systems. Soils that are a poor filter or are limited by depth to rock (Figure III-5) account for 58.7% of this classification. Only 5.2% of the soils within the entire Pawtuckaway Lake watershed have variable or moderate limitations for septic systems. Several parcels of soils with moderate limitations occur along the eastern shoreline of Pawtuckaway Lake where shorefront residential development exists.

Within a one mile buffer of Pawtuckaway Lake, the dominant soil limitations for septic systems are depth to rock (32.7%) and soils that are classified as being a poor filter (30.1%). Another 5.7% of the soil types are considered to have variable or moderate limitations for septic systems (Table III-2).

Table III-2
Soil Limitations for Septic Systems Within a One-mile Buffer of Pawtuckaway Lake

Limitation	Acres	Percentage
Ponding / Poor Filter	2.4	.04
Flooding / Depth to Rock	5.6	.1
Variable	22.8	.4
Percs Slowly	121.5	2.1
Wetness / Poor Filter	146.6	2.5
Ponding / Percs Slowly	169.4	2.9
Wetness / Percs Slowly	217.1	3.7
Moderate	310.7	5.4
Ponding Subsides	332.9	5.7
Water	829.8	14.3
Poor Filter	1,747.8	30.1
Depth to Rock	1,895.8	32.7

PAWTUCKAWAY LAKE WATERSHED: DEPTH TO BEDROCK

- Depth >60 in
- Depth >10 in. Urban
- Soil Complex 140
- Soil Complex 141
- Soil Complex 799
- Water or no value
- Watershed bndry.
- Subwatershed bndry.
- Town bndry.

SOIL COMPLEX	COMPONENT	DEPTH TO ROCK (IN)
140	Chatfield	20-40
	Hollis	10-20
	Canton	>60
141	Hollis	10-20
	Rock Outcrop	0
	Chatfield	20-40
799	Urban	>10
	Canton	>60

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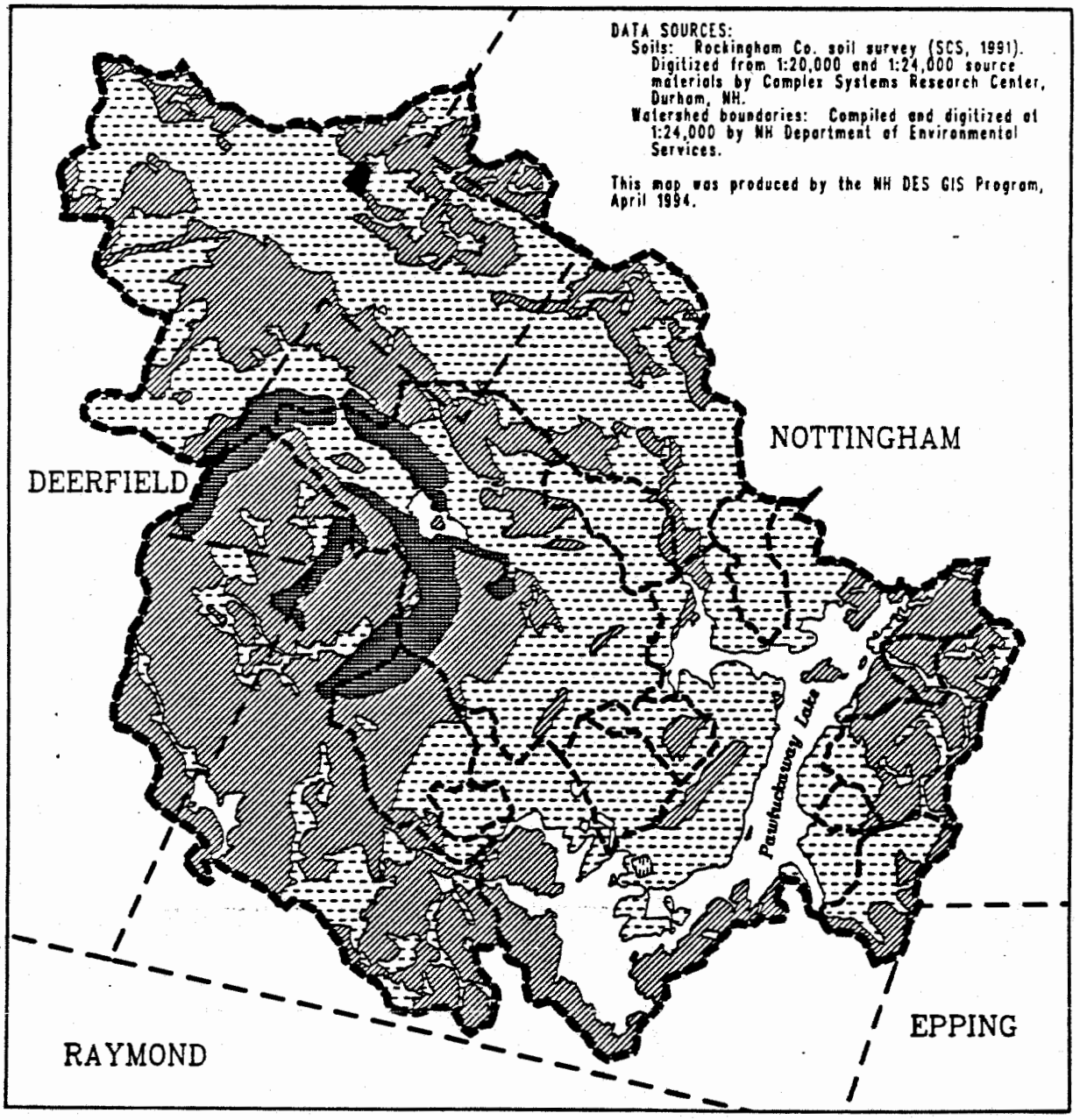

Figure III-5: Depth to Bedrock in the Pawtuckaway Lake Watershed

Within a half-mile buffer of Pawtuckaway Lake, 73.1% of the land is classified as having severe limitations for septic systems and another 0.6% is classified as variable (Table III-3). The remaining soil types have moderate limitations or exist as water within the half-mile buffer of the lake. As Table III-3 illustrates, the majority of the shoreline is limited by either depth to bedrock (27.3%) or by soils that act as a poor filter (31.0%). Moderate limitations exist along the eastern shoreline of the lake and in several areas of Pawtuckaway State Park in the southern end of the lake. Variable limitations which are classified as urban land exist within the state park and coincide with the beach and parking lots.

Table III-3
Soil Limitations for Septic Systems Within a Half-mile Buffer of Pawtuckaway Lake

Limitation	Acres	Percentage
Variable	22.8	.6
Percs Slowly	58.6	1.4
Wetness / Poor Filter	98.7	2.4
Ponding / Percs Slowly	112.2	2.8
Wetness / Percs Slowly	127.5	3.1
Ponding Subsides	205.6	5.1
Moderate	235.2	5.8
Water	829.9	20.4
Depth to Rock	1,107.8	27.3
Poor Filter	1,258.7	31.0

E. LAND COVER AND LAND USE REGULATION, GENERAL OVERVIEW

The water quality of a lake or pond is influenced, in part, by the type of human and natural activities that occur within the confines of a watershed. Much of the rainwater, snow melt-water and groundwater found within the watershed will eventually end up in the lake or

DEPTH TO BEDROCK ADJACENT TO PAWTUCKAWAY LAKE

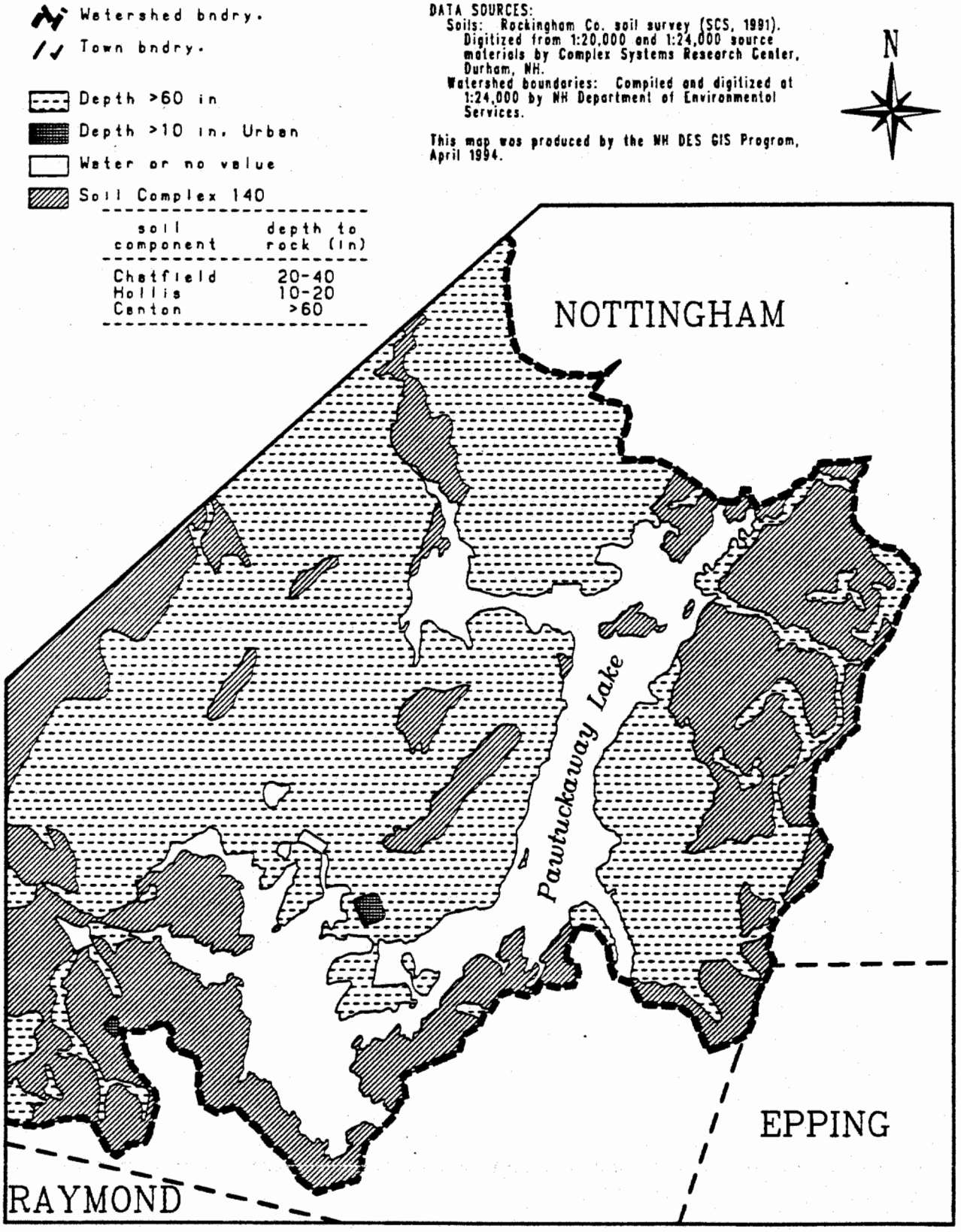

Figure III-6: Depth to Bedrock Adjacent to Pawtuckway Lake

pond. The downward migration of the surface and groundwater can carry pollutants found in the watershed, including nutrients such as phosphorus and nitrogen which can cause algae blooms and accelerated eutrophication.

Poor farming practices, the buildup of large urban areas, and the removal of native vegetation are the most common human activities that impair lake quality and accelerate cultural eutrophication. Human intrusions into a watershed will accelerate the degradation of water quality much faster than natural processes.

1. Pawtuckaway Lake Land Use

Data pertaining to existing land use in the Pawtuckaway Lake watershed was derived from a land use map prepared by the Strafford Regional Planning Commission (SRPC). The SRPC adapted land use data from 1987 ASCS aerial photographs with updated information to 1993 supplied from municipal sources. The following is an estimated breakdown of the current land use in the Pawtuckaway Lake watershed.

TABLE III-4
Pawtuckaway Lake Watershed Land Use by Percentage & Acreage
(Current to 1993)

Land Use	Acreage	Percentage
Forested	5,373.2	45.0
Public Recreational	4,868.4	40.7
Open Water	1251.2	10.2
Single Family Residential	517.4	4.3
Agriculture	157.0	1.3
Open Land	48.6	.4

As the table indicates, the predominant land cover type within the Pawtuckaway Lake watershed is forested and public recreational, encompassing 45.0% and 40.7% respectively. The 4,868.4 acres of public recreational designated land use exists as Pawtuckaway State Park situated along the western shoreline of Pawtuckaway Lake. This year-round multi-use recreational park

borders the lake from Neals Cove in the south and extends north to Fundy Cove. It protects a large parcel of the watershed from further subdivision and eliminates the possibility of this area from becoming an excessive nutrient contributor to the lake.

Another 45.0% or 5,373.2 acres of the watershed is designated as forested and has minimal development and no active agricultural usage. Large parcels of forest extend from the western border of Pawtuckaway State Park to the northwestern tip of the watershed in Deerfield. Large tracts of forest skirt the entire perimeter of Pawtuckaway State Park and extend to the border of the watershed.

Pawtuckaway Lake, Dead Pond, Deer Pond, Mountain Pond and Round Pond all lie within the bounds of the Pawtuckaway Lake watershed and cumulatively comprise 1,251.2 acres or 10.2% of the watershed.

The next two largest categories of land use in the watershed are single family residential and agricultural, accounting for 4.3% (517.4 acres) and 1.3% (157.0 acres) of the area respectively. The majority of high density single family residential development has occurred along the southeastern and southwestern shoreline of Pawtuckaway Lake and exists as first and second tier seasonal and year-round homes. The homes around the perimeter of the lake have individual sub-surface sewage disposal systems. Most of the houses are situated along dirt roadways on moderate to steep terrain. Several tributaries intersect developed areas before flowing into the lake. The remaining sections of the watershed have individual homes scattered in a rural wooded setting. They are widely spaced and for the most part are located on Deerfield Road and Route 156.

Agricultural practices within the Pawtuckaway Lake watershed are intermittently scattered in the northwestern region of the watershed and consist primarily of crop fields and small hobby farms. Additional agricultural parcels exist in Nottingham Square and along Route 156 in the eastern region of the watershed. A dairy farm located in Nottingham Square is situated in the headwater area of a tributary that feeds Pawtuckaway Lake and is suspected of contributing significant amounts of nutrients to the lake.

Agriculture and residential development have long been known to impact lake systems through the addition of nutrients. Sources of nutrients from these land uses include septic systems and fertilizer runoff. Land use within the individual subwatersheds for Pawtuckaway Lake is presented in Appendix III-2.

2. Land Use Within 1,000 Foot Buffer of Pawtuckaway Lake

The predominant land cover type within a 1,000 foot buffer of Pawtuckaway Lake is public recreational and accounts for 52% (767.2 acres) of the buffer area. The existence of Pawtuckaway State Park along the western shoreline of the lake protects a large parcel of land within the 1,000 foot buffer from further subdivision. The rural character of the State Park eliminates it as a significant nutrient source from direct runoff.

The next largest category of land use within the buffer is single family residential and comprises 30% (439.2 acres) of the buffer area. There are approximately 330 first tier seasonal and year-round residences along the southern and eastern shoreline of Pawtuckaway Lake. All first and second tier development within the 1,000 foot buffer area contain individual subsurface disposal systems and are considered to be a significant source of nutrients to the lake.

The remaining land use category within the buffer exists as forested land and accounts for 18% (269.5 acres) of the buffer area. This category has minimal development and no active agriculture occurring within the parcel. The forested areas within the 1,000 foot buffer of Pawtuckaway Lake are not considered a significant nutrient source. Figure III-7 illustrates general land use categories within the Pawtuckaway Lake watershed. Appendix III-3 presents the land use in the drainage area adjacent to Pawtuckaway Lake.

F. WETLANDS

Wetlands are ground features that are periodically or permanently inundated or saturated by surface or groundwater and support vegetation adapted for life in saturated soil. This definition includes swamps, marshes, bogs and similar areas. Wetlands provide fish and wildlife habitat, food chain production, nesting, spawning, rearing and resting sites for aquatic and land species, protection of other areas from wave action and erosion, storage areas for storm and flood waters, natural recharge areas where ground and surface water are interconnected, and natural water filtration and purification functions.

As Figure III-8 indicates, wetland areas are present throughout the entire Pawtuckaway Lake watershed. Wetland complexes are found within each of the thirteen inflowing tributary sub-watersheds and account for approximately 12% (1386 acres) of the entire watershed.

PAWTUCKAWAY LAKE WATERSHED: LAND COVER

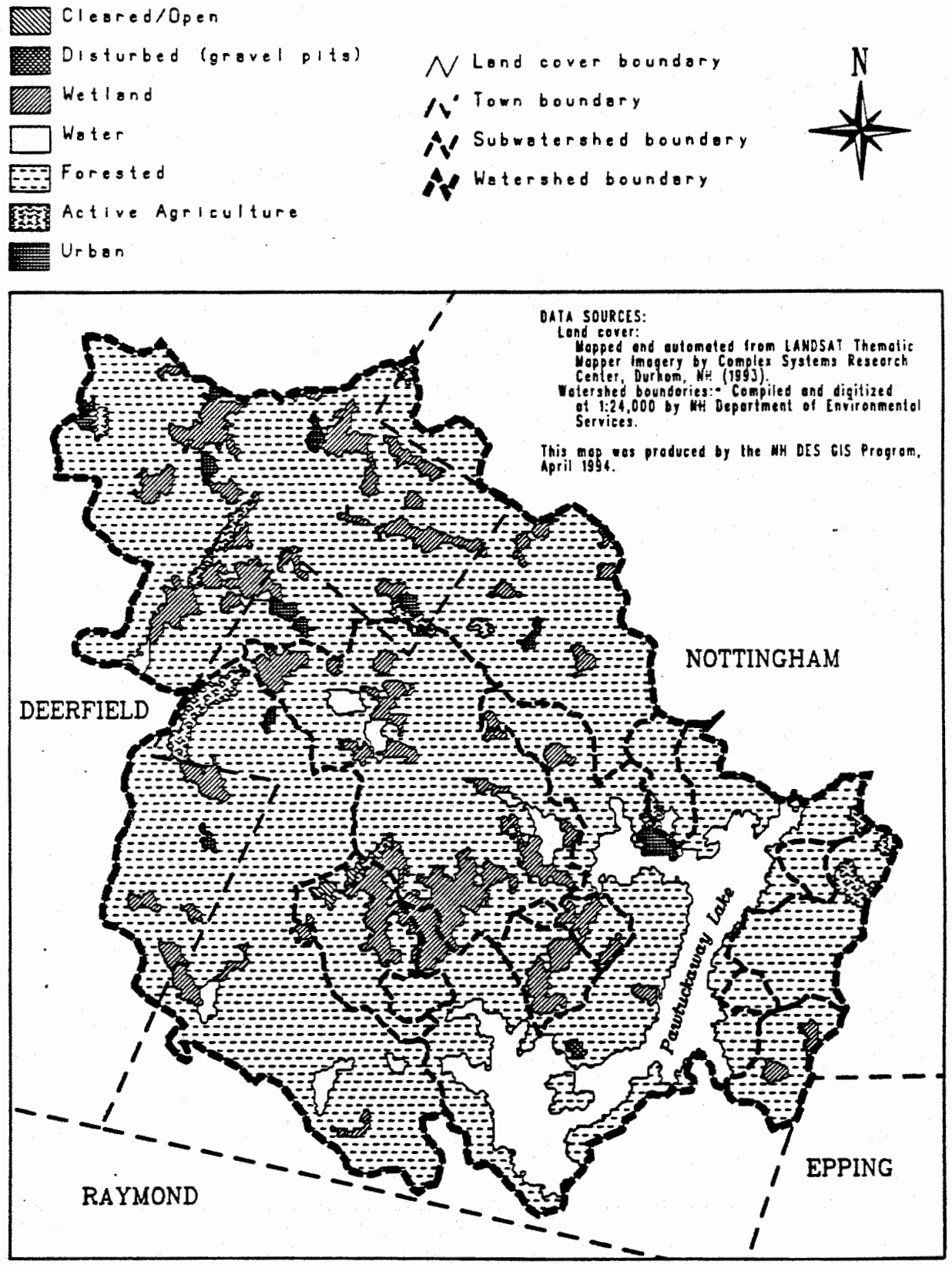

Figure III-7: Land Cover within the Pawtuckaway Lake Watershed

PAWTUCKAWAY LAKE WATERSHED: WETLANDS

DATA SOURCES:
Land cover:
Mapped and automated from LANDSAT Thematic Mapper Imagery by Complex Systems Research Center, Durham, NH (1993).
Watershed boundaries: Compiled and digitized at 1:24,000 by NH Department of Environmental Services.

This map was produced by the NH DES GIS Program, April 1994.

Stream or Shoreline
Town boundary
Subwatershed boundary
Watershed boundary

N

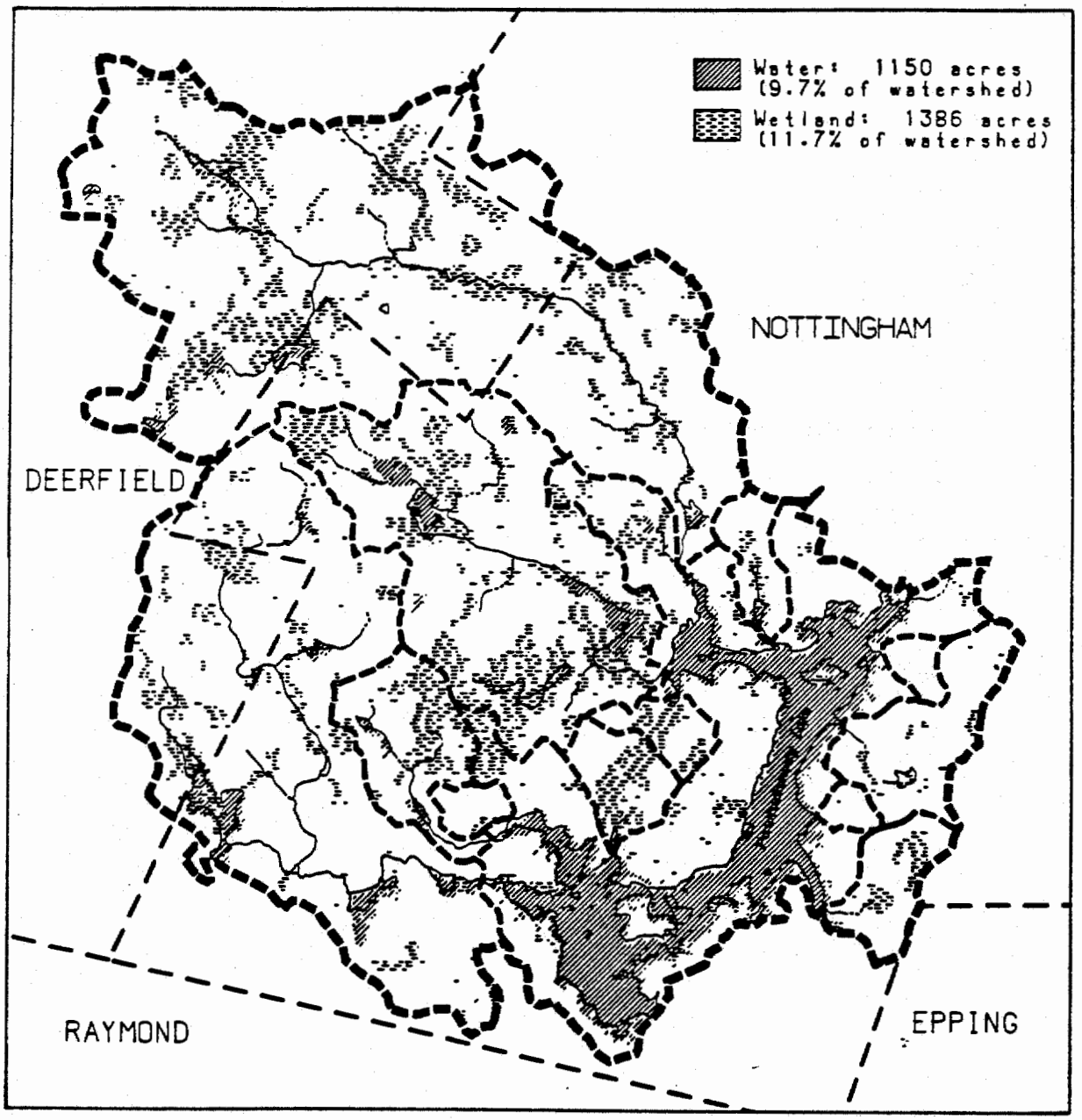

Figure III-8: Wetlands in the Pawtuckaway Lake Watershed

Wetlands play a vital role in filtering nutrients and purifying water before it reaches Pawtuckaway Lake. Wetlands within the Round Pond Brook subwatershed filter and purify the water exiting Round Pond which is a nutrient rich, eutrophic waterbody. Wetlands also provide large storage capacity for spring runoff and storm events within the watershed. This is a vital function within the Pawtuckaway Lake watershed since 1 inch of runoff increases the lake level 16 inches. Much of the hydrology within the watershed is influenced by the presence of wetland areas.

CHAPTER IV MONITORING PROGRAM, SCOPE AND METHODOLOGY

A. MORPHOMETRY

The Pawtuckaway Lake basin was formed as a result of channelized meltwater from glacial recession. The lake lies within the Town of Nottingham at 43°05'00"N latitude and 71°09'00"W longitude. The watershed is split between the towns of Nottingham and Deerfield with 74% lying in Nottingham and 26% in Deerfield. Pawtuckaway Lake is a north temperate dimictic lake (lake that has complete vertical mixing twice a year) with a shore length of 41,010.00 meters (134,547 ft) and an area of 478 hectares (1,180 acres). The lake's mean depth is 3.3 meters (9.84 ft) and the maximum depth is 15.3 meters (50.18 ft). It lies approximately 76.2 meters (250 ft) above sea level. The total volume of the lake is 15,812,628m^3. The watershed area which drains into the lake is 4795.9 hectares (11,851 acres). The physical morphometry of the lake is summarized in Table IV-1. A recent bathymetric map portraying the depth contours appears in Figure IV-1. Data to construct this map was obtained by conducting a series of transects with a digital fathometer. Lake volume was calculated by summing the volumes between successive contours using in-house software.

The watershed boundary was drawn from a USGS topographic map and its area was determined planimetrically.

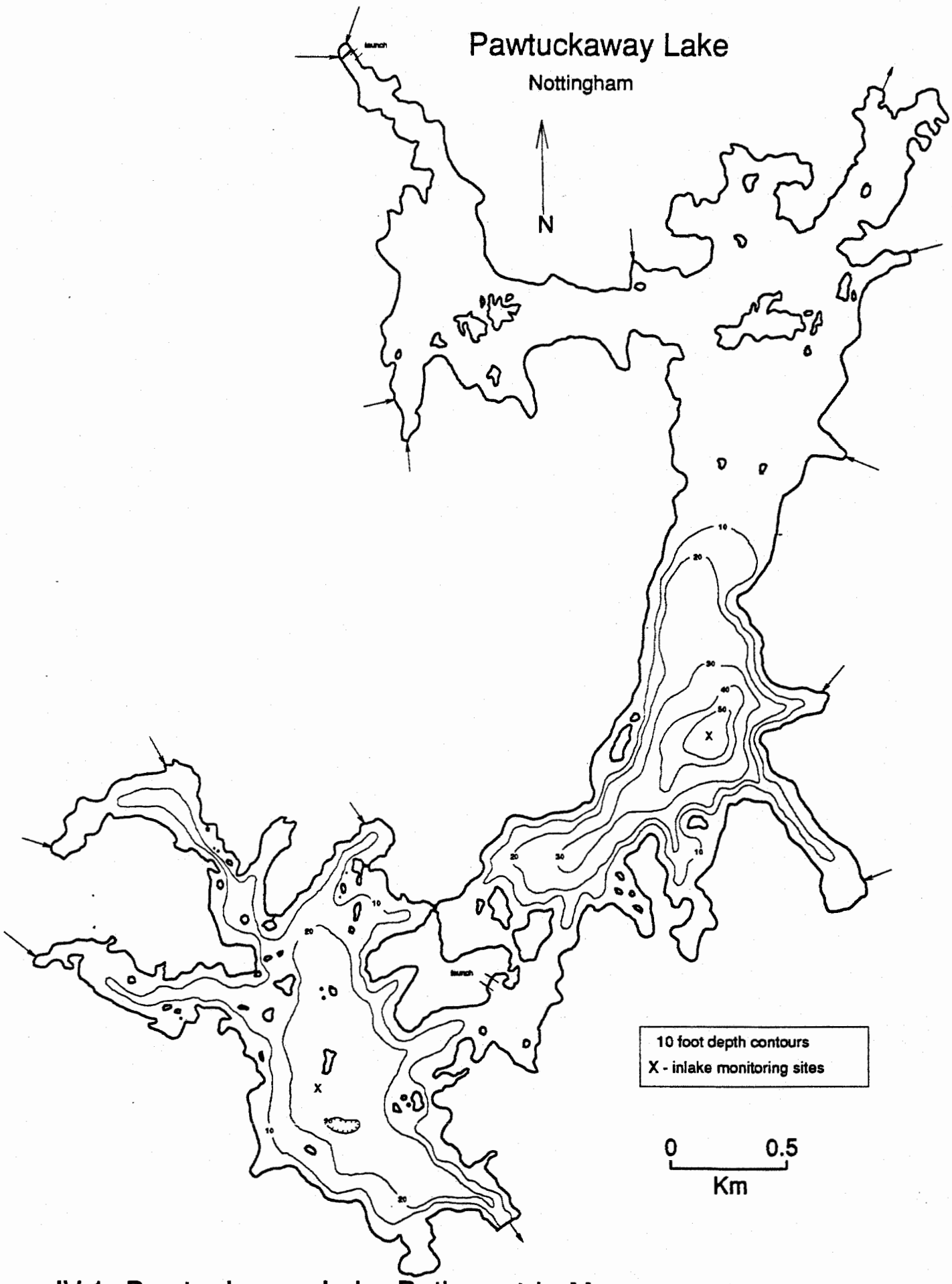

Figure IV-1: Pawtuckaway Lake Bathymetric Map

Table IV-1
Physical Morphometry Summary

Lake:	Pawtuckaway Lake	Lake area (ha):	478.00
Town:	Nottingham	Lake area (acres):	1,180.00
County:	Rockingham	Maximum depth (m):	15.30
River Basin:	Coastal	Mean depth (m):	3.30
Latitude:	43°05'00" N	Shore length (m):	41,010.00
Longitude:	71°09'00" W	Relative depth:	0.60
Lake type:	natural w/dam	Shore configuration:	5.29
Volume (m^3):	15,812,628.00	Areal water load (m/yr):	4.53
Elevation (ft):	250.00	Flushing rate (yr^{-1}):	1.71
Watershed area (ac):	11,851.00	P retention coeff.:	0.67
Watershed area (ha):	4,795.90	% watershed ponded:	0.20

B. STATION LOCATIONS AND DESCRIPTIONS

Sampling locations, depicted in Figure IV-2, were chosen to include all inlets and outlets. Table IV-2 presents a brief description of each tributary sample station. Two lake quality monitoring stations were established at the two deepest sections of Pawtuckaway Lake (15.3 meters and 6.5 meters). The North Station (15.3 meters) was sampled at one third and two thirds of the water depth during the unstratified season, and at three depths during the stratified season. The South Station (6.5 meters), was sampled at two depths, 2.0 and 5.0 meters throughout the study year because it remained unstratified year-round. Lake quality, in general, varied with depth, reflecting different density layers achieved in dimictic lakes.

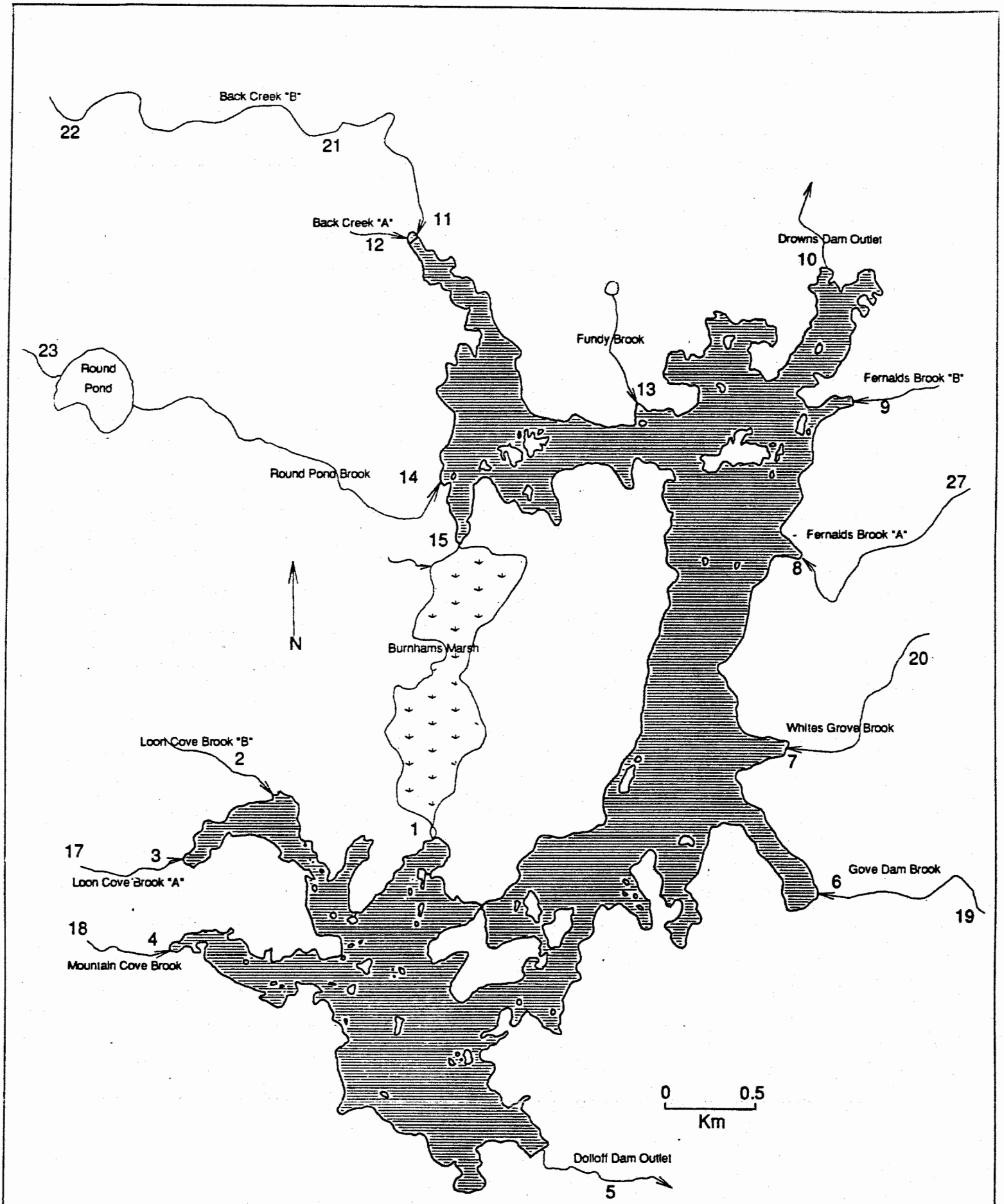

Figure IV-2: Pawtuckaway Lake Tributary Sample Locations

Table IV-2
Description of Sampling Stations

Station # & Site Name	Site Description
1. Burnhams Marsh Outlet (South)	Southern outlet of Burnhams Marsh discharges into lake next to State Park Beach through spillway.
2. Loon Cove Brook B	Culverted under State Park Road entering Loon cove from the northwest.
3. Loon Cove Brook A	Drains area along State Park boundary and enters lake at western terminus of Loon Cove.
4. Mountain Cove Brook	Accommodates outlet waters from Deer Pond and Mountain Pond before being culverted under State Park Road and Mountain Road. Enters lake at western terminus of Neals Cove.
5. Dolloff Dam Outlet	Runs adjacent to Dolloff Dam Road and culverts under Route 156.
6. Gove Dam Brook	Discharges into lake 100 yards north of Gove Dam.
7. Whites Grove Brook	Culverted under White Grove Road and enters lake adjacent of Whites Cottages beach area.
8. Fernalds Brook A	Culverted under Barderry Lane and discharges into lake through Lot 42.
9. Fernalds Brook B	Enters lake northeast of Log Cabin Island and passes through a wetland area.
10. Drowns Dam Outlet	Outlets adjacent to Nottingham Town Beach and culverts under Deerfield Road.
11. Back Creek B	Passes under Deerfield Road and discharges into Fundy Cove adjacent to boat ramp.
12. Back Creek A	Originates in State Park and merges with Back Creek B north of Fundy Boat ramp.
13. Fundy Brook	Drains forested area and enters lake at midpoint of Fundy Cove.
14. Round Pond Brook	Originates at outlet of Round Pond and discharges into southwestern lobe of Fundy Cove.
15. Burnhams Marsh Outlet (North)	Northern outlet of Burnhams Marsh enters Fundy Cove through spillway immediately south of Round Pond Brook.
17. Loon Cove Brook A (upstream)	Culverted under State Park Entrance Road.
18. Mountain Cove Brook (upstream)	Adjacent to Mountain Pond trail. Northwest of Mountain Road.
19. Gove Dam Brook (upstream)	Culverted under Route 156.
20. Whites Grove Brook (upstream)	Culverted under Barderry Lane.
21. Back Creek B (upstream)	Culverted under Deerfield Road in Nottingham.
22. Back Creek B (uptream)	Culverted under Deerfield Road in Deerfield.
23. Round Pond Brook (upstream)	Inlet to Round Pond.
27. Fernalds Brook A (upstream)	Culverted under Route156.

The lake has eleven major tributaries, several minor and seasonal tributaries and two outlets. Data from seasonal tributaries are sparse and not included in any statistical analysis. The major tributary, Back Creek B (#11), feeds into the lake at the northwest corner adjacent to the public boat launch in the Fundy area and drains 3698 acres of watershed. The tributary

passes predominantly through forest and large wetland areas. The tributary is culverted under Deerfield road at six different locations before discharging into Pawtuckaway Lake.

The next largest drainage area is the Mountain Cove Brook (#4) subwatershed. This 2,400 acre subwatershed receives a large amount of runoff from the Pawtuckaway Mountains and also serves as the outlet from Deer Pond. The tributary flows through wetland areas within the state park and is impounded by significant beaver activity before being culverted under Mountain Road and into the lake at Mountain Cove.

The third largest subwatershed area is drained by Round Pond Brook (#14). This brook is the outlet to Round Pond and its 1599 acre subwatershed lies completely within state park boundaries. It enters Pawtuckaway Lake in the northwest portion of Fundy Cove, just north of the Burnhams Marsh northern outlet.

The remaining tributaries are similar in areas and are listed in order of ascending station number. Burnhams Marsh Outlet South (#1) is an inlet to Pawtuckaway Lake that enters through a spillway and culvert adjacent to the state park beach. Loon Cove Brook B (#2) drains a small subwatershed within the state park and enters the lake in the northern portion of Neals Cove after being culverted under the state park road. Loon Cove Brook A (#3) drains several wetland areas within the state park and enters the lake in the northern portion of Neals Cove after being culverted under the state park road. Gove Dam Brook (#6) originates in a wetland area and passes under Route 156 before entering the lake just north of Gove Dike on the eastern side of Pawtuckaway Lake. Whites Grove Brook (#7) originates north of Barderry Lane and is culverted under both Barderry Lane and Whites Grove Road before discharging into the lake on the eastern shoreline. Fernalds Brook A (#8) enters the lake from the northeast and collects agricultural runoff from the Fernalds Farm pastures and grazing fields. The tributary meanders through several beaver impoundments before being culverted under Barderry Lane where it receives erosional debris from unstabilized slopes on Barderry Lane. Fernalds Brook B (#9) enters from the northeast and drains a steep forested area before flowing through a beaver impoundment and into the lake. Back Creek A (#12) originates from a wetland area in the northwest and enters the lake adjacent to Back Creek B in the northern tip of Fundy Cove. Finally, Fundy Brook

(#13) joins the lake at the northern midpoint of the Bay of Fundy area and drains a small pond in a wetland area.

The outlets of the lake are at opposite ends and discharge north and south. Drowns Dam (#10) outlets in the northeast corner of the lake and eventually joins the North River. Water discharged over Dolloff Dam in the south forms the Pawtuckaway River. Discharge from the two outlets at Pawtuckaway Lake eventually reaches the Lamprey River. Figure IV-3 presents subwatershed hydrology for each tributary within the Pawtuckaway Lake watershed.

C. LAKE FIELD PROCEDURES

Lake stations were sampled monthly from October 1991 through November 1992. Additional sampling was conducted during the summer of 1991, 1992 and 1993 by volunteer lake monitors from the Pawtuckaway Lake Improvement Association. These additional samples were collected under the New Hampshire Volunteer Lake Assessment Program.

Temperature and dissolved oxygen were measured at one meter intervals using a YSI model 50, 54 or 57 oxygen meter during open water periods, and hypolimnetic dissolved oxygen was measured using the Winkler method (azide modification), during the ice-cover period. Temperature was recorded to the nearest 0.1 degrees Celsius. Dissolved oxygen was recorded to the nearest 0.1 mg/L.

Water samples were collected with a Wildco Kemmerer water sampler. All samples were preserved according to EPA Standard Procedures. Samples were stored in a cooler and immediately returned to the NHDES laboratories in Concord, NH for analysis.

Transparency was measured to the nearest 0.1 meter using a 20 cm Secchi disk with alternate white and black quadrants. Net phytoplankton and zooplankton were collected by hauling an 80 micron mesh net vertically from the thermocline to the surface. One plankton sample was preserved in the field with Lugol's solution, a second was returned live to aid in species identification. Wholewater phytoplankton, for inverted microscope density counts, and chlorophyll-a samples were collected with an integrated water sampler (a weighted 1" ID tube), or by compositing Kemmerer samples from successive depths to the thermocline.

PAWTUCKAWAY LAKE: SUBWATERSHED HYDROLOGY

Surface Water
Wetland
Town Boundary
Stream or Shoreline
Intermittent Stream
Watershed Boundary
Subwatershed Boundary
(watershed acreage shown in parenthesis)

Data sources:
Watershed boundaries compiled and digitized at 1:24,000 by NH Department of Environmental Services.
Hydrography and political boundaries from 1:24,000-scale USGS Digital Line Graph (DLG) data.

This map was produced by the NH DES GIS Program, April 1994.

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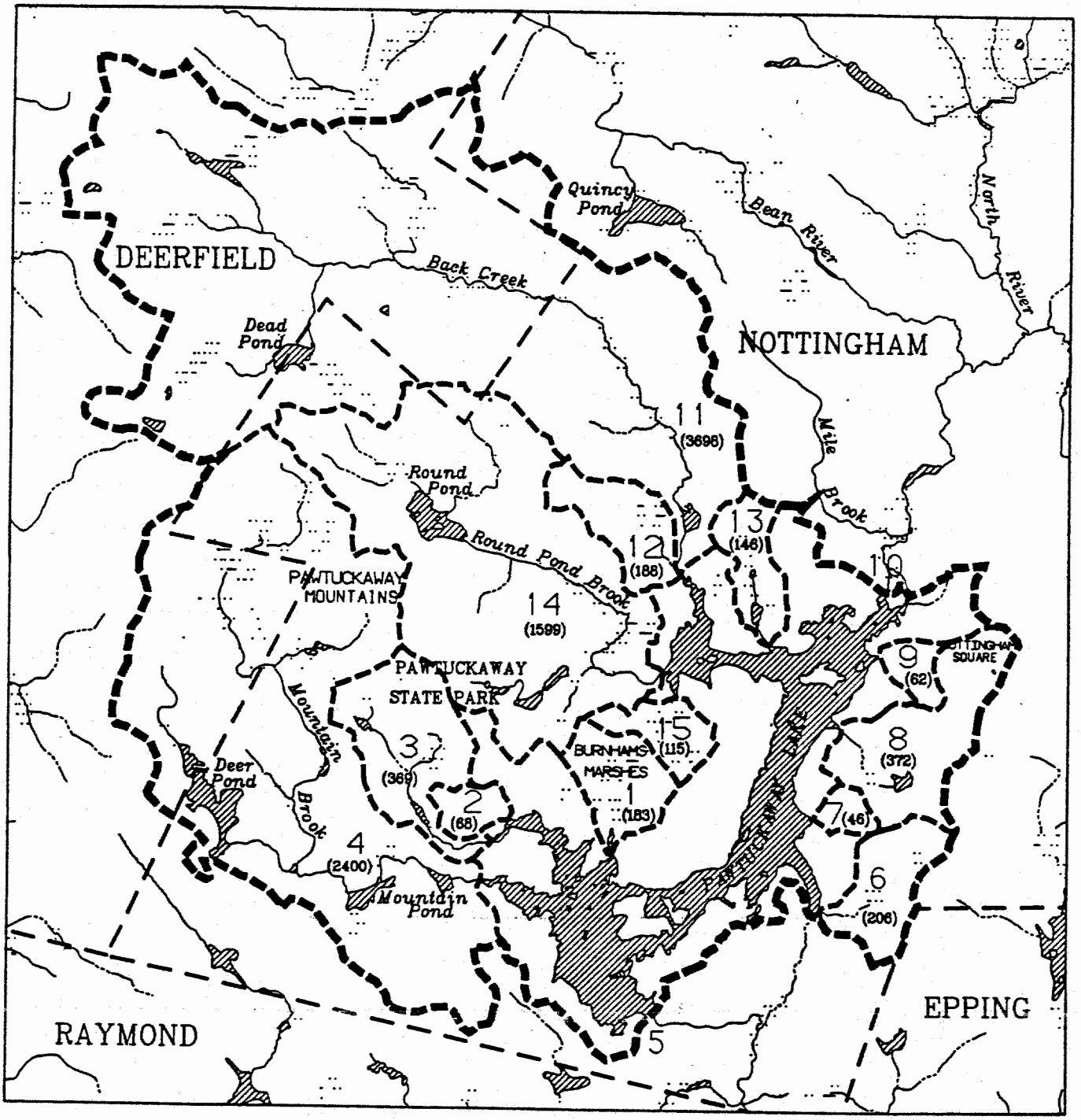


Figure IV-3: Subwatershed Hydrology of Pawtuckaway Lake

D. STREAM FIELD PROCEDURES

The tributary stations were sampled at least every two weeks from October 1991 through November 1992. Staff gage measurements were recorded bi-weekly; once by NHDES personnel and once by volunteers from the Pawtuckaway Lake Improvement Association. Flow measurements were taken during ice-out conditions using a Marsh McBirney FlowMate 2000 flow meter. Samples were collected by dipping laboratory bottles to mid-depth at mid-stream in flowing water. Table IV-3 summarizes the sampling parameters for the Pawtuckaway Lake Study.

Table IV-3
Sampling Parameters for Pawtuckaway Lake Study

Parameter:	Location:	Parameter:	Location:
Specific Conductance	Lake and Streams	pH	Lake and Streams
Total Kjeldahl Nitrogen	Lake and Streams	Chlorides	Lake and Streams
Acid Neutralizing Capacity	Lake and Streams	Color	Lake and Streams
Total Phosphorus	Lake and Streams	Sulfates	Lake and Streams
Nitrate Nitrogen	Lake and Streams	Chlorophyll-a	Lake
Temperature/Dissolved Oxygen	Lake	Plankton	Lake
Transparency	Lake	Turbidity	Streams

E. GROUNDWATER SEEPAGE FIELD PROCEDURES

Groundwater seepage into the lake was measured at least three times a month during the growing season at 14 locations around the shoreline of Pawtuckaway Lake. Seepage meters were constructed using the top and bottom thirds of 55 gallon drums (Connor, 1979). A cork with rigid tubing was inserted into the flat portion so that a plastic whirl pack, cork and tubing could be attached (see Figure IV-4). After one hour, the plastic whirl packs were removed, and the amount of seepage was measured and recorded.

An interstitial pore water sampler was used to collect groundwater for chemical analysis. See Figure IV-5 for a description of this specialized sampler. Interstitial pore water samples

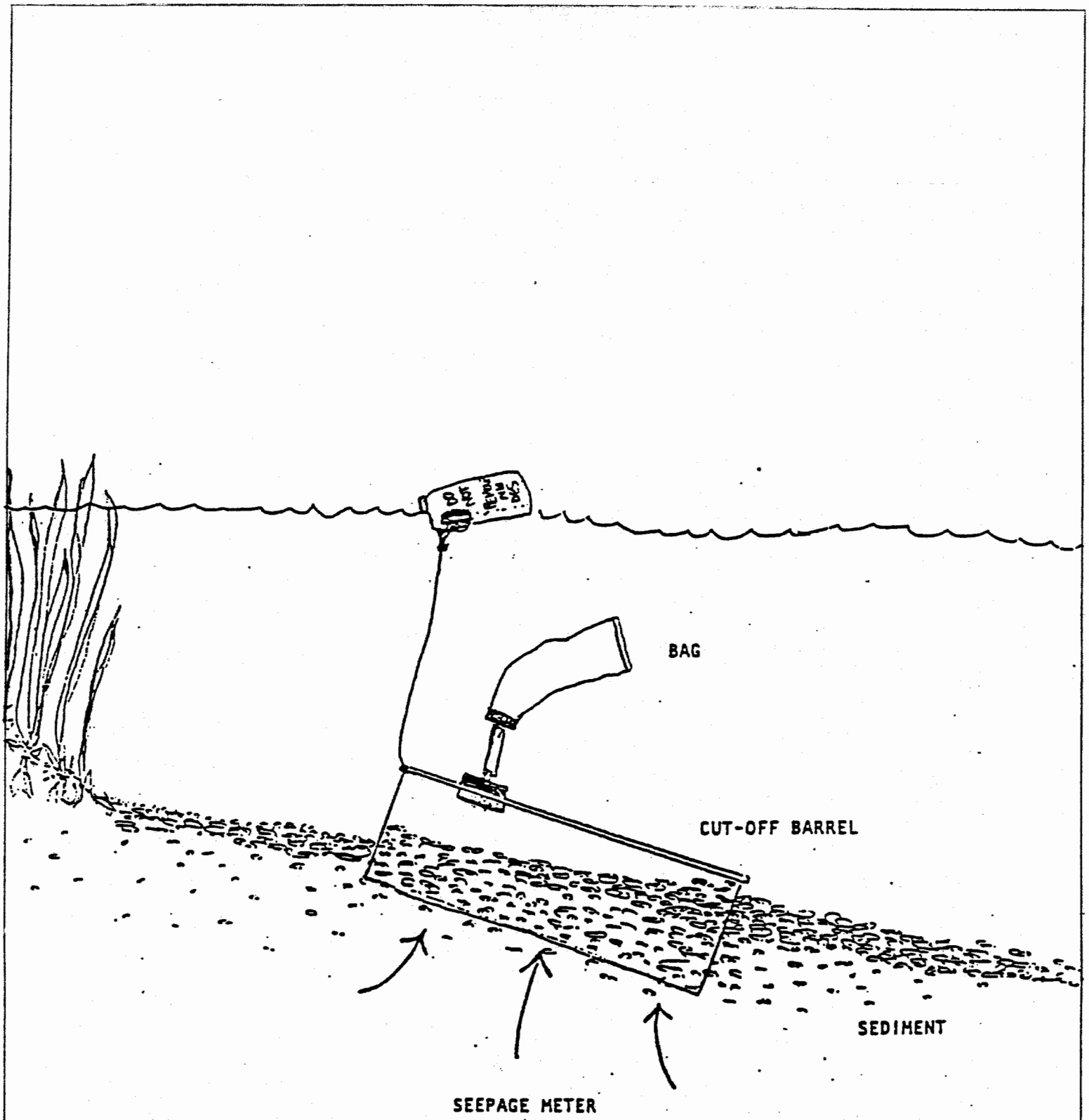


Figure IV-4: Seepage Meter Diagram

(IPWS) were collected at the 14 seepage meter locations within the lake.

Several shallow dug wells were also sampled and analyzed for nutrients in groundwater. Samples were collected from outside faucets or pumped directly from wells with a Masterflex pump. Figure IV-6 indicates seepage meter/IPWS locations as well as shallow dug well locations.

F. SEDIMENT ANALYSIS

Sediment cores were taken at both lake stations using a Wildco KB^{tm} coring device. Samples were analyzed for recoverable Al, Cd, Cu, Fe, Pb, Mg, Zn and P. A complete description of sediment analysis techniques and results appears in Chapter IX.

G. LABORATORY METHODOLOGY

1. Chemical and Physical

Table IV-4 presents the laboratory methods utilized for chemical and physical parameters. Acid neutralizing capacity, pH, specific conductance, and color analyses were performed by biologists in the Limnology Center. Chloride, sulfate, total phosphorus, nitrate nitrogen, and total Kjeldahl nitrogen analyses were performed by the Laboratory Services Unit. Both the Limnology Center and the Laboratory Services Unit are EPA inspected with approved quality assurance and quality control programs.

2. Biological

Table IV-4 also presents the laboratory methods utilized for biological parameters. All analyses were performed by biologists in the Limnology Center. Phytoplankton and zooplankton were identified to genus. Relative abundance was computed for net phytoplankton. Zooplankton and phytoplankton densities were also determined. Chlorophyll-a measurements, and actual cell densities were used to determine algal biomass.

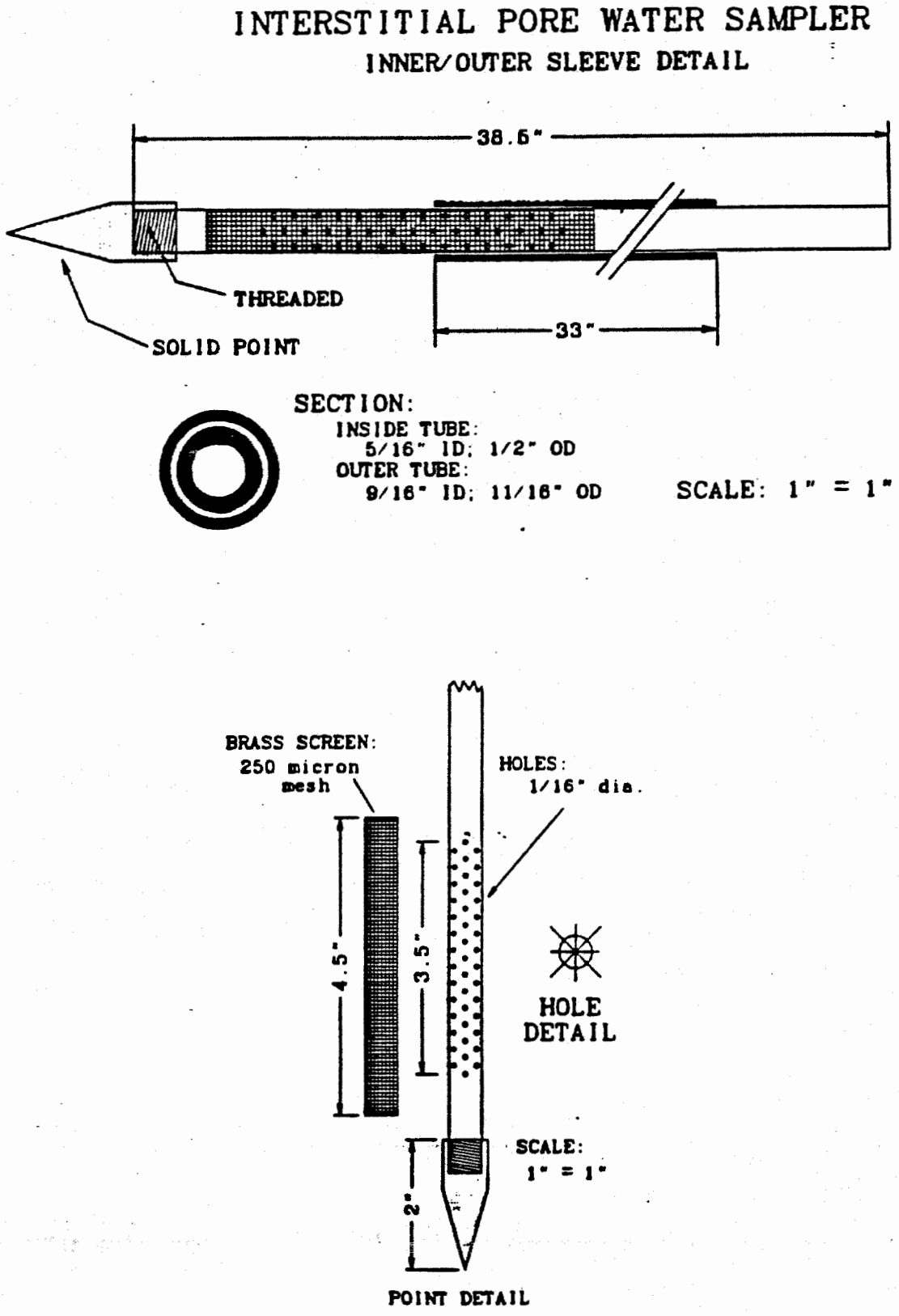


Figure IV-5: Interstitial Pore Water Sampler Diagram

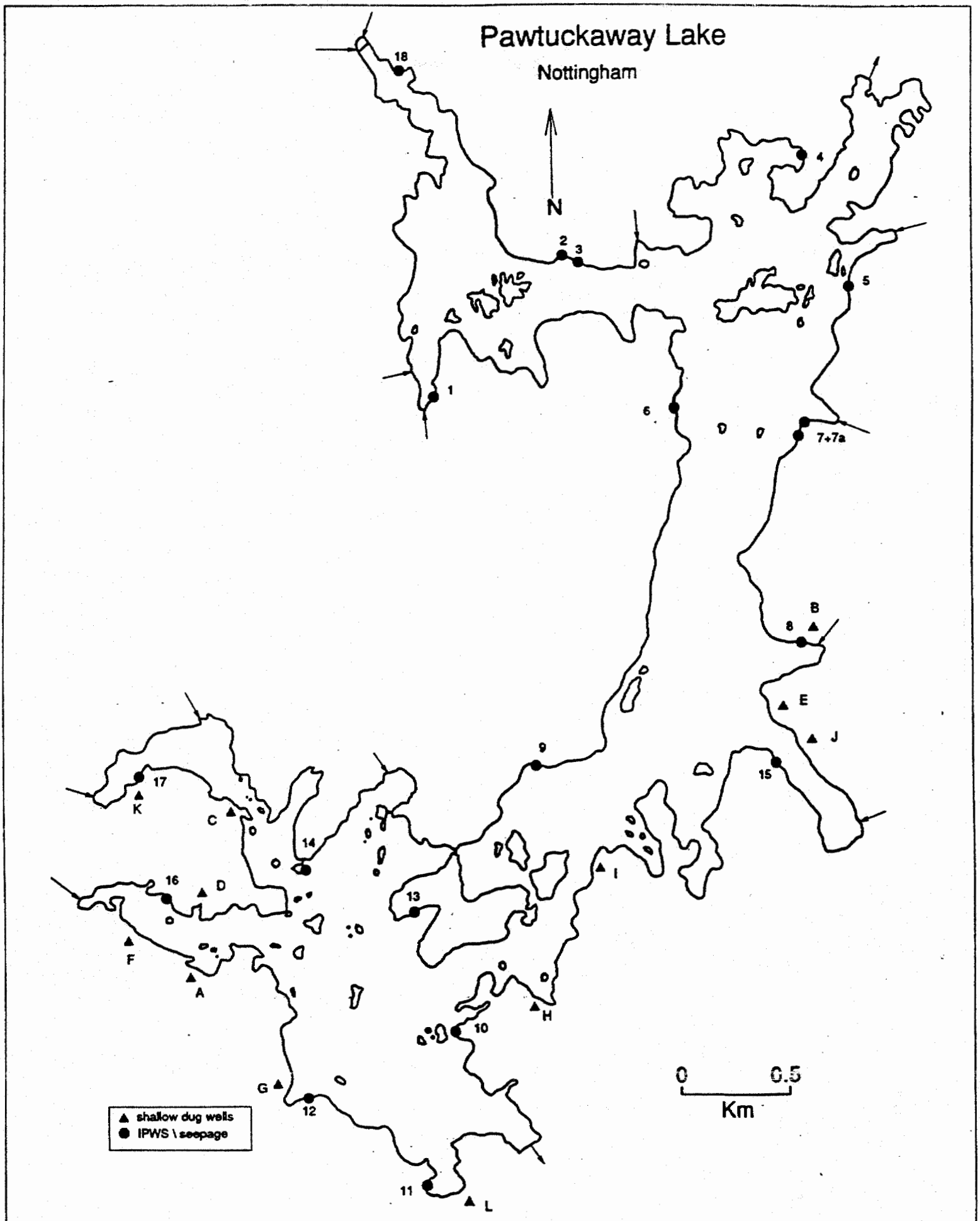


Figure IV-6: Pawtuckaway Lake Dug Wells and IPWS/Seepage Locations

Table IV-4

Laboratory Parameters and Methods Used for Analysis

Parameter:	Method:
pH	Electrometric
Acid Neutralizing Capacity	Titration, Electrometric, Granplot
Total Phosphorus	Colorimetric, Persulfate, Digestion **365.2 PQL 0.001 mg/L*
Specific Conductance	Wheatstone Bridge Type Meter
Apparent Color	Colorimetric, Platinum-cobalt
Chloride	Ion Chromatography ***300.0 *PQL 2mg/L*
Sulfate	Ion Chromatography ***300.0 detection limit 0.5mg/L*
Nitrate Nitrogen	Ion Chromatography ***300.0 *PQL 0.05mg/L*
Total Kjeldahl Nitrogen	Auto-Analyzer with Block Digester ***351.2 *PQL 0.10mg/L*
Net Phytoplankton (relative abundance)	Phase Contrast Microscopy, Sedgwick-Rafter Cell
Zooplankton (density counts)	Phase Contrast Microscopy, Sedgwick-Rafter Cell
Wholewater Phytoplankton	Inverted Microscope, Settling Chamber
Chlorophyll-a	Spectrophotometric, Trichromatic
Total Coliform MF, MPN	***SM-909A, 908A*
Fecal Coliform MF, MPN	***SM-909C, 908C*
*PQL = Practical Quantitation Level	***EPA Method*

CHAPTER V WATER QUALITY

A. TEMPERATURE AND DISSOLVED OXYGEN

Pawtuckaway Lake has a typical thermal stratification cycle for a north temperate dimictic lake. Stratification developed by the middle of May and remained until late October, with the depth of the thermocline becoming characteristically progressively deeper as the summer progressed. During June and July the thermocline existed from 3.0 to 7.0 meters at the North Station and from 4.0 to 5.0 meters at the South Station. During August, the thermocline depths ranged from 4.0 to 7.0 meters at the North Station and from 5.0 to 6.5 meters at the South Station. By mid-October the South Station was mixed, with less than a one degree temperature difference from the surface to the bottom (7.0 m). By early November the North Station had mixed, with less than a two degree temperature difference from the surface to the bottom (15.3 m). Pawtuckaway lake had isothermal conditions during spring and fall overturn, and was typically inversely stratified during ice-cover periods. Typical summer D.O./Temp profiles for the North and South Stations at Pawtuckaway Lake appear in Figures V-1 and V-2 respectively. Additional profiles and raw data are compiled in Appendix V-1.

The North Station of Pawtuckaway Lake exhibited anoxic conditions in the hypolimnion from early June through the fall turnover. A zone of anoxia became established from 11.0 meters to the bottom (14.5 m) by early July and expanded steadily as the summer progressed. By late September and into early October, anoxic conditions existed from 7.0 meters to the bottom of the lake. The South Station at Pawtuckaway Lake has a maximum depth of 6.8 meters and exhibited anoxic conditions from 6.5 meters to the bottom during early June and continued into early July. The water column at the South Station mixes more freely than the North Station and didn't develop a strong three layered stratification during the summer. As a result, anoxic conditions were not present at the South Station for the majority of the summer months.

Several factors contribute to hypolimnetic anoxia, including strong thermal stratification

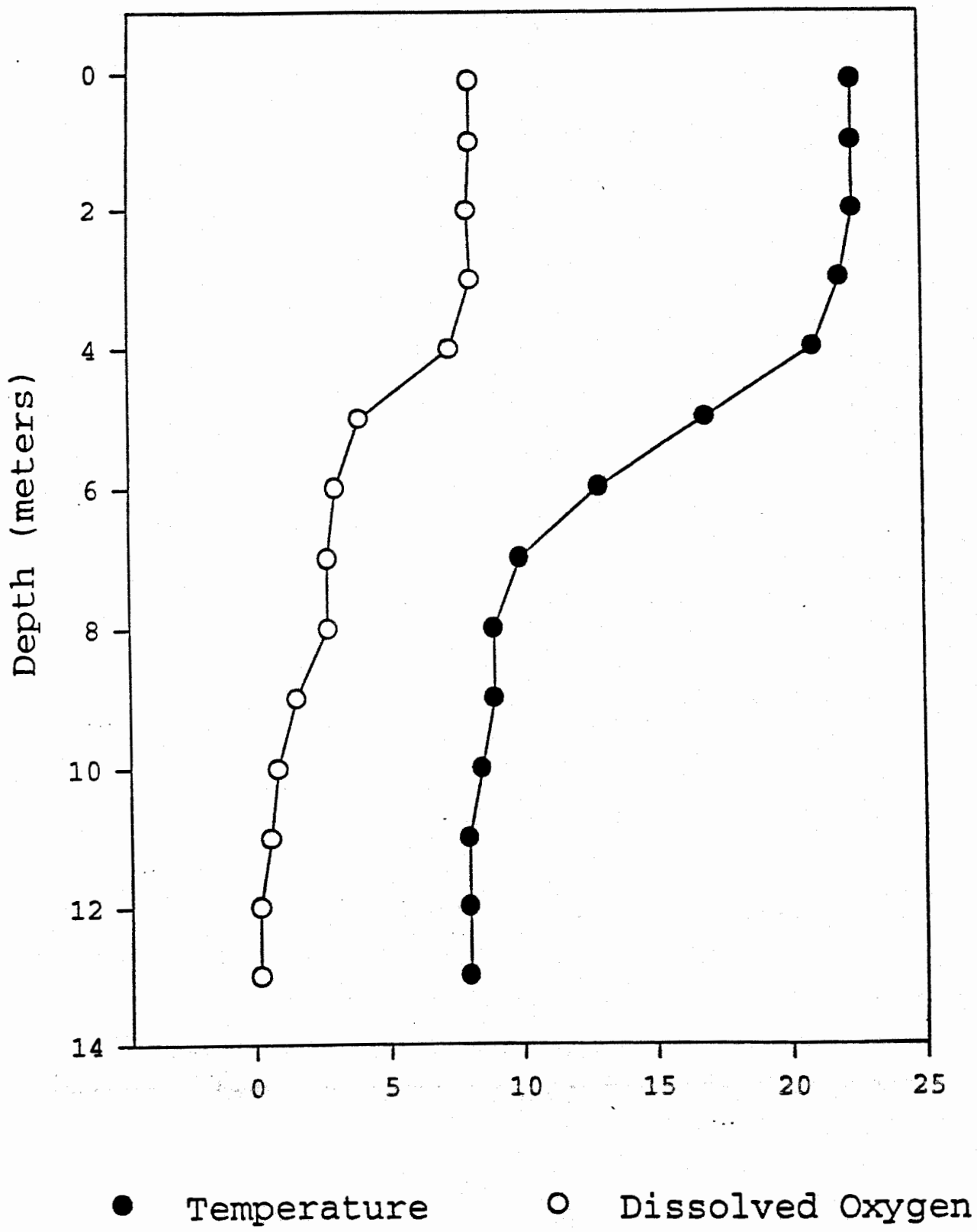


Figure V-1: Pawtuckaway Lake North Typical Summer D.O./Temp. Profile

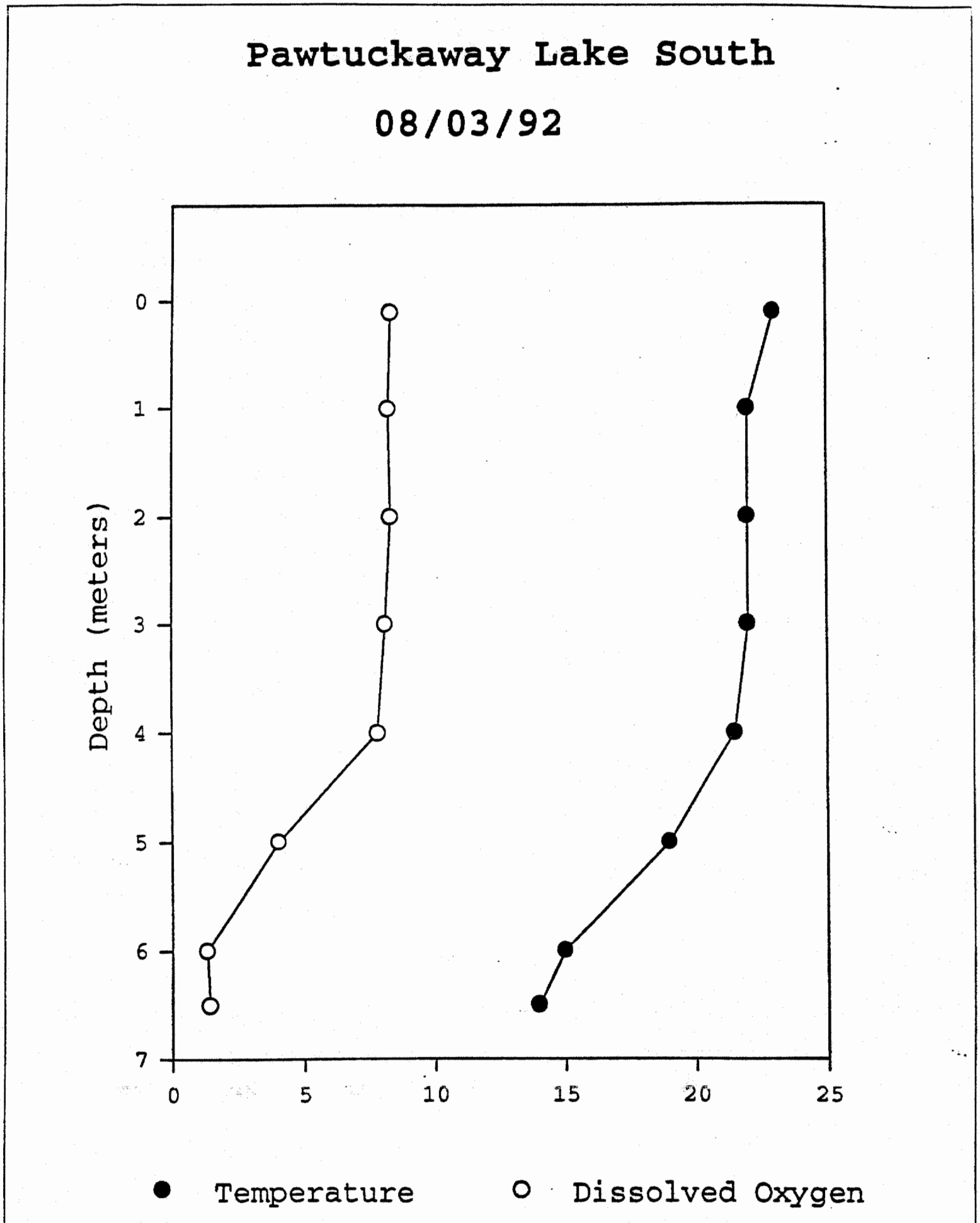


Figure V-2: Pawtuckaway Lake South Typical Summer D.O./Temp. Profile

and various biological and chemical interactions that occur in the hypolimnion. Significant biological utilizers of dissolved oxygen include the population of decomposing bacteria which break down all organic material that drifts to the pond's bottom. This process utilizes available oxygen and liberates carbon dioxide.

Hypolimnetic anoxia is significant in the North Station of Pawtuckaway Lake because it allows for the release of phosphorus from bottom sediments into the overlying water layer (internal loading). This liberated phosphorus, being a limiting nutrient for plant life, may cause seasonal planktonic blooms in the pond.

B. PH AND ACID NEUTRALIZATION CAPACITY (ANC)

The hydrogen ion concentration, or pH, is defined as the negative base 10 logarithm of the hydrogen ion activity in moles per liter. The pH scale ranges from 0-14 with 7 being a neutral value. "Pure" water has a pH of 7 which means it contains $1X10^{-7}$ moles per liter of hydrogen ions. The pH scale is logarithmic, therefore each unit change is a tenfold change. A pH of 5 is ten times more acidic than a pH of 6. "Natural" rain water at equilibrium with the atmosphere has a pH of 5.6. Most New Hampshire lakes are slightly acidic, with pH values between 6 and 7. When the pH value falls between 6 and 5.5 the waters are considered endangered. Lakes with pH's from 5.4 to 5 are considered in the critical range, and below this point lakes are considered acidified.

One of the most important reactions occurring in water, and one which affects pH, is that of dissolved carbon dioxide, represented by the following equilibrium equation:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \rightleftharpoons H^+ + CO_3^=$$

When phytoplankton consume CO_2 during daylight hours in photosynthesis, the equilibrium shifts toward the left. This results in fewer free H^+ ions, causing a decrease in H^+ ion concentration and thus an increase in pH. It is, therefore, not uncommon to find high pH values associated with an algal bloom.

The acid neutralizing capacity (ANC) of water is the capacity of water to accept protons,

or, in other words, to neutralize hydrogen ions. It is primarily a measure of the concentration of carbonates, bicarbonates, and hydroxides in the water. New Hampshire lake waters are generally low in ANC (ranging from 2 to 20 mg/L as $CaCO_3$). This is due in part to the State's granitic bedrock which contains few of these compounds. As a result, New Hampshire lakes have a poor buffering capacity, and thus are more susceptible to some ionic pollutants than higher ANC lakes.

1. Pawtuckaway Lake Tributary pH

The Pawtuckaway Lake tributaries had pH values ranging from a low of 5.20 units in Burnhams Marsh Outlet (North) to a high of 7.40 units in Loon Cove Brook B. The lowest true mean pH for the study year occurred in Fundy Brook and was 5.40 units. The highest true mean pH for the study year was 6.65 units in the Dolloff Dam outlet tributary. The minimum pH values recorded in Burnhams Marsh Outlet (North) and Fundy Brook reflect sub-watersheds that are dominated by wetland complexes which contribute organically derived acids such as humic and tannic acids that reduce the pH of receiving waters.

As Table V-1 illustrates, the seasonal distribution of pH values indicates that for the majority of the tributaries maximum values occurred in the summer. The range of true mean values during the summer was from 5.48 to 6.82 units. The summer is the time of maximum biological productivity within the watershed and this will cause elevated pH levels in surface waters. The only exception to this distribution was Dolloff Dam outlet which had its maximum true mean pH value during the fall.

Minimum pH values also had seasonal distribution patterns at Pawtuckaway Lake. The majority of tributaries had seasonal true mean value minima during the spring, with values ranging from 5.40 to 6.49 units. Two exceptions to this were Burnhams Marsh Outlet (South) and Fundy Brook, which experienced minimum pH values during the winter. The low pH values during the spring reflect the impact of spring runoff and the acidic characteristics of the melting snow that has accumulated within the watershed. The average pH of rainfall and snow during the study year was 4.26, with a seasonal low during the spring of 4.08 units. The two tributaries that experienced minimum seasonal pH values during the winter have subwatersheds dominated by large expanses of wetland complexes. During the winter season, biological productivity

decreases greatly, and thus there is a greater amount of free H^+ ions, and a resultant decrease in pH. Also, decomposition of organic matter in the wetland will generate CO_2, shifting the equilibrium equation to the right which rpoduces more free H^+ ions.

Table V-1
True Mean Study Period and Seasonal pH
for Pawtuckaway Lake Tributaries

Station # & Site Name	Study Period		Winter	Spring	Summer	Fall
	Mean	Median				
1. Burnhams Marsh Outlet (South)	6.39	6.40	5.82	5.95	6.77	6.64
2. Loon Cove Brook B	6.13	6.48	6.41	6.23	6.64	6.42
3. Loon Cove Brook A	6.31	6.47	6.47	6.03	6.77	6.49
4. Mountain Cove Brook	6.51	6.61	6.63	6.34	6.79	6.54
5. Dolloff Dam Outlet	6.65	6.72	6.62	6.49	6.80	6.81
6. Gove Dam Brook	6.13	6.16	6.17	5.93	6.62	6.20
7. Whites Grove Brook	5.79	5.86	5.93	5.60	6.23	5.81
8. Fernalds Brook A	6.61	6.66	6.69	6.48	6.82	6.62
9. Fernalds Brook B	6.46	6.46	6.44	6.36	6.72	6.51
10. Drowns Dam Outlet	6.35	6.47	6.22	6.20	6.65	6.49
11. Back Creek B	6.24	6.28	6.22	6.05	6.70	6.32
12. Back Creek A	6.29	6.36	6.30	6.08	6.65	6.45
13. Fundy Brook	5.40	5.40	5.32	5.40	5.48	5.41
14. Round Pond Brook	6.44	6.52	6.48	6.25	6.63	6.53
15. Burnhams Marsh Outlet (North)	5.91	6.25	6.15	5.57	6.22	6.2

The pH values of the Pawtuckaway Lake tributaries were, for the most part, within satisfactory levels. Twelve out of the fifteen tributaries monitored had study year true mean pH values above 6.0 units (Appendix V-4). The three exceptions were Whites Grove Brook, Fundy Brook, and Burnhams Marsh North which had study year means of 5.79, 5.40 and 5.91 respectively. The study year means for these three brooks place them in the endangered and

critical categories. However, the sub-watersheds of each tributary are dominated by wetlands and reflect the impact of the associated biological processes occurring within these areas.

Table V-2
Pawtuckaway Lake Tributaries
Mean Study Period and Seasonal Acid Neutralizing Capacity (mg/L as $CaCO_3$), December 1991 through November 1992

Station # & Site Name	Study Year		Winter	Spring	Summer	Fall
	Mean	Median				
1. Burnhams Marsh Outlet (South)	15.86	9.40	7.50	6.80	9.90	23.66
2. Loon Cove Brook B	5.88	5.20	4.40	3.70	9.50	5.90
3. Loon Cove Brook A	5.30	4.20	3.50	3.50	10.60	4.45
4. Mountain Cove Brook	7.14	6.40	7.10	5.10	13.50	5.00
5. Dolloff Dam Outlet	5.12	5.00	3.60	4.50	7.20	5.15
6. Gove Dam Brook	3.10	2.30	2.10	1.80	6.80	2.40
7. Whites Grove Brook	3.82	2.50	1.80	1.80	9.00	3.25
8. Fernalds Brook A	11.16	9.40	8.90	8.70	19.20	9.50
9. Fernalds Brook B	4.40	3.40	2.80	3.10	8.20	3.95
10. Downs Dam Outlet	4.38	4.30	5.70	3.60	4.30	4.15
11. Back Creek B	3.84	3.20	2.70	2.80	6.70	3.50
12. Back Creek A	4.38	4.10	2.00	3.50	7.30	4.55
13. Fundy Brook	1.24	1.00	0.80	1.00	2.30	1.05
14. Round Pond Brook	6.08	6.30	6.30	3.96	8.10	6.05
15. Burnhams Marsh Outlet (North)	4.10	4.00	5.20	2.40	6.00	2.80

2. Pawtuckaway Lake Tributary Acid Neutralizing Capacity

The mean ANC values for the Pawtuckaway Lake tributaries during the study period fell between a minimum of 1.24 mg/L as $CaCO_3$ in Fundy Brook and a maximum value of 15.86 in Burnhams Marsh Outlet South (Table V-2). The wide range of ANC values observed in the tributaries during the study period reflects the diverse environmental composition and underlying geology of the Pawtuckaway Lake watershed. Appendix V-4 depicts the tributary ANC range and mean values for the study period.

3. Pawtuckaway Lake In-lake pH

Biological activities can influence the pH of the water. Planktonic photosynthesis removes carbon dioxide from the lake, causing the pH to rise. For this reason the photic zone tends to have higher pH values than the underlying layers, and the highest values are recorded during the summer when phytoplankton populations are at their maximum levels. Spring and fall overturn values are usually similar throughout the water column.

pH values from the South Station of Pawtuckaway Lake followed this trend with the highest true mean pH values occurring during the summer months in the epilimnion where photosynthesis was the greatest (Table V-3).

The North Station at Pawtuckaway experienced maximum true mean pH values during the spring in the epilimnion (Table V-4). This coincided with the seasonal maximum chlorophyll-a values which occurred in April 1992 and reflects the abundance of photosynthetic activity occurring during this period.

In general, the pH values observed at both lake stations during the study year were well above the New Hampshire state mean of 6.0 units and fell within the satisfactory criteria for pH ranges. The only exception to this trend during the study year was the hypolimnetic pH values at the North Station which had a summer true mean value of 5.94 units. These values fall within the endangered category and reflect the void of photosynthetic activity occurring in the hypolimnion and the abundance of decomposition activity occurring in the bottom sediments. By fall turnover, the water column at the North Station had uniform pH values. Epilimnetic and hypolimnetic pH ranges for the study year at both the North and South Stations of Pawtuckaway Lake are presented in Appendix V-5.

4. Pawtuckaway Lake In-lake Acid Neutralizing Capacity (ANC)

In contrast to pH, ANC values tend to be higher at the bottom of a lake. This is caused by the release of buffering materials from the lake sediments to the overlying waters. This trend can be seen during the summer season and also to a lesser extent in the fall. As Tables V-3 and V-4 illustrate, the maximum ANC values for both the North and South Stations occurred during

Table V-3
Pawtuckaway Lake (South Station) In-lake Seasonal Chemistry Data
December 1991 through November 1992

WINTER	UPPER		LOWER	
	mean	median	mean	median
pH (units)	6.05	6.05	6.15	6.15
ANC (mg/L)	-	-	-	-
Conductivity (µmhos/cm)	42.90	42.90	45.65	45.65
TP (µg/L)	12.50	12.50	12.00	12.00
Turbidity (NTU's)	-	-	-	-
NO_3-N (mg/L)	0.12	0.12	0.11	0.11
Color (units)	38.00	38.00	40.00	40.00
CL^- (mg/L)	5.50	5.50	6.00	6.00
SO_4 (mg/L)	4.65	4.65	5.20	5.20
SPRING	UPPER		LOWER	
	mean	median	mean	median
pH (units)	6.86	6.80	6.60	6.67
ANC (mg/L)	4.50	4.50	-	-
Conductivity (µmhos/cm)	44.16	44.40	44.06	44.00
TP (µg/L)	15.00	11.00	11.66	12.00
Turbidity (NTU's)	1.10	1.10	0.60	0.60
NO_3-N (mg/L)	0.04	0.04	0.04	0.04
Color (units)	22.00	22.00	24.00	24.00
CL^- (mg/L)	6.00	6.00	6.00	6.00
SO_4 (mg/L)	5.00	5.00	5.00	5.00

Table V-3 (Cont.)
Pawtuckaway Lake (South Station) In-lake Seasonal Chemistry Data
December 1991 through November 1992

SUMMER	UPPER		LOWER	
	mean	median	mean	median
pH (units)	6.87	6.88	6.45	6.42
ANC (mg/L)	5.15	5.15	-	-
Conductivity (µmhos/cm)	44.40	44.45	44.78	45.05
TP (µg/L)	9.33	9.50	16.00	12.50
Turbidity (NTU's)	-	-	-	-
NO_3-N (mg/L)	0.02	0.02	0.13	0.13
Color (units)	-	-	-	-
CL^- (mg/L)	7.00	7.00	7.00	7.00
SO_4 (mg/L)	4.00	4.00	4.00	4.00
FALL	UPPER		LOWER	
	mean	median	mean	median
pH (units)	6.70	6.70	6.67	6.69
ANC (mg/L)	5.40	5.40	-	-
Conductivity (µmhos/cm)	43.56	43.30	43.92	44.20
TP (µg/L)	15.95	11.50	8.33	8.50
Turbidity (NTU's)	-	-	-	-
NO_3-N (mg/L)	-	-	0.06	0.06
Color (units)	24.67	20.00	24.66	18.00
CL^- (mg/L)	6.00	6.00	5.00	5.00
SO_4 (mg/L)	5.10	5.10	3.40	3.40

Table V-4
Pawtuckaway Lake (North Station) In-lake Seasonal Chemistry Data
December 1991 through November 1992

SUMMER	EPILIMNION		METALIMNION		HYPOLIMNION	
	mean	median	mean	median	mean	median
pH (units)	6.61	6.75	6.38	6.35	5.94	5.91
ANC (mg/L)	4.75	4.75	-	-	-	-
Conductivity (µmhos/cm)	44.18	44.05	45.00	45.20	45.95	45.80
TP (µg/L)	11.50	12.00	12.00	12.50	17.33	16.50
Turbidity (NTU's)	-	-	-	-	-	-
NO_3-N (mg/L)	0.02	0.02	-	-	0.02	0.02
Color (units)	-	-	-	-	-	-
CL^- (mg/L)	6.00	6.00	-	-	7.00	7.00
SO_4 (mg/L)	4.00	4.00	-	-	4.00	4.00

FALL	UPPER		LOWER	
	mean	median	mean	median
pH (units)	6.26	6.30	6.26	6.30
ANC (mg/L)	4.40	4.40	-	-
Conductivity (µmhos/cm)	44.38	44.45	51.20	49.45
TP (µg/L)	14.25	13.00	40.75	30.50
Turbidity (NTU's)	-	-	-	-
NO_3-N (mg/L)	0.05	0.05	0.05	0.05
Color (units)	41.50	41.50	95.00	95.00
CL^- (mg/L)	6.00	6.00	6.00	6.00
SO_4 (mg/L)	4.40	4.40	2.40	2.40

Table V-4 (Cont.)
Pawtuckaway Lake (North Station) In-lake Seasonal Chemistry Data
December 1991 through November 1992

WINTER	UPPER		LOWER	
	mean	median	mean	median
pH (units)	6.26	6.30	6.11	6.20
ANC (mg/L)	-	-	-	-
Conductivity (µmhos/cm)	44.60	44.00	45.13	45.00
TP (µg/L)	18.66	19.00	16.33	17.00
Turbidity (NTU's)	-	-	-	-
NO_3-N (mg/L)	0.07	0.07	0.05	0.05
Color (units)	46.00	46.00	38.00	38.00
CL^- (mg/L)	6.50	6.50	6.50	6.50
SO_4 (mg/L)	4.35	4.35	4.40	4.40
SPRING	UPPER		LOWER	
	mean	median	mean	median
pH (units)	6.72	6.74	6.16	6.16
ANC (mg/L)	4.60	4.60	-	-
Conductivity (µmhos/cm)	45.05	45.05	46.20	46.20
TP (µg/L)	14.50	14.50	13.00	13.00
Turbidity (NTU's)	1.30	1.30	1.80	1.80
NO_3-N (mg/L)	0.04	0.04	0.06	0.06
Color (units)	31.00	31.00	30.00	30.00
CL^- (mg/L)	7.00	7.00	7.00	7.00
SO_4 (mg/L)	4.00	4.00	4.00	4.00

the summer months with mean values of 4.75 mg/L and 5.15 mg/L respectively. ANC values generated during the study year at Pawtuckaway Lake fall below the New Hampshire lakes and ponds mean of 6.5 mg/L and are considered to be moderately vulnerable to acid inputs.

C. SPECIFIC CONDUCTANCE

Specific conductance (conductivity) is a measure of the capacity of water to conduct an electrical current. This ability to conduct electricity is determined primarily by the concentration of charged ionic particles present in the waters. The soft waters of New Hampshire generally have a low conductance relative to highly mineralized waters found in some parts of the country. The conductance of water is related to the presence of dissolved solids, and thus is usually higher in sewage than in natural waters. The mean conductivity value for all New Hampshire lakes is 56.0 µmhos/cm with a median of 39.8 µmhos/cm.

1. Pawtuckaway Lake Tributary Specific Conductance

Mean tributary conductivity values for the study period ranged from a low of 27.7 µmhos/cm in Burnhams Marsh outlet (North) to a maximum of 157.53 µmhos/cm in Fernalds Brook A (Appendix V-4). The majority of tributaries had a seasonal breakdown of conductivity that revealed fairly uniform values throughout the year. Conductivity within the majority of tributaries remained under 50.0 µmhos/cm which indicates little or no impact from man made sources. The exceptions to this trend are Whites Grove Brook and Fernalds Brook A, which had mean study year conductivity values of 112.2 µmhos/cm and 151.5 µmhos/cm respectively (Table V-5). Seasonal values for both tributaries exceeded 100.0 µmhos/cm and indicate a cultural source of ions. The elevated conductivity levels in both tributaries coincided with the highest recorded chloride levels for the study year.

The Fernalds Brook A subswatershed collects agricultural runoff from Fernalds Dairy Farm in Nottingham Square as well as erosional materials from Barderry Lane. An upstream sample site was established under Route 156 to evaluate water quality parameters in the headwaters of Fernalds Brook A. The upstream station had a mean conductivity value of 359.50

µmhos/cm for the study year and a mean winter value of 511.0 µmhos/cm. Route 156 is subjected to salting procedures during the winter months which would elevate conductivity levels due to the increased chloride concentrations. The Whites Grove Brook subwatershed is adjacent to the Fernalds Brook A subwatershed and at a lower elevation which allows for groundwater migration to occur. Groundwater aquifer interaction and soil structure suspected of contributing to the high conductivity and chloride levels found in Whites Grove Brook during the study year.

Table V-5
Pawtuckaway Lake Tributaries
Mean Study Period and Seasonal Specific Conductance (µmhos/cm)
December 1991 through November 1992

Station # & Site Name	Study Year		Winter	Spring	Summer	Fall
	Mean	Median				
1. Burnhams Marsh Outlet (South)	41.69	32.85	34.93	30.45	29.50	67.15
2. Loon Cove Brook B	28.65	28.30	28.26	25.80	31.33	29.56
3. Loon Cove Brook A	31.33	31.45	31.60	26.76	35.33	33.34
4. Mountain Cove Brook	41.36	41.90	42.26	38.22	43.66	42.58
5. Dolloff Dam Outlet	46.85	44.05	44.83	45.02	47.43	49.56
6. Gove Dam Brook	38.00	38.70	36.36	37.60	48.26	32.98
7. Whites Grove Brook	112.16	114.50	103.93	102.76	123.60	124.63
8. Fernalds Brook A	151.53	155.45	118.16	143.68	171.76	167.26
9. Fernalds Brook B	30.45	29.35	28.83	29.92	35.55	33.36
10. Drowns Dam Outlet	43.35	42.00	51.13	40.13	43.40	41.22
11. Back Creek B	44.01	43.15	46.86	42.36	45.80	42.88
12. Back Creek A	28.63	28.05	28.13	26.68	31.16	29.34
13. Fundy Brook	36.00	34.80	41.70	35.45	33.43	34.56
14. Round Pond Brook	30.14	29.50	33.36	27.98	31.50	29.14
15. Burnhams Marsh Outlet (North)	27.72	27.60	32.00	24.08	30.26	26.28
Upstream Stations						
27. Fernalds Brook A	359.50	359.50	-	511.00	-	-

2. Pawtuckaway Lake Specific Conductance

Conductivity measurements for the study year at the North and South Stations of Pawtuckaway Lake indicate epilmnetic values below the New Hampshire average of 56.0 µmhos/cm (Appendix V-5). Values at both lake stations were very similar throughout the water column for the duration of the study year. Mean seasonal conductivity values ranged from a minimum of 42.90 µmhos/cm in the upper layer of the South Station in the winter to a maximum value of 51.20 µmhos/cm during the fall in the hypolimnion of the North Station. This value may be due to the sediment release of ionic particles into the overlying waters. Lake data is presented in Tables V-3 and V-4.

D. CHLORIDE

Chloride is one of the major anions measured in water. Natural sources of chloride include the weathering of igneous and sedimentary rocks and rainfall (occurring as cyclic chlorides), while artificial sources include many point and nonpoint sources such as road salt runoff and faulty septic systems. The median chloride level for New Hampshire lakes is 5.0 mg/L.

1. Pawtuckaway Lake Tributary Chloride

Mean chloride levels for the tributaries during the study year ranged from 2.40 mg/L to 32.60 mg/L (Table V-6). Thirteen out of the fifteen tributaries monitored for chlorides had seasonal and study year means at or below 7.0 mg/L which indicate no impact from cultural sources. The exceptions to this trend were Whites Grove Brook and Fernalds Brook A which had study year mean values of 27.0 mg/L and 32.6 mg/L respectively (Appendix V-4). The Fernalds Brook A watershed receives agricultural runoff high in chlorides as well as road salt runoff from Route 156. Runoff that doesn't reach the brook infiltrates the groundwater and migrates into the Whites Grove Brook subwatershed resulting in elevated chloride levels within the brook as a result of groundwater recharge. The elevated chloride levels at these two sites

coincided with maximum conductivity values recorded during the study year. In addition to the agricultural runoff and road salt runoff, septic leachfields throughout the subwatersheds may contribute to chloride levels in the tributaries and groundwater.

Table V-6
Pawtuckaway Lake Tributaries
Mean Study Period and Seasonal Chloride (mg/L)
December 1991 through November 1992

Station # & Site Name	Study Year		Winter	Spring	Summer	Fall
	Mean	Median				
1. Burnhams Marsh Outlet (South)	5.00	3.00	3.00	3.00	3.00	7.00
2. Loon Cove Brook B	2.40	3.00	3.00	3.00	1.00	2.50
3. Loon Cove Brook A	2.40	3.00	3.00	3.00	1.00	2.50
4. Mountain Cove Brook	2.80	3.00	3.00	3.00	1.00	2.50
5. Dolloff Dam Outlet	5.00	5.00	3.00	6.00	5.00	5.50
6. Gove Dam Brook	4.40	4.00	5.00	6.00	3.00	4.00
7. Whites Grove Brook	27.00	25.00	23.00	25.00	24.00	31.50
8. Fernalds Brook A	32.60	34.00	25.00	34.00	37.00	33.50
9. Fernalds Brook B	2.40	3.00	3.00	3.00	1.00	2.50
10. Drowns Dam Outlet	5.60	6.00	5.00	6.00	6.00	5.50
11. Back Creek B	6.60	7.00	5.00	7.00	7.00	7.00
12. Back Creek A	3.40	17.00	3.00	3.00	6.00	2.50
13. Fundy Brook	5.60	6.00	6.00	5.00	6.00	5.50
14. Round Pond Brook	2.40	3.00	3.00	3.00	1.00	2.50
15. Burnhams Marsh Outlet (North)	2.50	3.00	1.13	3.00	1.00	3.00

2. Pawtuckaway Lake Chloride

Median study year chloride levels for Pawtuckaway Lake ranged from a minimum of 5.0 mg/L in the lower layer of South Station to a maximum of 7.0 mg/L in the upper and lower layers of both lake stations (Tables V-3 and V-4). Chloride values at the North and South Stations were relatively uniform throughout the study year and only exceeded the state median

by 2.0 mg/L. This indicates very little influence from cultural impacts such as leachfield drainage and road salt runoff.

E. SULFATE

Sulfates are utilized by all living organisms for protein synthesis. Sulfates are usually abundant in systems, entering through erosion of rocks, fertilizer runoff and through atmospheric transport by precipitation and dry fall. The median sulfate concentration for New Hampshire lakes is 4.0 mg/L.

Median study year sulfate concentrations at Pawtuckaway Lake ranged from a minimum of 2.4 mg/L in the lower layer of North Station to a maximum of 5.2 mg/L in the lower layer of South Station. The seasonal chloride maximums occurred during the fall and winter at the North Station with values of 4.4 mg/L in the upper layer and 4.4 mg/L in the lower layer respectively. Seasonal maximums occurred in the winter at the South Station with sulfate values of 5.2 mg/L recorded in the lower layer. As Tables V-3 and V-4 indicate, sulfate values at Pawtuckaway Lake coincide with the 4.0 mg/L median of New Hampshire's lakes and ponds.

F. APPARENT COLOR

Apparent color is the visual determination of the darkness of the water. Color in the water may result from substances in solution (iron, manganese and leachate from decaying organic matter) and suspended matter (plankton and silt). Tea colored waters [color values greater than 40 chloroplatinate units (CPU)] are generally naturally colored from decaying organic matter. For this reason, drainage from wetlands tend to have high color values. The median color value for New Hampshire lakes is 25 CPU. Raw color data is presented in Appendix V-3.

1. Pawtuckaway Lake Tributary Apparent Color

As Table V-7 indicates, median color values for the Pawtuckaway Lake tributaries during

the study year ranged from a minimum of 8.0 CPU at Fernalds Brook B to a maximum of 96.0 CPU at Fundy Brook. The majority of the tributaries experienced seasonal maximum color values occurring in the summer months when processes of decomposition within the watershed are peaking.

Tributaries that did not fit this trend included Dolloff Dam outlet and Drowns Dam Outlet which had maximum seasonal color values during the winter and fall with values of 60.0 CPU and 50.0 CPU respectively. These results reflect the fall drawdown procedures at Pawtuckaway Lake and the associated increase in flushing rates and turbidity.

Fundy Brook and Back Creek B also had seasonal maximum color values in the fall months with apparent colors of 105.0 CPU and 92.5 CPU respectively. This is most likely the result of the flush of decomposing material in upstream wetlands. Wetland complexes occupy 13.5% of the Back Creek B subwatershed and 10.0% of the Fundy Brook subwatershed (Appendix III-2).

Apparent color values for the Pawtuckaway Lake tributaries during the study year exceeded the New Hampshire median for lakes and ponds and reflects a watershed that is influenced by wetland ecology. The Pawtuckaway Lake watershed is comprised of nearly 1,500 acres of wetlands which accounts for 12.5 percent of the total area (Figure III-8). Appendix V-4 presents the tributary apparent color ranges and means for the study year.

2. Pawtuckaway Lake Apparent Color

Tables V-3 and V-4 present apparent color data for the North and South Stations of Pawtuckaway Lake. Apparent color values during the stratified season in the North Station displayed a wide range from epilmnetic waters to the hypolimnion. Color values during this period ranged from 41.5 CPU in the epilimnion to 95.0 CPU in the hypolimnion. Color usually increases in the water column towards the hypolimnion due to sediment release of materials and decomposition in the benthic area. Color values during the unstratified season at the North Station were relatively uniform throughout the water column, as they were throughout the study year at the unstratified South Station.

Table V-7
Pawtuckaway Lake Tributaries
Mean Study Period and Seasonal Apparent Color (CPU)
December 1991 through November 1992

Station # & Site Name	Study Year		Winter	Spring	Summer	Fall
	Mean	Median				
1. Burnhams Marsh Outlet (South)	82.33	75.50	86.00	60.00	150.00	66.00
2. Loon Cove Brook B	42.00	42.00	42.00	15.00	65.00	44.00
3. Loon Cove Brook A	31.40	32.00	32.00	13.00	48.00	32.00
4. Mountain Cove Brook	52.60	55.00	49.00	24.00	80.00	55.00
5. Dolloff Dam Outlet	29.20	23.00	60.00	27.00	19.00	20.00
6. Gove Dam Brook	48.80	52.00	52.00	24.00	65.00	51.50
7. Whites Grove Brook	22.40	22.00	22.00	15.00	22.00	26.50
8. Fernalds Brook A	47.20	48.00	44.00	30.00	48.00	57.00
9. Fernalds Brook B	11.20	8.00	15.00	5.00	8.00	14.00
10. Drowns Dam Outlet	37.40	32.00	27.00	32.00	28.00	50.00
11. Back Creek B	70.20	70.00	56.00	40.00	70.00	92.50
12. Back Creek A	36.40	38.00	33.00	17.00	55.00	38.50
13. Fundy Brook	88.80	96.00	96.00	48.00	90.00	105.00
14. Round Pond Brook	48.00	55.00	41.00	29.00	55.00	57.50
15. Burnhams Marsh Outlet (North)	58.75	61.00	62.00	33.00	60.00	80.00

G. TURBIDITY

Turbidity is caused by the presence of suspended or colloidal particles of clay, silt, organic matter, and algal cells. As light passes through the water, it is scattered, reflected or absorbed by particulate matter in suspension. Erosion creates high turbidity values, and turbidities are often highest during storm events. High tributary turbidities result in lake siltation and the introduction of phosphorus to the lake or pond.

The mean turbidity values for the Pawtuckaway Lake tributaries during the study year ranged from a minimum of 0.46 NTU in Fernalds Brook B to a maximum value of 1.69 NTU in Mountain Cove Brook. As Table V-8 indicates, the seasonal distribution of maximum

turbidity values is distributed throughout the spring, summer and fall for all the tributaries and reflects the diverse topography within the Pawtuckaway Lake watershed. All tributaries experienced minimum turbidity values during the winter months. The recorded tributary turbidities at Pawtuckaway Lake were typical when compared to other New Hampshire tributaries. Appendix V-4 presents the study year ranges and means for turbidity values in the Pawtuckaway Lake tributaries.

Table V-8
Pawtuckaway Lake Tributaries
Mean Study Period and Seasonal Turbidity (NTU),
December 1991 through November 1992

Station # & Site Name	Study Year		Winter	Spring	Summer	Fall
	Mean	Median				
1. Burnhams Marsh Outlet (South)	1.62	1.72	1.00	1.69	1.73	2.04
2. Loon Cove Brook B	0.94	0.70	0.70	0.80	1.46	0.87
3. Loon Cove Brook A	0.94	0.75	0.40	0.96	1.10	1.16
4. Mountain Cove Brook	1.69	1.15	0.90	1.72	2.00	1.96
5. Dolloff Dam Outlet	0.76	0.65	0.76	0.94	0.53	0.72
6. Gove Dam Brook	1.58	1.00	0.60	2.08	1.70	1.61
7. Whites Grove Brook	0.94	0.40	0.60	1.84	0.36	0.36
8. Fernalds Brook A	1.58	1.15	0.76	2.24	1.53	1.43
9. Fernalds Brook B	0.46	0.35	0.83	0.26	0.35	0.45
10. Drowns Dam Outlet	1.33	1.00	0.93	1.12	0.96	1.94
11. Back Creek B	0.98	0.70	0.76	1.32	0.93	0.79
12. Back Creek A	1.06	0.90	0.37	1.02	1.43	1.31
13. Fundy Brook	1.02	1.00	0.57	1.10	1.43	1.00
14. Round Pond Brook	1.02	1.10	0.96	0.84	1.26	1.06
15. Burnhams Marsh Outlet (North)	1.03	1.05	1.13	0.82	0.96	1.22
Upstream Stations						
27. Fernalds Brook A	10.20	10.15	-	15.30	-	-

H. ESCHERICHIA COLI

Escherichia coli (E. coli) is a type of bacteria found in the intestinal tract of warm blooded animals, including man.

New Hampshire state law states that for Class B waters, E. coli levels shall be no more than either a mean of 126 per 100 mL based on at least 3 samples obtained over a 60 day period, or 406 per 100 mL in any one sample. Designated beach areas shall contain not more than a geometric mean of 47 per 100 mL based on at least three samples obtained over a sixty-day period, or 88 per 100 mL in any one sample, unless naturally occurring. Class B waters are considered acceptable for fishing, swimming and other recreational purposes and, after adequate treatment, for use as water supplies.

Higher numbers, up to 1,000 in some instances, are not unusual, particularly during and after storm events and/or where urban or agricultural runoff occurs. These levels are generally not considered unsafe unless investigation indicates the source to be sewage. Elevated levels can also be caused by waterfowl or other warm-blooded animals.

Pawtuckaway Lake tributaries had mean E. coli levels during the study year ranging from 3.0 cts/100 mL in Fundy Brook to 54 cts/100 mL in Whites Grove Brook (Appendix V-4). Table V-9 indicates that thirteen out of the fifteen tributaries had seasonal E. coli maxima during the summer months. The range for summer E. coli means was 6.0 cts/100 mL in Fundy Brook to 151.0 cts/100 mL in Whites Grove Brook. The high numbers during the summer months may be an indication of agricultural runoff or cultural pollution via faulty or insufficient septic systems. However, E. coli levels measured in all tributaries throughout the study year remained within New Hampshire water quality criteria for Class B waters.

Upstream stations monitored for E. coli during the study year had mean values ranging from 10.0 cts/100 mL to 5,633 cts/100 mL (Table V-9). Maximum seasonal E. coli levels occurred during the summer months and in many cases exceeded the downstream sample site values for the same period indicating upstream sources of bacteria such as waterfowl and warm-blooded animals. The high values recorded in the Fernalds Brook A upstream station (#27) reflect the impact of agricultural runoff from Fernalds Farm in Nottingham Square. The headwaters of this brook originate at the base of the farm property where manure storage and overgrazing on steep slopes has been a problem in the past. Samples collected from the

Table V-9
Pawtuckaway Lake Tributaries
Mean Study Period and Seasonal Escherichia Coliform (counts/100 mL)
December 1991 through November 1992

Station # & Site Name	Study Year		Winter	Spring	Summer	Fall
	Mean	Median				
1. Burnhams Marsh Outlet (South)	5.80	1.00	0.33	1.80	21.00	-
2. Loon Cove Brook B	9.46	3.00	2.00	3.70	22.00	9.60
3. Loon Cove Brook A	17.58	2.00	0.00	19.60	38.75	9.20
4. Mountain Cove Brook	15.47	4.00	2.66	1.20	53.75	6.80
5. Dolloff Dam Outlet	9.82	3.00	1.33	2.00	34.00	3.40
6. Gove Dam Brook	46.18	4.00	4.00	0.40	131.75	48.80
7. Whites Grove Brook	54.33	20.00	41.66	8.00	150.75	15.66
8. Fernalds Brook A	31.64	10.00	18.33	53.20	26.50	22.20
9. Fernalds Brook B	4.00	2.00	2.33	2.00	11.00	2.33
10. Drowns Dam Outlet	11.06	1.00	0.00	0.00	38.00	2.80
11. Back Creek B	17.47	10.00	5.33	13.60	27.00	21.00
12. Back Creek A	11.25	1.50	0.00	0.40	30.50	11.20
13. Fundy Brook	2.50	0.00	0.00	0.75	6.00	2.60
14. Round Pond Brook	25.50	3.00	1.00	1.25	86.75	10.60
15. Burnhams Marsh Outlet (North)	4.50	1.00	0.66	0.75	4.75	9.75
Upstream Stations						
17. Loon Cove Brook A	20.00	20.00	0.00	-	40.00	-
18. Mountain Cove Brook	10.00	10.00	0.00	-	20.00	-
19. Gove Dam Brook	16.00	16.00	2.00	-	30.00	-
20. Whites Grove Brook	0.00	0.00	0.00	-	-	-
21. Back Creek B	6.50	6.50	3.00	-	10.00	-
22. Back Creek B	67.00	67.00	4.00	-	130.00	-
23. Round Pond Brook	10.00	10.00	-	-	10.00	-
27. Fernalds Brook A	5633.30	1700.00	-	1700.00	-	-

upstream station under Route 156 exceeded the New Hampshire limit for Class B waters (406 cts/100 mL) throughout the study year.

I. TOTAL PHOSPHORUS

Phosphorus is an essential element for plant growth, and is the limiting nutrient that regulates the productivity of New Hampshire lakes. Much effort in controlling the eutrophication of lakes has been directed toward controlling the phosphorus load to a lake. Unacceptable levels of phosphorus are often associated with human activities, and it appears that, in most cases, the removal or reduction of phosphorus from nonpoint sources will curtail algal productivity in lakes.

Total phosphorus was measured in this study by the persulfate digestion procedure, and includes all phosphorus forms in water. Total phosphorus is composed primarily of organic phosphorus, which includes phosphorus present in algal cells, and inorganic orthophosphate. The total phosphorus range for the summer epilimnetic values for lakes sampled in New Hampshire is between <1 and 121 µg/L, with a median value of 11 µg/L.

The major purpose of this study was to determine significant phosphorus sources to Pawtuckaway Lake and to propose remediation. Sources of phosphorus include: 1) precipitation 2) groundwater 3) surface runoff 4) septic leachate 5) tributary flux and 6) internal phosphorus cycling.

1. Pawtuckaway Lake Tributary Total Phosphorus

The highest mean total phosphorus concentration of the Pawtuckaway Lake tributaries was observed in Fernalds Brook A (74.7 µg/L) while the lowest mean was observed at Fernalds Brook B (10.2 µg/L). Fernalds Brook A experienced a maximum phosphorus concentration of 200 µg/L and a minimum of 38 µg/L during the study year. Fernalds Dairy Farm occupies approximately 10 percent of the Fernalds Brook A subwatershed and acts as the significant source of phosphorus to this tributary. Overgrazing on poorly vegetated slopes and improper manure handling in the past has made this area a constant source of nutrients to receiving waters.

The seasonal distribution of phosphorus shows that eleven of the thirteen inflowing tributaries had maximum seasonal mean concentrations during the summer months (Table V-10). The majority of these tributaries have subwatersheds characteriazed by wetlands, beaver impoundments and ponds (Appendix III02).

The fact that the majority of tributaries within the Pawtuckaway Lake watershed

experienced maximum seasonal phosphorus concentrations during the summer months, contradicts the expected function of wetlands to act as a filter during the growing season.

In fact, a review of the literature dealing with phosphorus dynamics in wetlands reveals a strong variability of results. Some researchers believe wetlands are sources of phosphorus, others believe they are sinks while some contend that they can be seasonal sources and sinks.

Richardson (1988) has examined the ecological value of wetlands in terms of the ability to filter materials, transform nutrients, or function as sources or sinks. Macrophytes are mainly responsible for the recycling of phosphorus through root uptake from the soil; plants are the source of phosphorus for the water rather than the reverse. Richardson concludes that wetlands are incorrectly depicted as sinks when, in fact, they should be recognized as transformers. Wetlands with organic soils, similar to the Pawtuckaway Lake watershed wetlands do not retain phosphorus as efficiently as forested systems and are often a source of nutrients rather than a sink for them (Connor and Martin 1989b).

The high phosphorus values contributed by the Pawtuckaway Lake tributaries during the summer months emulated the four year study conducted on Chadwick Meadows in North Sutton, New Hampshire (Connor and Martin 1989b). This study found that the Chadwick Meadows wetland complex was a significant source of total phosphorus within the Kezar Lake watershed, providing an average increased phosphorus loading of 4.79 Kg on a monthly basis over the study period. Further, an average of 18.5 KgP was contributed during the summer months of June, July, and August.

Three other tributaries within the Pawtuckaway Lake watershed had maximum seasonal phosphorus concentrations during the spring months. Whites Grove Brook and Fernalds Brook A have subwatersheds that are dominated by forest cover. The seasonal phosphorus concentrations peaks for these tributaries reflects the impact of spring runoff. Dolloff Dam outlet experienced a spring flux of phosphorus concentrations and reflects the large volumes of nutrient rich runoff reaching the lake during this time period.

Drowns Dam outlet had maximum seasonal phosphorus concentrations during the fall months with a total phosphorus value of 27.6 µg/L. The minimum concentration in this outlet was observed in the winter when water volumes were also at a minimum.

The upstream tributaries had mean phosphorus concentrations ranging from 20.8 µg/L (station #18) to 61.6 µg/L at Station #23. This station was established at the outlet of Round

Pond and reflects the eutrophic nature of the pond.

The maximum seasonal phosphorus concentration occurred during the fall in station #27 and had a phosphorus value of 342.0 µg/L (Table V-10). This station is an upstream site on Fernalds Brook A and receives runoff from Fernalds Dairy Farm. The high concentration during the fall can be attributed to the decrease in vegetation within the subwatershed and lack of nutrient absorption associated with vegetative cover. Total phosphorus ranges and study year means for the tributaries can be found in Appendix V-4.

2. Pawtuckaway Lake Total Phosphorus

Total phosphorus concentrations in the North Station of Pawtuckaway Lake exhibited relatively uniform values during the spring, summer and winter months. Mean total phosphorus concentrations during these seasons ranged from 11.50 µg/L in the epilimnion during the summer to a maximum of 18.6 µg/L in the upper layer during the winter.

The widest range of mean phosphorus concentration was observed during the fall months with a minimum value of 14.2 µg/L in the upper layer to 40.8 µg/L in the lower layer. This reflects the strong stratification that develops during the summer months and the subsequent development of anoxic conditions in the hypolimnion. The high phosphorus concentrations during the fall are an indication of internal phosphorus loading from the sediment when anoxic conditions exist. Fall mixing at the North Station doesn't occur until mid to late October due to the depth and severity of stratification. Phosphorus levels become uniform throughout the water column following fall turnover.

Total phosphorus concentrations observed at the South Station were relatively homogeneous throughout the study year. Mean concentrations ranged from 8.3 µg/L in the lower layer during

Table V-10
Pawtuckaway Lake Tributaries
Mean Study Period and Seasonal Total Phosphorus (µg/L), December 1991 through November 1992

Station # & Site Name	Study Year		Winter	Spring	Summer	Fall
	Mean	Median				
1. Burnhams Marsh Outlet (South)	25.81	24.00	12.83	31.00	35.83	22.42
2. Loon Cove Brook B	26.03	17.00	11.50	14.38	47.83	31.56
3. Loon Cove Brook A	18.06	16.00	8.50	16.22	27.83	19.78
4. Mountain Cove Brook	26.03	21.50	15.16	19.66	37.50	32.00
5. Dolloff Dam Outlet	13.93	11.00	12.66	23.11	9.33	8.66
6. Gove Dam Brook	22.61	15.50	13.83	20.66	30.33	25.22
7. Whites Grove Brook	13.07	11.00	13.16	15.78	12.33	9.66
8. Fernalds Brook A	74.73	68.00	73.16	89.78	86.33	53.00
9. Fernalds Brook B	10.17	5.00	14.00	9.12	14.75	3.60
10. Drowns Dam Outlet	20.96	19.50	12.50	17.86	20.33	27.56
11. Back Creek B	22.03	20.50	12.83	21.56	32.33	21.78
12. Back Creek A	14.06	12.00	10.33	12.88	18.66	14.66
13. Fundy Brook	26.90	24.00	12.83	23.25	44.16	28.00
14. Round Pond Brook	28.31	26.00	17.00	19.88	40.83	35.00
15. Burnhams Marsh Outlet (North)	25.04	23.00	17.33	21.50	33.33	28.57
Upstream Stations						
17. Loon Cove Brook A	26.30	29.50	9.00	34.00	37.00	25.00
18. Mountain Cove Brook	20.75	22.00	14.00	25.00	23.00	21.60
19. Gove Dam Brook	25.80	26.00	18.00	33.00	33.00	19.00
20. Whites Grove Brook	52.67	61.00	28.00	69.00	-	61.00
21. Back Creek B	29.00	27.00	20.00	29.00	42.00	25.00
22. Back Creek B	21.50	22.00	15.00	25.00	27.00	19.00
23. Round Pond Brook	61.67	74.00	-	18.00	93.00	74.00
27. Fernalds Brook A	58.20	1.30	-	2.10	-	342.00

the fall to 16.0 µg/L in the lower layer during the summer. The elevated concentrations during the summer indicate internal phosphorus loading as a result of anoxic conditions that develop at the sediment/water interface. The South Station at Pawtuckaway Lake displayed a weakly stratified water column during the summer months which allowed for mixing to occur more readily, creating a more uniform distribution of total phosphorus.

In general, epilimnetic total phosphorus concentrations at both lake stations were slightly higher than the New Hampshire State median of 11.0 µg/L (Appendix V-5). Tables V-3 and V-4 present the seasonal total phosphorus data for the North and South Stations respectively. Appendix V-3 presents the raw total phosphorus data for the study year.

J. NITROGEN

A component of proteins, nitrogen is a major nutrient essential for plant growth. Nitrogen may be present in water as dissolved nitrogen gas, organic nitrogen compounds and inorganic nitrogen compounds including ammonia, nitrite and nitrate.

With the exception of some bluegreen algae that utilize atmospheric nitrogen (N_2), most algae use inorganic nitrogen. Of the forms listed above, ammonia is the preferred source because it is already at the reduction level of organic nitrogen, and thus is assimilated into protein at a minimal energy cost. Ammonia nitrogen is gradually oxidized by nitrifying bacteria into nitrite and nitrate.

Sources of nitrogen include precipitation, nitrogen fixation in the water and sediments by bacteria and certain bluegreen algae, and inputs from surface and groundwater drainage. Natural sources of the most commonly used form, ammonia, include excretory products from ammonifying bacteria, zooplankton and the urea of higher animals such as found in raw sewage (Martin and Goff, 1972; Keeney, 1972; Brezonik et al. 1973).

Inorganic nitrate nitrogen was the form measured at Pawtuckaway Lake. The median value for nitrate nitrogen in New Hampshire lakes and ponds is <0.05 mg/L and includes data from 514 waterbodies.

1. Pawtuckaway Lake Tributary Nitrate

Mean and median nitrate tributary data is presented in Table V-11. The study period mean ranged from a minimum of 0.02 mg/L in Back Creek B, Whites Grove Brook and Burnhams Marsh Outlet South to a maximum of 2.44 mg/L in Fernalds Brook A.

The seasonal distribution of nitrates reveals that for the majority of tributaries, nitrates had very minimal flucuations from season to season. The exceptions to this trend were Fernalds Brook A and the two outlets from the lake which experienced above average seasonal maximums during the winter months. Wetzel (1983) states that the nitrogen content of snow is often much higher than that of rain, and can contribute up to half the nitrogen influx to a lake, even though snow generally constitutes a small portion of total precipitation. This may be a factor in understanding the two outlet tributaries which had winter nitrate values of 0.13 mg/L and 0.17 mg/L. The winter nitrate value in Fernalds Brook A was 12.0 mg/L and reflects the impact of agricultural runoff within the subwatershed as well as the cumulative contribution from snowfall. Tributary nitrate ranges and mean study year values are presented in Appendix V-4. Raw nitrate data for Pawtuckaway Lake and tributaries is presented in Appendix V-3.

2. Pawtuckaway Lake Nitrate

Nitrate data for the sample year at the North Station of Pawtuckaway Lake exhibited minimal seasonal variations in nitrate concentrations (Tables V-3 and V-4). Values ranged from a minimum of <0.02 mg/L during the summer to a maximum of 0.07 mg/L in the upper water layer during the winter. Nitrate concentrations did not significantly differ with water column depth and remained well within range of the New Hampshire median.

The seasonal nitrate concentrations recorded at the South Station of Pawtuckaway Lake reflected minimal variation between the upper and lower layer. Nitrate concentrations recorded during the winter, spring and fall months displayed a maximum difference in concentration of .01 mg/L. The maximum variation in nitrate values occurred during the summer months at the South Station when there was a .11 mg/L difference between the upper and lower layer.

Table V-11
Pawtuckaway Lake Tributaries
Mean Study Period and Seasonal Nitrate (mg/L), December 1991 through November 1992

Station # & Site Name	Study Year		Winter	Spring	Summer	Fall
	Mean	Median				
1. Burnhams Marsh Outlet (South)	0.02	0.02	0.03	<0.02	<0.02	0.03
2. Loon Cove Brook B	0.06	0.06	0.06	0.09	0.07	0.04
3. Loon Cove Brook A	0.04	0.04	0.04	<0.02	0.08	0.04
4. Mountain Cove Brook	0.03	0.03	0.03	<0.02	0.03	0.04
5. Dolloff Dam Outlet	0.06	0.05	0.13	0.03	0.04	0.06
6. Gove Dam Brook	0.04	0.04	0.04	<0.02	0.11	0.04
7. Whites Grove Brook	0.02	0.02	<0.02	<0.02	<0.02	0.04
8. Fernalds Brook A	2.44	0.05	12.00	0.03	0.09	0.04
9. Fernalds Brook B	0.04	0.02	0.07	<0.02	<0.02	0.04
10. Drowns Dam Outlet	0.08	0.06	0.17	0.04	0.06	0.08
11. Back Creek B	0.02	0.02	<0.02	<0.02	0.03	0.04
12. Back Creek A	0.04	0.05	0.05	0.07	0.05	0.04
13. Fundy Brook	0.04	0.04	0.04	<0.02	0.05	0.04
14. Round Pond Brook	0.04	0.02	<0.02	<0.02	0.07	0.04
15. Burnhams Marsh Outlet (North)	0.04	0.02	0.09	<0.02	<0.02	<0.02

CHAPTER VI AQUATIC ECOLOGY

Lakes and ponds naturally support phytoplankton (algae) and aquatic vascular plants. The amount of phytoplankton and plant growth is related to lake productivity and is determined by the amount of nutrients in the lake. An increase in phosphorus results in an increase in algae growth and a decrease in transparency.

A. PHYTOPLANKTON

Phytoplankton are microscopic algae that live in the photic zone of waterbodies. Wholewater phytoplankton include all sizes; net phytoplankton include only those that remain in a 80 micron mesh sampling net. Wholewater samples provide a more accurate representation of phytoplankton densities and dominance. However, net phytoplankton data is used for discussion of population dynamics for the study year, as whole water samples were collected only during open water seasons. Net phytoplankton raw data can be found in Appendix VI-I. Wholewater phytoplankton raw data is presented in Appendix VI-2.

1. Net Phytoplankton

Seasonal succession is the term used to describe the changes in phytoplankton population dominance at different times of the year. In general, these changes are believed to be the result of the organism's response to changing light, temperature and nutrient conditions, and also the result of zooplankton grazing. Different types of phytoplankton are suited to different conditions and become dominant when those conditions prevail.

The dominant net phytoplankton during both the winter and spring was the diatom Asterionella. Diatom seasonal succession has been observed in many temperate dimictic lakes. Diatoms are well suited to low light, low temperature environments such as occur under ice

conditions in the winter, and the cool water temperatures that follow until late spring. Spring turnover recirculates nutrients throughout the water column and contributes to diatom blooms. The spring diatom increase (SDI) will generally end when conditions change: the nutrients are depleted from the water column, the sunlight becomes stronger and the waters become warmer and stratify. Other factors for the end of the bloom may be zooplankton grazing and silica depletion.

In the summer and fall, the warmer water and internal phosphorus loading at both lake stations provided more favorable conditions for the dominance of blue-green algae (cyanobacteria). Gleocapsa and Anabaena co-dominated the phytoplankton community at both the North and South Stations until early September when the community succession shifted to Ceolosphaerium, Microcystis, and Merismopedia. The cyanobacteria or blue-greens remained dominant until early November when succession shifted to the cryptomonads. The cyanobacteria usually dominate during high levels of phosphorus and out-compete other phytoplankton. Their ability to regulate buoyancy allows them to surface for sunlight and sink for nutrients. When they out-compete other plankton types, they often cause unsightly blooms with noxious odors. Net phytoplankton dominance at Pawtuckaway Lake is presented in Table VI-I.

2. Wholewater Phytoplankton

Wholewater phytoplankton analyses include the smaller (<80µ) plankton types that are not collected in the typical net plankton sample. The total numbers of wholewater phytoplankton can be used as trophic state indicators. The following trophic classifications can be made for summer algae counts (units/mL): oligotrophic 0-1000; mesotrophic 1000-2000; eutrophic >2000 (Estabrook et al., 1991). Colonies, filaments and single cells are all counted as a single standard unit.

Three types of phytoplankton were dominant during the study year at Pawtuckaway Lake: Cryptophyceae, Bacillariophyceae (diatoms), and cyanobacteria (blue-greens). Cryptophyceae dominated the phytoplankton community at both lake stations during the fall months and into late spring. Densities of Cryptophyceae during this period generally remained within the oligotrophic range (<1000 units/mL), with the exception of samples collected on April 16 and November 9 at the North Station which were in the mesotrophic range. Bacillariophyceae (diatoms) were the

Table VI-1
Pawtuckaway Lake Net Phytoplankton
Percent Dominance, October 1991 through November 1992

Date	Station	Dominant Net Phytoplankton	% of Total	Date	Station	Dominant Net Phytoplankton	% of Total
10/15/91	North	Coelosphaerium	57	06/26/92	North	Tabellaria	44
		Asterionella	16			Asterionella	18
	South	Asterionella	32			Gleocapsa	12
		Coelosphaerium	28			Anabaena	12
		Uroglenopsis	16		South	Tabellaria	38
11/12/91	North	Asterionella	74			Gleocapsa	24
	South	Asterionella	56			Stephanodiscus	20
		Coelosphaerium	31	07/07/92	North	Tabellaria	30
12/16/91	North	Asterionella	94			Coelosphaerium	28
01/14/92	North	Asterionella	96		South	Gleocapsa	64
	South	Asterionella	90	07/21/92	North	Gleocapsa	80
02/13/92	North	Asterionella	99		South	Gleocapsa	81
	South	Asterionella	75	08/03/92	North	Anabaena	51
04/16/92	North	Asterionella	84			Gleocapsa	18
	South	Dinobryon	63		South	Anabaena	64
		Asterionella	34			Gleocapsa	15
05/07/92	North	Dinobryon	86	08/26/92	North	Anabaena	36
	South	Dinobryon	69			Filamentous Blue-Greens	16
05/26/92	North	Asterionella	68		South	Anabaena	46
	South	Asterionella	88			Filamentous Blue-Greens	24
06/10/92	North	Asterionella	59	09/09/92	North	Microcystis	30
		Tabellaria	32			Filamentous Blue-Greens	23
		Chrysosphaerella	24		South	Anabaena	24
	South	Asterionella	34			Microcystis	16
		Stephanodiscus	19	09/22/92	North	Coelospharium	20
		Tabellaria	17			Merismopedia	19

Table VI-1 (Cont.)
Pawtuckaway Lake Net Phytoplankton
Percent Dominance, October 1991 through November 1992

Date	Station	Dominant Net Phytoplankton	% of Total	Date	Station	Dominant Net Phytoplankton	% of Total
09/22/92	North	Microcystis	18	10/12/92	South	Microcystis	18
	South	Microcystis	23			Cryptomonas	14
		Merismopedia	20			Chroomonas	30
10/12/92	North	Coelospharium	30	11/09/92	North	Coelosphaerium	26
		Microcystis	17		South	Dinobryon	67
		Anabaena	15			Cryptomonas	23

Group Divisions:

Diatoms	Blue-Greens	Cryptomonads	Golden-Brown Flagellated
Asterionella	Anabaena	Chroomonas	Chrysosphaerella
Stephanodiscus	Coelosphaerium	Cryptomonas	Dinobryon
Tabellaria	Filamentous		Uroglenopsis
	Gleocapsa		

dominant phytoplankton class from late May until the end of June with densities generally in the mesotrophic range. The exception during this period was at South Station on June 10 which had densities in the eutrophic range. The cyanobacteria (blue-greens) dominated the phytoplankton community in August at the South Station with densities in the oligotrophic range. This occurrence is typical in temperate dimictic lakes during the summer months when environmental conditions are optimum for blue-green algae growth. Table VI-2 presents wholewater phytoplankton dominance and densities for the study year.

Table VI-2
Pawtuckaway Lake Wholewater Phytoplankton
Percent Dominance and Densities, October 1991 through November 1992

Date	Station	Units per mL Total Density	Dominant Phytoplankton Class	% of Total
10/15/91	North	738.7	Cryptophyceae	62
	South	885.6	Cryptophyceae	64
11/12/91	North	375.8	Cryptophyceae	48
	South	639.4	Cryptophyceae	39
04/16/92	North	1118.9	Cryptophyceae	45
	South	786.2	Cryptophyceae	26
05/07/92	North	963.4	Cryptophyceae	40
05/17/92	South	570.2	Cryptophyceae	22
05/26/92	North	1144.8	Bacillariophyceae	51
	South	1188.0	Bacillariophyceae	42
06/10/92	North	1494.7	Bacillariophyceae	38
	South	2043.4	Bacillariophyceae	69
06/26/92	North	656.6	Cryptophyceae	30
	South	928.8	Bacillariophyceae	48
07/29/92	North	479.5	Cryptophyceae	31
08/26/92	South	673.9	Cyanobacteria	24
10/12/92	North	561.6	Cryptophyceae	48
	South	440.6	Cryptophyceae	47
11/09/92	North	1093.0	Cryptophyceae	65
	South	717.1	Cryptophyceae	40

B. ZOOPLANKTON

Zooplankton are microscopic and macroscopic animals that live in aquatic ecosystems. In general, rotifers are found in greater abundance and the ratio of rotifers to crustaceans are generally higher in mesotrophic and eutrophic lakes. Oligotrophic lakes commonly reflect higher numbers of crustaceans and lower numbers of rotifers. Table VI-3 compares the mean zooplankton densities of Pawtuckaway Lake to the New Hampshire means. New Hampshire means were calculated using data from almost 350 lakes statewide. Raw data for zooplankton can be found in Appendix VI-I.

The rotifers Kellicottia and Keratella co-dominated the zooplankton community with the crustaceans Nauplius larva and Calanoid copepods at both lake stations for the study year. The mean rotifer densities at both lake stations were greater than the mean crustacean densities and the types and numbers of zooplankton found in Pawtuckaway Lake are typical of New Hampshire mesotrophic and eutrophic lakes. The dominant zooplankton for Pawtuckaway Lake are presented in Table VI-4.

Table VI-3
Rotifer and Crustacean Mean Densities for
Pawtuckaway North, Pawtuckaway South and New Hampshire

Site	Mean Rotifer Density (#/L)	Mean Crustacean Density (#/L)
Pawtuckaway Lake (North)	47.6	41.7
Pawtuckaway Lake (South)	44.8	34.28
N.H. Lakes	192.0	94.00

Table VI-4
Pawtuckaway Lake Zooplankton
Dominance and Densities, October 1991 through November 1992

Date	Station	#/mL	Dominant Zooplankton	% of Total
10/15/91	North	85.8	Polyarthra Kellicottia	53 24
	South	37.4	Kellicottia Daphnia	25 17
11/12/91	North	84.2	Polyarthra Kellicottia Calanoid copepod	26 24 20
	South	Sparse	No Dominant	
12/16/91	North	128.6	Codonella	26
01/14/94	North	88.4	Nauplius larva Keratella Kellicottia	43 26 17
	South	70.7	Nauplius larva	38
02/13/92	North	44.7	Nauplius larva Keratella	56 18
	South	74.5	Nauplius larva Kellicottia	38 11
04/16/92	North	200.6	Keratella Nauplius larva	31 23
	South	228.9	Polyarthra Nauplius larva	30 26
05/07/92	North	300.3	Nauplius larva Kellicottia	36 18
	South	360	Kellicottia Cyclopoid copepod	22 18
05/26/92	North	183.1	Kellicottia Calanoid copepod	12 8
	South	111.2	Kellicottia	21
06/10/92	North	39.2	Kellicottia Calanoid copepod	13 13
	South	63.2	Kellicottia Calanoid copepod	24 13.1

Table VI-4 (Cont.)
Pawtuckaway Lake Zooplankton
Dominance and Densities, October 1991 through November 1992

Date	Station	#/mL	Dominant Zooplankton	% of Total
06/26/92	North	74.1	Kellicottia	30
	South	48	Kellicottia	35
07/07/92	North	39.2	Kellicottia	15
	South	24.0	Daphnia	16
07/21/92	North	28.3	Nauplius larva	11
	South	45.8	Conochilus	30
08/30/92	North	146.1	Colotheca Nauplius lava	12 9
	South	85	Conochilus Nauplius larva	10 10
08/26/92	North	91.0	Nauplius larva Tiny ciliate Keratella	24 24 20
	South	141.96	Tiny ciliate Synchaeta	68 8
09/09/92	North	24.82	Nauplius larva	35
	South	23.66	Daphnia Kellicottia Nauplius larva	31 23 23
09/22/92	North	26.9	Nauplius larva	56
	South	34.32	Nauplius larva Daphnia	32 18
10/12/92	North	40	Daphnia	45
	South	Sparse	No Dominant	
11/09/92	North	Sparse	No Dominant	
	South	Sparse	No Dominant	

Group Divisions:

Rotifers		Crustaceans	Protozoans
Colotheca	Keratella	Daphnia	Codonella
Conochilus	Polyarthra	Calanoid copepod	Tiny ciliates
Kellicottia	Synchaeta	Cyclopoid copepod	
		Nauplius larva	

C. CHLOROPHYLL-A AND TRANSPARENCY

Chlorophyll-a is the green pigment found in plants that allow them to convert sunlight to energy. Chlorophyll-a measurements indicate the biomass (weight) of phytoplankton in a lake or pond. Transparency is a measure of water clarity. Suspended matter in the water column, both living and dead, and highly colored water reduces water clarity. Unless high concentrations of silt are present, there is generally an inverse correlation between chlorophyll-a and transparency. Trophic state not only refers to the nutrient status of the lake, but also to the biological production that occurs in the water and to the morphological characteristics of the lake basin. Increased lake fertilization with nutrients usually results in an increase in biological production that can be measured as chlorophyll-a. Comparisons between chlorophyll and transparency trends in New Hampshire as well as worldwide reflects a linear relationship between chlorophyll and transparency. As chlorophyll-a increases, transparency decreases.

Mean chlorophyll-a and transparency concentrations for New Hampshire lakes are 7.22 mg/m^3 and 3.8 meters respectively. Mean monthly values for Pawtuckaway Lake appear in Table VI-5. Raw data for chlorophyll-a and transparency are presented in Appendix VI-1.

The maximum chlorophyll-a concentrations measured at Pawtuckaway Lake occurred in April 1992 at both the North and South Stations with concentrations of 10.5 mg/m^3 and 6.34 mg/m^3 respectively. This spring bloom reflects the large volumes of runoff entering the lake during this season and the associated influx of nutrients. The ratio of watershed area to lake area at Pawtuckaway is such that 1 inch of runoff increases the lake level 16 inches. During the spring when the snow melts and the ground begins to thaw, significant runoff reaches the lake carrying nutrients that were stored in the watershed over the winter. These nutrients can trigger an early season algae bloom and a reduction in water clarity. An additional explanation for the spring maximum chlorophyll-a concentrations at Pawtuckaway Lake is associated with internal phosphorus loading. During the stratified summer months the hypolimnion becomes anoxic and phosphorus is released from the sediments into the hypolimnetic water column. Fall mixing distributes the hypolimnetic phosphorus throughout the water column where it becomes available for biological uptake. However, the lack of sunlight during the fall and winter limits the amount of algal growth. Ice-out conditions and increasing sunlight in the spring results in early season

algae blooms and increased chlorophyll-a concentrations.

The high chlorophyll-a values experienced in April 1992 corresponded with the lowest transparency readings at the North and South Stations with transparencies of 2.0 meters and 3.0 meters respectively.

Table VI-5
Pawtuckaway Lake Mean Chlorophyll-a and Transparency,
October 1991 through November 1992

Month/Year	NORTH		SOUTH	
	Chlorophyll-a (mg/m^3)	Transparency (m)	Chlorophyll-a (mg/m^3)	Transparency (m)
October 1991	2.44	3.20	2.42	4.20
November 1991	-	2.30	-	3.50
December 1991	-	-	-	-
January 1992	-	-	-	-
February 1992	-	-	-	-
March 1992	-	-	-	-
April 1992	10.46	2.0	6.34	3.0
May 1992	4.31	4.10	4.38	4.75
June 1992	4.66	3.70	4.97	3.90
July 1992	4.64	4.40	4.49	4.55
August 1992	3.98	4.15	3.79	4.25
September 1992	3.44	5.15	2.63	5.65
October 1992	2.92	4.70	4.15	4.20
November 1992	3.35	2.40	2.54	5.60

The lowest chlorophyll-a concentrations measured in Pawtuckaway Lake were 2.44 mg/m^3 and 2.42 mg/m^3 at the North and South Stations respectively. The chlorophyll-a minimum values were measured in October 1991 which was expected due to the amount of decreased sunlight and a decline in productivity throughout the water column during the fall. Maximum transparency

values were recorded for both lake stations during September 1992 with values of 5.30 meters in the North Station and 6.10 meters in the South Station. Appendix VI-3 presents transparency and chlorophyll-a ranges for the North and South Stations at Pawtuckaway Lake during the study year.

The chlorophyll-a and transparency results for the study year at Pawtuckaway are indicative of a borderline oligotrophic/mesotrophic waterbody. Figures VI-1 and VI-2 illustrate the seasonal variation of chlorophyll-a and transparency values for the study year at the North and South Station respectively.

D. AQUATIC VEGETATION

Aquatic vascular plants can often be observed around lakes and ponds. These plants can be emergent, submergent or floating. They are considered to be essential in maintaining a balanced lake ecosystem. Aquatic plants prevent erosion by binding soils and breaking waves. They also provide nesting materials and sites for various species of birds and fish. Weed beds are very important nursery areas for young game fish. The diverse food source aquatic plants provide is crucial to the lake ecosystems. Submerged plant leaves and stems provide an ideal surface for the growth of periphyton. These microscopic plants are grazed by small crustaceans and insects which in turn are an important food source for fish. Grasses such as wild rice are eaten by song birds and waterfowl. Aquatic plants are also eaten by deer, moose, beaver, muskrat and porcupines.

The macrophyte community at Pawtuckaway Lake during the study year was dominated by Sparganium (Bur Reed), Utricularia (Bladderwort), and Vallisneria americana (Tape grass). Eriocaulon septangulare (Pipewort), Graminae (Grass family) and Juncus (Rush), were also found in significant abundances throughout the entire shoreline. Bank vegetation was dominated by Cephalanthus occidentalis (Buttonbush), and Myrica gale (Sweet gale) with abundances of Vaccinium corymbosum or high bush blueberry occurring as well.

The macrophyte communities at Pawtuckaway Lake reach maximum abundances in the Fundy Bay area. The maximum depth in this area is 3.0 meters which allows for maximum sunlight penetration to the bottom which is organically rich and supports vegetative growth.

Pawtuckaway Lake North

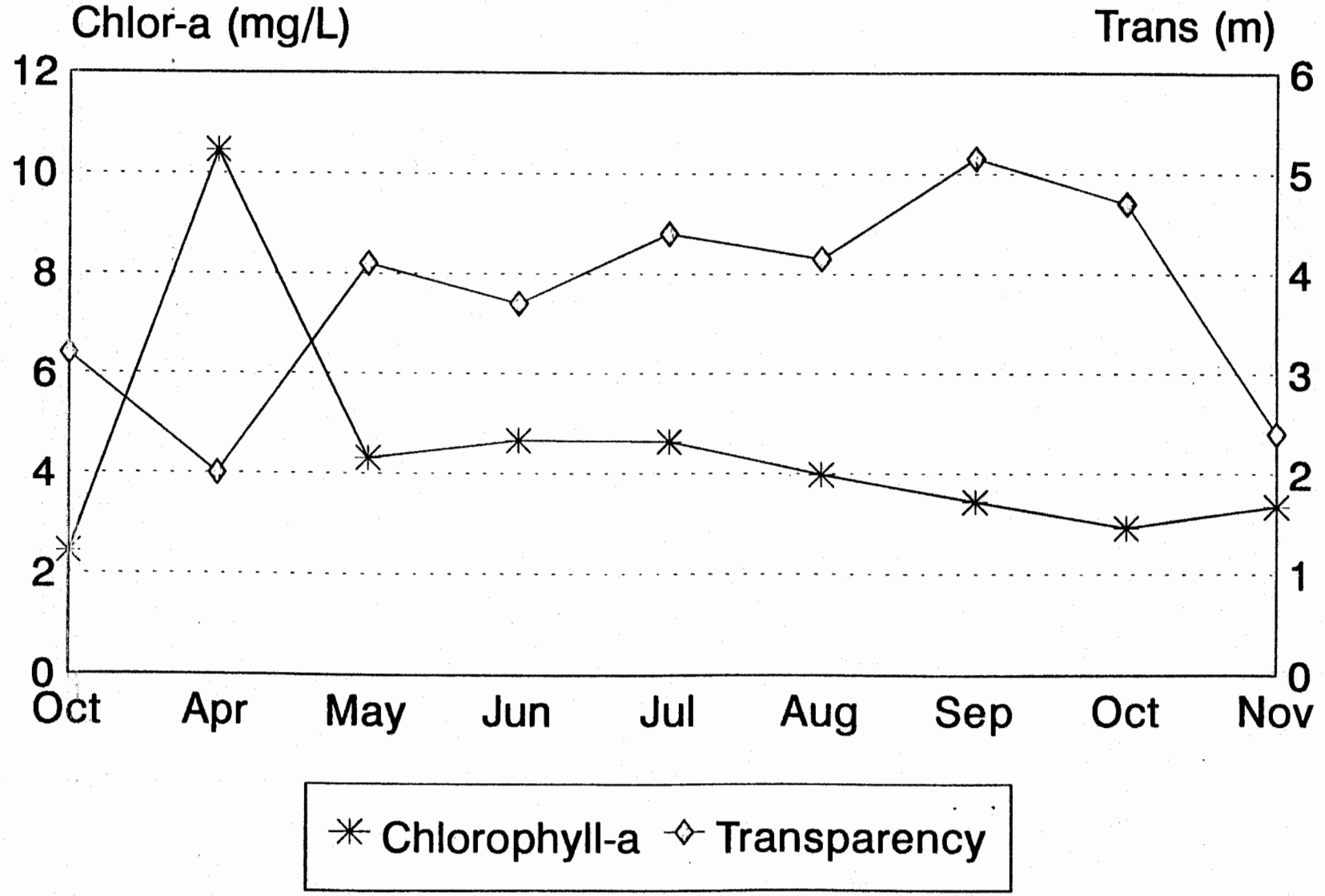


Figure VI-1: Pawtuckaway Lake North Chlorophyll-a and Transparency Trends (1991-1992)

Pawtuckaway Lake South

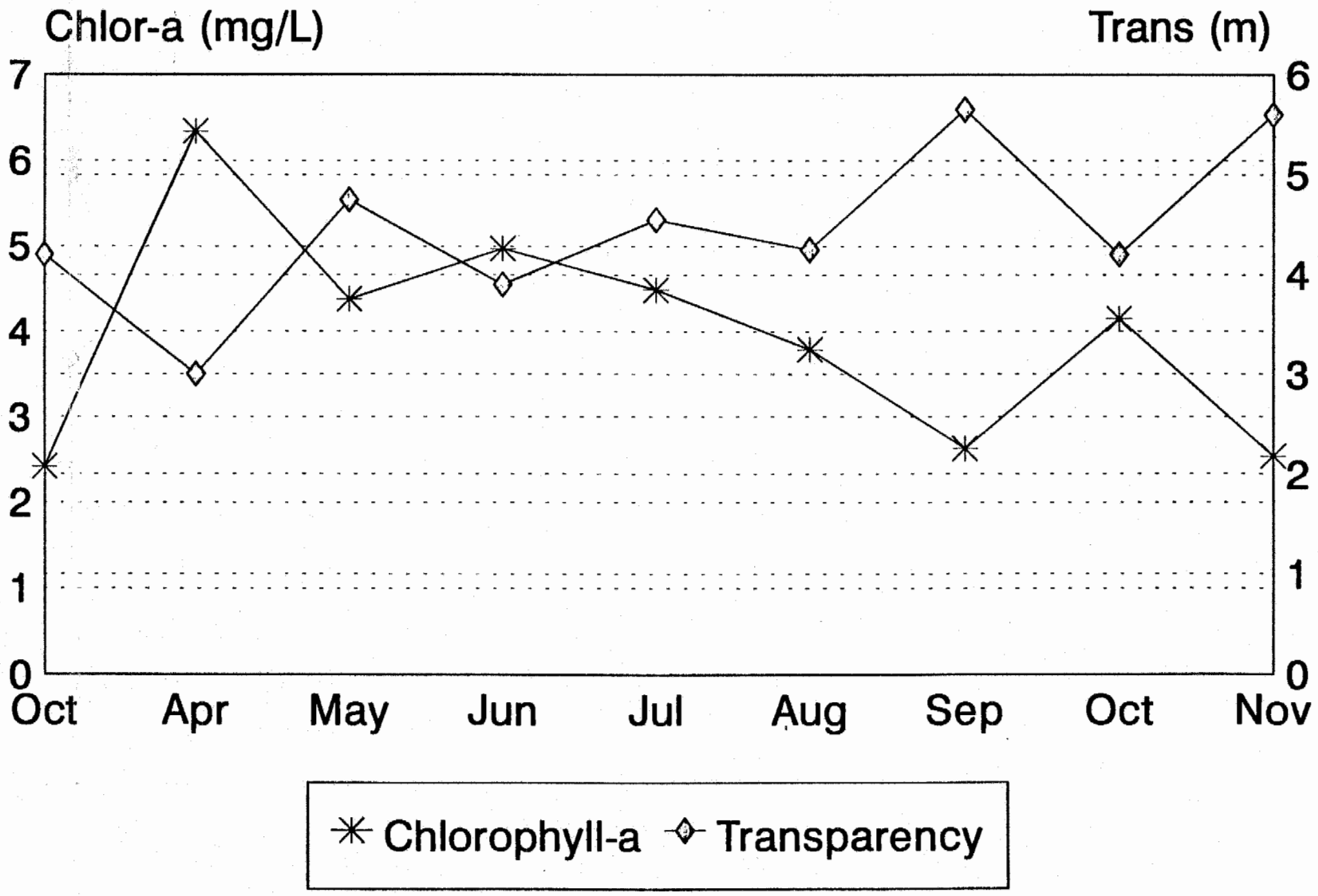


Figure VI-2: Pawtuckaway Lake South Chlorophyll-a and Transparency Trends (1991-1992)

Table VI-6
Pawtuckaway Lake Aquatic Plant Map Key 1994

AQUATIC PLANT SURVEY			
LAKE: PAWTUCKAWAY	TOWN: NOTTINGHAM		DATE: 09/01/94
KEY	PLANT NAME		ABUNDANCE
	GENERIC	COMMON	
A	Sagittaria	Arrowhead	Scat/Common
B	Brasenia schreberi	Water shield	Sparse
T	Typha	Cattail	Scattered
d	Dulichium arundinaceum	Three-way sedge	Scattered
D	Elodea nuttallii	Waterweed	Sparse
f		Filamentous algae	Scat/Common
G	Gramineae	Grass family	Common
F	Nymphoides cordatum	Floating heart	Sparse
M	Scirpus validus	Softstem bulrush	Sparse
O	Cephalanthus occidentalis	Buttonbush	Common/Abun
E	Eriocaulon septangulare	Pipewort	Common/Abun
Q	Isoetes	Quillwort	Sparse
b	Scirpus	Bulrush	Scattered
S	Sparganium	Bur reed	Abundant
V	Vallisneria americana	Tape grass	Abundant
U	Utricularia	Bladderwort	Abundant
a	Myrica asplenifolia	Sweet fern	Sparse
h	Gratiola	Hedge hyssop	Sparse
R	Potamogeton robbinsii	Robbins pondweed	Scattered
g	Myrica gale	Sweet gale	Common/Abun
n	Vaccinium corymbosum	High-bush blueberry	Scattered
K		Unknown woody flower	Sparse
e	Eleocharis	Spike rush	Scattered
I	Potamogeton nodosus	Spike rush	Scattered

Table VI-6 (cont.)
Pawtuckaway Lake Aquatic Plant Map Key 1994

AQUATIC PLANT SURVEY			
LAKE: PAWTUCKAWAY	TOWN: NOTTINGHAM		DATE: 09/01/94
KEY	**PLANT NAME**		**ABUNDANCE**
	GENERIC	**COMMON**	
k	Scutellatia	Skullcap	Sparse
Z	Solanum	Nightshade	Sparse
t	Ceratophyllum demersum	Coontail	Sparse
r	Clethra alnifolia	Sweet pepperbush	Scattered
C	Cyperaceae	non-flowering sedge	Sparse
H	Hypericum	St. John's-wort	Sparse
X	Carex	Sedge	Sparse
			OVERALL ABUNDANCE: Common/Abun

GENERAL OBSERVATIONS:

1. Tape Grass, Bur Reed and Bladderwort were very Abundant in the Fundy Bay area. Maximum densities of macrophyte communities also present in Fundy Bay.
2. Plants occur along entire shoreline, but not a nuisance for swimming or navigation in the main water areas of the lake.
3. Buttonbush, Sweet Gale and high bush blueberry were the dominant shoreline bank vegetation.
4. Filamentous algae clumps scattered along entire shoreline.

Abundances of macrophytes throughout the remainder of the lake are considered to be scattered with dense patches occurring in coves.

Overall, the amount of plant growth was classified as common/abundant, meaning that there were plants around the entire shoreline with thick patches in areas but not a problem to navigation in the deep open water areas of the lake. Table VI-6 shows each type of aquatic vascular plant found in Pawtuckaway Lake, its abundance and its code letter. Code letters serve as a key for Figure VI-3.

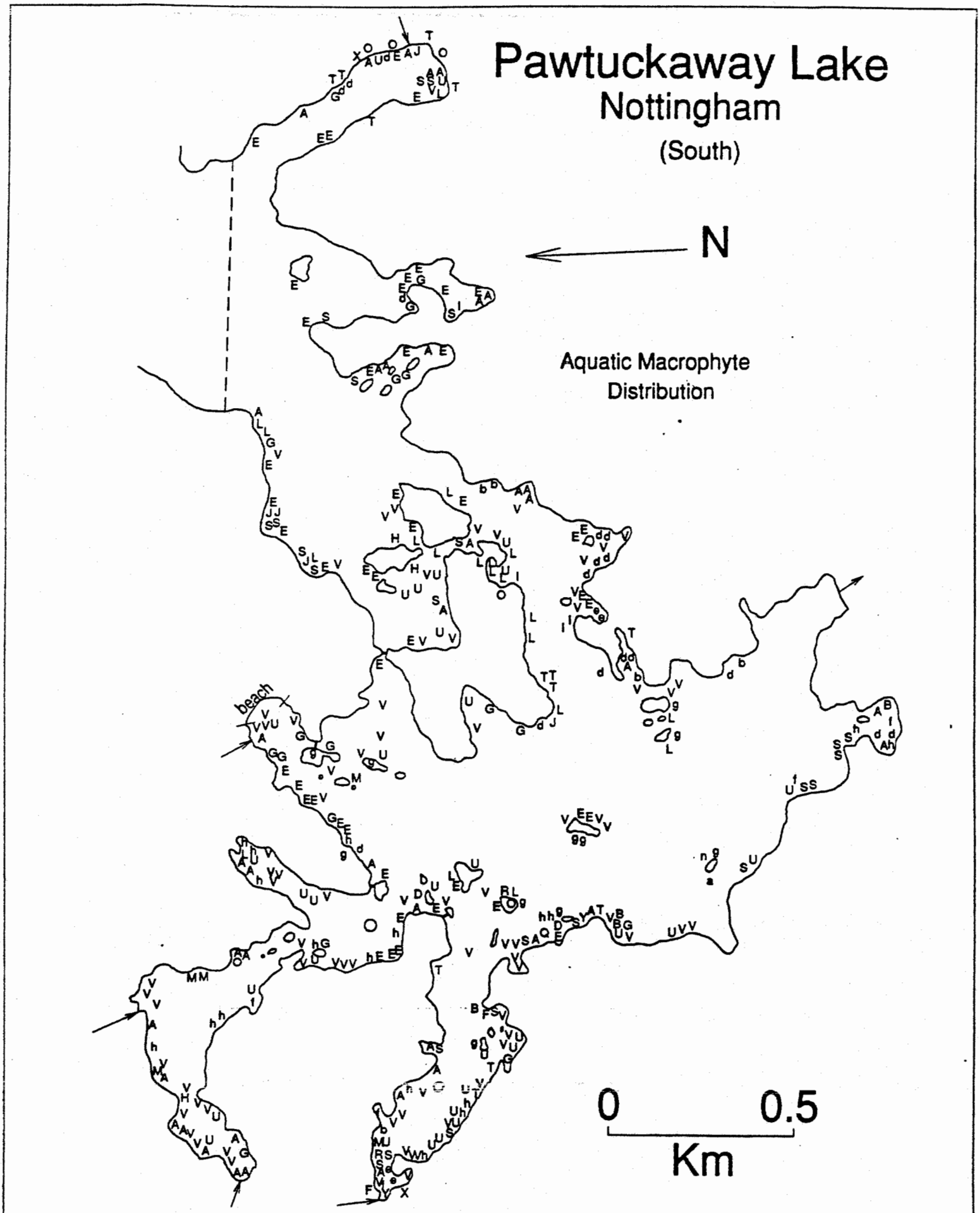


Figure VI-3: Pawtuckaway Lake Aquatic Macrophyte Distribution

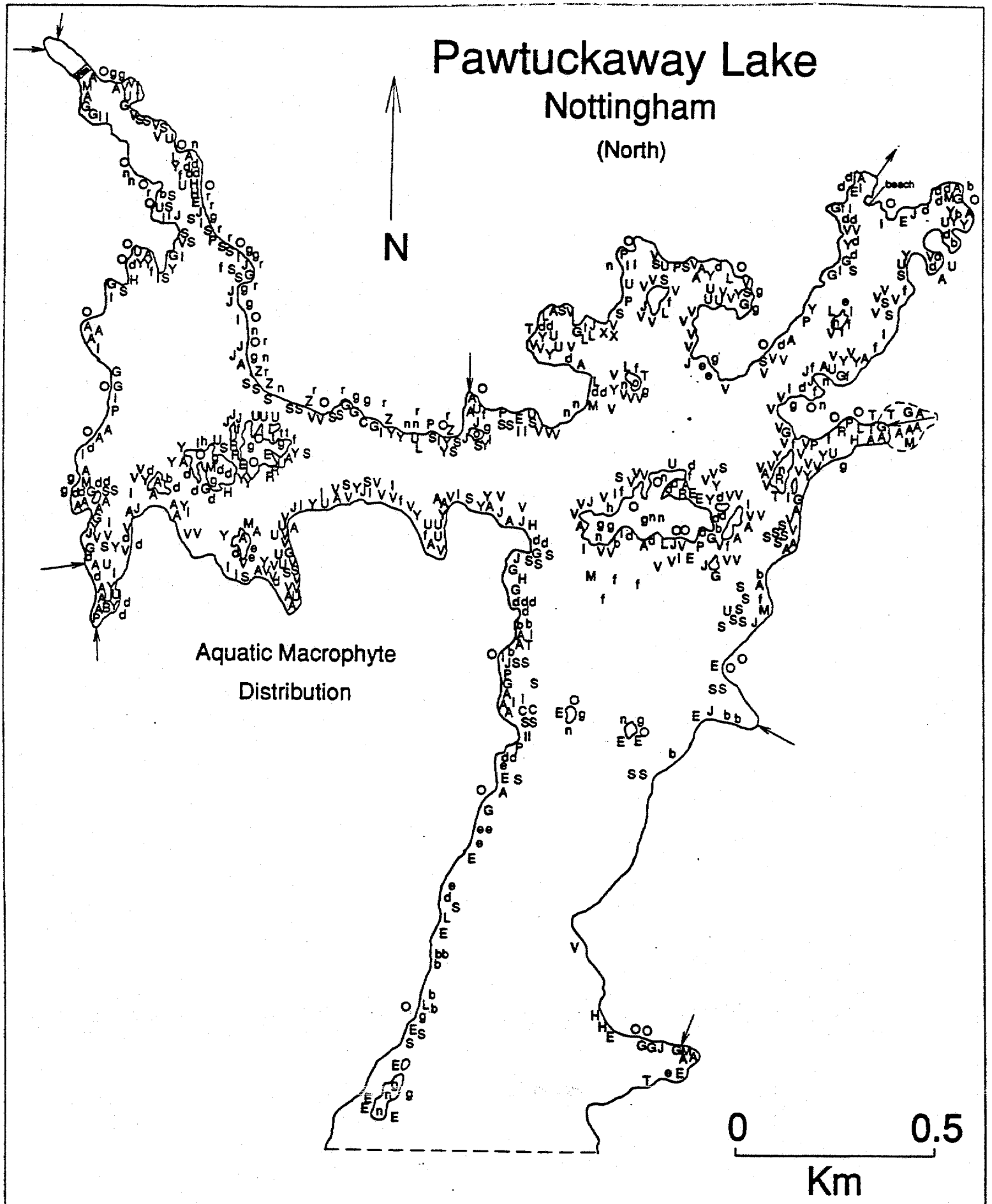


Figure VI-3(cont.):Pawtuckaway Lake Aquatic Macrophyte Distribution

CHAPTER VII HYDROLOGIC BUDGET

A. SURFACE AND GROUNDWATER HYDROLOGY

The hydrologic budget for a lake equates the total water input to the total water output for specified time increments during a specified period. The water flow rates through the lake are thereby quantified. The development of a hydrologic budget is essential in calculating the loading (mass per unit time) of eutrophying nutrients as well as in evaluating a lake's tolerance to these nutrients. The balance between hydrologic inputs and outputs influence the nutrient supply to the lake, the lake's water residence time, and consequently the lake's productivity and water quality. An accurate and detailed hydrologic budget will thus permit an accurate determination of current trophic status and will provide a sound basis for evaluating the effectiveness of watershed and in-lake management strategies for improving trophic status.

The quantification of the components of the Pawtuckaway Lake hydrologic budget was based on an intensive one-year stream gaging and precipitation measurement program. A budget for the gaging period (December 1991 through November 1992) was developed as a basis for a complete hydrologic year and phosphorus budget. The budget quantifies the monthly and annual water inflow from each source to Pawtuckaway Lake. Additionally, the monthly variations in the lake's hydraulic retention time and fraction of exchanged lake water volume are specified.

In conjunction with the hydrologic budget for Pawtuckaway Lake, mean monthly surface water discharge volumes for each station in the watershed were calculated and tabulated for the gaging year. This information is valuable for comparing the relative hydrologic (and hence nutrient) contributions from various tributary areas within the watershed. Section B describes the field monitoring program. Section C presents the hydrologic budget and other hydrologic data, and discusses their development.

B. FIELD MONITORING PROGRAM

Field investigations and data collection occurred during the period from September 1991 through December 1992. The actual gaging year budget presented in this chapter encompasses a complete year, beginning December 1, 1991, and ending November 30, 1992.

1. Stream Gaging and Precipitation Monitoring

Thirteen inflowing tributaries and two outlet stations were monitored for flow within the Pawtuckaway Lake watershed. To determine the stage-discharge relationships at each station, measurements of flow were obtained using current meters three or four times per month (depending on time of year and station when flow warranted). Stage-discharge relationships and discharge summaries for each station can be found in Appendix VII-1 and VII-2 respectively.

Direct discharge measurements do have some disadvantages. Schroeder (1979) and Dennis (1988) point out that periods of peak discharge during storm events and spring melt off may be missed, resulting in lower estimates of inflow and thus nutrient loading. In fact, both spring melt off and storm events could represent a high percent of the total hydrologic and phosphorus budget in a given watershed. To partially offset this disadvantage, specific heavy runoff and snowmelt sampling was conducted during the study.

A variety of methods have been utilized to calculate runoff and water budgets. Each method has drawbacks. Estimates of flow rates on tributary streams from interpolation of flows from neighboring watersheds can have significant errors. Dillon and Rigler (1974) caution against predicting water budgets through empirical methods using long-term runoff maps. He suggests that measurement versus estimation provides more accurate results and should be utilized where possible. In general, values will usually fall within 25% of those predicted using long-term runoff maps.

Daily rainfall and water equivalent snowfall data (Chapter III) were collected from NOAA climatological stations in Concord and Manchester, New Hampshire. The Manchester station is within 20 miles of the study area. Monthly rainfall and water equivalent snowfall data for Pawtuckaway Lake is presented in Table VII-1, along with the surface volume precipitation upon the lake. Monthly evaporation volume from Pawtuckaway is presented in Table VII-2.

Table VII-I
Pawtuckaway Lake Monthly Precipitation
December 1991 through November 1992

Month	Monthly Total (in)	Monthly Total (m)	Precip (m^3)	Precip ($10^3 m^3$)	Percent
Dec '91	3.37	0.086	410,675	410.7	9.4
Jan '92	2.05	0.052	248,315	248.3	5.7
Feb '92	1.72	0.044	210,113	210.1	4.8
Mar '92	2.68	0.068	324,720	324.7	7.5
Apr '92	1.85	0.047	224,439	224.4	5.2
May '92	1.99	0.051	243,540	243.5	5.6
Jun '92	2.99	0.076	362,922	362.9	8.4
Jul '92	4.22	0.107	510,956	510.9	11.8
Aug '92	5.12	0.13	620,788	620.8	14.4
Sep '92	2.09	0.053	253,090	253.1	5.9
Oct '92	3.59	0.091	434,551	434.6	10.1
Nov '92	4.00	0.102	487,080	487.1	11.2
Total	35.67			4331.1	100

Surface Area=4,775,291m^2 Precip (m3)=Monthly (m) X Surface area

Table VII-2
Pawtuckaway Lake Monthly
Evaporation Rates
(Pan Coef.)(Lake Surface Area)(Monthly Evap.)

Month	Total Evap (in)	Total Evap (m)	Evap (m^3)	Evap ($10^3 m^3$)	Evap (Pan Coef)
May '92	1.89	0.048	229,214	229.2	176.5
Jun '92	5.50	0.14	668,541	668.5	514.7
Jul '92	4.81	0.122	582,586	582.6	448.6
Aug '92	3.70	0.094	448,877	448.9	345.7
Sep '92	2.64	0.067	319,944	320.0	246.4
Oct '92	1.73	0.044	210,113	210.1	161.8
Total	20.27				1,893.7

Surface area = 3,642,200 m^2 Pan Coef = EV(10^3 m^3) X .77

2. Groundwater

One area which is poorly understood, and in which little information exists, is groundwater seepage and its nutrient contribution to surface waters. In many cases, groundwater seepage may represent a significant input of water and nutrients to an aquatic system. Recent, as well as past, field work has demonstrated significant interchange between lakes and groundwater lenses. Many lakes, rather than being isolated from groundwater bodies by lake bottom sediments, are closely connected with them, forming integral parts of dynamic groundwater flow systems (McBride and Pfankuch, 1975). Nitrogen and phosphorus are direct contributors to the productivity of lakes and streams. These nutrients are often encountered in high concentrations in groundwater and may represent a significant percentage of the nutrient loading to a given lake.

Lee (1972) and Connor (1979) found that seepage flow patterns generally showed an exponential decrease with increasing distance from shore. Shallow groundwater contributes the major volume of seepage to a lake.

Downing and Peterka (1978) and Connor (1979) observed that seepage meters collected more groundwater during rainy periods as compared to drier periods occurring during the summer months. It is speculated that as the water table rises due to rainfall, groundwater is forced by the hydraulic gradient into the lake.

Direct measurements of groundwater through the placement of seepage meters can quantify one factor in the hydraulic budget. In the same way, analysis of the seepage can supply important chemical information that can be utilized in nutrient budget calculations.

Groundwater seepage was measured directly in Pawtuckaway Lake. Seepage meters were constructed of fifty-five gallon drums (208.2 L) cut to form two sections approximately 44 cm in height for insertion into organic muck sediments. Sterile bacterial whirl packs, secured to one-holed rubber stoppers in the top of the drum by hard plastic tubing, were used as seepage collection devices (Connor and Belanger, 1981). Meters were placed at single site locations and two sites had duplicate meters that were used for quality control. Fourteen study sites were established within the lake's perimeter (Figure VII-1). Samples were collected from May of 1991 through September 1992.

Seepage rates were measured for the hydrologic budget by occluding the tubing of the

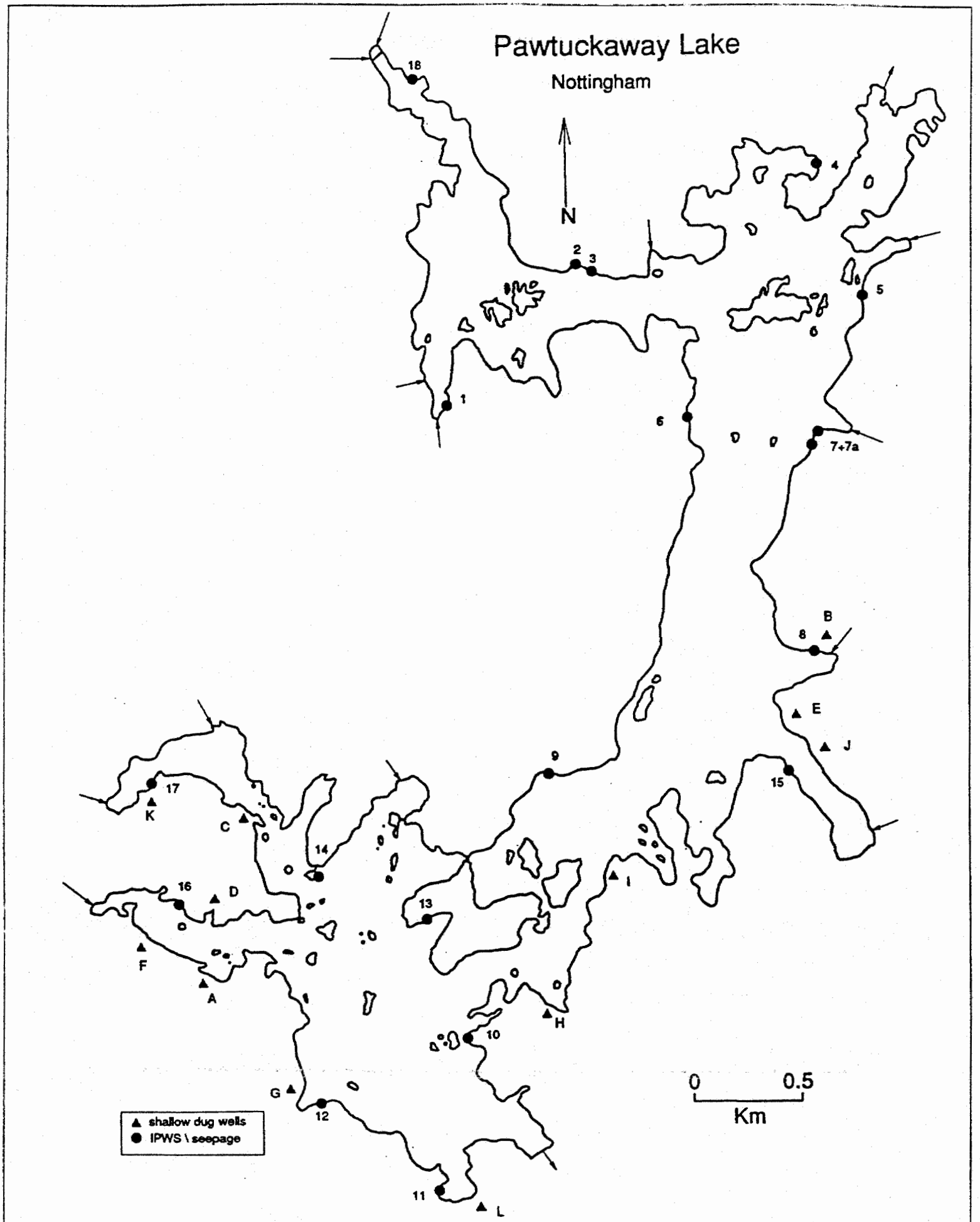


Figure VII-1: IPWS/SEEPAGE and Dug Well Locations

collection bag, attaching it to the seepage meter tubing and releasing the occlusion clamp (Figure VII-2). After the measurement interval, the volume of water obtained from the collection device was measured. The seepage rate was calculated by subtracting the initial volume and converting the collected volume (mL) to liters per square meter per day (L/m^2/day). Mean monthly seepage rates for both years were calculated for each of the areas surrounding each seepage meter (Figure VII-1). The areal addition of individual mean annual seepage rates resulted in total groundwater seepage for the entire sediment area of Pawtuckaway Lake for the study year. Raw seepage meter data, computed from over 100 seepage measurements, are presented in Appendix VII-3.

The greatest mean seepage rate for the study year in Pawtuckaway Lake was recorded at station twelve with a value of 21.67 L/m^2/day (Table VII-3). The maximum seepage rate of 63.85 L/m^2/day was also recorded at station twelve. This station was established on the western shoreline of the south basin of Pawtuckaway Lake. The soils in this region are classified as being well drained with a moderately rapid permeability. The substrate in which the seepage

Table VII-3
Mean Annual Seepage Rates
(L/m^2/Day)

STN	RATE	STN	RATE
1	10.46	8	1.68
*2	11.63	9	8.33
*3	12.02	10	10.99
4	11.72	11	18.39
5	10.99	12	21.67
6	16.73	13	18.35
*7	5.26	14	8.24
*7A	5.51		

* Control Sites

meter was placed at station twelve had a very sandy consistency with a thin organic layer on the surface. Evidence of significant groundwater activity becomes apparent during the winter months at this station when ice forms at the bases of several bedrock exposures indicating the presence

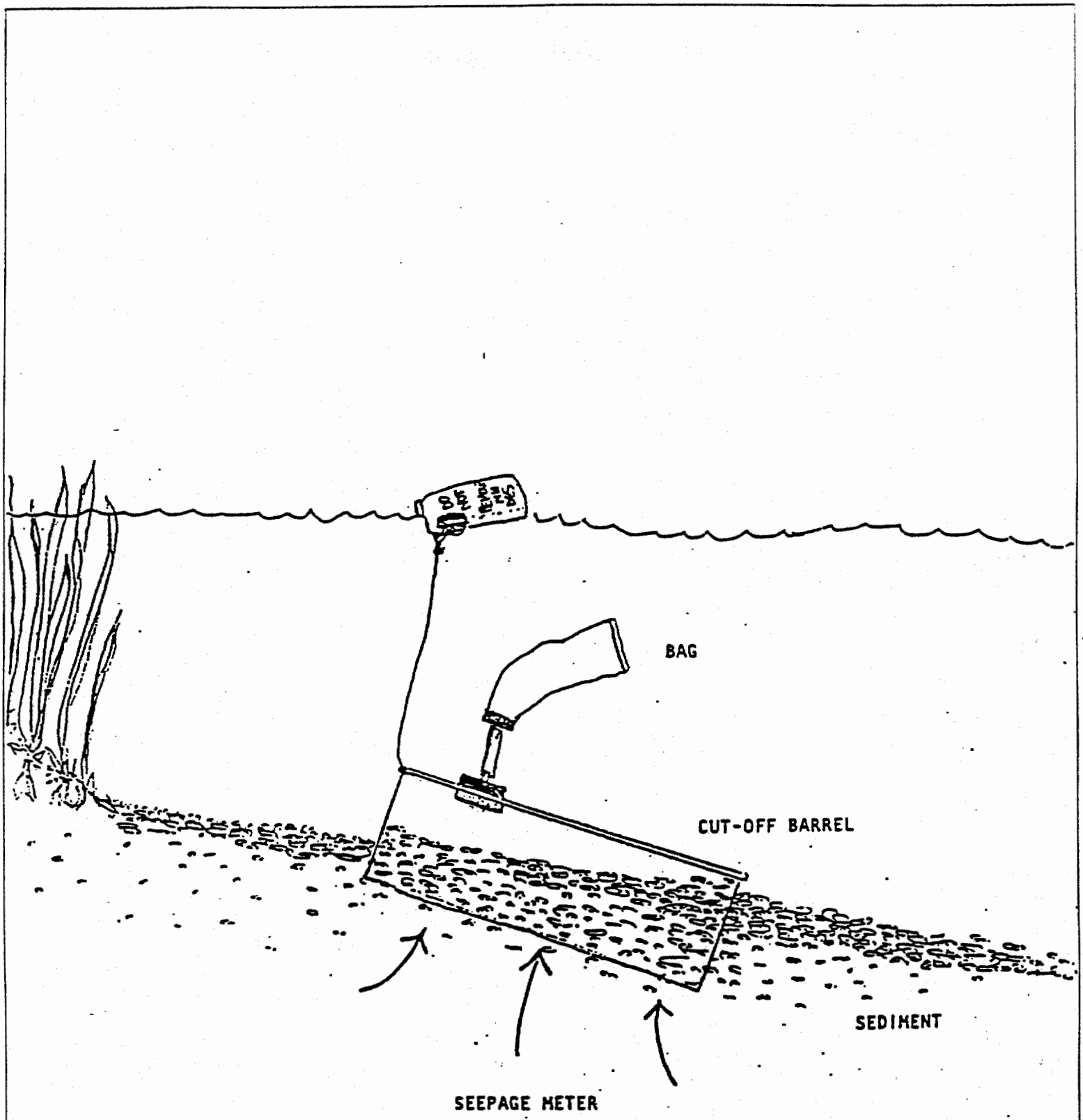


Figure VII-2: Seepage Meter Diagram

of springs. Station twelve had the highest mean monthly seepage rates for the months of July and September with seepage values of 41.84 L/m^2/day and 8.40 L/m^2/day respectively (Table VII-4).

Table VII-4
Mean Monthly Seepage Rates
(L/m^2/day)

STN	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
1	2.35	15.84	19.40	4.55	3.36
2	5.83	13.12	21.05	7.04	4.97
3		14.62	17.36	8.37	6.55
4	1.88	27.22	16.37	4.17	3.00
5	2.99	18.14	18.37	5.45	4.38
6	4.34	38.26	19.98	6.94	8.58
7		.71	11.79	4.14	1.80
7A			18.73	1.82	1.54
8		7.43	.66	-0.29	0.00
9		9.09	14.30	4.81	4.04
10		16.82	18.29	4.44	4.05
11		38.46	28.63	4.12	3.52
12		41.84	31.17	8.40	5.61
13		30.98	33.23	4.63	3.97
14		10.94	10.34	6.58	4.12

The mean yearly seepage rates recorded at stations six, eleven and thirteen were 16.73, 18.39 and 18.35 L/m^2/day respectively. Seepage rates measured from these three stations were among the highest recorded during the study year at Pawtuckaway Lake (Table VII-3). Maximum mean monthly seepage rates for October were recorded at station six (8.58 L/m^2/day) and for August were recorded at station thirteen (33.23 L/m^2/day). The subsurface characteristics surrounding these three seepage sites is considered to be well drained soil with a relatively shallow depth to bedrock. These conditions promote the rapid migration of groundwater towards Pawtuckaway Lake.

The lowest mean annual seepage rate recorded at Pawtuckaway Lake was 1.68 L/m^2/day from station eight (Table VII-3). Minimum mean monthly seepage rates for August, September and October were also recorded at station eight with values of 0.66, -0.29 and 0.00 L/m^2/day respectively (Table VII-4). The seepage meter at station eight was installed into substrate consisting of sand and cobble. The surrounding soils in this area consist of the stony Scituate-Newfields Complex which is characterized as having a moderately slow permeability.

The remaining seepage stations had mean annual seepage rates ranging from a minimum of 5.26 L/m^2/day at station seven to a maximum of 12.02 L/m^2/day at station two.

Two control sties were established at Pawtuckaway Lake to evaluate quality assurance and quality control for groundwater seepage measurements during the study year. Stations two and three were control meters installed together on the northern shoreline of Fundy Bay. Although the mean monthly seepage rates varied between these two meters, the mean annual seepage rates were 11.63 L/m^2/day at station two and 12.02 L/m^2/day at station three. The difference between the two meters for mean annual seepage rates for the study year was 0.39 L/m^2/day which indicates satisfactory quality assurance and quality control for field methods during the study year and validates the data collected.

Mean annual seepage rates collected from the control meters seven and seven "A" were 5.26 L/m^2/day and 5.51 L/m^2/day respectively. The difference for mean annual seepage rates was 0.25 L/m^2/day and indicates minimal variation in data collected from these two meters for the study year at Pawtuckaway Lake.

Statistical analysis of the data collected at each control site indicated that there wasn't a statistically significant difference between the data collected from meters two and three and seven and seven "A". A t-test was performed on calculated seepage rates collected at station two and station three in order to compare the data between seepage meters and determine the validity of the data. Data from station two and three passed both the normality test (P=0.0987) and the equal variance test (P=0.4925), indicating that usage and interpretation of data from this control site is valid.

When data is compared between station seven and seven "A", the normality test is failed (P=<0.0001) but the data passes the equal variance test (P=0.8995). One reason for the failed normality test at this site is the fact that there were fewer data points collected at this site compared to stations two and three. Also, stations seven and seven "A" have a greater difference

in standard deviations (4.21) when compared to stations two and three.

The statistical validity of the seepage rates collected at the two control sites during the study year indicate that groundwater seepage data generated throughout the Pawtuckaway Lake shoreline is valid and reflects proper quality assurance and quality control techniques. Fluctuations and observable differences in seepage rates calculated throughout the study year reflect the diverse substrate and underlying geology of the Pawtuckaway Lake watershed which influences groundwater flow regimes around the perimeter of the lake.

C. HYDROLOGIC BUDGET COMPONENTS

The hydrologic budget for the Pawtuckaway Lake watershed, equating all measurable inflowing and outflowing waters over a designated period of time, were determined by the following equation:

Inflow volume = outflow volume

Specifically for Pawtuckaway Lake

$$Qi_1 + Qi_2 + \ldots. Qi_{13} + R + P_{lake} + GWi = Qo_1 + Qo_2 + EV + GWo$$

Where,

Qi_1 = Back Creek (B)

Qi_2 = Mountain Cove Brook

Qi_3 = Round Pond Brook

Qi_4 = Gove Dam Brook

Qi_5 = Burnhams Marsh Brook (North)

Qi_6 = Fernalds Brook (A)

Qi_7 = Loon Cove Brook (A)

Qi_8 = Back Creek (A)

Qi_9 = Fundy Brook

Qi_{10} = Burnhams Marsh Brook (South)

Qi_{11} = White Grove Brook

Qi_{12} = Loon Cove Brook (B)

Qi_{13} = Fernalds Brook (B)

R = Surface water runoff from the direct drainage area

P_{lake} = Precipitation volume on lake

GW_i = Groundwater inflow (seepage)

Qo_1 = Dolloff Dam Outlet

Qo_2 = Drowns Dam Outlet

EV = Lake surface evaporation

GWo = Groundwater outflow (recharge)

Each component of this budget is in volumetric units of 10^3m^3 (1000 cubic meters).

1. Hydrologic Budget for Study Period (1991-1992)

The monthly contributions from the tributaries (Qi) were derived from the aforementioned stream monitoring stations. Groundwater seepage (GWi) was measured directly during the two year study period. Monthly direct runoff rates (R) were calculated by multiplying the runoff coefficient (m/yr) obtained from the Knox and Nordenson Atlas (1955) by the estimated area around the lake which drained directly into the lake.

Stream outflow (Qo) is the measured discharge from the Pawtuckaway Lake outlets. Evaporation from the lake surface (EV) was calculated by multiplying the lake surface area times the evaporation, using a pan coefficient of 0.77.

Groundwater outflow recharge zones (GWo) are difficult to measure unless reliable seepage meter data, including several meter transects to the deeper portions of the lake, are available. Groundwater recharge was measured through mass balance equations and was estimated to be a small portion of the water budget. This is because the surrounding groundwater gradients are predominantly oriented into the lake basin, and the zone through which groundwater outflow occurs is small.

The hydrologic budget for each month of the study period for Pawtuckaway Lake is presented in Table VII-5. Monthly water volume exchanges are graphically depicted in Figure VII-3. The months of October, November, January and February reflect periods in which total monthly outflow exceeded total monthly inflow. This is the period of time when water storage is decreased through the outlet structures of the lake. This is an annual event that is performed to reduce shore-line damage and erosion from ice and to diminish the possibilities of property

damage from flooding as a result of spring snowmelt.

During March, April and May the water inflow to Pawtuckaway Lake exceeded the amount of water that flowed out of the lake via the two outlet structures. This is the period of time when water is collected in the lake basin to bring the lake level back to full pond. This is the level which the lake remains from June through September.

2. Seasonal Flow Trends

Although seasonal precipitation rates influence the total inflow of water to the lake, seasonal precipitation rates may not follow seasonal inflow distribution patterns. Figure VII-4 shows that the spring season was the greatest producer of water to Pawtuckaway Lake, representing 36 percent of the seasonal flow of water. During this same period of time, the spring wetfall only accounted for 18 percent of the total annual precipitation.

The spring season typically delivers the greatest amount of water to northern New England lakes. The reason for the seasonal peak discharge is a combination of rainfall, frozen ground, which limits groundwater penetration, and the melting of the stored winter snowpack.

The summer contributed greatest seasonal precipitation representing 34.6 percent of the annual wetfall rate but yielded the lowest seasonal inflow distribution to the lake (16.6 percent). This is often typical in watershed studies. Summer storm events are usually of high intensity but are of short duration, as such, they are difficult to detect by manual stream monitoring techniques. Summer inflow distribution is usually underestimated but newly developed automated flow recorders will improve hydrologic budgets for the future.

Another aspect to consider when assessing a storm's significance is the environmental conditions at the time of the storm. August is typically a hot dry month in the Northeast and at the end of the growing season. The land is usually dry, with a low water table, and is primed for absorption of rainfall. However, July and August accounted for 23 percent and the summer season produced 35 percent of the rainfall for the Pawtuckaway study year. The high summer rainfall does not correspond to the moderate summer inflow to the lake. This low correlation between rainfall and lake inflow may be explained by higher soil infiltration rates during the summer and because high intensity, short duration rain events are difficult to monitor. The short duration rain events are often missed and not accounted for in the hydrologic or nutrient budgets.

Only if an organized summer wetfall event is measured or automated flow equipment is employed, can sophisticated hydrologic budgets be constructed.

The fall season contributed only 18.6 percent of the seasonal inflow to the lake. Typically northern New England receives substantial wetfall during the fall season. However, September was exceptionally dry for this study year, producing only 5.9 percent of the monthly rainfall.

The winter season accounted for 28.8 percent of the hydrologic budget. This contribution is higher than many other studies conducted and is a result of heavy December rainfall and frozen ground that limited the amount of rainfall from infiltrating the ground. High rainfall during this period is also the reason why tributary flow was greatest during the winter, representing 38 percent of the tributary supply of water to the lake.

Seasonal outflow characteristics during the fall, winter and spring are regulated by two dam structures and do not correspond with the seasonal inflow distribution. The summer season is the only period that is not artificially controlled by the dam structures. Correlations between the summer inflow distribution and summer outflow are presented in Figure VII-4.

3. Tributary Flow Contributions

The subwatershed areas of Back Creek "B" (3,698 acres), Mountain Cove Brook (2400 acres), and Round Pond Brook (1599 acres) comprise 65 percent of the Pawtuckaway Lake watershed and contributed 77 percent of the total tributary inflow to the lake.

Figure VII-5 displays the relative annual volume of each tributary flow to Pawtuckaway Lake. Back Creek (B) was the greatest tributary supplier of water to Pawtuckaway Lake contributing 38 percent of the tributary contribution to the hydrologic budget.

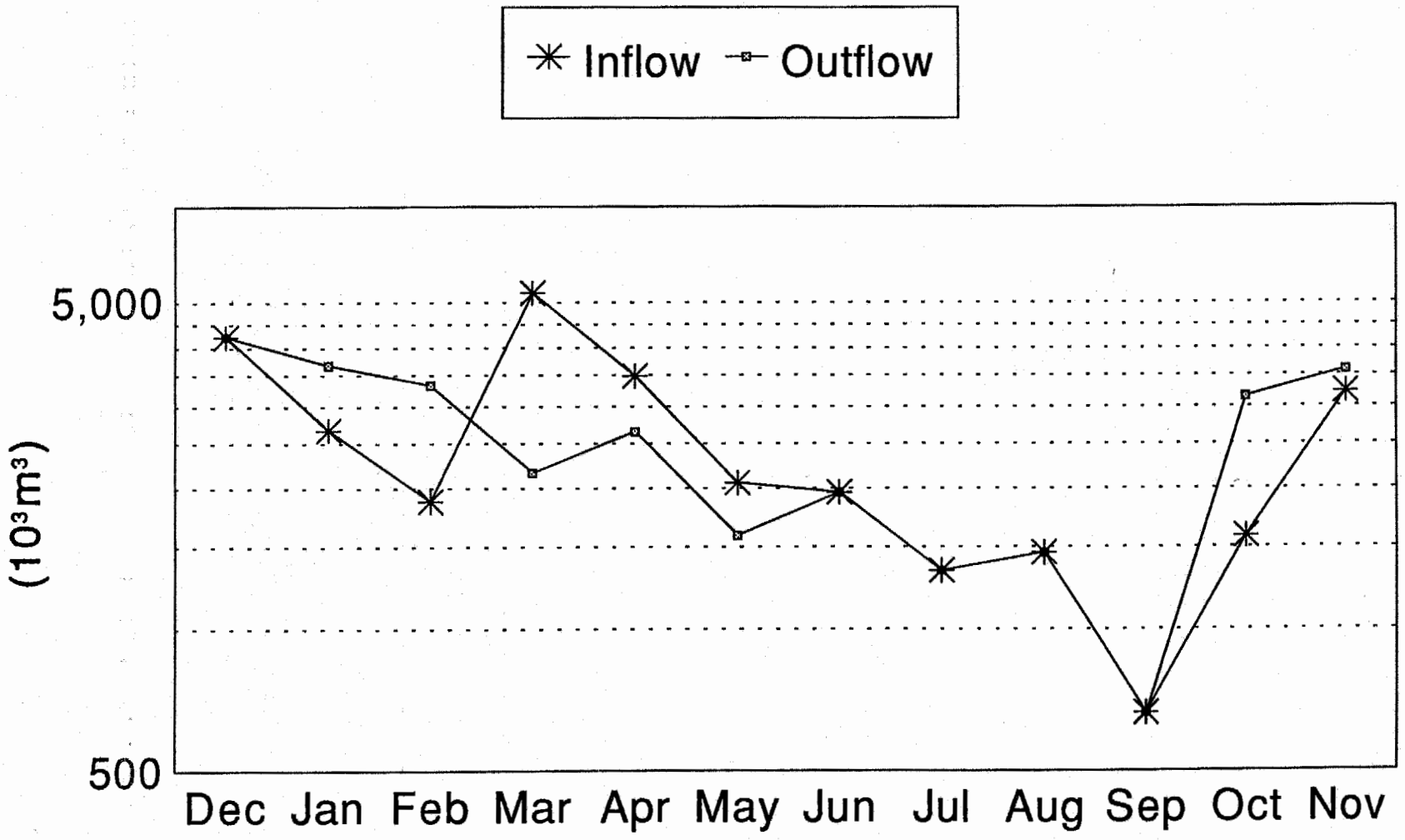
The subwatershed of this tributary is characterized by extensive wetland complexes which cover 500 acres or 13.5 percent of the subwatershed area. The drainage patterns in the Back Creek "B" watershed are also influenced by 40 acres of open water including Dead Pond (<10 acres). Back Creek "B" outlets into Pawtuckaway Lake adjacent to the boat launch in the Fundy Bay Natural Area.

Table VII-5
Pawtuckaway Lake Hydrologic Budget for Gaging Period (Dec'91 - Nov '92)
Water Volume ($10^3 m^3$)

Component	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total Annual	Mean Monthly
Qi_1	1502.0	1001.0	610.0	1525.0	1233.0	478.0	499.0	174.0	205.0	73.0	265.5	962.0	8527.5	710.6
Qi_2	804.0	652.0	404.0	1070.0	756.0	452.0	382.0	205.0	121.0	37.0	144.0	536.0	5563.0	463.6
Qi_3	470.0	364.0	247.0	531.0	536.0	303.0	103.0	38.0	44.0	15.0	53.0	338.0	3042.0	253.5
Qi_4	136.5	91.0	89.0	167.0	88.0	29.6	44.0	2.8	10.6	7.3	83.0	122.6	871.4	72.6
Qi_5	136.5	114.0	66.0	91.0	95.0	91.0	66.0	41.0	42.0	16.0	24.0	40.0	822.5	68.5
Qi_6	99.0	83.0	57.6	174.5	117.5	38.0	37.0	12.0	23.5	14.7	38.0	110.0	804.8	67.1
Qi_7	74.3	75.1	82.2	127.0	59.5	34.9	19.1	17.4	12.9	7.3	48.5	124.8	683.0	56.9
Qi_8	67.0	44.0	37.0	116.0	69.0	26.5	58.0	6.0	9.0	4.0	19.0	45.5	501.0	41.8
Qi_9	53.0	44.0	38.0	53.0	40.0	25.0	12.5	6.0	11.0	5.0	18.0	42.6	348.1	29.0
Qi_{10}	103.9	46.7	28.1	67.5	32.3	6.1	8.1	3.0	3.0	1.8	6.2	28.6	335.3	27.9
Qi_{11}	25.0	51.0	130.0	32.0	23.0	7.6	10.0	1.0	2.0	0.7	10.0	22.0	314.3	26.2
Qi_{12}	40.2	38.7	27.4	42.5	33.8	21.2	17.6	2.6	4.1	1.2	8.3	25.7	263.3	21.9
Qi_{13}	23.0	16.0	18.0	13.7	18.0	10.0	7.0	0.8	0.0	0.0	3.8	0.7	111.0	9.3
R	294.8	0.0	0.0	564.6	163.1	175.6	263.5	270.1	251.7	145.1	316.8	351.3	2796.6	233.1
P_{lake}	410.7	0.0	0.0	783.1	224.4	243.5	362.9	510.9	620.8	253.1	434.6	487.1	4331.1	360.9
GW_i	88.0	53.0	45.0	70.0	49.0	172.0	158.0	163.0	243.0	142.0	211.0	102.0	1496.0	124.7
Total Inflow	4327.9	2673.5	1879.3	5427.9	3537.6	2114.0	2047.7	1453.6	1603.6	723.2	1683.7	3338.9	30810.9	2567.6
Q_o1	4124.0	3505.0	2254.0	2043.0	2309.0	507.5	660.0	501.0	562.0	241.0	1370.9	3164.1	21241.5	1770.0
Q_o2	103.9	70.8	978.0	202.4	297.9	861.0	773.0	404.0	595.9	135.8	1613.0	440.0	6475.7	539.7
EV	0.0	0.0	0.0	0.0	0.0	176.5	514.7	448.6	345.7	246.4	161.8	0.0	1893.7	157.8
GWO	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	1200.0	100.0
Total Outflow	4327.9	3675.8	3332.0	2345.4	2706.9	1645.0	2047.7	1453.6	1603.6	723.2	3245.7	3704.1	30810.9	2567.6

NOTE: Abbreviations are listed and explained in text

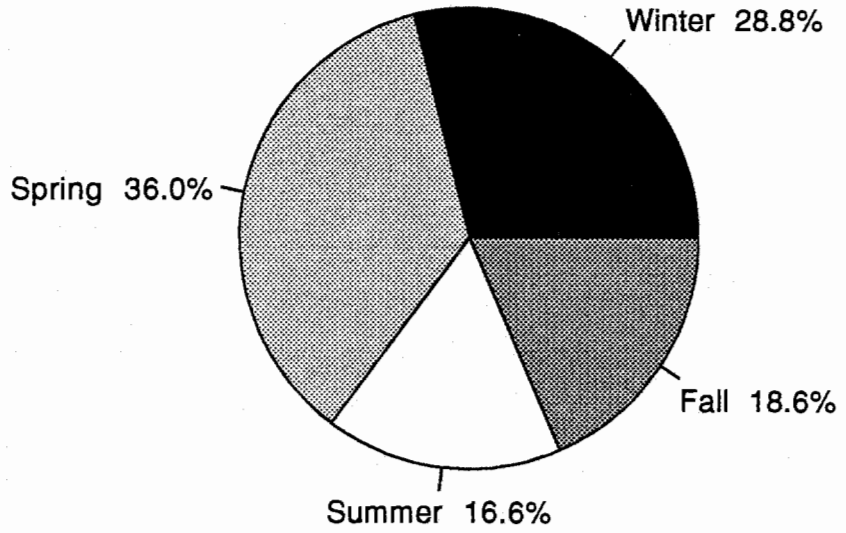
Pawtuckaway Lake



	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Inflow	4,229	2,674	1,879	5,242	3,484	2,055	1,961	1,333	1,457	664	1,581	3,222
Outflow	4,229	3,676	3,332	2,159	2,654	1,586	1,961	1,333	1,457	664	3,143	3,587

Figure VII-3: Pawtuckaway Lake Monthly Water Volume Exchanges

Pawtuckaway Lake
Seasonal Inflow Distribution



Pawtuckaway Lake
Seasonal Outflow Distribution

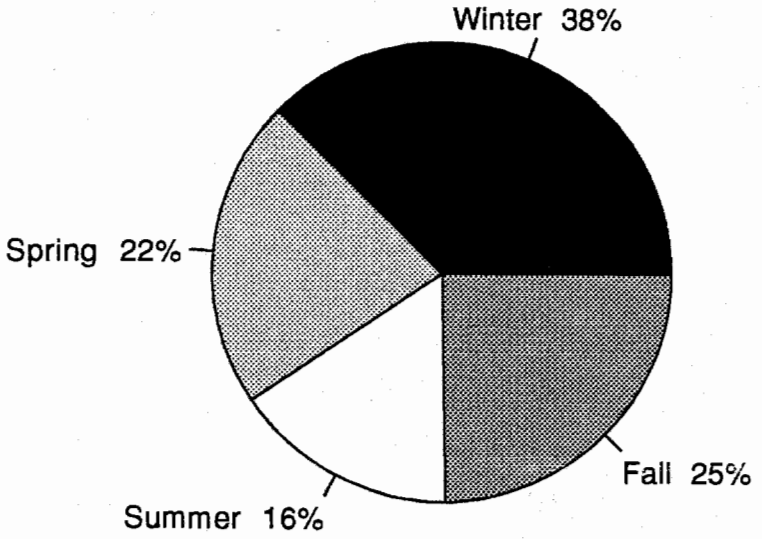


Figure VII-4: Pawtuckaway Lake Seasonal Water Volume Exchanges

Pawtuckaway Lake
Percent Tributary Inflow

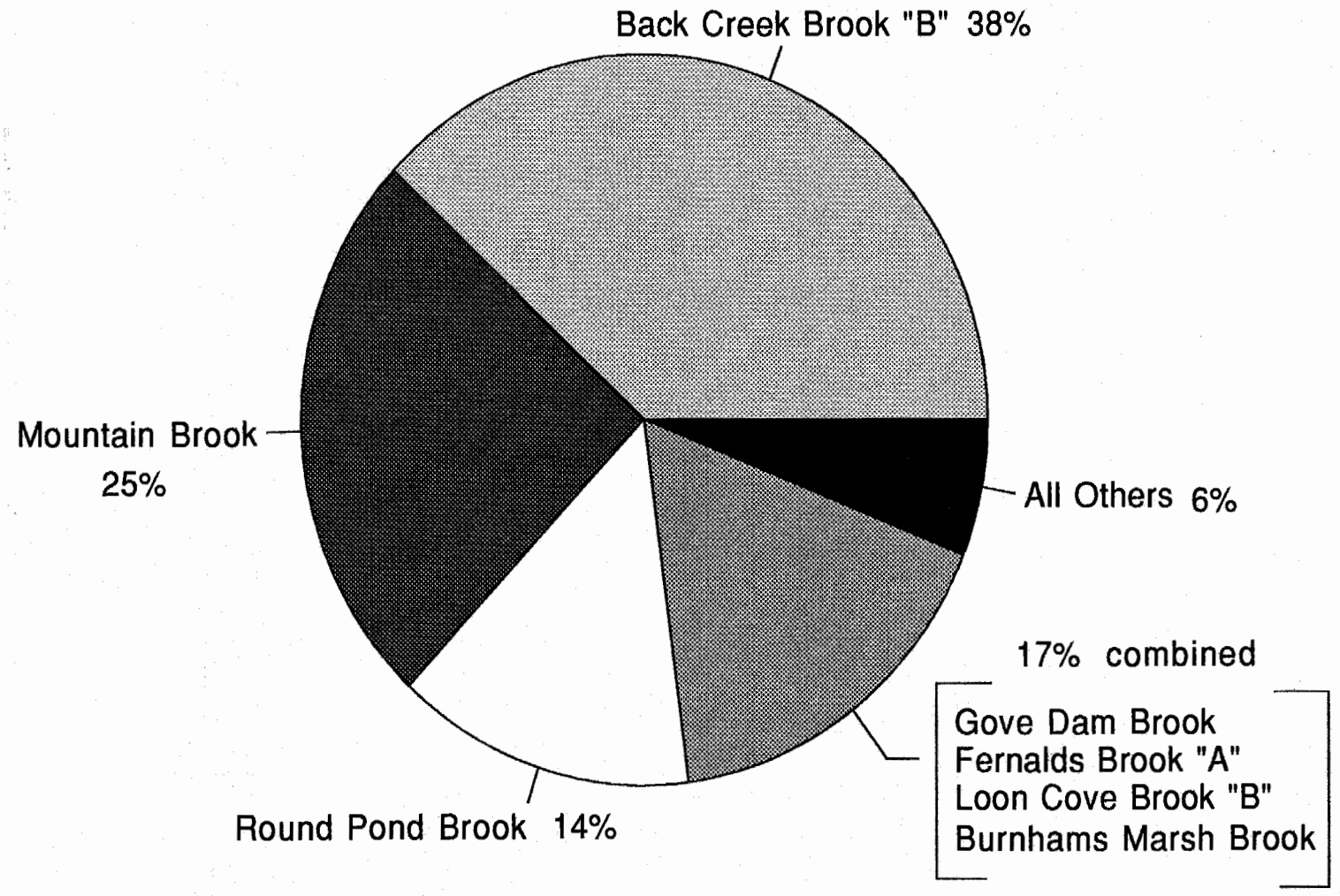


Figure VII-5: Percent Tributary Inflow

Mountain Cove Brook has a 2400 acre subwatershed that accounted for 25 percent of the total tributary inflow during the study year. This subwatershed occupies 20 percent of the Pawtuckaway Lake watershed and provides drainage for 72 acres of open water including Deer Pond (30 acres), and Mountain Pond (<10 acres). However, the predominant features throughout the subwatershed are the extensive wetlands which comprise 190 acres or 8.0 percent of the total subwatershed area. Flow volumes and drainage patterns in the Mountain Cove Brook watershed are often influenced by beaver activities and impoundments.

Round Pond Brook and its 1599 acre watershed contributed 14 percent of the total tributary inflow during the study year. This subwatershed occupies 13.5 percent of the total watershed area for Pawtuckaway Lake. The headwaters of Round Pond Brook originate in the Pawtuckaway Mountains and drain into Round Pond (11.0 acres). The outlet from Round Pond meanders through a portion of the 334 acres of wetlands found within the subwatershed and joins the outlets from several small ponds before it reaches Pawtuckaway Lake and discharges immediately north of Burnhams Marsh.

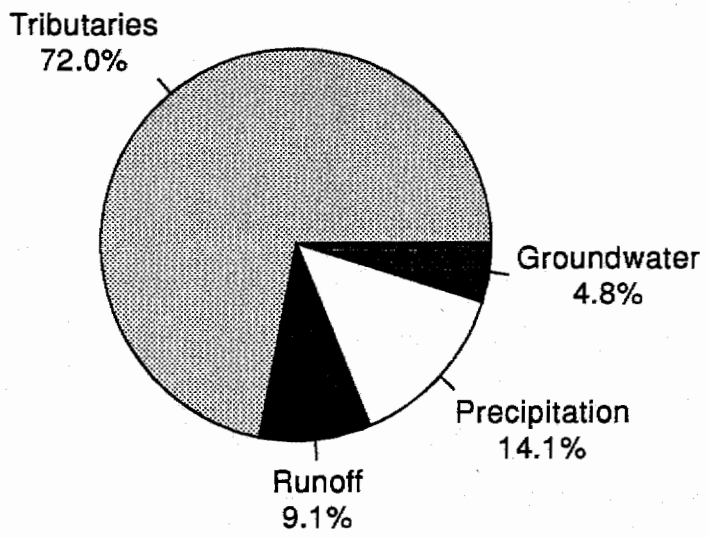
The dominant feature within the subwatersheds of Back Creek "B", Mountain Cove Brook, and Round Pond Brook are wetlands which cumulatively account for 69 percent (1024 acres) of all the wetlands found in the Pawtuckaway Lake watershed.

The flow contribution of four brooks (Gove Dam, Burnhams Marsh, Fernalds and Loon Cove) accounted for 17 percent of the tributary input to the lake while the remaining six brooks accounted for only six percent of the total tributary flow into Pawtuckaway Lake.

4. Total Annual Inflow and Outflow Budget Contributions

Figure VII-6 depicts the relative annual volumes of each inflowing and outflowing component of the Pawtuckaway Lake hydrologic budget. Tributary flow accounted for 22187.2 $10^3 m^3$ of the total 29779.8 $10^3 m^3$ flow, or 72.0 percent of the inflowing water to the lake, while direct precipitation represented 14.1 percent of the total water budget of Pawtuckaway Lake. Direct runoff to the lake from the surrounding shoreland accounted for 9.1 percent of the budget. Groundwater seepage contributed the remaining 4.8 percent of the inflowing water to the lake.

Pawtuckaway Lake
Inflowing Component Distribution



Pawtuckaway Lake
Outflow Component Distribution

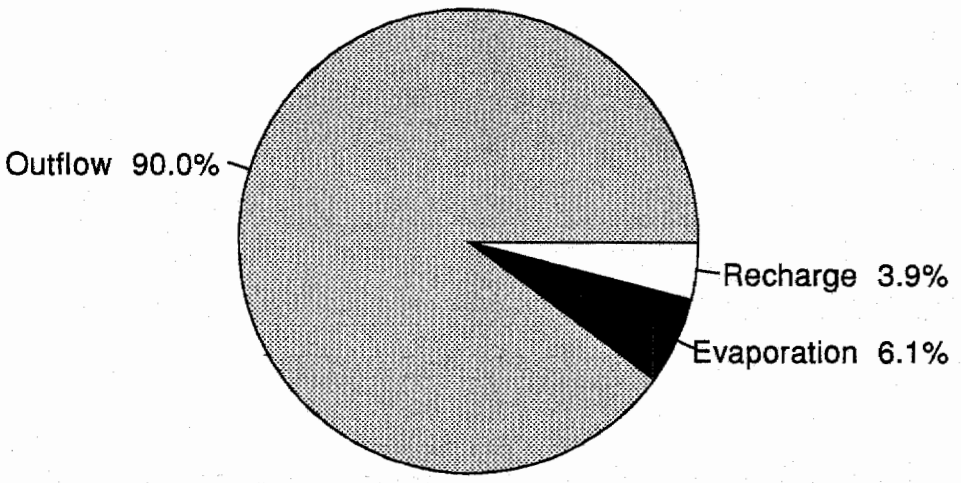


Figure VII-6: Pawtuckaway Lake Inflowing/Outflowing Component Distribution

Direct outflow or discharge represented 90 percent of the outflow budget for the sample year. Evaporation accounted for 6.1 percent of the outflow and water recharge into the groundwater was estimated to be only 3.9 percent of the total discharge from the lake (Figure VII-6).

5. Storm Event Hydrology

Stormwater runoff is a principal cause for degradation of rural lakes where agricultural runoff is present (Cooke et. al, 1986). Runoff water will likely contain the impurities in precipitation plus debris and other impurities deposited on the ground surface. Pollutants diffuse over the surface of the land and eventually enter the aquatic system (Wanielista, 1978).

Two types of storm events are important to the hydrologic and nutrient budget. High intensity, short duration storm events can represent a high percent of the total water budget and a significant percent of the phosphorus export to a lake. Since less water is able to percolate into the ground in high intensity storm events, more unfiltered surface runoff and more erosional material is carried to the lake and its tributaries.

The second type of rain event is the long duration, low intensity event. This type of event usually has lower priority for stormwater sample events. Generally, long duration, low intensity storms have lesser impacts on surface water quality from phosphorus, bacteria or solids loading. Wetfall from this type of event often infiltrates into the ground rather than travel overland. Less overland flow results in less turbidity and less phosphorus load to the lake.

The sample year rainfall total for Pawtuckaway Lake was 35.67 inches. This is below the 20 year mean for the state, which shows an average yearly rainfall value of 38.07 inches. Although 46 percent of the rainfall occurred during the growing season, from the months of May through September, many of the rain events were of long duration and low intensity. Biologists tried to sample during several wetfall events but each of these events were rejected because they did not meet the storm event specifications as written in the project's Quality Assurance Document.

CHAPTER VIII PHOSPHORUS BUDGET

A. DEVELOPMENT OF PHOSPHORUS BUDGETS

The calculation of a phosphorus budget is an essential step in the evaluation of a lake's trophic status. A phosphorus budget provides a means to evaluate and rank phosphorus sources that may contribute to algal problems. It is most important to determine the quantity of nutrients (especially phosphorus) entering the lake, as well as the ultimate fate of those nutrients. The phosphorus budget relies heavily upon the accuracy of the hydrologic budget for its input and output variables.

Many extensive nutrient budgets have been reported in the literature. Lake Washington in Seattle, Washington (Edmondson, 1972), Lake Erie (Burns, 1970), and Kezar Lake, North Sutton, New Hampshire (Connor and Smith, 1983) have been studied in great detail.

Nutrient loading rates have been reported as either "surface loading rates" or "volumetric loading rates" and are usually expressed in terms of mass per unit area-time, or mass per unit volume-time.

The purpose of this chapter is to quantify the various avenues of phosphorus inputs into Pawtuckaway Lake and to explore the various phosphorus sinks and exports from the watershed. Phosphorus loadings (flux) were calculated for each tributary inflow, outflow, direct runoff, atmospheric, groundwater, and septic leachate to Pawtuckaway Lake. A phosphorus budget was then prepared for the 1991-92 study year.

B. PHOSPHORUS BUDGET COMPONENTS

1. Tributary loading and discharge

Tributary phosphorus concentrations were analyzed and monthly loadings were calculated

for each of the Pawtuckaway Lake stations. Tributary phosphorus loadings to Pawtuckaway Lake were tabulated during the twelve month study period. Phosphorus loadings were determined by calculating mean monthly tributary flows (10^3m^3) and multiplying these values by mean monthly phosphorus concentrations (mg/L). The resultant values represent mean monthly phosphorus loading or flux (kg P). The summations of each of the calculated monthly values equals the total tributary annual phosphorus loading.

Table VIII-1
Tributary Phosphorus Loading to Pawtuckaway Lake
(Study Year 1991-92)

Tributary	Flow Volume (10^3m^3)	Mean Phosphorus Concentration (µg/L)	Phosphorus Loading (kg)	Phosphorus Loading (%)
Back Creek B	8528	18	155.6	33.0
Mountain Cove Brook	5563	20	112.8	23.9
Round Pond Brook	3042	25	75.6	16.0
Gove Dam Brook	871	18	15.7	3.3
Burnhams Marsh (North)	823	23	18.6	3.9
Fernalds Brook A	805	65	52.6	11.2
Loon Cove Brook A	683	13	9	1.9
Back Creek A	501	12	5.9	1.3
Fundy Brook	348	21	7.4	1.6
Burnhams Marsh (South)	335	21	6.9	1.5
Whites Grove Brook	314	17	5.2	1.1
Loon Cove Brook	263	18	4.7	1.0
Fernalds Brook B	111	10	1.1	0.2

Table VIII-I shows the monthly tributary phosphorus load to Pawtuckaway Lake. Back Creek B was the greatest tributary contributor of phosphorus to Pawtuckaway Lake providing 155.6 kg of phosphorus during the 1991-92 study year, or 33 percent of the tributary phosphorus load.

Back Creek B also contributed the greatest tributary supply of water to the lake (38 percent). Mountain Cove Brook provided almost 24 percent (112.8 kg) of the tributary loading to Pawtuckaway Lake but was also a large source of water (25 percent) to the lake. The third greatest phosphorus producer to Pawtuckaway Lake was Round Pond Brook which donated 75.6 kg or 16 percent of the phosphorus load. The three tributaries producing the greatest amount of water to the lake also contributed the greatest amount of phosphorus to the lake. These three tributaries accounted for 73 percent of the total phosphorus load to the lake.

Fernalds Brook A only provided 3.6 percent of the water to the lake yet contributed 11 percent (52.6 kg) of the annual phosphorus load to the lake. Fernalds Brook A also has the greatest phosphorus concentration when compared to other lake tributaries. Tributaries like Fernalds Brook that consistently have high phosphorus concentrations are important because they are usually good candidates for sub-watershed management. Each of the remaining nine tributaries combined accounted for only 15.8 percent of the total phosphorus budget. However, it is important to note that three tributaries (Burnhams Marsh North, Burnhams Marsh South and Fundy Brook) had study year mean phosphorus concentrations greater than 20 µg L.

2. Atmospheric

Atmospheric inputs consist of two major components: (1) wind transported material, commonly referred to as dryfall, removed from the air by sedimentation or impaction; and (2) soluble gases or salts that are scavenged by rainfall. Estimates for the dryfall portion alone may be as high as 70-90 percent of the total atmospheric load (Likens and Loucks, 1978).

In agrarian areas, increases in nutrient loads transported via the atmosphere can be attributed to agricultural activities and associated soil disturbances. Urban atmospheric inputs of nutrients can be attributed primarily to combustion emissions.

Atmospheric phosphorus loading (wetfall and dryfall) for Pawtuckaway Lake was determined by the direct measurement of phosphorus in rain samples collected in Concord, New Hampshire, while dryfall was calculated utilizing dryfall export coefficients (Reckhow, et al, 1980). The measured mean phosphorus concentration calculated for the sample season was then multiplied by the monthly rainfall and the lakes surface area to obtain the phosphorus loading to the lake. The atmospheric phosphorus contribution to Pawtuckaway Lake during the study period was 142.6 kg

with a mean monthly load of 11.9 kg. Since the phosphorus load from atmospheric deposition is dependent on annual weather patterns, the greatest phosphorus contributions occur during the wettest seasons. This will be discussed in greater detail in the phosphorus budget sections. The month of March contributed 18 percent of the total annual atmospheric phosphorus loading to Pawtuckaway Lake.

3. Direct Surface Runoff

Direct surface runoff includes the water and its transported phosphorus that does not enter a lake via tributary or groundwater. Direct surface runoff is the result of near shore snowmelt and rainfall, especially during high intensity storms.

Loadings in runoff from shoreline areas can be estimated indirectly. In many cases, indirect estimates of loading from an area can be derived from information on watershed characteristics. This method is based on the concept that two watersheds in the same region and with similar land use patterns and geology will tend to contribute the same loading of phosphorus per unit area. This permits extrapolation of data from one or more monitored watersheds to others.

Shoreline runoff areas at Pawtuckaway Lake were designated as mixed forest, urban low density residential and recreational. Table VIII-2 shows the selected export coefficient and total phosphorus export for each watershed designation. To obtain the direct phosphorus runoff

Table VIII-2
Pawtuckaway Lake Watershed Phosphorus Export

Watershed Designation	Percent	Area (ha)	Export Coefficient (kg/ha/yr)	Phosphorus Export (kg)
Forested/Mixed	23.8	162	0.20	32.4
Urban/Low Density Residential	30.5	206	0.50	103.0
Recreational/ Forested/ Low Density Residential	45.7	310	0.30	93.0
Total	100.0	678	-	228.4

contribution to Pawtuckaway Lake, the designated land use areas that did not drain into a monitored tributary were determined. A phosphorus coefficient for each land use was selected by matching

similar land uses at Pawtuckaway Lake to those with a known phosphorus export. The direct phosphorus runoff was calculated by multiplying the land use area by the phosphorus coefficient.

Increased phosphorus load to a lake from direct runoff corresponds to the area's weather patterns. Periods of frozen ground, snowmelt, and high intensity rainstorms usually contribute an increased phosphorus load via runoff.

Direct runoff contributed 228.4 kg of phosphorus to Pawtuckaway Lake during the study period. The mean monthly phosphorus contribution to Pawtuckaway Lake was 19 kg during the study year.

4. Septic Leachate and Groundwater Loading

Septic tanks and leachfields are another non-point source that must be considered as a nutrient source because of their potential for nutrient enrichment of the groundwater which flows into a lake.

Several studies (e.g., Jones and Lee, 1977; NHWS&PCC, 1975) have indicated that a properly designed, constructed, and maintained system will not generally contribute significant amounts of phosphorus to surface waters. However, because of their use in unsuitable areas or because of improper design, construction, or maintenance, it is estimated that over one-half of the systems in use today fail before their designed life of fifteen to twenty years is completed (Scalf et al., 1977).

The most common type of individual disposal system is the septic tank-leach field system. The tank functions to separate the solids, both floating and settleable, from the liquid material. The accumulated sludge should be pumped out every three to five years. The liquid is discharged from the tank through piping material and distributed over the leaching area, which is designed to absorb the effluent and to remove the impurities before it percolates to the groundwater.

In 1967, the New Hampshire legislature enacted a law to protect water supplies from pollution by subsurface disposal systems, and directed the Water Supply and Pollution Control Division to establish minimum, state-wide requirements for properly designed systems. The information required to estimate the phosphorus loading from septic systems is:

1. Location of the system with respect to the surface water body,
2. Soil permeability: the rate of water transmission through saturated soil, of which estimated soil retention coefficients varied with different lake sections,
3. Land slope: steep slopes may cause erosion problems when associated with soils of low permeability,

4. System age: soils have only a finite capacity for phosphorus absorption,
5. Per capita occupancy: (household population based on sanitary survey),
6. Fraction of year system is in use: (i.e., summer cottages or year-round dwellings), and
7. Additional water utilizing machinery: (e.g., washing machines, dish washers, or garbage disposals).

For this study, a survey of individual sanitary waste-disposal systems around the lake was conducted. The survey consisted of a visual inspection of the property, interviews with residents to discuss various problems, and the compilation of certain statistical information regarding the system, such as type of system, age, maintenance schedule, depth to groundwater etc.

This data was used to calculate the septic leachate contribution to the phosphorus budget. Permanent and seasonal home phosphorus loading was calculated using the following equation:

$$\text{kg P year}^{-1} = (\text{kg P Capita}^{-1}\ \text{year}^{-1})\ (\#\ \text{homes})(\#\ \text{Capita house}^{-1})\ (\#\text{years})\ (1\text{-soil retention coefficient})$$

Where:

$\text{kg P Capita}^{-1}\ \text{year}^{-1} = 0.8$

$\#\ \text{Capita house}^{-1} = 2.83$

Soil retention coefficient = 0.5

#years = 425 for year round and 106 for seasonal

The invention of new monitoring tools like the seepage meter and the Interstitial Pore Water Sampler (IPWS) have made groundwater sampling and analyses a more precise methodology. Whereas groundwater seepage and septic leachate had been treated as separate components of the phosphorus budget, they are now combined as one unit of the budget. Septic leachate phosphorus contributors were derived from the model equation and from actual interstitial water analyses combined with seepage rates. A comparison of phosphorus loading results from each method showed only a 19 percent (49 kg) difference in septic/groundwater phosphorus loading to Pawtuckaway Lake.

a. Sanitary Survey Summary. A sanitary survey was conducted at 172 of the estimated 300 shoreland septic systems (57 percent). The survey form (Appendix VIII-I) included questions on

the type of system, system age, number of occupants, months of occupancy, distance of system from lake and slope of land to the lake. Table VIII-3 summarizes the results of the sanitary survey. Septic tanks and leachfields were the most common type of wastewater disposal representing 76 percent of the surveyed systems. A septic tank with chambers was the second most widely used wastewater system representing 12 percent of the systems. Chambered systems are relatively new and the number of these systems will increase with future development. Other systems used around the lake include cesspools, holding tanks, chemical toilets and even a couple outhouses.

Table VIII-3
Sanitary Survey Data Summary

System Type	Number of Surveyed Systems	Functioning Systems	Suspected Failures	Failed Systems
Septic Tank & Leach Field	131	67	46	18
Septic Tank & Chambers	22	12	7	3
Cesspool	6	0	3	3
Holding Tank	5	3	1	1
Chem Toilet (BFI)	3	3	0	0
Dry-well	3	1	2	0
Outhouse	2	2	0	0
Survey Statistics				
Estimated Number of Systems Around Lake				300.0
Number of Survey Responses				172.0
Mean System Age (yr)				19.7
Per capita Mean Occupancy				2.9
Mean Monthly Occupancy				7.9
Mean Distance From Shore (ft)				155.6

The survey documented the average age of shoreline systems to be 19.7 years. Remember that the life expectancy of septic systems with leachfields is 15 to 20 years. The average occupancy of each shoreline dwelling was 2.9 people staying at the cottage for an average of 7.9 months. Many of the people living around the lake live there year-round rather than being transient home dwellers. Recent trends show that more people are making their lakeside dwellings year-round homes rather than just summer camps.

The survey also reflected a variable range in distance of septic systems from the water. System distance from the shoreline ranged from a minimum of 20 feet to a maximum of 2500 ft with a medium value of 96 feet. The most recent setback rules for septic system range from 75 ft to 150 ft depending on the soil characteristics.

The survey recorded 88 functioning systems with no problems, 59 systems that have potential problems and are suspected to be failing and 25 systems that are now in failure. The Pawtuckaway Lake Sanitary Survey Raw Data is presented in Appendix VIII-2.

b. Groundwater Phosphorus Monitoring. Relatively little is known of groundwater seepage nutrient concentrations and their importance to nutrient budgets. Lee (1977) first applied the direct seepage meter technique in Lake Sallie, Minnesota, in an attempt to monitor the contribution of nutrients from septic tanks located around the lake. Since anoxic conditions occur within the seepage meters after a period of time, direct measurement of phosphorus using this method may overestimate the groundwater contribution to the surface water. More recently, well water along the lake's boundary was analyzed for an estimate of nutrient input via seepage. The utilization of this type of methodology, however, does not account for nutrient concentration differences within the water table profile and does not include sediment interactions with seepage water (Connor, 1979). Biologists now derive groundwater phosphorus contribution to the lake by measuring the interstitial water concentration.

Groundwater monitoring was conducted throughout the shoreland area of Pawtuckaway Lake. A series of 18 seepage meters were placed along the shoreline area of Pawtuckaway Lake. Two sites had duplicate meters set up for quality control. A discussion of seepage meters and groundwater seepage rates can be found in Chapters VI and VII.

Groundwater analyses for phosphorus concentration was conducted by monitoring 12 shallow dug wells along the shoreline and using a special sampling device to monitor the interstitial water at each seepage meter site.

Table VIII-4 presents the shallow well phosphorus data analyzed over the study year. The study year mean ranged from 1.5 µg/L at station A to 38.6 µg/L at station K. All shallow wells were located from the mid section to southern section of the lake. With the exception of stations C and K, phosphorus concentrations are considered to be low to moderate and similar to groundwater phosphorus concentrations measured in other groundwater studies (Beaver Lake, Derry: TP range

= 1-30 µg/L and Robinson Pond, Hudson: TP range = 1-13 µg/L). The highest shallow well groundwater phosphorus was measured in Loon Cove while some of the lowest concentrations were measured in Mountain Cove. Much of the eastern lake shoreline reflected moderate groundwater phosphorus concentrations.

Table VIII-4
Pawtuckaway Lake Shallow Dug Wells
Total Phosphorus Concentrations (µg/L)
December 1991-November 1992

Station Number	Range		Study Year Mean
	Minimum	Maximum	
A	1	40	1.5
B	6	9	7.5
C	15	22	17.2
D	2	4	6.5
E	10	14	11.5
F	1	9	5.0
G	3	7	4.4
H	7	10	8.2
I	9	11	9.6
J	2	5	3.3
K	2	111	38.6
L	8	8	8.0

A specially designed Interstitial Pore Water Sampler (IPWS), (Figure IV-5) was used to collect interstitial water at each of the seepage meter locations (Figure IV-6). The IPWS was placed in the sediment while interstitial water was pumped through a fine screen and into a sample bottle.

Table VIII-5 is a summary of the phosphorus analyses performed on interstitial water, while Figure VII-1 illustrates the sample stations.

IPWS total phosphorus concentrations were significantly higher than the tributary and lake water samples and significantly higher than groundwater measured from the area's shallow wells.

The mean interstitial groundwater seepage phosphorus concentrations ranged from 43 µg/L to 1656 µg/L. With the exception of station 14 there appears to be a general relationship between sediment type and phosphorus concentrations. Other studies have shown an increase in phosphorus with an increase in percent organic muck.

Table VIII-5
Pawtuckaway Lake Interstitial Pore Water
Total Phosphorus Concentrations (µg/L)
December 1991-1992

Station Number	Range		Mean	Sediment Type
	Minimum	Maximum		
1	4	1,935	501.0	thick layer of organic muck over sand
2	46	176	88.2	medium grained
3	41	74	57.3	sand
4	23	155	84.0	sand/muck mix
5	17	110	75.2	sand/muck mix
6	4	107	56.5	fine grained sand
7	18	79	43.0	fine grained sand
8	53	670	274.8	coarse grained sand
9	60	5,190	1,414.8	unconsolidated mixed sizes of sand
10	28	385	192.0	med-coarse sand
11	10	169	80.8	muck/sand mix
12	22	385	200.2	medium grain sand with organic layer
13	26	3,020	1,215.5	muck/fine sand
14	202	4,490	1,655.5	gravel and coarse grain sand
15	243	243	243.0	med-fine sand
16	163	163	163.0	organic muck/fine sand
17	289	289	289.0	organic muck/fine sand
18	116	116	116.0	unconsolidated sand and gravel

The highest interstitial groundwater concentrations (285 µg/L - 1655 µg/L) were measured south and north of the Burnhams Marsh. The lowest groundwater phosphorus concentrations (43 µg/L - 88 µg/L) were measured in the northern lake sections which included Fundy, Fernalds and Drowns Dam. Intermediate groundwater phosphorus concentrations (163 µg/L - 275 µg/L) were monitored in the southern lake sections, which included Mountain Cove, Grove Dam and the White

Grove area. A recent study of Mendums pond (Connor et al., 1992) showed that the release of phosphorus to a lake from shoreline septic systems can be a significant source to the overall phosphorus budget. Groundwater seepage rates and areal interstitial phosphorus concentrations were utilized to calculate the input of phosphorus from septic systems into Pawtuckaway Lake.

Groundwater seepage and septic leachate phosphorus contributors were derived from the direct measurement of groundwater seepage and phosphorus analyses of interstitial water. Actual loading (kg P) was calculated using groundwater seepage rates (10^3m^3) and interstitial phosphorus concentration (mg/L-P). Groundwater seepage and leachate contributed 206 kg of phosphorus to Pawtuckaway Lake. This contribution represents 20 percent of the Pawtuckaway Lake phosphorus budget. Septic leachate and groundwater seepage loading to Pawtuckaway Lake was similar to the loading of four recently completed Diagnostic/Feasibility Studies: French Pond, Henniker (Connor and Martin 1988) and Mendums Pond, Barrington (Connor, McCarthy and O'Loan, 1992) at 24 percent, Beaver Lake, Derry (Connor and O'Loan, 1992) at 25 percent and Keyser Pond, Henniker (Connor and Martin, 1988) at 18 percent.

In summary, several groundwater sources were sampled throughout the Pawtuckaway Lake study. These groundwater sources included well water from drinking water sources around the lake, and interstitial water from the sediments of Pawtuckaway Lake. Although the results showed that the dug wells surrounding the pond had relatively low phosphorus concentrations, only the interstitial phosphorus analyses were utilized to calculate the phosphorus loading component to the budget. The groundwater interacts with the phosphorus rich sediments and with septic leachate water, contributing to higher amounts of phosphorus in the interstitial water. It is the interstitial water which more accurately reflects the phosphorus load to the lake via groundwater seepage.

5. Sediment Release and Uptake

a. Introduction. The fate of phosphorus in water is usually considered to consist of chemical, physical, or biological transformation of the ionic form into a particle, sedimentation of this particle to the bottom, particle breakdown in the sediment, and the release of some of the ionic phosphorus back into the lake water if conditions are favorable. Oxic conditions favor a decrease of internal phosphorus loading because phosphorus should sorb to oxidized iron complexes. There may be other sources of internal loading that could be more significant than release from pelagic sediments

into anoxic overlying water. These could include aerobic release from littoral sediment, plant decomposition, or littoral release from photosynthetically caused high pH.

The actual measurement of total phosphorus release or uptake from the sediment is an impractical task to attempt. Since sediment release and uptake are occurring simultaneously in different sections of a lake, and other chemical, physical and biological activities are also occurring, it is virtually impossible to establish a realistic total phosphorus release or uptake figure. However, an estimation of net differences between total uptake and total release can be derived by calculating an internal phosphorus loading model. A positive mass balance solution represents net phosphorus release (loading) and a negative solution represents net uptake.

b. Internal Phosphorus Cycling. An essential component of the nutrient budget is the monthly net release or uptake of phosphorus from or to the lake sediments. In order to quantify this component, a phosphorus mass-balance equation was solved for each month of the sample period. Thus, by knowing the masses of phosphorus entering the lake and flowing out of the lake and the change of mass in the lake, the equation can be solved for the mass released or adsorbed by the sediments.

Mass is calculated as the product of concentration and volume. Table VIII-6 shows how the phosphorus mass in Pawtuckaway Lake at the beginning of each month was calculated as the sum of masses in each stratum. The volume of each stratum was calculated from areal measurements of contours on the bathymetric map.

Table VIII-7 reflects monthly values of each variable of the mass-balance equation and the resulting net uptake or release from Pawtuckaway Lake sediment.

The mass-balance equation is:

$P_{int} = (P_2-P_1) - (P_{in}-P_{out})$

where:

P_{int} = net phosphorus release (+) or uptake (-) by the sediments

P_1 = in-lake phosphorus mass, beginning of month

P_2 = in-lake phosphorus mass, end of month

P_{in} = phosphorus mass flowing in during the month

P_{out} = phosphorus mass flowing out during the month

Table VIII-6
In-Lake Phosphorus Mass for Pawtuckaway Lake

Month	Thermal Layer	P Conc. (µg/L)	P mass (kg P)	Total Monthly P (kg P)
December 1991	Upper	23.0	162.5	185.6
	Lower	17.0	23.1	
January 1992	Upper	14.0	98.9	122.0
	Lower	17.0	23.1	
February 1992	Upper	19.0	134.2	154.6
	Lower	15.0	20.4	
March 1992	Upper	-	120.1	143.2
	Lower	-	23.1	
April 1992	Upper	19.0	134.2	153.2
	Lower	14.0	19.0	
May 1992	Epilimnion	14.5	186.8	222.0
	Metalimnion	11.0	20.6	
	Hypolimnion	13.0	14.6	
June 1992	Epilimnion	12.0	154.6	196.1
	Metalimnion	13.0	25.7	
	Hypolimnion	14.0	15.8	
July 1992	Epilimnion	11.0	141.7	184.5
	Metalimnion	12.0	23.7	
	Hypolimnion	17.0	19.1	
August 1992	Epilimnion	11.5	148.2	193.5
	Metalimnion	11.0	21.7	
	Hypolimnion	21.0	23.6	
September 1992	Epilimnion	9.5	122.4	171.8
	Metalimnion	8.5	16.8	
	Hypolimnion	29.0	32.6	
October 1992	Upper	9.0	63.6	111.1
	Lower	43.0	47.5	
November 1992	Upper	16.0	113.0	137.4
	Lower	18.0	24.4	

Figure VIII-I demonstrates the capacity of Pawtuckaway Lake to assimilate phosphorus. Pawtuckaway Lake acts as a phosphorus sink, accumulating phosphorus from the watershed and lake in the sediments. Pawtuckaway Lake assimilated phosphorus for ten months of the study year. The months of December, March, August and September were maximum uptake months where sediment phosphorus uptake was greater than 95 kg P/month. The only two months that recorded a release of phosphorus to the lake were January and April. Two months (February and October) showed a near balance of phosphorus exchange between the lake at its sediments. The total net sediment uptake of phosphorus from the lake was 712.9 kg P.

Table VIII-7
Monthly Internal Phosphorus Cycling
Pawtuckaway Lake 1991-1992 Gaging Year

Month	P_{in} Subtotal Inflow	P_{out} Total Outflow	P_{lake} 1 (kg)	P_{lake} 2 (kg)	P_{int} (kg)
Dec 91	95.2	59.9	185.6	122.0	-98.9
Jan 92	47	44.3	122.0	154.6	29.9
Feb 92	37.1	37.5	154.6	143.2	-11.8
Mar 92	143.8	23.3	143.2	153.2	-110
Apr 92	94.1	30.1	153.2	222.0	4.8
May 92	87.1	21.3	222.0	196.1	-91.7
Jun 92	99.5	29.2	196.1	184.5	-81.9
Jul 92	81.1	10.8	184.5	193.5	-61.3
Aug 92	99.6	14.0	193.5	171.8	-107.3
Sep 92	52.6	4.4	171.8	111.1	-108.9
Oct 92	93.8	58.7	111.1	137.4	-8.8
Nov 92	117.6	50.6	137.4	137.4	-67
				Total	-712.9

P_{in} = monthly subtotal of all P inputs (from P budget)
P_{out} = monthly outflow from outlet (from P budget)
P_{lake} 1 = monthly P (kg)
P_{lake} 2 = subsequent monthly P (kg)

Pawtuckaway Lake

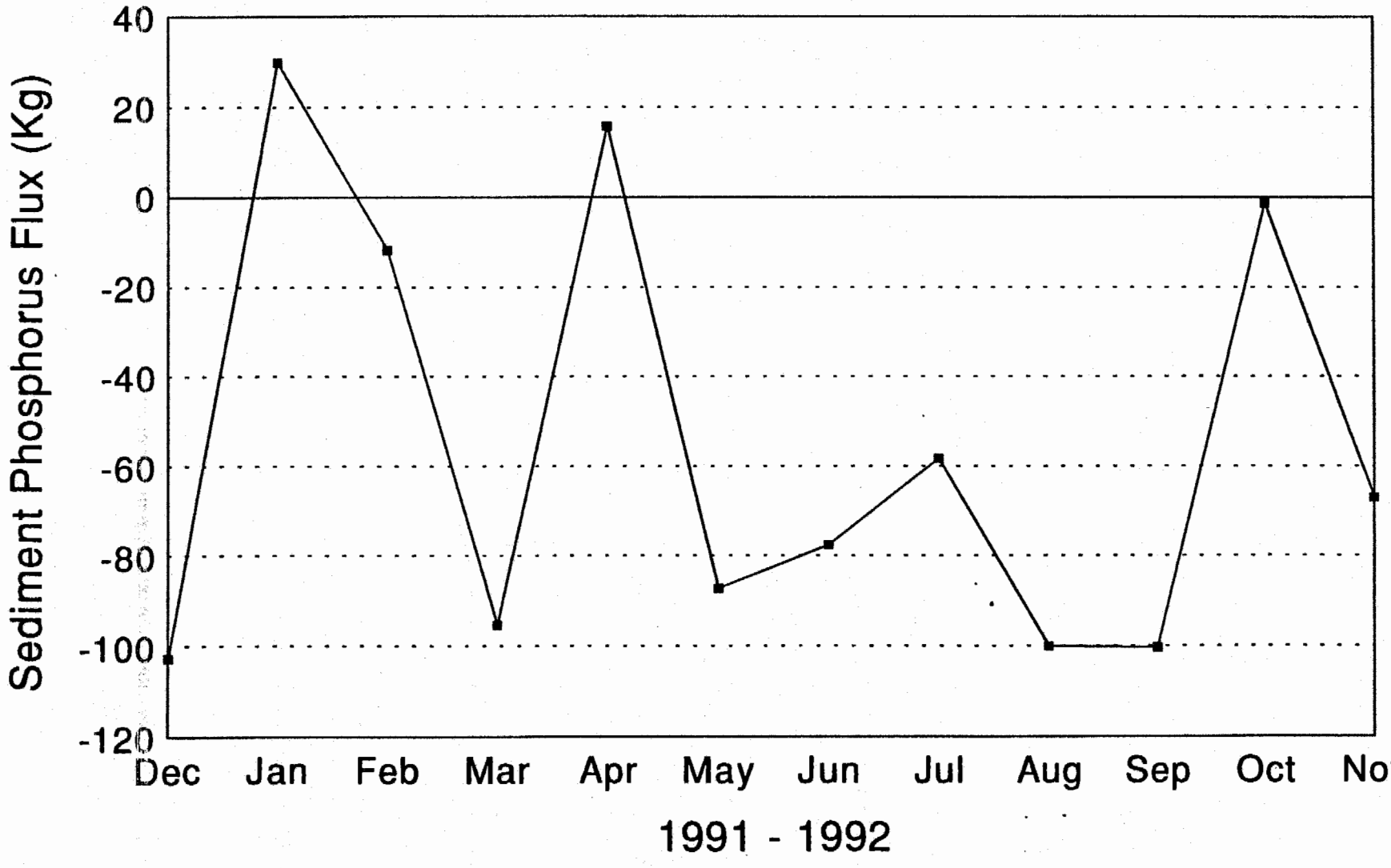


Figure VIII-1: Net Sediment Phosphorus Flux and Phosphorus Assimilation

C. SEASONAL PHOSPHORUS CONTRIBUTIONS TO PAWTUCKAWAY LAKE (1991-1992)

The monthly and total phosphorus budget was derived from the aforementioned components and measured phosphorus concentrations. The following discusses monthly or seasonal phosphorus loading by each of the components to Pawtuckaway Lake.

Budget components and phosphorus data were derived for the months December, 1991 through November, 1992. Monthly phosphorus loading to Pawtuckaway Lake by the major inflowing tributaries is presented in Figure VIII-2, while Figure VIII-3 shows the total phosphorus load from all the inflowing tributaries. Although the projects sample year was considered dry by comparison to the state's annual mean rainfall records, the seasonal phosphorus loading patterns for the major inflowing tributaries coincided with expected geographic and climatic trends. Phosphorus loading to the lake will fluctuate with the hydrologic year. A wet year will increase the phosphorus load to the lake while a dry year will decrease the phosphorus load to the lake. Total loading is directly related to the volume of water entering the lake and to the water velocity of runoff flowing from the watershed into the tributary. As the velocity of water runoff increases, the concentration of total and dissolved solids increase.

Typically, December, January and sometimes February show a decreasing trend in phosphorus loading to the lake. This was the case at Pawtuckaway Lake during the study year with the exception of December. The high phosphorus load to the lake in December was the result of heavy rainfalls during the early and mid month period. Much of the watershed runoff and phosphorus stripping is minimal during the winter months because water is being stored as ice and snow. There is usually little winter snowmelt and therefore little phosphours loading from the watershed. Normal hydrologic years reflect increased runoff during late February and into March. Much of the monthly phosphorus loading usually occurs in March and April when winter snowmelt erodes subwatershed particulate material and strips phosphorus that had accumulated since the fall. This high phosphorus load attributed to the snow pack is a result of the buildup of atmospheric particulate fallout onto the snow as well as the phosphorus concentration in the snow itself.

The spring season is also a time when the ground is still partially frozen and little infiltration into the ground occurs. However, the upper sediment layers are continuously being thawed during the day and frozen during the night. This freeze/thaw process causes the unstabilization of some

Pawtuckaway Lake

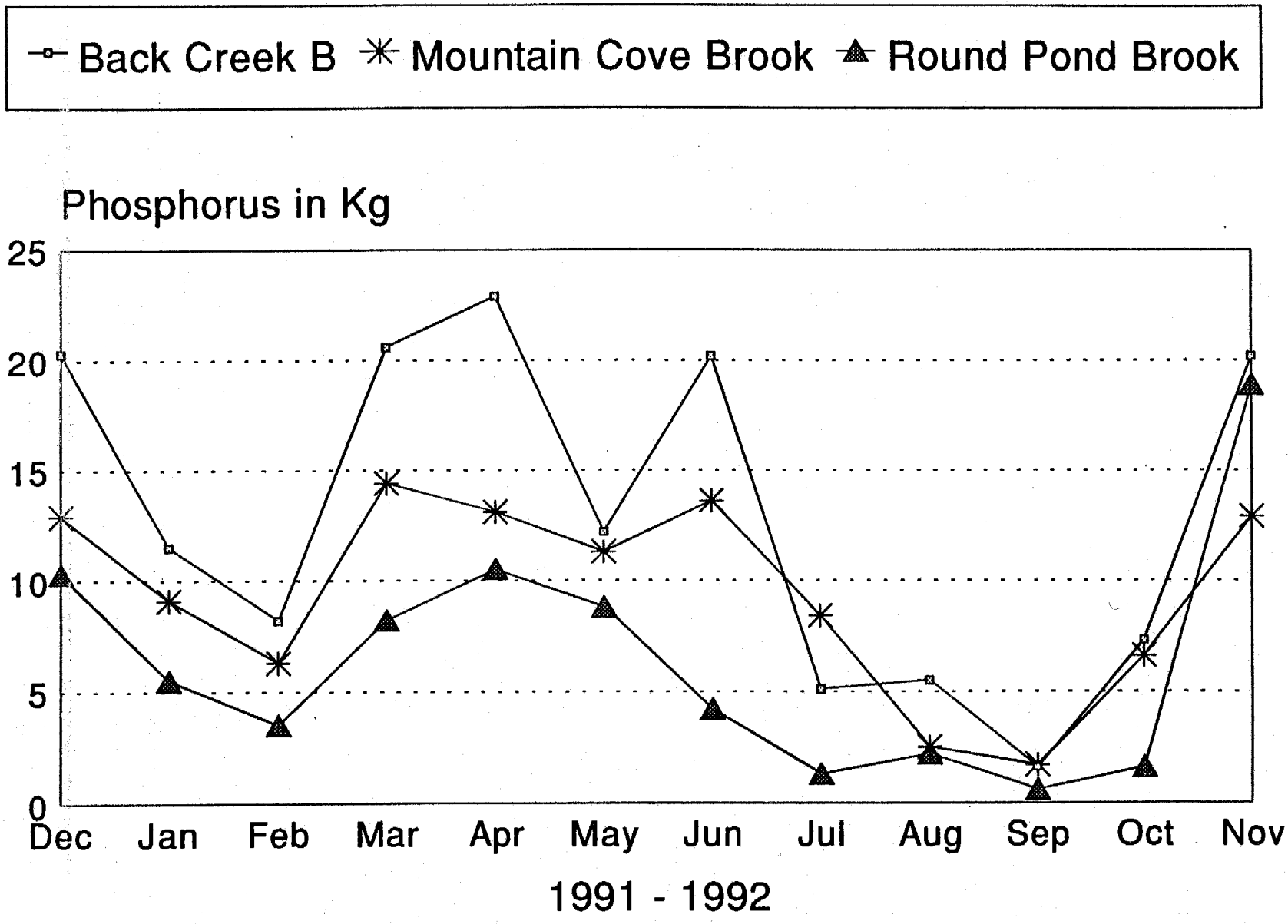


Figure VIII-2. Monthly Phosphorus Load to Pawtuckaway Lake by the Major Inflowing Tributaries

Pawtuckaway Lake

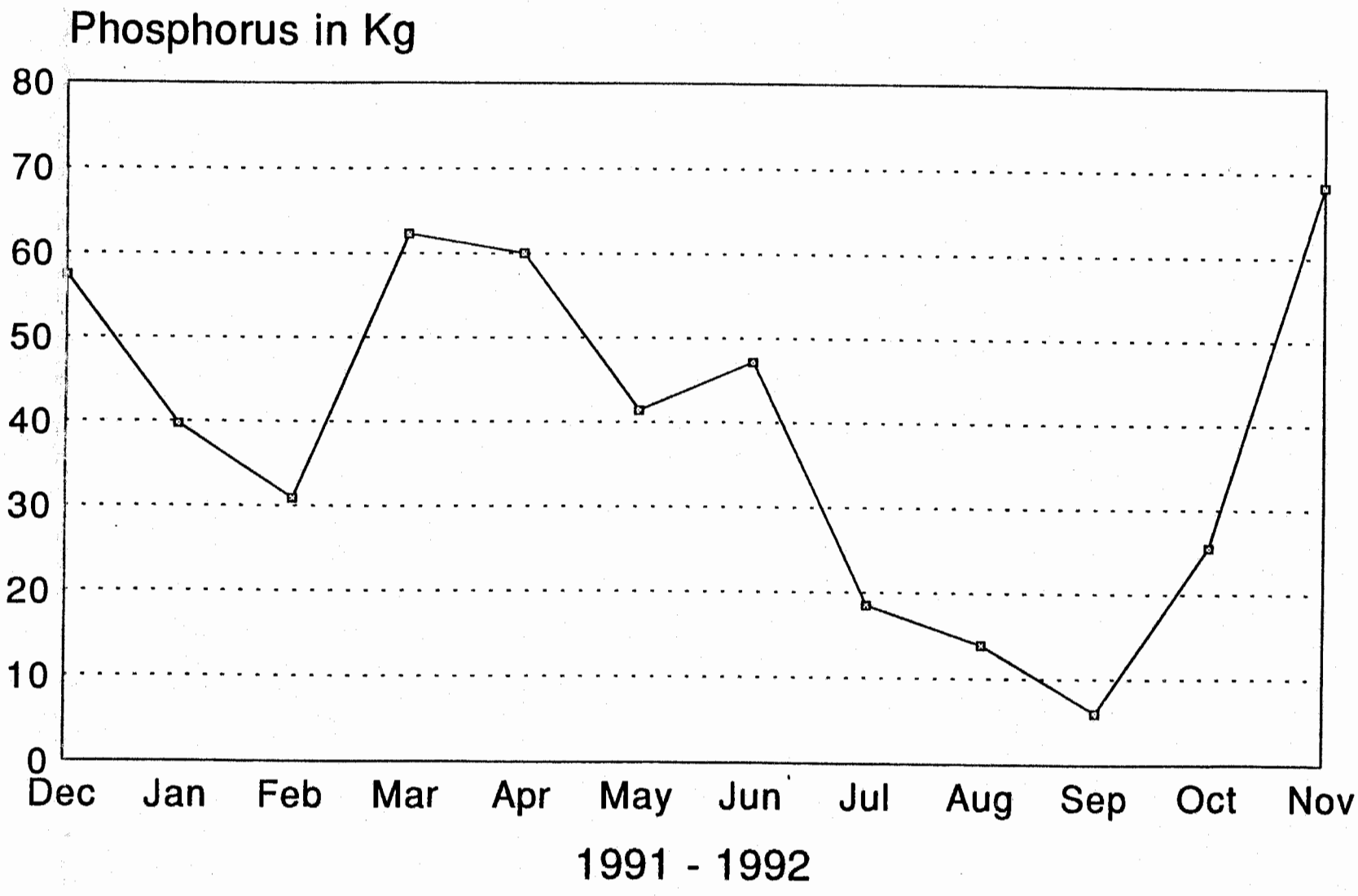


Figure VIII-3. Monthly Phosphorus Load by Inflowing Tributaries

vulnerable sediments. The result is an acceleration of the movement of these unstabilized sediments toward the lake.

By May, much of the phosphorus loading to the lake had subsided. During May, the subwatersheds are dry and the soils are stabilized with a healthy growth of vegetation. The June increase phosphorus load to two tributaries can be explained by increased rainfall and therefore an increase in tributary water volume. Round Pond Brook continued a trend of decreasing phosphorus load. Round Pond differs from the other two major tributaries in that it now has a storage capacity for water and a settling capacity for phosphorus. Although the apparent trend for July and August was decreased phosphorus load, these months are usually underestimated. Typically these months are the driest and ground infiltration and evapotranspiration are at their maximum. Much of the water and nutrients are now being taken up by the unsaturated soils and the lavish plant growth. However, these months also are characterized by short duration, high intensity storm events. These events are difficult to measure and, in fact, usually overload the hydrologic and phosphorus budget unless flows are being monitored by in stream gaging devices. Since these devices were not available for Pawtuckaway Lake, it is assumed that the phosphorus loading to the lake is underestimated for the 1992 summer season. July and August accounted for the greatest percentage of monthly precipitation for the study period.

Phosphorus loading to Pawtuckaway Lake reached a study year minimum in September. The phosphorus loading minimum correlates well with the low amount of rainfall (5.9%) and the subsequent reduction of watershed runoff.

As rainfall increased in both October and November and the growing season ended, phosphorus load to the lake significantly increased during November. This trend is also historically typical of seasonal phosphorus loading to New Hampshire lakes.

Monthly external phosphorus loading trends, exclusive of tributary loading, are presented in Figure VIII-4. Atmospheric contribution depends upon the amount of precipitation that occurs over a given period of time. Atmospheric contribution and runoff loading during the winter months are often low because precipitation is usually in the form of snow, and runoff is slight. As the phosphorus budget reveals (Table VIII-8), the greatest single monthly atmospheric contribution occurred in March when 21 percent (30.6 kg P) of the atmospheric phosphorus load entered the lake. The four months from July through October contributed almost 44 percent of the atmospheric phosphorus load to the lake.

Pawtuckaway Lake

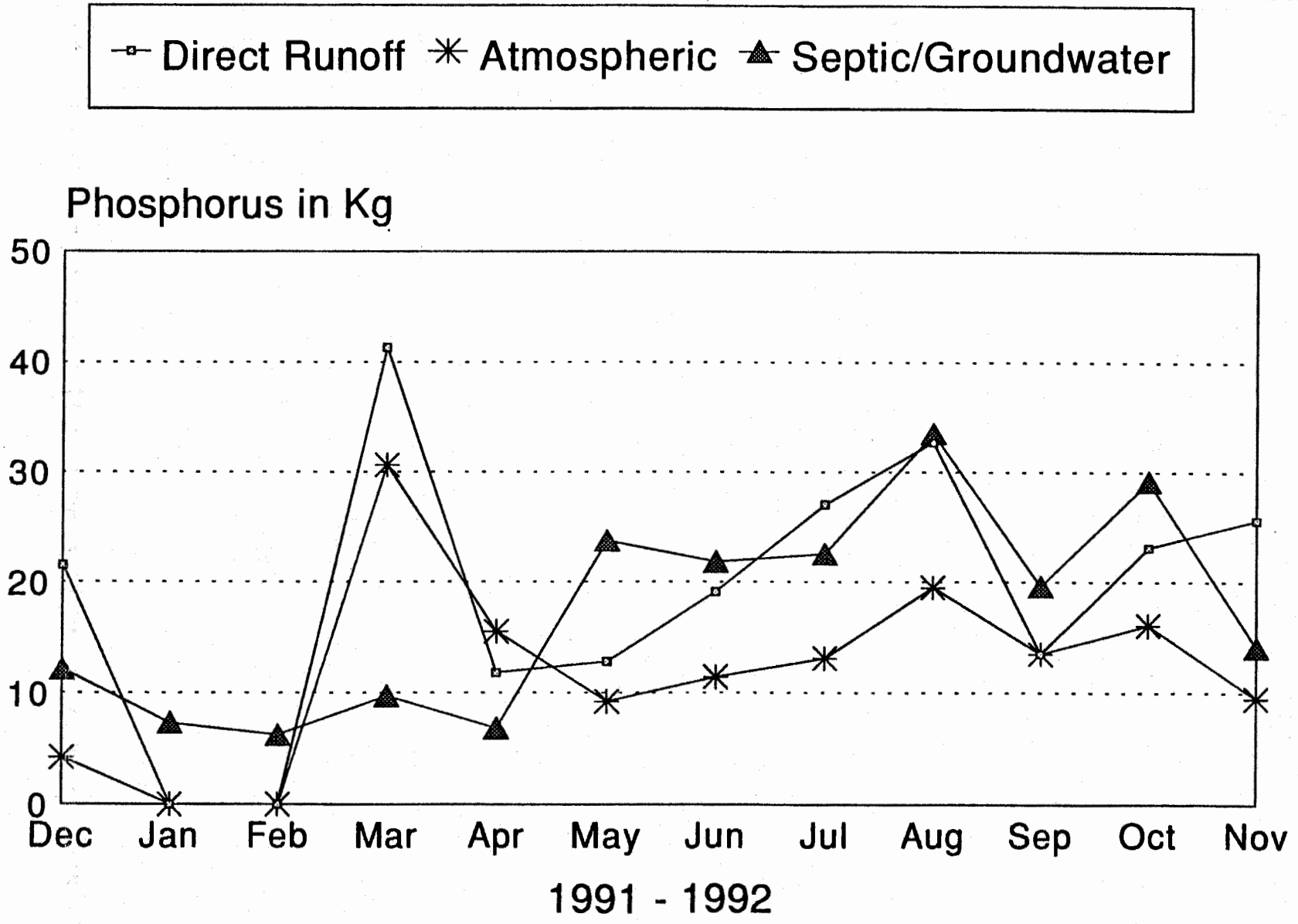


Figure VIII-4. Monthly External Phosphorus Load to Pawtuckaway Lake (Exclusive of Tributaries).

Table VIII-8
Pawtuckaway Lake Phosphorus Budget for Gaging Period (Dec'91 - Nov '92)
Phosphorus Loading (kg)

Component	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total Annual	Mean Monthly
Qi_1	20.3	11.5	8.2	20.6	22.9	12.2	20.2	5.1	5.5	1.6	7.3	20.2	155.6	13.0
Qi_2	12.9	9.1	6.3	14.4	13.1	11.3	13.6	8.4	2.5	1.7	6.6	12.9	112.8	9.4
Qi_3	10.3	5.5	3.5	8.2	10.5	8.8	4.2	1.3	2.2	0.6	1.6	18.9	75.6	6.3
Qi_4	1.6	1.1	1.6	1.8	0.9	0.5	1.0	0.1	0.2	0.2	4.6	2.1	15.7	1.3
Qi_5	2.5	1.9	1.3	1.5	2.2	2.5	1.8	1.4	1.6	0.5	0.6	0.8	18.6	1.6
Qi_6	5.8	7.1	4.3	9.9	6.3	3.1	3.4	1.1	0.8	0.8	2.1	7.9	52.6	4.4
Qi_7	0.6	0.6	0.7	0.9	0.7	0.8	0.5	0.5	0.2	0.2	1.1	2.2	9.0	0.8
Qi_8	0.5	0.4	0.5	1.0	0.7	0.4	0.9	0.1	0.2	0.1	0.3	0.8	5.9	0.5
Qi_9	0.6	0.5	0.6	0.9	1.0	0.8	0.5	0.3	0.5	0.2	0.7	0.8	7.4	0.6
Qi_{10}	1.6	0.5	0.3	1.9	1.0	0.3	0.3	0.1	0.1	0.1	0.1	0.6	6.9	0.6
Qi_{11}	0.1	0.5	3.2	0.4	0.2	0.1	0.1	<0.1	<0.1	<0.1	0.2	0.4	5.2	0.4
Qi_{12}	0.5	0.5	0.3	0.6	0.4	0.4	0.7	0.1	0.1	<0.1	0.3	0.8	4.7	0.4
Qi_{13}	0.1	0.5	0.1	0.1	0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.1	0.1
R	21.5	0.0	0.0	41.3	11.8	12.8	19.1	27.0	32.7	13.5	23.1	25.6	228.4	19.0
P_{lake}	4.2	0.0	0.0	30.6	15.5	9.2	11.4	13.1	19.5	13.5	16.1	9.5	142.6	11.9
Gwi/Septic	12.1	7.3	6.2	9.7	6.8	23.7	21.8	22.5	33.5	19.6	29.1	14.1	206.4	17.2
Sub-Total	95.2	47.0	37.1	143.8	94.1	87.1	99.5	81.1	99.6	52.6	93.8	117.6	1048.5	87.4
Net Sediment Release (+) Uptake (-)	-98.9	+29.9	-11.8	-110.0	+4.8	-91.7	-81.9	-61.3	-107.3	-108.9	-8.8	-67.0	-712.9	-54.7
Total Influx	-3.7	76.9	25.3	33.8	98.9	-4.6	17.6	19.8	-7.7	-56.3	85.0	50.6	335.6	27.9
Q_{01}	58.8	43.8	24.8	21.1	24.1	6.0	7.8	4.2	4.2	1.8	10.8	39.6	247.0	20.6
Q_{02}	1.1	0.5	12.7	2.2	6.0	15.3	21.4	6.6	9.8	2.6	47.9	11.0	137.1	11.4
Total Outflow	59.9	44.3	37.5	23.3	30.1	21.3	29.2	10.8	14.0	4.4	58.7	50.6	384.1	32.0

Note : Abbreviations are listed and explained in text.

Direct runoff of water to the lake is dependent on precipitation, soil conditions and the season. Generally, the spring melting of the winter snowpack in combination with semi-impermeable frozen soils lead to high direct phosphorus runoff. During warmer months high intensity rain events also increase direct runoff of phosphorus as little of the fallen precipitation has the opportunity to percolate through the soils. Low intensity storm events usually produce little direct runoff phosphorus from non-urbanized watersheds, as much of the water is absorbed into the usually dry summer soils.

Seasonally, little direct runoff was calculated for the winter months for Pawtuckaway Lake. Direct phosphorus runoff increased during March when the snowpack melted, and significantly decreased during April and May when wetfall was low and the growing season was underway. The direct phosphorus runoff is related to the seasonal weather patterns of the area: phosphorus loading from runoff increases as rainfall increases. Again, the months of July, August, October and November all produced phosphorus loading to Pawtuckaway Lake greater than the study year monthly mean of 19 kg P.

Groundwater seepage loading of phosphorus to the lake also followed seasonal patterns. An increase in water table forces more water and phosphorus into the lake. In the same manner, an increase in septic system usage will increase the quantity of water in the saturated lake shoreland water table, and increase the nutrient loading to the groundwater. Usually winter months are lower because less surface water can penetrate the frozen ground. Lake seepage rates increase in the spring when the ground becomes more saturated with water and is well thawed. Seepage phosphorus loading varies throughout the summer months depending on the hydraulic gradient and the use of septic systems. High groundwater phosphorus loading continued to occur through most of the fall, with septic systems still functioning and an increase in October wetfall.

Figure VIII-5 presents total monthly external loading over the 1991-1992 study period. Maximum phosphorus loading was achieved during March and November of 1992. These two months yielded 25 percent of the annual phosphorus load to Pawtuckaway Lake. However it is important to note again that phosphorus loading during July and August are probably underestimated because of the high intensity, short duration storms that are difficult to monitor.

Three months, January, February and September, were well below the annual mean phosphorus contribution of 87.4 kg. As we previously discussed the first two months were during the winter

Pawtuckaway Lake

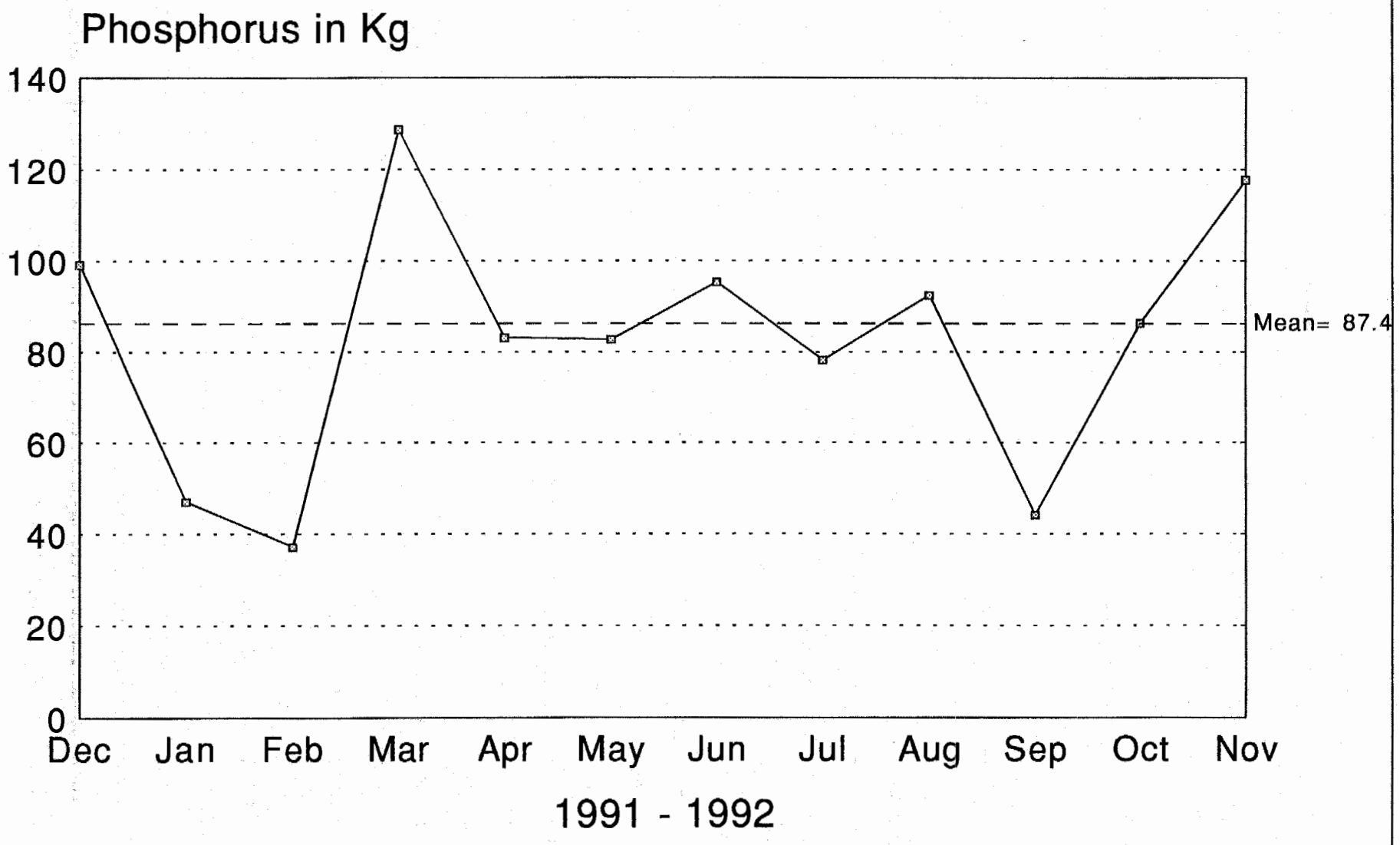


Figure VIII-5. Total Monthly External Loading

watershed snowpack storage period and September was a month of low precipitation. The period from April through August and the month of October proved to be periods where average amounts of external phosphorus was entering Pawtuckaway Lake.

D. ANNUAL PHOSPHORUS BUDGET FOR PAWTUCKAWAY LAKE (1991-1992)

The total phosphorus budget as a whole and the percent contribution of each component to Pawtuckaway Lake is one of the most important products of this study.

A pie diagram (Figure VIII-6) shows the external phosphorus contribution to Pawtuckaway Lake as percent of the total budget, while Table VIII-8 presents the 1991-1992 gaging year phosphorus budget for Pawtuckaway Lake. The combination of all 13 inflowing tributaries to Pawtuckaway Lake accounted for 45 percent of the phosphorus budget. The combination of three brooks, Back Creek (155.6 kg), Mountain Cove Brook (112.8 kg), and Round Brook (75.6 kg) represented 73 percent (471 kg) of the tributary phosphorus load to the lake.

When compared to other Diagnostic/Feasibility Studies throughout New Hampshire, the tributary loading portion of the Pawtuckaway budget was greater than Robinson Pond, Hudson (Connor, McCarthy and O'Loan, 1994) which contributed over 34 percent of the phosphorus flux. Tributary phosphorus loading to Pawtuckaway Lake was less than Beaver Lake at 65 percent (Connor and O'Loan, 1992) and less than both French Pond (Connor and Martin, 1988) and Kezar Lake (Connor and Smith, 1983) which both had tributary contributions of 73 percent of the phosphorus budget.

Direct runoff was the second greatest contributor of phosphorus to Pawtuckaway Lake. The vast amount of watershed surface area that surrounded the lake greatly influenced the direct runoff phosphorus contribution. Direct runoff represented 22 percent (228 kg) of the phosphorus budget.

Groundwater seepage/septic systems accounted for 20 percent (206 kg) of the phosphorus budget. As we previously discussed, the average septic system age around the Pawtuckaway shoreline is 19.7 years. The combination of septic system contributors to the groundwater and chemical reactions in the sediment-water interface influence the phosphorus concentration. The high groundwater rates are the result of the large littoral area that encompasses Pawtuckaway Lake. Higher seepage rates are known to be measured in the shallower areas of the lake. The combination

Pawtuckaway Lake

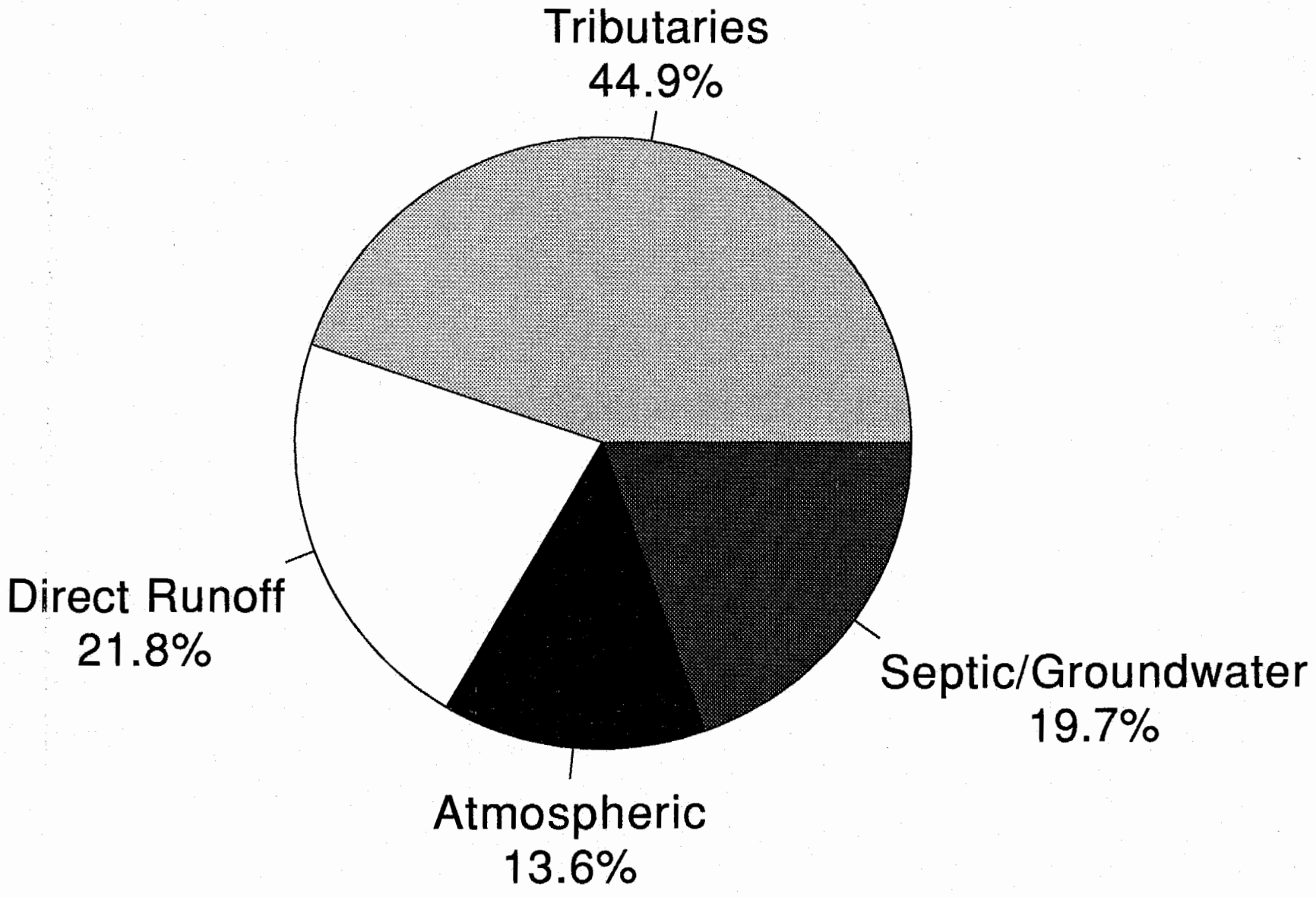


Figure VIII-6. External Phosphorus Contribution to Pawtuckaway Lake

of high seepage rates with relatively high interstitial phosphorus concentration makes Pawtuckaway Lake one of the highest groundwater contributors when compared to other Diagnostic/Feasibility Study lakes. Seepage phosphorus contributors generally range from nine to ten percent of the phosphorus budget. However, Robinson Pond groundwater contributed 27 percent of the phosphorus load to the lake. The recent increase of groundwater phosphorus loading to lakes may also be attributed to new technology recently adopted by the Biology Bureau. The measurement of interstitial groundwater phosphorus concentration and actual flow determinations are being used over model equations to define the groundwater phosphorus contribution to the budget.

Atmospheric deposition delivered almost 143 kg of wetfall and dryfall phosphorus to Pawtuckaway Lake during the 1991-1992 study year. This contribution represents 13 percent of the phosphorus budget and compares well to other studies completed.

Oxygen deficiencies were measured in the hypolimnion of Pawtuckaway Lake for approximately 30 percent of the study year. Hypolimnetic anoxia is highly conducive to the release of phosphorus from the sediment and interstitial water to the immediate water column. Increases in hypolimnetic phosphorus in Pawtuckaway Lake coincided with low hypolimnetic dissolved oxygen during July, August and early September. Hypolimnetic phosphorus and dissolved oxygen data reveal that there is currently a problem with internal phosphorus loading. Since this hypolimnetic area reflects internal phosphorus loading to the lake, much of the other lake areas must be accumulating phosphorus.

Although the Pawtuckaway Lake phosphorus budget shows a net uptake of phosphorus, it must be emphasized that sediment release and uptake are simultaneously occurring functions in different sections of the lake, and that other chemical, physical and biological activities are also occurring. While one section of the lake may be releasing phosphorus for some of the year, other areas of the lake are taking up phosphorus. As discussed previously in the sediment release section, only two months showed a net release of phosphorus to the water column. Hypolimnetic phosphorus data collected during the 1992 summer study period confirmed that internal phosphorus loading is a problem in Pawtuckaway Lake. A comparison between epilimnetic phosphorus (mean = 11 µg/L) and hypolimnetic phosphorus (mean = 22 µg/L) shows that hypolimnetic phosphorus was 2 times greater than epilimnetic phosphorus over the same period of time.

Storm events can be a significant factor in calculating a phosphorus budget. However, they are

one of the most difficult parts of the budget to quantify. Accumulating storm event data can be costly; equipment to sample and record flows must be purchased and operated. None the less, the expense is justified if an accurate phosphorus budget is to be developed. Dennis (1986) estimated that the four largest runoff events accounted for 65 percent of the total phosphorus export to a Maine lake and a single storm event contributed almost 50 percent of the phosphorus load to that same lake.

Many studies have shown that much of the phosphorus load can occur during the first centimeter of rainfall. A study conducted in a Maine watershed estimated that 69 percent of the phosphorus export occurred during the first centimeter of runoff while 90 percent and 97 percent occured during the first two centimeters and three centimeters respectively.

As we discussed in the hydrologic section, the rain events that did occur at Pawtuckaway Lake were of very short duration and therefore biologists never had the opportunity to monitor a rain event.

CHAPTER IX BOTTOM SEDIMENT COMPOSITION

A. INTRODUCTION

Lake sediments are important to limnologists because of their role in the determination of nutrient levels and productivity in the overlying waters.

A review of the factors that may affect sediment-water exchange reactions shows that there is insufficient knowledge at the present time to predict the extent and, in many cases, the net direction of exchange for many compounds in most natural waters. Lake sediments contain significant concentrations of many metals and nutrients. The lake sediments act as a buffer system for these elements to control concentrations in the overlying waters. The effect of this buffer system could be to keep the concentrations in the overlying waters relatively constant even though the concentrations of the element in the inflowing waters vary greatly (Lee, 1970).

One of the most important reactions of this type is the exchange of phosphorus between a lake's sediments and the overlying waters as related to the eutrophication of the waters. Lee (1970) states that lake sediments typically contain one to two parts per thousand of phosphorus per kilogram of dry sediment.

Knowledge is particularly lacking on the role of lake sediments in maintaining phosphorus levels in water. It is not known if the sediments of a lake act as a sink in which the majority of the phosphorus present is refractory, i.e., not available for exchange reactions, or as a source, contributing phosphorus to the lake to sustain plant growth.

Frink (1967) suggests that the center of a lake acts as a reservoir for both total and available nitrogen and phosphorus. He concludes that nutrients which accumulate in the bottom of a lake as eutrophication proceeds constitute a vast reservoir apparently capable of supporting plant growth in the event nutrient input is reduced. This was the case at Kezar Lake, North Sutton, New Hampshire. Even after phosphorus loading was dramatically reduced from a point source, phytoplankton blooms continued on an annual basis. Phosphorus rich sediments continued to release phosphorus into the upper water column supporting a vast population of

phytoplankton (Connor and Smith, 1983).

In addition to phosphorus, metal concentrations in the sediment can play a role in the ecological health of a lake. With the increasing concern of acidic precipitation in New Hampshire, lake or pond pH and ANC have become increasingly important to the lake's health. Studies have shown various mechanisms of response of the lake's biota to increased acidity, ranging from the direct toxicity of the elevated hydrogen ion concentration to disruptions of normal food-chain relations and behavioral patterns of animals. Biogeochemical cycles in the lake may also be affected and, in turn, disrupt the biota. Recent studies have shown increasing concentrations of heavy metals such as manganese, aluminum and zinc as a result of pH depressions below five units.

B. CHEMICAL CHARACTERIZATION

A Wildco KB™ coring device was utilized to extract a 20.0 cm sediment core from the South Station of Pawtuckaway Lake and a 26.0 cm core from the North Station. The cores were sectioned off into one centimeter sediment column intervals. Metals were digested using a CEM Model 81 microwave digestion unit and run on an inductively coupled plasma atomic emission spectrometer. Sediment phosphorus concentrations were determined colorimetrically after digestion. Such measurements provide information on deposition rates, toxic metal concentrations, phosphorus sediment accumulation, and spatial variability over time.

When assessing spatial variability over time one must use caution. Iskandar and Keeney (1974) stated that concentration distribution of any element in a sediment profile must be treated cautiously due to mixing of the sediments. This is reiterated by Lee (1970) who stated that at least partial mixing of the sediments occurs for 5-20 cm below the sediment surface. This mixing occurs due to both natural processes and man-induced conditions. Natural mixing processes include thermal gradients, wind pressure and waves, organism mobility (i.e. insect larvae and worms) and the formation of gas bubbles and pockets. Man-made mixing occurs due to recreational activities (i.e. boating) or artificial mixing of the lake. In addition to mixing, some elements can diffuse upward due to differing gradients in the overlying water. For this reason the general trends in concentrations are more relevant than the segment to segment variances. Comparison of other lake sediment core analyses performed in New Hampshire are

presented in Table IX-1. Summary tables of sediment analyses from Pawtuckaway Lake appear in Table IX-2 and IX-3.

C. SEDIMENTATION RATES AND SEDIMENT AGE

The relative age of the sediments of New Hampshire ponds are estimated using lead concentrations as an indicator. A typical sediment profile shows lead concentrations increasing with depth to a maximum at several inches below the surface, and subsequently decreasing again. This increase corresponds to the introduction and increased use of leaded gasoline during the 1920's and its later decline during the seventies with the introduction of unleaded gasoline. Values from lakes that do not have point source discharges usually display these trends.

The Connecticut Department of Environmental Protection estimated that 2.0 feet (0.61 meter) of sediment had been deposited in eutrophic Lake Lillionah between 1955 and 1980. This equals a sediment deposition rate of approximately 1 in. (2.5 cm) yr^{-1}. Sedimentation in Lake Lillionah is unusually high, as compared to most Connecticut lakes, in that Lillionah experiences dense summer blooms of blue-green algae and receives indirect discharge of treated wastewater from an upstream sewage treatment plant. Peterson et al., (1973) discusses sedimentation rates for Lake Trummen, located in Sweden. Approximately 40 cm of FeS-colored (black) fine sediment was deposited over a period of 25 years, or at a rate of about 0.6 in. (1.6 cm) yr^{-1}. Lake Trummen was also subjected to the discharge of wastewater effluent for many years, and the significance of internal nutrient recycling was well documented. At mesotrophic Stockbridge Bowl, located in Stockbridge, Massachusetts, Ludlam (1976) reported a much lower sedimentation rate of 0.12 inches (3.0-3.2 mm) $year^{-1}$. The Maine Department of Environmental Protection assumes an approximate sedimentation rate of 0.08 inches (2.0 mm) $year^{-1}$.

Although the North and South Stations do not reflect similar lead profiles, the South Station shows a typical New Hampshire lead deposition profile. Sediment lead increases dramatically at eleven centimeters and again at nine centimeters. Lead shows its maximum piak at four centimeters which is fairly recent. Lead decreases in the upper three centimeters reflect a reduction in atmospheric lead deposition as a result of the increased use of unleaded gas.

Table IX-1
Comparison of Surface Sediments (first inch) of Pawtuckaway Lake and New Hampshire Lakes and Ponds

Parameter/Lake	Classification	Al	Cd	Cu	Fe	Pb	Zn	P
Pawtuckaway Lake North Nottingham	Mestotrophic	36,181	11	61	43,807	497	356	4,397
Pawtuckaway Lake South Nottingham	Mestotrophic	48,196	10	48	45,570	384	317	3,287
Robinson Pond Hudson	Eutrophic	7,660	4	20	7,840	155	105	982
Ottarnic Pond Hudson	Eutrophic	7,547	5	26	19,136	494	179	1,484
Beaver Lake Derry	Eutrophic	23,760	5	26	26,460	139	227	2,359
Mendums Pond Barrington	Oligotrophic	16,800	<4	<80	13,120	101	80	7,128
*Webster Lake Franklin	Mesotrophic	20,500	1	17	26,000	94	140	4,735
Mtn. Pond Chatham	Oligotrophic	25,120	<24	<80	16,320	98	184	4,530
Loon Lake Plymouth	Mesotrophic	14,921	<24	<80	30,595	48	159	7,211
Kezar Lake Sutton	Eutrophic	23,585	<236	830	16,038	58	6,604	5,569
French's Pond Henniker	Eutrophic	16,812	<30	69	27,525	732	317	10,165

All values in mg/kg Dry Weight of Sediment
*Method Utilizing CEM Microwave (except Mn and Tp)

Table IX-2
Recoverable Metals From Pawtuckaway Lake (North) Sediments (mg/kg)

Sediment Section (cm)	Dry Weight (grams)	Al	Cd	Cr	Cu	Fe	Pb	Zn	P	Ca	Mg	K	Na
0-1	0.259	13,880	4.90	29.8	27.1	17,568	193	170	1,764	2,718	1,072	811	581
1-2	0.581	14,888	3.90	30.7	22.9	17,779	198	124	1,756	2,932	1,141	706	279
2-3	0.835	14,826	3.70	29.4	21.7	16,922	212	123	1,756	2,998	1,135	922	227
3-4	0.826	15,230	3.50	29.4	21.7	16,731	199	119	1,829	2,900	1,156	642	223
4-5	0.842	15,498	3.40	29.6	22.0	16,829	217	126	1,802	3,004	1,198	656	197
5-6	0.959	15,268	4.90	28.5	21.1	17,018	204	127	1,899	3,092	1,180	613	206
6-7	0.900	13,278	3.40	23.7	16.5	13,733	151	116	1,708	2,836	1,051	591	184
7-8	0.930	12,935	3.10	23.0	15.7	14,139	128	117	1,605	3,092	1,052	531	166
8-9	0.800	15,162	3.60	26.8	18.2	15,550	140	133	1,892	3,768	1,245	612	186
9-10	0.780	15,077	3.40	25.9	17.7	15,038	131	136	1,932	3,583	1,185	578	168
10-12	0.980	14,796	3.30	24.9	16.3	13,836	99	139	1,817	4,578	1,250	617	202
12-14	1.060	14,443	3.30	23.0	15.8	12,906	90	115	1,839	4,877	1,277	583	210
14-16	1.000	14,590	2.80	23.4	16.7	12,580	102	103	1,957	3,806	1,159	538	150
16-18	1.001	14,106	2.66	21.9	15.0	12,028	68	89	1,871	4,249	1,204	604	198
18-20	1.002	11,886	2.50	18.6	13.3	10,379	52	79	1,558	4,250	1,168	628	218
20-22	1.012	9,594	1.70	14.5	11.1	8,112	26	56	1,292	3,719	998	568	169
22-24	1.002	11,606	2.30	17.9	12.9	10,149	60	80	1,387	3,899	1,098	622	144
24-26	1.002	11,208	3.10	17.9	11.3	8,453	30	70	1,846	3,859	1,108	603	139

Table IX-3
Recoverable Metals From Pawtuckaway Lake (South) Sediments (mg/kg)

Sediment Section (cm)	Dry Weight (grams)	Al	Cd	Cr	Cu	Fe	Pb	Zn	P	Ca	Mg	K	Na
0-1	0.502	19,582	4.52	29.32	20.70	19,343	172.11	136	1,317	3,147	1,560	794	215
1-2	0.505	19,129	4.24	27.19	18.51	17,960	153.86	122	1,350	3,079	1,473	745	220
2-3	0.505	18,970	2.85	26.08	17.80	16,535	115.64	118	1,240	3,140	1,451	748	178
3-4	0.503	17,594	3.62	23.54	16.08	15,527	95.00	111	1,203	3,567	1,376	666	202
4-5	0.509	16,385	3.22	21.67	14.85	13,733	61.82	102	1,108	3,261	1,299	582	165
5-6	0.505	17,307	3.52	23.11	15.19	14,554	77.31	98	1,198	3,305	1,335	622	158
6-7	0.504	16,825	3.52	21.96	14.19	13,155	58.15	80	1,125	3,218	1,311	643	168
7-8	0.505	16,277	2.86	20.22	12.75	11,723	60.73	70	1,071	3,051	1,249	541	168
8-9	0.507	17,022	3.33	20.43	13.10	11,183	42.19	68	1,171	3,128	1,272	591	164
9-10	0.505	17,366	2.46	20.87	12.85	11,465	43.86	68	1,287	3,327	1,287	654	176
10-12	1.030	8,252	2.17	16.09	9.56	9,641	22.26	57	107	5,563	994	196	107
12-14	1.002	6,896	2.13	13.31	8.00	7,335	6.63	42	94	5,489	951	154	94
14-16	1.001	4,944	2.02	9.54	5.55	5,355	5.88	28	92	4,477	789	133	92
16-18	1.006	5,407	1.85	9.88	5.82	5,338	6.35	28	90	4,827	815	122	90
18-20	0.998	3,215	1.32	6.61	4.99	2,940	2.89	16	66	2,784	579	128	66

D. SEDIMENT METALS AND PHOSPHORUS

Values presented in the following discussion are for concentrations which were measured in the sediment and not in the water. Elevated metal concentrations would not be expected to be measured in lake water unless low pH values (below 5.0 units) were commonly measured within the lake.

1. Recoverable Aluminum

One of the most abundant elements on the face of the earth, aluminum occurs in many rocks but never as pure metal in nature. Although the metal itself is insoluble, many of its salts are readily soluble.

The toxicity of aluminum to the aquatic biota has been reviewed extensively with the recent interest in the resolublization of aluminum in acidic waters. Aluminum toxicity does not appear to be a significant problem, as long as pH is controlled and residual dissolved aluminum is not allowed to reach levels in the area of 50 µg/L. In areas where lakes have low ANC and acid rainfall is significant, lowering the lake pH could cause a sudden increase in aluminum and probable toxic effects to the lake biota.

Aluminum concentrations from the North and South Stations at Pawtuckaway Lake can be found in Tables IX-2 and IX-3. Aluminum values from the North Station of Pawtuckaway Lake (Zmax=14.5 meters) ranged from a minimum of 11,207 mg/kg (24-26 cm segment) to a maximum of 15,498 mg/kg (4-5 cm segment), while the South Station had values ranging from 3,215 mg/kg (18-20 cm segment) to 19,582 mg/kg (0-1 cm segment). Aluminum concentrations in the sediments of the North Station remained relatively stable throughout the profile, while concentrations in the South Station were lower than those of New Hampshire lakes and ponds in the 10-12 cm segment with a value of 17,366 mg/kg. Aluminum concentration remained relatively stable to the top of the profile (Figure IX-1). The elevated values coincide with the increased segment size analyzed from the profile.

The aluminum values for the first inch of sediment cores from the North and South Stations at Pawtuckaway Lake were higher than those found at other lakes and ponds in New Hampshire (Table IX-1).

Pawtuckaway Lake Sediment Analyses

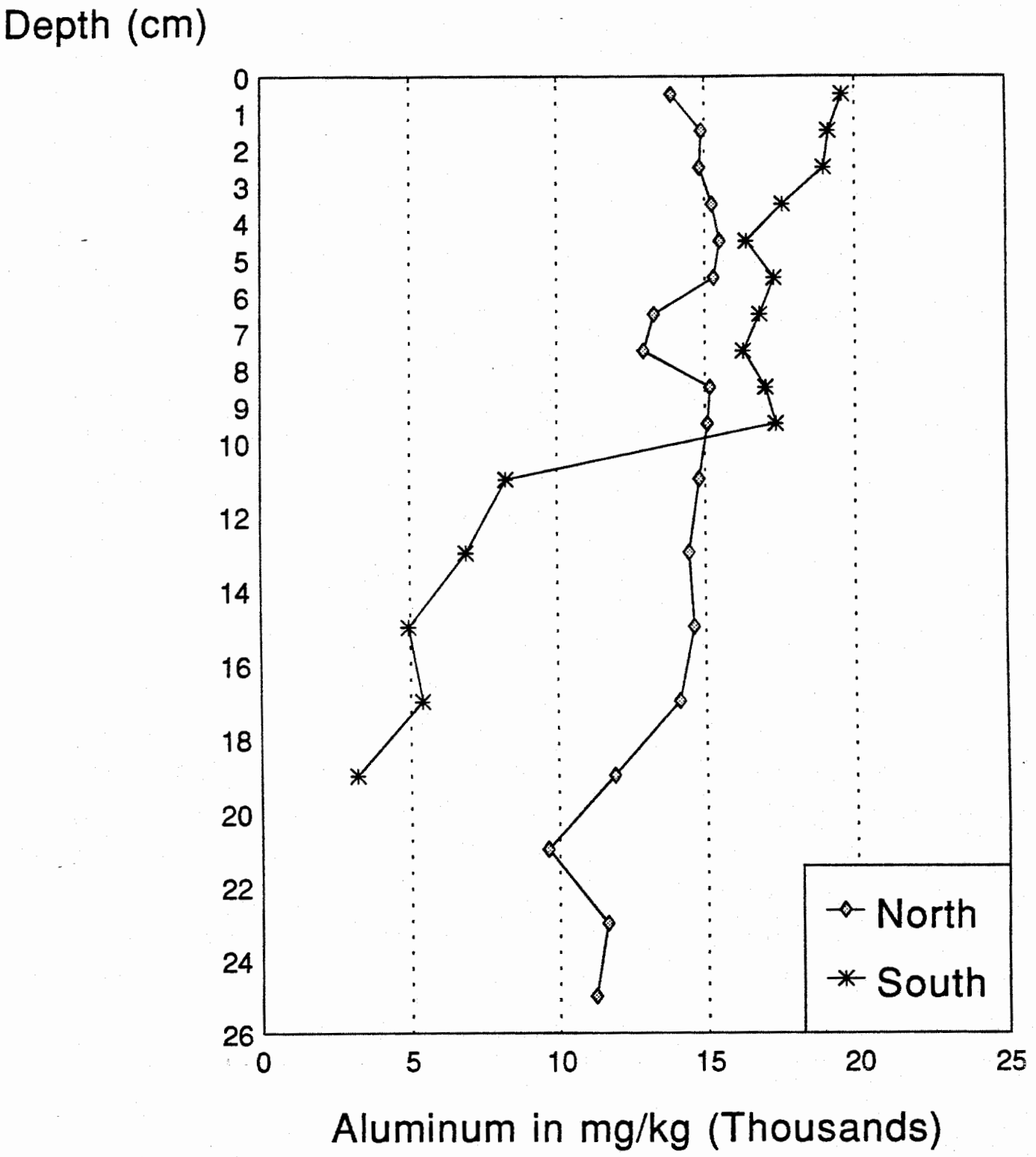


Figure IX-1: Aluminum Concentrations in Pawtuckaway Lake Sediments

2. Recoverable Cadmium

In the elemental form, cadmium is insoluble in water. It occurs in nature largely as a sulfide salt. Cadmium is used in metallurgy to alloy with copper, lead, silver, aluminum and nickel. It is also used in electroplating, ceramics, photography, and insecticides.

Cadmium levels analyzed from the sediment cores at both lake stations in Pawtuckaway Lake were below 5 mg/kg throughout the sediment profiles and remained relatively stable. As Figure IX-2 illustrates, the North and South Stations sediment profiles displayed a minimal increase in cadmium from the 18-20 cm segment to the top of the profile, with maximum cadmium values in the uppermost segment (0-1 cm) of each lake station. Cadmium levels in the sediment of the North Station ranged from 1.70 mg/kg (20-22 cm segment) to 4.90 mg/kg (0-1 cm segment) and remained well within the limits of data collected from other New Hampshire lakes and ponds (Table IX-1). A similar range in cadmium levels was observed in the South Station sediments with values ranging from 1.32 mg/kg (18-20 segment) to 4.52 mg/kg (0-1 cm segment). Cadmium data for the North and South Stations is presented in Tables IX-2 and IX-3 respectively.

3. Recoverable Copper

Copper salts occur in natural surface waters only in trace amounts, up to about 50 ug/L, and their presence is frequently due to the use of copper sulfate for the control of nuisance plankton species. Copper is used in many alloys, insecticides, fungicides, and wood preservatives. Copper values from the North and South Stations of Pawtuckaway Lake ranged from 11.1 mg/kg to 27.1 mg/kg and from 4.99 mg/kg to 20.70 mg/kg respectively (Tables IX-2 and IX-3). Copper values increased from the bottom to the top of the sediment profile at both lake stations (figure IX-3). In comparison with other New Hampshire lakes and ponds, surface sediments in both the North and South Stations at Pawtuckaway Lake contained levels of copper that fell within the observable mean (Table IX-1).

Pawtuckaway Lake Sediment Analyses

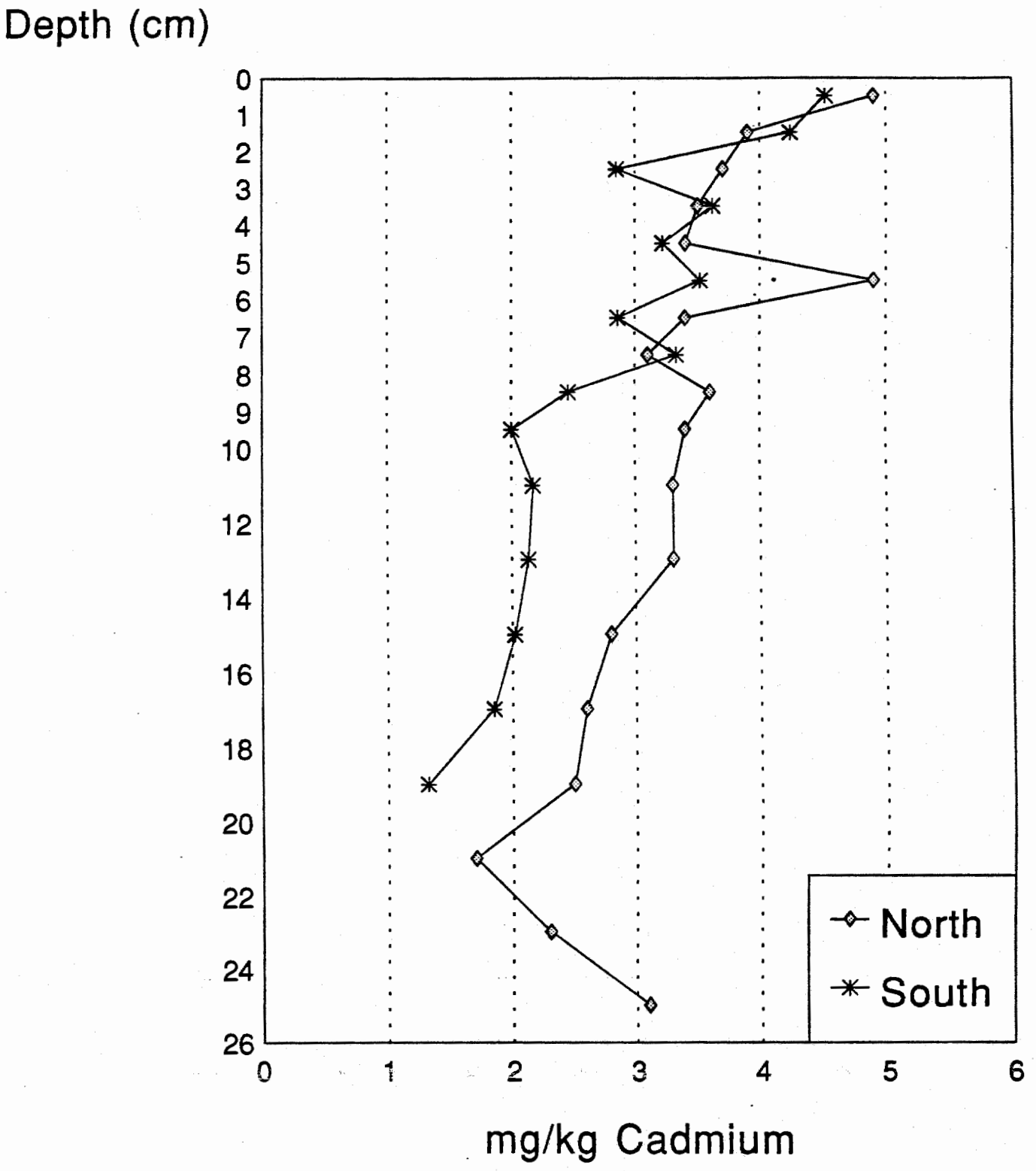


Figure IX-2: Cadmium Concentrations in Pawtuckaway Lake Sediments

Pawtuckaway Lake Sediment Analyses

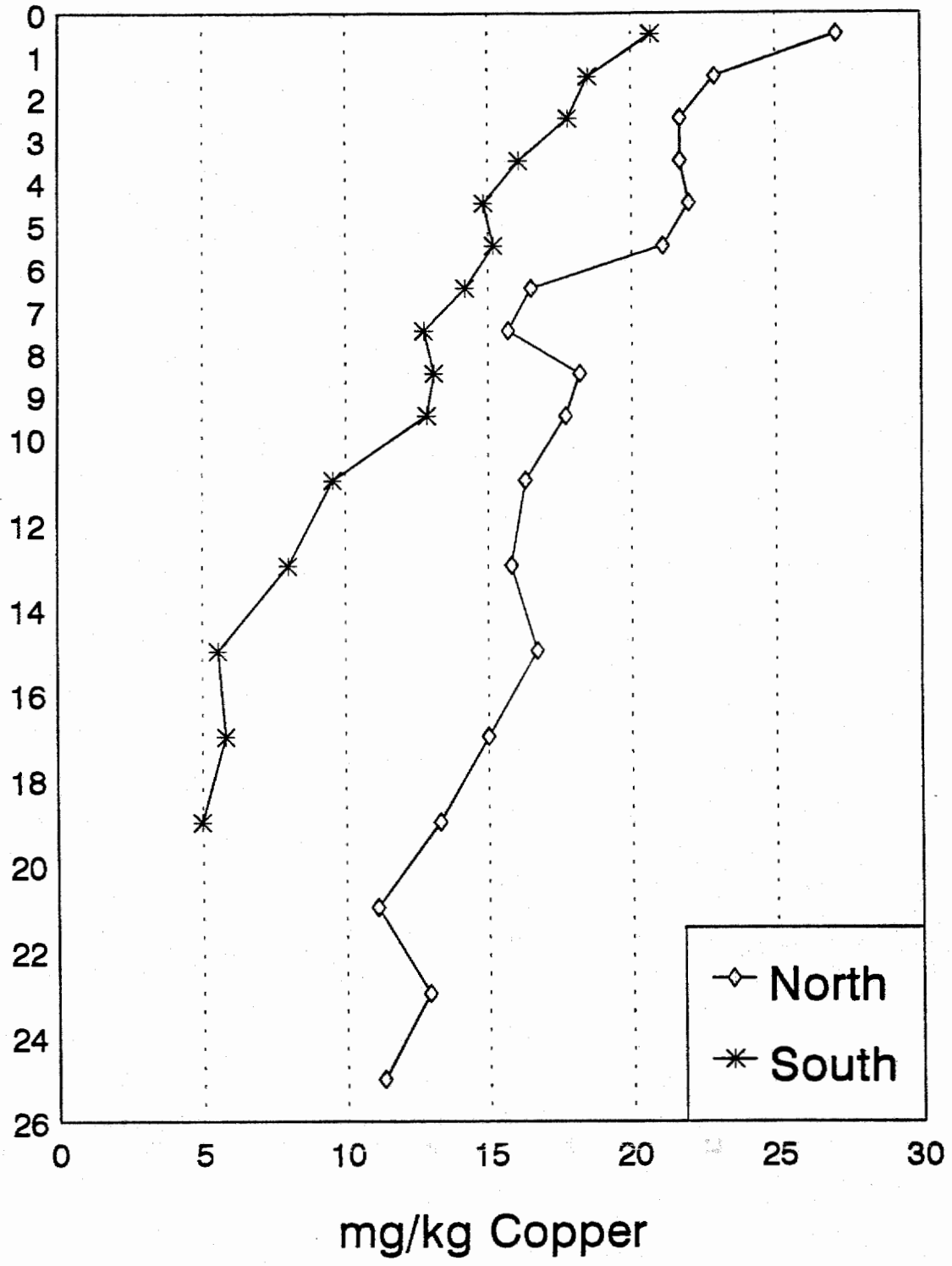


Figure IX-3: Copper Concentrations in Pawtuckaway Lake Sediments

4. Recoverable Iron

Iron is the fourth most abundant by weight of the elements that make up the earth's crust. Common in many rocks, it is an important component of many soils, especially the clay soils. Iron values for Pawtuckaway Lake sediments are displayed in Tables IX-2 and IX-3, and Figure IX-4. The Pawtuckaway Lake North Station at had a range of 8,112 to 17,779 mg/kg while that of the South Station was more variable, ranging from 2,940 to 19,343 mg/kg. Both lake stations had minimum iron values in the deepest sediments with concentrations increasing to the maximum at the surface sediments. The Pawtuckaway Lake North and South Stations contained high levels of iron in surface sediments when compared to other lakes and ponds sampled in New Hampshire (Table IX-1).

5. Recoverable Lead

Leaded gasoline, introduced in the 1920's, has been largely blamed for the increased levels of lead observed in the aquatic environment. While the introduction of unleaded gasoline in the early 1970's was responsible for a reduction in atmospheric deposition. The solubility of lead compounds in water depends heavily upon pH. Fish kept in water of pH 6.0 concentrate almost three times more lead than fish kept in water of pH 7.5. This is of startling significance for the northeast where lake waters are generally poorly buffered and acid precipitation is further decreasing the pH in many of our lakes and ponds.

Recoverable sediment lead concentrations ranged from a low of 2.89 mg/kg to a maximum of 172 mg/kg in the South Station and from 26 mg/kg to 217 mg/kg in North Station sediments. The North and South Stations at Pawtuckaway Lake displayed a wide variance in lead content with depth. The deepest segments had minimal values and the general trend showed a gradual increase until the 6-7 cm segment in the North Station and the 4-5 cm segment in the South Station, at which point the concentration rose sharply (Tables IX-2 and IX-3, Figure IX-5). A comparison of the surface sediment lead concentration of Pawtuckaway Lake with other lakes and ponds in New Hampshire shows greater than average levels in the North and South Stations (Table IX-1).

Pawtuckaway Lake Sediment Analyses

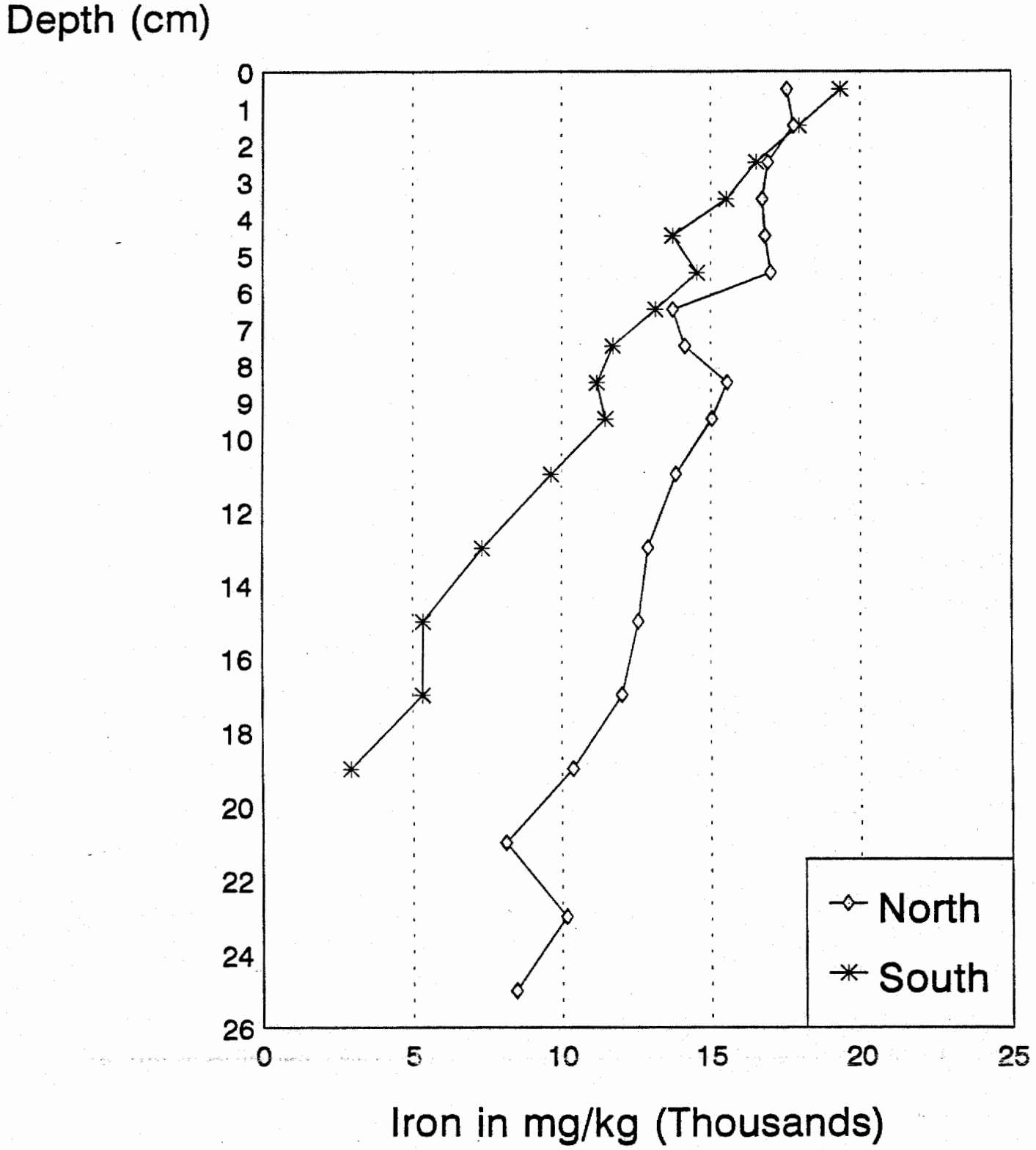


Figure IX-4: Iron Concentrations in Pawtuckaway Lake Sediments

Pawtuckaway Lake Sediment Analyses

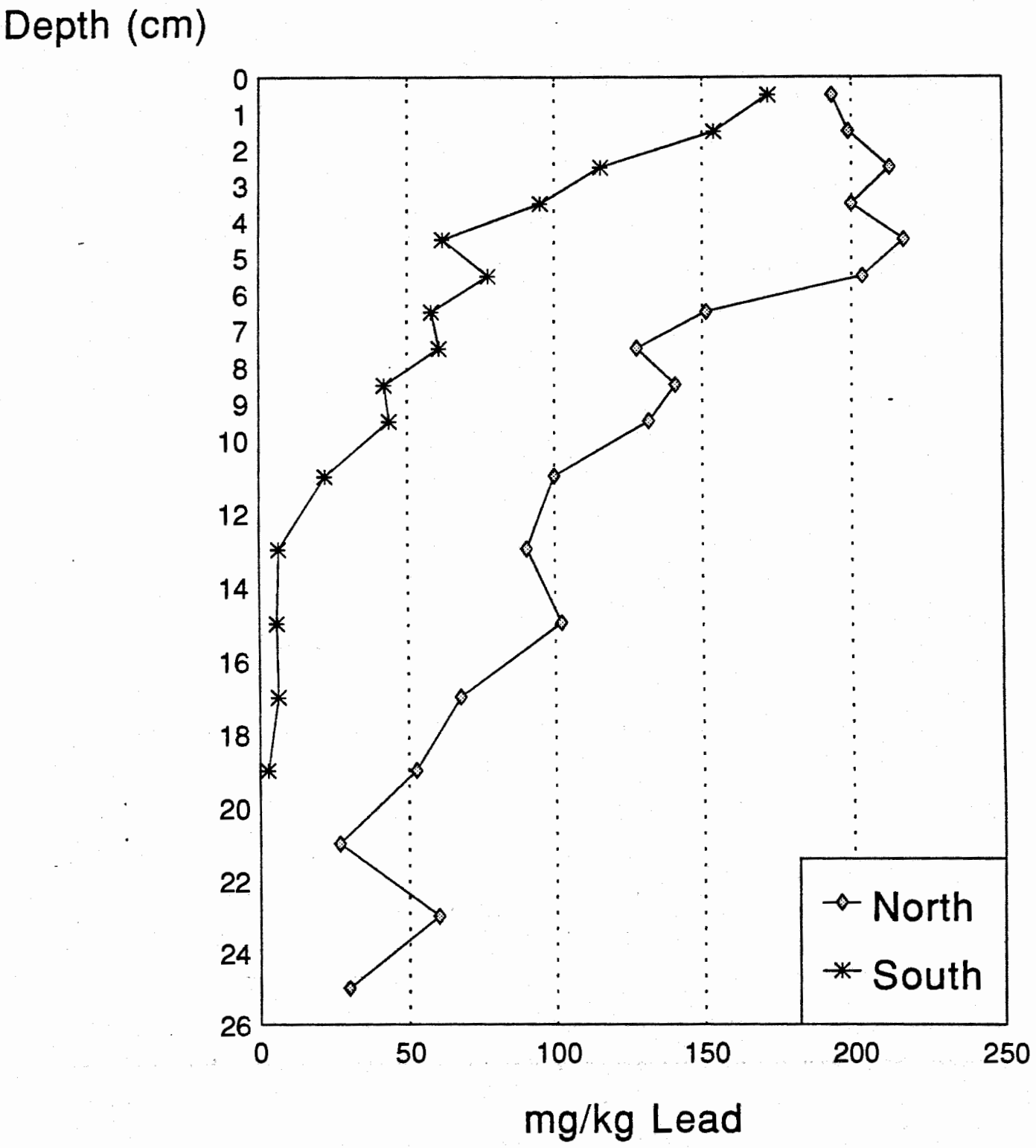


Figure IX-5: Lead Concentrations in Pawtuckaway Lake Sediments

6. Recoverable Zinc

Compounds of zinc are soluble in neutral and acidic solutions, so that zinc is readily transported in most natural waters and is one of the most mobile of the heavy metals. Zinc is used for the anti-corrosive coating in galvanized metals and rubber products.

Most of the zinc introduced into the aquatic environment is partitioned into the sediments by sorption onto hydrous iron and manganese oxides, clay minerals, and organic materials. All zinc forms are potentially toxic if they can be sorbed or bound by biological tissue.

Sediment zinc concentrations ranged from 16 mg/kg to 136 mg/kg in the South Station and from 56 mg/kg to 170 mg/kg in the North Station of Pawtuckaway Lake (Tables IX-2 and IX-3). As with most other chemicals analyzed, zinc levels for both lake stations had a general increase in concentration from the deepest segments to the surface of the sediment profiles (Figure IX-6). Comparison of values with the surface sediments of other New Hampshire lakes and ponds reveals that Pawtuckaway Lake had greater than average concentrations of zinc in the uppermost layers of the sediment profiles collected at both lake stations (Table IX-1).

7. Recoverable Phosphorus

The measurement of phosphorus concentration in a lake gives an indication of the extent of nutrient enrichment. The amount of phosphorus in New Hampshire lakes determines the level of plankton growth. Lake sediments often act as sinks and accumulate high concentrations of phosphorus over long periods of time. Phosphorus which has accumulated in the deep water sediments of a lake may be released into the water when the physical, biological and chemical conditions become conducive for its release. Usually, this release occurs during the summer months. If stratification is weak, this phosphorus migrates to the metalimnion to be utilized by the plankton community; otherwise, much of this hypolimnetic phosphorus is distributed to the entire water column during the fall overturn.

The identification of sediment phosphorus concentration is important to the phosphorus budget. Spatial distribution of sediment phosphorus with depth is important in the evaluation of lake restoration techniques and their feasibility. The uniform distribution of high concentrations of phosphorus throughout the sediment column would obviously make dredging an unfeasible

Pawtuckaway Lake Sediment Analyses

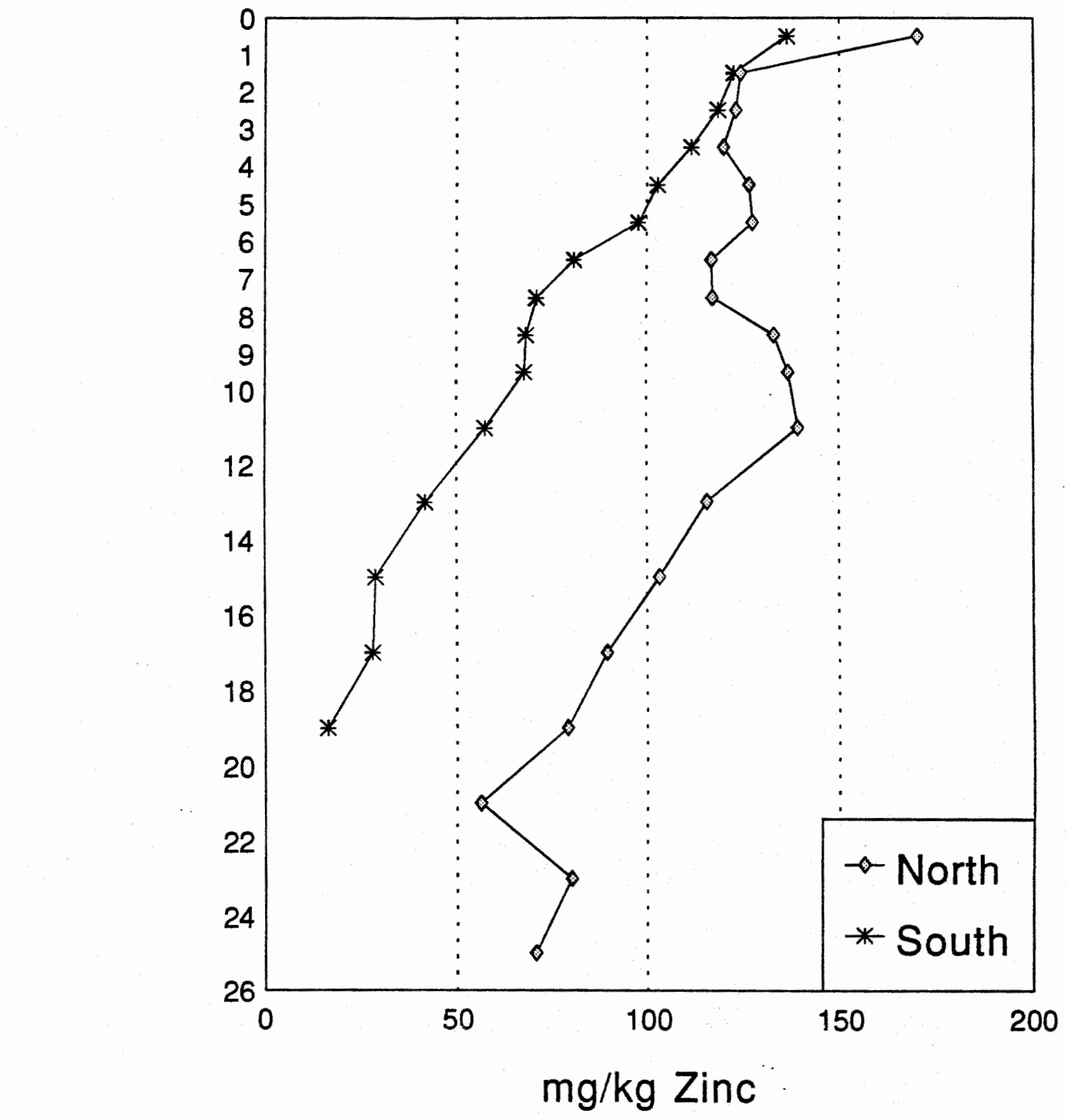


Figure IX-6: Zinc Concetrations in Pawtuckaway Lake Sediments

restorative technique. However, sediment sealing with aluminum as a restorative technique might be a solution for this type of problem.

Most studies show that lake sediments typically contain 1000-2000 mg/kg of recoverable phosphorus. In twenty-seven borderline mesotrophic/eutrophic lakes located in Massachusetts, the mean concentration was 1,268 mg/kg, while concentrations of recoverable sediment phosphorus in 15 New Hampshire lakes ranged from 100 to almost 14,000 mg/kg. Sediment phosphorus concentrations in Lake Washington, Washington State, (Edmondson, 1972) ranged from 1000 to 6000 mg/kg while the range in Lake Shagawa, Minnesota, was 1000-5000 mg/kg (Larson et al.,1975).

The minimum value of sediment phosphorus in the core collected from the North Station at Pawtuckaway Lake was 1292 mg/kg (20-22 cm segment), while the maximum was 1932 mg/kg in the 9-10 cm segment. The range of phosphorus values in the South Station core was much greater, with a minimum value of 66 mg/kg (18-20 cm segment) and a maximum of 1350 mg/kg in the 1-2 cm segment (Table IX-3). The trend of the sediment phosphorus concentration profile from the South Station is similar to its metal profiles, with minimal values in the deepest segment which increased to the surface layer. As Figure IX-7 illustrates, the phosphorus levels in the sediments from the North Station follow a relatively stable trend throughout the profile with the exception of a small decline from the 18-20 cm segment to the 22-24 cm segment (Table IX-23). The higher phosphorus values observed in the North Station reflect the differences in morphometry and bottom substrate composition at each lake station.

The surface sediments from both Pawtuckaway Lake sample stations were similar to the mean phosphorus concentrations of other New Hampshire Lakes and were well within the range (range=982-10,165) of other sediment phosphorus concentrations analyzed in New Hampshire (Table IX-1).

Pawtuckaway Lake Sediment Analyses

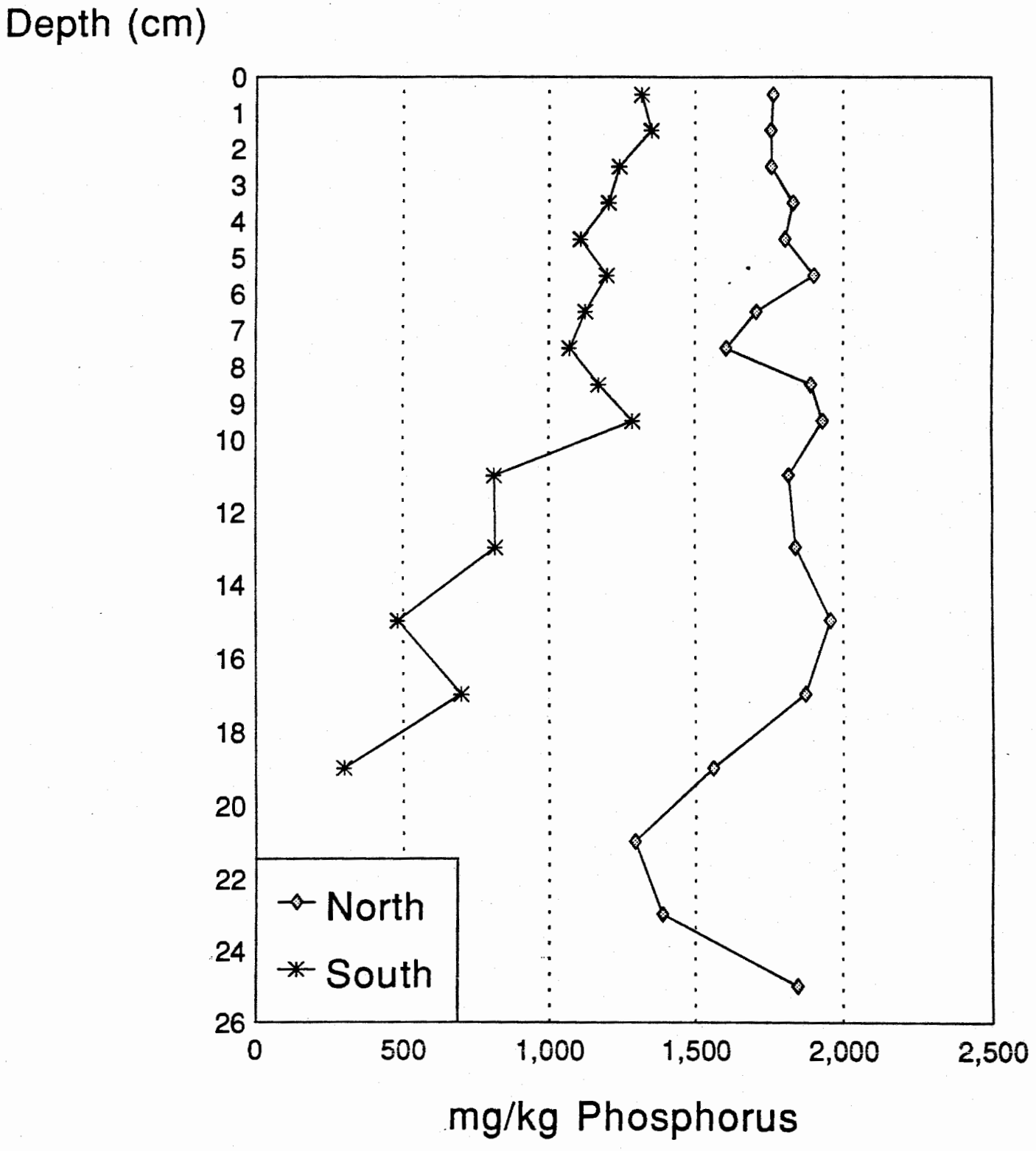


Figure IX-7: Phosphorus Concentrations in Pawtuckaway Lake Sediments

CHAPTER X TROPHIC STATUS AND PERMISSIBLE LOADINGS

A. INTRODUCTION

The trophic status of a waterbody is a hybrid concept. It refers to the nutritive state (especially phosphorus) of a lake or pond, but is often described in terms of the biological activity that occurs as a result of nutrient levels. Trophic state indices have been developed using a single parameter or several parameters.

Table X-1, reproduced in part from the EPA Clean Lakes Program Guidance Manual (1980), describes the lake water characteristics of the oligotrophic and eutrophic states. Mesotrophic conditions exist between the limits for eutrophy and oligotrophy. This chapter will examine several trophic classification and permissible loading schemes.

Table X-1
Summary of Quantitative Definitions of Lake Trophic Status

Characteristics	Oligotrophic	Eutrophic
Total phosphorus (μg/L, summer)	≤ (10 to 15)	≥ (20 to 30)
Chlorophyll-a (μg/L, summer)	≤ (2 to 4)	≥ (6 to 10)
Secchi disk depth (m, summer)	≥ (3 to 5)	≤ (1.5 to 2)

B. TROPHIC CLASSIFICATION SCHEMES

1. State of New Hampshire Trophic Classification System

The classification system developed by the DES Biology Bureau (Table X-2) utilizes four parameters (NHWSPCC, 1981). Table X-3 presents the calculated value of each classified parameter for the 1979 and 1989 surveys as well as the 1991/1992 study year along with the trophic points received and the trophic status.

In 1979, Pawtuckaway Lake received a total of four trophic points and was classified as oligotrophic. Vascular plants were rated as being common, chlorophyll-a was 3.51 µg/L(mg/m^3) and fell within the oligotrophic range. The transparency was also in the oligotrophic range with a depth of 4.0 meters. The bottom dissolved oxygen concentration was 3.5 mg/L at a depth of 8.5 meters.

The system used to trophically classify New Hampshire lakes and ponds was revised in 1989 (Table X-4). The purpose of the revision was to provide for equal points under each attribute and to reduce the impact of the bottom dissolved oxygen criterion. Unlike the previous system, the extent of oxygen depletion is evaluated in the new system.

Pawtuckaway Lake received eight trophic points during the 1989 survey and was classified as mesotrophic. The maximum depth in 1989 was 15.3 meters with anoxic conditions present from the bottom up to 11.0 meters. The two other factors that influenced the change in trophic status from 1979 to 1989 were the increase in chlorophyll-a (5.28 µg/L) and the subsequent reduction in transparency (3.60 meters). Vascular plant abundance remained stable over the ten year period.

The trophic classification system was applied to data collected at both the North and South Stations during the 1991/1992 study year at Pawtuckaway Lake. Mean values from the summer of 1992 were utilized to generate a trophic rating for each station. Although there are significant morphological differences between the North Station (Z max = 15.3 m; stratified), and the South Station (Zmax = 7.0 m; unstratified) during the summer months, both stations received a trophic classification of mesotrophic for the study year.

Table X-2
Trophic Classification System For New Hampshire Lakes and Ponds

1. Summer Bottom Dissolved Oxygen:	Trophic Points
a. D.O. ≥ 5 mg/L	0
b. 2 mg/L ≤ D.O. < 5mg/L & < 30 foot depth	1
c. 2 mg/L ≤ D.O. < 5mg/L & ≥ 30 foot depth	2
d. .5 mg/L ≤ D.O. <2 mg/L & < 30 foot depth	3
e. .5 mg/L ≤ D.O. <2 mg/L & ≥ 30 foot depth	4
f. D.O. < .5 mg/L & <30 foot depth	5
g. D.O. < .5 mg/L & ≥ 30 foot depth	6
2. Summer Secchi Disk Transparency:	**Trophic Points**
a. > 24 feet	0
b. > 12 feet to 24 feet	1
c. > 6 feet to 12 feet	2
d. > 3 feet to 6 feet	3
e. > 1 foot to 3 feet	4
f. > .5 foot to 1 foot	5
g. ≤ .5 foot	6
3. Aquatic Vascular Plant Abundance:	**Trophic Points**
a. Sparse	0
b. Scattered	1
c. Common	2
d. Abundant	3
e. Very Abundant	4
4. Summer Epilimnetic Chlorophyll-a (mg/M^3):	**Trophic Points**
a. Chl a < 5	0
b. 5 ≤ Chl a < 10	1
c. 10 ≤ Chl a < 20	3
d. Chl a ≥ 20	5

	Trophic Points	
Trophic Classification	Stratified	*Unstratified
Oligotrophic	0-5	0-3
Mesotrophic	6-10	4-6
Eutrophic	11-21	7-15

*Unstratified lakes are not evaluated by the bottom dissolved oxygen criterion.

Table X-3
Trophic Classification of Pawtuckaway Lake

Trophic Classification - 1979 Survey		
Parameter	**Value**	**Trophic Points**
Dissolved Oxygen	3.5 mg/L	1
Secchi Disk	4.0 m	1
Plant Abundance	Common	2
Chlorophyll-a	3.51 µg/L	0
Classification : Oligotrophic		Total = 4
Trophic Classification - 1989 Survey		
Parameter	**Value**	**Trophic Points**
Dissolved Oxygen	0.6 mg/L	3
Secchi Disk	3.6 m	2
Plant Abundance	Scattered-Common	2
Chlorophyll-a	5.28 µg/L	1
Classification : Mesotrophic		Total = 8
North Station Trophic Classification - 1991/1992 Study Year		
Parameter	**Value**	**Trophic Points**
Dissolved Oxygen	0.22 mg/L	4
Secchi Disk	4.08 m	2
Plant Abundance	Abundant	5
Chlorophyll-a	4.42 µg/L	1
Classification : Mesotrophic		Total = 12
South Station Trophic Classification - 1991/1992 Study Year		
Parameter	**Value**	**Trophic Points**
Dissolved Oxygen*	-	-
Secchi Disk	4.23 m	2
Plant Abundance	Common	3
Chlorophyll-a	4.42 µg/L	1
Classification : Mesotrophic		Total = 6

*Unstratified lakes are not evaluated by the bottom dissolved oxygen criterion.

Table X-4
Trophic Classification Systems for New Hampshire Lakes and Ponds
Revised 1989

1. Summer Bottom Dissolved Oxygen:	Trophic Points
a. D.O. > 4 mg/L	0
b. D.O. = 1 to 4 mg/L & hypolimnion volume ≤ 10% of lake volume	1
c. D.O. = 1 to 4 mg/L & hypolimnion volume > 10% of lake volume	2
d. D.O. < 1 mg/L in < 1/3 hypo. volume & hypo. volume < 10% lake volume	3
e. D.O. < 1 mg/L in ≥ 1/3 hypo. volume & hypo. volume ≤ 10% lake volume	4
f. D.O. < 1 mg/L in < 1/3 hypo. volume & hypo. volume > 10% lake volume	5
g. D.O. < 1 mg/L in ≥ 1/3 hypo. volume & hypo. volume > 10% lake volume	6
2. Summer Secchi Disk Transparency:	**Trophic Points**
a. > 7 m	0
b. > 5 m - 7 m	1
c. > 3 m - 5 m	2
d. > 2 m - 3 m	3
e. > 1 m - 2 m	4
f. > 0.5 m - 1 m	5
g. ≤ 0.5 m	6
3. Aquatic Vascular Plant Abundance:	**Trophic Points**
a. Sparse	0
b. Scattered	1
c. Scattered/Common	2
d. Common	3
e. Common/Abundant	4
f. Abundant	5
g. Very Abundant	6
4. Summer Epilimnetic Chlorophyll-a (mg/M^3):	**Trophic Points**
a. < 4	0
b. 4 - < 8	1
c. 8 - < 12	2
d. 12 - < 18	3
e. 18 - < 24	4
f. 24 - < 32	5
g. ≥ 32	6

	Trophic Points	
Trophic Classification	Stratified	*Unstratified
Oligotrophic	0-6	0-4
Mesotrophic	7-12	5-9
Eutrophic	13-24	10-18

*Lakes without hypolimnions are not evaluated by the bottom dissolved oxygen criterion.

2. Carlson's Trophic Index

Carlson's (1977) TSI system is based on Secchi depth as a means of characterizing algal biomass. This parameter, in the absence of turbidity and colored materials in water, is a direct measure of "plankton-algal manifested eutrophication processes" in natural waters. Its range of values can easily be transformed into a convenient scale. Further, by using empirically derived relationships between Secchi depth and both phosphorus and chlorophyll-a concentration, Carlson derived equations to estimate the same index value from these two parameters as well as from Secchi depth. Carlson's trophic index is basically a linear transformation of Secchi depth, such that each 10 unit increase in his TSI scale represents a halfing of the Secchi visibility. Conversely, for total phosphorus each 10 unit increase represents a doubling in phosphorus concentrations. The computational form of the equations for his trophic scheme is as follows:

$$\text{TSI (SD)} = 10\left(6 - \frac{\ln \text{SD}}{\ln 2}\right)$$

$$\text{TSI (Chl)} = 10\left(6 - \frac{2.04 - 0.68 \ln \text{Chl}}{\ln 2}\right)$$

$$\text{TSI (TP)} = 10\left(6 - \frac{\ln \frac{48}{\text{Tp}}}{\ln 2}\right)$$

Where:

SD = Secchi depth
TP = Total phosphorus concentration
Chl = chlorophyll-a concentration

According to Carlson (1977), this index system has the advantages of easily obtained data, simplicity, absolute TSI values, valid relationships, retrieval of data from the index, and can be grasped by the layman in much the same manner as the Richter earthquake scale. The TSI

incorporates most lakes in a scale of 0 to 100 as Figure X-1 demonstrates. Each major division (10, 20, 30, etc.) represent a doubling of phosphorus and about a 2.8 increase in algal biomass.

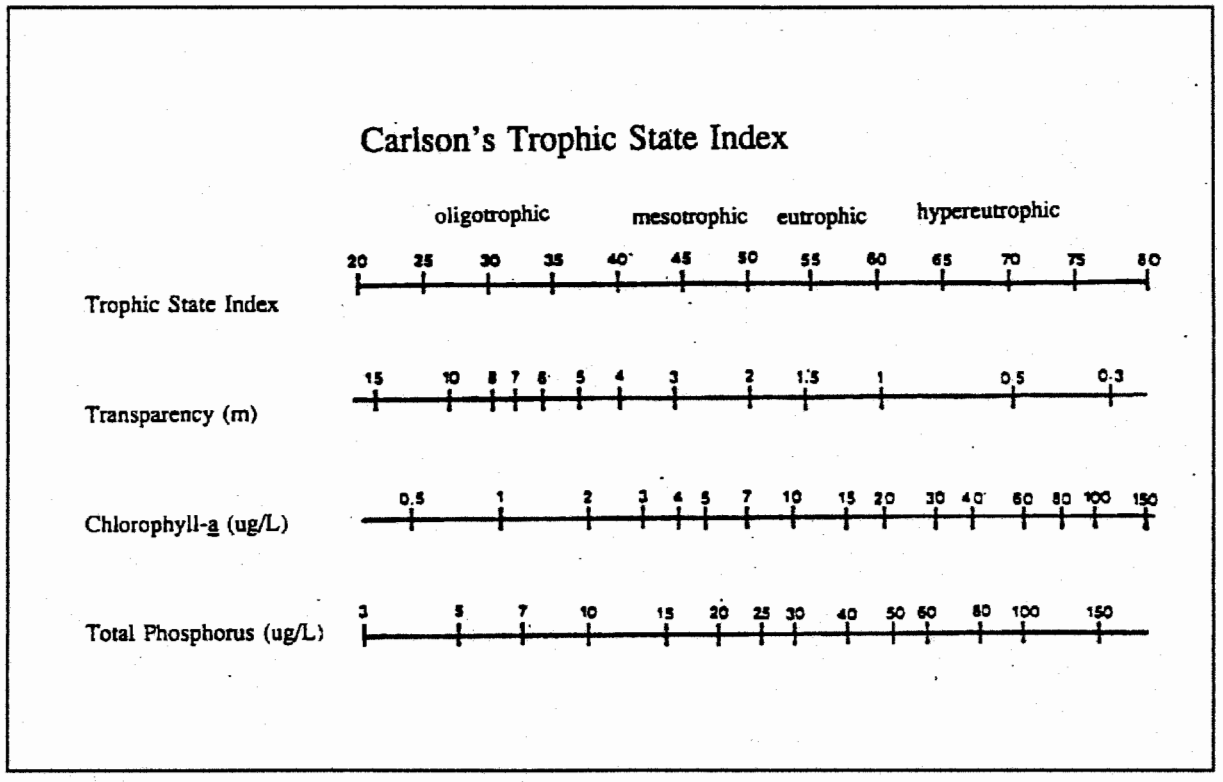
Results of the Carlson TSI were obtained by substituting summer mean Secchi depth, chlorophyll-a, and phosphorus values from the North and South stations of Pawtuckaway Lake into the equations to compute the TSI. Table X-5 shows the mean summer values, the TSI number and the classification for each measured parameter. The chlorophyll-a values observed at the North and South Stations of Pawtuckaway Lake reflected intermediate concentrations that are typical of mesotrophic waterbodies. Mean Secchi disk depths were also indicative of mesotrophic conditions at both lake stations. Mean summer phosphorus concentrations from the epilimnion and hypolimnion of the North Station reflected mesotrophic conditions throughout the water column.

Table X-5
Carlson Trophic Classification for the North and South Stations at Pawtuckaway Lake

NORTH STATION			
Parameter	**Mean Summer Value**	**Trophic Points**	**Classification**
Chlorophyll-a (µg/L)	4.42	45	Mesotrophic
Secchi Disk (m)	4.08	40	Mesotrophic
Epilimnetic Phosphorus (µg/L)	11.50	39	Mesotrophic
Hypolimnetic Phosphorus (µg/L)	17.00	45	Mesotrophic
SOUTH STATION			
Parameter	**Mean Summer Value**	**Trophic Points**	**Classification**
Chlorophyll-a (µg/L)	4.42	45	Mesotrophic
Secchi Disk (m)	4.23	39	Mesotrophic
Epilimnetic Phosphorus (µg/L)	9.30	37	Oligotrophic
Hypolimnetic Phosphorus (µg/L)	16.00	45	Mesotrophic

The mean phosphorus concentrations in the epilimnion of the South Station were indicative of oligotrophic conditions during the summer of 1992. Phosphorus concentrations in the lower layer of the South Station fell within the mesotrophic parameters and were similar to those values found in the hypolimnion at the North Station.

Figure X-1
Carlson's Trophic State Index



3. Dillon/Rigler Permissible Loading Model

Mathematical models can also be useful both in diagnosing lake problems and evaluating potential solutions. They represent in quantitative terms the cause-effect relationships that determine lake quality. In some cases, the determination of the trophic state of a lake involves a comparison of actual phosphorus loading to the lake with a maximum permissible loading that the lake can tolerate before excessive weed and algae growth occurs and transparency diminishes. The trophic model developed by Dillon/Rigler (1974) has been widely utilized and well documented by researchers. Its application classifies a lake as oligotrophic, mesotrophic or eutrophic by comparing calculated annual loadings with permissible annual loadings. The tolerance of the lake to phosphorus loading is predicted as a function of two morphological parameters, mean depth (z) and water retention time (T), which have been proven by several researchers to be the primary determinants of loading permissibility. Additionally, the model considers the phosphorus retention

in the lake sediments. The retention coefficient (R) may be empirically calculated from morphological data or may be derived from a definitive phosphorus budget.

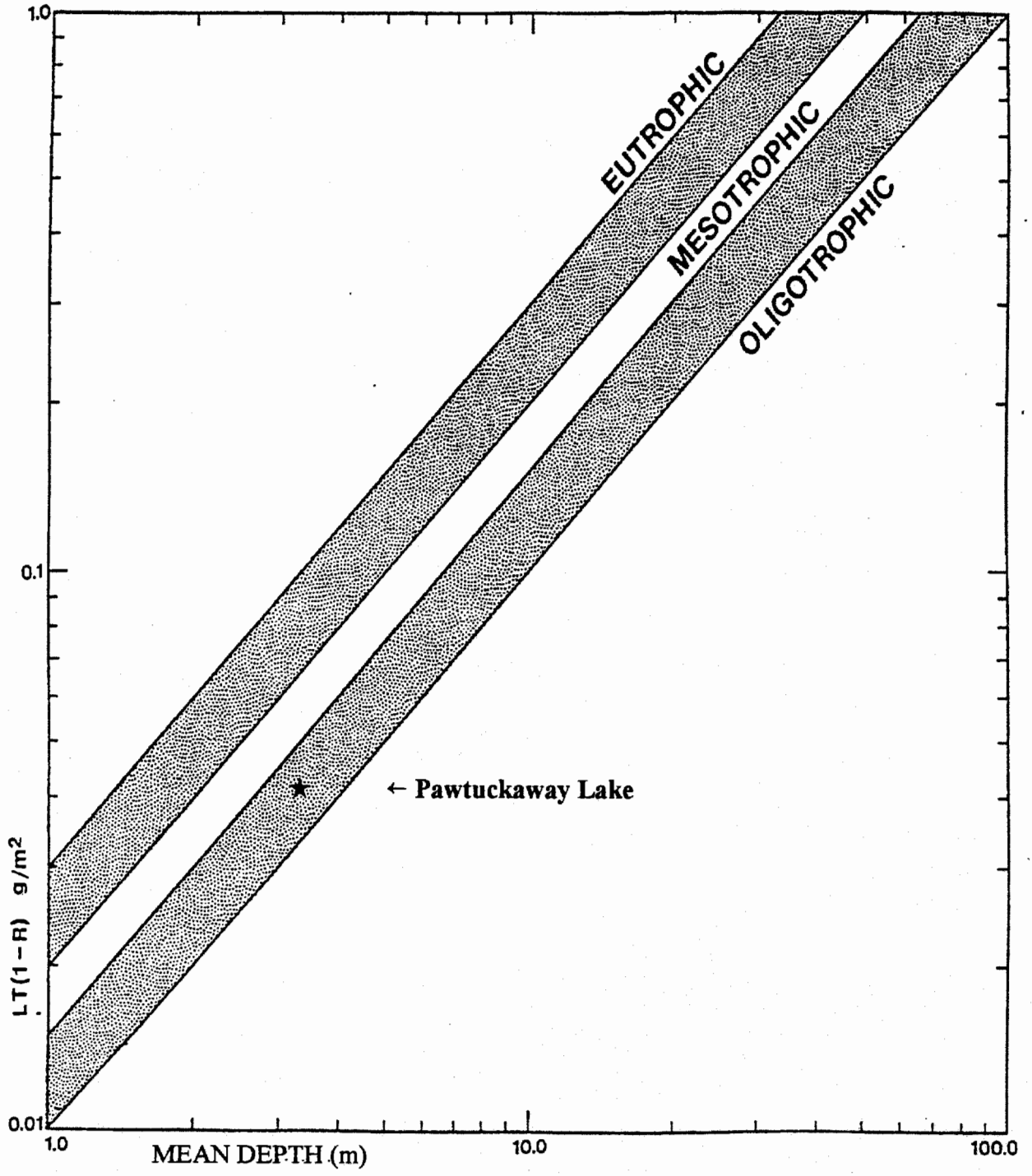
Table X-6 shows the qualitative relationship between the model input parameters and phosphorus loading tolerance.

Table X-6
Dillon/Rigler Permissible Loading Tolerance

High Phosphorus Loading Tolerance	Low Phosphorus Loading Tolerance
Large mean water depth	Small mean water depth
Rapid flushing rate	Slow flushing rate
High sediment retention	Low sediment retention

Thus, existing trophic status is set by existing values for these parameters and annual phosphorus loading. Similarly, historical trophic status can be determined from estimates of previous phosphorus loading. The degree of trophic state improvement, which would result from the implementation of watershed and in-lake management strategies, can be gauged from predicted changes of loading and morphology. Table X-7 presents the Dillon/Rigler trophic status calculations for Pawtuckaway Lake. Figure X-2 is a graphical representation of the Dillon/Rigler model showing trophic zones, plotted on axes of mean depth and areal loading (Table X-7) with the data point for the Pawtuckaway Lake study year. The solution of the Dillon/Rigler equation for Pawtuckaway Lake data (unaltered morphology) shows the existing oligotrophic/mesotrophic boundary to exist between 796 and 1189 $kgPyr^{-1}$ and the mesotrophic/eutrophic boundary to exist between 1544 and 2340 $kgPyr^{-1}$. These boundaries for loadings are based on a mean depth (z) of 3.3 m, a water retention time (T) of 0.59 yr and a phosphorus retention coefficient (R), derived from the phosphorus budget, of 0.66. The actual budgeted phosphorus loading for the study year at Pawtuckaway Lake was 992 $kgPyr^{-1}$, which classifies the lake as borderline oligotropic/mesotrophic. The model predicted that Pawtuckaway Lake received 998 $kgPyr^{-1}$. The Dillon/Rigler model demonstrates that an increased load of 546 $kgPyr^{-1}$ would decrease the lake quality enough to place Pawtuckaway at the mesotrophic/eutrophic borderline. It would take an increase of 1342 $kgPyr^{-1}$ to place Pawtuckaway Lake into the eutrophic lake classification.

FIGURE X-2
DILLON/RIGLER TROPHIC STATUS FOR PAWTUCKAWAY LAKE



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

Table X-7
Dillon/Rigler Trophic Status Calculations

Parameter	Calculation
Lake area (m^2)	4775290.6
Mean z (m)	3.3
Total loading (kg)	992
Flushing rate (yr^{-1})	1.7
Water retention time (yr) T	0.59
P coefficient R	0.66
Total areal loading ($g/m^2/yr$) Lp	0.21
LT (1-R) (g/m^2)	0.04

The Dillon/Rigler model also predicts in-lake phosphorus concentration. Utilizing the Dillon/Rigler equation P=Lp(1-R)/qs, the calculated predicted in-lake phosphorus concentration for Pawtuckaway Lake was 0.013 mg/L. This predicted value is lower than actual study year mean hypolimnetic phosphorus concentration of 0.017 mg/L and slightly higher than the study year mean epilimnetic phosphorus concentration of 0.012 mg/L. The actual mean epilimnetic phosphorus concentration was calculated from the summer phosphorus data collected by the Biology Bureau during the 1991 sample year.

4. Vollenweider Phosphorus Loading and Surface Overflow Rate Relationship

The Vollenweider model is based on a five year study involving the examination of phosphorus load and response characteristics for about 200 waterbodies in 22 countries in Western Europe, North America, Japan and Australia. Vollenweider, working on the Organization for Economic Cooperation and Development (OECD) Eutrophication Study, developed a model describing the relationship of phosphorus load and the relative general acceptability of the water for recreational use (Vollenweider, 1975). Vollenweider found that when the annual phosphorus load to a lake is plotted as a function of the quotient of the mean depth and hydraulic residence time,

lakes which were eutrophic tended to cluster in one area and oligotrophic lakes in another (Figure X-3, from Flanders, 1986 and Connor, et al. 1994).

Vollenweider developed a statistical relationship between areal annual phosphorus loading (Lp) to a lake normalized by mean depth (Z) and hydraulic residence time (T), to predict phosphorus lake concentration (P). Table X-8 summarizes the Vollenweider model parameters for the Pawtuckaway Lake sample year.

Table X-8
Vollenweider Phosphorus Concentration Prediction

Parameter	Equation	Pawtuckaway Lake
1. Hydraulic residence time (T)	$T=\frac{V}{Q}$	0.59 yr
2. Surface overflow rate (qs)	$qs=\frac{z}{T}$	5.59 (m/y)
3. Areal phosphorus load (Lp)	$Lp=\frac{P\ load}{lake\ surface\ area}$	0.21 ($g/m^2/y$)
4. Mean depth (Z)	measured	3.3 (m)
5. Phosphorus concentration prediction (P)	$P = \frac{Lp}{qs}\left[\frac{1}{1+\sqrt{\frac{z}{qs}}}\right]$	0.021 (mg/L)

Thus, based on the physical constraints that control water volume, the hydraulic residence time in the lake, and mean lake depth, combined with phosphorus loading, the Vollenweider model predicts the existing in-lake phosphorus concentration to be 0.021 mg/L in Pawtuckaway Lake. An examination of actual mean epilimnetic in-lake phosphorus concentrations during the 1991 summer study period, revealed that the mean measured phosphorus concentration of 0.012 mg/L was lower than the predicted value of 0.021 mg/L. However, the predicted phosphorus value compared more favorable with the mean summer hypolimnetic phosphorus value of 0.017 mg/L.

Figure X-3
OECD DATA / VOLLENWEIDER PLOT

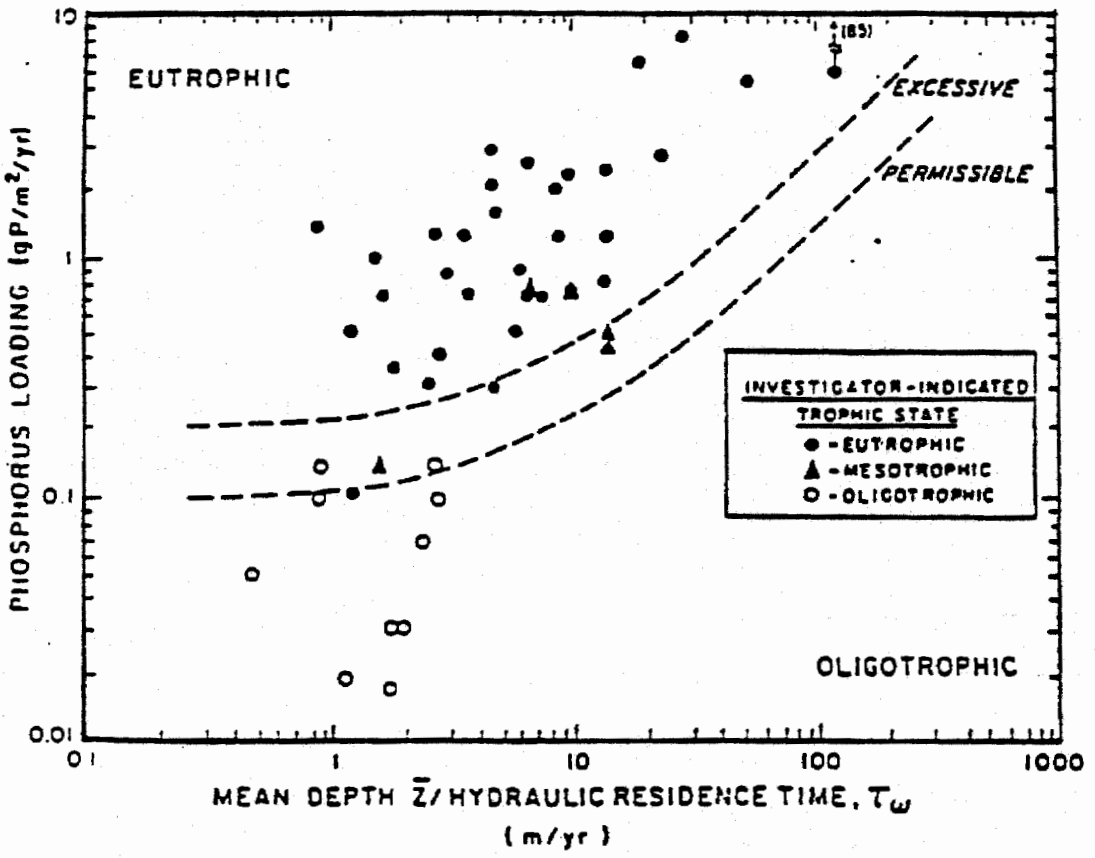


Figure X-4 graphically portrays the measured loading rates for Pawtuckaway Lake and compares the lake with other studied lakes in New Hampshire. Based on the permissible and excessive loading curves, it can be seen that Pawtuckaway Lake lies in the mesotrophic zone, in the vicinity of the moderate loading range.

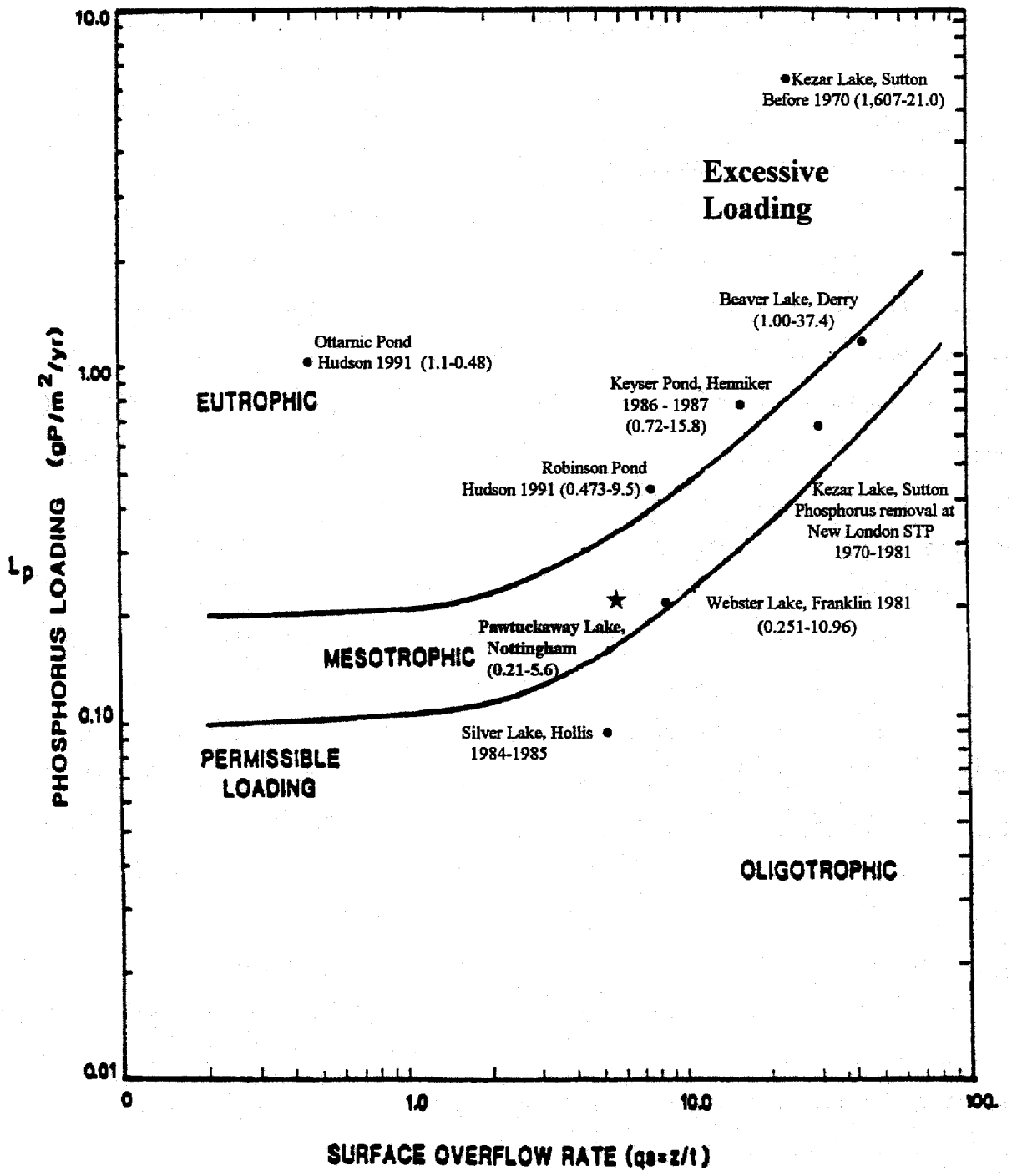
C. TROPHIC CLASSIFICATION SUMMARY

A summary of the four classification schemes utilized in this study (Table X-9) shows that the New Hampshire Lake classification system classifies Pawtuckaway Lake as mesotrophic. The Vollenweider Phosphorus Loading model classifies Pawtuckaway Lake as mesotrophic while the Dillon/Rigler model classifies the lake as a borderline oligotrophic/mesotrophic lake. The Carlson Trophic Status Index defines a trophic class for several parameters. Secchi disk transparency and epilimnetic phosphorus measurements in Pawtuckaway Lake fell into the upper mesotrophic range while chlorophyll-a and hypolimnetic phosphorus concentration fell into the mesotrophic range. On a permissible loading basis, the Dillion/Rigler model demonstrated that it would take an increased load of 546 $kgPyr^{-1}$ to decrease the lake quality enough to reflect characteristics of borderline mesotrophic/eutrophic conditions.

Table X-9
Pawtuckaway Lake Trophic Classification Summary

Classification Model	Trophic Classification
1. New Hampshire Lake Classification	Mesotrophic
2. Carlson's TSI	
Chlorophyll-a	Mesotrophic
Secchi Disk	Mesotrophic
Phosphorus (Epilimnion)	Mesotrophic
Phosphorus (Hypolimnion)	Mesotrophic
3. Dillon/Rigler	Oligotrophic/Mesotrophic
4. Vollenweider	Mesotrophic

Figure X-4
VOLLENWEIDER PHOSPHORUS LOADING AND SURFACE OVERFLOW RATE RELATIONSHIP



D. PREDICTING THE CAPACITY OF A LAKE FOR DEVELOPMENT

New Hampshire has experienced significant growth and development in the last two decades and is likely to continue to see such growth into the 1990's. This growth has greatly increased pressures on one of the very features that has attracted people to the state -- the lakes. While new development, both year-round and seasonal, and conversion/expansion of existing development allow more people to enjoy these resources, it also can threaten the quality of a lake environment.

A predictive computer model has been utilized to aid in quantifying the environmental impacts of development on a lake. This model, which measures the phosphorus loading to a lake resulting from the surrounding development, predicts the capacity of the lake for seasonal and/or permanent development that will not threaten existing lake quality. Utilizing available data on the particular lake of interest and relying on several conservative assumptions about phosphorus impacts from certain kinds of development, the model presents the results in the form of a maximum number of allowable units of development around the lake. This number is intended as a guide for local officials in evaluating the impacts of proposed development on lakes.

Phosphorus (P) is the nutrient most frequently controlling lake productivity and, therefore, trophic status in New Hampshire lakes. Therefore, predictions concerning the impact of development on the phosphorus concentration of a lake, and subsequently on parameters describing the trophic state, are central to a predictive management scheme. From the geology and land use considerations of a lake's drainage basin, it is possible to estimate the total phosphorus exported or washed out per unit area of watershed. When combined with the drainage area, this provides an estimate of the total phosphorus supplied to the lake from the land. The addition of phosphorus input from direct lake precipitation determines the natural phosphorus load to the lake. Existing development -- both year-round and seasonal -- is then measured (tax maps or field counts with the assistance of local officials), and the phosphorus loading from artificial sources is calculated with the assistance of certain coefficients and conservative assumptions. The total P loading, natural plus artificial, may then be combined with the lake morphometry (general physical characteristics -- size, depth, etc.) and water budget to predict a phosphorus concentration that is subsequently related to the average summer chlorophyll-a concentration. Chlorophyll-a is an indication of the planktonic algal biomass in the lake and is directly proportional to the phosphorus inputs. From the chlorophyll calculation one can calculate the lake clarity or Secchi disk transparency. Finally, the maximum

permissible artificial loading that will not lower lake quality in terms of chlorophyll-a or water clarity can be estimated. This maximum is expressed as the maximum of allowable development units (i.e., number of cottages).

This model is designed to predict the capacity of a lake for development without utilizing actual water quality data. In the case of Pawtuckaway Lake, actual watershed phosphorus loading has been calculated and input into the capacity model.

Table X-10 designates the capacity model data inputs. The model takes under consideration just those dwellings around the first tier of the lake. The model also considers loadings from Deer Pond and Round Pond which are both within the Pawtuckaway watershed.

Table X-11 presents the model results using two different chlorophyll-a criteria. A chlorophyll-a criterion of 5 mg/m^3 was chosen for the first model because it represents the mean productivity levels that presently occur in Pawtuckaway Lake. The lake productivity at this level of chlorophyll is considered by lake managers and New Hampshire recreationists to be acceptable for any water related activities. Transparency is often above four meters and algae blooms are usually not a problem.

The chlorophyll-a criteria of 5 mg/m^3 shows that Pawtuckaway Lake is currently balanced, with its total phosphorus supply (loading) approximating its permissible phosphorus supply. The model predicts that if the total supply of phosphorus to the lake is increased above its morphological permissible limits, water quality will suffer. The model suggests that in order to keep the total phosphorus supply in balance with the permissible supply, either additional watershed reduction must occur or further development around the Pawtuckaway shoreline must be precluded.

The model also predicted the amount of development that could occur if productivity was allowed to increase. A chlorophyll criteria of 6.0 mg/m^3 was chosen to estimate the amount of development that could occur within this chlorophyll range. Each of the stakeholders in the lake, including DRED, the PLIA and the Town, should realize that increasing productivity will lead to decreased recreational aesthetics. The model predicts that an additional 229 capita-years per year or (57 year-round homes or a combination of seasonal and year-round homes that equal 229 capita-years per year) can be achieved within the 6.0 mg/m^3 concentration boundary.

The ultimate goal of a lake manager is to balance the lake productivity to meet the needs of the lake user. This is a difficult job because different user groups have different goals and user conflicts often arise. The lakeshore property owner may enjoy a clear umproductive lake while the

Table X-10
Predicting the Capacity of a Lake for Development

MORPHOLOGY	Lake 1	Lake 2	Lake 3
	Pawtuckaway	Deer	Round
Surface area (m2):	4775291	121400	44500
Mean Depth (m):	3.3	0.8	3.7
Volume (m3):	15812628	94000	138000
Drainage Area (m2):	47959295	1031000	1373000
Direct Drainage A:	45555295	1031000	1373000
Flushing Rate:	1.70	5.20	4.80
Phosphorus retention coefficient	0.66	0.70	0.49
Present Development (dwellings)			
Year-round Homes:	143	0	0
Seasonal Homes:	121	0	0
Weekend Camps:	36	0	0
Campgrounds:	0	0	0
Present Development (capita-yrs/yr)			
Year-round Homes:	572	0	0
Seasonal Homes:	121	0	0
Weekend Camps:	10	0	0
Campgrounds:	0	0	0
TOTAL CAPITA YEARS/YR	703	0	0
Selected Export Coefficients			
Natural:	13.04	1.00	2.00
Residential:	0.75	0.01	0.01
Sub-Watershed Supply (kg/yr)			
Natural:	952.2	10.1	6.1
Residential:	527.3	0	0
Total:	1479.5	10.1	6.1
Downstream:	503	3	3.1

fishermen knows that high productivity means larger fish. However, decreasing nonpoint sources of phosphorus to the lake is the key issue in lake protection. Managers must balance human activities, such as logging, construction and land-use conversions, through watershed management techniques. These techniques offer best management practices that reduce phosphorus, runoff and the movement of unstabilized soils to the lake or its tributaries.

We all have to realize that towns usually don't favor moratoriums on developments even around a sensitive lake. Therefore, all stakeholders must work together to manage the surrounding watershed with the goal of protecting the waterbody that lies below.

Table X-11
Predicting the Capacity of a Lake for Development

Supply (kg/yr)	Chlorophyll-a criteria=5.0	Chlorophyll-a criteria=6.0
Natural	958.3	958.3
Artificial	527.3	527.3
Total	1485.6	1485.6
Permissible	1461.3	1657.1
Development (capita-yrs/yr)	**Total Supply>Permissible**	**Total Supply<Permissible**
Present	703.1	703.1
Permissible		931.7
Additional	Allow no further development	228.6
Homes	0	57

CHAPTER XI. FEASIBILITY OF RESTORATIVE ACTIONS

A. OVERVIEW

The subject of lake restoration and lake protection has been debated and researched extensively in the past decade. Although the need to do something about our degraded lakes is beyond dispute, the science of lake restoration is still in its infancy. Often, a judgement must be made about feasible limits of expenditure and effort without the reassurance of a solid basis for predicting results.

Once a project for lake restoration is undertaken, the results of this effort must be carefully monitored, evaluated and recorded. Although lakes differ biologically, chemically, and physically, so that one method may bring gratifying results in one lake and not in another, permanent lake rehabilitation begins with halting the introduction of undesirable substances.

Most successful lake restoration projects are easily appreciated by people familiar with the "before". A lake restored to health and beauty is an irresistibly exhilarating sight.

The previous sections of this report constitute a diagnostic study of Pawtuckaway Lake and its watershed. They describe the water quality problems and the sources and levels of the nutrients causing those problems. This section deals with the feasibility of implementing a variety of techniques to help reduce the problems that do exist and to protect the lake in the future.

The authors stress that Pawtuckaway Lake does not have a serious water quality problem at this point. In fact, lake modeling results, presented in chapter 10, predicted that Pawtuckaway Lake is a borderline oligotrophic/mesotrophic lake. This report will recommend no in-lake restoration techniques but will focus on lake protection through watershed management. The use of Best Management Practices (BMPs) have provided limnologists with new methodologies to protect the lake. This new technology reduces pollutants to the lake via watershed runoff. Although watershed management is stressed, popular lake restoration techniques will be included in this chapter for reference.

Techniques that are available for lake restoration and protection are commonly grouped into two basic types: those that attack the cause of the problem and those that attempt to mitigate the effects of the problem. While both approaches may sometimes have to be utilized, those that attack the cause of the problem are the only long-term solutions.

B. PROBLEM TREATMENT

1. Algaecide Treatment

The use of the algaecide copper sulfate in New Hampshire lakes was once quite common in relieving dense phytoplankton blooms. Although the method does not reverse the lake's eutrophication trend, it temporarily alleviates nuisance algal blooms and provides an acceptable recreational season. In recent years, the use of copper sulfate as an algaecide has been limited, for the most part, to the treatment of municipal water supplies.

Historically, Pawtuckaway Lake has shown signs of stress. Summer hypolimnetic oxygen depletion and moderate productivity reveal to the limnologist that problems exist. Generally, Pawtuckaway Lake does not exhibit large algae blooms, low transparency, unsightly surface scums, obnoxious odors or poor aesthetic conditions.

Although application of copper sulfate is no longer widely used to reduce algae blooms in recreational ponds, copper sulfate is utilized as a pre-treatment for other restoration techniques.

If copper were to be utilized for pre-treatment of Pawtuckaway Lake, the effective calculated chemical dosage would be approximately 2000 pounds. The price of copper sulfate may vary, but a reasonable current price for copper sulfate is approximately $0.70 per pound. At these prices, one could expect the chemical cost of treating to be in the $2100 range. The labor for this application would require four field persons working eight hours at approximately $50.00 per hour or $1600.00. Adding the costs of permit applications, equipment and travel costs of those individuals treating the pond, the total cost to apply copper sulfate to Pawtuckaway Lake would probably be in the $5,000 to $5,500 range or approximately $25.00/ha. Cooke et al. (1993) has calculated costs for using $CuSO_4$ crystals in several California lakes and found a range of $96 - $578/ha.

Although copper can be a highly effective algaecide, the effects are always temporary (days), annual costs can be high, there are major negative impacts on nontarget organisms, and sediment copper contamination is possible.

2. Artificial Circulation

Artificial circulation and hypolimnetic aeration are management techniques for oxygenating lakes subject to water quality problems such as algal blooms and fishkills. Artificial circulation is achieved by injecting diffused air into the lower waters, by mechanically pumping water from one depth stratum to another, or by inducing turbulence at the surface using large axial-flow pumps. Complete mixing leads to homogenous conditions throughout the water column (Pastorak, et al., 1981).

Circulation, theoretically, can result in reduced phytoplankton biomass. The principal cause is light limitation, brought about by providing greater depth of mixing. Limitation occurs by mixing plankton cells deep enough in the water column so that the total light received while in the shallower photic zone is insufficient for net photosynthesis. Using data from Kezar Lake, Lorenzen and Fast (1977) showed that by increasing the depth of mixing, the lake can potentially be returned to a winter condition when light is limiting.

Whole lake mixing may reduce regeneration of nutrients from profundal sediments, which may control blooms of blue-green algae. The elevation of epilimnetic CO_2 by destratification often causes a reduction in pH sufficient enough to shift algal communities from nuisance blue-green species to a mixed assemblage of green algae. While hypolimnetic treatment usually decreases phosphorus concentration in the bottom waters, the long term effects on internal loading of nutrients is unknown.

The New Hampshire Water Supply and Pollution Control Commission (NHWSPCC) installed and operated an artificial aeration system within Kezar Lake from July 1968 through August of 1974. The selected destratification system forced compressed air from four shore-located compressors through two-inch I.D., P.V.C. plastic piping to a terminal series of ceramic diffusers located on the bottom at the deepest point in the lake (8.0 meters) (Towne, 1970). Towne reported that Kezar Lake's visibility improved from one foot (0.3 m) to four feet (1.2 m), hypolimnetic

dissolved oxygen increased, temperature increased, total plankton numbers declined, and blue-green algae populations declined. Destratification was therefore declared a success in its first season of operation. Destratification continued to operate successfully through the 1971 sampling season. However, the effectiveness of the destratification process was considered somewhat less successful during the 1972 summer season.

In 1974, Kezar Lake once again experienced a bloom of the blue-green alga Aphanizomenon, despite ongoing destratification processes. The Aphanizomenon bloom lasted nine weeks, increasing chlorophyll-a concentrations to over 100 mg/m^3, increasing cell counts to over 500,000 cells mL^{-1}, and decreasing transparency to 0.5 m.

By the end of the 1974 season, destratification was deemed by the biological investigators as no longer effective for improving water quality and transparency in Kezar Lake. Biologists speculated the blue-green algae had somehow adapted to the annual lake circulations, enabling them once again to aesthetically reduce the lake's recreational value.

Kezar Lake was destratified for seven consecutive summer seasons, at a cost of $27,000. This treatment procedure was instituted as a temporary measure to control the phytoplankton blooms until phosphorus removal facilities (tertiary treatment) could be constructed at the New London sewage treatment plant. It provided a limited relief for the first few years, but almost no effect on controlling the phytoplankton blooms the last two years of operation (NHWSPCC Staff Report No. 79, 1975).

In other applications of the technique, highly variable results from case to case have occurred. In most instances, problems with low dissolved oxygen have been solved. In about half the cases, and where very small temperature differences from top to bottom have been maintained all summer, algal blooms were reduced (Pastorak et al., 1981; Cooke et al., 1986). In other cases, phosphorus and turbidity have increased and transparency decreased.

Failure to achieve the desired objective is often due to an underpowered air compressor. Lorenzen and Fast (1977) concluded that there must be less than 2-3 °C difference from top to bottom of the lake in order to achieve improvement in algal biomass. This requires an air flow of at least 30 ft^3 of air per thousand ft^2 (2.3 acres) of lake surface.

Artificial circulation has been recommended as an inexpensive, efficient restoration technique (Pastorak et al., 1981). Cost information on a project basis is scarce. The estimated annual cost to implement artificial circulation at Pawtuckaway Lake for two air compressors

producing an air flow rate of 1200 CFM at standard conditions is 146,000 (1990 dollars). At the recommended rate of 9.2 m3/min/Km2, this represents a cost of $390/ha (for the first year of operation). Median values for initial and annual costs, respectively, were $718 and $320/ha (1990 dollars). Davis (1980) presented costs for a compressor, pipe, and 1-year operation of $41,000 or about $340/ha, including installation.

3. Hypolimnetic Aeration

Depletion of oxygen in the hypolimnion of eutrophic lakes is one of the first signs of eutrophication. If enrichment becomes sufficient to exhaust all or a substantial portion of the hypolimnetic oxygen reserve before autumn destratification occurs, anoxia will result. Anoxia can produce several undesirable changes in lake quality, including accelerated internal recycling of nutrients, solubilization of metals and limitation of fisheries, especially coldwater species.

Hypolimnetic aeration is different than artificial circulation in objective and operation. Artificial circulation employs a curtain of bubbles to achieve complete mixing and isothermal conditions, while hypolimnetic aeration employs an airlift device to elevate cold hypolimnetic water to the surface of deep lakes. The water is aerated by atmospheric contact while carbon dioxide and methane are dispelled, and then the water is returned to the hypolimnion. Destratification is not achieved during this procedure (Olem and Flock, 1990). The objectives of hypolimnetic aeration are threefold:

- to raise the oxygen content of the hypolimnion,
- to provide an increased habitat and food supply for coldwater fish species, and
- to decrease the internal P load by establishing aerobic conditions at the sediment-water interface (Cooke et al., 1986).

There is, however, little documentation of its successful use to control nuisance algal blooms. Negative effects which have been observed are as follows:

- little increase in hypolimnetic dissolved oxygen if aerator is undersized,
- metalimnion oxygen depletion preventing the successful establishment of a cold water fishery, and
- aerators may partially destratify shallow lakes producing severe algal blooms.

Aqua Technique has reported the installation and operating costs for seven partial air-lift

projects (Cooke et.al., 1993). At a power rate of $0.09/kw/h, the average operating cost/Kg 0_2/d was 0.072 ± $0.026 (or 0.8 Kwh/Kg 0_2), and the average installed cost/d/Kg 0_2 was 457 ± $280 (1990 dollars). When the latter value is divided by 180d, the cost becomes $2.50/Kg 0_2, which is probably the most useful cost indicator for hypolimnetic aeration since success depends on satisfying an oxygen demand. Not included in this cost would be electrical trenching and a small building to house the compressor. The estimated cost to operate the system would be $10 to $15 per day.

C. CAUSE TREATMENT

Phosphorus is the plant nutrient in New England lakes that most often determines the level of plankton growth. By reducing the phosphorus levels, the cause of the algal problems is attacked. The following methodologies describe ways to reduce the phosphorus levels currently in the lake and entering the lake, and to prevent increases in phosphorus discharged to the lake from future watershed development. These techniques involve both in-lake and watershed controls.

1. Sediment Removal

Dredging of organic lake-bottom sediments is generally implemented for the following purposes (Peterson, 1981): (1) deepening for improved recreational (boating) usage, (2) removal of eutrophying nutrients, (3) removal of toxic substances and, (4) removal and growth reduction of rooted macrophytes. Currently, Pawtuckaway Lake has adequate depth for boating and there have been no known discharges of potentially toxic material entering the lake. Macrophyte weed growth is scattered and is considered a nuisance in only a few shallow, wetland cove locations. Therefore, the only potential benefit of dredging the lake would be the removal of nutrients which may be subject to release from the sediments. As discussed previously, Pawtuckaway Lake, like most waterbodies, acts as a net phosphorus sink on an annual basis (i.e., more phosphorus is deposited in the sediments from the lake water than is released by the sediments to the lake water). However, removal of phosphorus-enriched sediments could, conditions warranting, further retard the release of sediment phosphorus, thereby resulting in a greater net annual deposition of phosphorus. Additionally, dredging could increase the mean depth of the pond which might permit a greater

tolerance to phosphorus loading as depicted by the Dillon/Rigler trophic model.

Unfortunately, adverse sediment characteristics and the physical limitations of standard dredges would severely limit the effectiveness of dredging to improve the trophic status of Pawtuckaway Lake. There are two major techniques for sediment removal. Lake drawdown, followed by bulldozer and scraper excavation, has limited application. This technique is usually limited to small basins because these areas must be drained before sediment removal is initiated.

The most common sediment removal technique uses a dredge. Dredges are classified as either mechanical or hydraulic (or special purpose).

The mechanical clamshell bucket dredges are limited to a reach of 30 to 40 m, they leave a rough, uneven bottom, and create turbid water conditions. The advantages include their easy transport and they are not readily impeded by stumps and trash.

There are many variations of hydraulic dredges, including the suction dredge, the hopper, the dustpan, and the cutter-head dredge. A major advantage of hydraulic cutter suction dredges over bucket types is that they are not confined in operation by limitation of cable reaches. The operating procedure permits hydraulic dredges to produce large volumes of dredged material. However, as a result, relatively large disposal areas, with adequate residence times, must be designed to precipitate solids from the dredge slurry.

The depth to which a standard hydraulic dredge can operate is 15 feet below the lake surface, which would exclude the entire hypolimnetic bottom area of Pawtuckaway Lake. However, advances in hydraulic dredging technology in the last decade has produced more effective cutter bars capable of removing sediment quicker and at deeper depths. The sediment core analyses (Chapter IX) revealed that there was no significant decrease in phosphorus concentration with sediment depth. Therefore, the internal phosphorus loading would not be decreased by the removal of the upper sediment layers. The release of sediment phosphorus to the water column would probably be similar because the sediments are only reactive to a shallow depth (approximately 10 cm, Snow and DiGiano, 1976).

The Dillon/Rigler and other trophic models demonstrate that a lake's tolerance to phosphorus loading is highly dependent on its mean depth. Increasing the mean depth would result in an improvement in trophic status if the loading remained constant. However, phosphorus tolerance decreases with decreasing flushing rate. Dredging would increase the mean depth which would increase the lake volume and, hence, cause a decrease in flushing rate. These two factors thus

counteract each other.

Suitable dredge spoils disposal site(s) of substantial size and location would have to be determined, designed and constructed with protective features such as diking to provide containment and prevent release of nutrients and suspended solids. An outlet structure and sedimentation pond downstream of the disposal area would probably also be necessary. Some treatment of the decant water may be required pending further analysis and characterization of the sediments. No areas proximal to Pawtuckaway Lake are topographically amenable to the construction of a disposal area without substantial earth moving and berm construction.

There are several noteworthy adverse effects associated with sediment removal (Peterson, 1981). Sediment solids are resuspended during dredging activities, thus causing high turbidity in the lake water. Toxicants (unknown) may be liberated to the water column and downstream waterbodies. An algal bloom may be triggered by dredging, due to the release of high concentrations of nutrients in the disturbed sediments and released interstitial water. Lake water oxygen depletion may occur due to increased exposure of the water to bacterial decomposition. The benthic community may be temporarily destroyed. Most of the above concerns are short-term impacts, however, and may be mitigated with a well designed sediment removal plan.

Sediment removal is costly, and the net dredging and disposal cost per unit volume removed varies widely from lake to lake. It is dependent on the equipment (dredges, barges, pumps, etc.), the sediment transport distance to the disposal site, the cost of acquiring and developing the disposal site, and manpower and permit (e.g., Federal Section 404) costs. Peterson (1981) tabulated essential data (including costs) for 64 dredging projects nationwide. Peterson reported a cost range of $0.40 per cubic yard to $23.00 per cubic yard and found that costs from $2.00 to 3.00 (1988 dollars) were common and were considered reasonable for hydraulic dredging. Recent feasibility studies at Kezar Lake (Connor and Martin, 1989) estimated the dredging cost at that lake to be in the range of $1,000,000 to $5,000,000 exclusive of spoils containment design and construction costs. A 1994 Dredging Feasibility Study prepared by Fugro East Incorporated estimated the cost of dredging Flint Pond, Hollis, New Hampshire. Four dredging options were proposed ranging from the removal of 28,000 m^3 at $280,000 to removing 135,800 m^3 at $1,358,000. Cooke et al. (1993) did a rough analysis comparing nutrient inactivation and sediment removal. He found that nutrient inactivation holds a strong edge over dredging in terms of costs, but dredging introduces no foreign materials into the lake and actually removes them. Dredging is still the only practical method of restoration

if deepening a shallow lake is the objective, or if littoral zone removal of macrophytes is targeted. In order to remove the potential sediment phosphorus loading to Pawtuckaway Lake, the benthic areas that are anoxic during the summer months would have to be dredged.

Based on these findings, it is evident that sediment dredging at Pawtuckaway Lake as a restorative technique would be costly and of limited value.

2. Phosphorus Inactivation

a. Literature Review. Phosphorus precipitation and sediment inactivation are lake restoration techniques that reduce phosphorus concentration and thereby limit the growth of phytoplankton. Sediment phosphorus inactivation results in longer term lake quality improvement when compared to water column precipitation. Sediment inactivation is particularly useful in accelerating lake improvement in those areas where internal phosphorus release represents a significant contribution to the phosphorus budget (Cooke et al, 1977; Larson, 1979).

The chemical and physical justification for utilizing aluminum as an inactivant is its ability to form complexes, chelates and insoluble precipitates with phosphorus. Aluminum complexes and polymers are inert to redox changes, are effective in entrapment and removal of inorganic and particulate phosphorus in the water column, and have been shown to have no toxicity at the pH and dose required to improve lake conditions (Cooke and Kennedy, 1981).

Removal of phosphorus by aluminum can occur by precipitation of $AlPO_4$ (Recht and Chassemi, 1970), sorption of phosphates to the surface of aluminum hydroxide polymers or floc (Eisenreich et al., 1977), and/or by entrapment/sedimentation of phosphorus- containing particulate by aluminum hydroxide floc. Characteristically, lake water concentrations of total phosphorus are much less than 1 mg P/L (state median-0.011 mgP/L) while pH typically ranges from 6.0 to 7.0 units in non-acidified New Hampshire lakes. Under these conditions, OH^- competes with PO_4^{-3} for aluminum ions favoring the formation of aluminum hydroxide-phosphates.

Dissolved organic phosphates are less effectively removed by inactivation because of the complexity of their molecular structure. Failure to remove dissolved organic phosphorus could be of significance since certain blue-greens can produce phosphatase that removes inorganic phosphorus from any organic phosphates at rates sufficient to support elevated algae populations. Particulate phosphorus removal effectiveness is controlled by the quantity and quality of the

aluminum hydroxide floc. The potential for particulate entrapment should occur in the 6 to 8 pH range.

Once deposited, aluminum hydroxide can provide a continuous control of phosphorus. Kennedy (1978), under experimental conditions, demonstrated that treated sediments are active in retaining phosphorus. Low pH and high phosphorus concentrations in the interstitial water favor the formation of $AlPO_4$. The phosphorus-trapping effectiveness of the floc layer depends on aluminum concentration, pH, the phosphorus concentration and the rate at which phosphorus is supplied to the floc surface.

Within several months of the treatment, the floc consolidates with the sediments and is distinguishable as white-to-brown solid pellets.

A review of the literature provides us with a series of long-term inactivant projects that demonstrate the effectiveness of aluminum hydroxide floc in controlling internal phosphorus loading. The most successful phosphorus inactivation treatments are to continuously circulated lakes (polymictic). Weakly stratified dimictic lakes (Osgood Index <6) may also benefit. Even deeper lakes are likely to experience an improvement in late summer to fall surface lake quality after phosphorus inactivation because the treatment should eliminate the introduction of phosphorus-rich hypolimnetic waters to the surface as the lake begins autumn turnover. Cooke et al. (1993) warns that prospective users of phosphorus inactivation in dimitic lakes should consider whether summer algal blooms following phosphorus diversion are caused by phosphorus release from deep lake sediments, the traditional target of phosphorus inactivants.

Some of the important lake responses measured following the application of aluminum salts include decreases in lake phosphorus concentration, a sharp decrease in the accumulation of sediment-derived phosphorus to the hypolimnion, an increase in transparency, a reduction of phytoplankton populations and a shift in phytoplankton dominance from the more obnoxious Cyanobacteria to other less obnoxious classes.

Some potential negative impacts may be encountered if proper care is not exercised with regard to dose. The potential for toxicity responses is directly related to the acid neutralizing capacity (ANC) and pH of the lake water. Dosage rates, chemical ratios and responding decreases of ANC and pH must be determined under experimental laboratory conditions. Water ANC and pH decrease at a rate dictated by the initial buffering capacity of the water. In low ANC lakes, small doses of aluminum sulfate can exhaust the buffering capacity to a point that causes the pH to

decrease below 6. At pH 6 and below, $Al(OH)_2$ and dissolved elemental aluminum (AL^{+3}) become the dominant forms. Both of these species can be toxic to the lake biota. Therefore, sodium aluminate along with aluminum sulfate is required in these lakes to prevent undesirable pH shifts, toxic aluminum concentrations and to generate adequate $Al(OH)_3$ for sediment phosphorus inactivation.

Phosphorus inactivation literature reviews indicate that prior to 1980, 28 surface water bodies had been treated to precipitate or inactivate phosphorus (Cooke and Kennedy, 1981). Within the last ten years, several phosphorus inactivation projects were completed just within New England. However, most of these projects were completed within the past five years and the final restoration prognosis is yet to be determined. West Twin Lake, Kent, Ohio (Cooke et al., 1978), Annabessacook Lake, Winthrop, Maine, (Dominie, 1980), Long Lake, Kitsap County, Washington, (Jacoby et al., 1982) and Kezar Lake (Connor and Martin, 1989) are of specific interest. Due to their similarity to Pawtuckaway Lake in criteria and/or treatment, a detailed discussion of these cases follows.

i. <u>West Twin Lake</u>, Kent, Ohio (Cooke et al., 1978). In 1975, the hypolimnion of West Twin Lake was treated with alum. This treatment was directed primarily at covering the bottom sediments with a layer of aluminum hydroxide to absorb phosphorus molecules released from the sediments. West Twin Lake was classified as a eutrophic lake with an area of 34.02 hectares (ha), 4.3 M in mean depth, and a maximum depth of 11.5 M. Liquid alum was added to the 5 M contour, with 26 ha being treated in July of 1975. Dosage rates were based on ANC (102 - 149 mg/L $CaCO_3$) and the amount of aluminum sulfate (liquid alum) which could be added to the point at which pH began to decline and dissolved aluminum began to increase. The application of 91 metric tons was applied in three days at a dose of 27.6 mg Al/L to the hypolimnion. Phosphorus content fell precipitously and remained low through 1978. A small internal phosphorus release, calculated by a phosphorus budget method was not completely controlled, and was thought to be of littoral origin (Cooke and Kennedy, 1981). Cell volume and blue-green algae dominance decreased while transparency increased. There also was some indication of a decrease in microcrustacea diversity.

ii. <u>Annabessacook Lake</u>, Winthrop, Maine. (Dominie, 1980). Annabessacook Lake has a surface area of 575 ha and a hypolimnetic area of 150 ha. It is a soft water eutrophic lake (ANC

of 20 mg/L as $CaCO_3$), with a pH of 6-7, maximum depth of 14.9 m, and a mean depth of 5.4 m. Dominie calculated that 85% of summer phosphorus increase in the lake was due to internal phosphorus release, presumably from the sediments. The objective of the treatment was to control this phosphorus release. In order to maintain pH to near normal levels, and thereby also prevent the appearance of the toxic levels of dissolved aluminum, a mixture of aluminum sulfate (alum) and sodium aluminate was added to the hypolimnion of the lake in August, 1978. This hypolimnetic aluminum application was designed to accomplish two objectives: first, phosphorus precipitation and entrapment (which is most effective when done in mid to late summer when hypolimnetic phosphorus concentration is greatest) and second, chemical sealing of the sediment by aluminum floc which prevents future phosphorus release. Aluminum application dosages in the top meter of treated water were 25 mg/L for areas 7-10 m deep, and 34 mg/L in areas over 10 m deep. The aluminum application took approximately 18 days, averaging 10 hours per day, and was carried out where depths exceeded 8 m.

The results of aluminum application were at first very encouraging. However, post-monitoring data revealed increases in phosphorus, decreases in transparency and greater blue-green phytoplankton populations between the months of June and August.. There was no immediate reduction of phosphorus at Annabessacook, as was found at Horseshoe Lake (Peterson et al., 1973) and Medical Lakes (Gasperino and Saltero, 1978) after alum treatment. A large decline in the lake's phosphorus content was observed in September. From the time of treatment in 1977 to one year post treatment there was 65% reduction in maximum phosphorus mass in the lake.

iii. Long Lake, Kitsap County, Washington (Jacoby et al., 1982). Long Lake is a shallow, unstratified lake, with a mean depth of only 2 m, and a maximum depth of 3.7 m. High pH levels (8 to 10) occur in the summer because of the lake's low buffering capacity (ANC from 10 to 40 mg/L as $CaCO_3$) and the high productivity rates. Internal phosphorus loading in Long Lake was identified as a major eutrophying factor. The sediments in the deeper parts of the lake were shown to be the immediate source of this internal phosphorus loading (Jacoby et al., 1982). In addition, contribution of phosphorus by a dense macrophyte crop was believed to be substantial. A drawdown in the summer of 1979 to control macrophyte growth was unsuccessful, with recolonization approaching pre-drawdown levels by the summer of 1981.

In September 1980, alum was applied to Long Lake at a rate of 5.5 mg Al^{3+}/L to provide a

barrier to phosphorus release from the sediments. The alum floc remained well incorporated in the surficial sediments and served as an effective barrier to the vertical diffusion of soluble reactive phosphorus. Phosphorus control continued two years after treatment, in spite of a full macrophyte recovery. The alum may have continued to be effective by inactivating or complexing newly deposited phosphorus from macrophytes. One detrimental side effect was noted. The improved water column clarity resulted in increased density and distribution of Potamogeton praelongus and P. pectinatus in the deeper 3 m area of the lake, impacting boating and fishing activities. These areas of the lake previously had little macrophyte growth.

iv. Kezar Lake, North Sutton, New Hampshire (Connor and Martin, 1989). Aluminum sulfate and sodium aluminate were utilized as sediment phosphorus inactivants to improve the water quality of a northeastern eutrophic lake. The treatment occurred during June of 1984 and utilized a 40 mg Al/m2 concentration at a 2:1 ratio (AS:SA). A four-year monitoring program provided an extensive lake-database utilized to evaluate the short-and long-term effectiveness of sediment phosphorus inactivation as a lake restoration technique. An immediate impact of treatment was a reduction in hypolimnetic BOD and dissolved oxygen deficit, lower chlorophyll-a and phosphorus concentrations, improved transparency, and the elimination of obnoxious blue-green phytoplankton blooms. For two to three years after treatment, these parameters continued to exhibit both less variability and improved values over the pre-treatment conditions. The improved water quality conditions warranted an upgrade of the lake trophic status from eutrophic to mesotrophic. Ten years after treatment, transparency values are still acceptable for recreation, (ranging from a minimum of 1.8 m during the 1994 season to a maximum of 3.4 m during the 1992 season) while productivity was considered to be moderate (1994 chlorophyll ranged from 4.0 to 11.7 ug/L with a mean of 9.2) and internal phosphorus loading (mean epilimetic phosphorus concentration = 21 µg/L) was considered reasonable. A major benefit is an increase in the average attendance at the lake's State Park by almost 2,000 people per summer.

b. Environmental Effects of Phosphorus Inactivation Treatments. In order to assess the long-term environmental effects of phosphorus inactivation by treatment with aluminum, future research must be conducted to evaluate the effects on species diversity, fish populations, bioaccumulation of aluminum, potential impacts on human health, and related uses of lake water.

At this time, there is already some direct laboratory and field evidence concerning the short and long term effects of aluminum on aquatic biota and aquatic communities. Cooke, et al., 1982 observed few negative effects as a result of hypolimnetic alum treatment of West Twin lake (five years post-treatment) and Dollar Lake (six years post-treatment) Connor and Martin (1986) also observed few negative effects with an application of aluminum sulfate and sodium aluminate. Specific conductance, ANC, pH, sulfate, and dissolved aluminum were monitored regularly and no remarkable or excessive changes were noted. Residual dissolved aluminum (RDA), ANC, and pH all recovered rapidly after the treatment was completed. Transparency increased after aluminum application and remained high. These investigators report significant changes in species composition of phytoplankton and zooplankton following aluminum application. It appears that changes in this diversity may be attributable to increased clarity and decreased nutrient content, rather than toxicity. The decline in planktonic micro-crustacean diversity was apparently not due to aluminum toxicity in the water column, but to changes in the type of algae cells present, changes in pH, or perhaps RDA changes in the interstitial waters where resting stages of micro crustaceans might be found. Greatly increased transparency may enhance fish predation on zooplankton and contribute to reduced diversity.

Jacoby et al., (1982) also reported that increased water column clarity in alum treated Long Lake, Washington, resulted in an increase in the biomass of macrophytes in the deeper (3 m) area of the lake. Previously, this area had been relatively free of noticeable macrophytes, but had a dense algal biomass which decreased significantly after treatment. However, despite the overall improvement in lake quality and the lack of blue-green algae blooms, recreationists still complained of the impact of the macrophytes on boating and fishing activities on the lake.

Hypolimnetic aluminum sulfate treatment of Bullhead Lake, reported by Narf (1981), indicated that a reduction in phosphorus concentration apparently shifted the lake's microflora from a blue-green to a green dominant community.

Narf (1978) also reported an extensive evaluation of aluminum sulfate treatments on benthic insect communities. His study showed that the benthic insects suffered no toxic effects and generally increased the first year following the aluminum sulfate application. The presence of the aluminum flocculus did not appear to influence the species composition or numbers. Snake Lake, with one of the higher applied dosages of aluminum, produced the largest populations of benthic insects during the two years following treatment. At Long and Pickerel Lakes, the population shifts

were less dramatic, but indicated no decline immediately after treatment, or for a number of years following.

The use of aluminum apparently enhances the lake quality for benthic organisms for a time period dependent on lake conditions. Narf also reported that benthic insect-burrowing activities may greatly contribute to phosphorus recycling of lake sediments. He observed that the apparent secondary toxicity in laboratory bioassays, using 93 and 140 g Al_3/m^2, can be explained by the probable change of the flocculus to a more cohesive precipitate layer. This was less pervious to biological and chemical diffusion, thus suffocating the insects. Dominie (pers. comm.) also noted the same phenomenon in his bioassay procedure.

Several investigators have reported an absence of negative effects on fish (Kennedy and Cooke, 1974; Buergel and Soltero, 1983; Connor and Martin, 1986) after a lake treatment. Everhart and Freeman (1973) used a constant flow bioassay to test toxicity to rainbow trout. At 52 ug Al/L, there were no obvious effects on growth or behavior, leading Kennedy and Cooke to adopt this value as an upper RDA limit for lake treatment. Peterson et al. (1974, 1976), using static bioassay, reported that Chinook Salmon survived an RDA of about 20 ug Al/L. Higher concentrations were not tested. Buergel and Soltero (1983) studied the possibility of bioaccumulation in stocked rainbow trout after a whole lake application of alum to Medical Lake, Washington. This study was particularly pertinent because these trout and their prey were dependent upon habitat potentially higher in available aluminum than neighboring habitats. Trout tissue, plankton, and water were analyzed for total aluminum concentrations. Statistical comparisons revealed few overall differences in the level of aluminum in alum exposed and non-exposed fish, although significant differences existed among tissues within a given treatment and age class. Aluminum levels in plankton were approximately 10 times higher (dry weight comparison) than encountered in trout tissue, and may help to account for levels found in trout. The lack of aluminum in the muscle tissue suggests diminished vascularization or no metabolic means of storing aluminum. Further research is needed to study the impacts and fate of aluminum in tissues.

The modern phenomenon of acid precipitation, and the possible resultant mobilization of aluminum to the aquatic environment, warrants further research to study the potential biological impact of aluminum. Also, further study should be undertaken concerning the interactions of aluminum and the inherent environmental complexing agents of chelators and the subsequent toxicity potential. From the research performed thus far on the use of aluminum salts for phosphorus

inactivation, it appears that increases in aluminum caused by these treatments do not deleteriously affect species diversity of fish populations, and do not lead to bioaccumulation of aluminum in the fish.

c. Cost Comparisons for Aluminum Salts Application. A comparison of labor, equipment and chemical costs between seven phosphorus inactivation projects on seven different lakes is summarized in Table XI-1. With the exception of Sluice Pond, the cost effectiveness of phosphorus inactivation has increased since earlier (late 1970) treatments. Although the cost of aluminum has increased, the chemical application techniques have become more efficient and less labor intensive.

The cost effectiveness of aluminum salts injection can best be demonstrated by comparing labor, chemical and equipment costs. Table XI-1 demonstrates the aluminum salts application effectiveness of the modified harvester (Connor and Smith, 1986), an older barge system, and a modified treatment barge recently developed by Sweetwater Technology.

A comparison of the person-days worked per hectare revealed that the harvester was much more effective than the barge method utilized at Annabessacook Lake. The modified harvester utilized at Kezar, Morey, and Cochnewagon Lakes saved an average of 0.63 person-days/ha when compared to the barge method utilized at Annabessacook Lake. However, it appears the cost-effectiveness of aluminum salts injection decreased with lake areas under 20 hectares. A computerized chemical distribution system developed by Sweetwater Technology has increased the efficiency of chemical application, and a portable LORAN navigational system has increased the path accuracy to 9 inch/0.5 mi (225 cm/0.8 km). This one-person operation is capable of applying up to 35,000 gallons (133,000 L) of liquids per day. These improvements increase the efficiency and economical application of aluminum salts. The computerized barge saved an average 0.43 person-days/ha and an average of $512.00 per hectare over both the old barge and modified harvester systems.

d. Application Feasibility for Sediment Phosphorus Inactivation. The simultaneous application of two aluminum salts with either a specially modified aquatic weed harvester (Connor and Smith, 1986) or the new barge system (Sweetwater Technology) has proven to be an efficient

Table XI-1
A Comparison of Aluminum Dose, Cost, and Work Production Data for Phosphorus Inactivation*

Lake	Year Treated	Area Treated (ha)	Aluminum Dose	Cost for Chemicals Labor and Equip.	Manday/ha	Cost/ha
Medical Lake, Washington[1]	1977	60	8.0 g Al/m^3 Aluminum Sulfate	$132,093	No data	$2,202
Annabessacook Lake, Maine[1]	1978	121	25 g Al/m^3 Aluminum Sulfate Sodium Aluminate	$234,000	1.12	$1,934
Kezar Lake, New Hampshire[2]	1984	48	40 g Al/m^3 Aluminum Sulfate Sodium Aluminate	$65,604	0.50	$1,367
Lake Morey, Vermont[2]	1986	133	45 g Al/m^2 Aluminum Sulfate Sodium Aluminate	$165,640	0.57	$1,245
Cochnewagon Lake, Maine[2]	1986	97	18 g Al/m^3 Aluminum Sulfate Sodium Aluminate	$81,840	0.41	$844
Sluice Pond Massachusetts[2]	1987	6	20 g Al/m^2 Aluminum Sulfate Sodium Aluminate	$13,196	0.67	$2,199
3 Mile Pond, Maine[3]	1988	266	20 g Al/m^2 Aluminum Sulfate Sodium Aluminate	$170,240	0.06	$640

***Data from Connor and Smith, 1986; Gerald Smith, Aquatic Control Technology; and Richard H. Lepley, Sweetwater Technology Corp.**
[1] old barge system [2] modified harvester [3] new barge system

method of treating stratified lakes for both reduction of hypolimnetic phosphorus and inactivation of sediment phosphorus (Connor and Martin, 1989).

Pawtuckaway Lake has adequate accessibility for launching the necessary equipment and for tanker truck dispersion of chemicals to the distribution mechanism. Several locations could be utilized as chemical refill stations so the barge has less distance to travel for refills. Before cost estimates can be made, three important factors must be determined. Each of these factors will determine the ultimate success of the project in sediment phosphorus inactivation and will determine the ultimate project cost.

- The treatment area of the lake must be determined by defining the areas of the lake that contribute to internal phosphorus loading. In some cases this area may be confined to the stratified anoxic hypolimnetic area of a lake. A more practical approach involves mapping the benthic sediments to their type and depth. A rich organic sediment will yield a greater phosphorus load to the lake than an inorganic sandy substrate. Over 70 percent of the Kezar Lake sediment was treated with aluminum salts.
- Since New Hampshire lakes are low in ANC considered soft water, only small amounts of aluminum sulfate can be added before the pH falls below 6.0. In these lakes, sodium aluminate must also be added with aluminum sulfate. Sodium aluminate, which increases the pH of an aqueous solution, is utilized to maintain a pH above 6.0. The ratio of aluminum sulfate to sodium aluminate must be empirically determined. These ratios are determined by conducting jar tests utilizing water from the lake to be treated. Several tests including pH and aluminum are conducted to determine the proper ratio to be utilized during the treatment.
- The total aluminum dosage must be calculated for the lake. A basis for aluminum dose now exists. The Kennedy procedure (Kennedy & Cooke, 1980) is based on the assumption that as much aluminum as possible should be added, up to the pH where significant amounts of dissolved aluminum appear, since the goal is long term lake improvement. From our past experience with sediment phosphorus inactivation, we will assume an aluminum dose of 40 mg Al/m^2.

The estimated cost for sediment phosphorus inactivation of 222 ha for Pawtuckaway Lake will range from $142,000 to $303,500 (1990 dollars). Figures are dependent upon the application

methodology and include equipment, labor and chemical cost.

There is no apparent significant social impact of the phosphorus inactivation treatments of lakes. There will be minimal disruptions of the use of the lake and no restrictions placed on the subsequent water use. There are no disposal problems associated with the procedure, and no adverse impacts on docks, marinas, or other water structures.

3. Dilution and Flushing

Lake waters that exhibit low concentrations of phosphorus are unlikely to maintain algal blooms. While ideally it is more feasible to divert or treat phosphorus rich waters before they empty into a lake, it is possible to lower the concentration of phosphorus within the lake and to flush out algal cells by adding sufficient quantities of phosphorus-poor water from some additional source. High amounts of additional water can also be used to flush algae cells from the lake faster than they grow.

Lakes with low flushing rates are poor candidates because in-lake concentration could increase unless dilution water is essentially devoid of phosphorus and sufficient water is added to gain a high flushing rate. Internal phosphorus release could further complicate the effect.

Flushing can control algal biomass by cell washout. The flushing rate must be near the cell growth rate to be effective. Flushing rates of 10-15 percent of the lake volume per day are believed to be sufficient (Cooke et al. 1986). Since Pawtuckaway Lake flushes only 1.4 times per year, this may not be a feasible means of restoration. Few case histories that document the effectiveness of dilution and flushing exist. The greatest problem is locating a dilution source that is low in phosphorus. Cooke et al. (1986) describe one successful case where low-phosphate Columbia River water was diverted through Moses Lake, Washington. Water exchange rates of 10 to 20 percent/day were achieved, and transparency and productivity dramatically improved. Dilution and flushing can achieve improved quality in eutrophic lakes by diluting the phosphorus concentration and increasing the water exchange (flushing) rate. The advantages of using dilution water include (1) relatively low cost if low phosphorus water is available, (2) an immediate and proven effectiveness if phosphorus can be decreased, and (3) likely success if moderate phosphorus water is available.

Outlet structures must be capable of handling the added discharge, and increased volume released downstream may have water quality impacts to lakes and ponds located downstream. Also,

a large volume of low phosphorus water is not easily accessible and/or close enough to make pumping and transporting cost-effective.

4. Sediment Oxidation

Riplox, a highly experimental procedure (Ripl, 1976) has only a few existing case histories. The objective of this procedure is to decrease phosphorus release from sediments, in much the same way as with phosphorus inactivation. The addition of ferric chloride to the sediments enhances phosphorus precipitation. Lime is then added to adjust the sediment pH for optimum denitrification. The final step promotes the oxidation of organic matter and dentrification through a calcium nitrate injection of the top 10 inches of sediment. The chemical solutions are applied by direct injection into the sediment with a "harrow", a 6 to 10 m wide device equipped with flexible tubes that penetrate the sediment. As the device is dragged along the lake bottom, sediment is disrupted to a depth of 20cm and the chemical solutions are injected.

Lake Lillesjon, a 10.5 acre Swedish lake with a mean depth of 6.6 feet was treated at a cost of $130,000. Only $7,000 of the total cost was for chemicals while the remaining costs were for equipment development and research (Olem and Flock, 1990). Cooke et al. (1993) noted that the principal impediment to the selection of Riplox over other inactivation treatments is the lack of documented overall successes. Lake Lillesjon is the only case where the experimentally required dose was applied, the lake phosphorus substantially declined, and the oxidized state of the sediment persisted. External phosphorus loading apparently remained too high for significant recovery to occur in Trekanten (Sweden) and Long Lakes (Minnesota); and, although expected results were observed in White Lough (Ireland), the lake was under-dosed.

Sediment oxidation (Riplox) is a sound technique and represents an alternative to alum treatment and dredging as a long term control of internal phosphorus loading from anaerobic sediment release.

The cost of an ideal dose (40 g N/m^2) of calcium nitrate to White Lough was compared with that of an earlier (1980) treatment of the lake with iron/alum. The total costs (1990) for calcium nitrate and iron/alum were $23,970 and $6,400, respectively. The estimated cost per treated hectare was $5,200 and $1,390, respectively.

If we treated the same area estimated for sediment inactivation (222 ha) it would cost around

$1,154,400 for sediment oxidation of Pawtuckaway Lake. Riplox could be as much as four times the expense of sediment inactivation. However, it should be noted that the analyses of Pawtuckaway Lake sediments have revealed high iron concentrations distributed throughout the core depth. The high sediment iron content could preclude the addition of ferric chloride to the sediment and would save some expense.

5. Biomanipulation

Another highly experimental restoration technique utilizes zooplankton grazing for reducing plankton populations. Shapiro et al. (1975) proposed the term "biomanipulation" as a new lake management procedure. Shapiro (1990) defined biomanipulation as "a series of manipulations of the biota of lakes and their habitats to facilitate certain interactions and results which we as lake users consider beneficial -- namely reduction of algal biomass and, in particular, of blue-greens." Shapiro et al. (1975) used the term biomanipulation to include effects on algal biomass from both "top-down" biological processes (grazing), and "bottom-up" processes (nutrient cycling by fish). Shapiro et al. (1975) proposed that procedures or factors which significantly enhance and maintain the density of piscivorous fish should lead to a reduction in density of planktivorous fish, to an increase in survival of large-bodied zooplankton species, and to a reduction in algal biomass and/or an increase in water clarity. This biological approach to the improvement of lakes with pelagic algal blooms eventually may eliminate or reduce the need for mechanical or chemical controls. However, biological controls of algae biomass are still less precise than those methods. The type of plankton available as a food source to the herbivores and planktivores will have a direct effect on the project's outcome.

Knowledge of pelagic food webs and their interactions with littoral food webs is not at a level that permits prediction of responses to manipulation with a high degree of confidence.

A factor of importance to the successful use of zooplankton to reduce algal biomass involves palatability of phytoplankton. Daphnia not only are susceptible to fish predation, but also are severely affected by the presence of filamentous blue-green algae. Filaments and colonies may simply be unpalatable or too abundant, or toxic species of blue-greens may cause severe disruptions in the aquatic food chain through the release of antitoxins upon cell lysis. The palatability of algae, sources of blue-green algal blooms, and the roles of fish and birds are confounding factors in the

trophic cascade idea. Other important elements include geographic limitations of large-bodied species of Daphnia, eutrophying effects through fish bioturbation and most notably, how to make biomanipulation last. Biomanipulation will not be successful in every lake, and particularly not in lakes that continue to receive high external phosphorus loading or water-bodies which have depressed hypolimnetic oxygen concentrations. Anoxic hypolimnions eliminate a particular refuge from sight-feeding planktivores and this enhances zooplankton mortality.

Food web management to improve lake trophic state is an experimental procedure at this time and many interactions are poorly understood. Costs for biomanipulation are not readily available. Fish poisons are expensive and clean-ups are costly. The cost of restructuring a food web through enhancement of a predatory fish population will be specific to each lake (Olem and Flock, 1990). In the case of Pawtuckaway Lake, biomanipulation would have to be supplemented by the additional cost of hypolimnetic aeration.

D. SUBWATERSHED MANAGEMENT

1. Introduction

Nonpoint loading of phosphorus can be a significant cause of eutrophication to New Hampshire lakes. Best Management Practices (BMPs) to control nonpoint sources are considered to be the primary methods of protecting lakes from this type of loading. The implementation of proper watershed management techniques within the Pawtuckaway Lake watershed will help mitigate the decline in water quality. Continued population growth and the associated growth in residential and commercial development, hobby farming, and an increase in recreational use, combine to place a burden on the surface water resources within the region. Watershed management techniques designed to reduce this pressure include a variety of land use management, agricultural BMPs, stormwater management and public education of the permanent and transient population within the Pawtuckaway Lake watershed.

Each of these groups of management techniques plays a major role in the preservation of surface water quality within the watershed. The existing condition of the lake, and the nutrient supply sources identified by the study clearly point out the need to eliminate or reduce those factors

that might contribute to the decline in water quality. While it is not possible to place specific values on each management practice in terms of potential reduced loads, it is clear that these practices, taken individually or in combination, will help to ensure that future development will be conducted in a manner that does not accelerate the decline in water quality.

The implementation of surface water quality protection and watershed management techniques within the Pawtuckaway Lake watershed will focus upon areas identified by the diagnostic/feasibility study that contributed the greatest negative environmental impact to the lake.

Several nonpoint management strategies will be developed for Pawtuckaway Lake to mitigate the effects of nonpoint source pollution and will involve several or all of the following strategies to achieve the desired results.

- Sub-watershed Management and Pollutant Reduction Using BMPs for Agriculture (dairy farms, hobby farms, etc.)
- Stormwater Management, Erosion and Sediment Control
- Artificial Phosphorus Abatement Involving Individual Subsurface Disposal Systems
- Public Boat Launch Rehabilitation and/or Relocation
- Public Education

2. Subwatershed Management

Back Creek "B", Mountain Cove Brook and Round Pond Brook contribute the greatest phosphorus load to Pawtuckaway Lake, representing 33%, 24% and 16% of the tributary phosphorus load respectively. The 3,698 acre Back Creek "B" subwatershed is dominated by forest cover (77%), and wetlands (14%) and contains minimal urban development (4%) or active agriculture (3%). The Mountain Cove Brook subwatershed occupies 2,400 acres and lies almost entirely within the Pawtuckaway State Park boundaries. Forest (84%) and wetlands (8%) dominate the subwatershed with the majority of remaining area existing as ponds scattered throughout the Mountain Cove Brook drainage area. The last major contributor to Pawtuckaway Lake in terms of phosphorus loading is Round Pond Brook. This 1,599 acre subwatershed is dominated by Forest cover (71%), and wetlands (21%) and lies entirely within the Pawtuckaway State Park boundaries. The water quality in Round Pond Brook is influenced by the discharge from Round Pond which was determined to be the most eutrophic stratified pond that has been classified to date by the NHDES

Lake Inventory Program (NHDES-1994).

The amount of phosphorus reaching Pawtuckaway Lake from these three tributaries is directly related to the fact that Back Creek "B", Mountain Cove Brook and Round Pond Brook combined to contribute 77% of the total tributary inflow to the lake during the study year. The high volumes of water transported through these subwatersheds accumulate naturally derived phosphorus from wetlands which appear to be acting as nutrient sources rather than sinks. Evidence to support this condition exists in the mean seasonal total phosphorus values for these tributaries which experienced seasonal total phosphorus maxima during the summer months. This is contrary to many studies that have indicated that wetlands were net accumulators of phosphorus on an annual basis, and may have maximum seasonal removal efficiencies from 80 to 98 percent during the summer growing season.

Bentley (1969) studied four wetlands in Wisconsin and estimated that on a long-term basis, they were neither nutrient sources nor sinks, but that the marshes tended to accumulate nutrients during the growing season and release them during spring runoff. However, even during periods of active photosynthesis, the wetlands were not a barrier to nutrient transport. Richardson (1988) concluded that wetlands are incorrectly depicted as sinks when, in fact, they should be recognized as transformers. Wetlands with organic soils do not retain phosphorus as efficiently as forested systems and are often a source of nutrients rather than a sink for them.

A four year study was performed on the Chadwick Meadows complex in the Kezar Lake watershed located in New Hampshire by Connor and Martin (1989). The study indicated that Chadwick Meadows was a significant source of total phosphorus within the Kezar lake watershed, providing an average increased phosphorus load of 4.79 kg on a monthly basis over the study period. Further, an average of 18.5 kg of phosphorus is contributed during the summer months of June, July, and August (Connor 1989). The Chadwick Meadows study coincides with the seasonal influx of phosphorus occurring during the summer months in Back Creek B, Mountain Cove Brook and Round Pond Brook. The extensive wetland complexes in the subwatersheds display reduced phosphorus removal efficiencies with consistent loading under conditions of constant loading time.

Although these conclusions demonstrate that the wetlands in the three main subwatersheds of Pawtuckaway Lake have limited value in retaining phosphorus, their value as sediment traps remains unchallenged. The actual phosphorus concentrations reaching the surface waters of Pawtuckaway Lake are similar to epilimnetic phosphorus concentrations present throughout the

study year. Therefore, the impact of nutrient loading from these subwatersheds is minimized and doesn't raise the in-lake concentration of phosphorus. Edmondson (1972) pointed out that conventional calculations of nutrient income or loading identify the major sources in terms of total contribution, but they make no allowance for the fact that a given amount of nutrient has a different effect depending on the amount of water in which it is contained (that is, the concentration at which it is delivered) when it enters the lake. A given amount of phosphorus in a concentrated source, like sewage effluent or agricultural runoff, can raise the general concentration in the receiving water. The same amount delivered at the same concentration as that in the receiving water does not raise the general concentration by mixing (Edmondson 1972).

Based upon this information, it is clear that the subwatersheds of Back Creek B, Mountain Cove Brook and Round Pond Brook identified as being the major phosphorus contributors of the Pawtuckaway Lake tributaries have a very minimal impact to the internal phosphorus levels of Pawtuckaway Lake. Therefore, subwatershed management efforts will focus upon areas containing concentrated phosphorus levels in surface water and a readily identifiable source of nonpoint source pollution.

Fernalds Brook A contributes eleven percent of the tributary phosphorus load to Pawtuckaway Lake and drains a subwatershed dominated by forest cover (82%), and active agriculture (9%). Another four percent of the subwatershed exists as wetlands, with another three percent categorized as urban. A significant portion of the headwaters within the Fernalds Brook A subwatershed originate as agricultural runoff from Fernalds Dairy Farm in Nottingham Square. Historically, manure handling on the property consisted of field stacking until conditions were optimum for spreading in the spring. Livestock had unlimited access to surface water on the property which promoted water quality degradation and erosion of stream banks and slopes. Surface water in Fernalds Brook A drains through several wetland areas before finally discharging into Pawtuckaway Lake. An upstream water quality monitoring station was established on Fernalds Brook A to evaluate the ability of the existing wetlands to uptake nutrients and to determine whether they were acting as a sink or a source of phosphorus to Pawtuckaway Lake. Phosphorus concentrations upstream of the wetlands ranged from a minimum of 120 µg/L to a maximum of 3,900 µg/L with a mean of 1,246 µg/L. Phosphorus concentrations reaching Pawtuckaway Lake through Fernalds Brook A ranged from a maximum of 200 µg/L to a minimum of 38 µg/L with a study year mean of 75 µg/L. Phosphorus reduction in the subwatershed attributed to wetland

nutrient attenuation provided an eighty to ninety-six percent reduction in phosphorus concentration during periods of typical seasonal flow patterns.

The nutrient storage efficiency of the wetlands was reduced to sixty-two percent during a spring runoff event. This coincides with the maximum seasonal total phosphorus values and the maximum phosphorus loading figures for the study year, both of which occurred during the spring months. In addition to the high concentrations and loading figures for phosphorus in the spring, the maximum study year mean for total tributary phosphorus occurred in Fernalds Brook A as well as the maximum seasonal total phosphorus values for the study year (Table V-10).

Although Fernalds Brook A is not a significant hydrologic contributor to Pawtuckaway Lake, it is the major contributor of concentrated phosphorus which greatly exceeds the nutrient levels of the receiving waters, and poses a significant risk of accelerating eutrophication. Subwatershed nonpoint source management techniques should be evaluated to minimize the amount of nutrients reaching the surface waters of Fernalds Brook A. Implementation of BMPs at Fernalds Farm would significantly reduce the amount of contaminated runoff reaching the brook and would improve the efficiency of the wetlands in the subwatershed to act as nutrient sinks.

a. Pollutant Reduction Using BMPs for Agriculture. Improperly managed livestock operations can cause nonpoint source water pollution in at least two ways. Improper manure storage and utilization can eventually contaminate water, while livestock grazing can cause soil erosion that later results in water pollution.

Manure from livestock can impair both ground and surface water if it is not properly managed. Animal manure can contaminate drinking water with nitrates and cause eutrophication of lakes, ponds and estuaries through the excessive release of phosphorus.

Many manure-related impairments of surface and groundwater originate from nonpoint sources. For example, in unconfined livestock operations, manure and sediment runoff can be significant, particularly where livestock are free to trample and defecate in and along streams and ponds (USEPA 1992). Runoff from animal loafing areas, such as those associated with dairy operations, can be damaging because daily trampling eliminates the vegetative cover that could take up nutrients or reduce the movement of runoff to surface waters. In addition, farmers may not properly store manure or may land-apply it during times of the year when the ground is frozen, promoting the excessive runoff of contaminated surface water.

These forms of nonpoint source pollution can be limited in several ways. To prevent stream and pond disturbance resulting from direct access of livestock to such waters, barriers can be constructed to prevent access to surface waters and alternative water sources such as watering troughs fed by ground water sources could be installed. EPA's Clean Lakes Program has successfully demonstrated that these water sources reduce animal trampling along streams and ponds, which in turn reduces manure and sediment runoff (USEPA 1992).

Another option is to rotate cattle among several smaller sized loafing areas so that vegetative cover can regenerate. If proven effective, cattle rotation could significantly reduce sediment and manure movement to streams.

A final option available to farmers with an emphasis on dairy operations is to switch to a confinement system which has the most significant reduction in manure and sediment runoff. A common scenario and mode of operation at a dairy farm often includes a stanchion barn for cows currently being milked while heifers and replacement stock are occupying pastures and designated loafing areas. The ideal situation designed to minimize environmental impacts would involve two separate barns; one to house the milking herd and another to house heifers and replacement animals. A manure storage facility designed to accommodate waste volumes from both barns would be installed. This manure pit or lagoon would have at least a nine month storage capacity which would allow for proper storage until environmental conditions were favorable for field application of manure and incorporation into the soil. This method would minimize contaminated runoff and increase crop yield by retaining nutrients.

Another method of nutrient containment is the management of milk house and parlor wash water separately from manure to avoid migration of nutrients to brooks, streams and lakes. Wash water carrying nutrients and manure can be disposed of using land application, filter strips, constructed wellands, organic matter beds, lagoons, subsurface disposal, storage structures, or by mixing with manure for land application (N.H. Department of Agriculture, 1993).

One final approach to minimizing surface water quality degradation from agricultural operations is to contain and filter runoff from impervious surfaces on the property. It is estimated that approximately sixty percent of the runoff generated on agricultural properties originates from impervious surfaces such as roofs, walkways and parking areas. One method of reducing the negative environmental impacts of this runoff is to install suspended roof gutters and incorporate filtration devices such as dry wells or swale areas. By diverting roof water away from barnyards and

feedlots, the volume of runoff containing nutrients will be minimized.

The New Hampshire Department of Agriculture has compiled a comprehensive list of nutrient BMPs for agricultural nonpoint source pollution. Several or all of the following BMPs may be necessary to achieve the desired results. Local conditions may dictate that other BMPs be used as available.

BMPs (N.H. Department of Agriculture. 1993).

- Control access of livestock to waterbodies.

  Minimize the direct deposition of manure by controlling access of livestock to waterbodies.

- Control runoff from barnyards and feedlots.

  Divert clean runoff to reduce the amount of water that runs through these areas. Control the manure-related pollutants that run off barnyards and feedlots with filter strips, grass areas below the barnyards and feedlots, and/or settling basins.

- Divert runoff away from barnyards and feedlots.

  Divert roof water to minimize the volume of runoff containing nutrients.

- Manage barnyards and feedlots to minimize concentrations of manure.

  Timely cleaning and removal of manure will reduce buildup, retain nutrients and prevent runoff.

- Manage pastures to reduce concentrations of manure.

  Careful placement of livestock watering facilities and herd management areas and paddock layout can reduce concentrations of manure and associated impact on waterbodies.

- Where practical, compost manure to reduce the volume of material requiring land application.

  Composting converts nutrients into organic forms that are more slowly available to plants when incorporated into the soil. Leaching potential of nutrients is reduced when using compost. Composted material has little or no odor and is suitable for use as a soil amendment in residential areas. The soil structure and fertility of lawns and gardens are improved by the use of

compost. Employ Agricultural Compost BMPs.

- Store manure in properly constructed facilities or field stack during periods when land application is not suitable.

  During periods when suitable sites for land application of manure are not available, the use of properly located and constructed manure storage facilities is recommended. These will provide storage until conditions permit land applications and incorporation. Field stacking is a storage alternative which requires a higher level of management than daily spreading. An intense period of labor is required to spread the stacked or stored manure.

- Maintain a balance between the number of livestock and acres of agricultural land available for spreading manure.

- Incorporate manure applications where and when appropriate, as soon as possible after application.

  This practice can reduce bacteria, organic matter and nutrient contributions from manure applications to runoff water. This in turn limits their contribution to surface waterbodies. Incorporation also eliminates odor problems. More nutrients are available for plant growth than from manure applied and left on the ground surface.

- Avoid the application of manure on frozen ground or snow-covered fields.

  Manure applications on frozen ground or snow-covered fields usually increases the amount of manure-related pollutants that reach surface waterbodies.

- Avoid applying manure directly on exposed bedrock and reduce application rates on shallow soils.

  Manure should not be applied directly to exposed bedrock. Most bedrock is fractured and those fractures provide excellent pathways for nutrient migration to groundwater sources. Additionally, manure application rates should be reduced on shallow soils to reflect the reduced ability to retain nutrients for plant uptake.

- Minimize soil erosion.

  Soil erosion facilitates mechanical transport of nutrients, pathogens and

organic matter to surface waterbodies.

- Maintain filter strips next to surface waters receiving runoff from crop fields where manure is applied.

  A filter strip of perennial vegetation maintained between agricultural lands and adjoining streams and lakes will filter out some of the nutrients and contaminants before they reach the water. Minimum width of these strips can be determined by the width of any agricultural equipment used to harvest or otherwise manage the vegetation. The minimum width should be 10 feet for average slopes of less than 1 percent and proportionally up to at least 20 feet for slopes of 15 percent. Tillage should not be performed in this strip except for establishment or maintenance purposes.

- Control spillage of manure when transporting from the storage area to the field.

  Manure along roadways presents a nuisance and safety problem especially near urban areas. Runoff from roadways can carry the spilled material into streams causing water quality problems. Use hauling equipment consistent with the type of manure generated. Limit passage of hauling equipment through the manure as much as possible to reduce tracking on roads. Effort should be made to clean up excess amounts of manure deposited on public roads.

- Manage milk house and parlor wash water to avoid migration of nutrients to brooks, streams and lakes.

  Wash water carrying nutrients and manure can be disposed of using land application, filter strips, constructed wetlands, organic matter beds, lagoons, subsurface disposal, storage structures, or by mixing with manure for land application.

- Control odors as necessary.

  Movement and distribution of manure will create odors even under the best practices. Every effort should be made to minimize odor problems from daily operations by: (a) keeping neighbors informed of activities, (b) condensing spreading time in each field to minimize periods when odors can be most offensive, (c) incorporating manure immediately on tilled fields, and

(d) utilizing vegetative barriers that can buffer odor drift.

b. Pollutant Removal From Stormwater Runoff. Development of residential areas around lakes and ponds has two main effects on stormwater. The first is the increase in the volume and rate of runoff as development takes place in a watershed. The second effect is the significant increase in the potential for degrading water quality not only for surface water but for groundwater as well (RCCD, 1992). In addition to promoting erosion and sedimentation, increased runoff acts as a medium for transporting pollutants which can contaminate surface waters and contribute to cultural eutrophication.

When development occurs, vegetation is removed and replaced with impervious surfaces in many instances. These surfaces include roads, streets, parking lots, roof tops, driveways, walks, etc., which reduce the amount of rainfall that can filtrate into the soil and therefore create more runoff into the surface water system. Natural drainage patterns are also modified as a result of development and runoff is transported via road ditches, drainage swales and constructed channels. These modifications increase the velocity of the runoff, which in effect decreases the time that it takes for runoff to travel through the watershed. The increase in flow and decreased travel time of runoff has an adverse impact on the natural stream channel. The increased runoff volumes caused by residential development cause flooding to occur more frequently which causes the stream channel to naturally widen and deepen to accommodate the increased flows. This natural process of stream channel erosion creates a sediment problem downstream. In addition to the pollution problem caused by the sediment, the stream bed ecosystem is adversely impacted not only in the downstream area by the lake but in the stream channel section being eroded. Erosional sediment deposits destroy vegetation, wildlife, impair aesthetic qualities, plug road culverts, and degrade water quality.

Stormwater runoff increases the pollution potential within a watershed. Several nonpoint pollution sources commonly associated with stormwater runoff are listed below, (RCCD,1992);

- The largest residential nonpoint pollution source is sediment and the nutrients and trace metals attached to it. In addition to this, the runoff from these areas may also carry bacteria, toxic chemicals hydrocarbons and organic substances.
- Runoff from construction sites during residential development is the largest source of sediment. Sediment fills road ditches, streams, rivers, lakes and wetlands. A good erosion and sediment control plan can substantially decrease the amount of sediment

being produced from residential areas and transported off site.

- Nutrients from residential areas are a major concern to surface water quality because of their effects on water bodies. The two major nutrients are nitrogen and phosphorus. Phosphorus is the limiting nutrient to New Hampshire lakes and even in small concentrations, increases algae growth. Nitrogen consumes oxygen in the nitrification process and is necessary for algal growth. Both conditions can impair the use of our surface waters for water supply, recreation and fish and wildlife habitat.
- The main source of nutrients in developed areas can be related to improper use of fertilizers including over fertilization, and organic matter from lawn clippings and leaves.
- Bacteria levels can increase due to increased development. Most of this bacterial contamination is coliform bacteria which can be associated with animal wastes and from failed septic systems.
- Salt is used in large quantities in New Hampshire during the winter to melt ice from sidewalks, roads, streets, and parking lots. Salt is very soluble and therefore ends up in both the surface water and groundwater. In addition, contamination from salt and sand-salt stockpiles that are inadequately protected can cause water quality problems, particularly in the groundwater.

Uncontrolled runoff, accelerated soil erosion and the associated increase in pollution potential result in costly and unnecessary environmental degradation and damage. Well planned implementation of stormwater management BMPs can prevent or control much of this damage.

The following is a select list of stormwater management BMPs for New Hampshire (RCCD, 1992).

- ***Detention and Retention Basins*** control the runoff from a given storm event and release the excess runoff in a way to reduce the impact on downstream systems. The basin releases the temporarily stored runoff over an extended period of time at a rate equal to or less than the pre-development conditions. The existing stream system will experience no greater flooding than would have occurred before development took place. However, longer duration flows may cause some stream degradation.

It should be understood that detention and retention basins generally do not decrease the volume of runoff, but do decrease the rate of runoff. This practice applies to sites where the physical conditions are conducive to constructing an embankment, emergency spillway, a storage area and a structural outlet system.

- ***Diversions*** intercept and divert water from areas where it is in excess to sites where it can be used or disposed of safely.

  Diversion are used to:

  - Divert runoff from highly erodable areas where the runoff is damaging property, causing erosion, or interfering with establishment of vegetation;
  - Divert surface flow and subsurface flow away from steeply sloping land;

- An ***infiltration trench*** provides temporary storage of runoff in the void spaces around the stone and allows the stored runoff to infiltrate into the surrounding soil. This practice applies to sites where the soils are sufficiently permeable to provide a reasonable rate of infiltration. The water table and bedrock must be lower than the design depth of the trench. This practice is not recommended where runoff water contains a high percentage of suspended materials, oils and greases unless measures are taken to remove them before they reach the trench.
- An ***extended detention dry basin*** is used to reduce peak discharges from a given storm event by controlling the release rate and to improve water quality by removing pollutants from runoff. This practice applies to sites where the physical conditions are conducive to constructing an embankment, emergency spillway, a storage area, and a designed outlet system.
- A ***dry well*** is similar to an infiltration trench. It provides temporary storage of runoff in the constructed chamber and/or in the void spaces in the aggregate and allows the stored runoff to infiltrate into the soil. This practice applies to sites where the soils are sufficiently permeable to provide a reasonable rate of infiltration. Both the water table and bedrock must be lower than the design depth of the well. This practice is not recommended where runoff water contains high concentrations of sediment, oils, greases, and floatable organic materials unless measures are taken to remove them

before they reach the well. Dry wells are generally used to store runoff from roof top areas; however they can be used to provide storage and infiltration from catch basins where conditions permit.

- A ***level spreader*** changes concentrated flow into sheet flow and then outlets it onto stable areas without causing erosion. An example would be at the outlet of a diversion or a waterway. The level spreader is used where it can be constructed on undisturbed soils, where the area directly below the spreader is stabilized by existing vegetation, where the water will not re-concentrate immediately below the spreader, and where there is at least 100 feet of vegetated area between the spreader and surface water.
- ***Rock riprap*** protects soil from erosion due to concentrated runoff. It is used to stabilize slopes that are unstable due to seepage. It is also used to slow the velocity of concentrated runoff which in turn increases the potential for infiltration. Rock riprap can be used at the outlets of pipes and constructed channels where the velocity of flow from these structures exceeds the capacity of the downstream area to resist erosion. Rock riprap can be used for wave protection on lake shores and beaches. The practice can be used for storm drain outlets, in channels, in roadside ditches, on unstable slopes, at the toe of slopes, and for drop structures.
- A ***vegetated filter strip*** improves water quality by removing sediment and other pollutants from runoff as it flows through the filter strip. Some of the sediment and pollutants are removed by filtering, absorption, adsorption and settling as the velocity of flow is reduced. This practice applies to any site where adequate vegetation can be established and maintained. Vegetative filter strips can be used effectively:
    - surrounding stormwater management infiltration practices to reduce the sediment load delivered to the structures;
    - adjacent to all water courses such as waterways and diversions and water bodies such as streams, ponds, and lakes;
    - at the outlets of stormwater management structures; or
    - along the top of and at the base of slopes.
- ***Vegetated swales*** improve water quality by the treatment and removal of pollutants

from stormwater runoff, increase infiltration, and reduce potential erosion from the discharge of runoff. This practice applies to all sites where a dense stand of vegetation can be established and where either a stable outlet exists or can be constructed as a suitable conveyance system to safely dispose of the runoff flowing from the swale. The swale can be used by itself or in combination with other stormwater management and/or erosion and sediment control practices to achieve the water quality improvement or flood peak reduction desired.

Stormwater management within the Pawtuckaway Lake watershed will focus on developing and implementing appropriate BMPs on a site specific basis for individual sub-watersheds.

3. Management of the Fernald's Brook A Subwatershed

Although Fernalds Brook A only contributes 3.6 percent of the water to Pawtuckaway Lake, it accounts for 11.0 percent (52.6 kg) of the annual phosphorus load.

Fernalds Brook A also contributes the greatest tributary phosphorus concentration to Pawtuckaway Lake when compared to the twelve other inflowing tributaries.

The high concentrations of phosphorus reaching the lake through Fernalds Brook A have the potential for causing the greatest negative impact to the receiving waters. Fernalds Brook A had a study year mean of 75.0 µg/L for total phosphorus concentration which greatly exceeds the mean epilimnetic concentration of 12.0 µg/L. This concentrated influx of phosphorus can raise the general phosphorus concentration of Pawtuckaway Lake and accelerate the process of cultural eutrophication. Because of the significance of phosphorus loading source, Fernalds Brook A is a significant component to the nutrient budget Fernalds Brook A is one phosphorus source that can be controlled and will be a key recommendation for watershed management.

a. Nutrient Reduction Utilizing Agricultural Best Management Practices. Fernalds Dairy Farm currently operates in Nottingham Square on property that is drained by the headwaters of Fernalds Brook A. Historical manure handling practices consisted of field stacking manure during the winter months until conditions were favorable for land application in the spring.

The cumulative effects of annual field stacking procedures along with overgrazing and devegetation of sloping pastures led to significant water quality degradation within the Fernalds

Brook A subwatershed. In 1992, construction of a manure storage pit, milk-room waste settling basin, and constructed wetland for treatment of milkroom waste were completed in an effort to address the non-point source pollution problem generated on the property. The constructed agricultural Best Management Practices (BMPs) provide adequate storage and treatment for the manure and parlor room wastes generated in the main diary barn. However, the problems associated with roof runoff, erosion, manure deposition and water quality degradation caused by the unconfined herd of replacement animals has not been addressed. Implementation of additional agricultural BMPs specifically designed for this site will effectively eliminate nutrient sources and prevent further water quality degradation from occurring in the head water area of Fernalds Brook A.

In 1994, technical assistance and design criteria for the development of a Best Management System were provided by personnel from the Rockingham County Soil Conservation Service. Designs for the individual component BMPs were the product of several site visits and surveys, as well as a number of meetings between SCS personnel, the field coordinator of the Diagnostic/Feasibility Study and the owner of the farm. BMPs were targeted to achieve maximum levels of pollutant removal from agricultural runoff and associated activities while offering the landowner low maintenance alternatives, improved working conditions, and reduced nutrient loss from manure. It is anticipated that the implementation of these additional BMPs at Fernalds Farm will reduce one of the most significant sources of phosphorus to Pawtuckaway Lake.

i. Construction of Heavy Use Area. The current dairy barn and existing BMPs provide containment for the milking herd manure and milk-room wastes generated in the barn. However, no provisions were made for the unconfined replacement herd that comprises approximately fifty animals (heifers & calves). Construction of a concrete heavy use area sized for fifty animals would confine the replacement herd during feeding and retain large volumes of manure on an impervious surface where it can be easily managed. This 45'x40' concrete pad will eventually become part of the floor for a proposed heifer/calf barn which will provide confinement for the entire herd. This will allow for rotational grazing practices on the property which will minimize the impacts of overgrazing on unstabilized soil and ensure proper manure handling techniques. Construction of a heavy use area would result in the following component costs:

Concrete: ±60 yd^3 @ \$55.00/yd^3 = \$3,300.00

Welded Wire Fabric	= $ 300.00
Bank-Run Gravel: ±70 yd^3 @ 7.00/yd^3	= $ 490.00
Labor (for forming & pouring concrete)	= $2,000.00
Total Cost	= $6,090.00

ii. Construction of Manure Storage Facility. Construction of a concrete-lined manure pit sized for 100 young stock and replacement animals (~800 lb) will provide 6 months worth of manure storage for the newly constructed heavy use area and proposed confinement barn. The earthen berm storage facility will be constructed on the south side of the new heavy use area adjacent to the existing manure pit. This will allow for efficient manure handling and storage as well as providing overflow containment for the exiting manure pit. A concrete ramp and loading area will be incorporated into the pit design to ensure safe transfer of the manure from the pit into spreading equipment and allow for efficient and timely waste removal. Once constructed, the manure storage facility will provide complete containment for manure produced in the dairy barn and the proposed heifer/calf barn, thereby eliminating a significant nutrient source from the property. Construction costs for the manure pit and concrete loading area with ramp are estimated below:

Concrete (pit floor): ±81 yd^3 @ $55.00/$yd^3$	=$ 4,500.00
Concrete (push-off wall with footing): ± yd^3 @ $55.00/$yd^3$	=$ 440.00
Welded Wire Fabric & Rebar:	=$ 500.00
Labor (for forming & pouring concrete):	=$ 3,000.00
Bank-Run Gravel: 125 yd^3 @ $7.00/$yd^3$	=$ 875.00
Concrete (ramp & loading area): ±36 yd^3 @ $55.00/$yd^3$	=$ 1,980.00
4" Diameter Tile Drainage Pipe: ±200 linear ft @ $80.00/250' roll	=$ 80.00
30 ea. 3'x3'x3' concrete blocks @ $35.00/Block	=$ 1,050.00
Total Cost	=$12,425.00

iii. Construction of Suspended Roof Gutters. Approximately sixty percent of the runoff generated on the farm originates from the roofs of several buildings and the existing (200' x 60') dairy barn. These large volumes of unmanaged runoff begin as clean rainwater. Upon reaching the

ground, nutrients, bacteria, sand and silt are incorporated creating contaminated surface runoff. This uncontrolled runoff reduces the storage capacity of the existing manure pit and the settling basin designed to treat milk-room wastes.

Proper management of roof runoff can increase the holding capacity of manure storage facilities and other BMPs by reducing the volume occupied by water. Improved management will reduce the potential for soil erosion and will eliminate a primary means of nutrient transport from agricultural areas.

Construction of suspended roof gutters will divert rain runoff away from constructed BMPs and areas susceptible to erosion. This practice will reduce runoff volume by approximately 60% and minimize the negative impacts to surface waters originating from this area. The proposed roof gutters will empty into catch basins and be discharged through underground PVC outlets to stable vegetated surface areas . Construction of level spreaders will evenly discharge clean water as sheet flow and ensure proper infiltration by soils and vegetation.

Constructing suspended roof gutters on existing structures and the proposed heifer/calf barn would create the following component costs:

(SDR) 6" Diameter Pipe	
1/2 section for roof gutter and full section used for downspout):	
±600 linear ft @ $1.90 ft	=$ 1,140.00
6" Diameter sched. 40 PVC (for underground outlets):	
±1000 linear ft @ ±$4.20/ft	=$ 4,200.00
8" Diameter Sched. 40 PVC (for underground outlets):	
±400 linear ft @ ±6.80/ft	=$ 2,720.00
10 ea. 4'x4'x4' diameter concrete catch basins @ ±200.00 ea.	=$ 2,000.00
2"x10' Pressure Treated Wood (for facia boards)	=$ 2,000.00
Fabricated or Standard Brackets	=$ 800.00
3" Deck Screws	=$ 100.00
Labor (for cutting pipe & building gutters)	=$ 1,000.00
Total Cost	=$13,960.00

iv. Construction of a Sod Waterway. The upper pasture at Fernalds Dairy Farm is situated

on the west side of Route 156 and is susceptible to erosion during rain events and spring runoff. Runoff from impervious roof tops, parking areas, as well as the overflow from the constructed wetland for milkhouse treatment is channeled through the upper pasture, eventually discharging into a constructed retention pond at the base of the pasture.

The current drainage channel is severely eroded and offers little or no opportunity for nutrient filtration or sediment removal from the concentrated runoff reaching the pasture. Construction of a sod waterway will provide for the safe transport of runoff water with reduced erosion potential and will promote soil infiltration and nutrient uptake by vegetation.

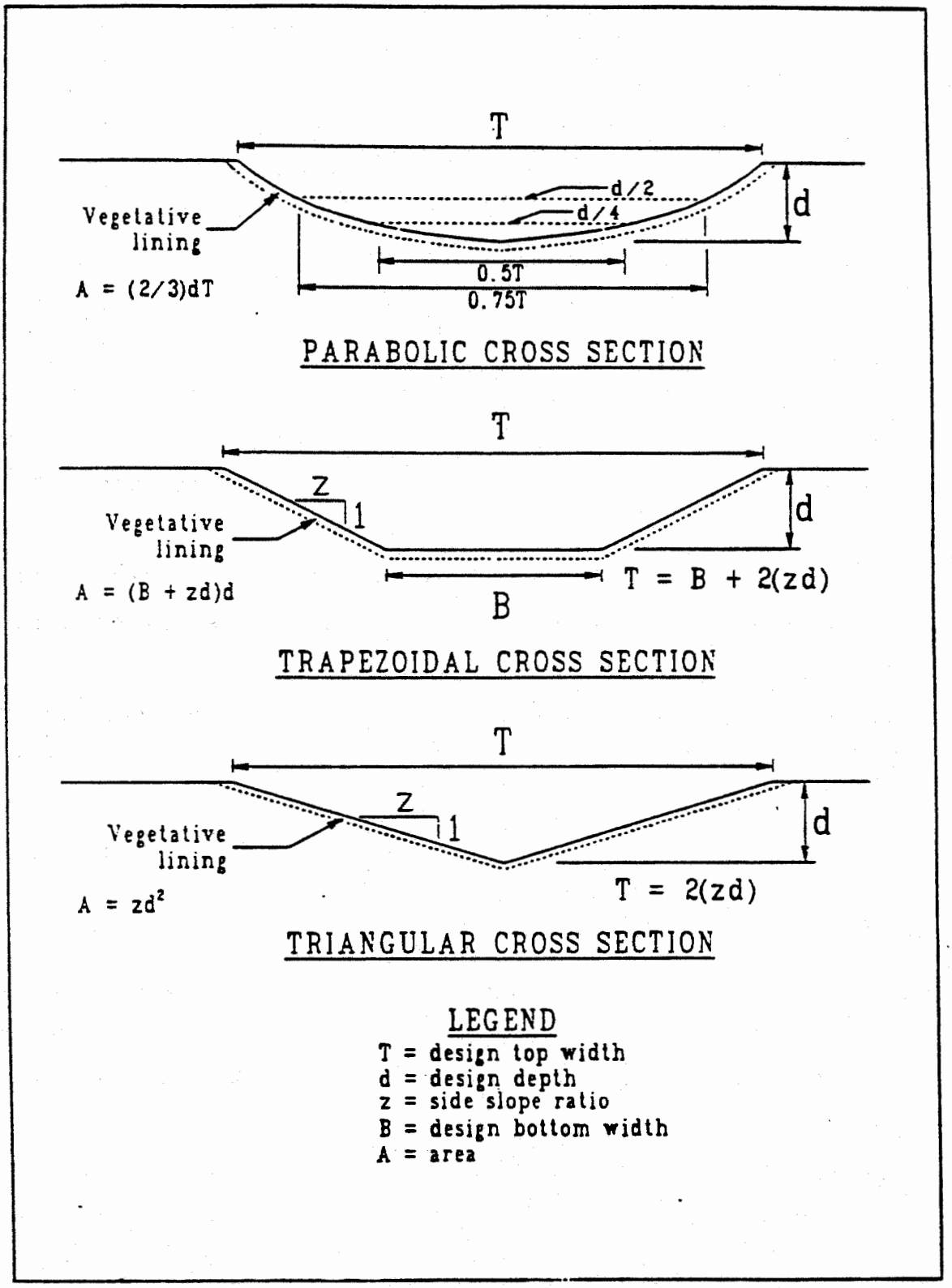
Although various designs exist for sod waterways (Figure XI-1), a parabolic grassed swale will provide the farm operator with the optimum maintenance conditions while offering efficient treatment and control of surface runoff. To ensure sheet flow into the lower pasture and to prevent scouring and erosion, the construction of a level spreader may be required at the sod waterway outlet.

The construction of a sod waterway at Fernalds Dairy Farm will involve some minor earthwork and grading of existing slopes. Seeding of the waterway will be conducted by the owner when the pasture is reseeded for hay. The overall costs for construction of the waterway are included under equipment time for the entire project which is estimated to be approximately $9,960.00. The component costs for equipment time are listed below:

Excavator: 8 days @ $90.00/hr		=$5,760.00
Bulldozer: 7 days @ $75.00/hr		=$4,200.00
	Total Cost	=$9,960.00

The total estimated cost for the installation of all additional agricultural BMPs as designed for the Fernalds Dairy Farm is approximately $42,500.00. Once the BMPs have been installed, the problems of proper manure storage and concentrated runoff will be virtually eliminated. The construction of the heifer/calf barn will provide complete confinement of the replacement herd during potential periods of severe erosion and promote improved manure management practices. Also, the rotational grazing of small numbers of animals on the upper pastures during dry periods will significantly reduce erosion and promote the establishment of improved vegetative cover.

Significant water quality improvements are anticipated within Fernalds Brook A upon the



Source: Rockingham County Conservation District

Figure XI-I
Typical Water Way Cross Section

completion of the proposed agricultural BMPs for Fernalds Dairy Farm. Complete designs and cost estimates for this project were prepared by personnel from the Rockingham County Soil Conservation Services and appear in Appendix XI-2.

b. Pollutant Removal from Stormwater Runoff. Although considerable first and second tier development has occurred around the shoreline of Pawtuckaway Lake, no provisions have been made to collect stormwater runoff. The uncontrolled stormwater runoff within the Pawtuckaway Lake watershed contributes to the annual phosphorus budget as well as depositing large volumes of sand and silt into tributaries and eventually the lake itself.

Dennis (1986) estimated that the four largest runoff events accounted for 65 percent of the total annual phosphorus export to a Maine lake, and a single storm event contributed almost 50 percent of the phosphorus load to that same lake. Many studies have shown that much of the phosphorus load to a lake can occur during the first centimeter of rainfall. A study conducted in a Maine watershed estimated that 69 percent of the phosphorus export occurred during the first centimeter of runoff while 90 percent and 97 percent occurred during the first two centimeters and three centimeters respectively.

Best Management Practices designed for stormwater runoff within the Fernalds Brook A subwatershed as well as the entire Pawtuckaway Lake watershed should focus on erosion and sediment control and water quality control. Uncontrolled runoff channels and roadside drainage ditches that drain into tributaries or directly into Pawtuckaway Lake should be eliminated in favor of a three tier approach of flow reduction, particle settlement and infiltration. One means of achieving these goals is to replace uncontrolled runoff sites that have eroded land segments with a rock riprap channel that grades into either a vegetated filter strip or vegetated swale. Another option for stormwater management in the Pawtuckaway Lake watershed is to investigate new stormwater treatment technologies that have been developed which provide a cost-effective solution to mitigating stormwater impacts to lakes and streams.

i. Installation of Rock Riprap Channel. Rock riprap is a permanent, erosion-resistant layer of loose, well-graded stones, having sufficient size, gradation, and thickness to provide stability and protection to underlying materials (RCCD, 1992). The key capacity of a riprap channel installed within the Fernalds Brook A subwatershed would be to slow the velocity of concentrated

runoff along Barderry Lane before it enters a vegetated swale.

A well-graded mixture of rock sizes should be used for riprap rather than rocks of a uniform size. Properly sized bedding or geotextile fabric is needed to prevent erosion or undermining of the natural underlying material. The thickness of the riprap layer shall be 1.5 times the maximum stone equivalent diameter. The cost of constructing a riprap channel or infiltration trench varies depending on the area of the trench, the availability of stone fill and whether or not the Nottingham Public Works Department performs the construction. Generalized component costs for constructing a typical 100'x6'x6' stormwater infiltration trench are listed below:

Excavation (if contracted) of a ±133 yd^3 trench @ \$10.00/yd^3	= \$1,333.00
Rock Riprap (4"-6" stone): ±133 yd^3 @ \$25.00/yd^3	= \$3,325.00
Geotextile Filter Fabric: ±200 yd^3 @ \$3.00/yd^2	= \$ 600.00
Total Cost	= \$5,258.00

ii. Vegetated Swale Construction. Vegetated swales are either natural or constructed broad channels with dense vegetation that are designed to treat runoff and dispose of it safely into the natural drainage system. Vegetated swales treat and remove pollutants from stormwater runoff, increase infiltration, and reduce potential erosion from the discharge of runoff. When used in conjunction with another stormwater management and/or erosion and sediment control practice such as a rock riprap trench (Figure XI-2), a high level of water quality improvement and reduction in erosion and sedimentation can be achieved. This combined stormwater management technique would provide significant improvements on Barderry Lane where Fernalds Brook A discharges through a culvert under the road. The combined benefits of a rock riprap trench complemented by a vegetated swale will reduce the severe erosional damage occurring in the drainage ditch on the east side of the road. During the study year, it was not uncommon to find 10 to 14 inches of sand in the Fernalds Brook A culvert and stream bed after a significant rain event.

The Rockingham County Conservation District recommends the following planning considerations and design criteria for maximizing the effectiveness of vegetative swales:

- The seasonal high water table should be at least one to two feet below the bottom of the swale in order to provide for more effective infiltration and treatment of the runoff and to provide better growing conditions for the vegetation.

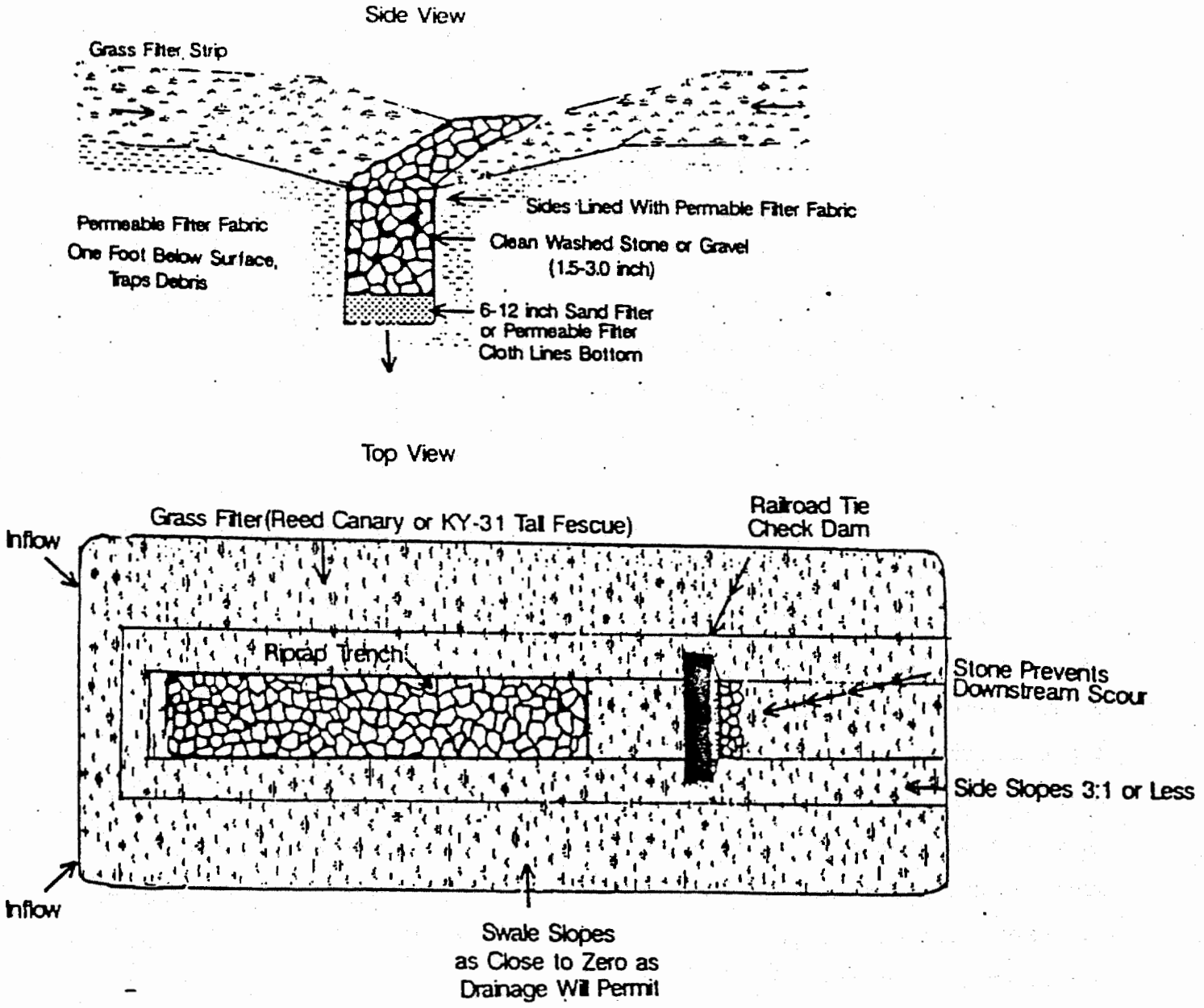


Figure XI-2
Proposed Best Management Practices Model for Stormwater Treatment

- The swale should be constructed prior to the rock riprap trench which will drain into it and flow should be diverted out of the swale until adequate vegetation is established.
- The minimum capacity shall be that required to convey the peak runoff expected from a 10 year frequency 24-hour duration storm.
- The maximum design velocity for a vegetated swale shall be 1.0 foot per second during a 10-year frequency storm.
- The minimum length of a vegetated swale shall be 100 feet.
- There should be base flow present in the swale and a temporary diversion should be used to divert runoff away from the swale until vegetation is established that is capable of preventing erosion.
- Timely maintenance is essential to keep the vegetation in the swale in good condition. The swale should be inspected periodically and after every major storm to determine the condition of the swale.
- Check dams may be incorporated into the swale design to promote settling and infiltration. Rock riprap should be placed on the downstream side of the dam to prevent scouring.
- The construction of a 100 x 15 foot vegetated swale at the base of a rock riprap channel would incur the following costs:

Excavation (if contracted) of a ±56 yd^3 swale @ $10.00/yd3	= $560.00
Rock Riprap (below check dam): ±6 yd^3 @ $25.00/$yd^3$	= $150.00
Vegetative Swale Seeding (Type 44): ±4.0 lbs. @ $6.00/lb.	= $ 24.00
Total Cost	= $734.00

iii. Alternative Stormwater Treatment Technology. Many new stormwater treatment devices have been developed recently which provide a cost-effective solution to mitigating stormwater impacts upon water quality in streams, lakes, wetlands and groundwater. One new technology developed by Storm Treat Systems, Inc. consists of a series of 9-foot diameter polyethylene tanks that combine the benefits of sedimentation chambers, filtering screens and wetland filtration to reduce the negative impacts of stormwater (Figure XI-3).

The stormwater system is designed to connect directly to existing drainage structures (most commonly a catch basin), and accommodates the first flush of runoff (one-half inch of rain), believed to contain the vast majority of pollutants. The remainder of the runoff will bypass the system as overflow into a rock riprap channel. However, approximately 90% of the storm events in New England are one-half inch or less which significantly reduces overflow volumes of stormwater.

Several pilot projects, demonstration studies and EPA funded 319 grants have utilized the storm treat systems throughout New England. Along with significant removal rates of solids and settleables, a 90 percent pollutant removal efficiency has been reported. Bacteria, phosphorus and suspended solids have documented removal rates of 91 percent, 32 percent and 94 percent respectively (Horsley, 1995).

This alternative method to stormwater management is designed to treat stormwater high in the watershed close to its source, capturing the first flush of stormwater runoff which can contain over 90 percent of the pollutants generated in a storm event. The feasibility of installing this stormwater treatment device within the Fernalds Brook A subwatershed should be investigated. The cost of the stormwater system is $3,000.00 for the 9-foot diameter tanks (handling 1/10 acre of impervious surface for 1/2 inch runoff). The number of tanks required is determined by the area of impervious surfaces within the drainage area.

Assuming that the existing uncontrolled runoff channel adjacent to Barderry Lane comprises 4/10 acres of impervious surface area, the required number of storm treat tanks would be four with an overall installation cost of $12,000. However, installation of one or two treatment tanks in conjunction with a vegetated filter strip and rock riprap channel could provide cost effective stormwater treatment within the Fernalds Brook A subwatershed as well as the entire Pawtuckaway Lake watershed.

E. ARTIFICIAL PHOSPHORUS ABATEMENT

1. General Discussion

Several studies (Jones and Lee, 1977; NHWSPCD, 1975) have indicated that a properly

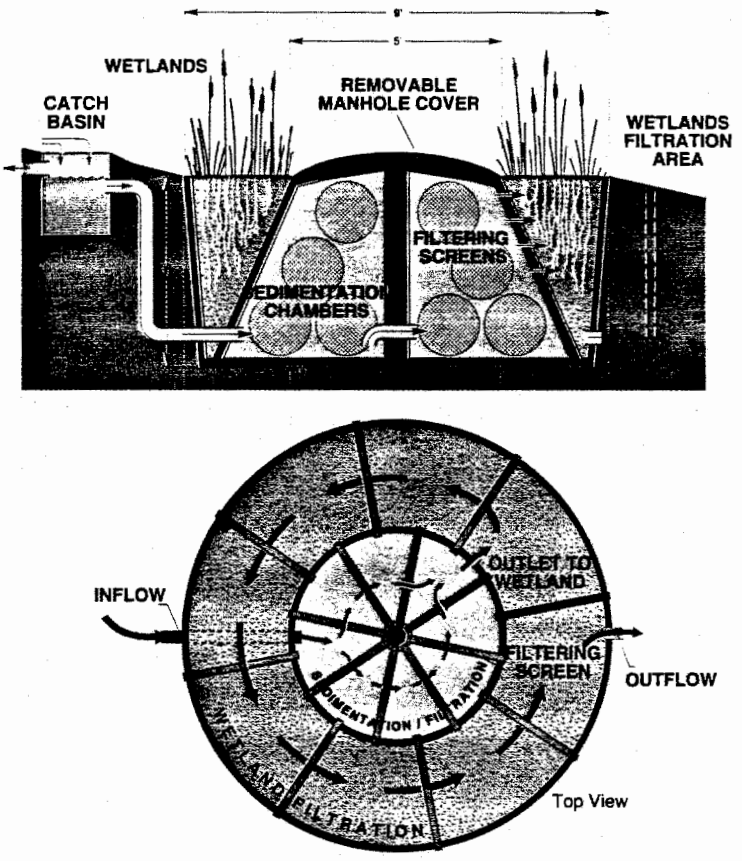


Figure XI-3
Storm Treat Systems Alternative Treatment Stormwater Collection System

designed, constructed, and maintained septic system will not generally contribute significant amounts of phosphorus to surface waters or cause extensive fertilization. However, because of their use in unsuitable areas or because of improper design, construction, or maintenance, it is estimated that over one-half of the systems in use today fail before their designed life of fifteen to twenty years is completed (Scalf etal., 1977).

The most common type of individual disposal system is the septic tank - leachfield system (Figure XI-4). The septic tank functions to separate the solids, both floating and settleable, from the liquid material. The accumulated sludge should be pumped out every three to five years. The liquid is discharged from the tank through piping material and distributed over the leaching area, which is designed to absorb the effluent and to remove the impurities before it percolates to the groundwater.

In 1967, the New Hampshire legislature enacted a law to protect water supplies from pollution by subsurface disposal systems, and directed the Water Supply and Pollution Control Division to establish minimum, state-wide requirements for properly designed systems. However, this law provided no control over existing systems. The requirements most pertinent to the prevention of surface water contamination by phosphorus are:

- Location of the system with respect to the surface water body,
- Soil permeability: the rate of water transmission through saturated soil, of which estimated soil retention coefficients varied with different lake sections,
- Land slope: steep slopes may cause erosion problems when associated with low permeability soils,
- System age: soils have only a finite capacity for phosphorus absorption,
- Per capita occupancy: (household population based on sanitary survey),
- Fraction of year system is in use: (i.e., summer cottages or year-round dwellings), and
- Additional water utilizing machinery: (i.e., washing machines, dish washers, or garbage disposals).

2. Pawtuckaway Lake Sanitary Survey Results

A sanitary survey of the Pawtuckaway Lake shoreline was conducted during the summer and

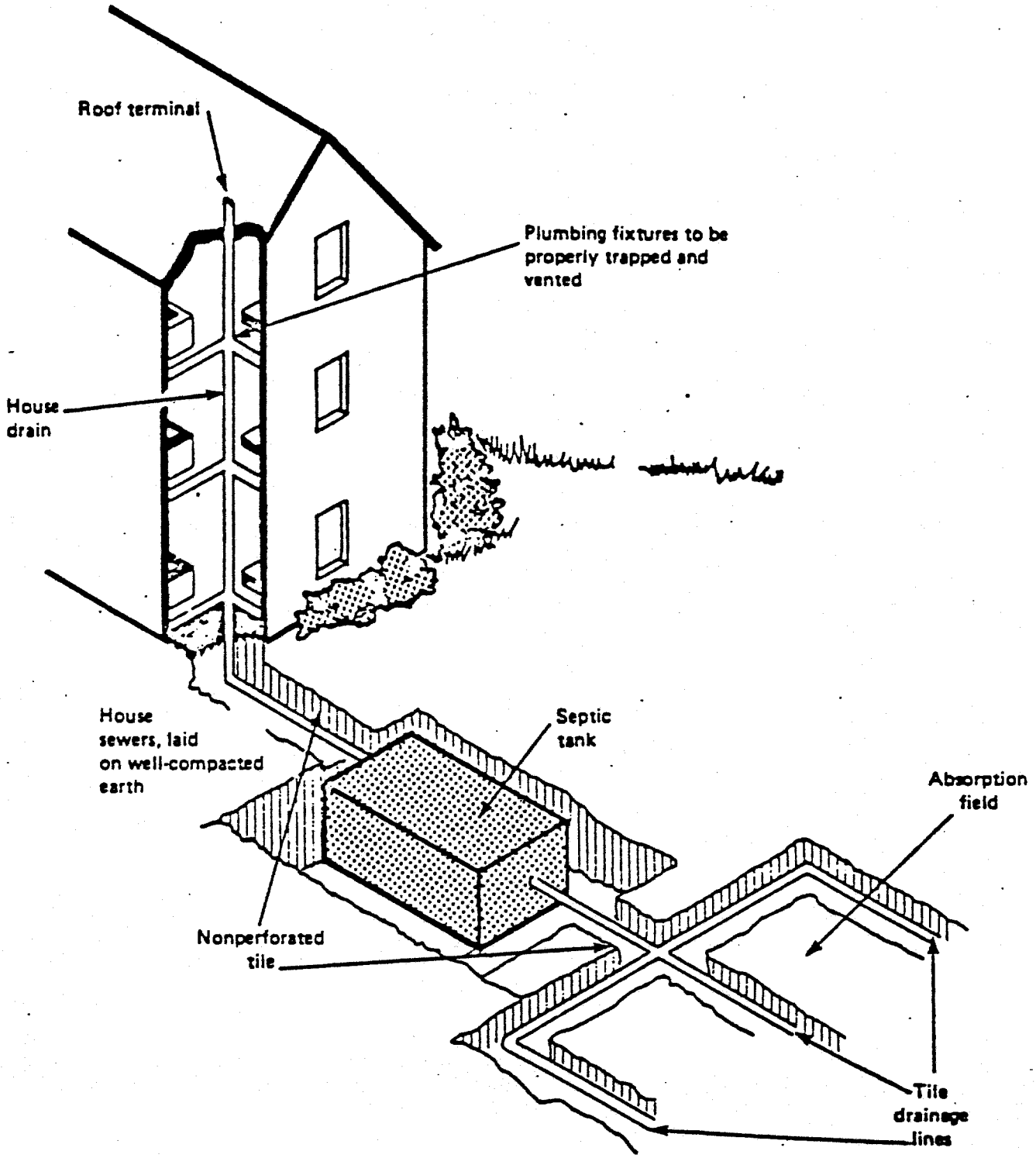


Figure XI-4
General Septic System Design

fall of 1992 (Appendix VIII-2). A sanitary survey typically consists of a visual inspection of the property, interviews with residents to discuss various problems and the compilation of information regarding the system, such as type of system, age, maintenance schedule, depth to groundwater etc. This is an extremely time consuming task, often requiring numerous visits to find people home, and the information obtained is questionable at best. After several weeks of visiting first tier homes around Pawtuckaway Lake, only 27% of the 326 shorefront lots had been accounted for. During the fall of 1992, a sanitary survey questionnaire was distributed to the homeowners around Pawtuckaway Lake in an effort to gather more information about septic systems. The questionnaires received in the fall of 1992 from Pawtuckaway Lake residents accounted for an additional 26% of the first tier residences on the lake. The questionnaires combined with field visits accounted for 172 first tier homes or 57% of the developed shoreline. Although a greater percentage of interviewed homeowners is generally desired, given the number of assumptions inherent in the calculations and the type of information obtained, it was not felt that further effort would significantly increase the reliability of the projections. In addition, information on slope and distance to the lake and groundwater could be judged in many instances without an actual interview.

The 1992 sanitary survey of Pawtuckaway Lake revealed that out of the 172 completed surveys, 88 systems (51%) were functioning properly, 59 systems (34%) were suspected failures and the remaining 25 systems (14%) were determined to be failed individual subsurface disposal systems. A suspected failure was assigned if a system was less than 75 feet from the lake or greater than 20 years old. A failed system was determined to be any system exhibiting each of the characteristics mentioned above.

Many of the systems around Pawtuckaway Lake predate the 1967 rules and regulations establishing design and installation criteria. In fact, the average age of systems surveyed during the 1992 study year was twenty years. This indicates that although systems are perceived to be functioning properly at present, a large portion of systems will be older than twenty years very shortly and will have passed their expected design lives and will be considered potential problems. The upgrading of septic systems could occur through four channels:

- Voluntary replacement;
- Proven failure and subsequent order to replace from the health officer or the DES Subsurface Bureau;
- Conversion from seasonal to year round use or addition of bedrooms; or

- Engineering study conducted prior to the house sale showing evidence that the septic system was in need of repairs or replacement.

The pollution abatement alternatives of no action, regional treatment, group or cluster systems, and upgrading of individual systems were evaluated.

The estimated impact of phosphorus from groundwater was measured directly. Much of the 20.8% phosphorus loading from the groundwater is from septic system leachate. An occupancy of 2.77 people for year-round, and 5 people for seasonal dwellings is estimated by the N.H. Office of State Planning for the following wastewater treatment alternatives. A per capita sewage contribution of 75 gallons per day is assumed based on actual flows to a treatment plant in the area, and generally accepted per capita flows for New England.

3. Wastewater Treatment Alternatives

a. No Action. One option is to take no action to abate the identified and suspected pollution. The impact of this alternative would be continued degradation of the water quality of Pawtuckaway Lake.

When septic systems fail, they present a potential health hazard associated with the presence of untreated human wastes above ground and in surface waters. Groundwater contamination and subsequent pollution of drinking water is probable in many areas. Many older systems will leach phosphorus into the groundwater and lake, accelerating the eutrophication process in Pawtuckaway Lake.

On the basis of the sanitary survey, numerous individual systems do not meet accepted design standards. Many of these systems are suspected failures now and may develop problems at any time.

b. Regional Waste Treatment. There is no feasible regional waste treatment alternative for Pawtuckaway Lake at this time. The closest municipal wastewater treatment facility to Pawtuckaway Lake is located in Epping, New Hampshire which is approximately six miles from the lake. At the current time, the Epping municipal wastewater treatment plant (WWTP) is under a moratorium for all new connections to the system.

In addition to the current moratorium on new connections to the WWTP, the construction

of conventional or low pressure sewers around the lake to incorporate the entire shore front community would be extremely cost prohibitive.

c. Cluster Systems. Cluster systems are innovative systems that collect and treat sewage for many homes or groups of homes around a lake. First tier development around Pawtuckaway Lake could elect for the alternative of subsurface treatment systems with conventional collection from clusters or groups of individual homes. These cluster systems are usually simple and a cost effective alternative for the secondary treatment of small flows. Installations range from 500 gpd to 300,000 gpd. One company has developed a system that removes nitrogen and phosphorus. This system was developed especially for areas that are environmentally sensitive.

Cluster systems are becoming more popular as alternative systems and research conducted on these units show that more nutrients are trapped so less enter the waterbody. There are several cluster systems that are now operational in New England and the Pawtuckaway Lake community could benefit from this type of waste treatment technology.

Acquisition of funds by the Town of Nottingham through the State's Revolving Loan Fund (SRF) would be the most cost-effective method of constructing cluster systems around the Pawtuckaway Lake shoreline. SRF funds are loaned to communities at a low rate of interest for eligible non-point source pollution control management programs. These funds cover one hundred percent of the project costs and may be paid back to the state over a five to twenty year period depending on the town budget and loan agreement.

Although a user fee would be required of all involved homes around the lake, the environmental and economic benefits greatly outweigh the option of individual subsurface system upgrades which can cost up to $10,000.

The feasibility of developing cluster type subsurface wastewater systems and the acquisition of funds from the SRF program should be investigated by the Town of Nottingham.

d. Upgrading of Individual Systems. A wide range of individual treatment systems has been explored in the last few years due to a renewed interest in on-site disposal systems. The Federal Environmental Protection Agency has a thorough review system in their draft report "Innovative and Alternative Technology Assessment Manual." The fact sheets from that manual give a good outline of available alternatives. A discussion of many of these alternatives will follow.

i. Septic Tank and Leaching Field. Individual treatment systems installed in recent years normally consist of a septic tank for solids separation and degradation, and a soil absorption system or leachfield to aid liquid percolation into the soil. The size of the tank is proportional to the expected usage and the leaching field is sized according to both usage and soil characteristics. When soils are poor (i.e., low permeability) or flows are high, the leaching field must be large. Problems arise when the required design of the field is impractical or impossible due to lot restrictions and/or soil and groundwater conditions.

ii. Compost Toilets. A reduction in wastewater volume entering the leaching field is possible by the use of a waterless toilet of the composting type. A discussion of this alternative requires an understanding of domestic wastewater composition. Wastewater is the by-product of all water used within the home including toilet facilities, cleaning, cooking and personal hygiene. The wastewater associated with toilet and urinal usage is considered concentrated human waste and classified as black water. Gray water comprises the remainder of the domestic wastewater such as water from baths, showers, sinks and clothes washers. By eliminating toilet and urinal usage (black water) about a 40% reduction in total flow can be achieved.

Compost toilets decompose human wastes by a natural biological process. With the aid of air and/or some heat, human waste will degrade itself over an extended period of time. This process is similar to the compost process in composting leaves and manure piles used for garden and agricultural crop enrichment. Basically, there are two types of compost systems. One utilizes a large compost chamber that must be installed in the basement or underground, and is called an external unit. The larger external units rely completely on natural processes. They have no external heat addition or composting aids as in the smaller internal units. The addition of heat and compost aids (such as a starter bed or enzymes) speeds the degradation process thereby decreasing the required volume. The treatment process is the same in each. Toilet wastes enter through a toilet chute and accumulate in the compost chamber. Here, with air supplied through ventilation, warm temperatures and humidity, the waste begins to decompose. The process should create no odor since released gases and water are removed by outside ventilation and evaporation. Organic material such as food wastes should be introduced into the chamber to aid in the composting process. The total decomposition time ranges from 1-1/2 to 2 years initially, and from 3 to 12 months thereafter. At the end of this time, the wastes have been reduced to a rich, odorless humus that can be removed and

used as garden soil. This is the only required maintenance except for the occasional addition of enzymes for certain internal units. For the internal units, electricity is required for heating and a ventilation fan, while some external units utilize convection currents for ventilation. The amount of humus produced varies with the system and ranges from 15 to 60 pounds per year per person.

Composting toilets would provide an excellent alternative to Pawtuckaway State Park which currently utilizes conventional septic tanks and leachfields.

iii. Individual Treatment and Recycle. The recycle system is a self-contained, package treatment unit specifically designed to treat black water. Wastes are transported in about 2 quarts of water per flush, by means of vacuum, to the self-contained unit where the black water is treated by a combination of anaerobic and aerobic decomposition, settling, filtering, and purification by ultraviolet light. This treatment and purification process operates efficiently at temperatures between 55°F and 120°F and must be protected against freezing. The recycled water is returned to a flush holding tank. The recycle toilet operates on 110 volts AC and consumes from 300 to 500 KWH of electricity per month of operation. The system requires regular maintenance. Since the recycle toilet uses cultured bacteria to accelerate digestion of solids, the bacteria must be added periodically in the form of dry packets. The water level should be checked every two weeks. Periodic replacement of some parts is required. Activated carbon, used in the filtering system, needs annual replacement as does the ultraviolet lamp bulb used in purification, the air filter cartridges on the vacuum and aeration pumps and the three-way solenoid valve regulating vacuum and aeration.

iv. Low Water Flush Toilets. Several low water flush toilets are available which utilize from one quart to two gallons of water instead of the average five to eight gallons used by a standard flush toilet. A limited capacity self-contained tank controls the volume of flushing water. Air in the tank is compressed as it is filled with water. When flushed, the compressed air forces the water through the toilet bowl at a faster rate thereby requiring a lower volume to empty the bowl.

Other low water flush toilets involve mechanical equipment and use either vacuum or pressure to empty the toilet bowl. Basically, the components for a one toilet vacuum system are the toilet, vacuum pump, and plumbing. The vacuum pump maintains a vacuum in the plumbing at all times. A valve separates the toilet bowl and the plumbing. When activated, the valve opens allowing the contents of the toilet bowl to be drawn into the plumbing. These wastes remain under

vacuum until they reach the holding or discharge tank. The maintenance required is minimal, but mechanical equipment is involved to maintain the pressure or vacuum. Although the water content is lowered, the amount of organics, solids, toxics, etc. is still the same as the conventional flush toilet.

v. Gray Water Flow Reduction. Unlike concentrated human waste, gray water cannot be completely eliminated as domestic wastewater by recycling or composting. However, many devices are available for water conservation that greatly reduce gray water quantities. Flow restrictors and regulators can be placed on faucets and shower heads. The average person showering will use 6 gallons of water per minute for 7.5 minutes with a standard shower head. Should a 3-gallon per minute flow reduction be installed, an average family of four persons could save 90 gallons of water per day, assuming each took one shower a day.

Water conservation and wastewater treatment methods described above may result in significant flow reduction to the ultimate treatment and disposal system. Assuming the average family produced 75 gallons per day per person, an estimated flow for their household is about 300 gallons/day. Table XI-2 displays estimated resulting flows.

Table XI-2
Household Wastewater Flow Quantities With Water Conservation and Separation

Item	Design Criteria	Percentage Flow Reduction	Reduced Wastewater Flow*
1. Compost incinerator or recycle toilet	Flow-300 gpd for average dwelling	3.5%	195
2. Low water gravity flush toilet	Flow-300 gpd limited to 3½ gallons per cycle	7.5%	278
3. Low water vacuum flush toilet	Flow-300 gpd, limited to 3½ gallons per cycle	7.5%	278
4. Shower flow control device	Limited to 2 gpm	4.0%	288
5. Combination of 1 and 4 above		7.5%	483
6. Combination of 2 or 3 and 4		11.5%	566

*Per Day

vi. Aerobic Wastewater Treatment Unit. Many alternative individual systems utilize an aerobic process. The operating principle of aerobic treatment units is the same as that used in many conventional municipal wastewater treatment plants of the activated sludge type. In essence, these household/on-site systems are miniature models of the larger municipal plants. Some units are complex while others are simply an aeration chamber.

This process of aeration and subsequent settling is called secondary treatment. It is a biological process that removes organics which cannot be settled out in primary treatment such as the septic tank. The incoming wastewater is initially treated in order to make it acceptable for aeration. This primary treatment is accomplished by various methods including settling of heavy solids, grinding of large particles or rough filtering. The wastewater then enters the aeration chamber where it undergoes aerobic decomposition. Solids formed by the aerobic degradation process are subsequently allowed to settle out in the settling chamber. After the settling chamber, the effluent is discharged to the ground. The end product, though better quality than septic tank effluent, does contain substantial amounts of pollutants which must be removed by the soil.

The biological secondary treatment process utilized in these units is a sensitive one. This, in addition to the mechanical equipment involved, requires that a unit be monitored and maintained on a continual basis. If this equipment is purchased, it is highly recommended that the home owner obtain a service contract with a reliable repair service and set up a schedule of maintenance calls (at least four times a year). Alarms can also be supplied which are wired into the house and activate when malfunctions occur.

vii. Wastewater Treatment Alternatives Summary. A variety of alternatives is possible for the upgrading of individual treatment systems. Each alternative has limitations for proper operation including difficult climate, terrain, soils and/or groundwater conditions, personal acceptance, technical and administrative problems.

A summary of advantages and disadvantages is shown in Table XI-3 for all alternatives previously discussed.

e. Septage Handling Alternatives. The cluster system alternative includes large septic tanks that require pumping every other year. One septage handling alternative would involve pumping of the septage by a tank truck, owned and operated by a management district for

Pawtuckaway Lake or the Town of Nottingham. Septage would be hauled to the nearest approved disposal site or wastewater treatment plant for further treatment. Hauling of raw septage to an existing wastewater treatment plant would only require the payment of a tipping fee. Wastewater treatment facilities in New Hampshire presently charge a septage disposal fee of seventy-five cents per gallon. Disposal at a land treatment site owned and operated by a town or district may be less costly once site development costs are met.

Another septage handling alternative would include contracting with a private septage hauler to periodically pump all septic tanks and be responsible for disposal. Contracting cost-estimates recently solicited from local private haulers averaged eight cents per gallon.

f. Environmental Assessment of Alternatives. The environmental effects for the various sanitary pollution abatement alternatives were evaluated. Potential environmental impacts may be summarized as follows:

i. Water Quality. The alternatives of regional and/or cluster treatment would meet present State and Federal regulations regarding acceptable treatment levels of sewage. A beneficial effect of treatment on the aquatic habitat is increased dissolved oxygen content of the water because of a reduction of organic matter and phosphorus presently flowing into the lake.

During construction of a selected alternative, the contractor will be required to provide a means to minimize both siltation and erosion. All appropriate areas of construction will be sufficiently seeded and mulched, upon completion, to prevent erosion. Where necessary, drainage swales and culverted trenches will direct surface runoff. Siltation basins will be used to intercept silt and eroded material before they enter any watercourses. Construction and implementation of the project should not appreciably affect the hydraulics of any stream.

Presently there is no municipal water supply for the lake. The private wells around the lake should not be affected by properly designed and constructed alternatives.

TABLE XI-3
INDIVIDUAL INNOVATIVE/ALTERNATIVE TREATMENT SYSTEMS

TREATMENT METHOD	ADVANTAGES	DISADVANTAGES
1. Septic tank and field	Simple operation and maintenance. Good public acceptance.	Dependent on soil and site conditions - percolation rate, depth to ledge, seasonal high water level, distance to well or surface water.
2. Compost toilets.	Eliminates black water flow.	Gray water still requires septic tank and soil absorption system. Potential for breeding of flies, odors and hydraulic overload. Problem with public acceptance.
3. Individual treatment and recycle.	Reduces flow from home.	Still requires septic tank and soil absorption system. High cost and high maintenance.
4. Low water flush	Reduces black water flows.	Concentration of organic loading still high. Gray water still requires treatment and disposal.
5. Gray water flow	Reduces volume of wastewater requiring treatment.	Concentration of organic loading still high. Treatment and disposal still required.
6. Aerobic treatment absorption bed.	Achieves higher BOD removals than conventional septic tank systems.	Variable effluent quality, semiskilled operation and maintenance required. Requires conventional soil absorption system. Does not, in general, remove phosphorus.
7. Aerobic treatment surface discharge with disinfection.	Achieves higher BOD removals than conventional septic tank systems. Avoids need of soil absorption system.	Variable effluent quality requires semiskilled O&M. Requires surface stream discharge. Does not, in general, remove phosphorus.

ii. Wetlands. All wetlands around Pawtuckaway Lake have been mapped. Although no significant environmental impact is expected, the regional treatment alternatives considered would include collection systems that must pass through wetland areas. Adequate precautions and permits will be required to minimize the primary impact of construction, with special emphasis on control of sedimentation and siltation due to erosion. Regional treatment alternatives were determined to be unfeasible and cost prohibitive at the present time which eliminates the possibility of any negative environmental impacts from occurring in wetlands around Pawtuckaway Lake.

iii. Historical and Cultural Value. It is not anticipated that the proposed alternatives will affect areas designated as having historical or cultural value. Facilities proposed for collection and treatment would be constructed below ground level, with those areas of construction being returned essentially to their original state. If treatment facilities are to be constructed in previously undisturbed areas, an archaeological study would be required.

iv. Hydrologic Impacts. The hydrologic areas of concern include increased rates of runoff, transfer of water to another watershed, modification to the water table, and transportation of groundwater contaminants. Modification of any of these factors could adversely affect the hydrologic cycle.

Increased runoff would be minimized by proper design and control during construction. If a subsurface treatment alternative is selected, a study of the transport of groundwater contaminants would be required. No other adverse impacts are anticipated.

v. Air Quality. There are no anticipated problems that would arise from the operation of the alternatives relative to air quality. Any pumping stations will be completely enclosed below ground with only a hatch for access. Any odors that may occur would only be detectable in the immediate vicinity of the pumps during maintenance.

vi. Noise. The only noise generated by the alternatives would be from pumping units. Since the pumps are located below ground in the pump station enclosure, little or no noise will be

discernible outside. During construction, noise will be generated by a variety of equipment used to excavate, grade and backfill. Construction noise is, for the most part, unavoidable. It will be necessary for the contractor to comply with existing regulations to minimize noise by employing mufflers and other devices that limit noise levels.

vii. Secondary Effects. It is not anticipated that secondary effects induced by the proposed alternatives will be significant. The proposed alternatives will service all problem areas of existing development around the lake.

Implementation of watershed management techniques will help to mitigate the decline in water quality and potential secondary effects. Management techniques include a variety of land-use and land-management practices, involving regulatory controls and BMPs.

4. State and Town Regulation for Individual Subsurface Disposal Systems

A septic system inspection program for lake residents as well as those who live on tributaries to the lake should be initiated. A rotating three year inspection program will prompt those who have inadequate systems to get them replaced.

RSA 485-A Revised Statutes Annotated of the State of New Hampshire is specifically intended to prevent pollution of surface water by "inadequate sewage or waste disposal systems". Under the power of this chapter, the New Hampshire Water Supply and Pollution Control Division regulates the design standards and construction of subsurface disposal systems. Generally, local ordinances in the Pawtuckaway Lake Watershed conform to the state regulations. Regardless of state approval, the Planning Board should state that it may require changes and additions to a proposed sewage disposal system. Most town health officers, through the power of the Planning Board may issue a cease and desist order if the system becomes non-functional. The Town of Nottingham may want to consider local regulations concerning septic system approvals that would allow the town additional control in several areas. Building permits for home conversions from seasonal to permanent use are now covered under state law.

Of particular concern at Pawtuckaway Lake is the large proportion of seasonal residences in the lake shore area. Sewage disposal systems which may be adequate for temporary use are often overloaded when conversion of a residence to year-round use occurs.

Effective January 1989, a new state law, RSA 485-A, requires landowners of all developed property to obtain state approval to increase the load on a sewage disposal system. RSA 485-A states that prior to expanding any structure or occupying any existing structure on a full time basis, which would increase the load on a sewage disposal system, the owner of such structure shall submit an application for approval of the sewage system to the Water Supply and Pollution Control Division.

The state also requires a site assessment study on all pending property sales on water frontage or Great Ponds. RSA 485-A states that prior to offering for sale any developed waterfront property using a sewage system, the owner of the property shall, at his expense, engage a licensed sewage disposal system designer to perform a site assessment study to determine if the site meets the current standards for sewage disposal systems established by the Division. This law protects potential waterfront property owners from purchasing inadequate and outdated septic systems.

An amendment to Nottingham's zoning bylaws should define seasonal and permanent use and should alert residents to state law RSA 485-A. These laws should help the Zoning and Planning Boards regulate lake shore and other conversions. The latter restrictions are particularly appropriate since they provide some control over existing sewage disposal systems.

Although not always specifically designed for protection of surface and groundwater quality, zoning bylaws concerning lot sizes may influence local water quality, particularly where on-site subsurface disposal systems are used.

F. PUBLIC BOAT ACCESS MANAGEMENT

1. Introduction

Public boat access at Pawtuckaway Lake currently exists in the northern tip of Fundy Cove. This site consists of a boat ramp, an access road and a parking lot which accommodates ten to fifteen cars. In 1980 several improvements to this site were made which included widening the access road, grading the parking area, and improving the launch site.

The Fundy Cove access facility is host to approximately ten annual bass tournaments which can launch anywhere from twenty to sixty boats during a one day event. This, in conjunction with weekend parking congestion, can account for as many as eighty cars and trailers crowded into the

existing parking lot and access road. There is also a complete lack of sanitary facilities at this site which has undoubtedly degraded the environmental quality and park aesthetics in the area. Several environmental concerns have been raised about the continued use of this area as a public boating access facility. These concerns involve:

- Erosion of the Fundy Cove shoreline due to the wakes of passing boats,
- Phosphorus release from sediments due to propeller backwash in the shallow cove,
- Hydrocarbon buildup from the use of power boats in the cove area,
- Damage to abundant wetlands along the extensive shoreline of Fundy Cove, and
- Lack of environmentally sound sanitation facilities.

Boats launched from the Fundy Cove access facility must navigate through a relatively narrow channel with an average depth of nine feet to reach the main body of Pawtuckaway Lake. Also, the entire Fundy cove area is a designated no-wake zone which means boats must travel approximately one mile through Fundy Cove at headway speed in order to reach unrestricted waters. This increases the possibility for environmental damage to occur within this environmentally fragile area. In fact, in a 1985 report on the conditions and trends of New Hampshire State Park properties, the Fundy access site was described as being one of the biggest mistakes in park system history due to the continued use of the designated natural area as a boat launching site (NHDRED, 1985).

The ideal location for a public boat launching facility on Pawtuckaway Lake that would minimize environmental impacts would be either on Big Island or on the eastern shoreline of the lake. The advantages to these sites include:

- Deep water and immediate access to the main body of the lake,
- No danger of impacting environmentally fragile areas or designated natural areas,
- Close proximity to major highway routes 101 and 4 via route 156, and
- Better opportunity for management and emergency response.

Although these areas offer exceptional environmental benefits, the social and economic drawbacks make these sites highly unfeasible and cost prohibitive. Any site developed for public access within the developed areas of the state park would involve considerable engineering costs and create user conflicts and management problems for park visitors and personnel.

The option of developing private parcels of land on the eastern shore of the lake would require right-of-way acquisition from numerous parcels of adjoining land. Vehicular access to a public launch along the eastern shoreline is difficult and confusing. Roads to the shoreline are

usually long, winding and narrow and any attempt to improve these roads would be extremely costly. Acceptance of this option among the lake community is low.

By 1991, concerns with the existing boat launch prompted the New Hampshire Department of Resources and Economic Development (DRED) and the Fish and Game Department to examine alternative ways of managing the site and to evaluate other potential alternative boat access sites on Pawtuckaway Lake (Dubois & King, 1994). The environmental engineering firm of Dubois and King, Inc. was contacted to fully evaluate public access options and generate a feasibility analysis from an unbiased perspective. The feasibility study for public access on Pawtuckaway Lake was designed to consider:

- The need for public access at Pawtuckaway Lake
- Area and Lake conditions
- Boat access requirements and site criteria
- Site identification
- Site evaluation

Based upon the above criteria and consultations with various state and local officials as well as field investigations a list of possible boat launch areas was developed. This list was characterized and prioritized for potential development. The following potential boat access sites were identified as possible public boat launch facilities on Pawtuckaway Lake (Dubois and King, 1994):

- Neals Cove - This site is located on the north side of Neal's Cove, in Pawtuckaway State Park. This site is currently acting as a hand launched canoe site.
- State Park Boat Docking Facility - This site is located on the north side of Neal's Cove, near the entrance to the cove. The site is adjacent to the park's general store and a developed campsite area, and across the cove from the main park beach area. The site currently exists as a boat docking facility; no launching facilities are present.
- East of Bridge to Horse Island - This site is located in the park on the southeast shore of Big Island, approximately 100 yards east of the bridge to Horse Island. The site is undeveloped.
- Park campsite #106 - This site is located in the park on the southeast shore of Big Island. The site is situated in an established campsite area.
- Northwest of Dolloffs Dam - This site is located on the lake's southern shoreline, just north of the dam. The site is owned by the State of New Hampshire.

- Seamans Point Area - This area is located on the eastern shore of the lake. The shoreline in this area is extensively developed with residential and vacation dwellings.
- East of Gove's Dike - This site is located adjacent to and northeast of Gove's Dike on the eastern shoreline of the lake. The site is currently developed with residential and vacation dwellings.
- East of Drowns Dam - This site is located at the northern edge of the lake, just east of the dam. The area is currently being utilized as the Town of Nottingham's beach.
- Existing Fundy Cove Site - This site is located on the shoreline near the tip of Fundy Cove. This site is situated in the park and currently serves as a public boat access site.
- Neck of Fundy Cove Site - This site is located on the northern shoreline of Fundy Cove. The site is situated in the park and is in an undeveloped area.

Each of the above access sites were assessed for individual site ability to fulfill established site criteria. The three sites that provided the best balance of social, environmental and user requirements are the existing Fundy Cove site, the site east of the bridge to Horse Island and the boat dock facility in the state park. The existing Fundy Cove site received the highest overall ranking and fulfilled the most criteria among the chosen sites.

The final recommendations from the study requested the upgrading of the existing boat access facility to best minimize social, environmental and fiscal impacts while maximizing public boating access to Pawtuckaway Lake (Dubois and King, 1994). Therefore, the rehabilitation and upgrading of the existing public access site by the appropriate state agencies will be supported. Recommendations for the upgrade will be an integral part of the water quality and watershed management plan designed for Pawtuckaway Lake.

2. Management of the Fundy Cove Public Access Site

The existing public access facility at Pawtuckaway Lake is located in a designated primitive area within State Park boundaries. Boats launched from this site must navigate through Fundy Cove which is a designated no-wake area and travel approximately one mile to the main body of the lake. The problems of sediment suspension, shoreland erosion, damage to wetlands and no-wake

violations are a constant concern as a result of the continued use of this site as a public access facility. However, no alternative public boat access sites exist on the lake that are ideal. Therefore, the negative environmental impacts associated with the current and future use of this facility should be minimized. The following recommendations should be incorporated into any future management plan developed for this site:

- Expansion of existing parking lot to provide enough area for the determined "in kind" number of vehicles and trailers that coincides with the lakes carrying capacity.
- Improvements to access road and installation of swale areas where necessary to prevent runoff from degrading wetlands.
- Installation of an infiltration trench at the top of the boat ramp to provide storage for parking lot runoff and to filter pollutants from the first flush of a storm event.
- Implementation of bank stabilization techniques adjacent to boat ramp; e.g. rock riprap.
- Installation of an approved sanitary facility to eliminate subsurface contamination. Composting toilets and holding tanks should be evaluated for efficiency and economic feasibility for this site.
- Construction of a placard designed to provide educational materials to the individuals utilizing the public access. Information provided should include the following:
    - Pawtuckaway Lake maps illustrating the designated no-wake areas as well as other sensitive areas such as loon nesting habitats and wetlands.
    - information on boating regulations and safety issues.
    - lake ecology and protection tips geared toward the transient recreational population.
    - information on local, state and federal programs that are functioning to preserve and protect Pawtuckaway Lake.

The New Hampshire Department of Resources and Economic Development (DRED) and the Fish and Game Department are currently reviewing the feasibility analysis report submitted by Dubois and King, Inc. for public boat access to Pawtuckaway Lake. It is expected that the preceding recommendations will be taken into consideration when the final management strategy for public access at Pawtuckaway Lake is finalized. The desired management strategy for this site would

involve the acquisition of the land comprising the access road and launch facility from DRED by the New Hampshire Fish and Game Department. This would allow for public access development or rehabilitation to occur under the guidelines of the federally funded public boat access program for New Hampshire. This program utilizes design criteria that coincide with BMPs for stormwater management and nonpoint source pollution.

The field coordinator and project manager for the Diagnostic/Feasibility Study on Pawtuckaway Lake will be involved in the final development of a management strategy for public boat access to Pawtuckaway Lake.

G. PUBLIC EDUCATION

The Pawtuckaway Lake Improvement Association (PLIA) and Pawtuckaway State Park should initiate an education program aimed at educating lake residents, transient lake recreationists, state park visitors and private/public beach users. This educational program should be designed to incorporate residents within the entire watershed specifically targeting developed areas adjacent to surface waters. The ultimate goal of this type of program is to reduce the amount of nonpoint source pollution within the watershed and to eliminate the effects of cultural eutrophication upon Pawtuckaway Lake.

Given a choice and a better understanding of the consequences of their actions, most people will opt to improve their environment. If all residents of the Pawtuckaway Lake watershed could enjoy the benefits of a choice recreational facility, they would likely take a greater interest in protecting water quality. The PLIA has been aggressive in the implementation of public education programs for several years. In 1992, the PLIA received an award of excellence through the NHDES Volunteer Lake Assessment Program (VLAP) for their public outreach and education programs within the Pawtuckaway Lake watershed. The association has also coordinated an annual state park camper education weekend in conjunction with Pawtuckaway State Park personnel. This public outreach program focuses on the transient recreationists utilizing the park facilities and acts to heighten public awareness in the areas of lake ecology, nonpoint source pollution and responsible watershed management practices. Additional projects initiated by the PLIA designed to enhance public education have included the production of a video focusing on lake protection tips, annual

meetings designed around a particular theme including guest speakers from local and state agencies, and several informal lake related educational activities.

The PLIA is a valuable and effective vehicle for conveying information to the residents and transient population of Pawtuckaway Lake and its watershed. The existing infrastructure and long term goals of the PLIA will coincide with the recommendations for public education outlined in this study and should include the following:

- Continuation of PLIA sponsored activities revolving around public education as it pertains to shoreland protection, watershed management and lake ecology.
- Continued participation in the New Hampshire Volunteer Lake Assessment Program.
- Intensify the level of cooperation between the PLIA and Pawtuckaway State Park to raise the environmental awareness of park visitors and individuals utilizing the public boating access facility in Fundy Cove.
- The PLIA with support from NHDES, New Hampshire Department of Agriculture and Soil Conservation Services should develop an educational program or workshop on BMPs for those people in the watershed who practice animal husbandry or manage "hobby-farms". Since small farms contribute to nonpoint sources of phosphorus and may even contribute more phosphorus than larger farms that practice BMPs, an educational program is needed on BMPs for manure handling and pasture management.
- The town of Nottingham should encourage their elementary and secondary schools to participate in the NHDES Interactive Lake Ecology program. This program is designed to educate the young on principles of lake ecology and preservation of these resources, ensuring that the future residents of the area have the necessary education to be the safeguards of their water resources.

The increased frequency of seasonal to year-round residence conversions on Pawtuckaway Lake coupled with the increasing numbers of state park visitors and public boat access utilization emphasize the necessity of a comprehensive educational program within the Pawtuckaway Lake watershed. Implementation of the recommendations listed above will act to mitigate nonpoint source pollution around Pawtuckaway Lake and reduce the impacts of cultural eutrophication.

H. SHORELAND AND WATERSHED PROTECTION

1. Master Plan

The Town of Nottingham has a current master plan that was adopted by the planning board in 1987, and amended in 1990. A master plan and the planning process basis are important expressions of community desires for guiding future land use in Nottingham. As conditions change, it is important to reassess and revise the goals and policies. Legally, there are important reasons for maintaining a current master plan, since it serves as the basis for land use regulations and capital improvement programs for the town.

Nottingham's Master Plan includes several goals and objectives to protect natural resources, many specific to surfacewater and groundwater.

2. Local Water Resources Management and Protection Plans

In 1986, the New Hampshire legislature established the Water Protection Assistance Program within the Office of State Planning (OSP) (RSA 4-C:19). The purpose of the program is to encourage municipalities to evaluate their water resources and to develop measures for the protection of both groundwater and surface water. The statute directed OSP to develop administrative rules to provide guidance for municipalities in the development of local water resources management and protection plans, to be adopted as part of the conservation and preservation section of their master plans. The original rules took effect on January 20, 1988. Subsequent revisions to the rules were made on August 20, 1990, to simplify and add flexibility to the planning process. According to the rules, a local water plan should provide a descriptive evaluation of a municipality's watersheds to include wetlands, floodplains, lakes, ponds, rivers and perennial streams. Groundwater resources within the town should also be evaluated, to include bedrock as well as stratified drift aquifers. The water plan should identify potential threats to water resources and project the municipality's future need for these resources. After providing an analysis of the town's existing regulatory framework, the plan should present a strategy of both regulatory and non-regulatory mechanisms for the long term management and protection of the town's water resources. A local waterplan must be submitted to OSP for review and written comment relative to

its consistency with the State rules, prior to local adoption.

Nottingham should enter into a formal cooperative effort to prepare a regional water resource management and protection plan that is consistent between municipalities. The Planning Board should adopt the portion of that plan that pertains to their municipality as part of the conservation and preservation section of their master plans (RSA 674:2, VIII).

3. Zoning

The Zoning Ordinance and Building Code Regulations for the Town of Nottingham were amended in 1994. The purpose of a zoning ordinance is to regulate the use of land in a manner that promotes the health and welfare of a municipality. It includes requirements to lessen congestion in the streets, secure safety from fires, panic and other dangers, to provide adequate light and air, to prevent the overcrowding of land and to avoid undue concentrations of populations. The ordinance should be designed to facilitate adequate provision of an infrastructure to meet municipal needs for such services as transportation, solid waste facilities, water, sewerage, schools and parks.

a. Introduction. RSA 674:16 authorizes the local legislative body of a city or town to adopt and amend a zoning ordinance for the purpose of promoting the health, safety or general welfare of the community. Such ordinances are designed to regulate and restrict the use of land within the municipality. They often include maximum limitations for the density, height, number of stories and sizes of buildings and other structures. They specify areas, or zones, within the municipality where land and structures can be used for business, industrial, residential and other purposes. A listing of land uses that are permitted and prohibited, or permitted by special exception, is usually included for each zone within the community. A variety of zoning techniques are available for lake management and protection; some are listed in Table XI-4.

b. Environmental Characteristics Zoning. It is common for municipalities to recognize the importance of critical resource areas by adding protective overlay districts to their town-wide zoning ordinances. An overlay zone is so called because it adds special protective requirements or higher standards within an area that is delineated as a special resource. The boundaries of that resource usually do not coincide with those of the regular zoning districts. Where the requirements

Table XI-4
A Variety of Zoning Techniques

Topic	Definition
Zoning	The regulation of building types, densities, and uses permitted in districts established by law.
Special Permits/ Special Exceptions/ Conditional Use Permits	Administrative permits for uses that are generally compatible with in a particular use zone, but that are permitted only if certain specified standards and conditions are met.
Variances	Administrative permits for uses that are generally compatible with in a particular use zone, but that are permitted only if certain specified standards and conditions are met.
Floating Zones	Use zones established in the text of a zoning ordinance, mapped until a developer proposes and the legislative body adopts such a zone for a particular site.
Conditional Zoning	An arrangement whereby a jurisdiction extracts promises to limit the future use of land, dedicate property, or meet any other conditions. The arrangement is either stated in general terms in the zoning ordinance or imposed on a case-by-case basis by the legislative or administrative body, prior to considering a request for a rezoning.
Contract Zoning	An arrangement whereby a jurisdiction agrees to rezone specified land parcels subject to the landowner's execution of restrictive covenants or other restrictions to dedicate property or meet other conditions stated in the zoning ordinance or imposed by the legislative or administrative body.
Cyclical Rezoning	The periodic, concurrent consideration of all pending rezoning applications, generally as part of an ongoing rezoning program, focusing upon one district at a time.
Comprehensive Plan Consistency Requirement	Provisions that require all zoning actions, and all other government actions authorizing development, be consistent with an independently adopted comprehensive plan.
Zoning Referendum	Ratification of legislatively approved land use changes before such changes become law.
Prohibitory Zoning	The exclusion of all multifamily, mobile, modular, industrialized, prefabricated, or other "undesirable" housing types from an entire jurisdiction, or from most of the jurisdiction.

Table XI-4 (continued)
A Variety of Zoning Techniques

Topic	Definition
Agricultural Zoning/Large Lot Zoning Open Space Zoning	The establishment of "permanent" zones with large (that is multiacre) minimum lot sizes and/or a prohibition against all nonagricultural development of single-family residences and, possibly, selected other uses).
Phased Zoning/ Holding Zones/ Short-Term Service Area	The division of an area into (1) temporary holding zones closed to most nonagricultural uses and/or with large minimum lot sizes, and (2) service areas provided with urban services and open for development in the near term (for example 5 years).
Performance Zoning/Performance Standards	An arrangement whereby all or selected uses are permitted in a district if they are in compliance with stated performance standards; that is, if they meet stated community and environmental criteria on pollution, hazards, public service demands, etc.
Flexible Zoning/ Cluster Zoning/ Density Zoning	Freedom from minimum lot size, width, and yardage regulations, enabling a developer to distribute dwelling units over individual lots in any manner the developer desires, provided (usually) that the overall density of the entire subdivision remains constant.

From the Lake and Reservoir Restoration Guidance Manual, Second Edition, EPA, 1990.

Table XI-5
Overlay Zoning Techniques: Key Characteristics

Wetlands	Floodplains	Watershed	Aquifer	Steep Slopes	Shoreline
Permitted and prohibited uses*	Permitted and prohibited uses*	Permitted and prohibited uses*	Permitted and prohibited uses*	Requirements for location or prohibition of septic systems vs. roads and structures*	Buffers, setbacks and rationale*
Setbacks for septic tanks/leachfields*	Setbacks for septic tanks/leachfields*	Performance standards more stringent than generally required by zoning*	Definition and methodology for delineation of district	Site specific data requirement option	BMPs for lawn management natural vegetative buffers, etc.*
Setbacks for roads and structures*	Setbacks for wells, structures, roads*	Site specific data requirement option	More stringent performance standards than watershed*		Requirements for shoreline structures*
Buffers*	Zero increase in peak flood elevation		Limitations or percent coverage by impervious materials*		Site specific data requirement option
Definition of wetlands and methodology for delineation*	Site specific data option		Site specific data requirement option		
Site specific data requirement option					

Note: *Need to examine scientific basis. Source: NH Office of State Planning, Water Protection Assistance Program, 1990.

of the districts differ, the more stringent of the two apply. This type of zoning has traditionally been used to protect wetlands, floodplains, watersheds, aquifers, steep slopes and shorelines. Table XI-5 presents a summary of the types of requirements that are likely to be found in overlay zoning ordinances to address these resources.

Delineation of the environmental overlay zoning districts usually depends on existing maps and data prepared by federal agencies such as the Soil Conservation Service, United States Geological Survey, Federal Emergency Management Agency and others. Although such maps provide the planning board with a general idea of the extent of the resource in question, they are generally not sufficient in detail to identify a precise location of the district boundary. Where this is the case, it is important that the overlay zoning ordinance allows applicants to provide the planning board with more technical, site specific information to delineate the boundary. It is helpful to both the planning board and applicants if that section of the ordinance clearly defines the methodology or options for methodologies to be used to delineate the district in the field. The ordinance may provide for an independent review of the data which has been provided by the applicant, or by a qualified consultant hired by the planning board at the applicant's expense. This type of review and professional consultation assists the planning board in making an informed decision based on technical information about the sensitive resource that the ordinance aims to protect. The ordinance may also spell out conditions under which the planning board may require site specific investigations.

i. Wetlands Zoning. Many municipalities adopt wetlands overlay zoning regulations to protect the natural functions or values which make wetlands a critical resource within a watershed. These important functions include flood protection and flow stabilization, wildlife habitat, filtration of nutrients, trapping of sediments, and ecological productivity. Such ordinances need to define or delineate the extent of the overlay district boundary. There are a number of ways to establish the extent of wetland boundaries. Wetland overlay ordinances typically have requirements for setbacks from wetlands for the location of septic system tanks and leachfields, roads and structures. Some ordinances establish buffers around wetlands within which land uses are either restricted or required to adhere to performance standards. It is common for wetland ordinances to allow the planning board to require that site specific information relative to the location of the wetland boundary be supplied by the applicant. This is usually for sites where considerable acreage of wetlands is

proposed for alteration, or the wetlands exhibit particular resource values that are significant to the municipality.

The Town of Nottingham has adopted a Wetlands Conservation Area. The Following description is taken from Article IX of the Zoning Ordinance and Building Code Regulations.

IX. WETLAND CONSERVATION AREAS

A. Description

1. The Wetlands Conservation Areas are those areas identified as poorly drained and very poorly drained soils in the publication, "Soil Survey of Rockingham County, New Hampshire," issued August 1985 and as amended. The Wetland Conservation Areas as herein defined are shown on a Soil Condition Map as a supplement to the Official Map of the Town of Nottingham, New Hampshire.

2. Reference material on soils is included in the publication "Soil Survey of Rockingham County, New Hampshire" August, 1985 and as amended, on file with the Town Clerk, Planning Board and Board of Adjustment.

3. All pertinent notations, soil mapping unit designations, and other information shown in the publication "Soil Survey of Rockingham County, New Hampshire" August 1985 and as amended, shall be as much a part of this Ordinance as if the matters and things set forth by the document were fully described herein.

4. Specific description of freshwater wetlands is described in Statutory Authority RSA A:4-a, I and V specifically in chapter definitions "fresh water wetlands" with its Appendix A.

B. Pollution Control - No privy, cesspool, septic tank, sewage disposal area or area for the stockpiling of animal manures or other waste materials shall be constructed or maintained less than seventy-five (75') horizontal feet from the edge of a public water body, floodplain, wetland, intermittent streams or seasonably wet soil. No other structure shall be built or maintained less than fifty (50') horizontal feet from any poorly drained hydric B soils and less than seventy-five (75') horizontal feet from any very poorly drained hydric A soils. However, the passage of the Comprehensive Shoreland Protection Act (RSA 483-B) in July 1994 supercedes these requirements.

C. Nonconforming Structures and Uses - Any nonconforming use or structure which was legal prior to adoption of this Zoning Ordinance or any amendment thereto, may continue except as provided herein:

1. When ever a lot which is nonconforming due to insufficient area, frontage, or setback abuts other property either owned in common or having one or more owners in common, all such property or lots shall be considered as a

single tract for purposes of further development or for the sale of any portion thereof. This provision may be modified by the Planning Board, if it has established that substantial development has created vested interests which make change to conformity unreasonable or unjust.

D. *Permitted Uses - uses that do not result in the erection of any structure or alter the surface configuration of the land by the addition of fill or by dredging such as:*

1. *forestry - tree farming,*
2. *agriculture, including grazing, farming, truck gardening and harvesting crops but not including the stockpiling of manure,*
3. *construction of well water supplies,*
4. *wildlife habitat development and management,*
5. *parks and such recreation uses as are consistent with the purpose and expressed intentions of this ordinance,*
6. *conservation areas and nature trails, and*
7. *open space in accordance with subdivision regulations and other sections of this ordinance.*

E. *Reclassification of Soils - in the event that a soil classification is challenged by the applicant, abutter, or Planning Board, the Planning Board will make an onsite inspection. If the Planning Board considers the classification to be correct, then the applicant may challenge this decision by presenting evidence by a soil scientist or others qualified in soil classification. The Board may determine that the restrictions pertaining to the challenged soil classifications in this ordinance do not apply, at any time after the onsite inspection.*

ii. Floodplain Zoning. Floodplains are sensitive resources that are often protected by local zoning. Their values include their ability to protect adjacent properties from damage by assimilating flood waters during storm events. Many also serve as critical wildlife areas, and either are wetlands or are associated with wetland habitats. Communities are required by the Federal Emergency Management Agency (FEMA) to pass certain minimal zoning restrictions for floodplain development in order to be eligible for the federal flood insurance program. Many communities choose to adopt floodplain requirements in their zoning ordinances which are more stringent than the minimum required by the FEMA program. The FEMA program allows construction within sensitive floodplain areas if the structures are "floodproofed." Filling in or paving over floodplains decreases the peak flow capacity of the riverine system. The cumulative impacts of filling or paving, over time, can have a significant impact on downstream properties. Municipalities can adopt more stringent overlay zoning requirements than FEMA's to provide protection measures for floodplain areas. Floodplain ordinances can include setbacks and site specific data requirements that

are similar to those found in wetlands ordinances. Requirements for maximum or no increases in peak flood levels are often considered in floodplain zoning ordinances.

The Town of Nottingham has an article on Flood Hazard Areas in its zoning codes, which applies to all lands designated as flood hazard areas by FEMA. It requires that new and replacement water supplies and wastewater disposal systems are located, constructed and designed to minimize and/or avoid destruction caused by flood events. The article, taken from the Zoning Ordinances of the Town of Nottingham appears here.

X. FLOOD HAZARD AREAS

A. Special Flood Hazard Areas - the Flood Hazard Boundary Map #3301370001-0004, dated September 7, 1979, as promulgated by the Department of Housing and Urban Development, Flood Insurance Administration, as amended, shall be a supplement to the Official Map of the Town of Nottingham. Zone A on said map delineates the area within which the requirements of this Article will be enforced (See II.C.).

B. Residential Structures - no residential building will be allowed (See II.C.).

C. Permitted Uses - the following uses shall be permitted within the Special Flood Hazard Areas to the extent that such uses are not prohibited by any other provisions of this Ordinance and provided that building, fill or storage of materials or equipment is not required.

D. Uses Allowed by Special Exception - the following uses may be allowed within the Special Flood Hazard Areas by special exception with Planning Board recommendation. Such recommendations shall include the following where applicable:

1. the agency of the proposed water supply and sanitation systems,

2. the compliance with applicable Town and State regulations and laws,

3. the compatibility of the proposed use with existing and anticipated development as indicated in the master plan.

4. the relationship of the proposed use to any Floodplain Management Program in effect for the area,

5. uses of building necessary to facilitate use, maintenance of or access to open space,

6. railroads, streets, bridges and essential services,

7. *marinas, boat rentals, docks, piers, and wharves,*

8. *outdoor storage,*

9. *off-street parking space or parking facilities, and*

10. *other uses similar to those described in 3 above and consistent with the purpose of this ordinance.*

E. *Standards for Granting Special Exceptions*

1. *In acting upon special exceptions applications, the Board of Adjustment shall use reasonable judgment for the following factors:*

   a. *The proposed use complies with all other applicable sections of this ordinance, all other applicable Town, State, and Federal regulations and laws.*

   b. *Danger to life and property shall not result due to increased flood heights or velocities caused by encroachments.*

   c. *Materials will not be swept onto other lands or downstream to the injury of others.*

   d. *Alternative locations not subject to flooding are unavailable without hardship, for the proposed use.*

   e. *Access to the property in times of flood for ordinary and emergency vehicles is not excessively hazardous.*

   f. *Any building by special exception shall comply to whatever extent may be reasonably necessary with the floodproofing requirements of this ordinance. Any building shall be elevated on adequately anchored pilings or columns, and securely fastened to such piling or columns so that the lowest portion of the structure is elevated to or above the base flood level.*

2. *The Board of Adjustment may waive compliance, in a building allowed by special exception, with the requirements of base flood elevation for floodproofing, if the Board finds that such building would be functionally impaired by such compliance. In granting a special exception, the Board may impose such conditions as it finds reasonably appropriate to serve the purpose of the Special Flood Hazard Areas.*

3. *An application for a special exception , as provided herein, which involves new construction or floodproofing of existing properties will provide the following information:*

a. *That the proposed construction is protected against flood damage; is designed and anchored to prevent flotation, collapse or lateral movement; uses construction materials and utility equipment that are resistant to flood damage; uses construction methods and practices that will minimize flood damage; and is elevated above base flood level in the case of new construction.*

b. *In addition, the Board may require that the applicant filing an application for a special exception must submit a plan certified by a registered professional engineer to the effect that the proposed floodproofing measures conform with the ordinance.*

F. *Nonconforming Structures and Uses - any nonconforming use or structure which was legal prior to adoption of this Zoning Ordinance or any amendment thereto, may continue except as provided herein:*

1. *Whenever a lot which is nonconforming due to insufficient area, frontage or setback abuts other property either owned in common or having one or more owners in common, all such property or lots shall be considered as a single tract for purposes of further development or for the sale of any portion thereof. This provision may be modified by the Planning Board, if it is established that substantial development has created vested interests which make change to conformity unreasonable or unjust.*

G. *Floodproofing - floodproofing shall consist of the following as appropriate:*

1. *anchorage to resist flotation and lateral movement,*

2. *installation of watertight doors, bulkheads and shutters,*

3. *reinforcement of walls to resist water pressure,*

4. *use of paints, membranes or mortars to reduce seepage of water through walls,*

5. *addition of weight to building to prevent flotation,*

6. *installation of pumps to reduce water levels in buildings,*

7. *construction of water supply and waste treatment systems so as to prevent the entrance of flood waters,*

8. *pumping facilities for subsurface external foundation wall and basement floor,*

9. *construction to resist rupture or collapse caused by water pressure or floating debris,*

10. *cutoff valves on sewer lines and the elimination of gravity-flow basement drains,*

11. installation above base flood level of all water heaters, furnaces, electrical installations, with separate electrical circuits dropped from above to serve basement, and

12. venting tanks above base flood elevations.

H. Disclaimer of Liability - the degree of flood protection required by this Ordinance is considered reasonable for regulatory purposes and is based on accepted engineering and scientific standards. This ordinance does not imply that area outside the Special Flood Hazard Area boundaries or land uses permitted within such areas will be free from flooding or flood damage. This ordinance does not create liability on the part of the Town of Nottingham or any officer thereof for any flood damage that results from reliance on this Ordinance or any administrative decision lawfully made hereunder.

iii. Watershed Zoning. Some communities have recognized the importance of particular watersheds by adopting watershed protection overlay districts. This is common where there is either a public surface water supply or a particular watershed contributing recharge to a groundwater supply. It is also common for watershed zoning to be used to protect a surface waterbody that is considered a critical resource for reasons other than drinking water supply. Such ordinances usually specify land-uses which are permitted or prohibited within the watershed. With outright prohibition of land uses within an entire watershed, the potential for a "taking" issue may come into play. The emphasis, therefore, is usually on performance standards that are somewhat more specific or stringent than those required for the rest of the community. Such standards should be designed to address protection of the specific resource values for which the watershed is considered locally important. In many instances the land of a significant watershed may lie within a number of municipalities. In these cases it may be appropriate for each community to adopt the same performance standards for the portion of the watershed that is within their town. This is one way to assure consistent protection throughout the entire hydrologic system.

The watershed zoning approach should be considered by the Town of Nottingham.

iv. Aquifer Zoning. There has been an increased interest in local groundwater protection, stemming from a growing public awareness about groundwater contamination occurrences. The State-USGS cooperative aquifer mapping program is making available improved information about stratified sand and gravel aquifers on a statewide basis. In order to protect these areas for future use

as potential water supplies, many municipalities have adopted aquifer zoning districts. These ordinances generally list permitted and prohibited uses. To a large extent, they also rely on performance standards for future land uses to minimize the chances of aquifer contamination resulting from new development. Such standards often include provisions that require containment structures for uses involving the presence of dangerous materials. Treatment swales to control stormwater flows and ensure infiltration for groundwater recharge are also common. Due to their high rates of transmissivity and permeability, aquifer areas that may serve as existing or future water supplies are sensitive to potential pollutants. This is generally considered to be justification for more stringent performance standards than are imposed throughout the municipality.

At the present time there are no surface waters within Nottingham which are utilized as water supplies. Consumers in Nottingham utilize a mixture of shallow dug wells, drilled wells and fractured bedrock wells for water supply.

A detailed investigation into the geohydrology and water quality of stratified drift aquifers in the Exeter, Lamprey and Oyster River Basins was revised in 1990 by the U.S. Geological Survey in Cooperation with the New Hampshire Department of Environmental Services, Water Resources Division. Information from this report (Water-Resources Investigations Report 88-4128) was used to determine the number, size and feasibility of aquifers located in the Nottingham area. Two stratified-drift aquifers of low yield (transmissivity < 500 ft^2/day) are located within the town boundary of Nottingham. Although there is no demand for these aquifers at the present time, future development in the area may place strains on the current water supply and cause their value as a natural resource to increase.

The New Hampshire Department of Environmental Services has declared, as part of its permit process, that all groundwater of the State is a potential water supply. Potential groundwater sources are of two types: surficial deposits (sand and gravel aquifers) or bedrock aquifers. Unfortunately, more information is available regarding the water-bearing potential of the sand and gravel aquifers than about the bedrock aquifers. Until expensive and time-consuming hydrogeological investigations are undertaken, and their results made available, groundwater protection efforts should concentrate on the sand and gravel aquifers. We recommend that the salt storage facilities and snow dumping areas be restricted not only from aquifer zones but also from the environmentally sensitive zones around surface water.

The Town of Nottingham has adopted an Aquifer Conservation District in its zoning

ordinance.

VIII. AQUIFER CONSERVATION DISTRICT

A. *Purpose: The intent of this Ordinance is to provide for the protection of the water resources from contamination by polluting, hazardous or toxic materials. The objectives, by establishing an Aquifer Protection District are:*

1. *To protect the public health and general welfare of the citizens of Nottingham and adjacent affected towns.*

2. *To prevent development and land use practices that would contaminate or reduce the recharge of the identified aquifers; including primary and secondary recharge areas.*

3. *To provide for future growth and development of the Town, in accordance with the Master Plan, by insuring the future availability of adequate public and private water supplies.*

4. *To encourage uses that can appropriately and safely be located in the aquifer recharge areas.*

B. *District Boundaries*

1. *Location*

The Nottingham Aquifer Protection District is defined as the area shown on the map entitled, "Aquifer Protection District."

The Aquifer Protection District is a zoning overlay district which imposes additional requirements and restrictions to those of the underlying district. In all cases the more restrictive requirements(s) shall apply.

2. *Recharge Areas*

For purposes of this ordinance, each primary recharge area for each identified aquifer is considered to be co-terminus (abutting) with that aquifer.

C. *Use Regulations*

1. *Minimum Lot Size*

The minimum lot size within the Aquifer Protection District for each dwelling unit if a residential use, shall be five (5) acres.

2. *Maximum Lot Coverage*

Within the Aquifer Protection District, no more than ten percent (10%) of a single lot, including the portion of any new street abutting the lot, may be rendered impervious to groundwater infiltration for residential, commercial, industrial, and institutional uses.

3. *Prohibited uses*

The following uses are prohibited in the Aquifer Protection Zone except where permitted to continue as non-conforming uses. Prohibited uses shall include, but not be limited to:

a. *Disposal of solid waste (as determined by NH RSA 149-M) other than brush or stumps generated on the property which they are to be disposed.*

b. *On-site disposal, storage, processing or recycling of toxic or hazardous materials or wastes.*

c. *Disposal of liquid or leachable wastes except domestic sewage effluent from residential subsurface disposal systems.*

d. *Buried storage of petroleum fuel and other refined petroleum products except as regulated by the N.H. Water Supply and Pollution Control Division (Ws 411 Control of Nonresidential Underground Storage and Handling of Oil and Petroleum Liquids).*

e. *Outdoor unenclosed or uncovered storage of road salt and other de-icing chemicals.*

f. *Dumping of snow containing road salt or other de-icing chemicals.*

g. *Animal Feedlots.*

h. *Automotive service and repair shops, junk and salvage yards. Laundry and car wash establishments not served by a central sewer system.*

i. *Dry Cleaning establishments.*

j. *Industrial uses which discharge contact type wastes on site. Discharge of non-contact cooling water determined to contain no toxic or hazardous substances is permitted.*

k. *Waste injection wells.*

l. *Non-municipal wells that may result in an aquifer volume reduction that*

exceeds the recharge rate.

4. *Permitted Uses*

The following activities may be permitted provided they are conducted in accordance with the purposes and intent of this ordinance:

a. *Any use permitted the under lying district of the Zoning Ordinance, except as prohibited in Section 4c (Prohibited Uses) or regulated by Conditional Use in section 4d (Conditional use) of this Article.*

b. *Maintenance, repair or any existing structure, provided there is no increase in impervious surface above the limit established in Section 4b of this Article.*

c. *Farming, gardening, nursery, forestry, turf management, harvesting and grazing of no more than five (5) animals, provided that fertilizers, pesticides, manure, and other leachables are used according to the best management practices as prescribed by the Rockingham County Conservation District, if applicable, and at levels that will not cause groundwater contamination. All said leachables must be stored under shelter.*

5. *Special Exception for Lots of Record*

Upon application to Zoning Board of Adjustment, a special exception shall be granted to permit the erection of a structure within the Aquifer Protection District on a non-conforming lot provided that all of the following conditions are found to exist:

a. *The lot upon which an exception is sought was an official lot of record as recorded in the Rockingham County Registry of Deeds, prior to the date of which this amendment was posted and published in the Town.*

b. *The use for which the exception is sought cannot feasibly be carried out on a portions of the lot which are outside the Aquifer Protection District.*

c. *Due to the provisions of the Aquifer Protection District, no reasonable and economically viable use of the lot can be made without exception.*

d. *The design and construction of the proposed use will, to the extent practical, be consistent with the purpose and intent of this Section.*

6. *Non-conforming Use*

No nonconforming use may be expanded, changed to another nonconforming use, or renewed after it has been discontinued for a period of 12 months or more.

D. *Hydrogeologic Study*

1. *Within the Aquifer Protection District, a hydrogeologic study shall be required, at the applicant's expense, for the following:*

A. *developments involving the subdivision of three (3) lots or greater.*

2. *Standards*

Hydrogeologic studies shall be performed by a qualified hydrogeologist. These studies shall be sufficiently detailed to evaluate the development's impacts to groundwater within the parcel to be developed and the surrounding land.

E. *Design and Performance Standards*

1. *Nitrate Loading*

No development shall cause the nitrate-nitrogen (NO_3-N) concentration to exceed 5 mg/L in the groundwater beyond the site.

2. *Safeguards*

Provisions shall be made to protect against toxic or hazardous materials discharge or loss resulting from corrosion, accidental damage, spillage, or vandalism through measures such as: spill control provisions in the vicinity of chemical or fuel delivery points; secured storage areas for toxic or hazardous materials; and indoor storage provisions for corrodible or dissolvable materials.

For operation which allow the evaporation of toxic or hazardous materials into the interiors of any structures, a closed vapor recovery system shall be provided for each such structure to prevent discharge of contaminated condensate into the groundwater.

3. *Location*

Where the premises are partially outside of the Aquifer Protection Overlay Zone, potential pollution sources such as on-site waste disposal systems should be located outside and down gradient of the Zone to the extent feasible.

4. *Drainage*

All runoff from impervious surfaces shall be recharged on the site, and diverted toward areas covered with vegetation for surface infiltration to the extent possible. Dry wells shall be used only where other methods are not feasible and shall be preceded by oil, grease, and sediment traps to facilitate removal of contaminants.

5. *Septic System Design and Installation*

Septic systems shall be constructed in accordance with the "Subdivision and Individual Sewage Disposal System Design Rules" (N.H. Code of Administrative Rules, Chapter Ws 1000). However, any Town Ordinance or regulation that is more restrictive shall apply. All new or reconstructed on-lot waste water disposal systems constructed in the Aquifer Protection District shall be designed by a Sanitary Engineer licensed in New Hampshire. These systems shall be installed under the supervision of said engineer.

The designated town engineer or septic system inspector of the Town shall inspect the installation of each new system prior to covering, and shall certify that the system has been installed as designed.

The following site requirements shall apply to all septic system construction in the Aquifer Protection District:

a. *At least 24 inches of natural permeable soil shall exist above the seasonal high water table.*

b. *At least four feet of natural soil shall exist above bedrock.*

c. *At least three feet of natural permeable soil shall exist above any impermeable subsoil.*

d. *No filling of wetlands shall be allowed to provide the minimum distance of septic to wetlands.*

e. *Fill material used for septic system construction shall be generally homogeneous and shall not contain:*

- *more than 15% organic soil by volume,*
- *more than 25% cobbles (6 in. in diameter) by volume,*
- *more than 15% of clay (0.002 mm particles or smaller) by weight,*
- *tree stumps, mulch, bark, or other large organic matter.*

F. *Administration*

General

All development proposals, other than single or two-family residential constructions shall be subject to subdivision or site plan review and approval in accordance with the Planning Board Rules and Regulations. Such review and approval shall precede the issuance of any building permit by the Town.

G. *Enforcement*

The Board of Selectmen shall be responsible for the enforcement of the provisions and conditions of the Aquifer Protection District. If the Board of Selectmen find that a nonconforming use posts a direct hazard to ground water or recharged areas or are actually causing some potentially hazardous foreign substances (oils, salts, chemicals, pesticides, etc.) to be introduced into the aquifer, then they may seek to enjoin same such use in an appropriate legal forum.

v. Steep Slopes Zoning. Steep slopes are quite vulnerable to erosion and subsequent sedimentation of water courses when exposed by disturbance of land and vegetation. For this reason, many communities prohibit the location of roads, structures and septic systems in areas with excessive slopes. Some communities have mapped areas with a slope greater than a certain percentage, and consider these areas as an overlay district. Some simply specify, in the text of the ordinance, that land with greater than a certain percent slope cannot be built upon or used in calculations to fulfill minimum lot size requirements.

The Steepness of slopes on Nottingham's terrain, like the elevations, are highly variable. The 25 percent and greater slopes are most prevalent in the south and southeast sections of Nottingham, particularly in Pawtuckaway State Park. As a whole, Nottingham is mostly composed on slopes less than 15 percent.

Slope is easily calculated by determining the ratio of vertical change to horizontal change (often referred to as rise over run). It is important to identify Nottingham's slopes as they help determine site suitability for development.

The primary reason for controlling development on steep slopes is the potential for increased runoff. As construction occurs on steep slopes and vegetation is cleared, more land is exposed to direct rainfall. In addition to substantial increases in erosion rates, over-land flow increases because the course of runoff is unaltered and water is no longer deflected or absorbed by vegetation.

Banks along many of Nottingham's ponds are greater than 25 percent. North River Pond, Merritt Pond, Mulligan Pond, Quincy Pond, Cedar Waters Pond, and Pawtuckaway Lake have slopes in excess of 25 percent. Development in these sensitive areas may cause accelerated eutrophication processes in the ponds. The east shore of Pawtuckaway Lake is of particular concern because of second home development. This is a targeted spot by developers given its rural setting and substantial recreations and natural resources. Chapter VI of the Nottingham Master Plan

addresses the feasibility of development on varying slopes in Nottingham and lists the following recommendations:

To control the degradation of water resources caused by rapid runoff and erosion, the following recommendations are made:

1. *On subdivision with 3 units or more, require future developers to assess the topography of a proposed development site and determine the slopes for that given parcel.*

2. *For slopes between 0 and 3 percent, most land uses are suitable. Priority land uses should include industry, commercial, high density, residential, major roads, and highways and business districts. These land uses often create rapid runoff as well as large areas of impervious surfaces. However, very flat slopes may pose drainage problems and should be identified as such in the site plan.*

3. *All development with the exception of passive recreational land uses (i.e., hiking trails) should be prohibited on slopes of 25 percent or more.*

vi. Shoreland Zoning. A concern about disturbance of natural shorelands arose from the increase in demand for and the value of waterfront property. Devegetated, exposed shorelands are subject to erosion from increased wave action due to storm and boating pressures. Further removal of natural shore vegetation leaves the land vulnerable to storm event related erosion. The installation of lawns along the shore often leads to the introduction of fertilizers and pesticides. Many municipalities with lake and river shorelands are responding to this concern by developing overlay zoning ordinances that address specific lacustrine (lake) and riverine habitat problems.

The waterbodies of Nottingham are protected at the present time by the Wetlands Conservation District, as described previously.

The Town of Nottingham has done much to ensure safekeeping of their water resources. The Wetland Conservation District ensures that these valuable assets will have protection in the future.

We recommend that a Lake Protection District be set up by the Town of Nottingham. This District is defined as an environmentally sensitive area surrounding the lakes and ponds of Nottingham in which development activities are closely regulated to preserve the lake quality. This protection district should also include each sub-drainage basin to the lake. Since land use in the lake's watershed is the key to nutrient and sedimentation rates to the lake, more effort must be devoted to this important element. The adoption of the State's Shoreland Protection Act (presented

in Appendix XI-2) is a great benefit to protecting the town's waterbodies.

The Shoreland Protection Act was passed in 1991 and it became effective, in its entirety, on Juyl 1, 1994. With the concern that the protection of this state's waterbodies is a primary goal, the general court found:

- The shorelands of the state are among its most valuable and fragile natural resources and that their protection is essential to maintain the integrity of public waters.
- The public waters of New Hampshire are valuable resources held in trust by the state and the state has an interest in preserving those waters and has the jurisdiction to control the use of the public waters and the adjacent shoreland for the greatest public benefit.
- There is great concern throughout the state relating to the utilization, protection, restoration and preservation of shorelands because of their effect on state waters.
- Under current law the potential exists for uncoordinated, unplanned and piecemeal development along the state's shorelines, which could result in significant negative impacts on the public waters of New Hampshire.

To fulfill the state's role as trustee of its waters and to promote public health, safety, and the general welfare, the General Court declared that the public interest requires the establishment of standards for the subdivision, use and development of the shorelands of the state's public waters. The development standards provided in this Chapter shall be the minimum standards necessary to protect the public waters of the State of New Hampshire. These standards shall serve to:

- Further the maintenance of safe and healthful conditions.
- Provide for the wise utilization of water and related land resources.
- Prevent and control water pollution.
- Protect fish spawning grounds, aquatic life, bird and other wildlife habitats.
- Protect buildings and lands from flooding and accelerated erosion.
- Protect archeological and historic resources.
- Protect commercial fishing and maritime industries.
- Protect freshwater and coastal wetlands.
- Control building sites, placement of structures and land uses.
- Conserve shore cover, and visual as well as actual points of access to inland and coastal waters.

- Preserve the state's rivers, lakes, estuaries and coastal waters in their natural state.
- Promote wildlife habitat, scenic beauty, and scientific study.
- Protect public use of waters, including recreation.
- Conserve natural beauty and open spaces.
- Anticipate and respond to the impacts of development in shoreland areas.
- Provide for economic development in proximity to waters.

The Shoreland Protection Standards are designed to minimize shoreland disturbance so as to protect the public waters, while still accommodating reasonable levels of development in the protected shoreland. Development outside the protected shoreland shall conform to local zoning and local ordinances and shall not be subject to standards established in this chapter.

The minimum Shoreland Protection Standards are listed below and summarized in Figure XI-5. Within the protected shoreland the following restrictions shall apply:

- The establishment or expansion of salt storage yards, automobile junk yards, and solid or hazardous waste facilities shall be prohibited.

- Primary structures shall be set back behind the primary building line. This line shall initially be set back 50 feet from the reference line. Upon the establishment of a shoreland building setback by a municipality, that standard, whether greater or lesser than 50 feet, shall define the primary building line in that municipality.
- A water dependent structure, meaning one which is a dock, wharf, pier, breakwater, or other similar structure, or any part thereof, built over, on, or in the waters of the state, shall be constructed only as approved by the wetlands board pursuant to RSA 482-A.
- No fertilizer, except lime and wood ash, shall be used on lawns or areas with grass on residential properties.

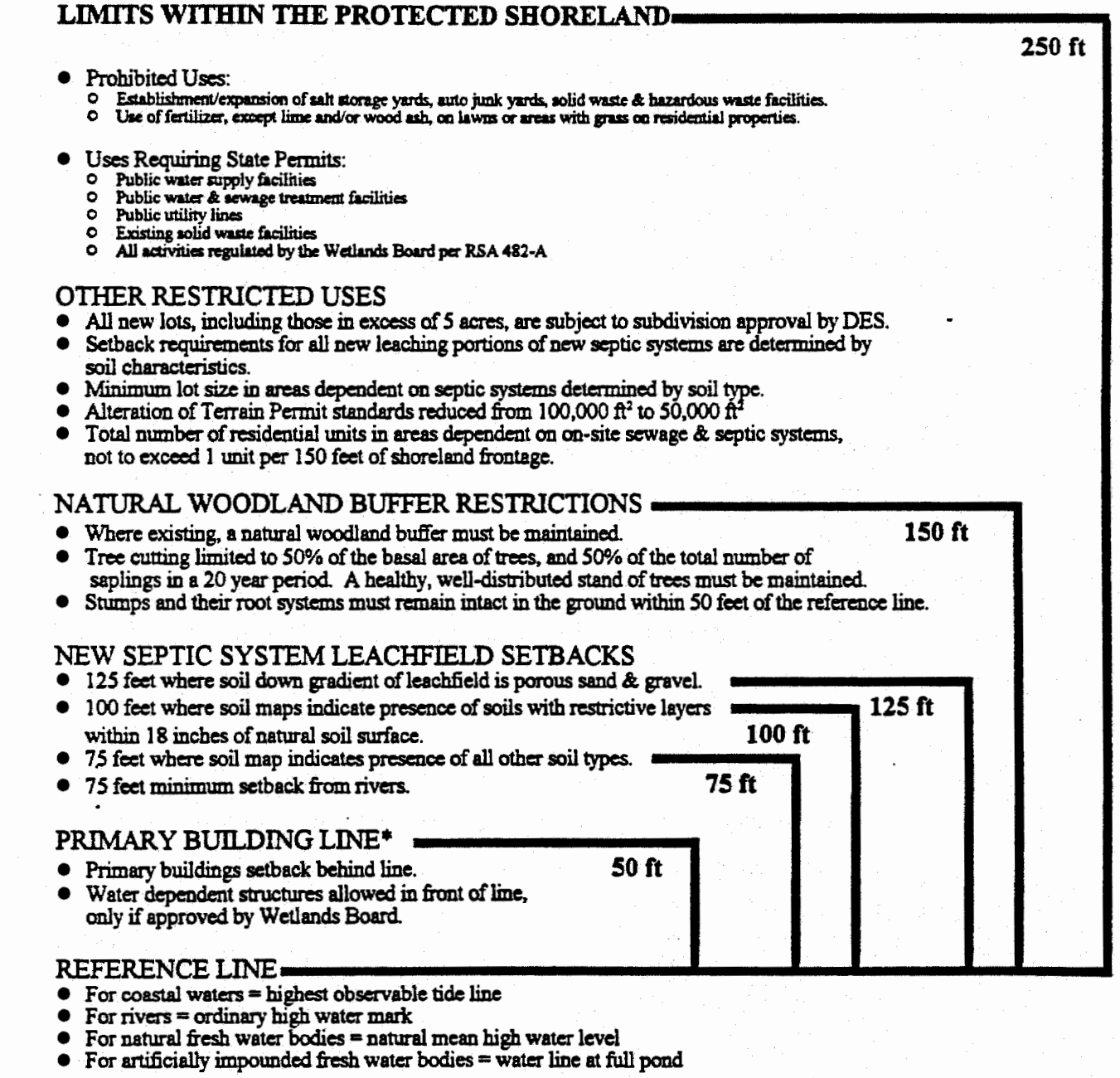
The following minimum standards shall apply to the protected shoreland provided that forestry, involving water supply reservoir water management or agriculture conducted in accordance with BMPs, shall be exempted from the provisions of this chapter:

- Where existing, a natural woodland buffer shall be maintained to protect the quality of public waters by minimizing erosion, preventing siltation and turbidity, stabilizing soils, preventing excess nutrients and chemical pollution, maintaining natural water

NEW HAMPSHIRE DEPARTMENT OF
Environmental Services

Comprehensive Shoreland Protection Act, RSA 483-B

Minimum Shoreland Protection Standards



* If a municipality establishes a shoreland setback for primary buildings, whether greater or lesser than 50 feet, that defines the Primary Building Line for that municipality.

Adapted from NH Office of State Planning document. 1994.

Figure XI-5
Minimum Shoreland Protection Standards

temperatures, maintaining a healthy tree canopy and under story, preserving fish and wildlife habitat, and respecting the overall natural condition of the protected shoreland.

- Within the natural woodland buffer of the protected shoreland under conditions defined in RSA 483-B:9, V the following prohibitions and limitations shall apply:
  - Not more than a maximum of 50 percent of the basal area of trees, and a maximum of 50 percent of the total number of saplings shall be removed for any purpose in a 20-year period. A healthy, well-distributed stand of trees, saplings, shrubs and ground covers and their living, undamaged root systems shall be left in place. Replacement planting with native or naturalized species may be permitted to maintain the 50 percent level.
  - Stumps and their root systems which are located within 50 feet of the reference line shall be left intact in the ground.

Septic Systems

- All new lots, including those in excess of 5 acres, created within the protected shoreland are subject to subdivision approval by the division of water supply and pollution control, subsurface systems bureau under RSA 485-A:29.
- The following conditions, based on the characteristics of the receiving soil as they relate to U.S. Department of Agriculture, soil conservation service drainage classes, shall dictate the setback requirements for all new leaching portions of new septic systems, as follows:
  - Where the receiving soil down gradient of the leaching portions of a septic system is a porous sand and gravel material with a percolation rate faster than 2 minutes per inch, the setback shall be at least 125 feet from the reference line;
  - For soils with restrictive layers within 18 inches of the natural soil surface, the setback shall be at least 100 feet from the reference line; and
  - For all other soil conditions, the setback shall be at least 75 feet from the reference line.

Erosion and Siltation

All new structures within protected shoreland shall be designed and constructed in accordance with rules adopted by the department pursuant to 541-A, relative to terrain alteration under RSA 485-A:17, for controlling erosion and siltation of public waters, during and after construction.

Minimum lots and residential development. In the protected shoreland:

- The minimum size for new lots in areas dependent upon on-site septic systems shall be determined by soil type lot size determinations, as established by the Water Supply and Pollution Control Division.
- For projects in areas dependent upon on-site sewage and septic systems, the total number of residential units in the protected shoreland, whether built on individual lots or grouped as cluster or condominium development, shall not exceed one unit per 150 feet of shoreland frontage.

4. Land Management and State Government

As we have stressed throughout this chapter, the manner in which man uses the land/or its resources within the watershed will play a major role in the maintenance or degradation of water quality standards. Each of the major categories of management practices is reviewed in the following sections and recommendations made relative to the proper application of each, along with a notation of applicable state laws which regulate the manner in which these practices are carried out.

a. Agriculture. A variety of management practices, implemented at individual farm sites, can reduce or eliminate the potential for adverse water quality impacts.
These include:

- Manure Storage and Spreading - Manure should be stored in a facility which reduces or eliminates the potential for runoff or leaching of nutrients into watercourses. Manure spreading should be conducted only when the ground is not frozen or wet. In those instances where plowing is anticipated, such action should commence as near to the date of spreading as possible.

- Land clearing - In all instances where land areas are cleared for the purpose of providing additional cropland or pasture land, the clearing operation should be conducted in a manner that reduces the potential for erosion and sedimentation. (See Silvicultural Activities.)
- Alteration of drainage courses, pond construction and filling of wetlands - Management practices designed to increase the amount of land utilized for cultivation, unless conducted in a manner acceptable to the appropriate state agencies and their established guidelines, can significantly affect the level or water quality within the watershed. Existing and altered drainage courses must be managed so that the potential for stream bank erosion is eliminated. Strict guidelines relative to pond construction, which reduce or eliminate sedimentation and erosion during construction and eliminate the potential for dam failure or improper overflow during peak flow periods, should be followed. Wetlands and marsh areas, especially near stream systems, should be protected as a means of reducing flow velocities, thereby reducing erosion potential and dispersing and reducing sediments and nutrient loading.
- Access to running water - In all cases, direct access to running water (streams, rivers, etc.) by farm animals should be eliminated. Water supply to farm animals should be provided from a tank or alternate system which is located at a reasonable distance from all sources of surface water.
- Chemical fertilization - pesticide, herbicide and fungicide - In those instances where chemical fertilizers or pesticides are used, the application of such should be conducted in a manner which limits the potential for runoff and/or contamination of water systems. This can be achieved by tilling the soil immediately following the application of fertilizer and reducing the use of fertilizers and pesticides within a 125 foot distance of standing or running water.

Each of these recommended management practices relies almost entirely upon the individual landowner for compliance. Some will require capital outlays to achieve these goals. Financial assistance from U.S.D.A. agencies and educational programs directed toward landowners should be made available whenever possible. Existing state laws that govern specific agricultural practices are included in Table XI-6.

Table XI-6
State Laws Governing Agricultural Practices

Revised Statute Annotate	Subject	Governing Agency
RSA 482-A	Dredge and Fill	DES, WRD
RSA 485-A:17	Significant alteration of the terrain	DES, WSPCD
RSA 224:44-a	Cutting near public water or highways	Forest and Lands
RSA 485-A:12-15	Limiting disposal of waste	DES, WMD
RSA 79:10	Notice of intent to cut	NH Dept. of Revenue
RSA 430:28-48	Pesticide control act	Pesticide Control Division
RSA 430:2848	Economic Poisons Act	Pesticide Control Division
RSA 431:33	Regulation of handling of Manure, Agricultural Compost and Chemical Fertilizers	Dept of Agriculture

b. Silvicultural Activities. Timber harvest and silviculture practices, if conducted in an improper manner, can contribute significantly to stream sediment and nutrient levels, thereby affecting the level of water quality within the watershed. The following management practices are recommended as a means of reducing adverse impacts from theses activities.

- Road Construction - Properly designed skid roads, which do not exceed a gradient of 10% and incorporate the use of water bars for drainage purposes, substantially reduce the potential for erosion and sedimentation. In those instances where stream crossings are required, construction of a log bridge and proper attention to stream bank alteration should be implemented by the logger.
- Clear Cutting - In areas of thin soil cover or shallow to bedrock soil characteristics, clear cutting should be minimized to reduce the potential for erosion and nutrient release. In addition, in all areas in which clear cutting practices are conducted, a vegetation buffer area in excess of 100 feet should be maintained around all surface water areas.

The statutes which regulate silviculture practices and timber harvesting are included in Table XI-7.

Table XI-7
State Laws Governing Silviculture Practices

Revised Statute Annotated	Subject	Governing Agency
RSA 224:44-a	Cutting near public water or highway	Forest and Lands
RSA 224:44-6	Care of slash or mill wastes	Forest and Lands
RSA 79:10	Notice of intent to cut	NH Dept of Revenue
RSA 485-A:17	Significant alteration of the terrain	DES, WSPCD
RSA 482-A	Dredge and fill	DES, WRD

c. Construction Practices. Construction operations, whether it be a single family home or a major industrial expansion, can place a severe burden on water quality within the watershed unless closely monitored. Standard practices which reduce the level of erosion and sedimentation should be incorporated at all times. These practices can be enforced by the building inspector of the local municipality as well as by state officials to ensure conformity. These practices include:

- Building Permits - Included within a standard building permit application should be a provision which requires the contractor to incorporate management practices which reduce the potential for soil erosion and sedimentation. Nonconformity to these practices should result in the revocation of such a permit and the issuance of a cease and desist order.
- Site Work - During actual construction, care should be taken to reduce erosion through such control measures as mulching of disturbed soils surfaces and excessive gradients, construction of sediment retention ponds in those instances where surface water is disrupted and phasing of construction when possible to reduce the gross land area which may be exposed or disturbed at any one point in time. Site preparation, such as clearing or grading, should be monitored and practices incorporated similar to those outlined under Timber Harvest and Silviculture Practices.
- Road Construction - Construction of new roadways and the alteration of existing roadways should be conducted so as to eliminate erosion problems. Roadway lane surfaces (dirt roads) and shoulders should be constructed so as to reduce erosion.

Roadside gradients should be no more than 3:1 and mulched as soon after construction as possible. Proper drainage should be provided through use of appropriately designed culverts and ditching alongside roadways. Drainage should be designed such that stormwater runoff from roads and other impervious surfaces is minimal. Construct areas that allow for infiltration of the stormwater.

The incorporation of these broad construction practices can produce substantial results. However, it cannot be left solely to the contractor to ensure the implementation of such practices. While local municipalities can enforce proper practices through the building permit program, assistance and support from the state is available through the enforcement of the statutes listed in Table XI-8.

d. Lawn Fertilizers. The practice of lawn fertilization in areas adjacent to surface waters has the potential of increasing nutrient loading to the water. The Shoreland Protection Act restricts the use of fertilizers, except lime or wood ash, on lawns, grass areas and all existing and future residential properties, within 250 feet of any surface water. This sort of ordinance requires close monitoring by the local municipality and area lake associations during the spring and summer months.

Table XI-8
State Laws Governing Construction Practices

Revised Statute Annotated	Subject	Governing Agency
RSA 79:10	Notice to intent to cut	NH Dept of Revenue
RSA 36:19-29 & 34	Local subdivision regulation	Municipality
RSA 485-A:29-35	Subdivision regulations	DES, WSPCD
RSA 482-A:21	Excavation & dredging	DES, WRD
RSA 485-A:17	Significant alteration of the terrain	DES, WSPCD
RSA 224:44-a	Cutting near public water or highways	Forest and Lands

e. Gravel Pits. The location of gravel pits and the manner in which the material is removed from the site should be closely monitored by local officials. Gravel pits should not be permitted in any location where increased runoff will result in sedimentation of surface waters due to erosion. Where possible, inactive pits should be graded to reduce excessive slopes, thereby reducing the potential for runoff and sedimentation.

RSA 155-E governs the excavation of earth. This law places the burden upon the landowner to obtain a permit from the municipality within which the proposed excavation is planned. In this manner control over excavation of material is retained by the municipality.

5. Watershed Management Summary

Development within the watershed of a lake that fails to take into account the carrying capacity of the land will serve to lessen the value of the lakes. Management of the watershed, which ensures the maintenance of adequate water quality standards and prevents future degradation of water quality, is of obvious importance to the local municipalities from both an economic and environmental standpoint.

Each of the recommended management practices outlined above will require incentives to ensure conformity to, and implementation of, these recommendations. Management practices are more difficult to monitor and enforce than regulatory controls and therefore require alternative means of implementation.

In order to provide for proper management, specific regulatory controls should be incorporated at the local level. Controls should include the determination of lot sizing according to the soil and slope characteristics, enforcement of shoreline setbacks and the control of seasonal cottage conversions to year round residences. Existing state laws lend support to the incorporation of these specific practices. Land management practices relative to agriculture, timber harvest, construction and gravel pit operation require more of a commitment by individual landowners and operators. Enforcement of specific regulations relative to management practices exists primarily at the state level. However, local municipal officials should play a major role in the identification and documentation of potential violations. Local ordinances can be adopted which conform closely to existing state regulations. In this manner, local ordinances supplement state regulations and provide support for existing state laws. Each recommendation will involve some degree of personal

sacrifice. However, this price is small in comparison to the economic, environmental and aesthetic values to be realized by a watershed with a high level of water quality.

Most other management practices require monitoring by local officials who can then notify state authorities when violations of state regulations are documented. This review by the municipal officials is the most effective manner in which these laws can be monitored and enforced.

Programs currently exist at the federal level, through the United States Department of Agriculture (U.S.D.A.) which provide for cost sharing of certain conservation projects. Educational methods can be incorporated by the Soil Conservation Service and can help to point out practices which benefit the farmer as well as reduce the potential for water quality degradation.

I. RECOMMENDATION SUMMARY

The Town of Nottingham, the Nottingham Conservation Commission and the Pawtuckaway Lake Improvement Association (PLIA) have invested considerable amounts of time and effort to ensure the safekeeping of water resources within Nottingham. The Wetlands Conservation Area, Aquifer Protection District and the participation of the PLIA in the New Hampshire Volunteer Lake Assessment Program ensures that the water resources in Nottingham will have protection in the future. In order to create a more intensive and comprehensive protection and preservation strategy for water resources in Nottingham, specifically within the Pawtuckaway Lake watershed, the coordinators of the Diagnostic/Feasibility Study recommend the following watershed management strategies.

1. Lake Protection District

A Lake Protection District should be set up by the Town of Nottingham. This district is defined as an environmental sensitive area surrounding the lakes and ponds of Nottingham in which development activities are closely regulated to preserve the lake quality.

This protection district should also include each sub-drainage basin to the lake. Since land use in the lake's watershed is the key to nutrient and sedimentation rates to the lake, more effort must be devoted to this important element. The adoption of the State's Shoreland Protection Act

to each subwatershed area as discussed earlier in this chapter would be a great benefit to protecting the town's waterbodies.

2. Education

The Town of Nottingham and the Pawtuckaway Lake Improvement Association should initiate an education program and intensify existing educational efforts aimed at educating lake residents, transient lake recreationist, state park visitors and private/public beach users.

Given a choice and a better understanding of the consequences of their actions, most people will opt to improve their environment. If all residents of the Pawtuckaway Lake watershed could enjoy the benefits of a choice recreational facility, they would likely take a greater interest in protecting water quality.

The use of the local media to provide tips on lake protection can be a valuable source of information. Signs posted at public beaches, launches and the state park help educate the transient users on things they should not be doing while utilizing the waterbody. The following is a list of practices that property owners and lake users should follow to help protect lake water quality.

- Lawn fertilization has the potential to create excessive nutrient runoff to drainage and surface water directly. The use of such fertilizers is prohibited within 250 feet of surface waters. Education of the public to the deleterious effects of fertilizers is recommended.
- Develop an education program to inform lake property owners of the specifics of the Shoreland Protection Act.
- Leaf control is important in reducing the phosphorus load to a waterbody. All leaf and grass dumping or burning on the banks of the lake should be eliminated. The removal of dead, non-rooted vegetative material to an area away from the lake will reduce the phosphorus source.
- Land clearing should be kept to a minimum and bare areas should be revegetated to minimize erosion into the waterbody. Maintain a buffer zone of natural vegetation along the shore to contain erosion and assimilate phosphorus.
- Do not bathe, shampoo, or wash anything in the lake with soap or any detergent.
- Do not urinate or defecate in the lake, and don't allow domestic animals to do the

same. Animals should not be housed near the lake where the phosphorus in their manure can be washed into the lake by runoff.

- Waterfowl management should be practiced at Pawtuckaway Lake. Enough natural food substances exist around lakes and ponds to feed duck and geese populations. Property owners and state park personnel should discourage the feeding of waterfowl. Studies have shown that duck and goose excrement is very high in phosphorus and nitrogen concentrations. The combination of a waterfowl population and the host snail significatnly increases the risk of contracting swimmers itch.

The Town of Nottingham should encourage their elementary and secondary schools to participate in the Department of Environmental Services' Interactive Lake Ecology Program. This program is designed to educate the young on principles of lake ecology and preservation of these resources, ensuring that the future residents of the area have the necessary education to be the safeguards of their water resources for future generations to enjoy.

3. Volunteer Monitoring

The Pawtuckaway Lake Improvement Association (PLIA) should continue to participate in the New Hampshire Volunteer Lake Assessment Program on an annual basis. The continued compilation of long term water quality trends is an essential tool in the construction of lake and watershed protection plans for Pawtuckaway Lake. The current scope of the volunteer monitoring program at Pawtuckaway Lake will be adjusted to focus upon the anticipated water quality improvements resulting from the recommended watershed management techniques and Best Management Practices. The volunteer monitors from the PLIA will expand their summer monitoring program to include an intensive water quality study in the Fundy Cove area to establish baseline criteria adjacent to the public access area. Monitoring in this area will continue after the public boat access is rehabilitated to document any water quality improvements or discernible changes.

The Department of Environmental Services Biology Bureau will work with the PLIA monitors to develop an expanded monitoring program during the summer of 1995.

4. Best Management Practices for Agriculture

The Department of Environmental Services will pursue the acquisition of a federally funded nonpoint source grant (Section 319 of the Clean Water Act) that will provide funding for the installation of the recommended agricultural BMPs for Fernalds Dairy Farm. The owner of the farm will provide the soft match for the installation of BMPs which are expected to eliminate a significant source of phosphorus to Pawtuckaway Lake.

An educational program should be made available on BMPs for those people in the watershed who practice animal husbandry or manage "hobby farms".

Hobby farms, with one or more animals, may have poor grazing practices, too many animals per acre, unrestricted access to streams, poor waste management practices and poorly drained soils. Such farms have limited space and capital with which to construct facilities for animal management. They have not traditionally been eligible for cost-sharing grants from federal or state programs.

Since small farms contribute to non-point sources of phosphorus and may even contribute more phosphorus than larger farms that practice BMPs , an educational program is needed on BMPs for waste and pasture management.

5. Best Management Practices for Silviculture

Siviculture activities in the Pawtuckaway Lake watershed must be strictly enforced and regulated. Frequent inspections of silviculture activities may detect a potential water quality problem before it is too late for remedial action.

Forests and public recreational lands are the most common type of land-use cover in the Pawtuckaway Lake watershed. As such, there is potential for water quality impacts due to silvicultural activities. Performance standards and plan review for silvicultural activities are regulated by the state through timber harvesting and water quality protection laws. Regulation prohibits the placement of slash and mill waste in or near waterways, and limits clear-cutting near great ponds and streams. These requirements may mitigate to some degree water quality impacts associated with timber harvesting. More stringent local regulations could increase the setback requirements for disposal of slash.

A major cause of water quality degradation associated with forestry activities is soil erosion

caused or aggravated by logging and skidder roads. Disruption of the vegetative cover, disturbance by heavy equipment, and the often steep slopes on which cutting is carried out, combine to create conditions favoring rapid and severe erosion. Where access to harvest areas involves crossing a waterway, eroded material can rapidly impact downstream waterbodies. The New Hampshire Department of Environmental Services responds to complaints of poor logging practices that impact water quality. The development of local forestry bylaws, under the administration of the Conservation Commission or Planning Board, would provide additional protection to the water resources in the Town of Nottingham.

6. Restricted and Permitted Land Use

Land use regulation is an alternative commonly recommended as a supplement to other watershed and in-lake management measures for control of eutrophication. A number of state and local regulations concerning land use activities are intended to protect surface and groundwater quality, or indirectly serve that function in addition to their intended purpose. Several factors must be weighed when considering a nutrient source control program that is based upon local regulation. To be effective, a control measure should meet three conditions. First, it must be aimed at sources which are controllable. Second, it must be workable and enforceable through the jurisdictional framework within which it is to be implemented. Third, it must be flexible enough to accommodate innovative development options or feasible engineering alternatives while discouraging other, perhaps deleterious, land use practices. Land use regulations typically serve to modify or limit non-point sources of pollutants in a watershed. Thus, the impact of existing regulations, or the effect of implementing new regulations, cannot be adequately determined. Many of these land use regulations discussed in the Shoreland Zoning section should be included in the shoreland protection ordinance.

a. Restricted Uses. Some land uses, by their nature, pose a threat to water quality by introducing or concentrating potential pollutants in the watershed.

Other uses such as sawmills, auto repair garages, riding stables, and storage and disposal of solid waste should be assessed. Surface stormwater drainage for subdivisions poses a threat to water quality and should not be allowed to drain directly into a waterbody. Any development should treat

stormwater runoff in a way which is deemed acceptable by the Department of Environmental Services. In granting exceptions for such uses, or others which could threaten ground or surface water quality, the Board of Adjustment should consider professional advisement on setting conditions and safeguards for water quality protection. Indirect restrictions of some land uses are provided by the Nottingham zoning bylaws, by listing only the uses permitted for each district.

b. Permitted Uses. The most effective method of guarding against deteriorating water quality due to permitted uses is the setting of specific performance standards for certain activities. In the Pawtuckaway Lake watershed, the most pertinent land use activities may be forestry, agriculture, earth removal, and subdivision development. Earth removal should be monitored and inspected on a frequent basis to guard against erosion of materials into any waterbody. Such activities are also governed by state statutes concerning earth removal; RSA-45-A:17 requires permits for construction, earth moving or other significant alteration of the terrain.

Subdivision regulations of Nottingham require that due regard be given to the protection of brooks, streams and other waterbodies. Required improvements for subdivision developments should include stormwater drainage systems that assure minimal changes in the quantity of runoff. An additional recommendation would be to require that comprehensive soil erosion and sedimentation control plans are part of each subdivision filing.

7. Stormwater Runoff Management

There is no stormwater runoff or management plan for roads surrounding Pawtuckaway Lake. Town engineers, lake residents and State Park personnel should map out all uncontrolled direct discharges of stormwater into Pawtuckaway Lake and inflowing tributaries. A best management plan should be designed to treat or reduce the nutrients and pollutants that enter the lake via stormwater runoff.

The Department of Environmental Services Biology Bureau will pursue a federally funded nonpoint source grant to acquire matching funds to install vegetated swales, riprap channels and possible alternative stormwater treatment devices to reduce the water quality impacts associated with stormwater runoff.

8. Sewering

a. Introduction. Based on the analysis of this study, sewering Pawtuckaway Lake or sections of the lake might eliminate up to 20 percent of the entire phosphorus load to the lake. In 1990, Beaver Lake in Derry was sewered at a substantial cost to the lake property owner. It is still too early to ascertain the effect that the sewering of Beaver Lake had on the lake quality. It is probable that the current nonpoint watershed management programs recently implemented will be necessary to improve the quality of Beaver Lake.

The negative aspect of sewering is that new avenues of development may occur. Areas that could not have supported growth because of limitations to septic system use, may now be prime locations for development. In this event, more impervious structures (pavement, building, etc) will be constructed leading to more runoff into the lake, more erosion of sediment into the lake and greater phosphorus loading. Additional lake users might also have a negative effect on the lake quality.

Only the combination of sewering and a strict shoreland protection ordinance will have a beneficial effect upon the lake quality of Pawtuckaway Lake.

b. Subsurface Systems. In the event that sewering Pawtuckaway Lake is cost prohibitive to the Town and lake residents, an annual septic tank pumping program for Pawtuckaway Lake should be initiated through the lake association and Town Health Officer. Many concerned lake residents would volunteer for this worthwhile program. Records of those participating in the program and dates of pumping should be updated each year.

A septic system inspection program for lake residents as well as those who live on tributaries to the lake should also be initiated. A rotating three year inspection program will prompt those who have inadequate systems to get them replaced.

The Town Planning Board should state that it may require changes and additions to a proposed sewage disposal system. Also, the town health officer should issue a cease and desist order if the system becomes non-functional.

A major concern at Pawtuckaway Lake is the conversion of seasonal residences to year-round usage in the lake shore area. An amendment to Nottingham zoning bylaws should define seasonal and permanent use and should alert residents to state law RSA 485-A. These laws should

help the Zoning and Planning Boards regulate lake shore and other conversions.

Zoning bylaws concerning lot sizes may influence local water quality, particularly where on-site subsurface disposal systems are used. Most pertinent to the water quality of Pawtuckaway Lake are the lot size requirements for land surrounding the lake.

J. PROJECT SCHEDULE AND MONITORING PROGRAM

Management of non-point source pollution and local education within the Pawtuckaway Lake watershed comprises the basis of the Pawtuckaway Lake restoration program.

Hypolimnetic anoxia and the measured increase of sediment derived phosphorus would also make Pawtuckaway Lake a good candidate for hypolimnetic phosphorus inactivation, hypolimnetic aeration or sediment oxidation. However, no in-lake restoration techniques should be attempted unless a watershed management plan is adopted and Best Management Practices are implemented to control nonpoint sources of phosphorus to Pawtuckaway lake.

The extent to which the restoration/management strategies developed by Pawtuckaway Lake are eventually implemented will largely be dependent on the availability of local, state and federal funds. Implementation will also depend on local interest and non-financial/volunteer programs set up by the community and the Pawtuckaway lake Improvement Association.

The New Hampshire Department of Environmental Services' Biology Bureau has submitted a grant proposal to the non-point source program coordinator in June of 1995. This grant proposal consists of a comprehensive watershed management strategy developed for Pawtuckaway Lake as a result of the Diagnostic/Feasibility Study. It is anticipated that the Pawtuckaway Lake 319 grant proposal will have a high priority when compared to other grant applications due to the high level of public commitment, lake association involvement and the fact that an intensive Diagnostic/Feasibility Study has been completed on the lake that has identified several sources of non-point source pollution.

Assuming that sufficient funds are available and Pawtuckaway Lake is awarded a 319 nonpoint source program grant, watershed management implementation could begin during the autumn of 1996. The watershed management techniques developed for Pawtuckaway Lake, such as installation of Agricultural BMPs and stormwater BMPs within the Fernalds Brook A

subwatershed as well as stormwater management implementation around Pawtuckaway Lake itself, are dependent on non-point source funding. Any in-lake restoration would not begin until the watershed management, educational and watershed zoning phases are complete.

The following recommendations can all begin immediately: strong shoreland protection ordinance; creating an educational program for lake users and school-aged children; adopting BMPs for hobby farms, agriculture and silviculture and intensifying the volunteer monitoring program. Water quality and biological monitoring of Pawtuckaway Lake and tributaries to the lake should coincide with the proposed watershed management activities. An intensive monitoring program will be initiated on Fernalds Brook A to monitor the efficiency of the proposed agricultural BMPs to reduce the bacterial and phosphours loading to the lake. A monitoring program will also be designed to evaluate the efficiency of the proposed stormwater management practices to reduce sedimentation to the lake and tributaries. Pawtuckaway Lake and selected tributaries will be monitored by aquatic biologists from DES and by volunteer monitors from the Pawtuckaway Lake Improvement Association (PLIA). The expanded volunteer monitoring program for Pawtuckaway Lake will be initiated before watershed management implementation occurs and will continue for a three year period to document changes within the impacted subwatershed. Monthly or bi-weekly sampling of Pawtuckaway Lake and Fernalds Brook A is proposed for the three year period to ascertain any change in trophic status and to evaluate the effectiveness of BMPs. Depth integrated sampling within the lake and analysis for phosphorus, various lake quality and biologic parameters will be continued.

Biocriteria monitoring within the Fernalds Brook A subwatershed will be initiated prior to implementation of the proposed agricultural BMPs at Fernald Farm in order to establish baseline biocriteria data. Multiple macroinvertebrate surveys will be conducted by DES aquatic biologist with assistance from PLIA volunteers for a three year period surrounding BMP installation. These efforts will reflect any change in the aquatic community resulting from the watershed management practices.

An expanded volunteer lake assessment program will be developed for Pawtuckaway Lake immediately which will focus on collecting water quality data and trends from the Fundy Cove area surrounding the public boat access facility. The scope of this monitoring effort will focus on evaluating the proposed rehabilitation of the existing launch facility. The monitoring program will be designed to bracket the study area in order to ascertain any non-point source impacts before

construction begins and to evaluate the effectiveness of the proposed rehabilitation and suggested stormwater BMPs for this site when complete. A monthly or bi-weekly monitoring program during the appropriate seasons will be developed by volunteers and DES aquatic biologists. This monitoring project will be integrated into the 1995 Summer Volunteer Lake Assessment Program for the Pawtuckaway Lake Association. Table XI-9 provides a suggested preliminary project implementation schedule. A preliminary monitoring program and schedule, designed to gage the effectiveness of the different restoration strategies is shown in Table XI-10. Table XI-11 is a summary of recommendations that DES feels necessary to protect the quality of Pawtuckaway Lake.

Table XI-9

Preliminary Project Implementation Schedule

Task Year	1995		1996				1997			
Quarter	3	4	1	2	3	4	1	2	3	4
Watershed and Lake Protection Zoning Ordinances										
Review and Possible Revision of Zoning Ordinances		★	★	■	■					
Adopt BMP Ordinances For Silviculture, Agriculture, and Hobby Farms		★	★							
Watershed										
319 Proposal		♦	♦							
Agricultural BMPs	★	★	★	■	■	■				
Subsurface System Upgrade Program	★	★	★		■	■				
Stormwater Management		★	★	■	■	■				
Upgrade Efforts to Monitor Watershed	■				■				■	
In-Lake										
Reevaluate Lake Quality Conditions	■	■			■	■			■	■
Shoreline Survey	★				■				■	
Education										
School System		★	★	■				■		
Lake Users		★	★	★	■				■	

Key

♦	Grant Application Submittal, Review, Award and Procure Local Match
★	Evaluation/Design
■	Implementation

Table XI-10
Preliminary Monitoring Program and Schedule

Task/Year	1995				1996				1997				1998				1999			
Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Water Chemistry																				
Public Access		●	●			●	●			●	●			●	●			●	●	
Fish Tournaments		■	■			■	■			■	■			■	■			■	■	
Stormwater Runoff					+	+	+		+	+	+		+	+	+		+	+	+	
NHVLAP Lake and Tributaries		+	●			+	●			+	●			+	●			+	●	
Sub-Watershed Monitoring Program		+	●			+	●			+	●			+	●			+	●	
Biological																				
Fernalds Brook		B	B			B	B			B	B			B	B			B	B	
In-Lake			A/C				A/C				A/C				A/C				A/C	
Hydrologic																				
Fernalds Brook		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Stormwater Runoff				+	+	+	+	+		+	+			2	3					
Physical																				
Septic Pumpout			D				D				D				D				D	
Shoreline Survey			D				D				D				D				D	

Key

●	Continuous Monthly or Bi-Weekly Sampling	■	Event Monitoring	B	Macroinvertebrates	D	Physical/Visual Survey
+	Single Sampling Round	A	Macrophyton	C	Plankton		

Table XI-11
DES Recommendations Summary for Pawtuckaway Lake

Zoning Amendments

- Lake Protection District (Adoption of Shoreland Protection Ordinance)
  - Restricted Uses
  - Permitted Uses

Education

- Local Education - Lake Related
  - Lake Residents
  - Transient Users
  - State Park Visitors

- Local Education - Watershed Concerns
  - BMPs for Hobby Farms, Dairy, Agriculture
  - BMPs for Silviculture

- Interactive Lake Ecology Program for Nottingham and Deerfield School Systems

- Volunteer Lake Assessment Program

Watershed Management/Lake Restoration

- Agricultural BMP Implementation

- Stormwater BMP Implementation

- Alternative Subsurface System Evaluation

- Subsurface Pumpout Program

In-Lake Restoration/Management

- Evaluate Lake Quality
- Evaluate Hypolimnetic Anoxia
- Evaluate Hypolimnetic Internal Phosphorus Loading

K. PROPOSED BUDGET FOR THE 1996-1997 IMPLEMENTATION YEARS

1. Construction and Contractual

a. Agricultural Best Management Practices

Construction of Manure Storage Facility	$ 12,400
Construction of Heavy Use Area	$ 6,100
Installation of Suspended Roof Gutters	$ 14,000
Construction Equipment Use	$ 10,000
Agricultural BMP Costs	$ 42,500

b. Stormwater Best Management Practices

Construction of Rip Rap Trench	$ 5,300
Construction of Vegetated Swale	$ 800
Alternative Treatment Technology	$ 4,000
Stormwater BMP Costs	$ 10,100

Total Construction and Contractual Costs	$ 52,600

2. Personnel

Biologist I (50 percent of the time)	
1996 year	$ 15,000
1997 year	$ 16,000
Total Personnel	$ 31,000

3. Benefits

1996 year	$ 5,250
1997 year	$ 5,600
Total Benefits	$ 10,850

4. Indirect Costs (2.17%)

1996 year	$ 440
1997 year	$ 470
Total Indirect Costs	$ 910

5. Administrative Support

Total Administrative Support	$ 2,100

6. Travel

Total Travel	$ 1,000

7. Laboratory Services

1996 year	$ 3,000
1997 year	$ 4,000
Total Laboratory Costs	$ 7,000

8. Supplies

ILE Education Program	$ 500
Lab and Field	$ 1,500
Total Supplies	$ 2,000

9. Equipment

Total Equipment Costs	$ 5,000

10. Audit

Total Audit	$ 115
Total Proposed Budget Costs	$112,575

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APPENDIX II-1

Pawtuckaway Lake
New Hampshire Fish and Game Department
Historical Water Quality Data

Date	Trans (feet)	Depth (feet)	Temp (^{0}F)	pH (units)	O_2 (ppm)	CO_2 (ppm)
8/25/37	11	surface	76.3	6.4		
		10	71.1	6.4	5.2	
		20	52.7	5.6	2.1	9.0
		33	48.9	5.6	2.0	12.0
7/11/47	10	surface	81.0	6.6	7.5	3.0
		10	72.0	6.2	5.5	8.0
		20	59.0	6.0	5.7	9.0
		30	59.0	6.0	5.9	10.0
		40	55.0	6.2	3.9	13.0

APPENDIX II-2

DEPARTMENT of ENVIRONMENTAL SERVICES
Water Supply & Pollution Control Division - Biology Bureau

LAKE TROPHIC DATA

MORPHOMETRIC:

Lake:	PAWTUCKAWAY LAKE	Lake Area (ha):	364.22
Town:	NOTTINGHAM	Maximum depth (m):	15.3
County:	Rockingham	Mean depth (m):	3.0
River Basin:	Coastal	Volume (m^3):	10953000
Latitude:	43°05'00" N	Relative depth:	0.7
Longitude:	71°09'00" W	Shore configuration:	4.09
Elevation (ft):	250	Areal water load (m/yr):	6.67
Shore length (m):	27700	Flushing rate (yr^{-1}):	2.20
Watershed area (ha):	5363.5	P retention coeff.:	0.61
% watershed ponded:	0.2	Lake type:	natural w/dam

BIOLOGICAL:	15 February 1990	25 July 1989
DOM. PHYTOPLANKTON (% TOTAL) #1	ASTERIONELLA 98%	COELOSPHAERIUM 35%
#2		SPHAEROCYSTIS 30%
#3		MICROCYSTIS 25%
PHYTOPLANKTON ABUNDANCE (cells/mL)		1975.0
CHLOROPHYLL-A (µg/L)		5.28
DOM. ZOOPLANKTON (% TOTAL) #1	NAUPLIUS LARVA 39%	NO DOMINANT
#2	KELLICOTTIA 30%	
#3		
ROTIFERS/LITER	13	22
MICROCRUSTACEA/LITER	31	11
ZOOPLANKTON ABUNDANCE (#/L)	44	33
VASCULAR PLANT ABUNDANCE		Scattered-Common
SECCHI DISK TRANSPARENCY (m)		3.6
BOTTOM DISSOLVED OXYGEN (mg/L)	5.9	0.6
BACTERIA (fecal col., #/100 ml) #1		
#2		
#3		

SUMMER THERMAL STRATIFICATION:

stratified

Depth of thermocline (m): 4.2
Hypolimnion volume (m^3): 1127000

CHEMICAL:

Lake: PAWTUCKAWAY LAKE
Town: NOTTINGHAM

	15 February 1990		25 July 1989		
DEPTH (m)	4.0	8.0	2.0	5.0	7.5
pH (units)	6.0	6.1	6.8		
A.N.C. (Alkalinity)	4.8	4.6	4.1		
NITRATE NITROGEN	0.17	0.21			
TOTAL KJELDAHL NITROGEN	0.47	0.62			
TOTAL PHOSPHORUS	0.021	0.021	0.009	0.013	0.014
CONDUCTIVITY (µ mhos/cm)	56.9	57.3	48.4	48.8	50.3
APPARENT COLOR (cpu)	48	47	28	32	36
MAGNESIUM			0.72		
CALCIUM			2.4		
SODIUM			4.8		
POTASSIUM			0.70		
CHLORIDE	8	8			
SULFATE	4	4			
TN : TP	30	40			
CALCITE SATURATION INDEX			3.5		

All results in mg/L unless indicated otherwise

TROPHIC CLASSIFICATION: 1989

D.O.	S.D.	PLANT	CHL	TOTAL	CLASS
3	2	2	1	8	Meso.

COMMENTS:

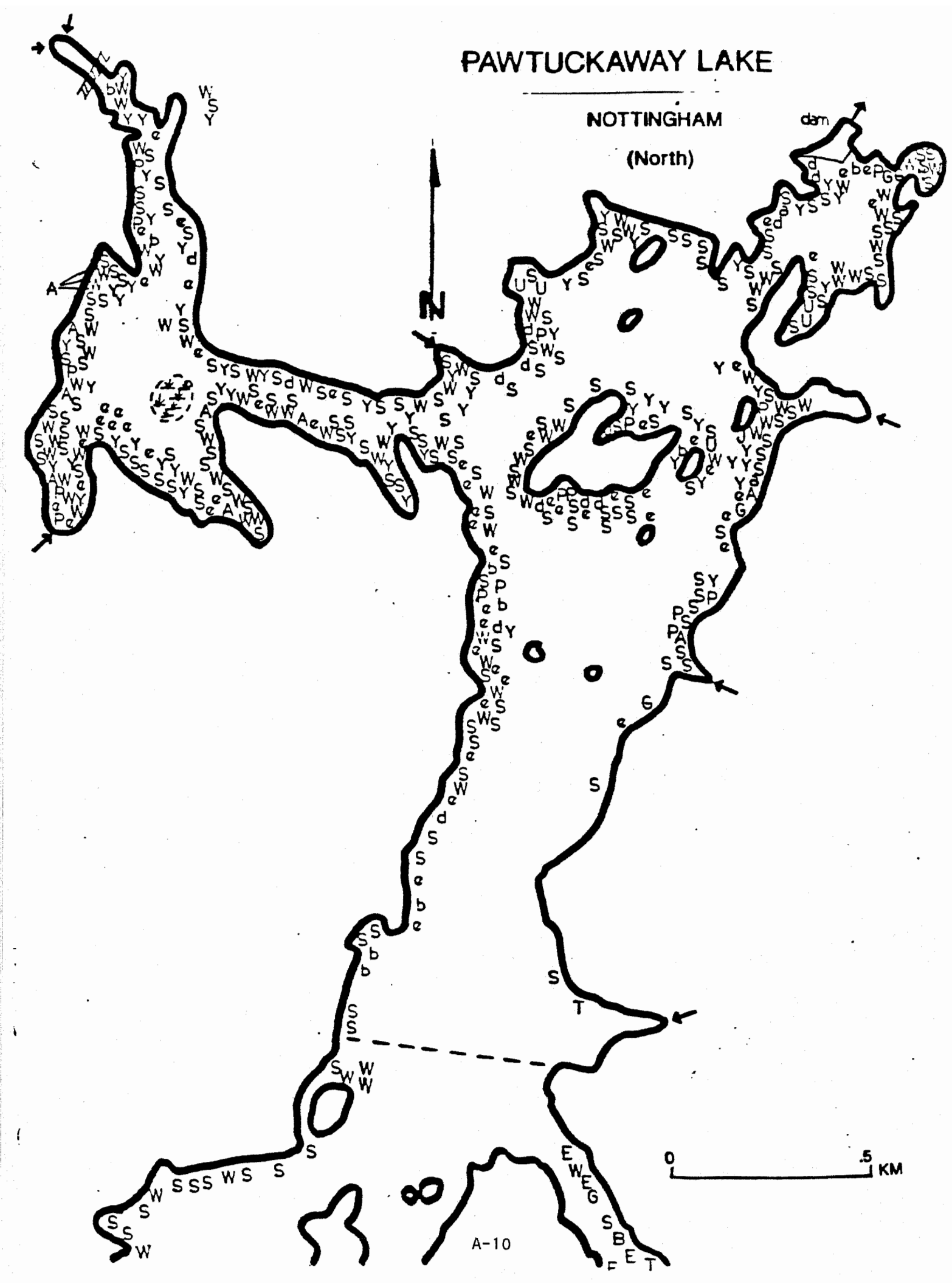
AQUATIC PLANT SURVEY

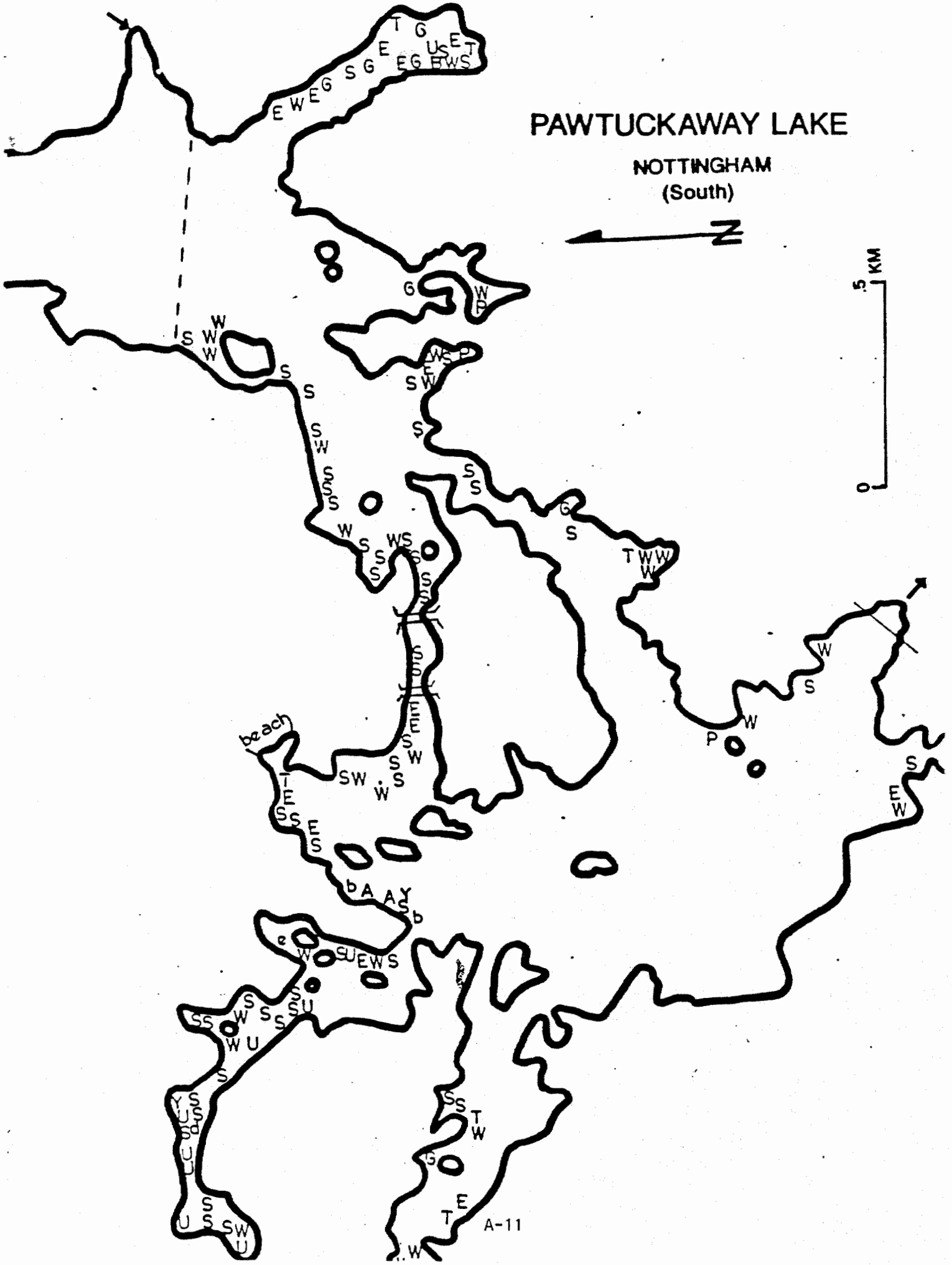
LAKE: PAWTUCKAWAY LAKE TOWN: NOTTINGHAM DATE: 07/25/89

Key	PLANT NAME		ABUNDANCE
	GENERIC	COMMON	
E	Eriocaulon septangulare	Pipewort	Sparse
W	Potamogeton	Pondweed	Sparse
G	Gramineae	Grass family	Sparse
S	Sparganium	Bur reed	Scattered
T	Typha	Cattail	Sparse
B	Brasenia schreberi	Water shield	Sparse
U	Utricularia	Bladderwort	Scattered
P	Pontederia cordata	Pickerelweed	Sparse
N	Nymphaea	White water lily	Sparse
b	Scirpus	Bulrush	Sparse
e	Eleocharis	Spike rush	Scattered
A	Sagittaria	Arrowhead	Sparse
Y	Nuphar	Yellow water lily	Scattered
a	Peltandra virginica	Arrow arum	Sparse
d	Dulichium arundinaceum	Three-way sedge	Sparse

OVERALL ABUNDANCE: Scattered-Commo

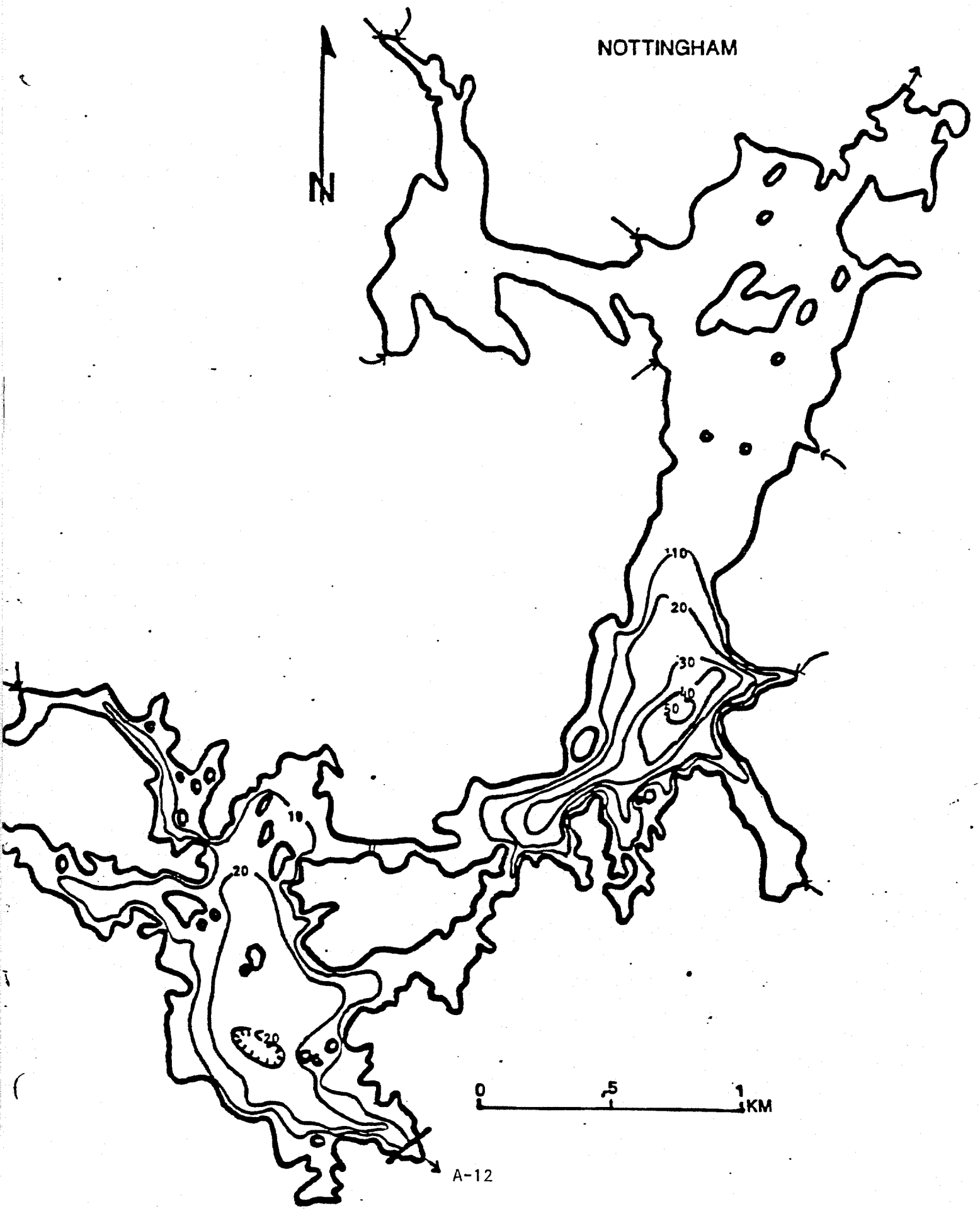
GENERAL OBSERVATIONS:


PAWTUCKAWAY LAKE
NOTTINGHAM
(North)
dam
N
0
.5
KM


PAWTUCKAWAY LAKE
NOTTINGHAM
(South)
N
.5 KM
0
beach
bAAY
A-11

PAWTUCKAWAY LAKE

NOTTINGHAM



FIELD DATA SHEET

LAKE: PAWTUCKAWAY LAKE
DATE: 07/25/89

TOWN: NOTTINGHAM
WEATHER: HAZY, HOT & HUMID

	DEPTH (M)	TEMP (°C)	*DISSOLVED OXYGEN	OXYGEN SATURATION
	0.1	27.5	8.9	110 %
	1.0	27.0	8.9	110 %
	2.0	25.9	8.9	106 %
	3.0	23.9	8.9	102 %
	4.0	20.8	6.1	67 %
	5.0	15.8	3.6	35 %
	6.0	13.0	3.4	32 %
	7.0	11.0	3.2	29 %
	8.0	10.0	3.1	27 %
	9.0	9.8	2.2	19 %
	10.0	9.0	1.2	10 %
	11.0	8.8	0.9	7 %
	12.0	8.2	1.0	8 %
	13.0	8.0	1.1	9 %
	14.0	8.0	1.1	9 %
	15.0	8.0	0.6	5 %

SECCHI DISK (m): 3.6

BOTTOM DEPTH (m): 15.4

TIME: 1347

COMMENTS:

*Dissolved oxygen values are in mg/L

TROPHIC CLASSIFICATION OF N.H. LAKES AND PONDS

NAME Pawtuckaway Lake TOWN Nottingham CO Rockingham RIVER BASIN Piscataqua/coastal

I. POTENTIAL FOR NUTRIENT ENRICHMENT

A. NATURAL PHYSICAL FACTORS

1. Area (ha) 324.20
2. Max. depth (m) 13.7
3. Mean depth (m) 2.5
4. Elevation (ft) 250
5. Shore length (m) 27,700
6. Volume (m^3) 7,984,000
7. Volume/shore length 290
8. % Stratification 14
9. Watershed area (ha) 5,363.5
10. Watershed area / Volume 6
11. Bottom slope 0.7
12. Shore config. 4.34
13. Flushing rate 3.0
14. Water renewal time 0.3
15. Drainage density -
16. % Watershed ponded 0.2
17. Phos. retent. coeff. R 0.59

B. CULTURAL FACTORS

1. % Shore developed
2. Number nearshore homes
3. # nearshore homes/mile shore
4. Volume lake/# nearshore homes
5. Estimate of non-point Tot-P loading:
   a. Land Use
   b. Precipitation
   c. Subsurface disposal
   d. Other

II. INDICATORS OF TROPHIC CONDITION (mg/l unless indicated otherwise)

A. Winter Data:

Date January 17, 1978 Weather Overcast: -2°C; no wind

Depth(m)	3.0	6.0
Alkalinity	2.0	2.0
PO_4-P	0.001	0.002
Total-P	0.010	0.016
NO_2+NO_3-N	0.08	0.08
Kjeld-N	0.23	0.28
Total-N	0.31	0.36
Tot-N/Tot-P	31	22
NO_2+NO_3-N/PO_4-P	80	40

Bottom: Depth 6.5 m D.O. 9.9 % Sat. 72

% Organic matter sediment 36.5

Dom. Phytopl. 1. Asterionella - 45%
2. Coelosphaerium - 20%

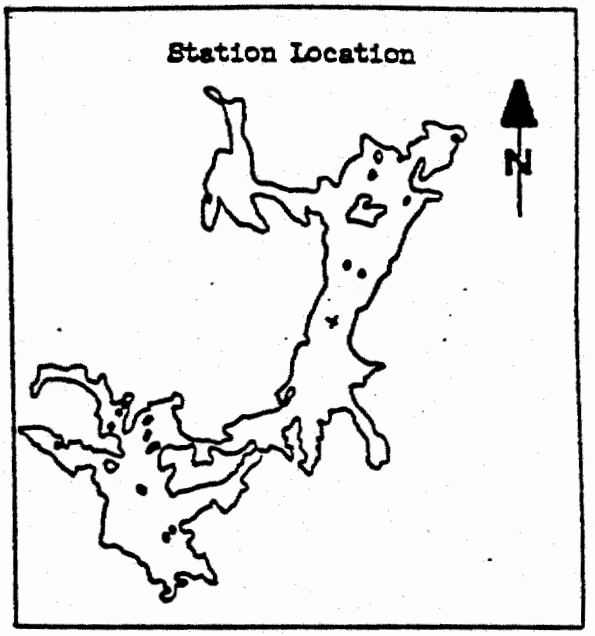
Dom. Zoopl. 1. Kellicottia - 45%
2.

B. Summer Data:

Date August 14, 1979 Weather Overcast - light rain, wind

	Mid-ep	Mid-therm	Mid-hyp
Depth (m)	2.0	5.0	7.5
pH (units)	6.2.	6.0.	5.3.
Alkalinity	9.0	3.0	5.0
PO_4-P	<0.001	<0.001	<0.001
Total-P	0.003	0.005	0.007
NO_2+NO_3-N	<0.05	<0.05	0.07
Kjeld-N	0.23	0.23	0.14
Total Residue	37	-	-
Color (units)	20	20	30
Turb. (NTU)	0.7	0.6	0.7
Spec. Conduct. (μMhos/cm)	36.6	36.9	38.9
Tot. Org. Carbon	8	-	-
Chloride	2	2	2
Mg	0.66	-	-
Ca	3.7	-	-
Na	3.9	-	-
K	0.4	-	-
[Mg+Ca] / [Na+K]	1.01	-	-
Tot-N/Tot-P	-	-	-
NO_2+NO_3-N/PO_4-P	-	-	-

Station Location



Bottom: Depth 8.5 m D.O. 3.5 % Sat. 30

Epilimnetic alkalinity decrease -7.0

PO_4-P ratio: epi/hyp 0

Total-P ratio: epi/hyp 0.43

Secchi disk transparency (M) 4.0

% organic Matter sediment -

Vascular Plants Common

Dom. Vasc. Plants: 1. Vallisneria
2. Sparganium
3. Potamogeton

Ash-Free Dry Weight

Chlorophyll a 3.51 (mg/m^3)

Tot. Zoopl. Cnts. 204 (cells/liter)

Dom. Phytopl. 1. Tabellaira - 30%
2. Sphaerocystis - 25%

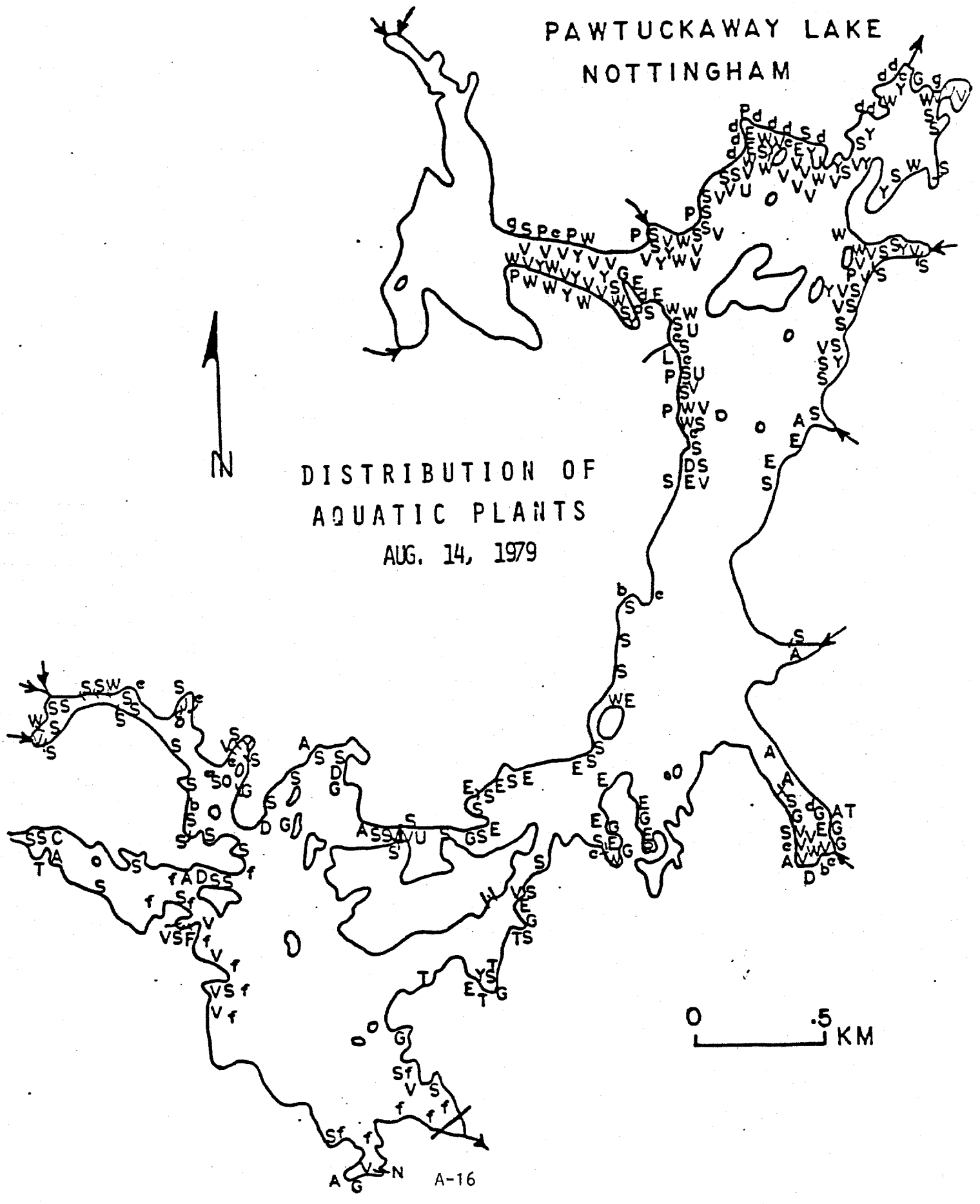
Dom. Zoopl. 1. Vorticella - 30%
2. Nauplius larva - 20%

TROPHIC CLASSIFICATION 1979 :

	D.O.	S.D.	Vasc. Plants	Chl a	Total	Class.
Classification Points:	1	1	2	0	4	Oligo.

COMMENTS:

1. This is a man-made pond.


PAWTUCKAWAY LAKE
NOTTINGHAM
N
DISTRIBUTION OF
AQUATIC PLANTS
AUG. 14, 1979
0
.5
KM

AQUATIC PLANT SURVEY

LAKE Pawtuckaway Lake TOWN Nottingham DATE Aug. 14, 1979 BY WSPCC

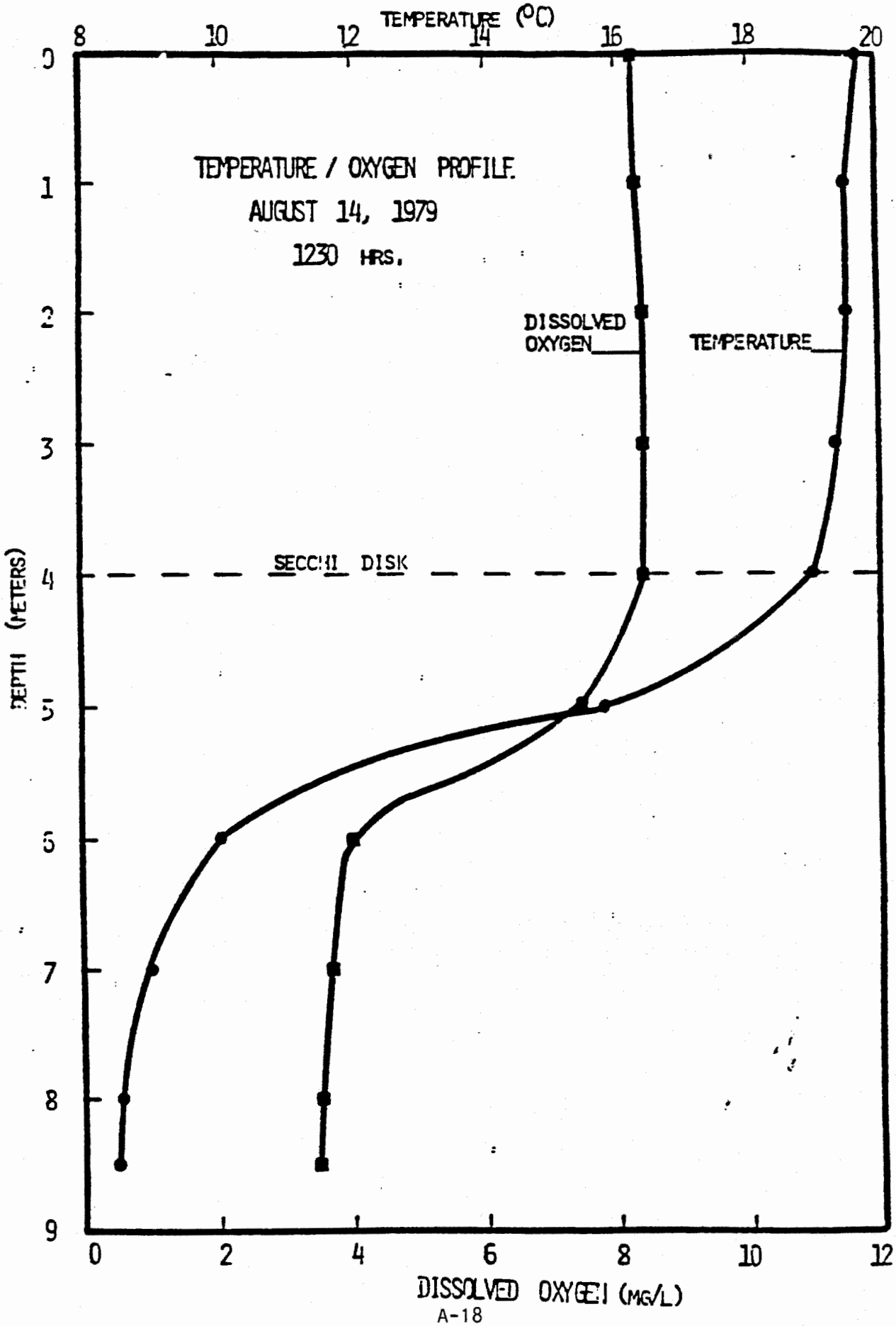
No.	PLANT NAME		ABUNDANCE
	GENERIC	COMMON	
V	Vallisneria americana	Tape Grass	Abundant
T	Typha	Cattail	Scattered
E	Eriocaulon septangulare	Pipewort	Common
G	Gratiola lutea	Hedge Hyssop	Scattered
S	Sparganium	Bur Reed	Abundant
Y	Nuphar	Yellow Water Lily	Common
N	Nymphaea	Water Lily	Sparse
A	Sagittaria	Arrowhead	Scattered
C	Carex	Sedge	Sparse
D	Decodon verticillatus	Swamp Loosestrife	Scattered
b	Scirpus validus	Softstem Bulrush	Scattered
W	Potamogeton	Pondweed	Common
U	Utricularia	Bladderwort	Scattered
e	Eleocharis	Spike Rush	Scattered
L	Lysimachia	Swampcandle	Scattered
d	Dulichium arundinaceum	Three-way Sedge	Scattered
P	Pontederia cordata	Pickerelweed	Scattered
g	Gramineae	Grass Family	Sparse
X	Polygonum	Smartweed	Sparse
f	Oscillatoria	Filamentous Blue-green Algae	Scattered

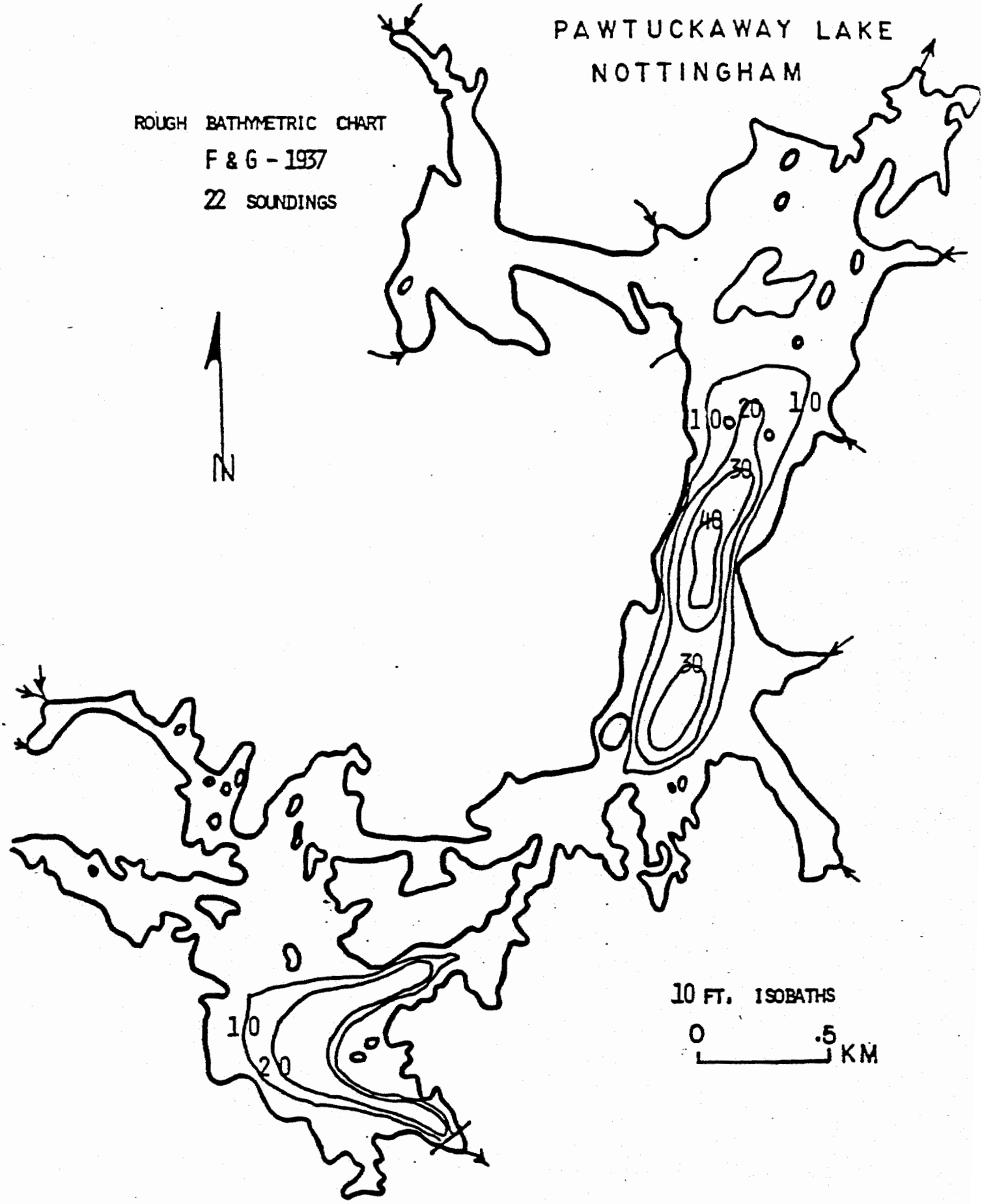
OVERALL ABUNDANCE Common

GENERAL OBSERVATIONS:

1. Plants were very common along much of the shore, and were abundant in the northern undeveloped area. However, they were not really a nuisance to boating or swimming in the main lake area where most of the cottages are located.

2. Clumps of Oscillatoria were locally abundant in the area of the southern dam, but scarce north of Horse Island.


PAWTUCKAWAY LAKE, NOTTINGHAM
TEMPERATURE (°C)
8
10
12
14
16
18
20
TEMPERATURE / OXYGEN PROFILE
AUGUST 14, 1979
1230 HRS.
DISSOLVED OXYGEN
TEMPERATURE
SECCHI DISK
DEPTH (METERS)
0
1
2
3
4
5
6
7
8
9
0
2
4
6
8
10
12
DISSOLVED OXYGEN (MG/L)


PAWTUCKAWAY LAKE
NOTTINGHAM
ROUGH BATHYMETRIC CHART
F & G - 1937
22 SOUNDINGS
N
10
20
10
30
40
30
10
20
10 FT. ISOBATHS
0
.5
KM

APPENDIX II-3

pH summary for current and historical sampling seasons.
Values in units, listed by station and year.

Station	Year	Minimum	Maximum	Mean
BACK CREEK A				
	1988	6.64	6.84	6.72
	1989	6.44	6.76	6.61
	1990	6.97	6.97	6.96
	1991	6.50	7.29	6.67
BACK CREEK B				
	1988	6.59	6.59	6.59
	1989	6.15	6.56	6.33
	1990	5.94	6.89	6.28
	1991	6.50	6.91	6.71
DALLOFF DAM				
	1991	6.92	6.97	6.94
DOLLOFF DAM				
	1988	6.70	6.74	6.71
	1989	6.83	7.03	6.91
	1991	6.90	6.90	6.89
DROWNS DAM				
	1988	6.13	6.75	6.33
	1989	6.45	6.87	6.62
	1990	6.56	6.56	6.56
	1991	6.40	6.84	6.58
EPILIMNION				
	1988	6.68	6.85	6.75
	1989	6.50	7.70	6.79
	1990	6.73	6.96	6.82
	1991	6.61	6.80	6.70
FERNALDS A				
	1988	6.82	6.82	6.81
	1989	6.89	6.93	6.90
	1990	6.76	7.30	6.94
	1991	6.80	7.16	6.93
FERNALDS B				
	1988	6.81	6.81	6.80
	1989	6.29	6.29	6.28
	1991	6.90	6.90	6.89
FUNDY BK				
	1988	5.01	5.14	5.07
	1989	5.02	5.41	5.18
	1990	5.29	5.55	5.39
	1991	5.38	5.70	5.48
GOVE DAM				

PAWTUCKAWAY LAKE
NOTTINGHAM

pH summary for current and historical sampling seasons.
Values in units, listed by station and year.

Station	Year	Minimum	Maximum	Mean
	1989	6.22	6.50	6.36
	1990	6.57	6.65	6.60
	1991	6.40	6.61	6.49
HYPOLIMNION				
	1988	5.93	5.93	5.93
	1989	6.10	7.70	6.41
	1990	5.90	6.55	6.11
	1991	6.10	6.80	6.27
LOON COVE A				
	1989	5.58	5.58	5.58
	1990	6.60	6.65	6.62
	1991	6.70	7.02	6.86
LOON COVE B&C				
	1990	6.73	6.73	6.73
LOON COVE B				
	1989	6.56	6.64	6.59
	1990	6.80	6.84	6.81
	1991	6.60	6.90	6.72
LOON COVE C				
	1989	6.62	6.62	6.61
METALIMNION				
	1988	6.08	6.29	6.17
	1989	6.33	7.70	6.59
	1990	6.08	6.80	6.40
	1991	6.40	6.94	6.55
MOUNTAIN BK				
	1988	6.41	6.98	6.60
	1989	6.79	6.84	6.81
	1990	6.24	7.01	6.55
	1991	3.70	6.80	4.17
NEIL'S COVE				
	1989	6.72	6.72	6.72
ROUND POND BK				
	1988	6.36	6.56	6.44
	1989	6.31	6.49	6.40
	1990	6.48	6.80	6.65
	1991	6.60	6.76	6.68
WHITE GROVE BK				
	1988	6.44	6.44	6.43
	1989	6.07	6.47	6.24
	1990	6.24	6.63	6.39

PAWTUCKAWAY LAKE
NOTTINGHAM

Summary of current and historical Acid Neutralizing Capacity. Values expressed in mg/L as $CaCO_3$.

Epilimnetic Values

Year	Minimum	Maximum	Mean
1988	3.80	4.20	4.00
1989	4.00	4.10	4.03
1990	4.10	4.70	4.40
1991	3.50	4.40	4.03

PAWTUCKAWAY LAKE
NOTTINGHAM

Specific conductance results from 1991 and historic sampling seasons. Results in umhos/cm.

Station	Year	Minimum	Maximum	Mean
BACK CREEK A				
	1988	38.6	47.3	42.9
	1989	33.1	44.2	37.4
	1990	31.2	31.2	31.2
	1991	33.2	43.9	37.2
BACK CREEK B				
	1988	47.3	47.3	47.3
	1989	27.3	47.6	40.3
	1990	43.6	55.9	50.8
	1991	45.4	46.4	45.9
DALLOFF DAM				
	1991	40.7	44.7	42.7
DOLLOFF DAM				
	1988	41.8	44.7	43.2
	1989	45.6	45.8	45.7
	1990	46.5	46.5	46.5
	1991	43.9	43.9	43.9
DROWNS DAM				
	1988	40.0	42.7	41.4
	1989	43.3	45.3	44.3
	1990	44.0	44.0	44.0
	1991	41.1	47.2	43.2
EPILIMNION				
	1988	42.1	43.3	42.7
	1989	46.5	48.4	47.4
	1990	47.9	48.3	48.1
	1991	41.6	43.6	42.4
FERNALDS A				
	1988	18.9	18.9	18.9
	1989	211.9	2030.0	1120.9
	1990	153.5	189.0	171.1
	1991	163.6	185.8	173.6
FERNALDS B				
	1988	44.2	44.2	44.2
	1989	37.4	37.4	37.4
	1991	45.7	45.7	45.7
FUNDY BK				
	1988	43.8	44.7	44.2
	1989	39.7	42.8	41.7
	1990	40.5	45.7	42.5
	1991	34.4	39.2	36.4
GOVE DAM				
	1989	54.6	66.5	59.2

PAWTUCKAWAY LAKE
NOTTINGHAM

Specific conductance results from 1991 and historic sampling seasons. Results in umhos/cm.

Station	Year	Minimum	Maximum	Mean
	1990	43.2	61.2	50.8
	1991	42.8	75.3	59.0
HYPOLIMNION				
	1988	45.1	47.9	46.5
	1989	47.9	50.9	49.7
	1990	48.3	51.8	50.4
	1991	42.8	48.9	45.1
LOON COVE A				
	1990	23.5	30.0	26.7
	1991	34.7	40.4	36.9
LOON COVE B&C				
	1990	27.9	27.9	27.9
LOON COVE B				
	1989	31.5	34.4	32.9
	1990	32.3	40.0	36.1
	1991	29.1	37.4	34.6
LOON COVE C				
	1989	33.1	33.1	33.1
METALIMNION				
	1988	43.9	44.0	44.0
	1989	47.9	48.8	48.3
	1990	47.3	49.6	48.1
	1991	42.3	43.8	42.9
MOUNTAIN BK				
	1988	44.4	44.4	44.4
	1989	37.5	40.2	38.8
	1990	37.7	49.4	41.7
	1991	45.6	125.0	73.4
ROUND POND BK				
	1988	28.2	29.8	29.0
	1989	26.5	29.1	27.9
	1990	28.2	29.9	29.0
	1991	29.3	34.1	31.1
WHITE GROVE BK				
	1988	140.1	140.1	140.1
	1989	120.5	129.6	124.6
	1990	126.5	135.1	130.7

PAWTUCKAWAY LAKE
NOTTINGHAM

Summary of 1991 and historical apparent color data.
Results in color units.

Station	Year	Minimum	Maximum	Mean
BACK CREEK A				
	1988	84	95	89
	1989	39	58	51
	1990	65	65	65
	1991	12	116	64
BACK CREEK B				
	1988	110	110	110
	1989	100	104	102
	1990	90	136	108
	1991	75	200	120
DALLOFF DAM				
	1991	15	18	16
DOLLOFF DAM				
	1988	20	23	21
	1989	23	24	23
	1990	20	20	20
	1991	19	19	19
DROWNS DAM				
	1988	31	38	34
	1989	38	47	42
	1990	33	33	33
	1991	32	46	36
EPILIMNION				
	1988	22	26	24
	1989	23	29	26
	1990	22	28	25
	1991	17	27	21
FERNALDS A				
	1988	75	75	75
	1989	68	80	74
	1990	48	70	57
	1991	70	100	85
FERNALDS B				
	1988	30	30	30
	1989	43	43	43
FUNDY BK				
	1988	126	180	153
	1989	113	120	116
	1990	100	156	125
	1991	85	110	97
GOVE DAM				
	1989	76	120	98

PAWTUCKAWAY LAKE
NOTTINGHAM

Summary of 1991 and historical apparent color data.
Results in color units.

Station	Year	Minimum	Maximum	Mean
	1990	73	85	79
	1991	28	65	46
HYPOLIMNION				
	1988	33	45	39
	1989	29	36	33
	1990	21	65	48
	1991	23	110	54
LOON COVE A				
	1989	15	15	15
	1990	21	90	55
	1991	48	55	52
LOON COVE B&C				
	1990	68	68	68
LOON COVE B				
	1989	75	86	80
	1990	75	140	107
	1991	50	64	54
LOON COVE C				
	1989	86	86	86
METALIMNION				
	1988	25	30	27
	1989	27	32	29
	1990	22	28	26
	1991	19	25	22
MOUNTAIN BK				
	1988	85	108	96
	1989	84	92	88
	1990	100	110	106
	1991	64	120	91
ROUND POND BK				
	1988	65	84	74
	1989	40	105	66
	1990	60	109	78
	1991	50	75	63
WHITE GROVE BK				
	1988	20	20	20
	1989	20	30	24
	1990	14	19	16

PAWTUCKAWAY LAKE
NOTTINGHAM

Summary historical and 1991 sampling season Total Phosphorus data. Results in ug/L.

Station	Year	Minimum	Maximum	Mean
BACK CREEK A				
	1988	41	50	45
	1989	12	47	27
	1990	25	25	25
	1991	7	48	30
BACK CREEK B				
	1988	51	51	51
	1989	32	39	35
	1990	34	61	49
	1991	39	54	47
DALLOFF DAM				
	1991	3	18	10
DOLLOFF DAM				
	1988	10	10	10
	1989	6	8	7
	1990	19	19	19
	1991	5	5	5
DROWNS DAM				
	1988	17	23	20
	1989	12	16	14
	1990	13	13	13
	1991	12	19	16
EPILIMNION				
	1988	6	11	8
	1989	7	13	9
	1990	11	17	13
	1991	9	10	9
FERNALDS A				
	1988	11	11	11
	1989	4	207	102
	1990	90	138	115
	1991	111	190	143
FERNALDS B				
	1988	26	26	26
	1989	34	34	34
	1991	28	28	28
FUNDY BK				
	1988	85	97	91
	1989	42	61	52
	1990	40	64	50
	1991	40	62	51
GOVE DAM				

PAWTUCKAWAY LAKE
NOTTINGHAM

Summary historical and 1991 sampling season Total Phosphorus data. Results in ug/L.

Station	Year	Minimum	Maximum	Mean
	1989	34	59	47
	1990	39	44	41
	1991	18	43	30
HYPOLIMNION				
	1988	13	24	18
	1989	5	14	11
	1990	12	34	26
	1991	15	51	28
LOON COVE A				
	1990	13	50	31
	1991	25	37	33
LOON COVE B&C				
	1990	45	45	45
LOON COVE B				
	1989	21	44	32
	1990	47	94	70
	1991	41	45	43
LOON COVE C				
	1989	53	53	53
METALIMNION				
	1988	17	18	17
	1989	10	13	11
	1990	16	23	18
	1991	7	14	11
MOUNTAIN BK				
	1988	44	49	46
	1989	30	56	39
	1990	38	42	39
	1991	39	58	47
ROUND POND BK				
	1988	55	78	66
	1989	36	75	51
	1990	41	104	66
	1991	41	126	78
WHITE GROVE BK				
	1988	56	56	56
	1989	6	27	16
	1990	11	31	24

PAWTUCKAWAY LAKE
NOTTINGHAM

Chlorophyll-a results (mg/m^3) from 1991 and historical sampling periods.

Year	Minimum	Maximum	Mean
1988	4.05	4.32	4.18
1989	2.96	5.69	4.18
1990	0.14	4.76	2.54
1991	3.06	3.63	3.34

PAWTUCKAWAY LAKE
NOTTINGHAM

Summary of current and historical Secchi Disk transparency results (in meters).

Year	Minimum	Maximum	Mean
1988	3.5	4.0	3.7
1989	3.1	3.8	3.4
1990	3.5	3.5	3.5
1991	3.2	3.4	3.3

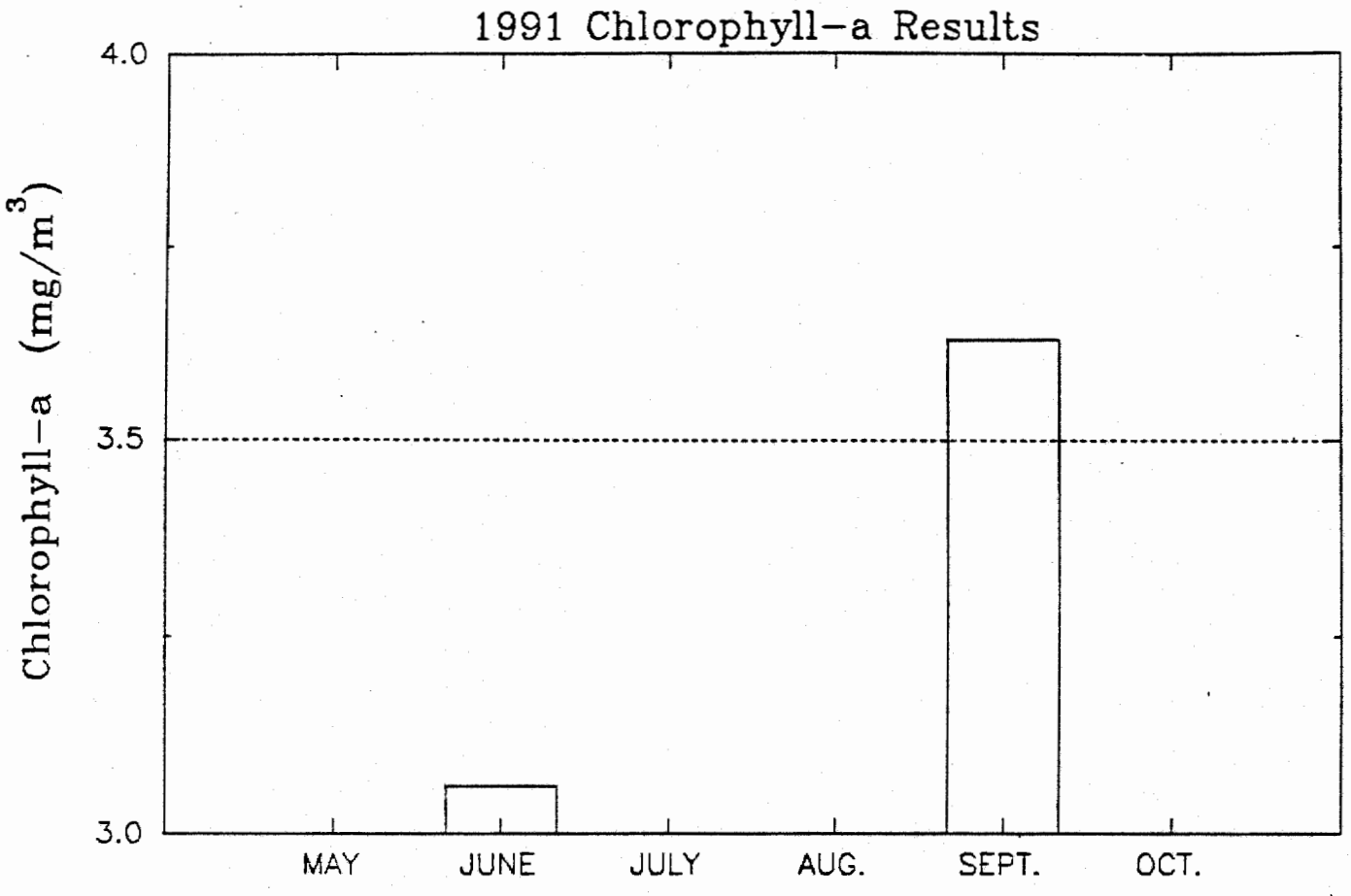
PAWTUCKAWAY LAKE
NOTTINGHAM

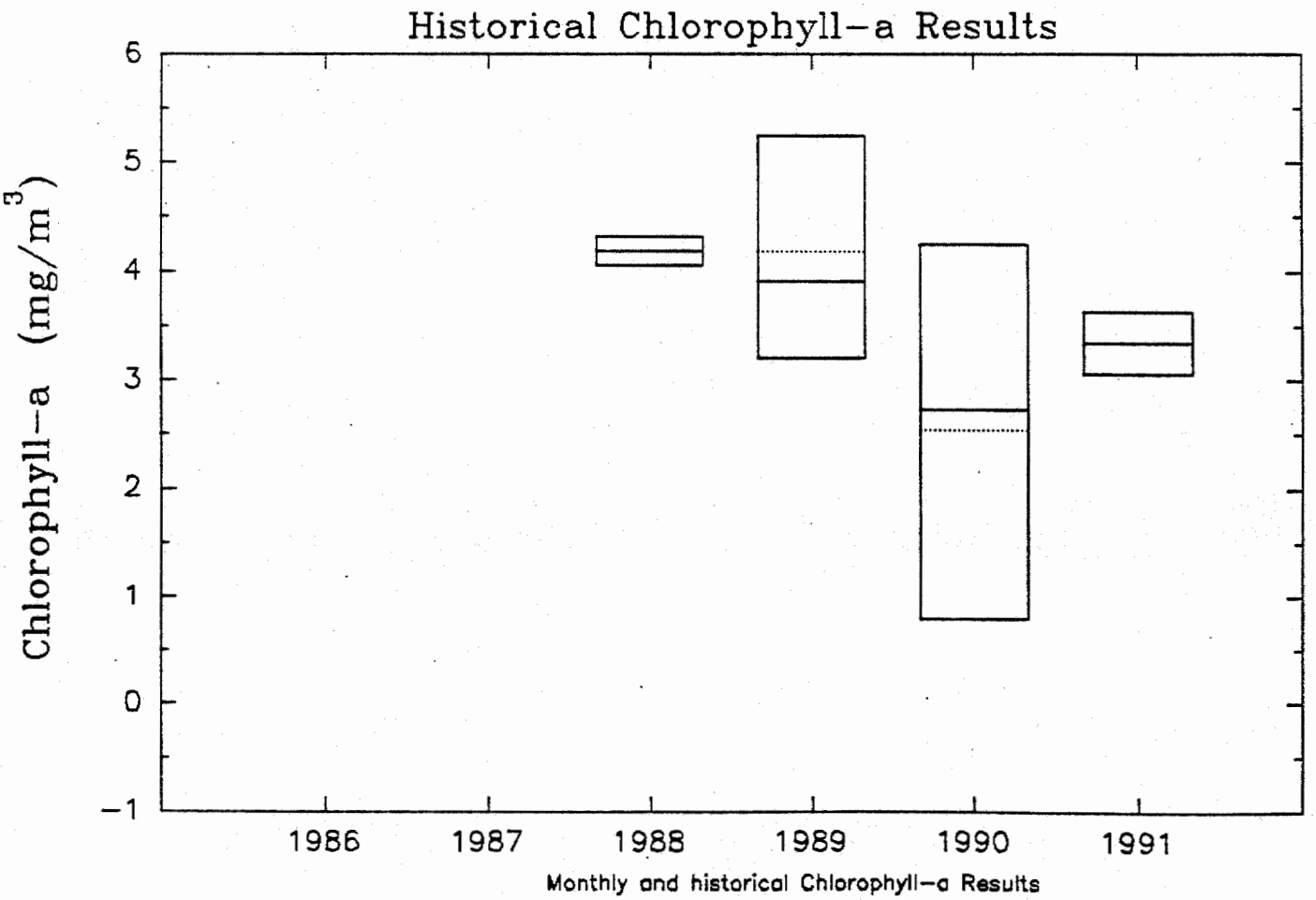
Phytoplankton species and relative percent abundance.
Summary for current and historical sampling seasons.

Date of Sample	Species Observed	Relative % Abundance
07/12/88	SPHAEROCYSTIS	41
	ASTERIONELLA	40
07/25/89	COELOSPHAERIUM	36
	SPHAEROCYSTIS	32
	MICROCYSTIS	28
07/24/90	CHROOCOCUS	66
07/08/91	ASTERIONELLA	37
	STAURASTRUM	15

PAWTUCKAWAY LAKE
NOTTINGHAM

Pawtuckaway Lake

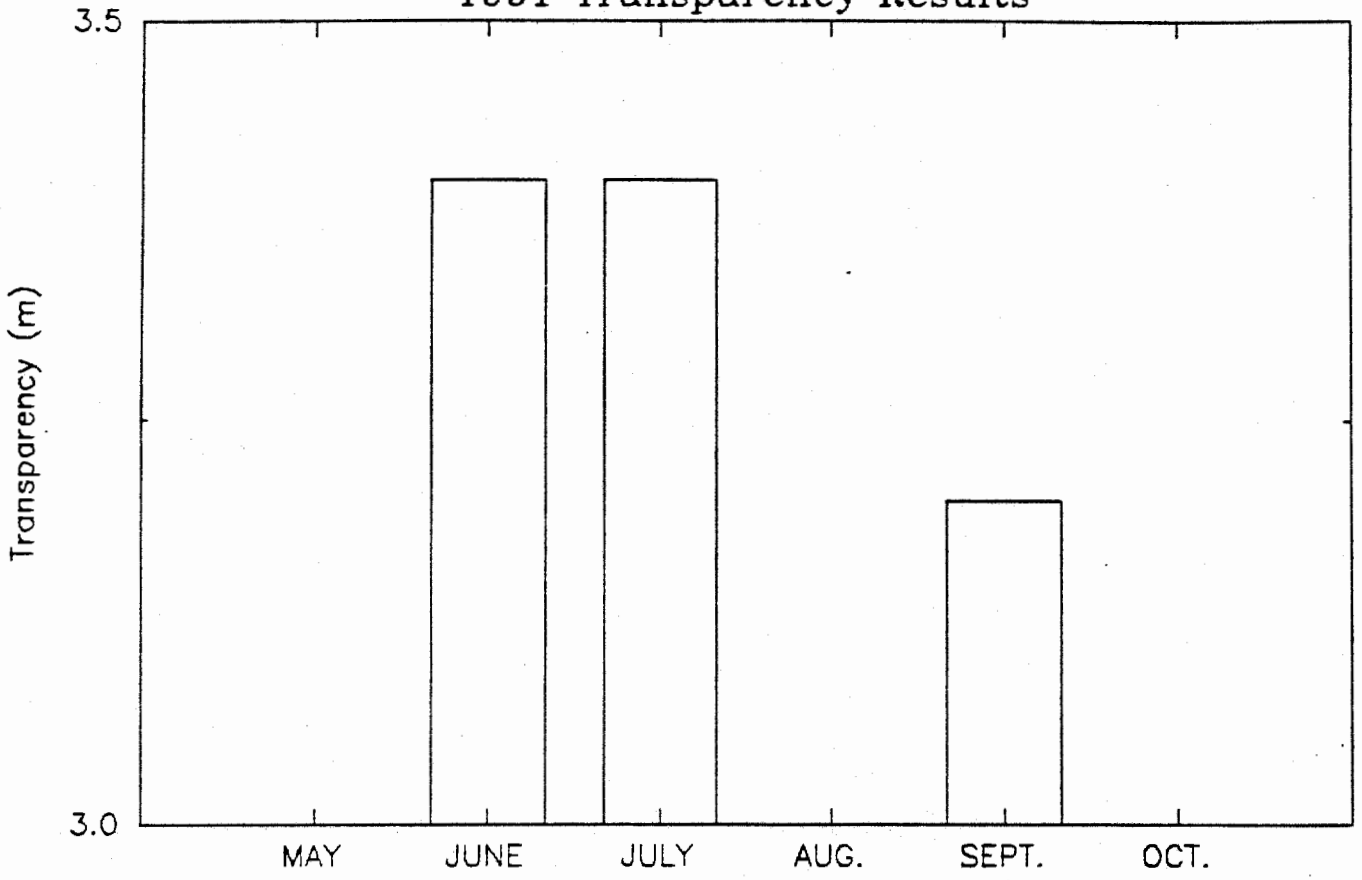




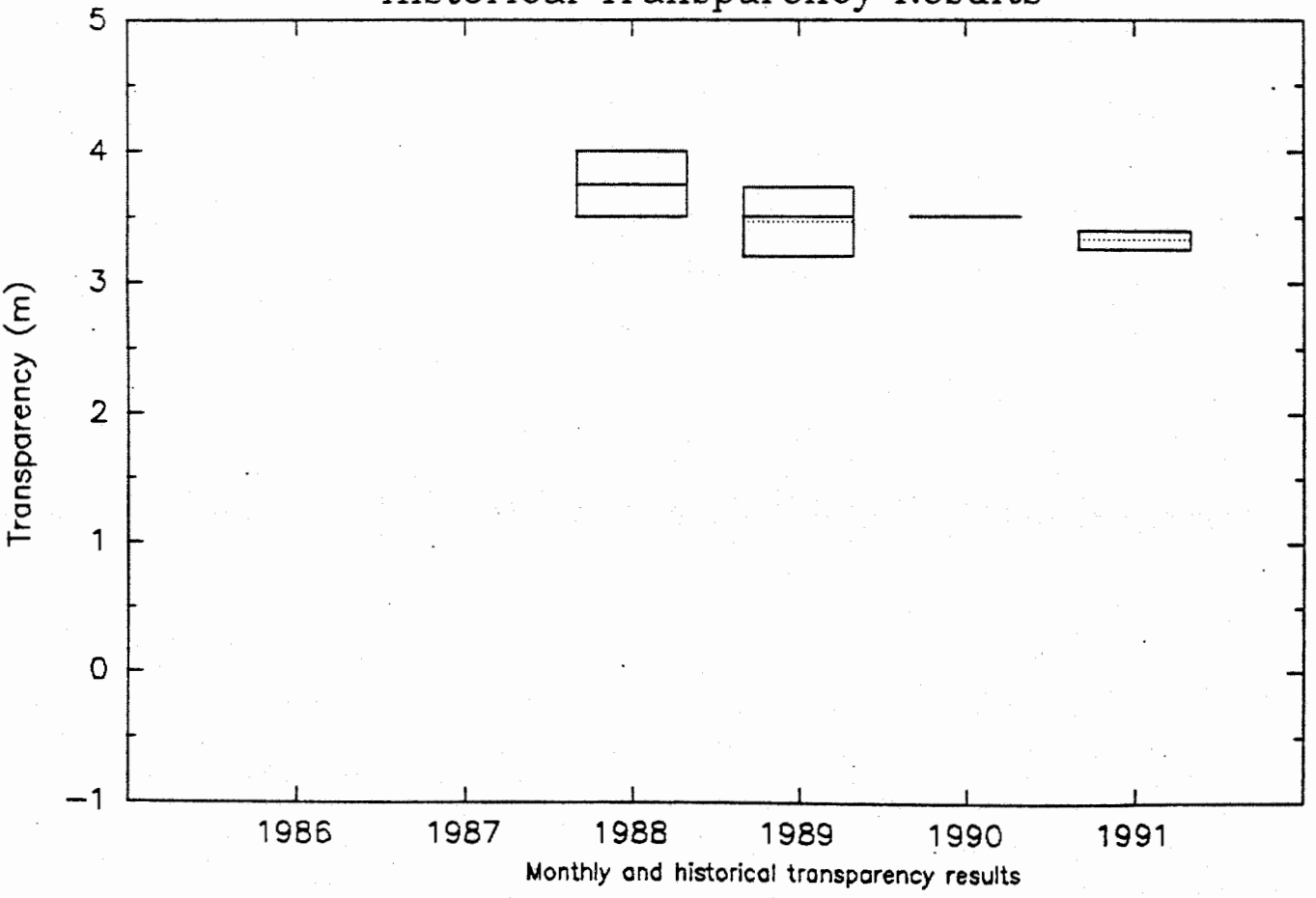
Monthly and historical Chlorophyll-a Results

Pawtuckaway Lake

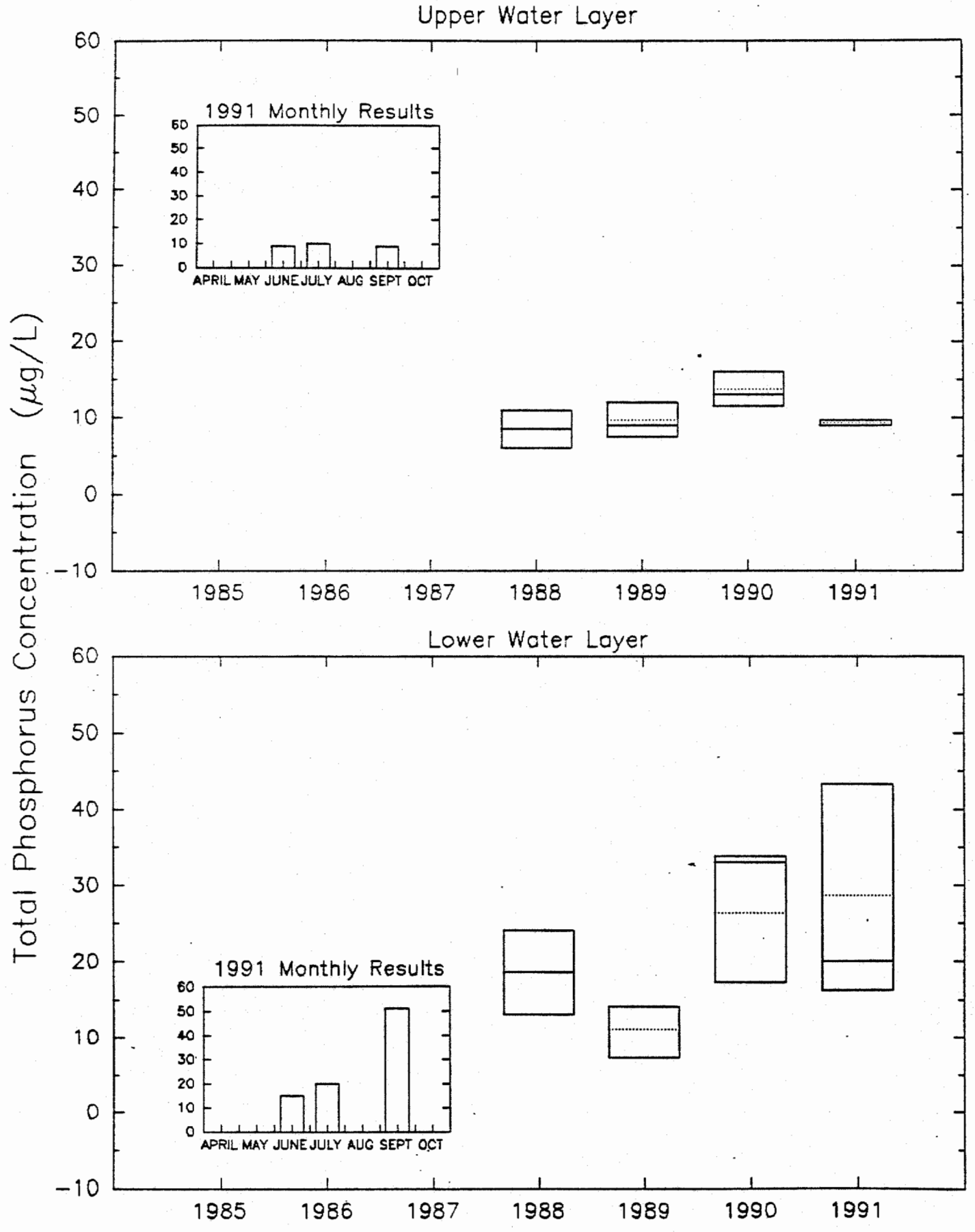
1991 Transparency Results



Historical Transparency Results

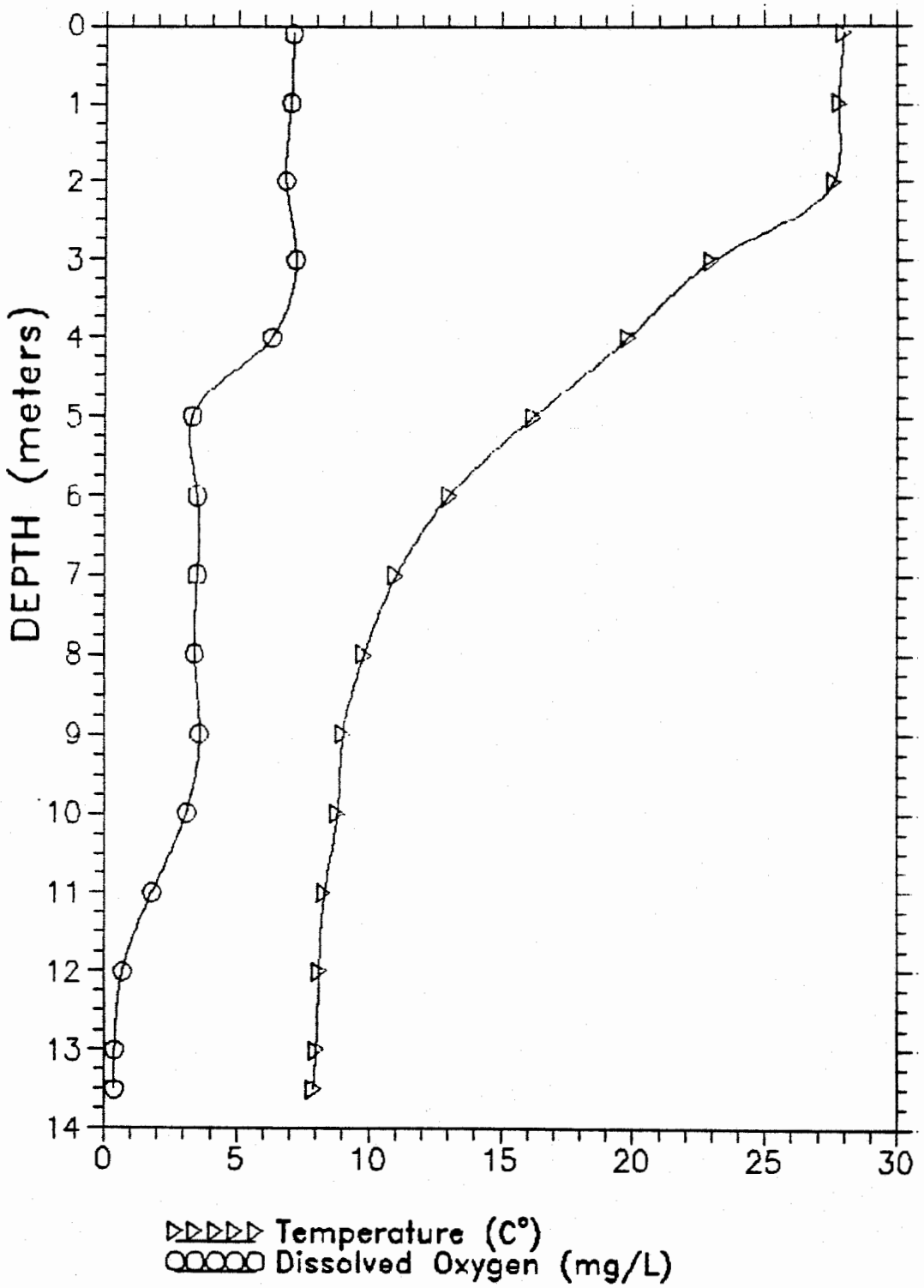


Pawtuckaway Lake

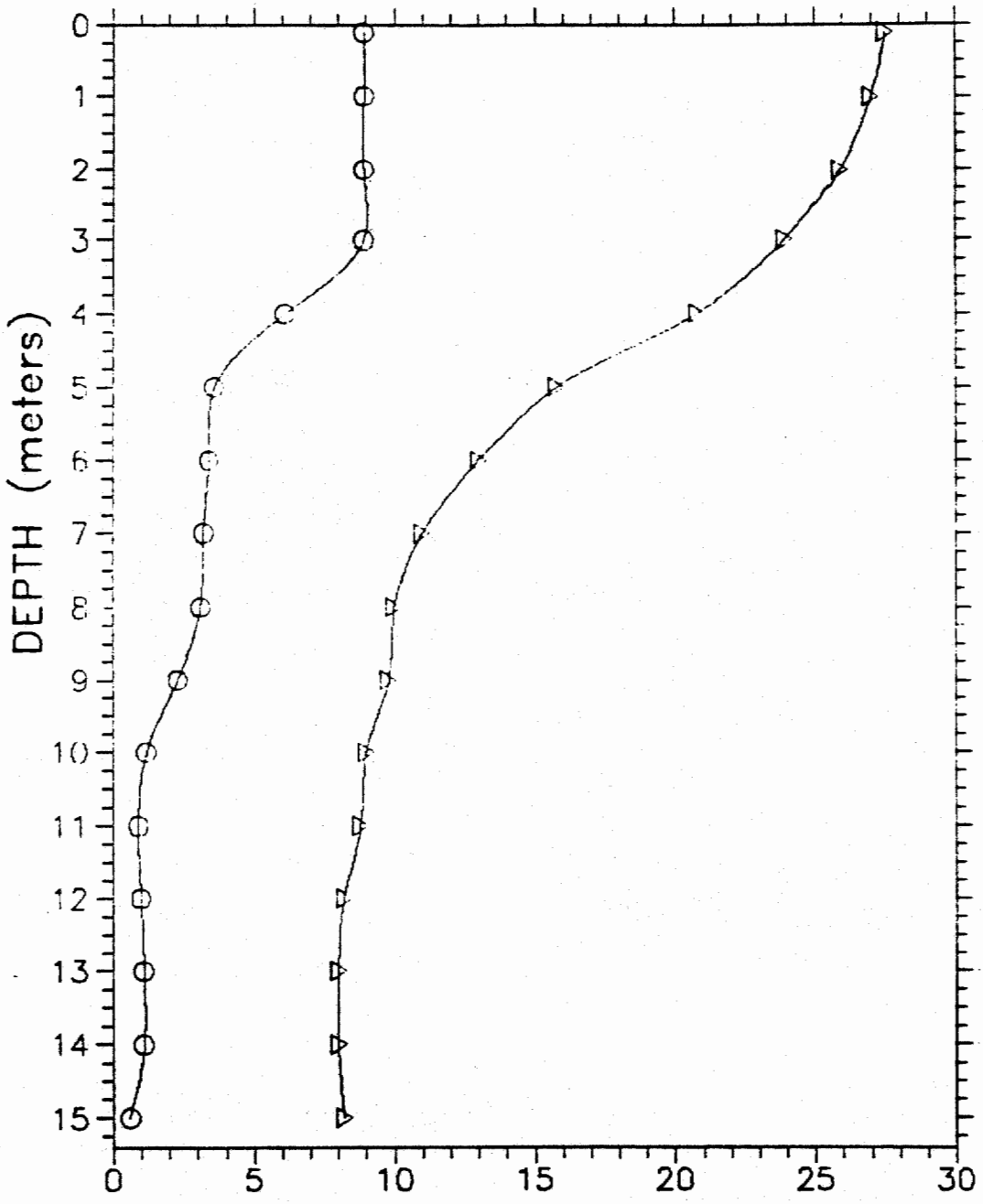


Monthly 1991 and historical total phosphorus data.

PAWTUCKAWAY LAKE
07-12-88



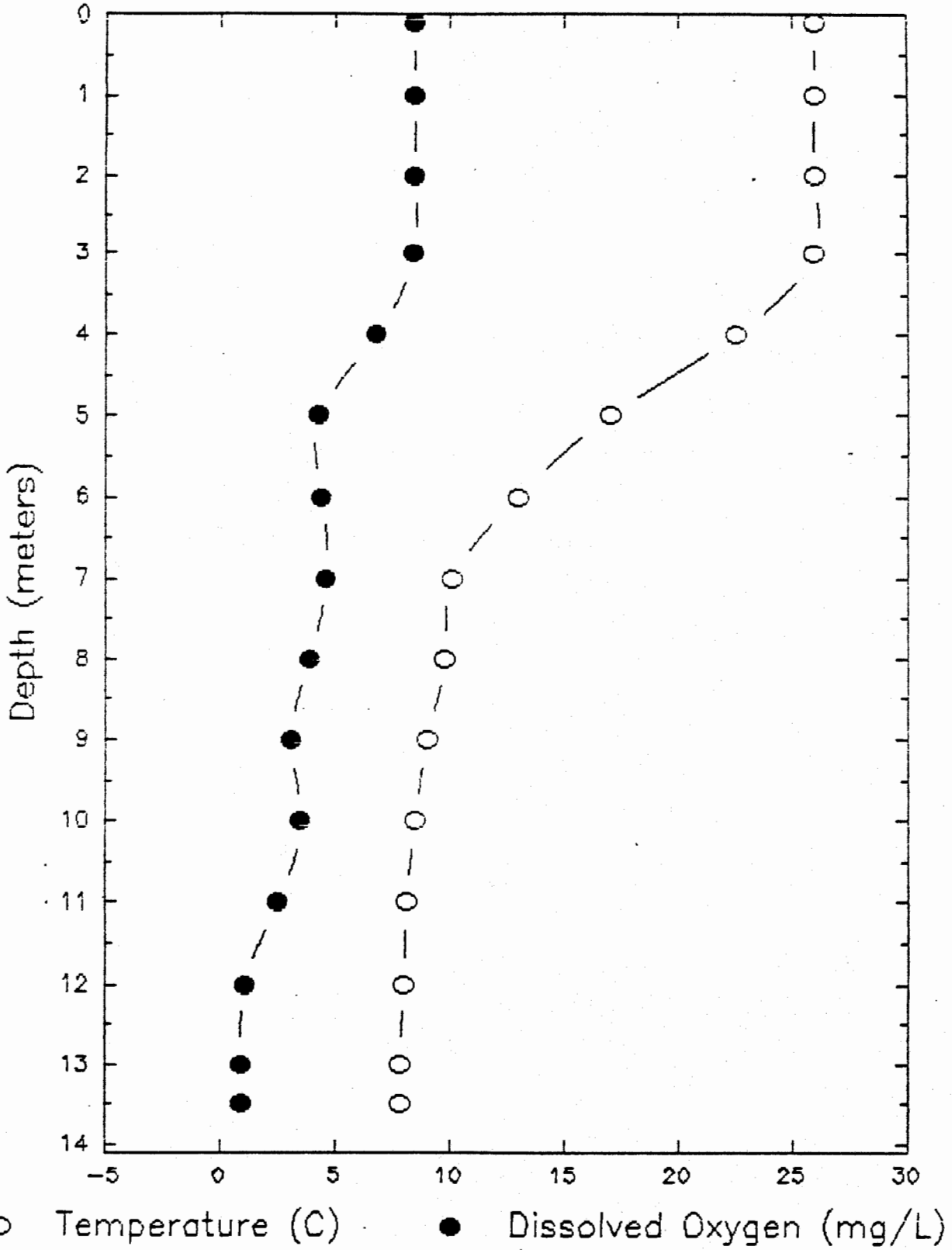
PAWTUCKAWAY LAKE, NOTTINGHAM
07-24-89



Dissolved oxygen/temperature profile

Pawtuckaway Lake, Nottingham

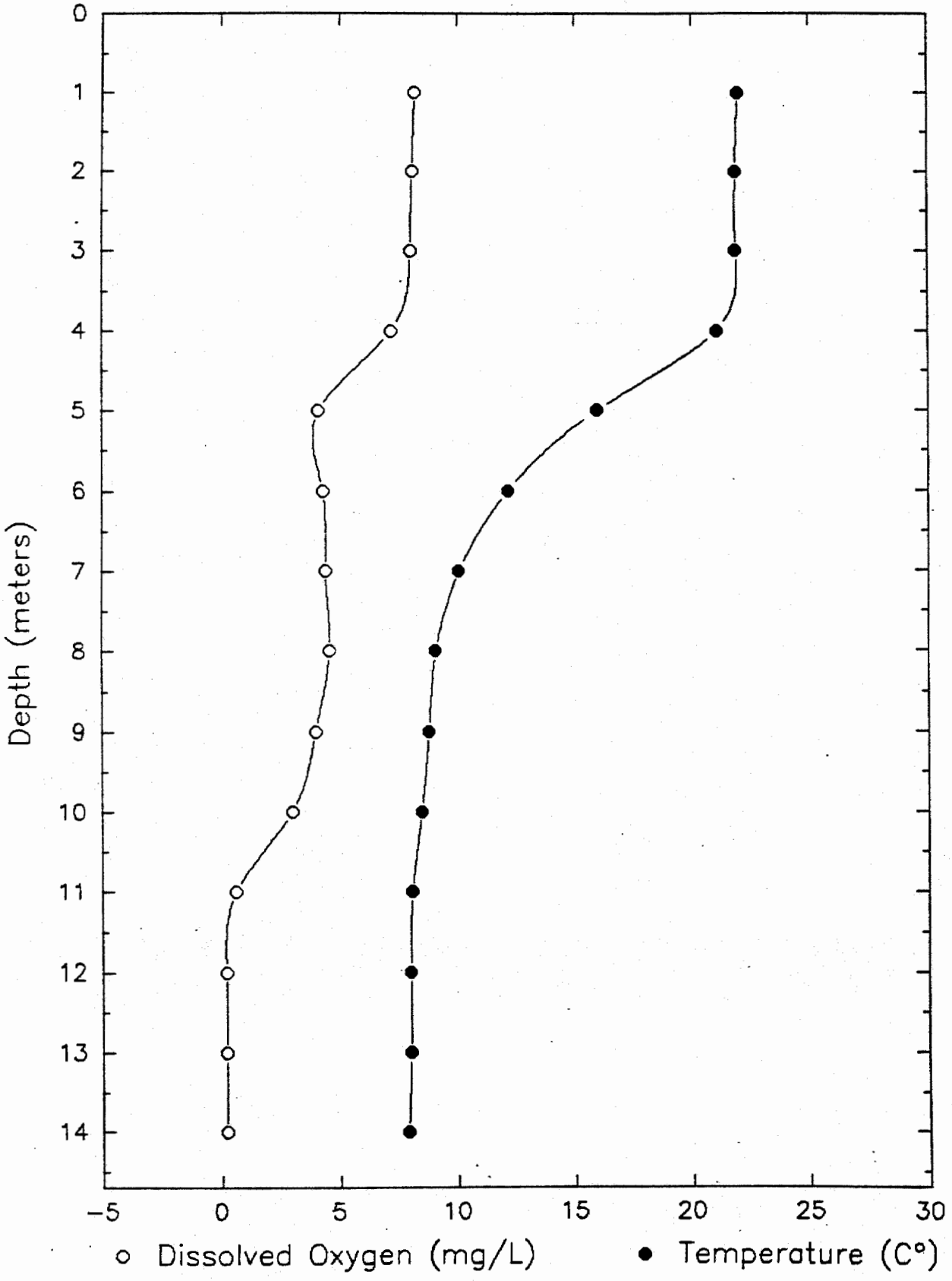
07-24-90



1990 Dissolved Oxygen/Temperature Profile

Pawtuckaway Lake, Nottingham

07-08-91



Dissolved Oxygen / Temperature profile

APPENDIX II-4

AQUATIC PLANT SURVEY

LAKE Pawtuckaway Lake TOWN Nottingham DATE Aug. 14, 1979 BY NSPCC

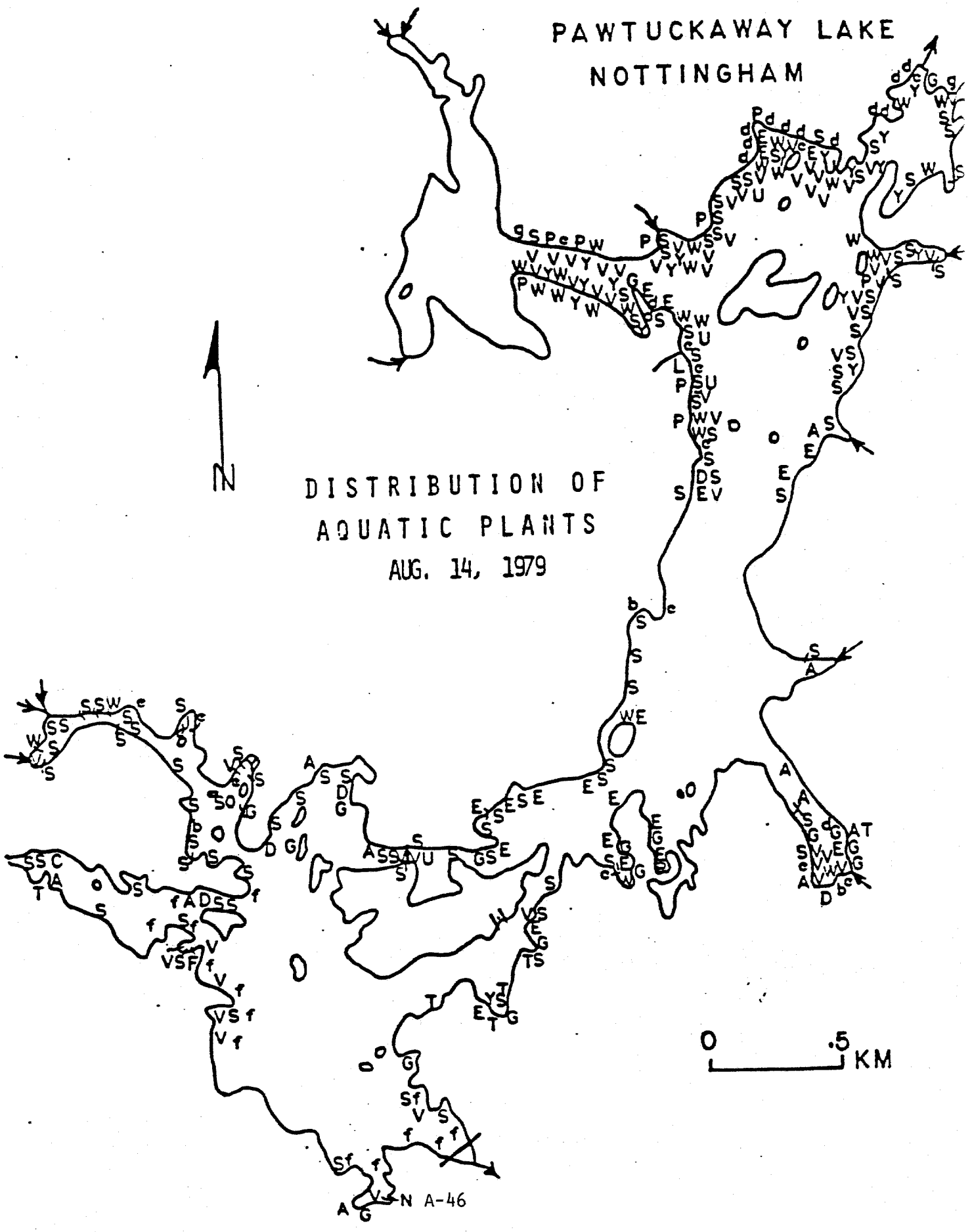
No.	PLANT NAME		ABUNDANCE
	GENERIC	COMMON	
V	Vallisneria americana	Tape Grass	Abundant
T	Typha	Cattail	Scattered
E	Eriocaulon septangulare	Pipewort	Common
G	Gratiola lutea	Hedge Hyssop	Scattered
S	Sparganium	Bur Reed	Abundant
Y	Nuphar	Yellow Water Lily	Common
N	Nymphaea	Water Lily	Sparse
A	Sagittaria	Arrowhead	Scattered
C	Carex	Sedge	Sparse
D	Decodon verticillatus	Swamp Loosestrife	Scattered
b	Scirpus validus	Softstem Bulrush	Scattered
W	Potamogeton	Pondweed	Common
U	Utricularia	Bladderwort	Scattered
e	Eleocharis	Spike Rush	Scattered
L	Lysimachia	Swampcandle	Scattered
d	Dulichium arundinaceum	Three-way Sedge	Scattered
P	Pontederia cordata	Pickerelweed	Scattered
g	Gramineae	Grass Family	Sparse
X	Polygonum	Smartweed	Sparse
f	Oscillatoria	Filamentous Blue-green Algae	Scattered

OVERALL ABUNDANCE Common

GENERAL OBSERVATIONS:

1. Plants were very common along much of the shore, and were abundant in the northern undeveloped area. However, they were not really a nuisance to boating or swimming in the main lake area where most of the cottages are located.

2. Clumps of Oscillatoria were locally abundant in the area of the southern dam, but scarce north of Horse Island.


PAWTUCKAWAY LAKE
NOTTINGHAM
N
DISTRIBUTION OF
AQUATIC PLANTS
AUG. 14, 1979
0
.5
KM

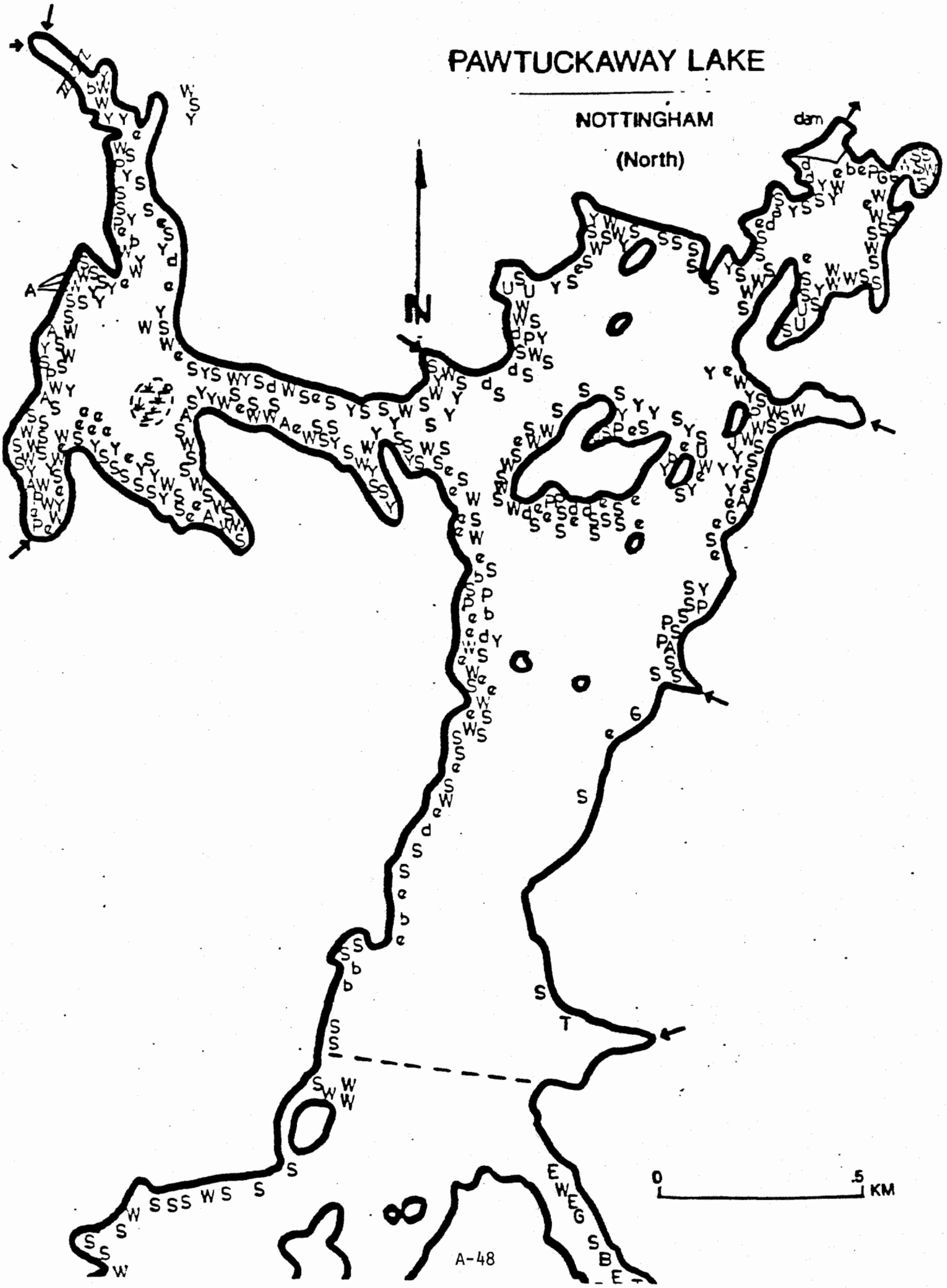
AQUATIC PLANT SURVEY

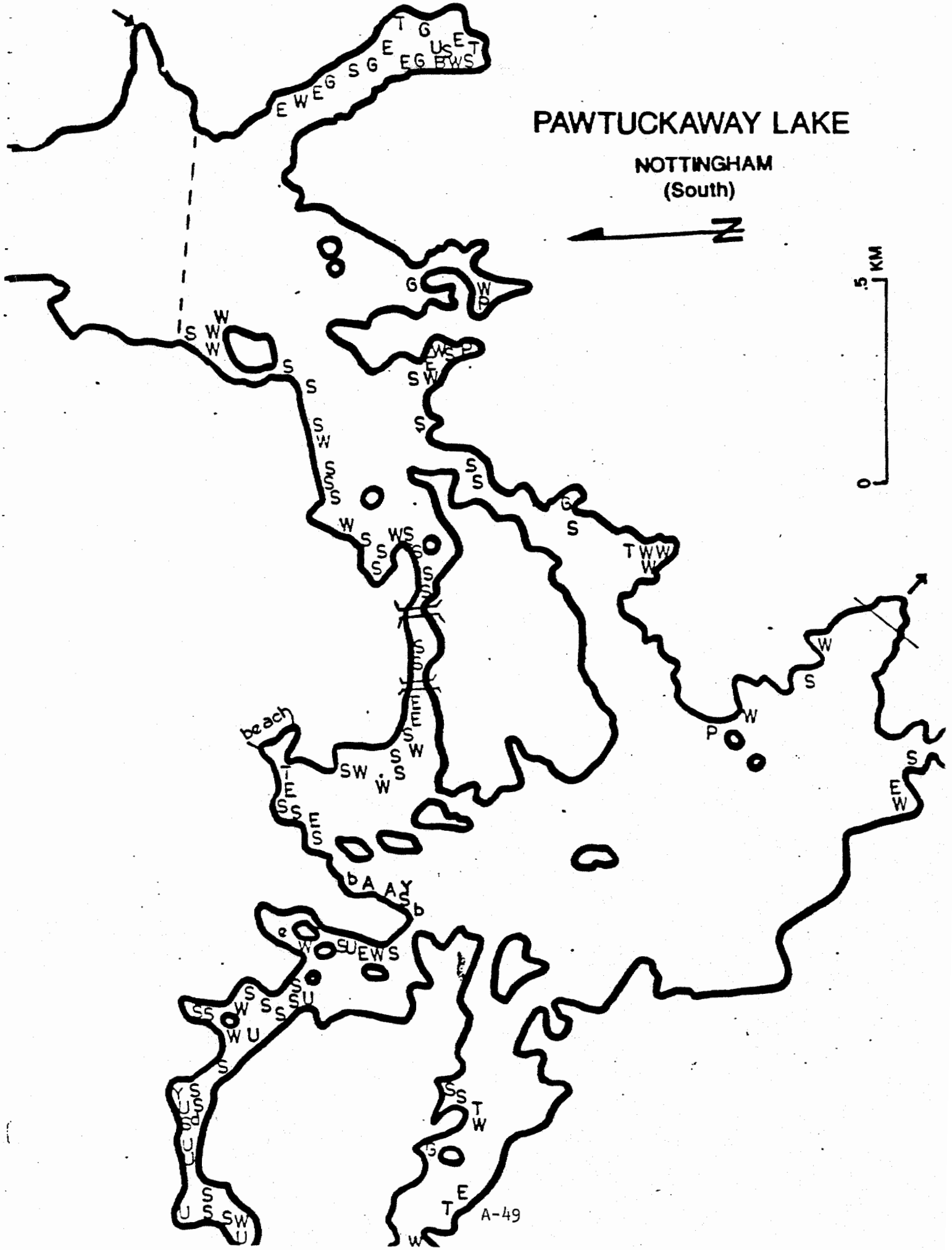
LAKE: PAWTUCKAWAY LAKE TOWN: NOTTINGHAM DATE: 07/25/89

Key	PLANT NAME		ABUNDANCE
	GENERIC	COMMON	
E	Eriocaulon septangulare	Pipewort	Sparse
W	Potamogeton	Pondweed	Sparse
G	Gramineae	Grass family	Sparse
S	Sparganium	Bur reed	Scattered
T	Typha	Cattail	Sparse
B	Brasenia schreberi	Water shield	Sparse
U	Utricularia	Bladderwort	Scattered
P	Pontederia cordata	Pickerelweed	Sparse
N	Nymphaea	White water lily	Sparse
b	Scirpus	Bulrush	Sparse
e	Eleocharis	Spike rush	Scattered
A	Sagittaria	Arrowhead	Sparse
Y	Nuphar	Yellow water lily	Scattered
a	Peltandra virginica	Arrow arum	Sparse
d	Dulichium arundinaceum	Three-way sedge	Sparse

OVERALL ABUNDANCE: Scattered-Com

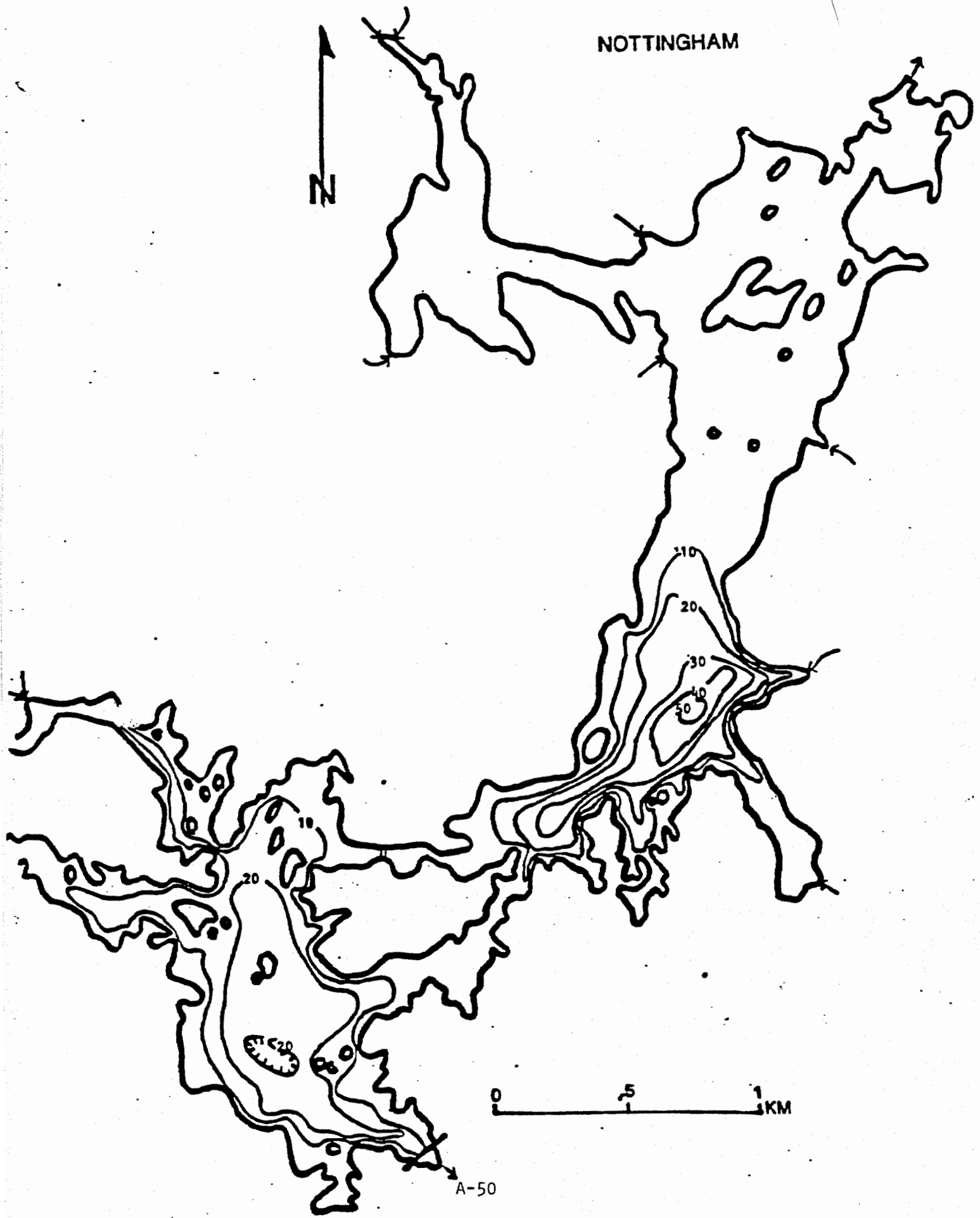
GENERAL OBSERVATIONS:


PAWTUCKAWAY LAKE
NOTTINGHAM
(North)
dam
N
0
.5
KM


PAWTUCKAWAY LAKE
NOTTINGHAM
(South)
N
.5 KM
0
beach
bAAY

PAWTUCKAWAY LAKE

NOTTINGHAM



APPENDIX III-1

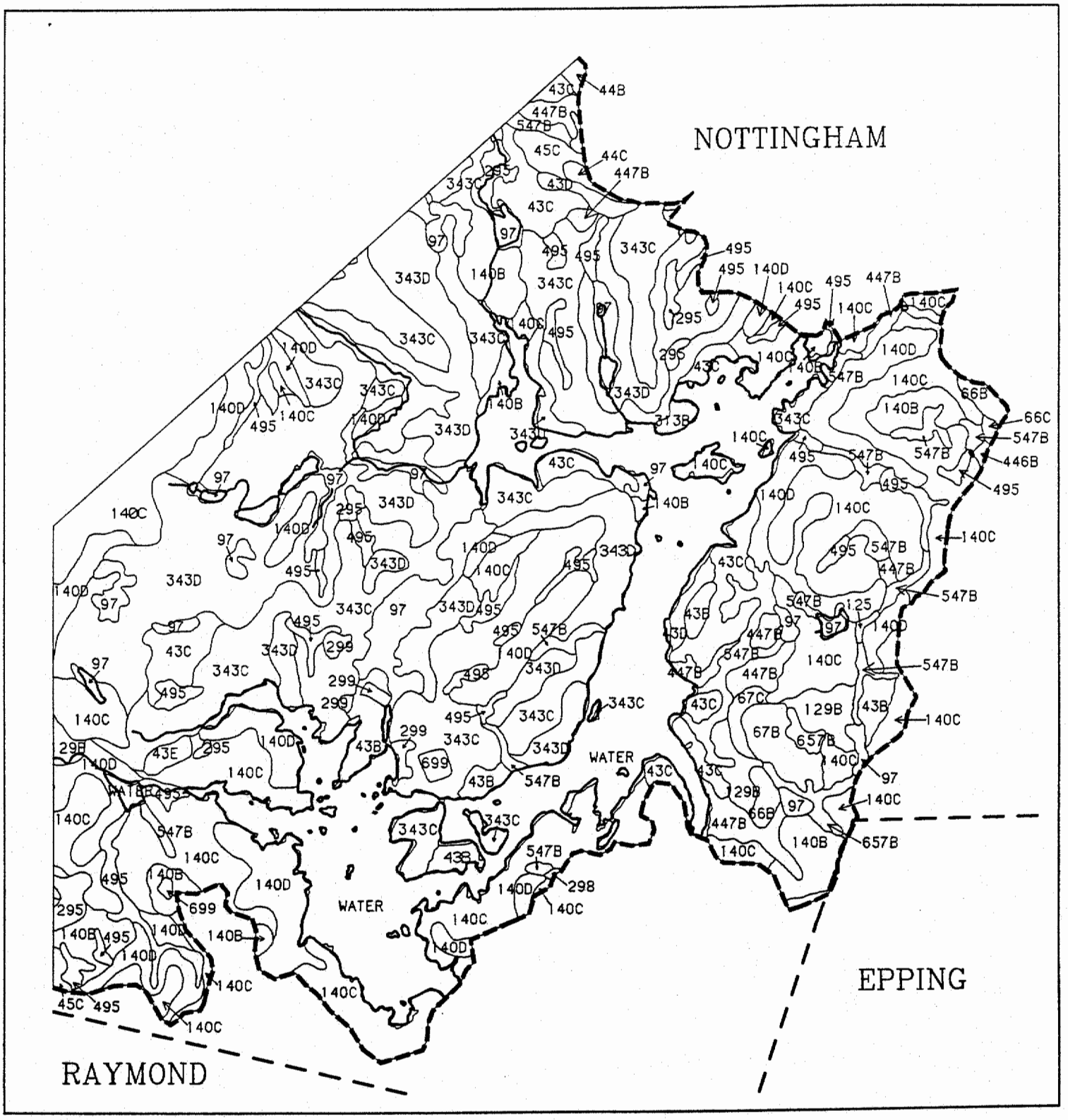
SOILS ADJACENT TO PAWTUCKAWAY LAKE

- Soil unit boundary
- Town boundary
- Shoreline
- Watershed boundary

DATA SOURCES:
Soils: Rockingham Co. soil survey (SCS, 1991). Digitized from 1:20,000 and 1:24,000 source materials by Complex Systems Research Center, Durham, NH.
Watershed boundaries: Compiled and digitized at 1:24,000 by NH Department of Environmental Services.

This map was produced by the NH DES GIS Program, April 1994.

N



PAWTUCKAWAY LAKE WATERSHED: SOILS

Soil unit boundary
Shoreline
Watershed boundary
Subwatershed boundary
Town boundary

DATA SOURCES:
Soils: Rockingham Co. soil survey (SCS, 1991). Digitized from 1:20,000 and 1:24,000 source materials by Complex Systems Research Center, Durham, NH.
Watershed boundaries: Compiled and digitized at 1:24,000 by NH Department of Environmental Services.

This map was produced by the NH DES GIS Program, April 1994.

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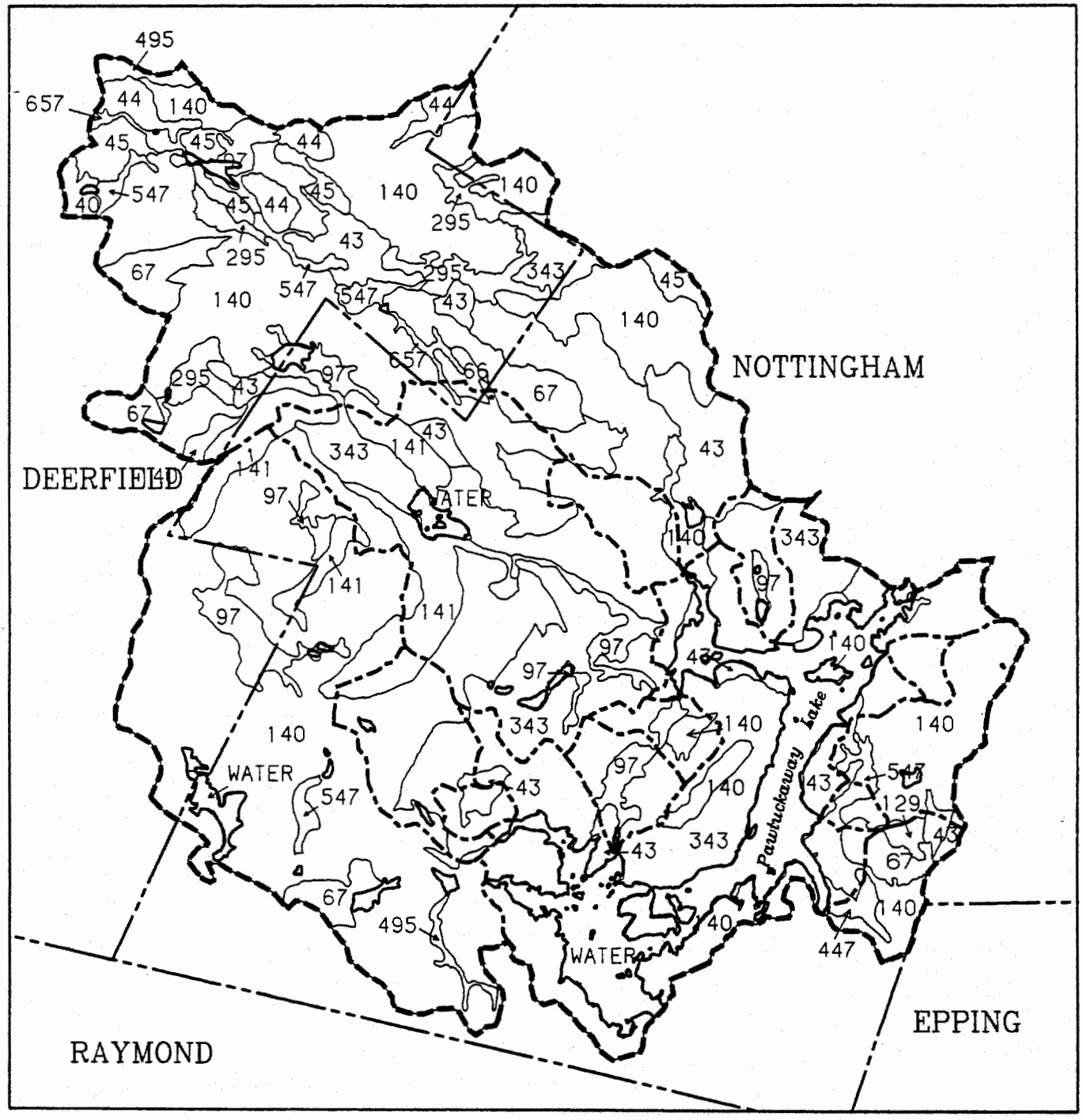


Soil Types Within the Pawtuckaway Lake Watershed

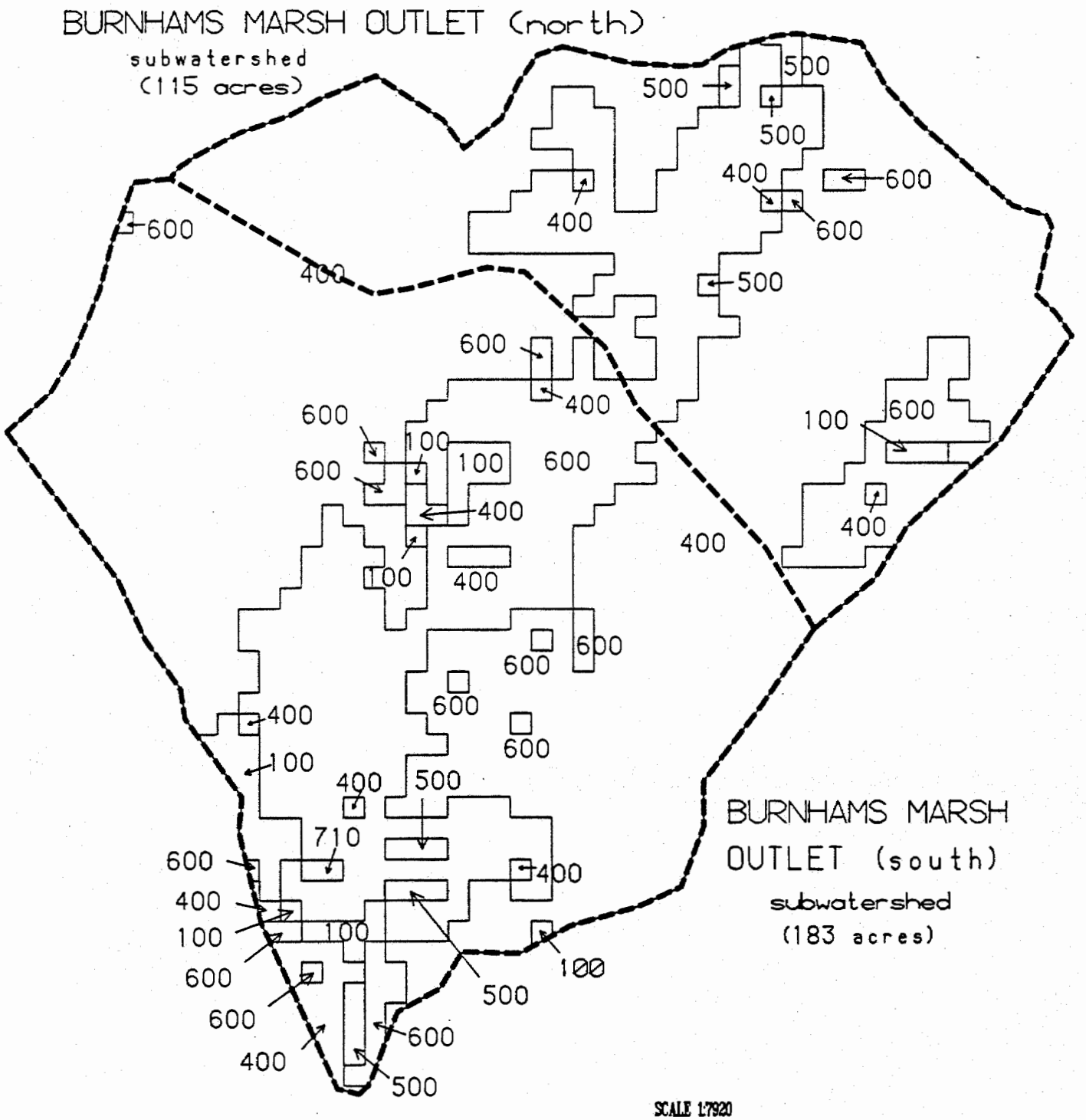
Soil Number	Soil Taxonomic Name	Soil Statistics	
		Percentage	Acreage
125	Scarboro Series, Stony	0.06	6.77
129	Woodbridge Series, Stony	0.66	78.29
140	Chatfield-Hollis-Canton Complex, Stony	40.29	4774.84
141	Hollis-Rock Outcrop-Chatfield Complex	4.46	529.12
295	Greenwood Series	2.60	307.87
298	Gravel Pits	0.03	3.86
299	Udorthents	0.12	13.92
313	Deerfield Series	0.07	7.96
343	Canton Series, Bouldery	18.26	2164.40
42	Canton Series	0.12	14.23
43	Canton Series, Stony	5.00	592.35
44	Montauk Series	1.62	192.00
45	Montauk Series, Stony	0.06	7.69
446	Scituate-Newfields Complex	1.80	213.05
447	Scituate-Newfields Complex, Stony	1.97	233.08
495	Ossipee Series	2.38	281.49
546	Walpole Series	0.00	0.01
547	Walpole Series, Stony	2.48	293.33
66	Paxton Series	0.91	107.59
67	Paxton Series, Stony	0.85	101.31
657	Ridgebury Series, Stony	3.48	412.98
699	Urban Land	0.08	8.89
799	Urban Land-Canton Complex	0.10	11.31
97	Greenwood and Ossipee Soils, Ponded	5.04	597.09
	Water	7.58	898.34

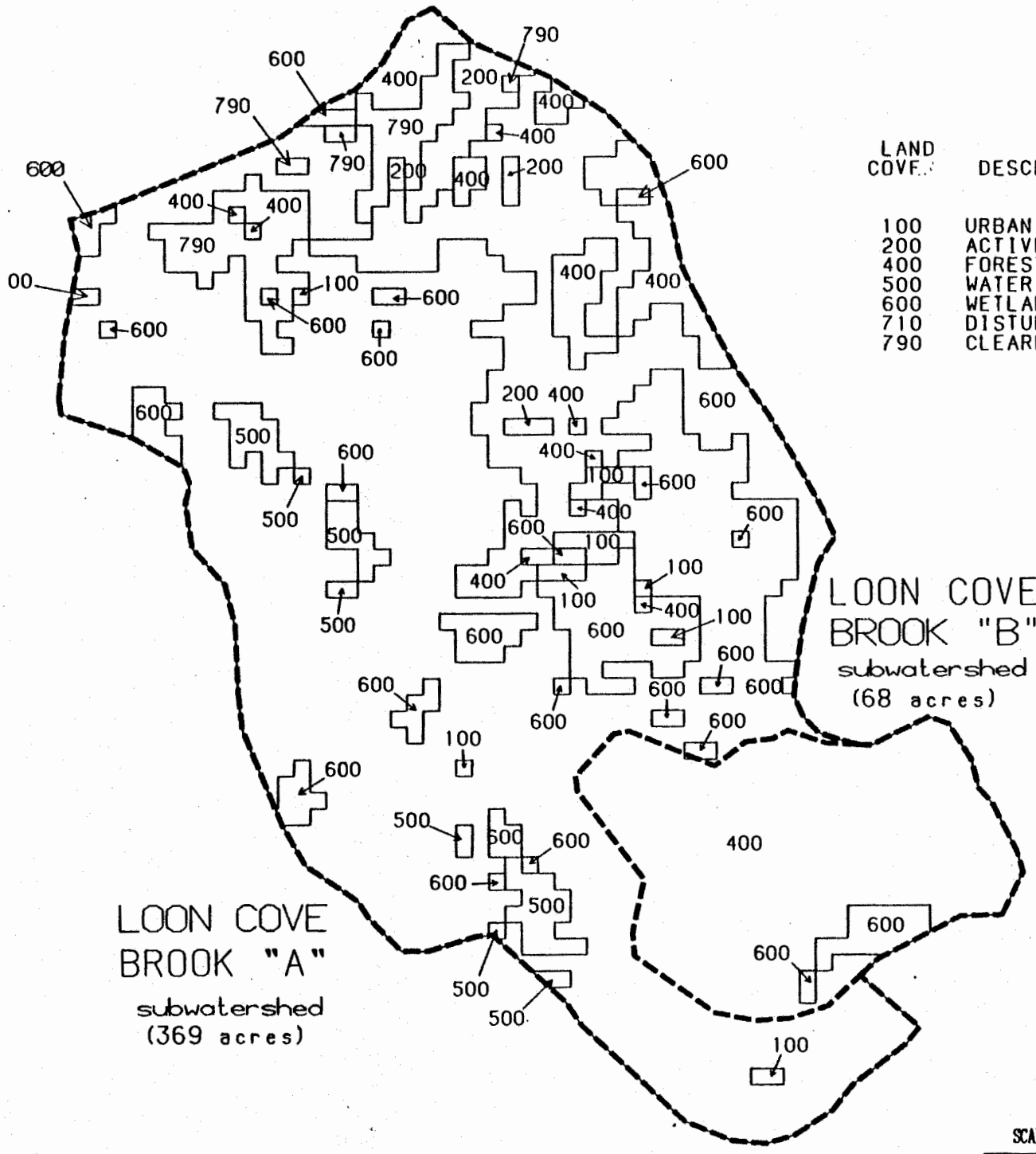
APPENDIX III-2

DATA SOURCES:
Land cover:
Mapped and automated from LANDSAT Thematic Mapper Imagery by Complex Systems Research Center, Durham, NH (1993).
Watershed boundaries: Compiled and digitized at 1:24,000 by NH Department of Environmental Services.

This map was produced by the NH DES GIS Program, April 1994.

LAND COVER	DESCRIPTION	PERCENT BURNHAMS NORTH	PERCENT BURNHAMS SOUTH
100	URBAN	0.5	3.6
200	ACTIVE AGRICULTURE	0	0
400	FOREST	70.2	66.7
500	WATER	1.2	1.1
600	WETLAND	28.1	28.3
710	DISTURBED (gravel pits)	0	0.2
790	CLEARED/OPEN	0	0



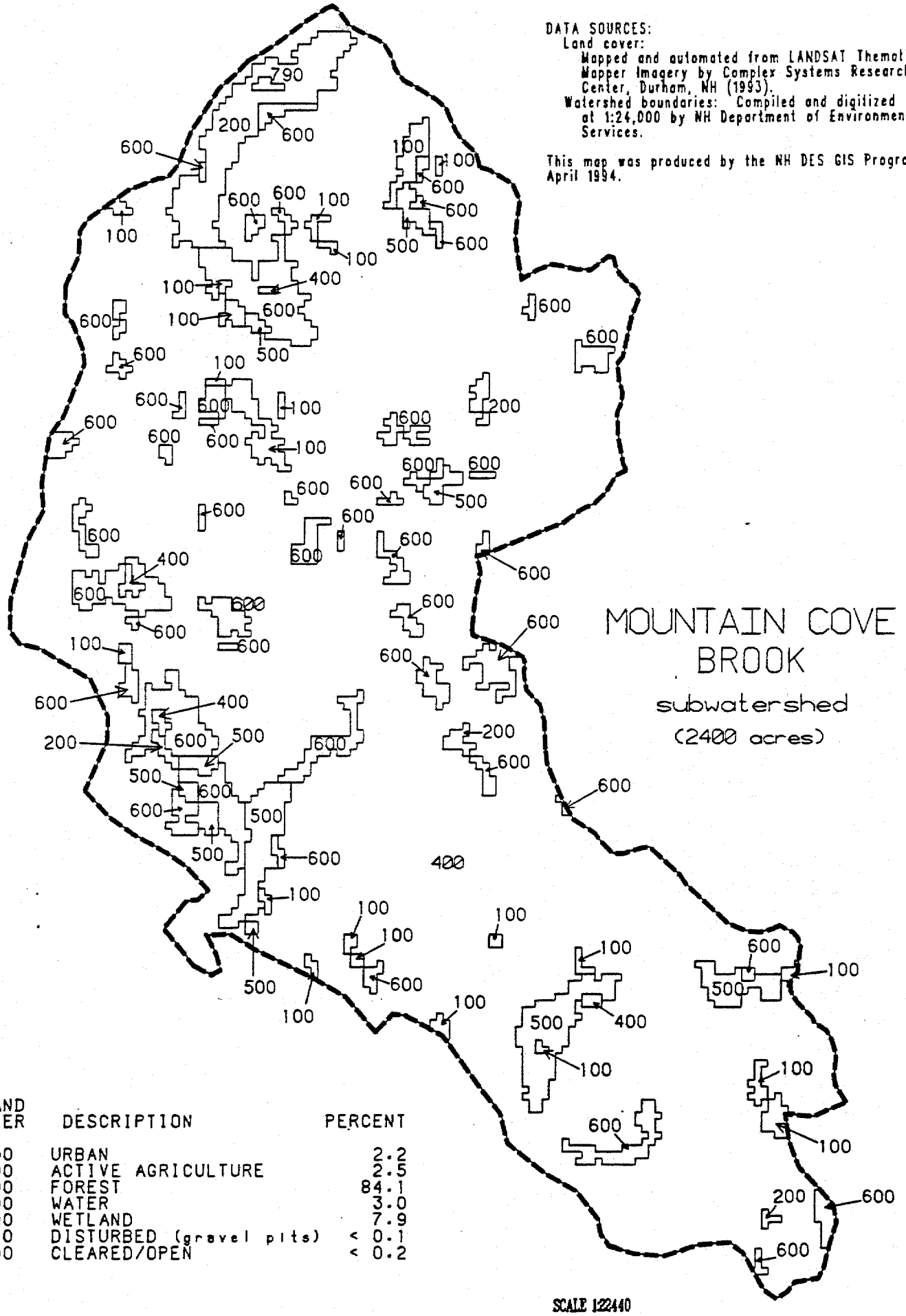


LAND COVER	DESCRIPTION	PERCENT LOON COVE A	PERCENT LOON COVE B
100	URBAN	1.2	0
200	ACTIVE AGRICULTURE	0.4	0
400	FOREST	68.1	94.6
500	WATER	2.6	0
600	WETLAND	21.8	5.4
710	DISTURBED (gravel pits)	0	0
790	CLEARED/OPEN	5.9	0

DATA SOURCES:
Land cover:
Mapped and automated from LANDSAT Thematic Mapper Imagery by Complex Systems Research Center, Durham, NH (1993).
Watershed boundaries: Compiled and digitized at 1:24,000 by NH Department of Environmental Services.

This map was produced by the NH DES GIS Program, April 1994.

SCALE 1:10560

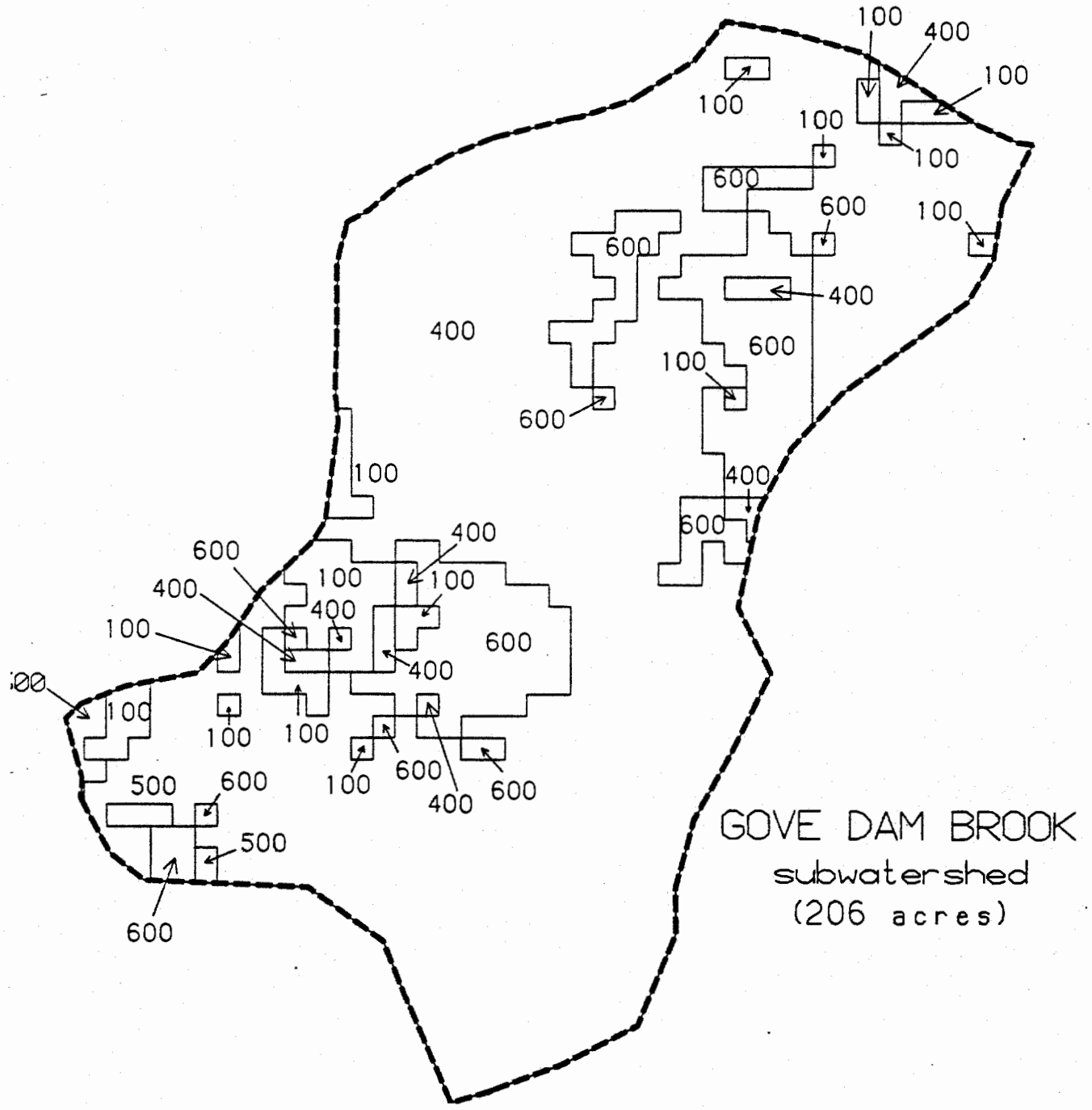


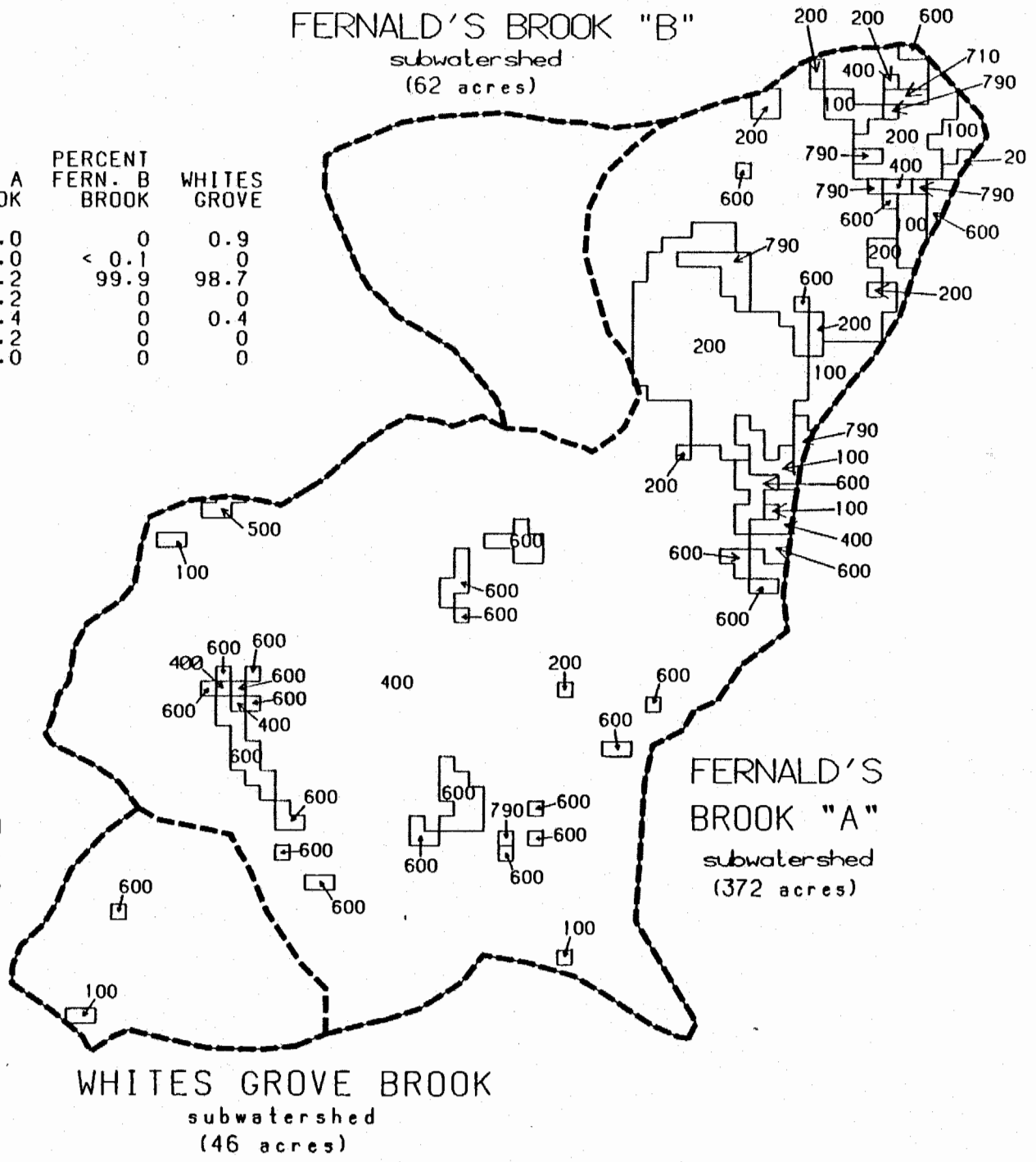
LAND COVER	DESCRIPTION	PERCENT
100	URBAN	2.2
200	ACTIVE AGRICULTURE	2.5
400	FOREST	84.1
500	WATER	3.0
600	WETLAND	7.9
710	DISTURBED (gravel pits)	< 0.1
790	CLEARED/OPEN	< 0.2

LAND COVER	DESCRIPTION	PERCENT
100	URBAN	5.1
200	ACTIVE AGRICULTURE	0
400	FOREST	80.1
500	WATER	0.9
600	WETLAND	13.9
710	DISTURBED (gravel pits)	0
790	CLEARED/OPEN	0

DATA SOURCES:
Land cover:
Mapped and automated from LANDSAT Thematic Mapper imagery by Complex Systems Research Center, Durham, NH (1993).
Watershed boundaries: Compiled and digitized at 1:24,000 by NH Department of Environmental Services.

This map was produced by the NH DES GIS Program, April 1994.





LAND COVER	DESCRIPTION	FERN. A BROOK	PERCENT FERN. B BROOK	WHITES GROVE
100	URBAN	3.0	0	0.9
200	ACTIVE AGRICULTURE	9.0	< 0.1	0
400	FOREST	82.2	99.9	98.7
500	WATER	0.2	0	0
600	WETLAND	4.4	0	0.4
710	DISTURBED (gravel pits)	0.2	0	0
790	CLEARED/OPEN	1.0	0	0

DATA SOURCES:
Land cover:
Mapped and automated from LANDSAT Thematic Mapper Imagery by Complex Systems Research Center, Durham, NH (1993).
Watershed boundaries: Compiled and digitized at 1:24,000 by NH Department of Environmental Services.

This map was produced by the NH DES GIS Program, April 1994.

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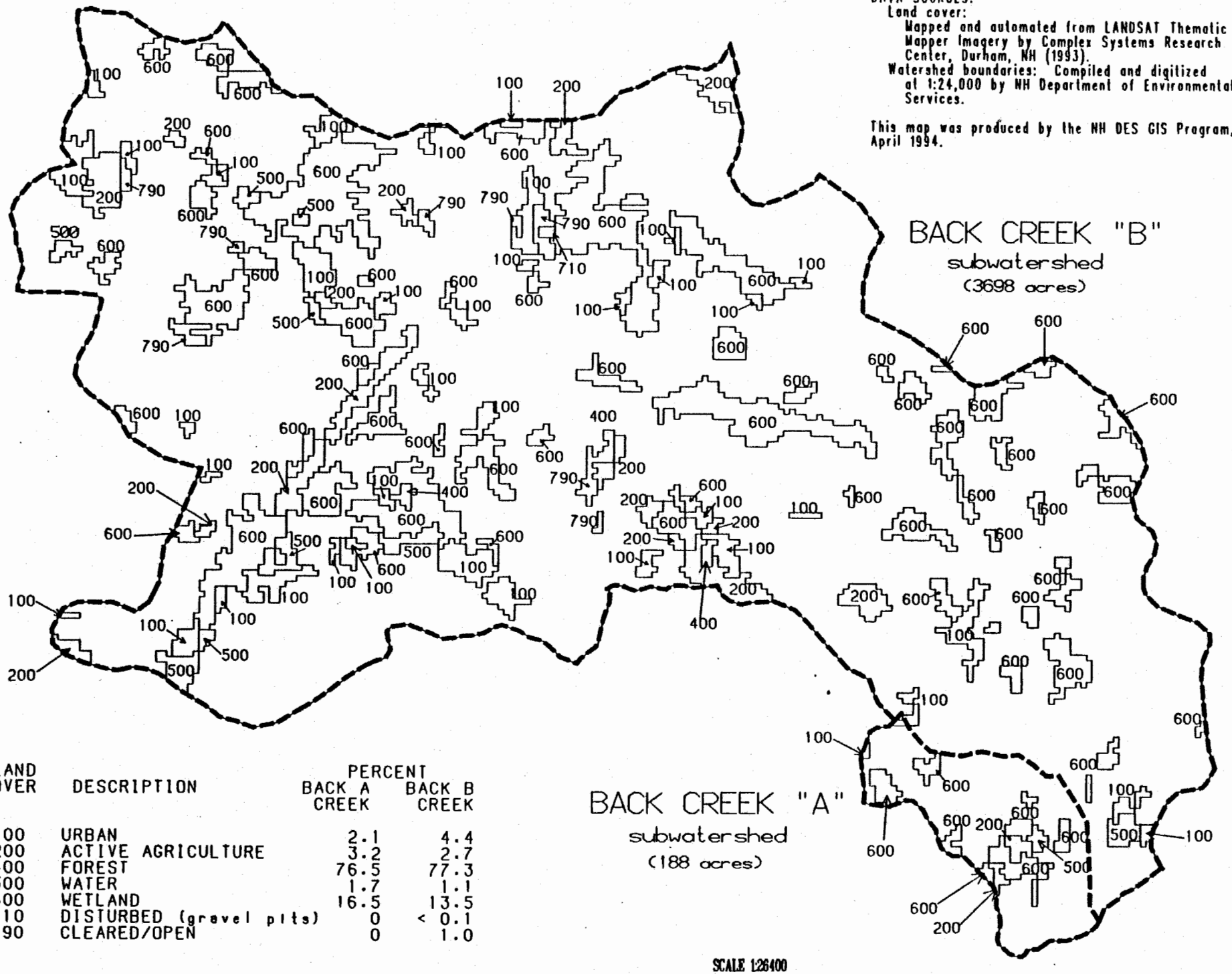
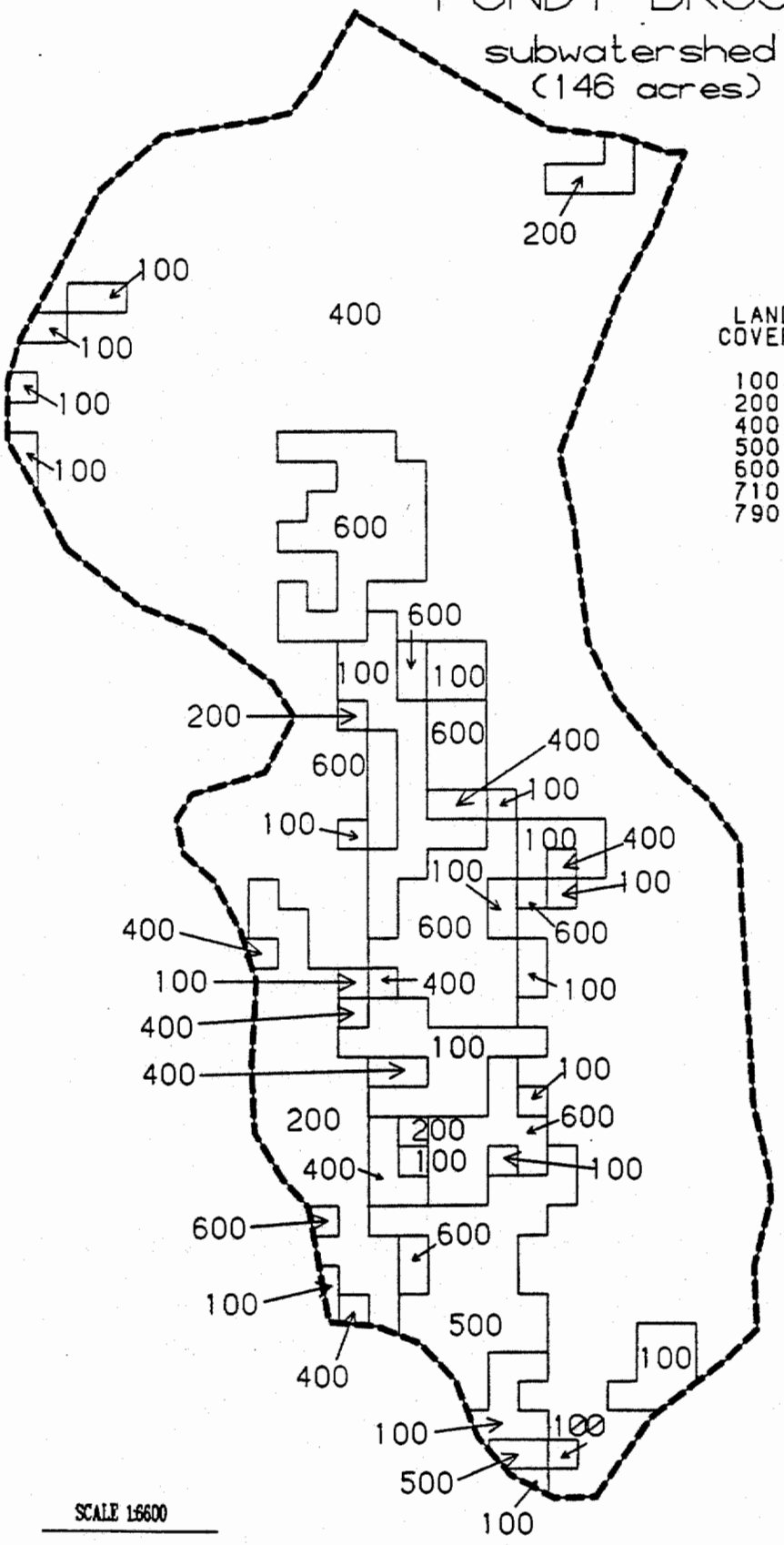


LAND COVER	DESCRIPTION	PERCENT BACK A CREEK	PERCENT BACK B CREEK
100	URBAN	2.1	4.4
200	ACTIVE AGRICULTURE	3.2	2.7
400	FOREST	76.5	77.3
500	WATER	1.7	1.1
600	WETLAND	16.5	13.5
710	DISTURBED (gravel pits)	0	< 0.1
790	CLEARED/OPEN	0	1.0

FUNDY BROOK

subwatershed (146 acres)



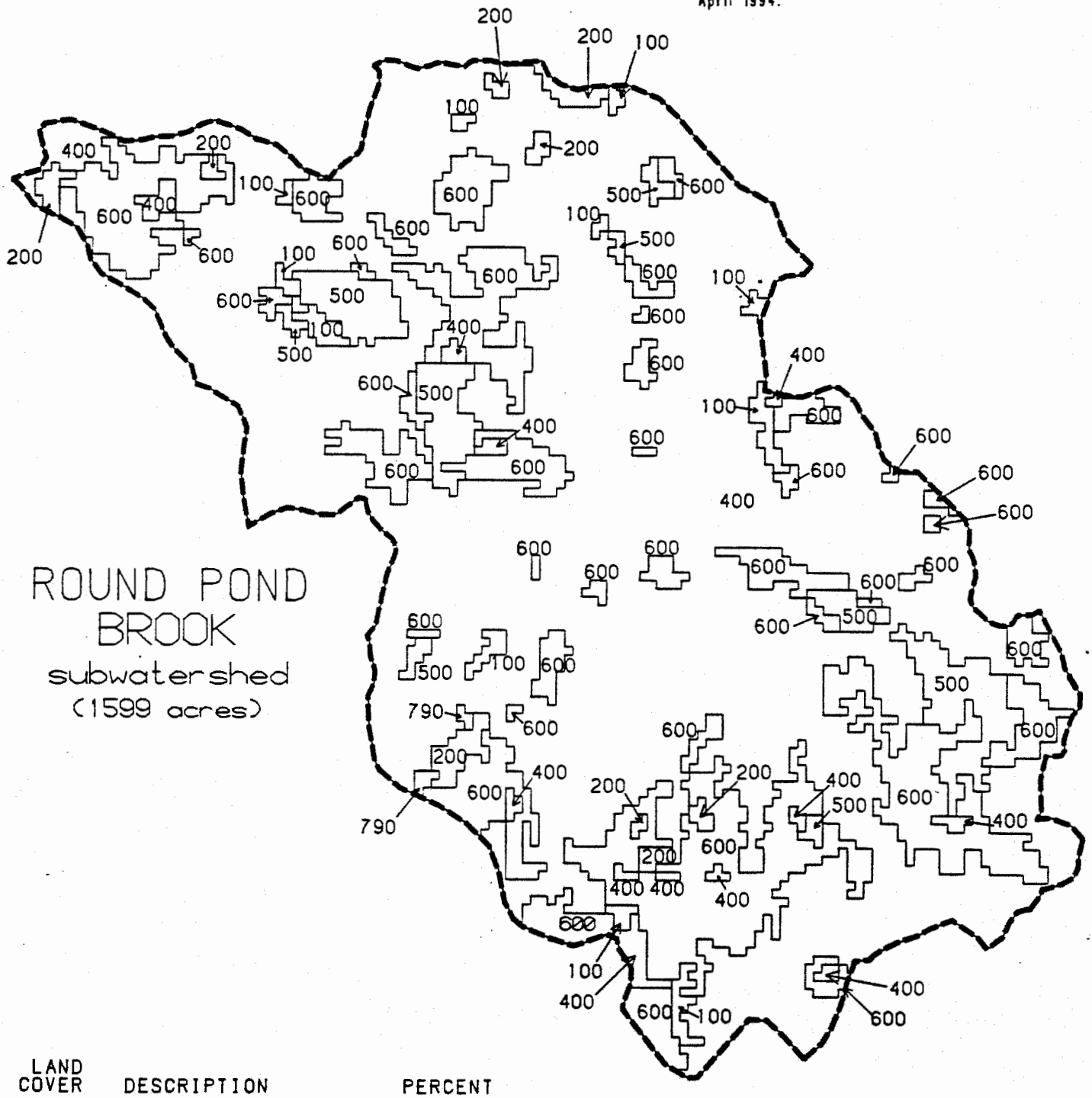
LAND COVER	DESCRIPTION	PERCENT
100	URBAN	9.9
200	ACTIVE AGRICULTURE	5.9
400	FOREST	70.1
500	WATER	4.1
600	WETLAND	10.0
710	DISTURBED (gravel pits)	0
790	CLEARED/OPEN	0

DATA SOURCES:
Land cover:
Mapped and automated from LANDSAT Thematic Mapper Imagery by Complex Systems Research Center, Durham, NH (1993).
Watershed boundaries: Compiled and digitized at 1:24,000 by NH Department of Environmental Services.

This map was produced by the NH DES GIS Program, April 1994.

DATA SOURCES:
Land cover:
Mapped and automated from LANDSAT Thematic Mapper Imagery by Complex Systems Research Center, Durham, NH (1993).
Watershed boundaries: Compiled and digitized at 1:24,000 by NH Department of Environmental Services.

This map was produced by the NH DES GIS Program, April 1994.



LAND COVER	DESCRIPTION	PERCENT
100	URBAN	1.8
200	ACTIVE AGRICULTURE	1.6
400	FOREST	70.9
500	WATER	4.6
600	WETLAND	20.9
710	DISTURBED (gravel pits)	0
790	CLEARED/OPEN	0.2

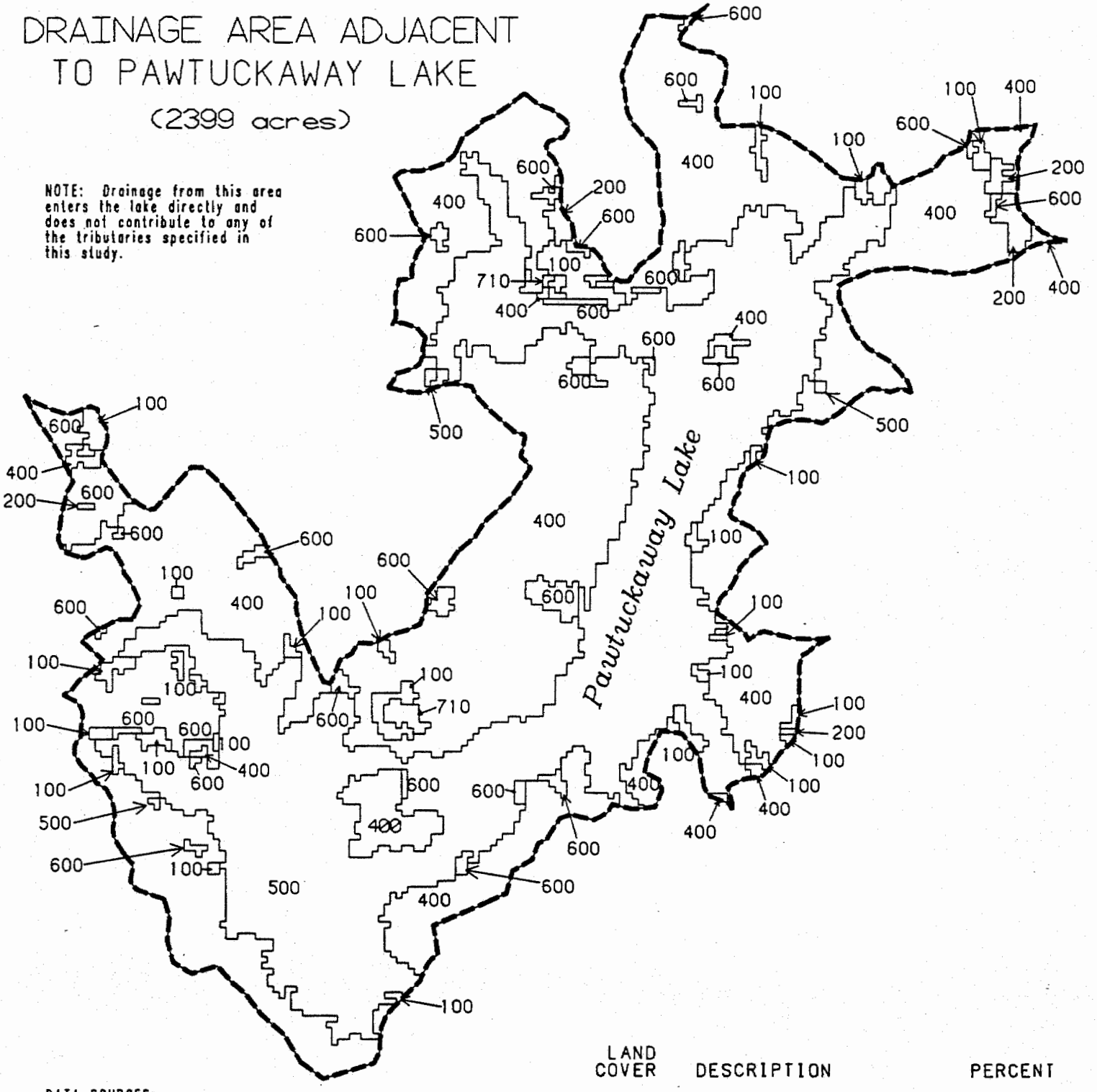
SCALE 1:9800

APPENDIX III-3

DRAINAGE AREA ADJACENT TO PAWTUCKAWAY LAKE

(2399 acres)

NOTE: Drainage from this area enters the lake directly and does not contribute to any of the tributaries specified in this study.



LAND COVER	DESCRIPTION	PERCENT
100	URBAN	3.2
200	ACTIVE AGRICULTURE	0.7
400	FOREST	52.4
500	WATER	39.1
600	WETLAND	4.2
710	DISTURBED (gravel pits)	0.3
790	CLEARED/OPEN	< 0.1

DATA SOURCES:
Land cover:
Mapped and automated from LANDSAT Thematic Mapper Imagery by Complex Systems Research Center, Durham, NH (1993).
Watershed boundaries: Compiled and digitized at 1:24,000 by NH Department of Environmental Services.

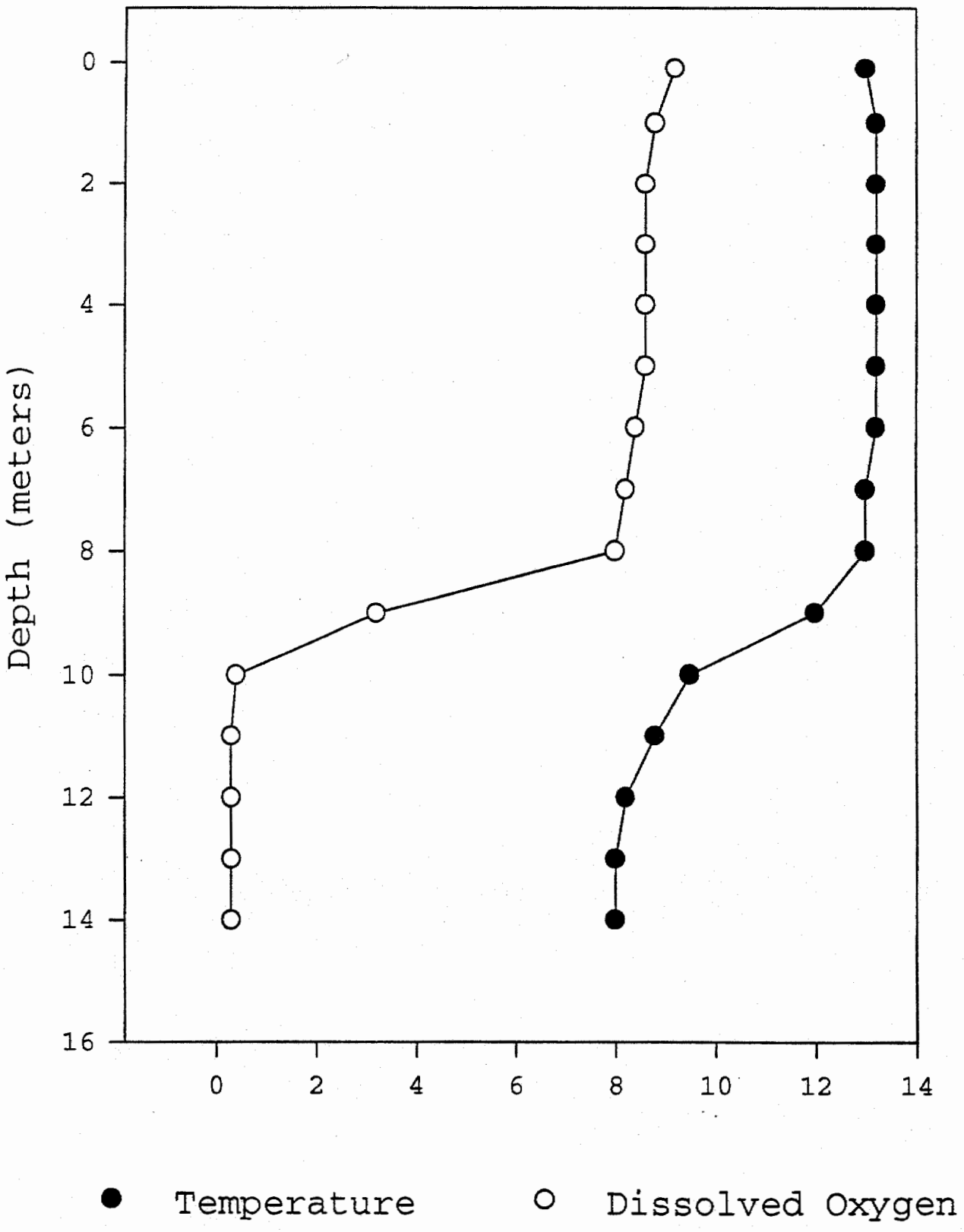
This map was produced by the NH DES GIS Program, April 1994.

SCALE 1:26400

APPENDIX V-1

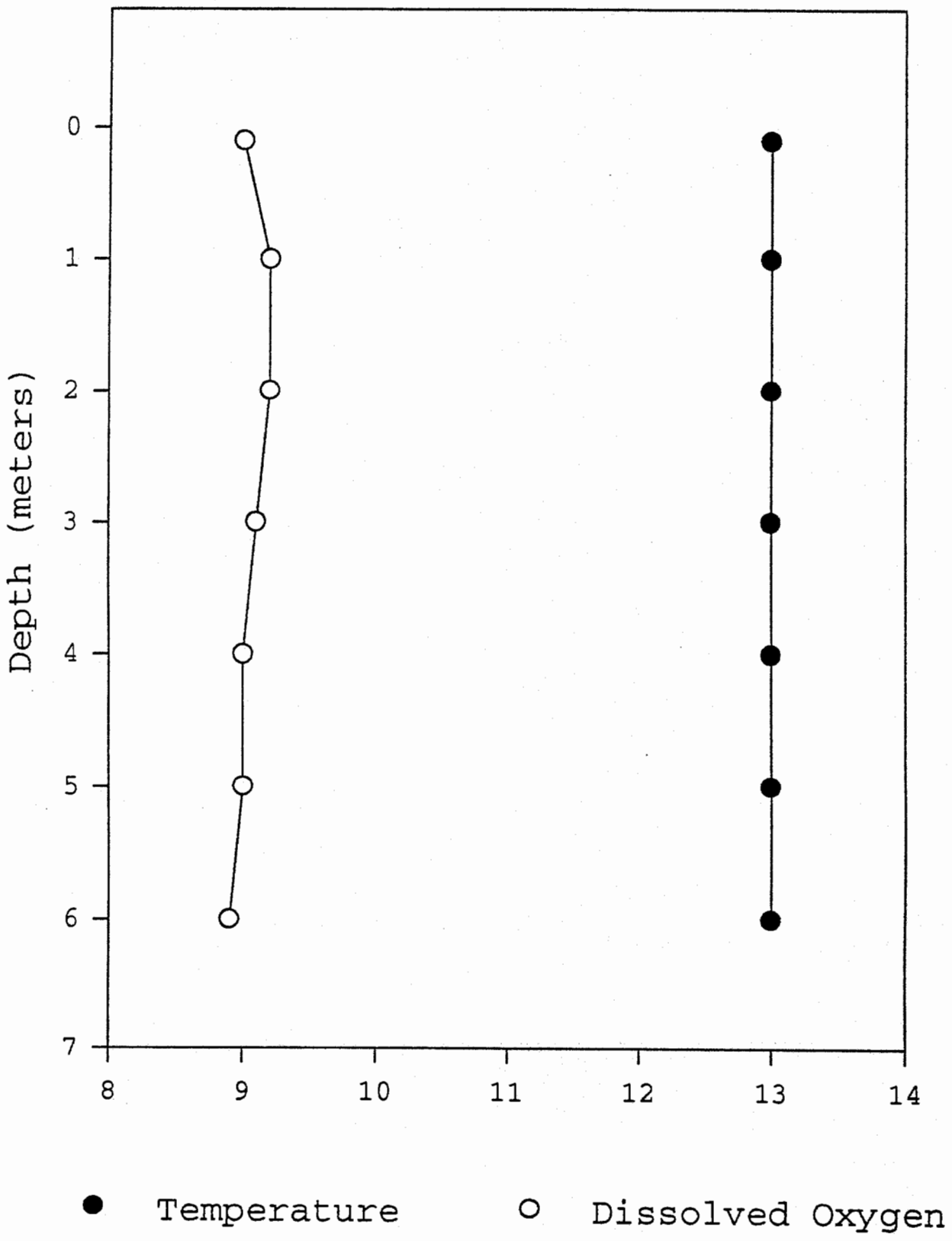
Pawtuckaway Lake North

10/15/91



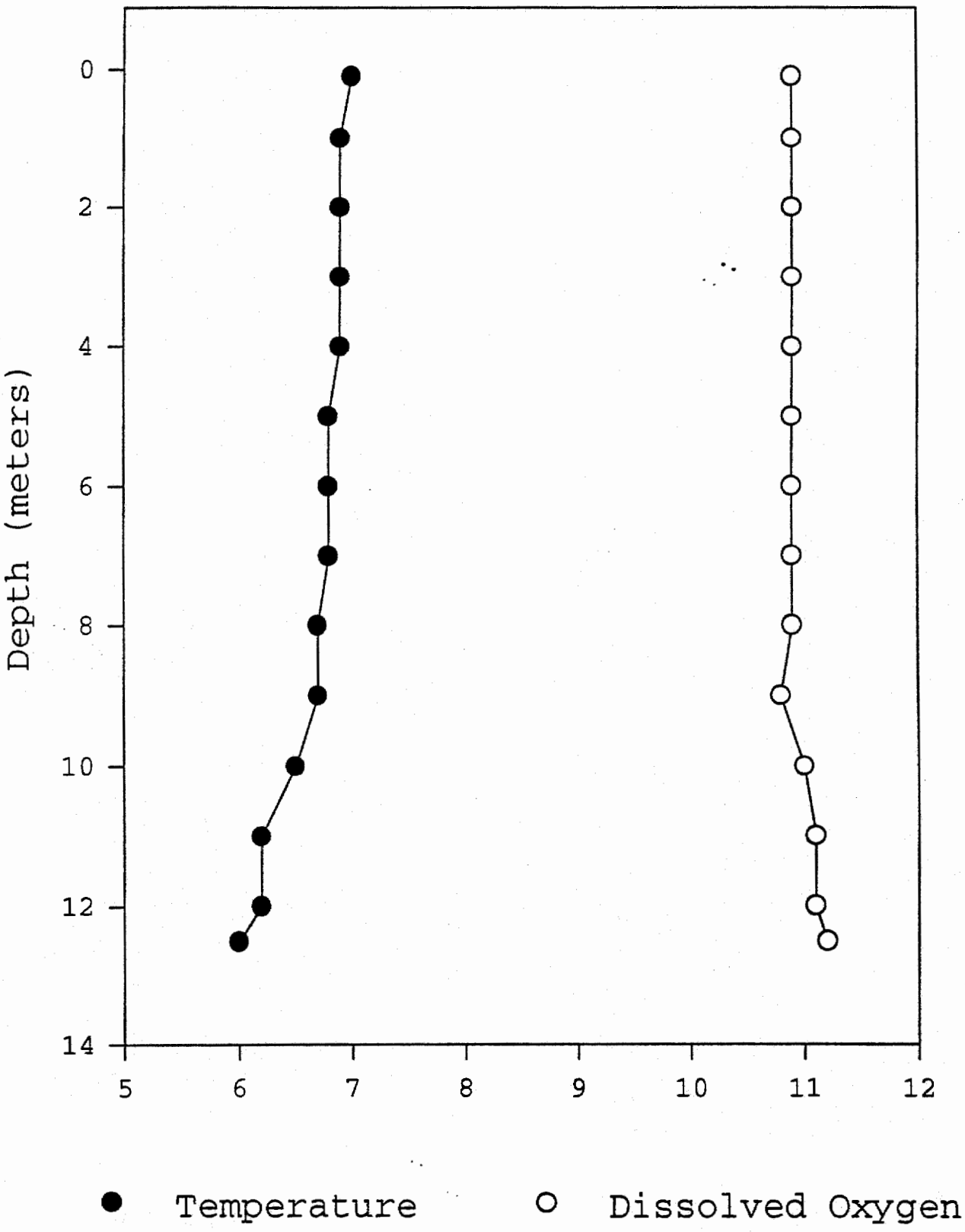
Pawtuckaway Lake South

10/15/91



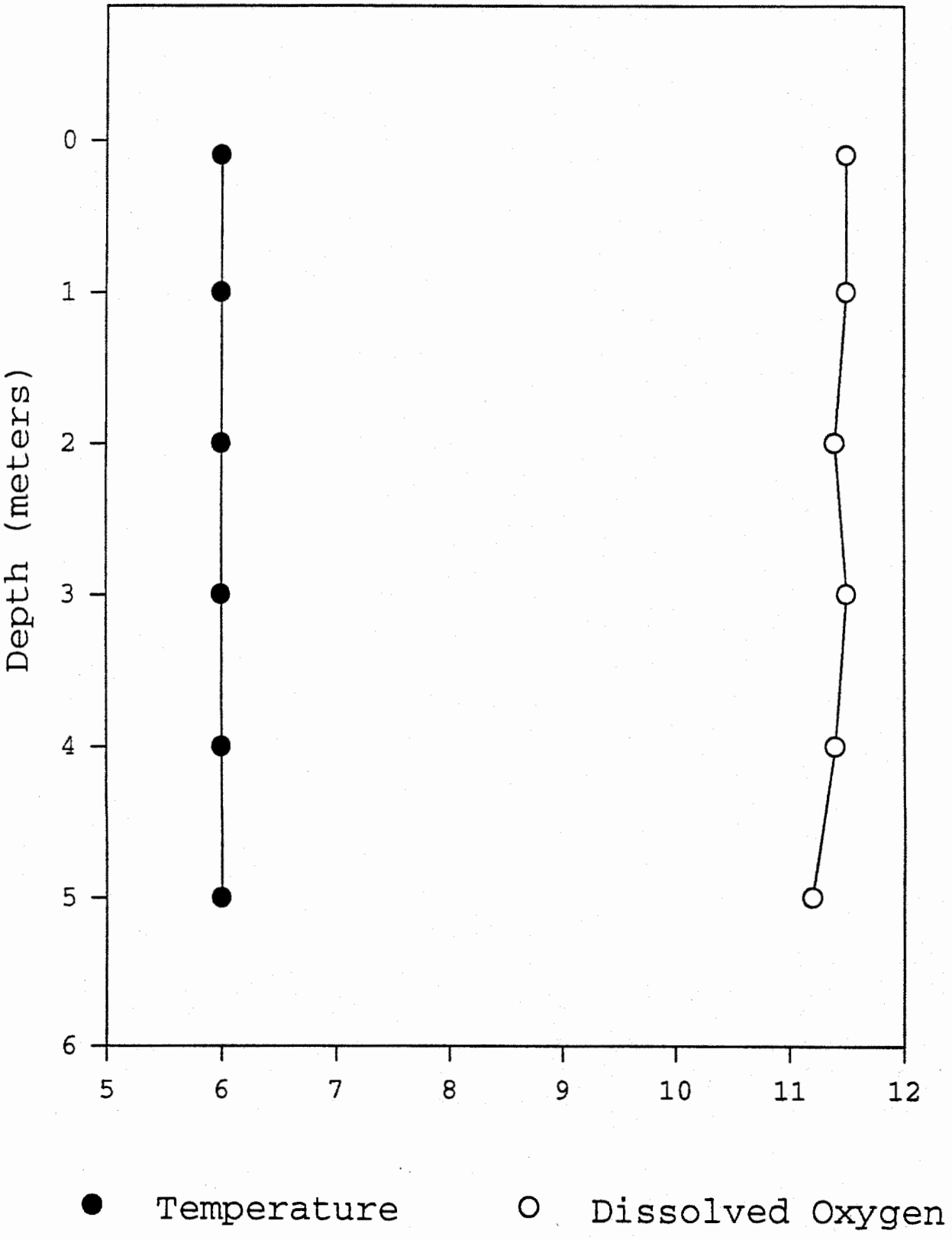
Pawtuckaway Lake North

11/12/91



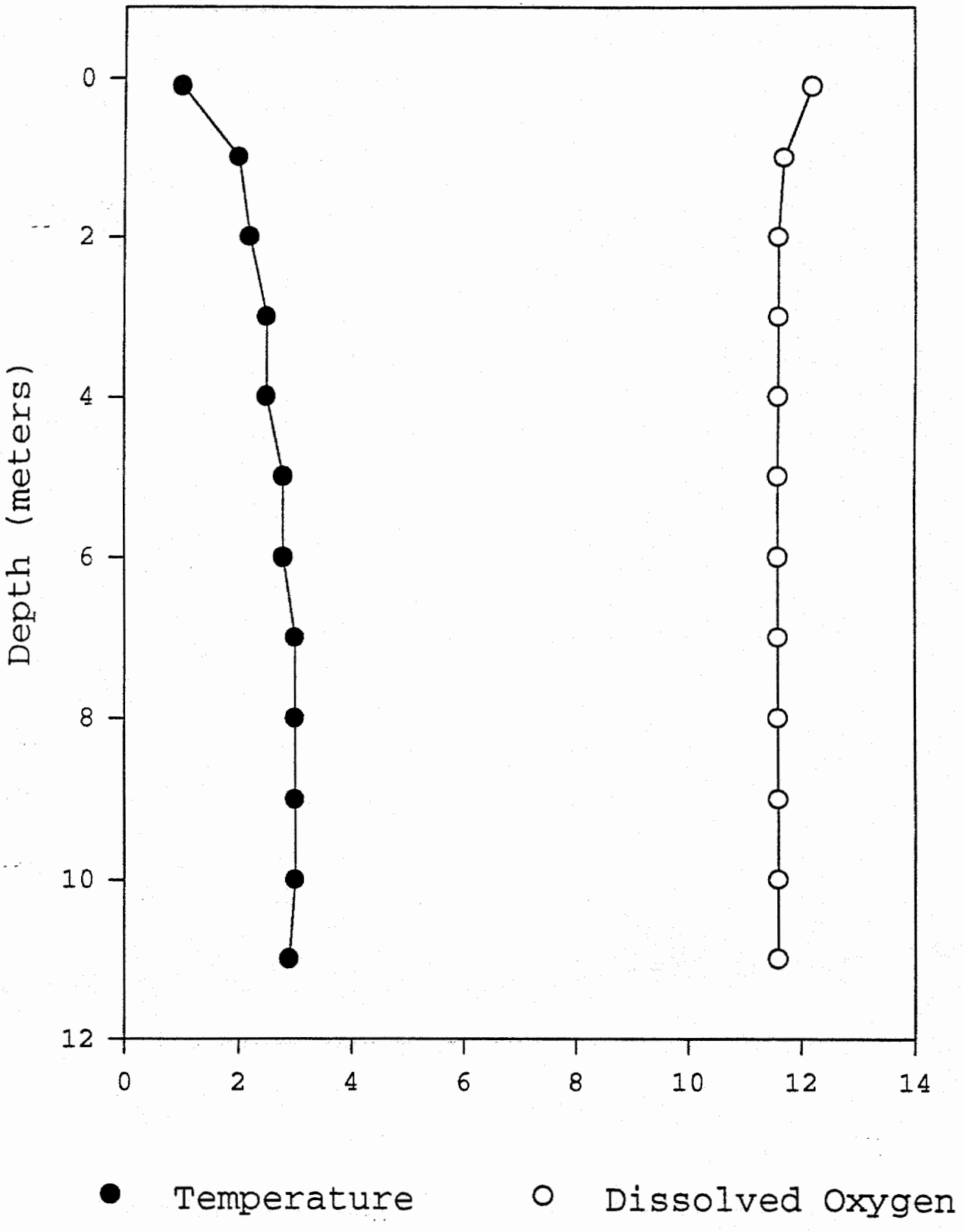
Pawtuckaway Lake South

11/12/91



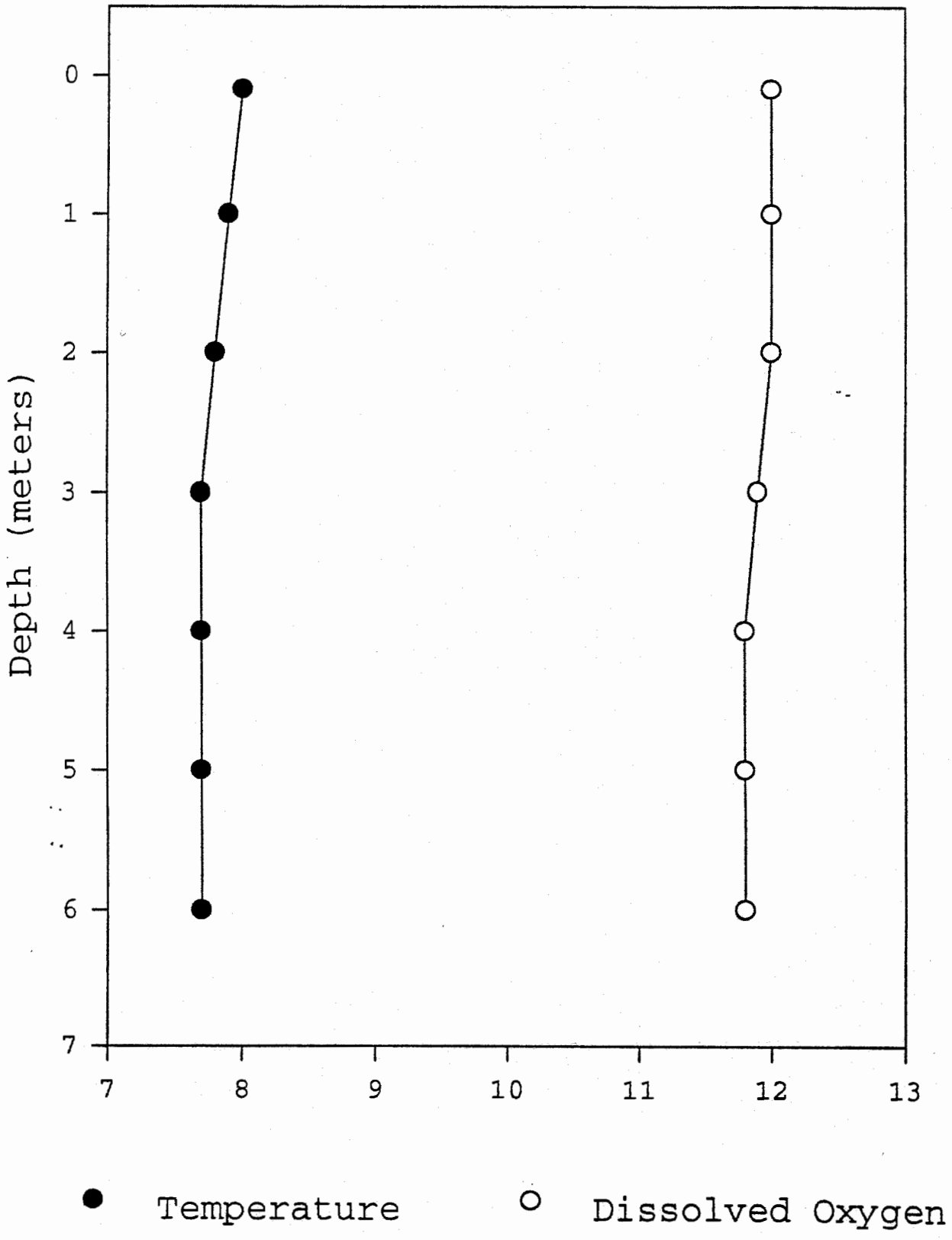
Pawtuckaway Lake North

12/16/91



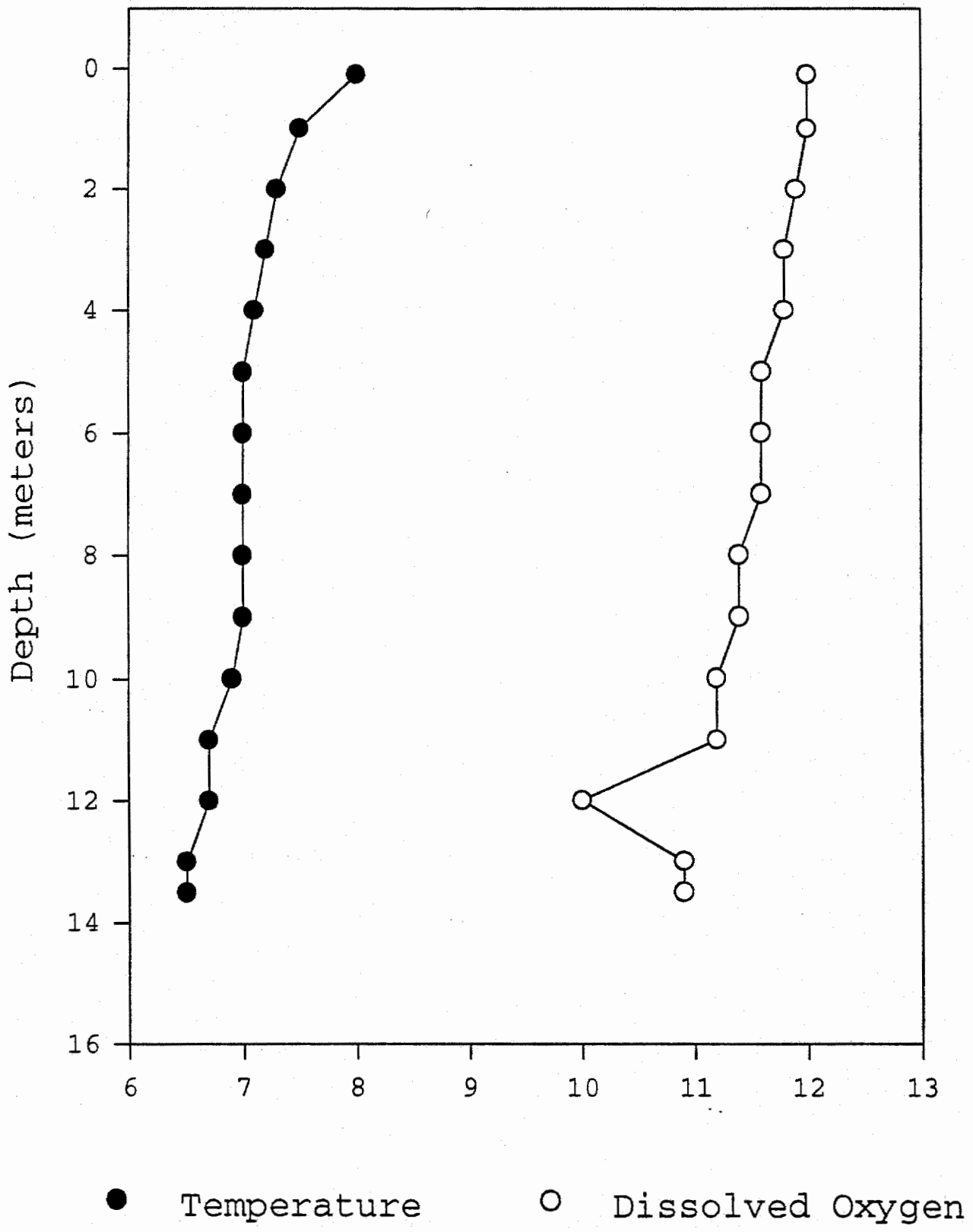
Pawtuckaway Lake South

04/16/92



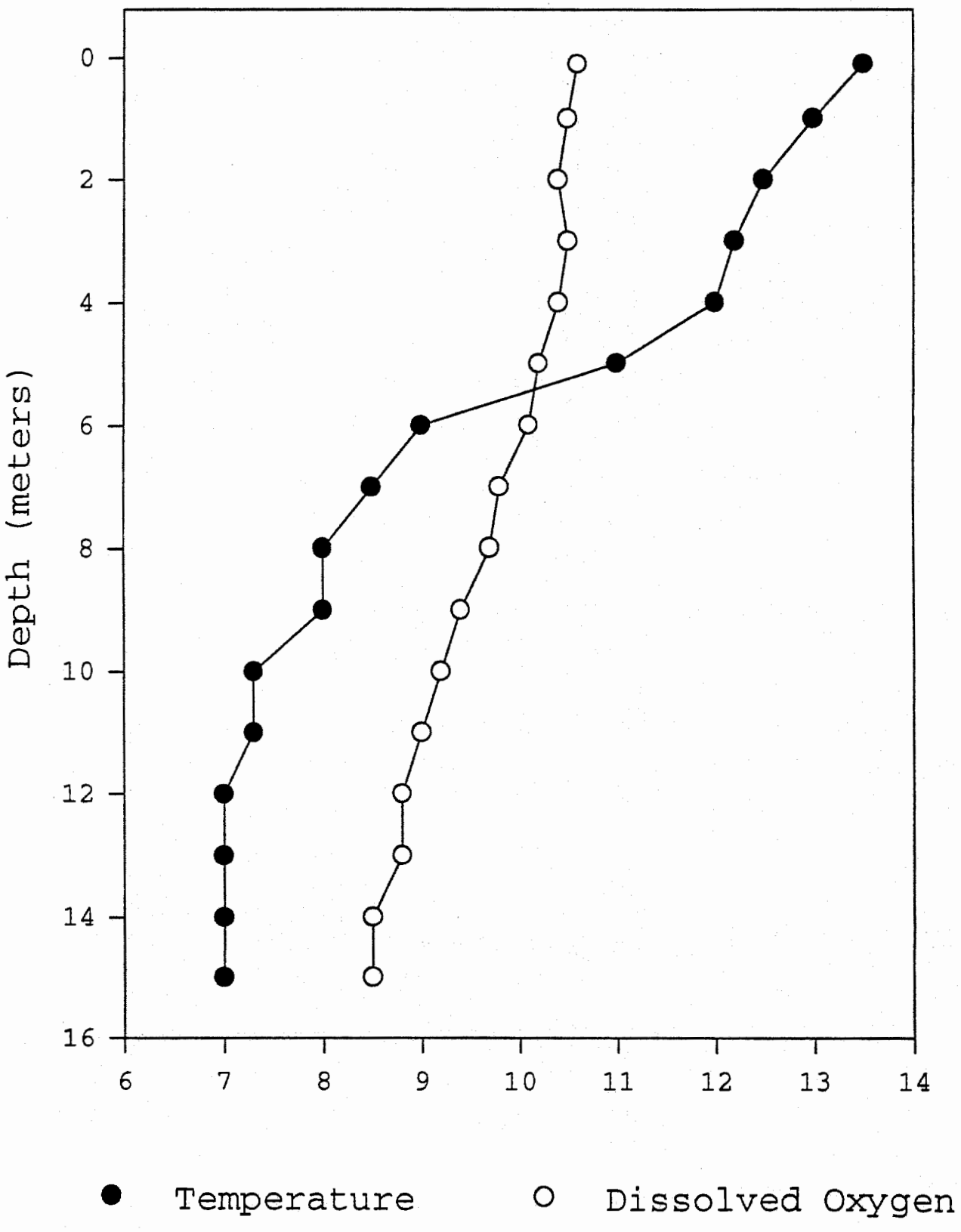
Pawtuckaway Lake North

04/16/92



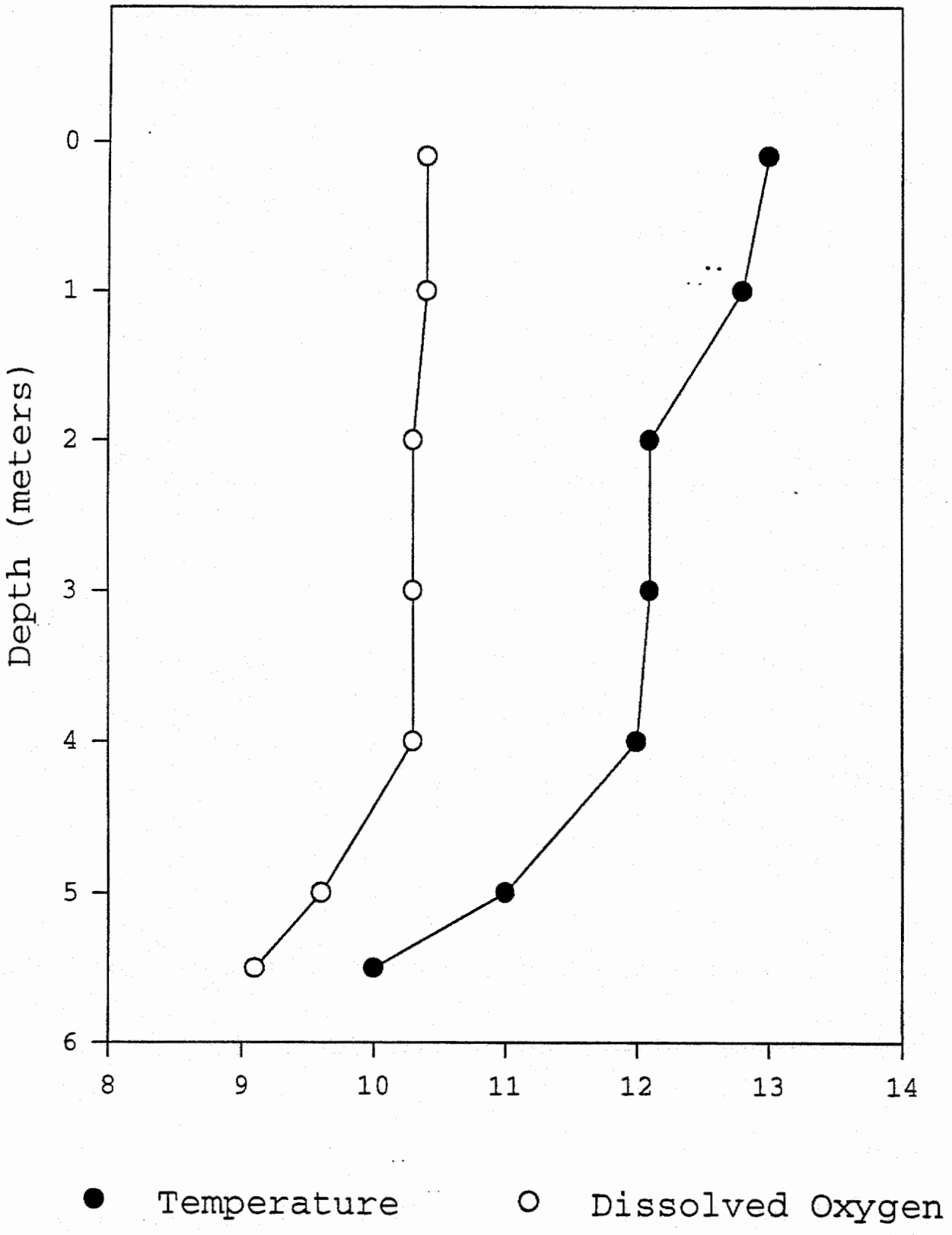
Pawtuckaway Lake North

05/07/92



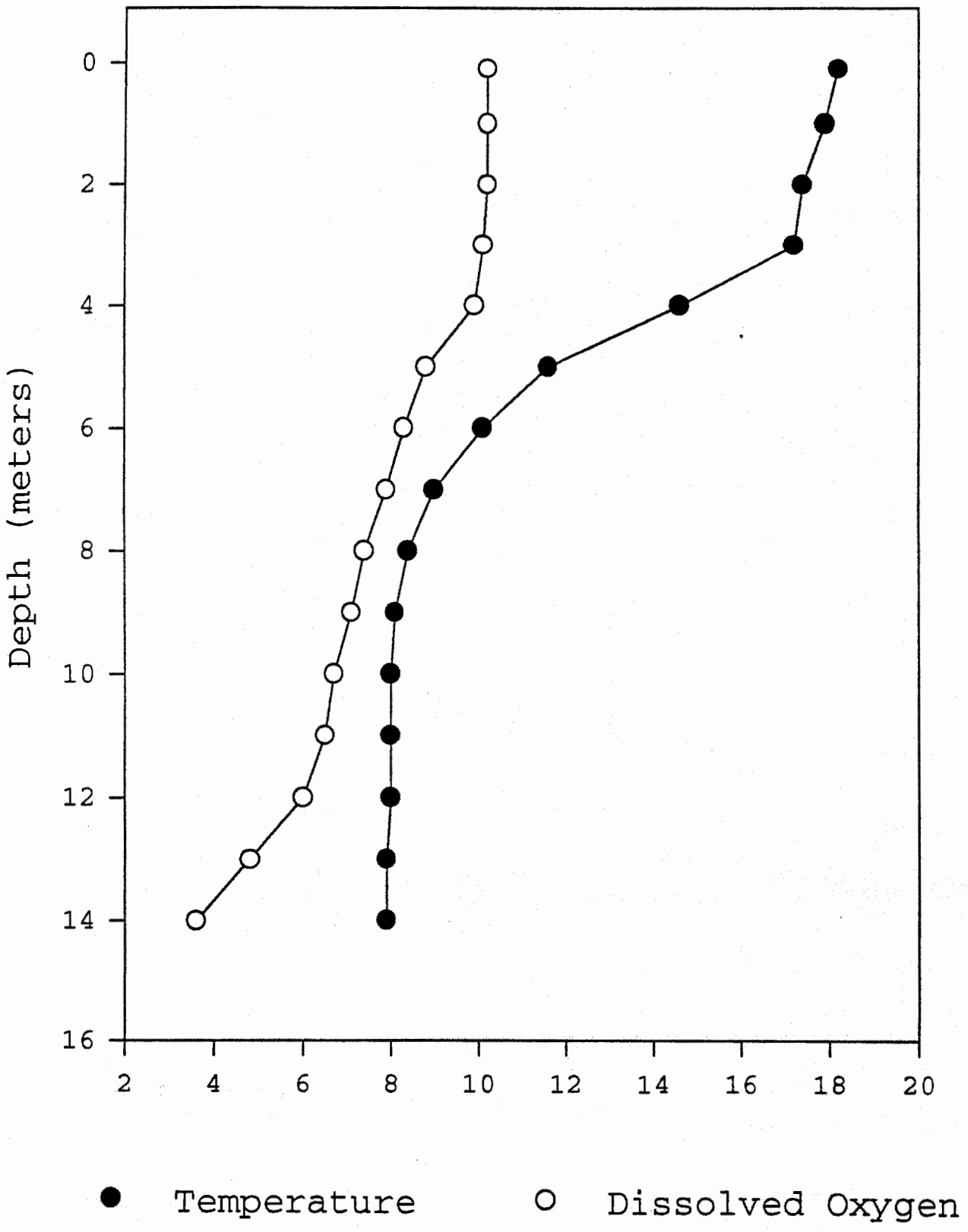
Pawtuckaway Lake South

05/07/92



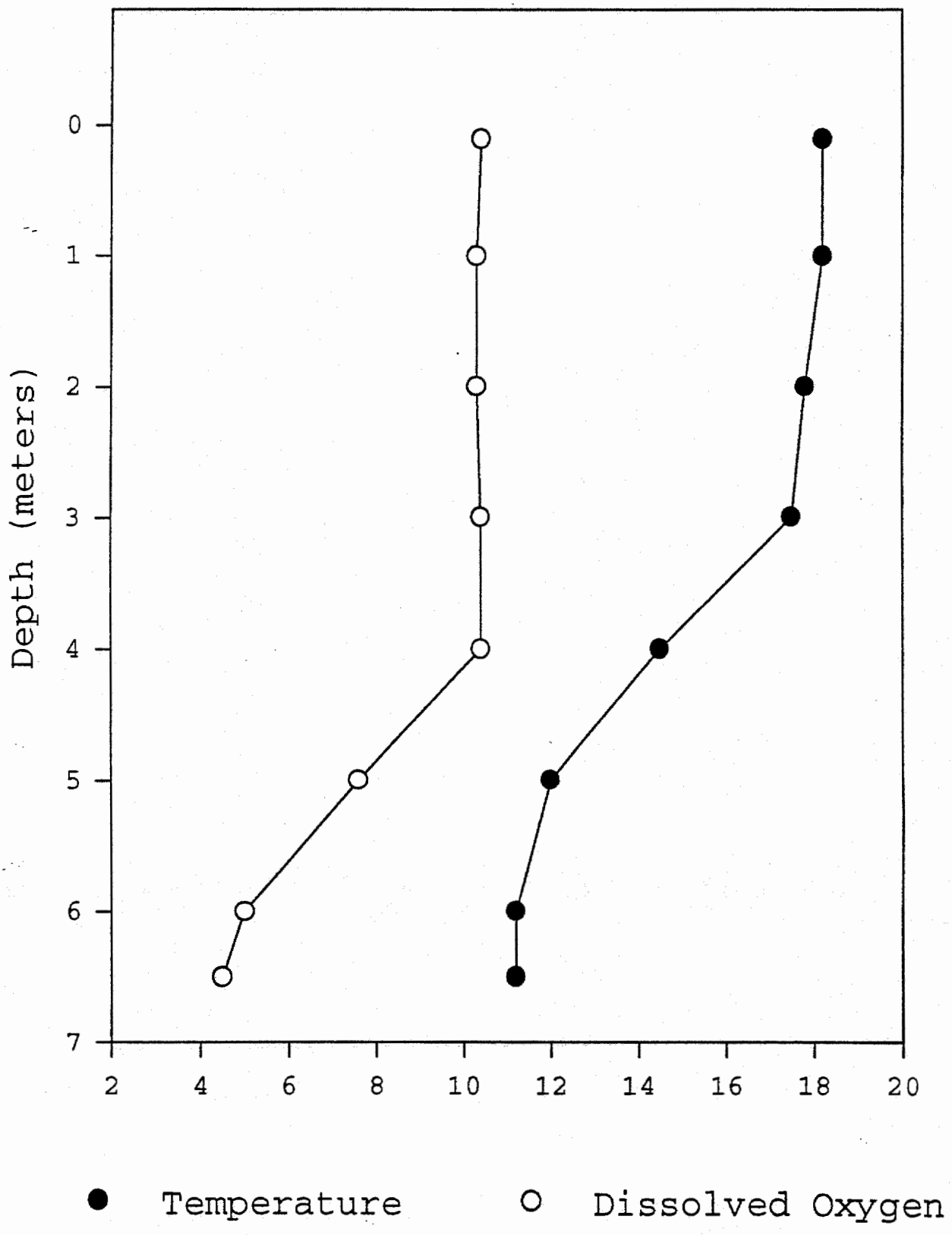
Pawtuckaway Lake North

05/26/92



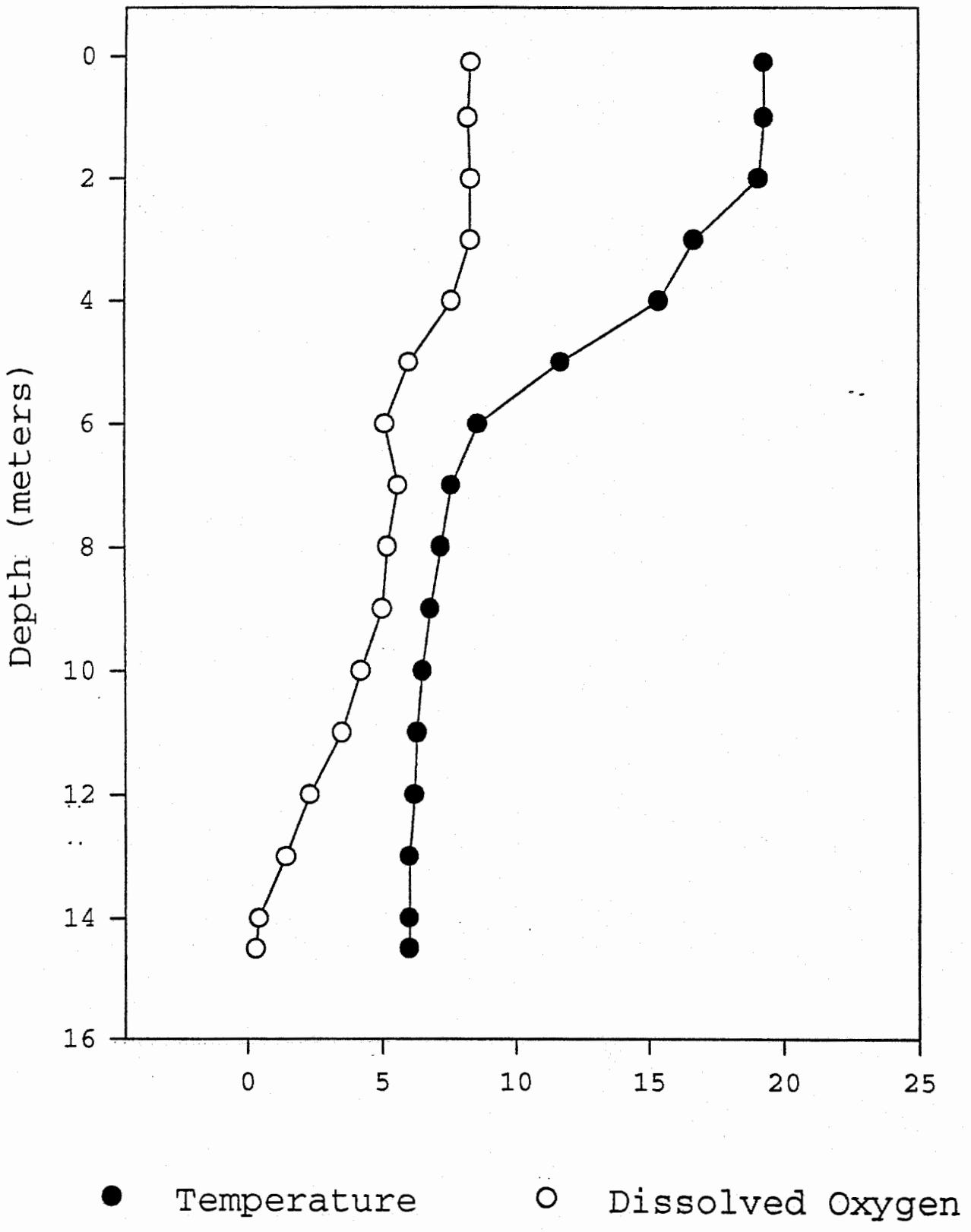
Pawtuckaway Lake South

05/26/92



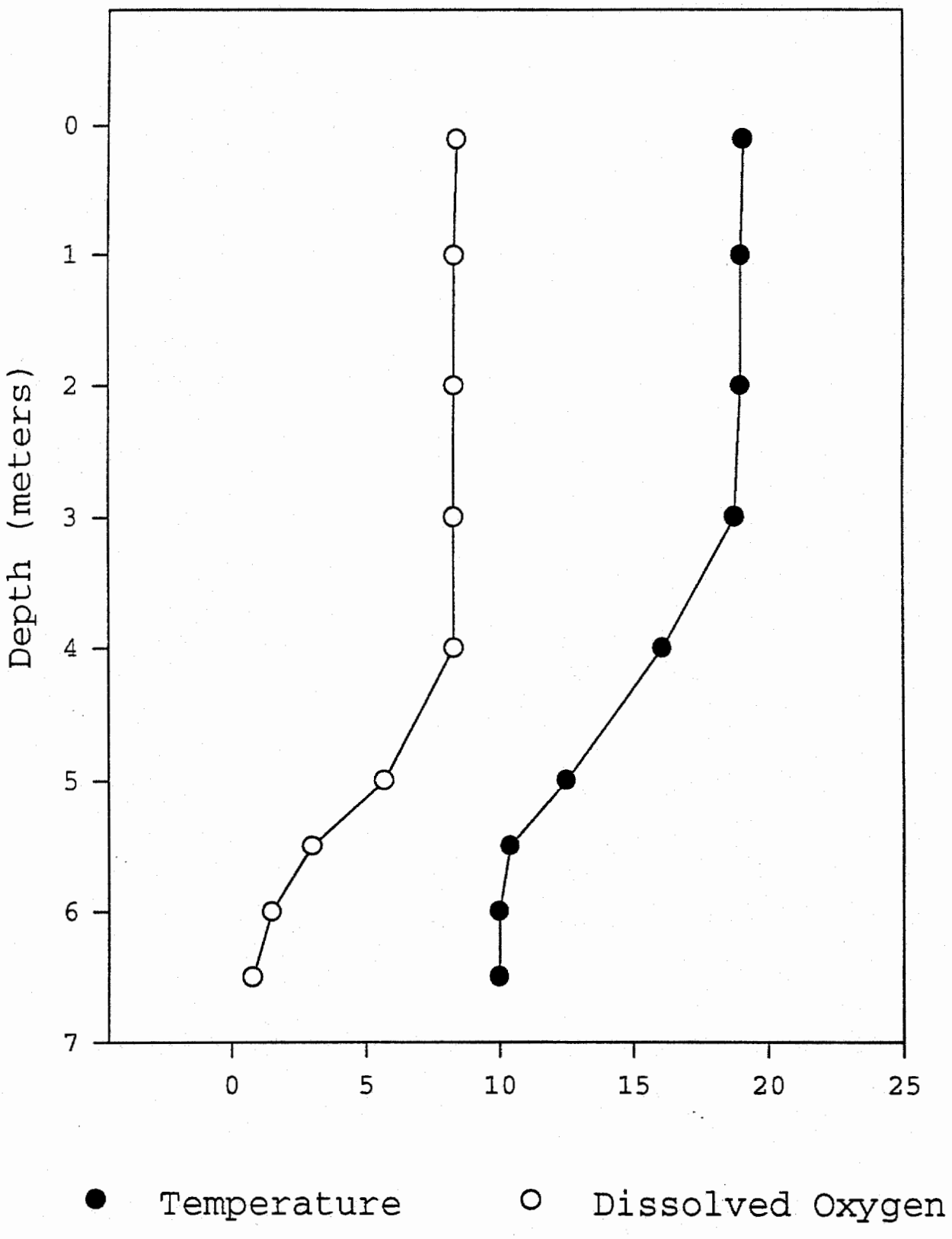
Pawtuckaway Lake North

06/10/92



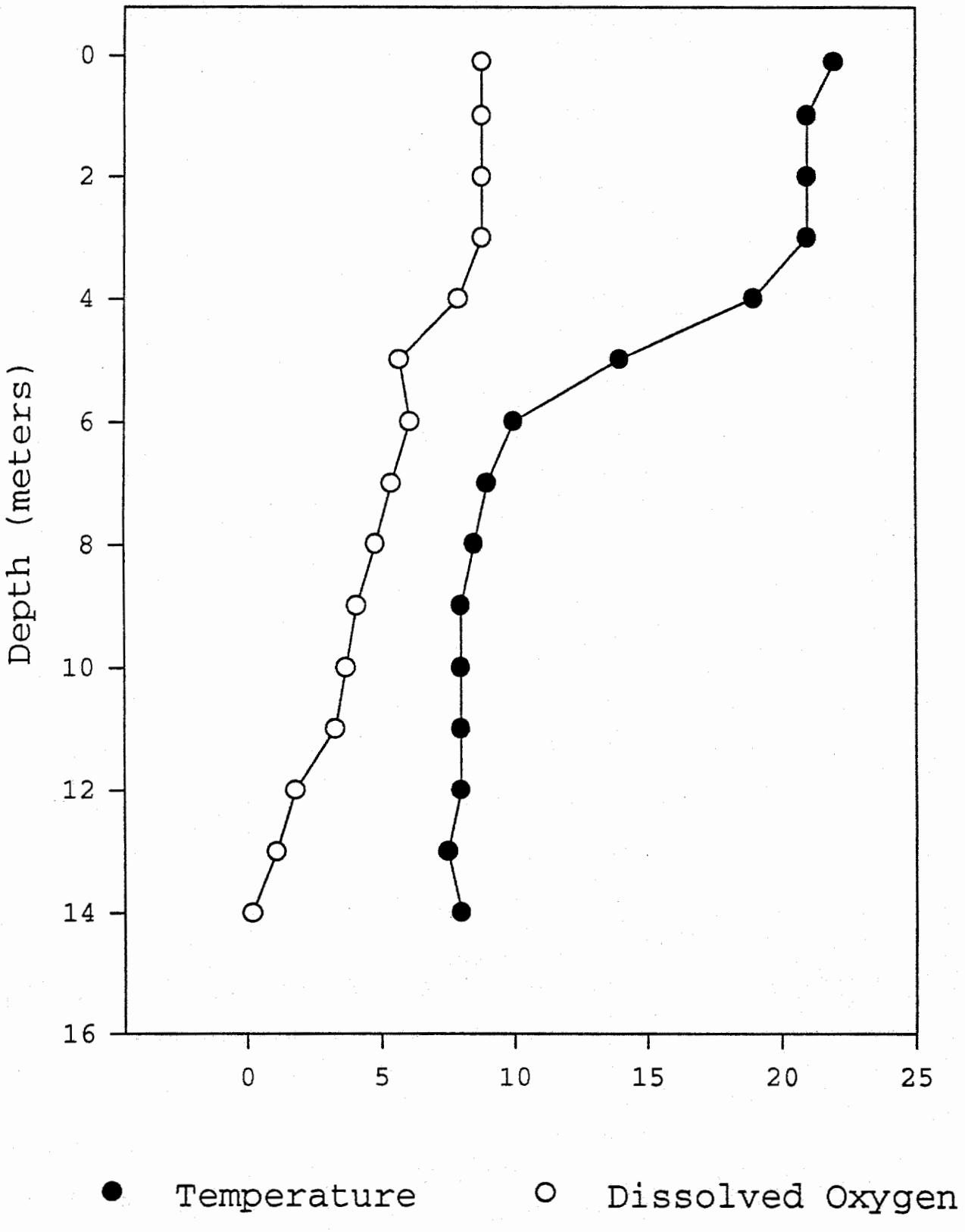
Pawtuckaway Lake South

06/10/92



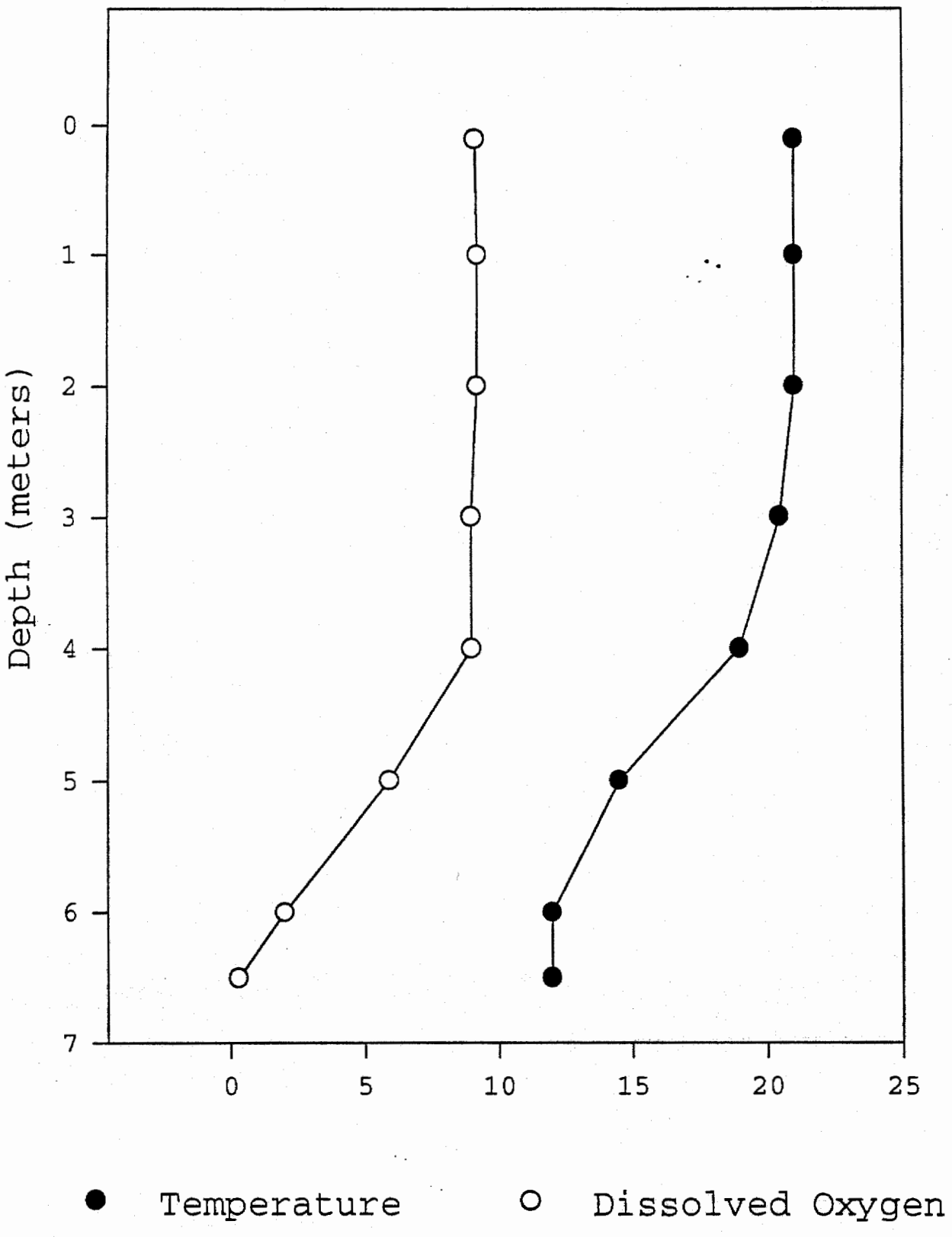
Pawtuckaway Lake North

06/26/92



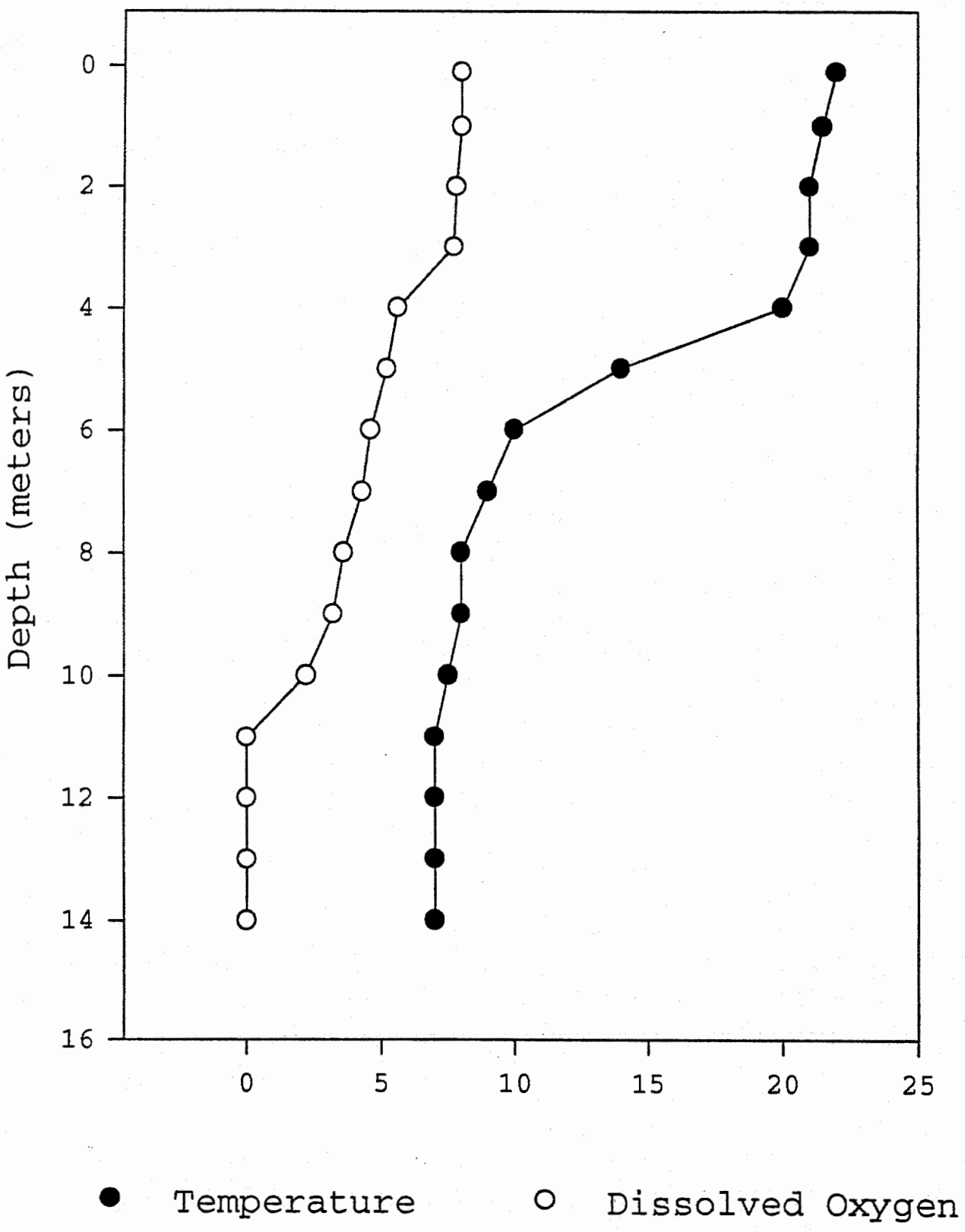
Pawtuckaway Lake South

06/26/92



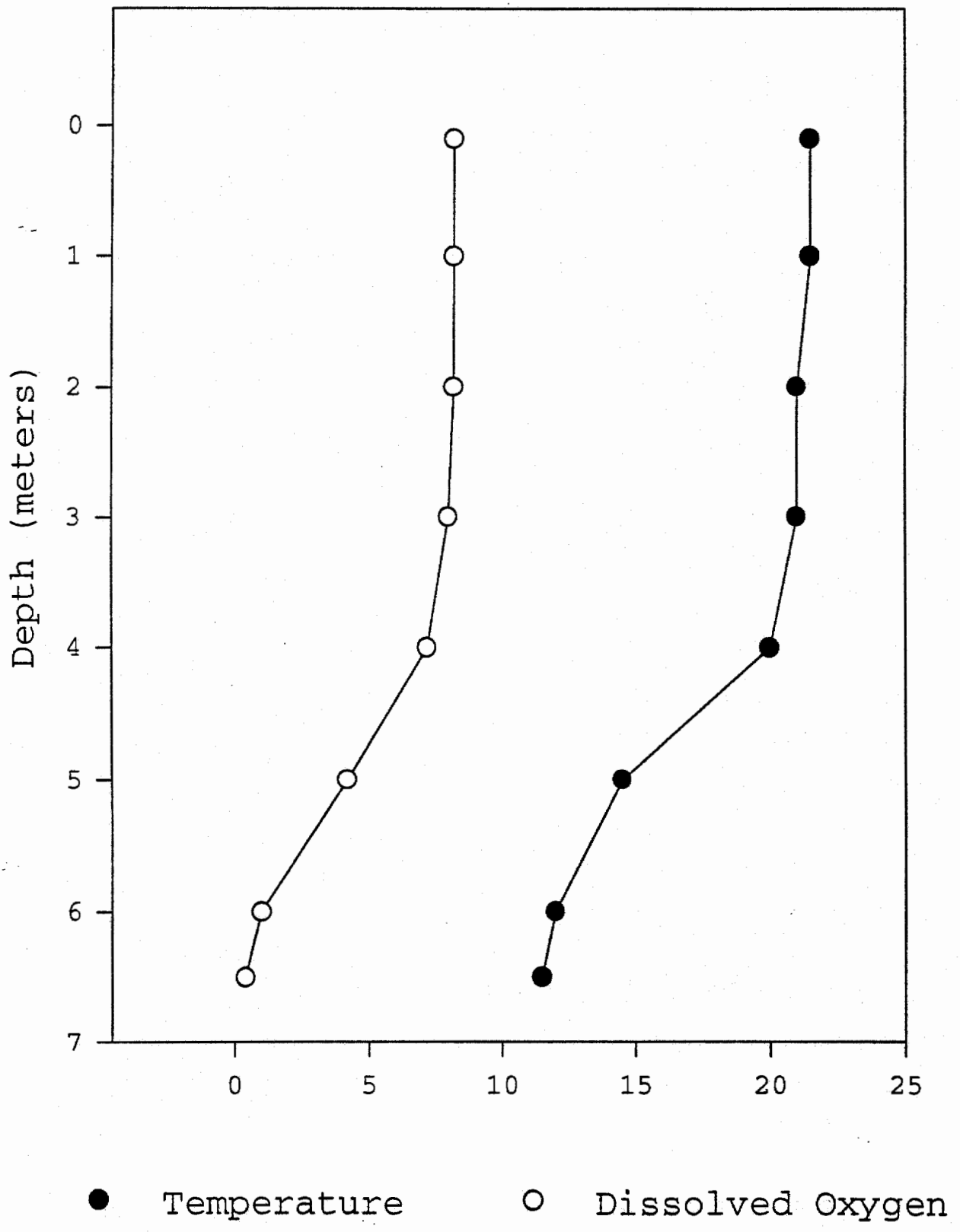
Pawtuckaway Lake North

07/07/92



Pawtuckaway Lake South

07/07/92



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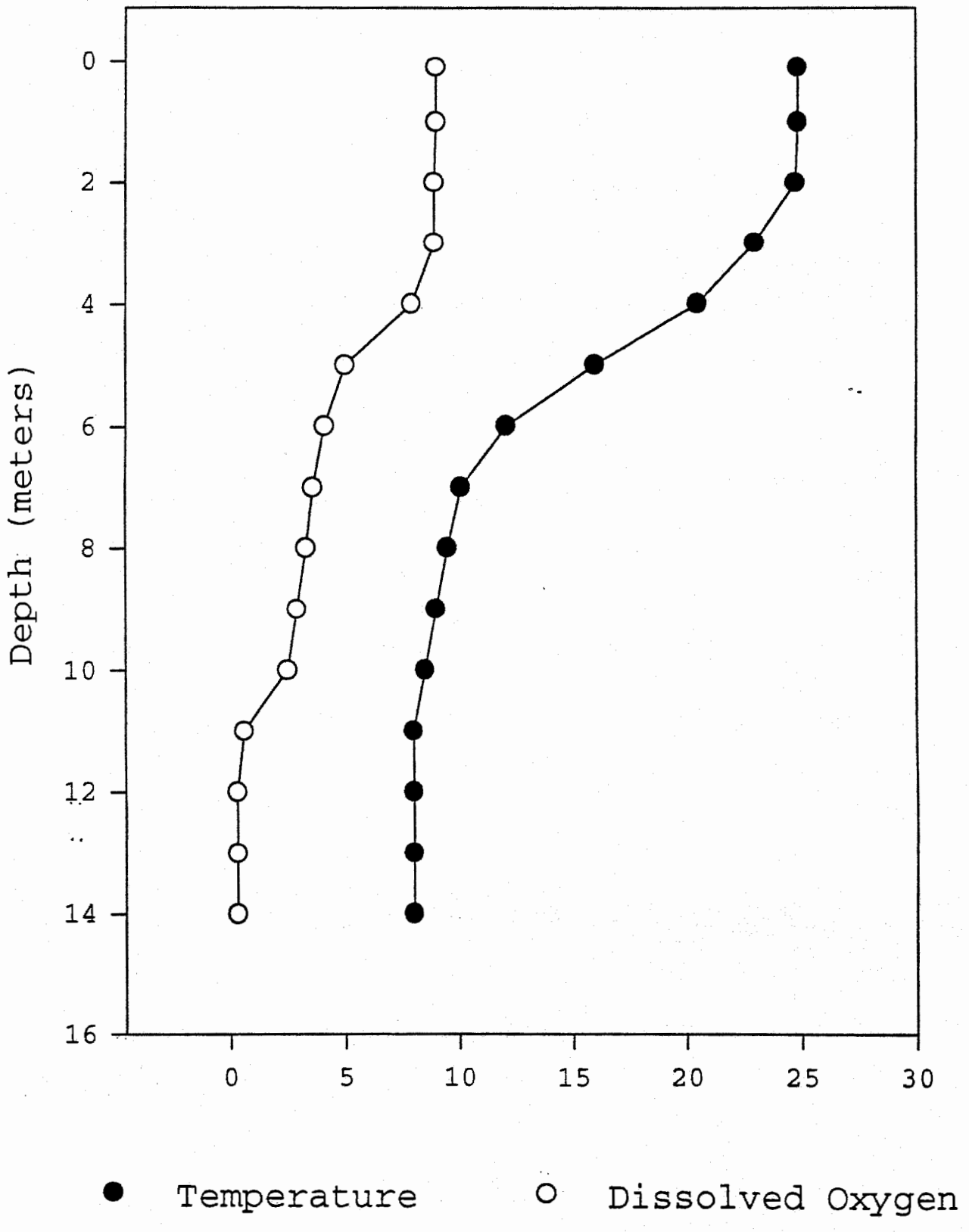
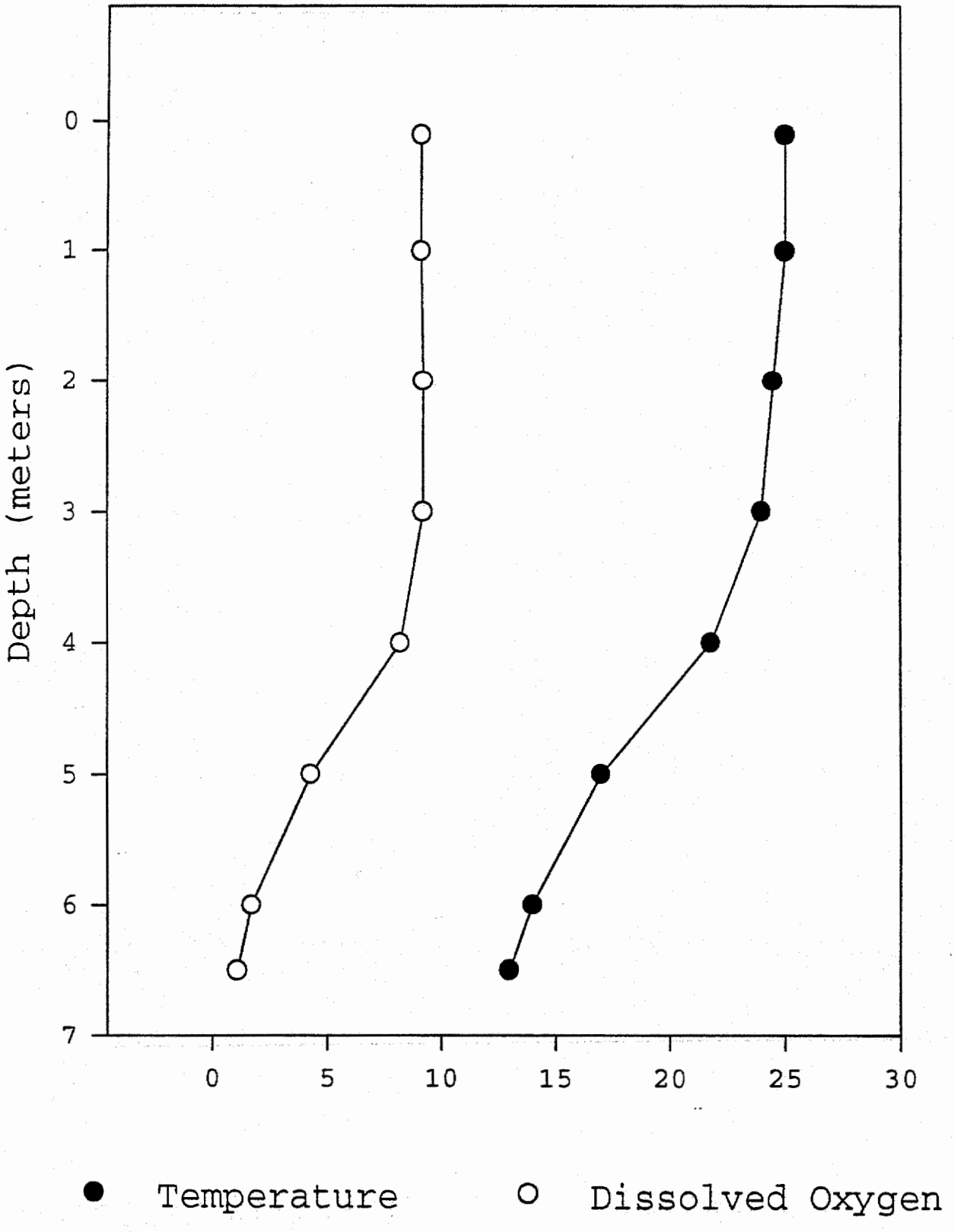
07/21/92



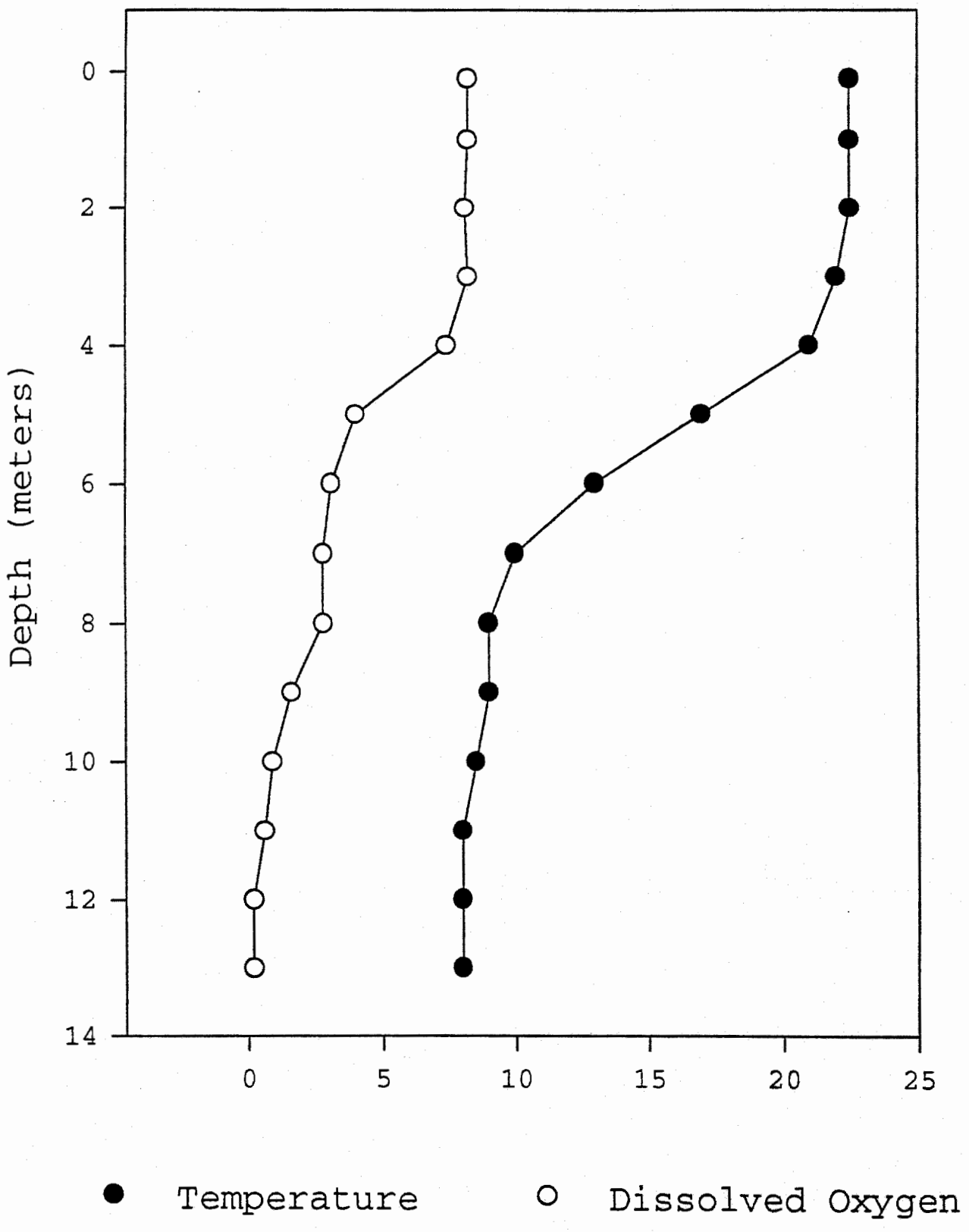
Pawtuckaway Lake South

07/21/92



Pawtuckaway Lake North

08/03/92



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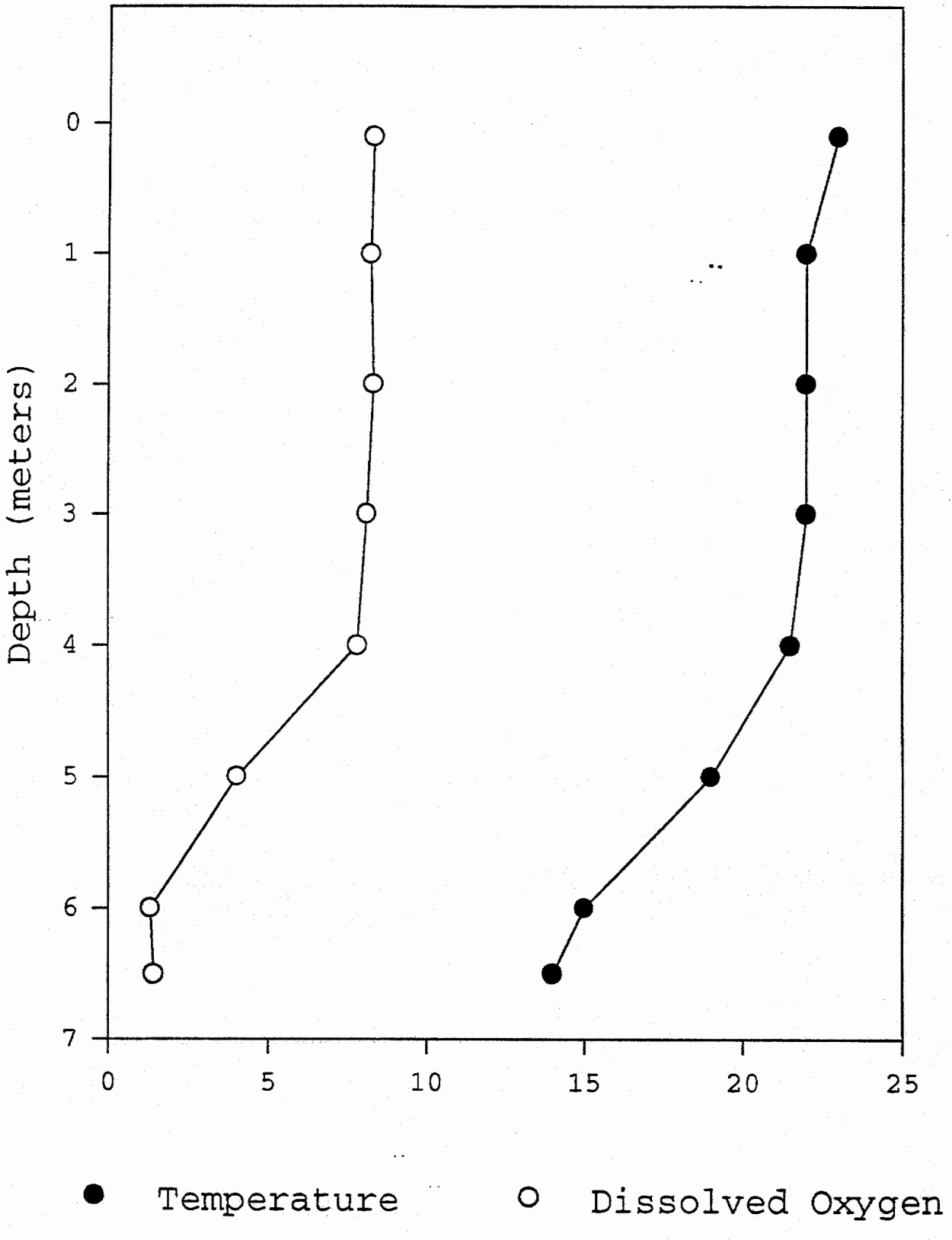
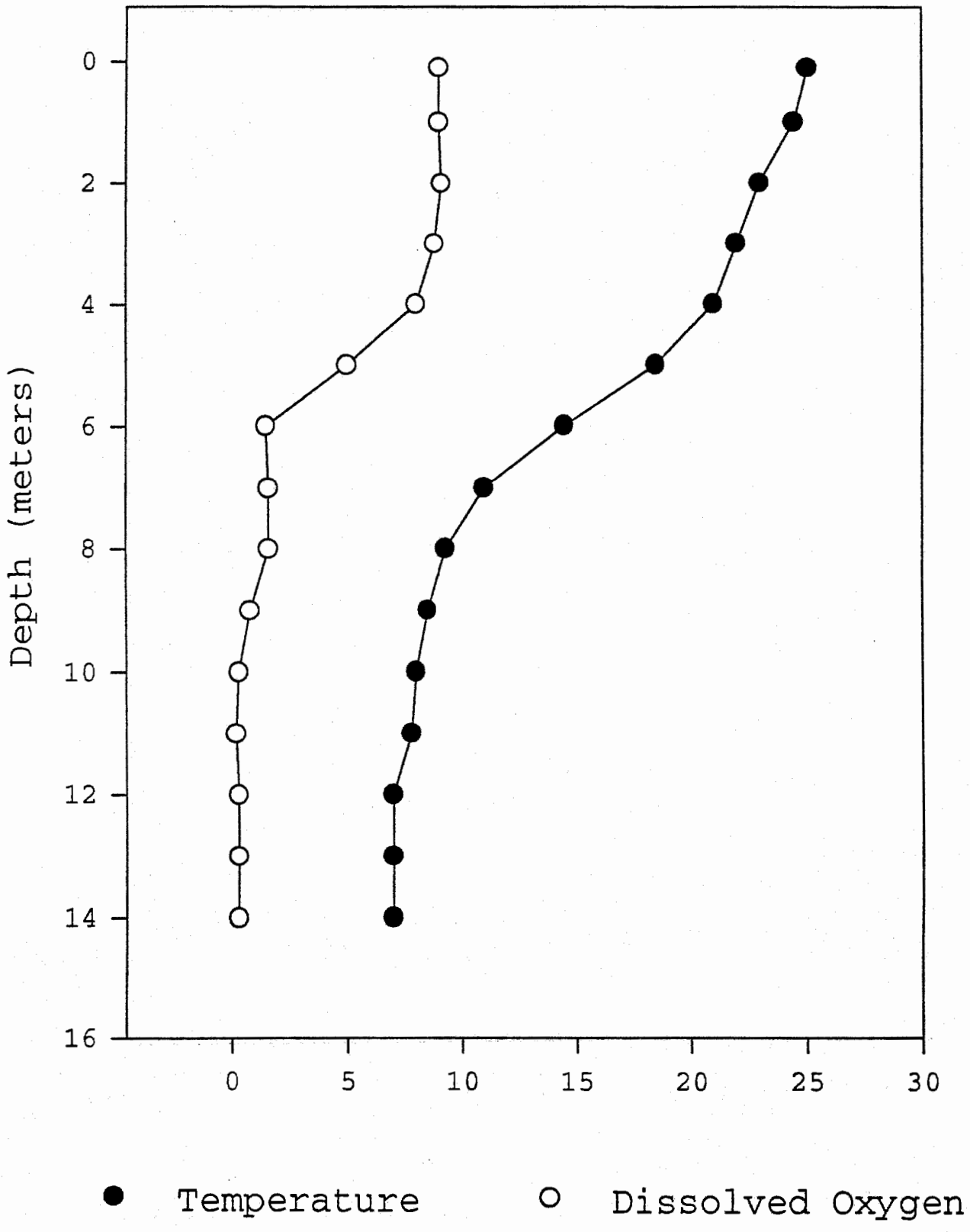
08/03/92



Pawtuckaway Lake North

08/26/92



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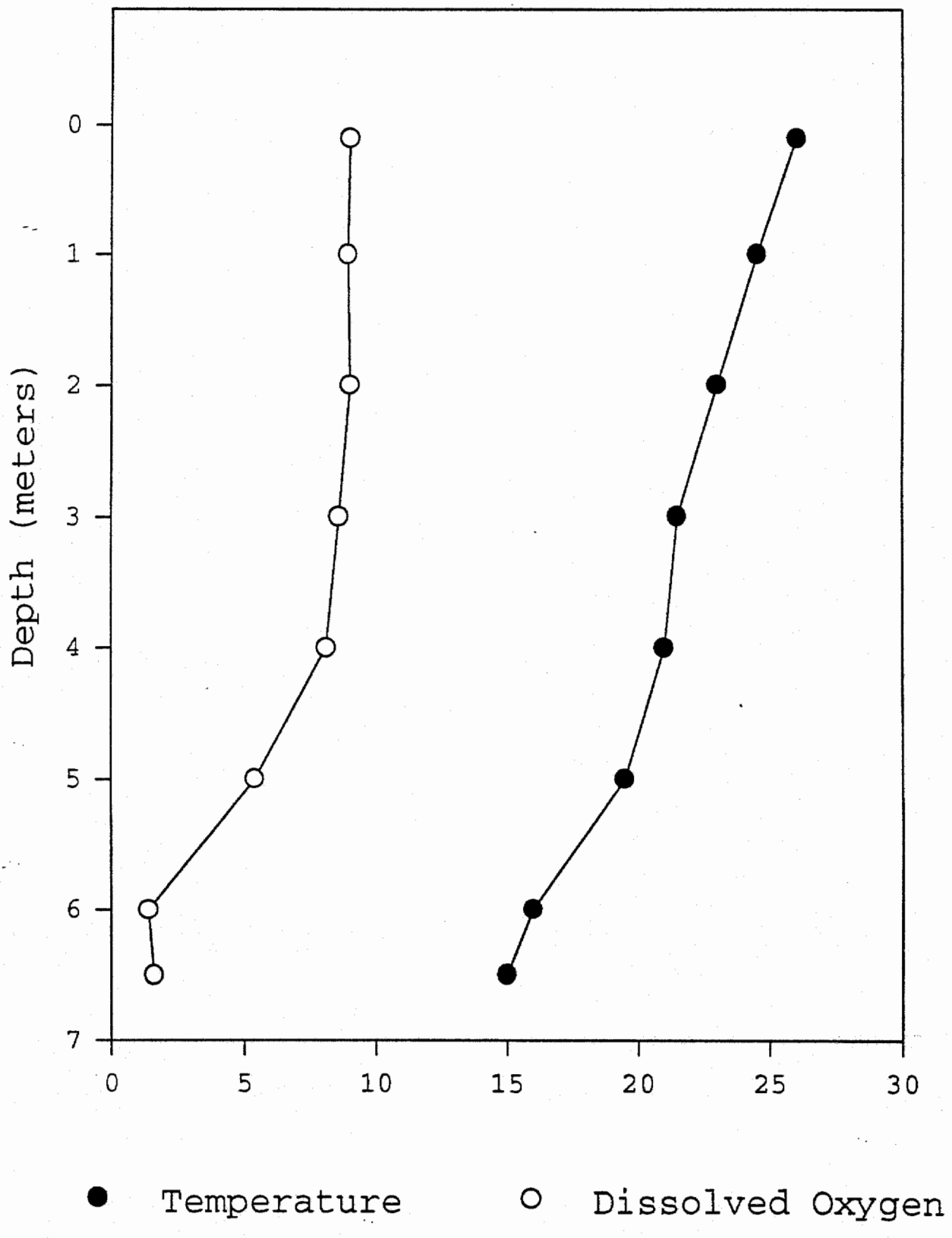
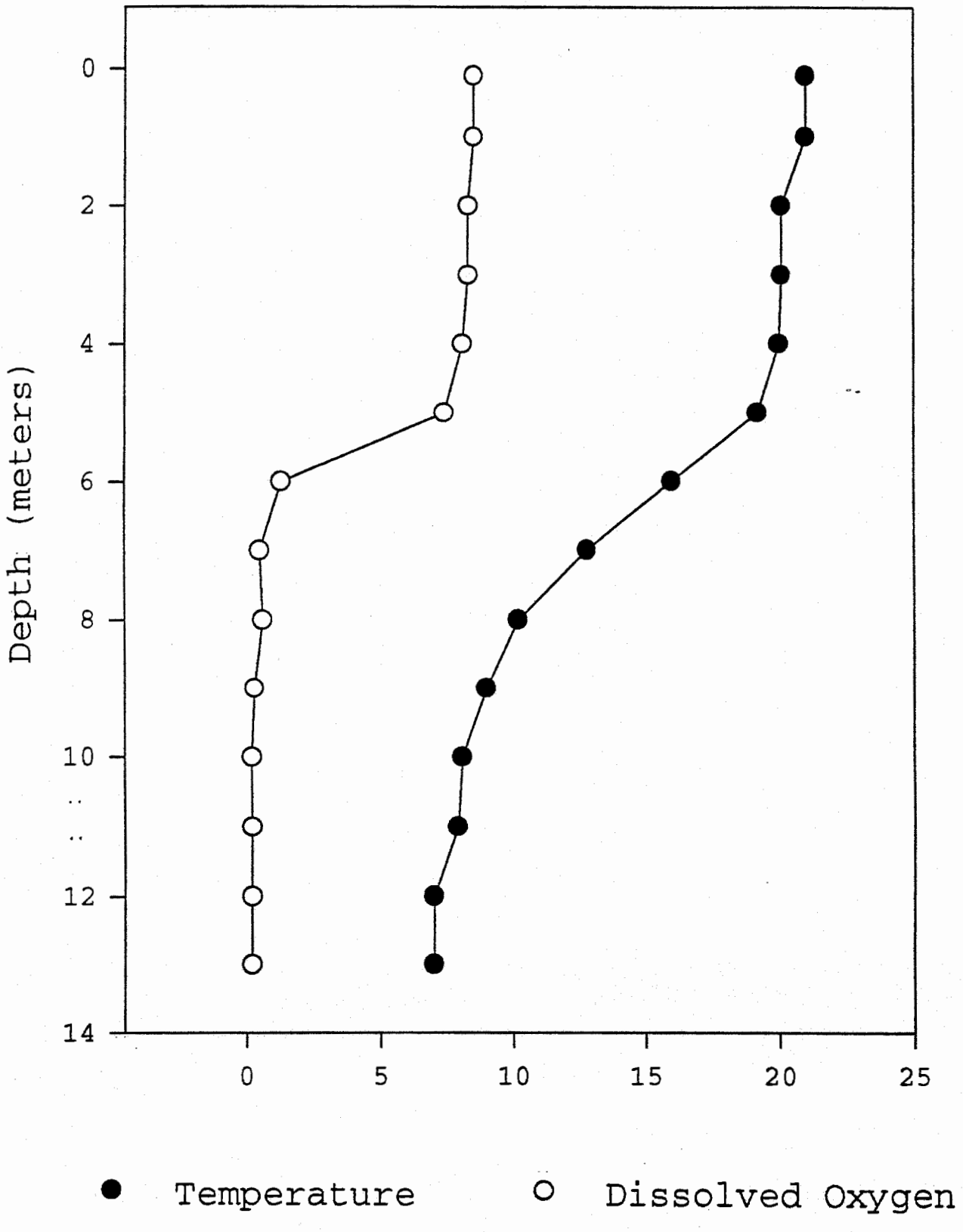
08/26/92



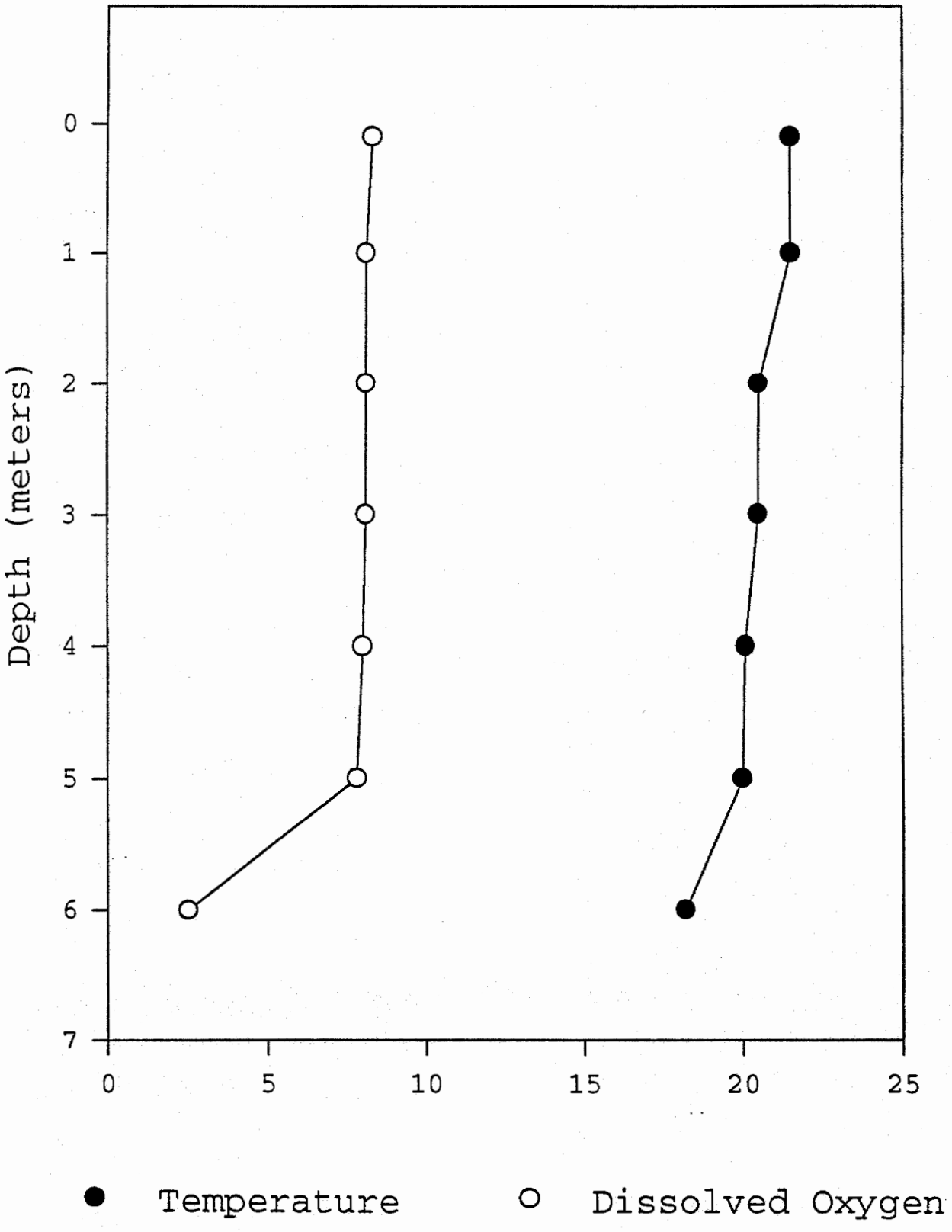
Pawtuckaway Lake North

09/09/92



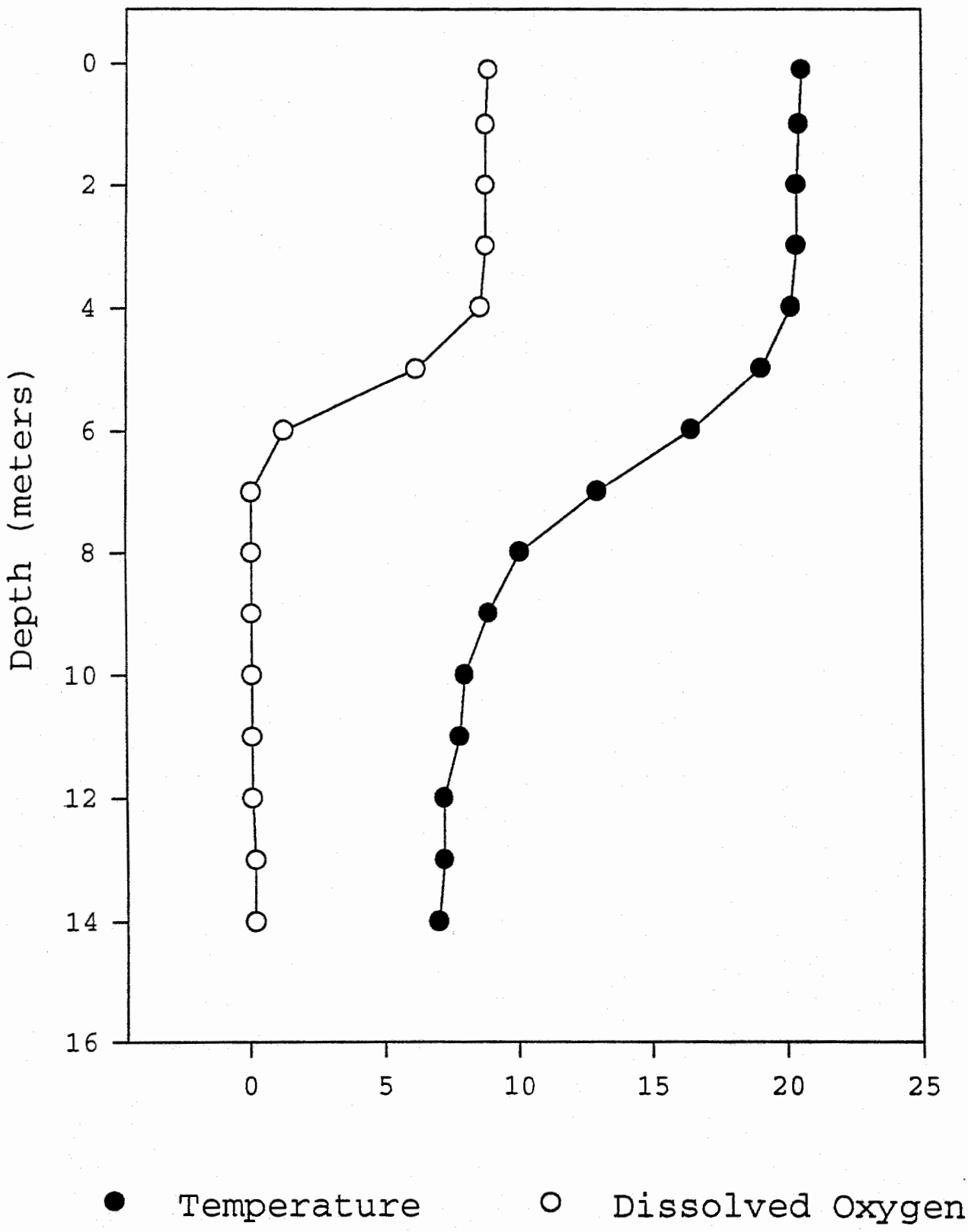
Pawtuckaway Lake South

09/09/92



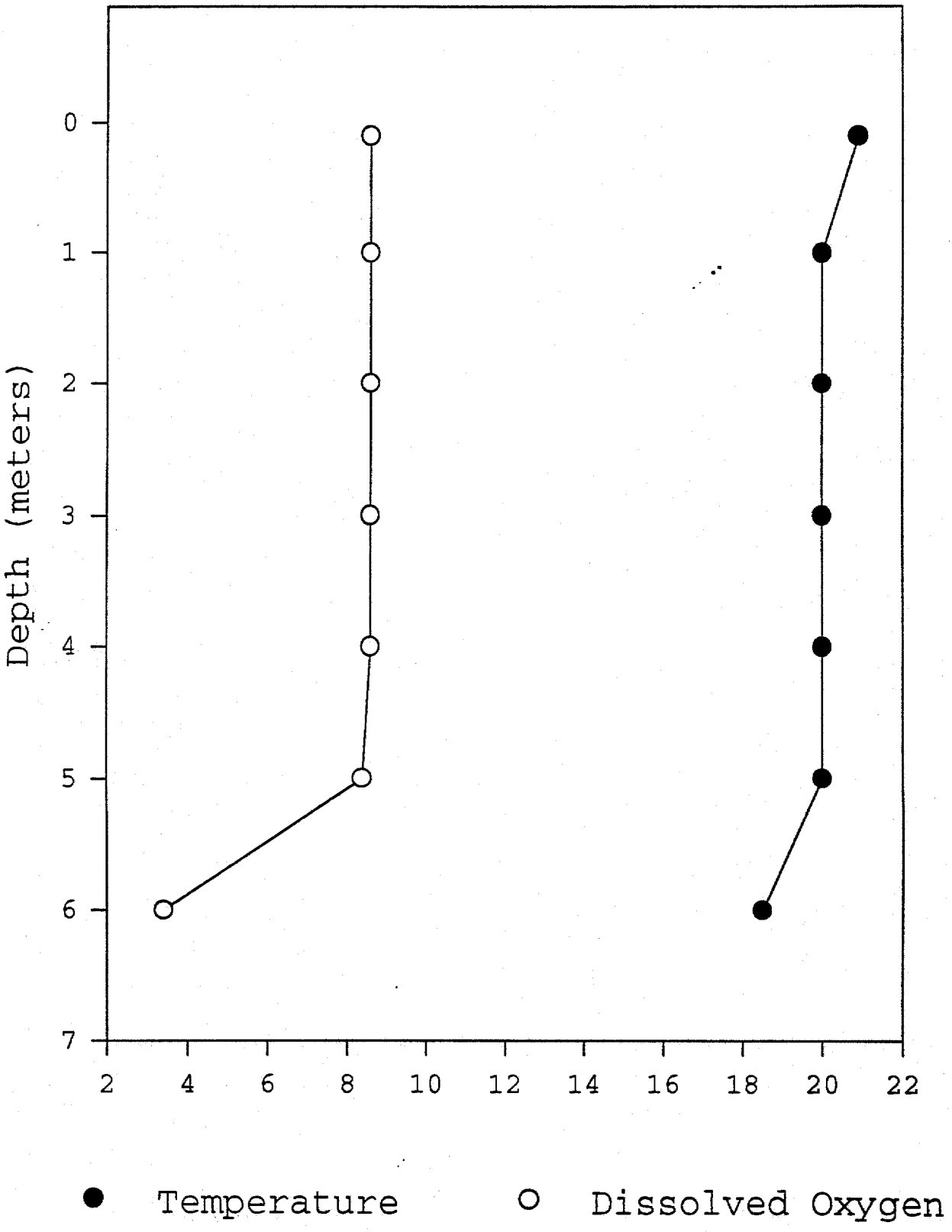
Pawtuckaway Lake North

09/22/92



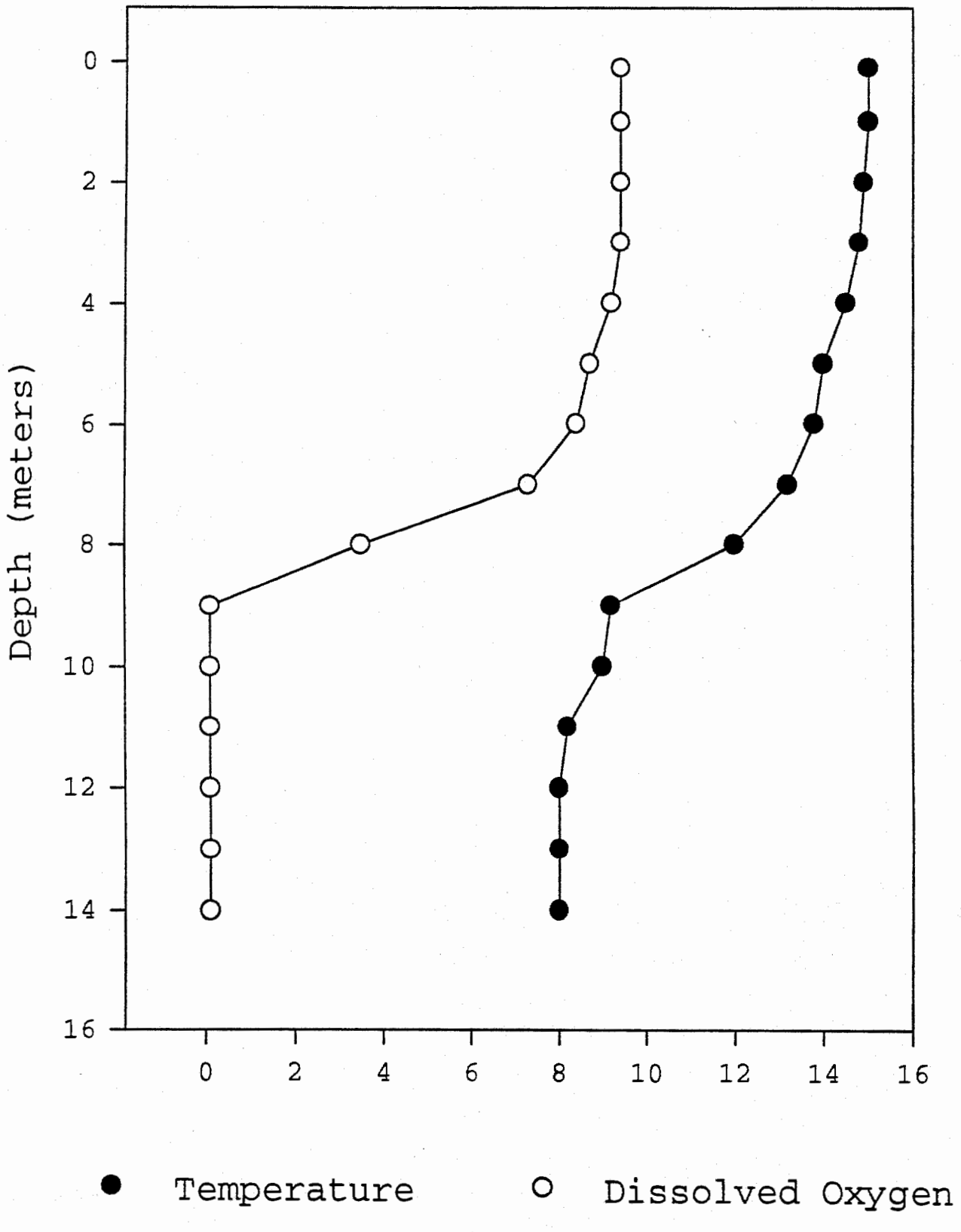
Pawtuckaway Lake South

09/22/92



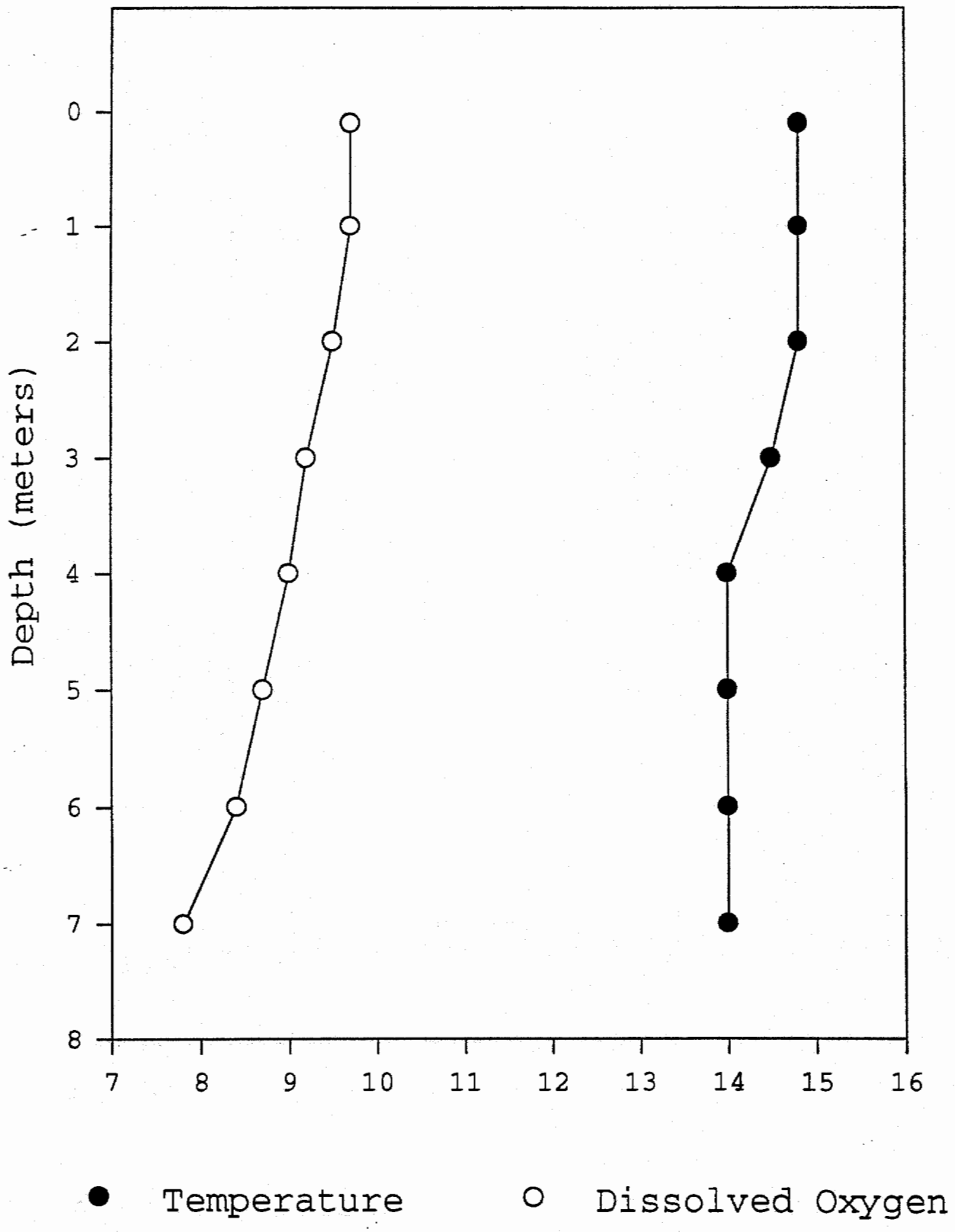
Pawtuckaway Lake North

10/12/92



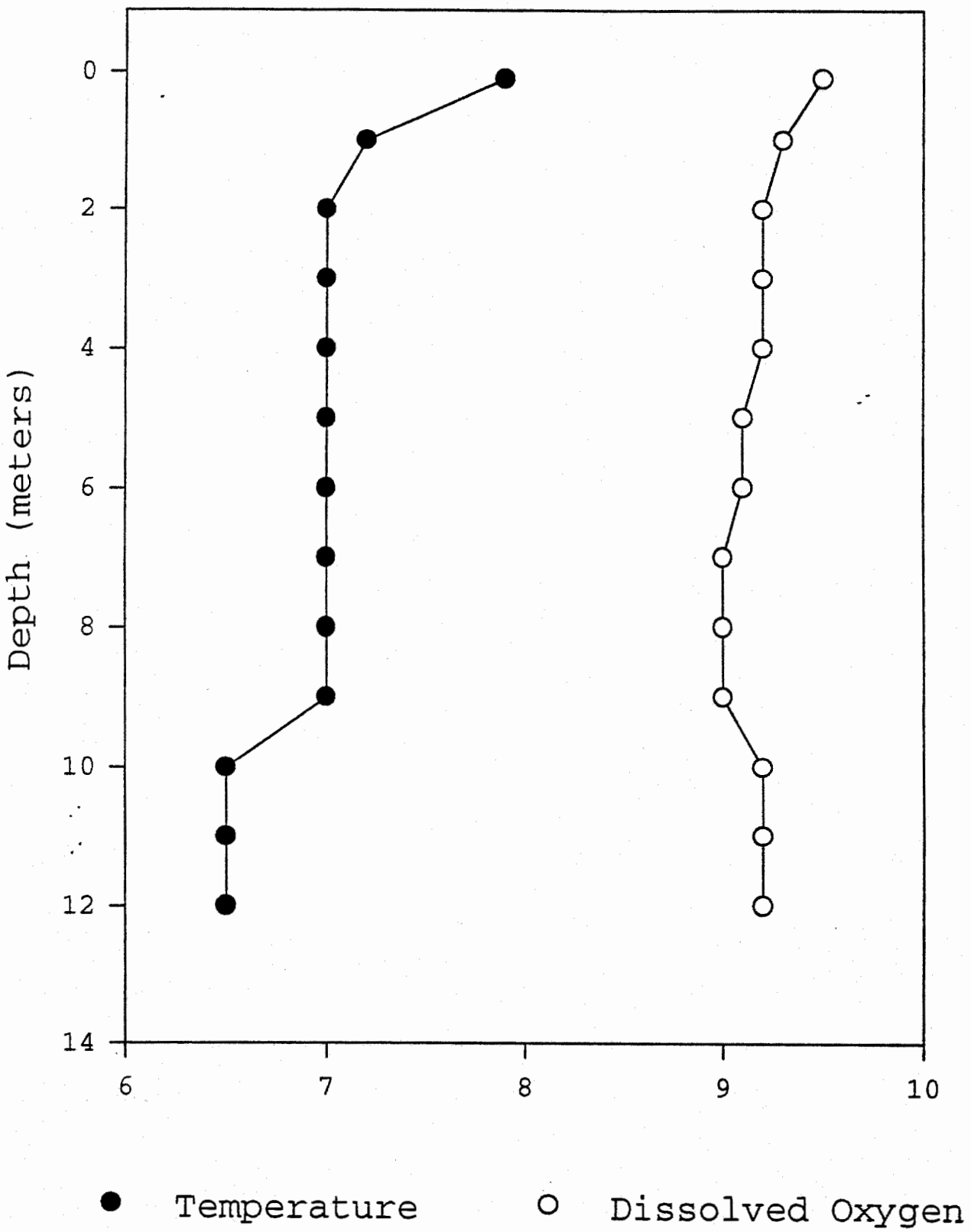
Pawtuckaway Lake South

10/12/92



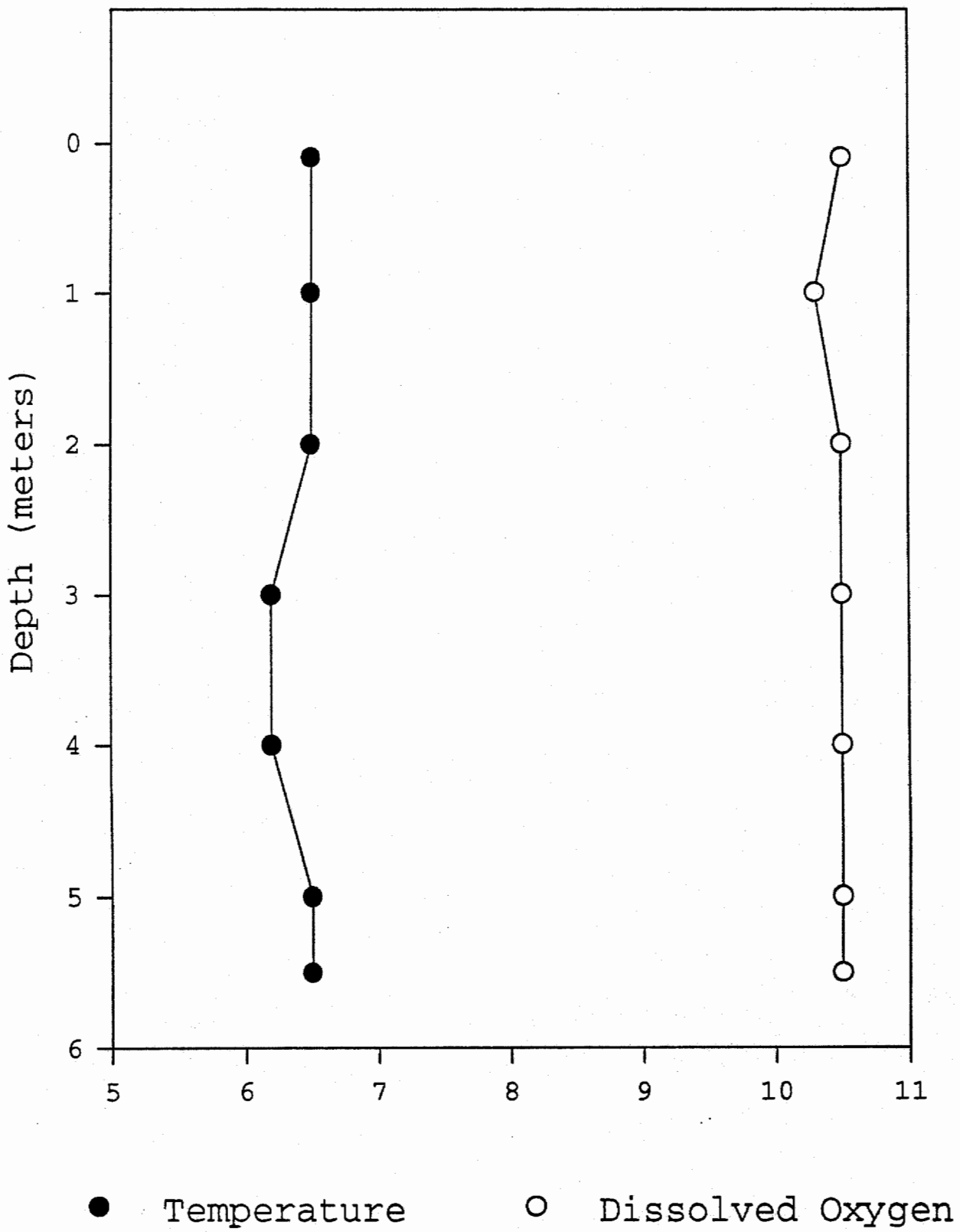
Pawtuckaway Lake North

11/09/92



Pawtuckaway Lake South

11/09/92



APPENDIX V-2

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
10/15/91	NORTH	0.1	13.0	9.2	86.8	1200	14.3	cloudy, calm, cool.
	NORTH	1.0	13.2	8.8	83.0		0.0	
	NORTH	2.0	13.2	8.6	81.1		0.0	
	NORTH	3.0	13.2	8.6	81.1		0.0	
	NORTH	4.0	13.2	8.6	81.1		0.0	
	NORTH	5.0	13.2	8.6	81.1		0.0	
	NORTH	6.0	13.2	8.4	79.2		0.0	
	NORTH	7.0	13.0	8.2	77.4		0.0	
	NORTH	8.0	13.0	8.0	75.5		0.0	
	NORTH	9.0	12.0	3.2	29.6		0.0	
	NORTH	10.0	9.5	0.4	3.4		0.0	
	NORTH	11.0	8.8	0.3	2.5		0.0	
	NORTH	12.0	8.2	0.3	2.5		0.0	
	NORTH	13.0	8.0	0.3	2.5		0.0	
	NORTH	14.0	8.0	0.3	2.5		0.0	
	SOUTH	0.1	13.0	9.0	84.9	1100	6.2	cloudy, calm, cool.
	SOUTH	1.0	13.0	9.2	86.8		0.0	
	SOUTH	2.0	13.0	9.2	86.8		0.0	
	SOUTH	3.0	13.0	9.1	85.8		0.0	
	SOUTH	4.0	13.0	9.0	84.9		0.0	
	SOUTH	5.0	13.0	9.0	84.9		0.0	
	SOUTH	6.0	13.0	8.9	84.0		0.0	
11/12/91	NORTH	0.1	7.0	10.9	89.3	1100	12.8	sunny and cold.
	NORTH	1.0	6.9	10.9	87.2		0.0	
	NORTH	2.0	6.9	10.9	87.2		0.0	
	NORTH	3.0	6.9	10.9	87.2		0.0	
	NORTH	4.0	6.9	10.9	87.2		0.0	
	NORTH	5.0	6.8	10.9	87.2		0.0	
	NORTH	6.0	6.8	10.9	87.2		0.0	
	NORTH	7.0	6.8	10.9	87.2		0.0	
	NORTH	8.0	6.7	10.9	87.2		0.0	
	NORTH	9.0	6.7	10.8	86.4		0.0	
	NORTH	10.0	6.5	11.0	88.0		0.0	
	NORTH	11.0	6.2	11.1	88.8		0.0	

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	NORTH	12.0	6.2	11.1	88.8		0.0	
	NORTH	12.5	6.0	11.2	89.6		0.0	
	SOUTH	0.1	6.0	11.5	92.0	1030	5.1	sunny and cold.
	SOUTH	1.0	6.0	11.5	92.0		0.0	
	SOUTH	2.0	6.0	11.4	91.2		0.0	
	SOUTH	3.0	6.0	11.5	92.0		0.0	
	SOUTH	4.0	6.0	11.4	91.2		0.0	
	SOUTH	5.0	6.0	11.2	89.6		0.0	
12/16/91	NORTH	0.1	1.0	12.2	85.9	1100	11.5	overcast, snow, some ice
	NORTH	1.0	2.0	11.7	84.2		0.0	
	NORTH	2.0	2.2	11.6	83.5		0.0	
	NORTH	3.0	2.5	11.6	83.5		0.0	
	NORTH	4.0	2.5	11.6	83.5		0.0	
	NORTH	5.0	2.8	11.6	83.5		0.0	
	NORTH	6.0	2.8	11.6	83.5		0.0	
	NORTH	7.0	3.0	11.6	85.9		0.0	
	NORTH	8.0	3.0	11.6	85.9		0.0	
	NORTH	9.0	3.0	11.6	85.9		0.0	
	NORTH	10.0	3.0	11.6	85.9		0.0	
	NORTH	11.0	2.9	11.6	83.5		0.0	
02/14/92	NORTH	12.0	3.0	12.1	89.6	1200	12.4	clear and cold.
	SOUTH	4.0	2.9	11.2	80.6	1100	4.5	clear and cold.
04/16/92	NORTH	0.1	8.0	12.0	101	1100	13.6	cloudy and windy.
	NORTH	1.0	7.5	12.0	98.4		0.0	
	NORTH	2.0	7.3	11.9	97.5		0.0	
	NORTH	3.0	7.2	11.8	96.7		0.0	
	NORTH	4.0	7.1	11.8	96.7		0.0	
	NORTH	5.0	7.0	11.6	95.1		0.0	
	NORTH	6.0	7.0	11.6	95.1		0.0	
	NORTH	7.0	7.0	11.6	95.1		0.0	
	NORTH	8.0	7.0	11.4	93.4		0.0	
	NORTH	9.0	7.0	11.4	93.4		0.0	
	NORTH	10.0	6.9	11.2	89.6		0.0	
	NORTH	11.0	6.7	11.2	89.6		0.0	

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	NORTH	12.0	6.7	10.0	80.0		0.0	
	NORTH	13.0	6.5	10.9	87.2		0.0	
	NORTH	13.5	6.5	10.9	87.2		0.0	
	SOUTH	0.1	8.0	12.0	101	1032	6.1	windy,cloudy,cold.
	SOUTH	1.0	7.9	12.0	98.4		0.0	
	SOUTH	2.0	7.8	12.0	98.4		0.0	
	SOUTH	3.0	7.7	11.9	97.5		0.0	
	SOUTH	4.0	7.7	11.8	96.7		0.0	
	SOUTH	5.0	7.7	11.8	96.7		0.0	
	SOUTH	6.0	7.7	11.8	96.7		0.0	
05/07/92	NORTH	0.1	13.5	10.6	100	1115	15.4	few clouds, warm and
	NORTH	1.0	13.0	10.5	99.1		0.0	
	NORTH	2.0	12.5	10.4	96.3		0.0	
	NORTH	3.0	12.2	10.5	97.2		0.0	
	NORTH	4.0	12.0	10.4	96.3		0.0	
	NORTH	5.0	11.0	10.2	91.9		0.0	
	NORTH	6.0	9.0	10.1	87.1		0.0	
	NORTH	7.0	8.5	9.8	82.4		0.0	
	NORTH	8.0	8.0	9.7	81.5		0.0	
	NORTH	9.0	8.0	9.4	79.0		0.0	
	NORTH	10.0	7.3	9.2	75.4		0.0	
	NORTH	11.0	7.3	9.0	73.8		0.0	
	NORTH	12.0	7.0	8.8	72.1		0.0	
	NORTH	13.0	7.0	8.8	72.1		0.0	
	NORTH	14.0	7.0	8.5	69.7		0.0	
	NORTH	15.0	7.0	8.5	69.7		0.0	
	SOUTH	0.1	13.0	10.4	98.1	1045	6.0	warm, breezy, high thin
	SOUTH	1.0	12.8	10.4	96.3		0.0	
	SOUTH	2.0	12.1	10.3	95.4		0.0	
	SOUTH	3.0	12.1	10.3	95.4		0.0	
	SOUTH	4.0	12.0	10.3	95.4		0.0	
	SOUTH	5.0	11.0	9.6	86.5		0.0	
	SOUTH	5.5	10.0	9.1	80.5		0.0	
05/26/92	NORTH	0.1	18.2	10.2	107	1145	14.1	sunny with some clouds

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	NORTH	1.0	17.9	10.2	105		0.0	
	NORTH	2.0	17.4	10.2	105		0.0	
	NORTH	3.0	17.2	10.1	104		0.0	
	NORTH	4.0	14.6	9.9	95.2		0.0	
	NORTH	5.0	11.6	8.8	79.3		0.0	
	NORTH	6.0	10.1	8.3	73.5		0.0	
	NORTH	7.0	9.0	7.9	68.1		0.0	
	NORTH	8.0	8.4	7.4	62.2		0.0	
	NORTH	9.0	8.1	7.1	59.7		0.0	
	NORTH	10.0	8.0	6.7	56.3		0.0	
	NORTH	11.0	8.0	6.5	54.6		0.0	
	NORTH	12.0	8.0	6.0	50.4		0.0	
	NORTH	13.0	7.9	4.8	39.3		0.0	
	NORTH	14.0	7.9	3.6	29.5		0.0	
	SOUTH	0.1	18.2	10.4	110	1045	6.8	sunny with few clouds
	SOUTH	1.0	18.2	10.3	108		0.0	
	SOUTH	2.0	17.8	10.3	106		0.0	
	SOUTH	3.0	17.5	10.4	107		0.0	
	SOUTH	4.0	14.5	10.4	100		0.0	
	SOUTH	5.0	12.0	7.6	70.4		0.0	
	SOUTH	6.0	11.2	5.0	45.0		0.0	
	SOUTH	6.5	11.2	4.5	40.5		0.0	
06/10/92	NORTH	0.1	19.3	8.3	89.2	1030	14.8	clear and warm
	NORTH	1.0	19.3	8.2	88.2		0.0	
	NORTH	2.0	19.1	8.3	89.2		0.0	
	NORTH	3.0	16.7	8.3	83.8		0.0	
	NORTH	4.0	15.4	7.6	74.5		0.0	
	NORTH	5.0	11.7	6.0	54.1		0.0	
	NORTH	6.0	8.6	5.1	42.9		0.0	
	NORTH	7.0	7.6	5.6	45.9		0.0	
	NORTH	8.0	7.2	5.2	42.6		0.0	
	NORTH	9.0	6.8	5.0	40.0		0.0	
	NORTH	10.0	6.5	4.2	33.6		0.0	
	NORTH	11.0	6.3	3.5	28.0		0.0	

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	NORTH	12.0	6.2	2.3	18.4		0.0	
	NORTH	13.0	6.0	1.4	11.2		0.0	
	NORTH	14.0	6.0	0.4	3.2		0.0	
	NORTH	14.5	6.0	0.3	2.4		0.0	
	SOUTH	0.1	19.1	8.4	90.3	1145	7.0	sunny and warm
	SOUTH	1.0	19.0	8.3	89.2		0.0	
	SOUTH	2.0	19.0	8.3	89.2		0.0	
	SOUTH	3.0	18.8	8.3	87.4		0.0	
	SOUTH	4.0	16.1	8.3	83.8		0.0	
	SOUTH	5.0	12.5	5.7	52.8		0.0	
	SOUTH	5.5	10.4	3.0	26.5		0.0	
	SOUTH	6.0	10.0	1.5	13.3		0.0	
	SOUTH	6.5	10.0	0.8	7.1		0.0	
06/26/92	NORTH	0.1	22.0	8.8	100	1100	14.5	clear and warm
	NORTH	1.0	21.0	8.8	97.8		0.0	
	NORTH	2.0	21.0	8.8	97.8		0.0	
	NORTH	3.0	21.0	8.8	97.8		0.0	
	NORTH	4.0	19.0	7.9	84.9		0.0	
	NORTH	5.0	14.0	5.7	54.8		0.0	
	NORTH	6.0	10.0	6.1	54.0		0.0	
	NORTH	7.0	9.0	5.4	46.6		0.0	
	NORTH	8.0	8.5	4.8	40.3		0.0	
	NORTH	9.0	8.0	4.1	34.5		0.0	
	NORTH	10.0	8.0	3.7	31.1		0.0	
	NORTH	11.0	8.0	3.3	27.7		0.0	
	NORTH	12.0	8.0	1.8	15.1		0.0	
	NORTH	13.0	7.5	1.1	9.0		0.0	
	NORTH	14.0	8.0	0.2	1.7		0.0	
	SOUTH	0.1	21.0	9.1	101	1015	6.8	clear and warm
	SOUTH	1.0	21.0	9.2	102		0.0	
	SOUTH	2.0	21.0	9.2	102		0.0	
	SOUTH	3.0	20.5	9.0	97.8		0.0	
	SOUTH	4.0	19.0	9.0	96.8		0.0	
	SOUTH	5.0	14.5	5.9	56.7		0.0	

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	SOUTH	6.0	12.0	2.0	18.5		0.0	
	SOUTH	6.5	12.0	0.3	2.8		0.0	
07/07/92	NORTH	0.1	22.0	8.0	90.9	1030	14.4	sunny and warm
	NORTH	1.0	21.5	8.0	88.9		0.0	
	NORTH	2.0	21.0	7.8	86.7		0.0	
	NORTH	3.0	21.0	7.7	85.6		0.0	
	NORTH	4.0	20.0	5.6	60.9		0.0	
	NORTH	5.0	14.0	5.2	50.0		0.0	
	NORTH	6.0	10.0	4.6	40.7		0.0	
	NORTH	7.0	9.0	4.3	37.1		0.0	
	NORTH	8.0	8.0	3.6	30.3		0.0	
	NORTH	9.0	8.0	3.2	26.9		0.0	
	NORTH	10.0	7.5	2.2	18.0		0.0	
	NORTH	11.0	7.0	0.0	0.0		0.0	
	NORTH	12.0	7.0	0.0	0.0		0.0	
	NORTH	13.0	7.0	0.0	0.0		0.0	
	NORTH	14.0	7.0	0.0	0.0		0.0	
	SOUTH	0.1	21.5	8.2	91.1	1130	6.9	sunny and warm
	SOUTH	1.0	21.5	8.2	91.1		0.0	
	SOUTH	2.0	21.0	8.2	91.1		0.0	
	SOUTH	3.0	21.0	8.0	88.9		0.0	
	SOUTH	4.0	20.0	7.2	78.3		0.0	
	SOUTH	5.0	14.5	4.2	40.4		0.0	
	SOUTH	6.0	12.0	1.0	9.3		0.0	
	SOUTH	6.5	11.5	0.4	3.6		0.0	
07/21/92	NORTH	0.1	24.9	9.0	106	1115	14.3	hot and cloudy
	NORTH	1.0	24.9	9.0	106		0.0	
	NORTH	2.0	24.8	8.9	105		0.0	
	NORTH	3.0	23.0	8.9	102		0.0	
	NORTH	4.0	20.5	7.9	85.9		0.0	
	NORTH	5.0	16.0	5.0	50.5		0.0	
	NORTH	6.0	12.1	4.1	38.0		0.0	
	NORTH	7.0	10.1	3.6	31.9		0.0	
	NORTH	8.0	9.5	3.3	28.4		0.0	

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	NORTH	9.0	9.0	2.9	25.0		0.0	
	NORTH	10.0	8.5	2.5	21.0		0.0	
	NORTH	11.0	8.0	0.6	5.0		0.0	
	NORTH	12.0	8.0	0.3	2.5		0.0	
	NORTH	13.0	8.0	0.3	2.5		0.0	
	NORTH	14.0	8.0	0.3	2.5		0.0	
	SOUTH	0.1	25.0	9.1	108	130	6.9	hot and cloudy
	SOUTH	1.0	25.0	9.1	108		0.0	
	SOUTH	2.0	24.5	9.2	108		0.0	
	SOUTH	3.0	24.0	9.2	108		0.0	
	SOUTH	4.0	21.8	8.2	91.1		0.0	
	SOUTH	5.0	17.0	4.3	44.3		0.0	
	SOUTH	6.0	14.0	1.7	16.3		0.0	
	SOUTH	6.5	13.0	1.1	10.4		0.0	
08/03/92	NORTH	0.1	22.5	8.2	93.2	1145	14.0	cloudy and warm
	NORTH	1.0	22.5	8.2	93.2		0.0	
	NORTH	2.0	22.5	8.1	92.0		0.0	
	NORTH	3.0	22.0	8.2	93.2		0.0	
	NORTH	4.0	21.0	7.4	82.2		0.0	
	NORTH	5.0	17.0	4.0	41.2		0.0	
	NORTH	6.0	13.0	3.1	29.2		0.0	
	NORTH	7.0	10.0	2.8	24.8		0.0	
	NORTH	8.0	9.0	2.8	24.1		0.0	
	NORTH	9.0	9.0	1.6	13.8		0.0	
	NORTH	10.0	8.5	0.9	7.6		0.0	
	NORTH	11.0	8.0	0.6	5.0		0.0	
	NORTH	12.0	8.0	0.2	1.7		0.0	
	NORTH	13.0	8.0	0.2	1.7		0.0	
	SOUTH	0.1	23.0	8.3	95.4	210	6.8	warm and cloudy
09/22/92	NORTH	0.1	20.6	8.9	96.7	1115	14.8	dense fog
08/03/92	SOUTH	1.0	22.0	8.2	93.2		0.0	
	SOUTH	2.0	22.0	8.3	94.3		0.0	
	SOUTH	3.0	22.0	8.1	92.0		0.0	
	SOUTH	4.0	21.5	7.8	86.7		0.0	

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	SOUTH	5.0	19.0	4.0	43.0		0.0	
	SOUTH	6.0	15.0	1.3	12.7		0.0	
	SOUTH	6.5	14.0	1.4	13.5		0.0	
08/26/92	NORTH	0.1	25.1	9.0	107	1130	14.8	hot and hazy
	NORTH	1.0	24.5	9.0	106		0.0	
	NORTH	2.0	23.0	9.1	105		0.0	
	NORTH	3.0	22.0	8.8	100		0.0	
	NORTH	4.0	21.0	8.0	88.9		0.0	
	NORTH	5.0	18.5	5.0	52.6		0.0	
	NORTH	6.0	14.5	1.5	14.4		0.0	
	NORTH	7.0	11.0	1.6	14.4		0.0	
	NORTH	8.0	9.3	1.6	13.8		0.0	
	NORTH	9.0	8.5	0.8	6.7		0.0	
	NORTH	10.0	8.0	0.3	2.5		0.0	
	NORTH	11.0	7.8	0.2	1.6		0.0	
	NORTH	12.0	7.0	0.3	2.5		0.0	
	NORTH	13.0	7.0	0.3	2.5		0.0	
	NORTH	14.0	7.0	0.3	2.5		0.0	
	SOUTH	0.1	26.0	9.0	110	140	7.0	hot and hazy
	SOUTH	1.0	24.5	8.9	105		0.0	
	SOUTH	2.0	23.0	9.0	103		0.0	
	SOUTH	3.0	21.5	8.6	95.6		0.0	
	SOUTH	4.0	21.0	8.1	90.0		0.0	
	SOUTH	5.0	19.5	5.4	58.1		0.0	
	SOUTH	6.0	16.0	1.4	14.1		0.0	
	SOUTH	6.5	15.0	1.6	15.7		0.0	
09/09/92	NORTH	0.1	21.0	8.5	94.4	1115	13.5	sunny and warm
	NORTH	1.0	21.0	8.5	94.4		0.0	
	NORTH	2.0	20.1	8.3	90.2		0.0	
	NORTH	3.0	20.1	8.3	90.2		0.0	
	NORTH	4.0	20.0	8.1	88.0		0.0	
	NORTH	5.0	19.2	7.4	79.6		0.0	
	NORTH	6.0	16.0	1.3	13.1		0.0	
	NORTH	7.0	12.8	0.5	4.6		0.0	

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	NORTH	8.0	10.2	0.6	5.3		0.0	
	NORTH	9.0	9.0	0.3	2.6		0.0	
	NORTH	10.0	8.1	0.2	1.7		0.0	
	NORTH	11.0	7.9	0.2	1.6		0.0	
	NORTH	12.0	7.0	0.2	1.6		0.0	
	NORTH	13.0	7.0	0.2	1.6		0.0	
	SOUTH	0.1	21.5	8.3	92.2	109	6.5	sunny and warm
	SOUTH	1.0	21.5	8.1	90.0		0.0	
	SOUTH	2.0	20.5	8.1	88.0		0.0	
	SOUTH	3.0	20.5	8.1	88.0		0.0	
	SOUTH	4.0	20.1	8.0	87.0		0.0	
	SOUTH	5.0	20.0	7.8	84.8		0.0	
	SOUTH	6.0	18.2	2.5	26.3		0.0	
09/22/92	NORTH	0.1	20.6	8.9	96.7	1115	14.8	thick fog
	NORTH	1.0	20.5	8.8	95.7	-99	-99	
	NORTH	2.0	20.4	8.8	95.7	-99	-99	
	NORTH	3.0	20.4	8.8	95.7	-99	-99	
	NORTH	4.0	20.2	8.6	93.5	-99	-99	
	NORTH	5.0	19.1	6.2	66.7	-99	-99	
	NORTH	6.0	16.5	1.3	13.1	-99	-99	
	NORTH	7.0	13.0	0.1	0.9	-99	-99	
	NORTH	8.0	10.1	0.1	0.9	-99	-99	
	NORTH	9.0	8.9	0.1	0.8	-99	-99	
	NORTH	10.0	8.0	0.1	0.8	-99	-99	
	NORTH	11.0	7.8	0.1	0.8	-99	-99	
	NORTH	12.0	7.2	0.1	0.8	-99	-99	
	NORTH	13.0	7.2	0.2	1.6	-99	-99	
	NORTH	14.0	7.0	0.2	1.6	-99	-99	
	SOUTH	0.1	20.9	8.6	93.5	230	6.6	warm and foggy
	SOUTH	1.0	20.0	8.6	93.5	-99	-99	
	SOUTH	2.0	20.0	8.6	93.5	-99	-99	
	SOUTH	3.0	20.0	8.6	93.5	-99	-99	
	SOUTH	4.0	20.0	8.6	93.5	-99	-99	
	SOUTH	5.0	20.0	8.4	91.3	-99	-99	

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	SOUTH	6.0	18.5	3.4	35.8	-99	-99	
10/12/92	NORTH	0.1	15.0	9.4	92.2	103	14.5	overcast
	NORTH	1.0	15.0	9.4	92.2	-99	-99	
	NORTH	2.0	14.9	9.4	90.4	-99	-99	
	NORTH	3.0	14.8	9.4	90.4	-99	-99	
	NORTH	4.0	14.5	9.2	88.5	-99	-99	
	NORTH	5.0	14.0	8.7	83.7	-99	-99	
	NORTH	6.0	13.8	8.4	79.2	-99	-99	
	NORTH	7.0	13.2	7.3	68.9	-99	-99	
	NORTH	8.0	12.0	3.5	32.4	-99	-99	
	NORTH	9.0	9.2	0.1	0.9	-99	-99	
	NORTH	10.0	9.0	0.1	0.9	-99	-99	
	NORTH	11.0	8.2	0.1	0.8	-99	-99	
	NORTH	12.0	8.0	0.1	0.8	-99	-99	
	NORTH	13.0	8.0	0.1	0.8	-99	-99	
	NORTH	14.0	8.0	0.1	0.8	-99	-99	
	SOUTH	0.1	14.8	9.7	93.3	1147	7.3	overcast
	SOUTH	1.0	14.8	9.7	93.3	-99	-99	
	SOUTH	2.0	14.8	9.5	91.3	-99	-99	
	SOUTH	3.0	14.5	9.2	88.5	-99	-99	
	SOUTH	4.0	14.0	9.0	86.5	-99	-99	
	SOUTH	5.0	14.0	8.7	83.7	-99	-99	
	SOUTH	6.0	14.0	8.4	80.8	-99	-99	
	SOUTH	7.0	14.0	7.8	75.0	-99	-99	
11/09/92	NORTH	0.1	7.9	9.5	77.9	1145	12.6	36 degrees clear and calm.
	NORTH	1.0	7.2	9.3	76.2	-99	-99	
	NORTH	2.0	7.0	9.2	75.4	-99	-99	
	NORTH	3.0	7.0	9.2	75.4	-99	-99	
	NORTH	4.0	7.0	9.2	75.4	-99	-99	
	NORTH	5.0	7.0	9.1	74.6	-99	-99	
	NORTH	6.0	7.0	9.1	74.6	-99	-99	
	NORTH	7.0	7.0	9.0	73.8	-99	-99	
	NORTH	8.0	7.0	9.0	73.8	-99	-99	
	NORTH	9.0	7.0	9.0	73.8	-99	-99	

Date	Station	Depth	Temperature	Dissolved Oxygen	Percent Saturation	Time	Bottom Depth	Weather
	NORTH	10.0	6.5	9.2	73.6	-99	-99	
	NORTH	11.0	6.5	9.2	73.6	-99	-99	
	NORTH	12.0	6.5	9.2	73.6	-99	-99	
	SOUTH	0.1	6.5	10.5	84.0	1030	5.8	32 degrees, clear and calm.
	SOUTH	1.0	6.5	10.3	82.4	-99	-99	
	SOUTH	2.0	6.5	10.5	84.0	-99	-99	
	SOUTH	3.0	6.2	10.5	84.0	-99	-99	
	SOUTH	4.0	6.2	10.5	84.0	-99	-99	
	SOUTH	5.0	6.5	10.5	84.0	-99	-99	
	SOUTH	5.5	6.5	10.5	84.0	-99	-99	

APPENDIX V-3

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
10/15/92	1	7.43	49.50	151.60	12.000	0.510	0.02	23	16	6.0	-99.0	-10
10/03/91	2	-99.0	-99.0	-99.00	28.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	3	-99.0	-99.0	-99.00	17.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	4	-99.0	-99.0	-99.00	23.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	5	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	6	-99.0	-99.0	-99.00	14.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	7	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	8	-99.0	-99.0	-99.00	60.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	9	-99.0	-99.0	-99.00	4.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	10	-99.0	-99.0	-99.00	19.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	11	-99.0	-99.0	-99.00	24.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	12	-99.0	-99.0	-99.00	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	13	-99.0	-99.0	-99.00	26.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/03/91	14	-99.0	-99.0	-99.00	19.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/22/91	1	6.50	8.90	36.20	27.000	-99.00	0.05	110	2	-99	1.72	0
10/22/91	2	6.40	5.20	30.00	17.000	-99.00	0.05	39	2	-99	0.35	9
10/22/91	3	6.30	4.70	31.90	18.000	-99.00	0.05	32	2	-99	0.43	16
10/22/91	4	6.40	3.60	41.10	26.000	-99.00	0.06	55	3	-99	1.10	5
10/22/91	5	6.70	5.00	71.60	9.000	-99.00	0.06	23	5	-99	0.61	3
10/22/91	6	6.00	2.50	32.60	13.000	-99.00	0.05	38	4	-99	0.27	28
10/22/91	7	5.70	2.50	136.00	8.000	-99.00	0.05	10	35	-99	0.08	11
10/22/91	8	6.40	9.40	127.00	45.000	-99.00	0.05	49	26	-99	0.67	9
10/22/91	9	6.60	4.50	34.40	4.000	-99.00	0.05	7	2	-99	0.25	2
10/22/91	10	6.40	4.30	40.70	22.000	-99.00	0.05	55	5	-99	0.91	1
10/22/91	11	6.30	3.80	42.70	20.000	-99.00	0.05	85	6	-99	0.45	9
10/22/91	12	6.40	5.00	28.90	10.000	-99.00	0.05	38	2	-99	0.57	3
10/22/91	13	5.20	0.80	33.50	20.000	-99.00	0.05	110	5	-99	0.68	0
10/22/91	14	6.30	5.80	29.50	31.000	-99.00	0.05	55	2	-99	0.68	9
11/05/91	1	-99.0	-99.0	-99.00	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	2	-99.0	-99.0	-99.00	58.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	3	-99.0	-99.0	-99.00	6.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	4	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	5	-99.0	-99.0	-99.00	3.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
11/05/91	6	-99.0	-99.0	-99.00	6.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	7	-99.0	-99.0	-99.00	1.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	8	-99.0	-99.0	-99.00	43.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	9	-99.0	-99.0	-99.00	1.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	10	-99.0	-99.0	-99.00	25.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	11	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	12	-99.0	-99.0	-99.00	3.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	13	-99.0	-99.0	-99.00	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	14	-99.0	-99.0	-99.00	38.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/05/91	15	-99.0	-99.0	-99.00	17.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/19/91	1	6.65	-99.0	43.30	19.000	-99.00	-99.0	-99	-99	-99	2.40	1
11/19/91	2	6.37	-99.0	28.10	14.000	-99.00	-99.0	-99	-99	-99	0.50	3
11/19/91	3	6.42	-99.0	31.00	11.000	-99.00	-99.0	-99	-99	-99	0.30	1
11/19/91	4	6.60	-99.0	39.80	18.000	-99.00	-99.0	-99	-99	-99	0.90	3
11/19/91	5	6.84	-99.0	43.70	11.000	-99.00	-99.0	-99	-99	-99	1.00	1
11/19/91	6	6.17	-99.0	32.40	12.000	-99.00	-99.0	-99	-99	-99	0.30	2
11/19/91	7	5.81	-99.0	122.20	6.000	-99.00	-99.0	-99	-99	-99	0.00	14
11/19/91	8	6.56	-99.0	127.40	38.000	-99.00	-99.0	-99	-99	-99	0.30	83
11/19/91	9	6.58	-99.0	32.10	3.000	-99.00	-99.0	-99	-99	-99	0.20	2
11/19/91	10	6.31	-99.0	41.10	58.000	-99.00	-99.0	-99	-99	-99	5.70	9
11/19/91	11	6.18	-99.0	44.00	16.000	-99.00	-99.0	-99	-99	-99	0.20	17
11/19/91	12	6.31	-99.0	27.80	7.000	-99.00	-99.0	-99	-99	-99	0.20	0
11/19/91	13	5.30	-99.0	38.00	16.000	-99.00	-99.0	-99	-99	-99	0.30	0
11/19/91	14	6.50	-99.0	29.00	35.000	-99.00	-99.0	-99	-99	-99	1.10	1
11/19/91	15	6.55	-99.0	28.00	52.000	-99.00	-99.0	-99	-99	-99	1.20	1
12/05/91	1	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	2	-99.0	-99.0	-99.00	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	3	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	4	-99.0	-99.0	-99.00	20.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	5	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	6	-99.0	-99.0	-99.00	14.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	7	-99.0	-99.0	-99.00	5.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	8	-99.0	-99.0	-99.00	52.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
12/05/91	9	-99.0	-99.0	-99.00	8.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	10	-99.0	-99.0	-99.00	20.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	11	-99.0	-99.0	-99.00	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	12	-99.0	-99.0	-99.00	7.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	13	-99.0	-99.0	-99.00	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	14	-99.0	-99.0	-99.00	26.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/05/91	15	-99.0	-99.0	-99.00	20.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/10/91	1	5.86	-99.0	33.70	-99.00	-99.00	-99.0	-99	-99	-99	1.20	0
12/10/91	2	6.41	-99.0	28.80	-99.00	-99.00	-99.0	-99	-99	-99	0.60	2
12/10/91	3	6.51	-99.0	32.80	-99.00	-99.00	-99.0	-99	-99	-99	0.30	0
12/10/91	4	6.65	-99.0	40.50	-99.00	-99.00	-99.0	-99	-99	-99	0.80	5
12/10/91	5	6.73	-99.0	42.40	-99.00	-99.00	-99.0	-99	-99	-99	1.20	3
12/10/91	6	6.12	-99.0	34.60	-99.00	-99.00	-99.0	-99	-99	-99	0.80	6
12/10/91	7	5.92	-99.0	101.10	-99.00	-99.00	-99.0	-99	-99	-99	0.40	22
12/10/91	8	6.66	-99.0	101.10	-99.00	-99.00	-99.0	-99	-99	-99	0.70	3
12/10/91	9	6.48	-99.0	29.10	-99.00	-99.00	-99.0	-99	-99	-99	1.10	3
12/10/91	10	6.22	-99.0	45.70	-99.00	-99.00	-99.0	-99	-99	-99	1.20	0
12/10/91	11	6.19	-99.0	43.30	-99.00	-99.00	-99.0	-99	-99	-99	1.10	7
12/10/91	12	6.35	-99.0	28.60	-99.00	-99.00	-99.0	-99	-99	-99	0.30	0
12/10/91	13	5.25	-99.0	41.70	-99.00	-99.00	-99.0	-99	-99	-99	1.00	0
12/10/91	14	6.47	-99.0	32.20	-99.00	-99.00	-99.0	-99	-99	-99	1.10	2
12/10/91	15	6.44	-99.0	31.90	-99.00	-99.00	-99.0	-99	-99	-99	1.20	0
12/30/91	1	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	2	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	3	-99.0	-99.0	-99.00	7.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	4	-99.0	-99.0	-99.00	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	5	-99.0	-99.0	-99.00	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	6	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	7	-99.0	-99.0	-99.00	6.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	8	-99.0	-99.0	-99.00	66.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	9	-99.0	-99.0	-99.00	1.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	10	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	11	-99.0	-99.0	-99.00	14.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
12/30/91	12	-99.0	-99.0	-99.00	8.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	13	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	14	-99.0	-99.0	-99.00	18.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/30/91	15	-99.0	-99.0	-99.00	17.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/07/92	1	5.81	7.50	34.00	1.000	-99.00	0.03	86	3	-99	0.90	0
01/07/92	2	6.54	4.40	28.80	9.000	-99.00	0.06	42	3	-99	0.30	1
01/07/92	3	6.50	3.50	31.00	6.000	-99.00	0.04	32	3	-99	0.60	0
01/07/92	4	6.64	7.10	43.20	12.000	-99.00	0.03	49	3	-99	1.00	1
01/07/92	5	6.54	3.60	44.90	12.000	-99.00	0.13	60	3	-99	0.70	0
01/07/92	6	6.11	2.10	35.70	8.000	-99.00	0.04	52	5	-99	0.40	2
01/07/92	7	5.97	1.80	97.40	3.000	-99.00	0.02	22	23	-99	0.50	101
01/07/92	8	6.83	8.90	120.00	81.000	-99.00	12.00	44	25	-99	0.80	25
01/07/92	9	6.43	2.80	27.80	59.000	-99.00	0.07	15	3	-99	1.30	1
01/07/92	10	6.39	5.70	51.20	7.000	-99.00	0.17	27	5	-99	0.80	0
01/07/92	11	6.26	2.70	45.00	8.000	-99.00	0.02	56	5	-99	0.70	8
01/07/92	12	6.36	2.00	28.30	5.000	-99.00	0.05	33	3	-99	0.30	0
01/07/92	13	5.33	0.80	41.00	9.000	-99.00	0.04	96	6	-99	0.30	0
01/07/92	14	6.60	6.30	33.70	15.000	-99.00	0.02	41	3	-99	0.70	0
01/07/92	15	6.31	5.20	32.80	15.000	-99.00	0.09	62	3	-99	1.50	0
01/21/92	1	-99.0	-99.0	-99.00	22.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	2	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	3	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	4	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	5	-99.0	-99.0	-99.00	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	6	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	7	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	8	-99.0	-99.0	-99.00	90.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	9	-99.0	-99.0	-99.00	3.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	10	-99.0	-99.0	-99.00	-99.00	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	11	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	12	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	13	-99.0	-99.0	-99.00	14.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/21/92	14	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
01/21/92	15	-99.0	-99.0	-99.00	19.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	1	-99.0	-99.0	-99.00	17.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	2	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	3	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	4	-99.0	-99.0	-99.00	14.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	5	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	6	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	7	-99.0	-99.0	-99.00	7.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	8	-99.0	-99.0	-99.00	56.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	9	-99.0	-99.0	-99.00	4.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	10	-99.0	-99.0	-99.00	-99.00	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	11	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	12	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	13	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	14	-99.0	-99.0	-99.00	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	15	-99.0	-99.0	-99.00	17.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/05/92	16	-99.0	-99.0	-99.00	6.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
02/20/92	1	5.80	-99.0	37.10	6.000	-99.00	-99.0	-99	-99	-99	0.90	1
02/20/92	2	6.30	-99.0	27.20	10.000	-99.00	-99.0	-99	-99	-99	1.20	3
02/20/92	3	6.40	-99.0	31.00	7.000	-99.00	-99.0	-99	-99	-99	0.30	0
02/20/92	4	6.60	-99.0	43.10	17.000	-99.00	-99.0	-99	-99	-99	0.90	2
02/20/92	5	6.60	-99.0	47.20	11.000	-99.00	-99.0	-99	-99	-99	0.40	1
02/20/92	6	6.30	-99.0	40.00	20.000	-99.00	-99.0	-99	-99	-99	0.60	4
02/20/92	7	5.90	-99.0	113.30	43.000	-99.00	-99.0	-99	-99	-99	0.90	2
02/20/92	8	6.60	-99.0	133.40	94.000	-99.00	-99.0	-99	-99	-99	0.80	27
02/20/92	9	6.40	-99.0	29.60	9.000	-99.00	-99.0	-99	-99	-99	0.10	3
02/20/92	10	6.10	-99.0	56.50	13.000	-99.00	-99.0	-99	-99	-99	0.80	0
02/20/92	11	6.20	-99.0	52.30	16.000	-99.00	-99.0	-99	-99	-99	0.50	1
02/20/92	12	6.20	-99.0	27.50	17.000	-99.00	-99.0	-99	-99	-99	0.50	0
02/20/92	13	5.40	-99.0	42.40	17.000	-99.00	-99.0	-99	-99	-99	0.40	0
02/20/92	14	6.40	-99.0	34.20	15.000	-99.00	-99.0	-99	-99	-99	1.10	1
02/20/92	15	5.90	-99.0	31.30	16.000	-99.00	-99.0	-99	-99	-99	0.70	2
02/20/92	16	5.90	-99.0	68.30	23.000	-99.00	-99.0	-99	-99	-99	0.80	3

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
02/20/92	17	-99.0	-99.0	-99.00	9.000	-99.00	-99.0	-99	-99	-99	-99.0	0
02/20/92	18	-99.0	-99.0	-99.00	14.000	-99.00	-99.0	-99	-99	-99	-99.0	0
02/20/92	19	-99.0	-99.0	-99.00	18.000	-99.00	-99.0	-99	-99	-99	-99.0	2
02/20/92	20	-99.0	-99.0	-99.00	28.000	-99.00	-99.0	-99	-99	-99	-99.0	0
02/20/92	21	-99.0	-99.0	-99.00	20.000	-99.00	-99.0	-99	-99	-99	-99.0	3
02/20/92	22	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	4
03/10/92	1	5.80	-99.0	32.00	35.000	-99.00	-99.0	-99	-99	-99	2.00	0
03/10/92	2	6.30	-99.0	26.00	14.000	-99.00	-99.0	-99	-99	-99	0.60	0
03/10/92	3	6.30	-99.0	29.00	8.000	-99.00	-99.0	-99	-99	-99	0.40	4
03/10/92	4	6.50	-99.0	42.00	15.000	-99.00	-99.0	-99	-99	-99	1.00	0
03/10/92	5	6.70	-99.0	43.00	100.00	-99.00	-99.0	-99	-99	-99	0.40	0
03/10/92	6	6.10	-99.0	41.00	13.000	-99.00	-99.0	-99	-99	-99	0.70	0
03/10/92	7	5.80	-99.0	101.00	18.000	-99.00	-99.0	-99	-99	-99	0.30	0
03/10/92	8	6.60	-99.0	129.00	70.000	-99.00	-99.0	-99	-99	-99	1.10	1
03/10/92	9	6.40	-99.0	28.00	6.000	-99.00	-99.0	-99	-99	-99	0.10	8
03/10/92	10	6.30	-99.0	44.00	11.000	-99.00	-99.0	-99	-99	-99	0.80	0
03/10/92	11	6.20	-99.0	43.00	13.000	-99.00	-99.0	-99	-99	-99	0.70	7
03/10/92	12	6.20	-99.0	28.00	10.000	-99.00	-99.0	-99	-99	-99	1.30	0
03/10/92	13	5.30	-99.0	38.00	14.000	-99.00	-99.0	-99	-99	-99	2.30	0
03/10/92	14	6.40	-99.0	29.00	14.000	-99.00	-99.0	-99	-99	-99	1.00	3
03/10/92	15	5.90	-99.0	25.00	16.000	-99.00	-99.0	-99	-99	-99	0.50	1
03/24/92	1	-99.0	-99.0	-99.00	22.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	2	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	3	-99.0	-99.0	-99.00	6.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	4	-99.0	-99.0	-99.00	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	5	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	6	-99.0	-99.0	-99.00	8.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	7	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	8	-99.0	-99.0	-99.00	44.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	9	-99.0	-99.0	-99.00	4.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	10	-99.0	-99.0	-99.00	20.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	11	-99.0	-99.0	-99.00	14.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	12	-99.0	-99.0	-99.00	7.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
03/24/92	13	-99.0	-99.0	-99.00	19.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	14	-99.0	-99.0	-99.00	17.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
03/24/92	15	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/08/92	1	6.64	6.80	31.60	35.000	-99.00	0.02	60	3	-99	2.20	0
04/08/92	2	6.27	3.70	26.10	8.000	-99.00	0.09	15	3	-99	0.30	0
04/08/92	3	6.32	3.50	25.70	7.000	-99.00	0.02	13	3	-99	1.00	0
04/08/92	4	6.63	5.10	37.30	15.000	-99.00	0.02	24	3	-99	1.20	0
04/08/92	5	6.64	4.50	43.40	11.000	-99.00	0.03	27	6	-99	1.50	0
04/08/92	6	6.14	1.80	39.30	12.000	-99.00	0.02	24	6	-99	1.00	0
04/08/92	7	5.81	1.80	103.20	12.000	-99.00	0.02	15	25	-99	0.20	0
04/08/92	8	6.62	8.70	150.60	45.000	-99.00	0.03	30	34	-99	0.60	0
04/08/92	9	6.45	3.10	28.10	6.000	-99.00	0.02	5	3	-99	0.40	0
04/08/92	10	6.52	3.60	40.30	23.000	-99.00	0.04	32	6	-99	1.70	0
04/08/92	11	6.42	2.80	42.20	17.000	-99.00	0.02	40	7	-99	1.00	0
04/08/92	12	6.32	3.50	27.40	10.000	-99.00	0.07	17	3	-99	0.20	1
04/08/92	13	5.45	1.00	33.80	24.000	-99.00	0.02	48	5	-99	0.70	0
04/08/92	14	6.37	3.90	27.10	20.000	-99.00	0.02	29	3	-99	1.20	0
04/08/92	15	6.30	2.40	23.00	23.000	-99.00	0.02	33	3	-99	1.20	1
04/21/92	1	-99.0	-99.0	-99.00	24.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	2	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	3	-99.0	-99.0	-99.00	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	4	-99.0	-99.0	-99.00	19.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	5	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	6	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	7	-99.0	-99.0	-99.00	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	8	-99.0	-99.0	-99.00	48.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	9	-99.0	-99.0	-99.00	7.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	11	-99.0	-99.0	-99.00	18.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/12/92	12	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	13	-99.0	-99.0	-99.00	24.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	14	-99.0	-99.0	-99.00	19.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	15	-99.0	-99.0	-99.00	23.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/21/92	23	-99.0	-99.0	-99.00	18.000	-99.00	-99.0	-99	-99	-99	-99.0	0

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
10/15/91	30	6.50	4.40	43.20	10.000	-99.00	0.05	28	6	4.4	-99.0	-99
10/15/91	31	6.50	-99.0	61.50	85.000	-99.00	0.05	130	6	2.4	-99.0	-99
10/15/91	35	6.60	5.10	42.10	13.000	-99.00	3.46	20	6	5.1	-99.0	-99
10/15/91	36	6.60	-99.0	42.20	10.000	-99.00	0.06	18	5	3.4	-99.0	-99
11/12/91	30	6.60	-99.0	45.00	22.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/12/91	31	6.60	-99.0	44.40	17.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/12/91	35	6.70	-99.0	43.30	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/12/91	36	6.70	-99.0	44.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/16/91	30	6.44	-99.0	42.00	23.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
12/16/91	31	6.37	-99.0	42.50	17.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
01/15/92	30	6.30	-99.0	44.00	14.000	-99.00	0.05	46	6	4.0	-99.0	-99
01/15/92	31	6.20	-99.0	45.00	17.000	-99.00	0.01	38	6	4.0	-99.0	-99
01/15/92	35	6.00	-99.0	39.00	13.000	-99.00	0.22	38	5	4.0	-99.0	-99
01/15/92	36	6.20	-99.0	44.00	13.000	-99.00	0.14	40	6	5.0	-99.0	-99
02/13/92	30	6.10	-99.0	47.80	19.000	-99.00	0.09	-99	7	4.7	-99.0	-99
02/13/92	31	5.90	-99.0	47.90	15.000	-99.00	0.10	-99	7	4.8	-99.0	-99
02/13/92	35	6.10	-99.0	46.80	12.000	-99.00	0.03	-99	6	5.3	-99.0	-99
02/13/92	36	6.10	-99.0	47.30	11.000	-99.00	0.08	-99	6	5.4	-99.0	-99
04/16/92	30	6.52	-99.0	43.90	19.000	-99.00	0.04	31	7	4.0	1.30	-99
04/16/92	31	6.45	-99.0	44.00	14.000	-99.00	0.06	30	7	4.0	1.80	-99
04/16/92	35	6.79	-99.0	43.00	11.000	-99.00	0.04	22	6	5.0	1.10	-99
04/16/92	36	6.80	-99.0	44.00	10.000	-99.00	0.04	24	6	5.0	0.60	-99
04/27/92	1	-99.0	-99.0	-99.00	30.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	2	-99.0	-99.0	-99.00	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	3	-99.0	-99.0	-99.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	4	-99.0	-99.0	-99.00	18.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	5	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	6	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	7	-99.0	-99.0	-99.00	8.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	8	-99.0	-99.0	-99.00	69.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	9	-99.0	-99.0	-99.00	5.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	10	-99.0	-99.0	-99.00	20.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	11	-99.0	-99.0	-99.00	21.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
04/27/92	12	-99.0	-99.0	-99.00	8.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	13	-99.0	-99.0	-99.00	24.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	14	-99.0	-99.0	-99.00	20.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	15	-99.0	-99.0	-99.00	23.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	16	-99.0	-99.0	-99.00	5.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	24	-99.0	-99.0	-99.00	18.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	25	-99.0	-99.0	-99.00	6.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
04/27/92	26	-99.0	-99.0	-99.00	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/05/92	1	6.40	-99.0	30.60	33.000	-99.00	-99.0	-99	-99	-99	1.80	9
05/05/92	2	6.28	-99.0	25.60	13.000	-99.00	-99.0	-99	-99	-99	0.30	0
05/05/92	3	6.50	-99.0	28.70	11.000	-99.00	-99.0	-99	-99	-99	0.40	92
05/05/92	4	6.70	-99.0	41.70	20.000	-99.00	-99.0	-99	-99	-99	0.80	4
05/05/92	5	6.80	-99.0	41.90	10.000	-99.00	-99.0	-99	-99	-99	0.30	6
05/05/92	6	6.17	-99.0	38.60	12.000	-99.00	-99.0	-99	-99	-99	0.50	1
05/05/92	7	5.81	-99.0	124.30	6.000	-99.00	-99.0	-99	-99	-99	0.20	20
05/05/92	8	6.72	-99.0	172.10	66.000	-99.00	-99.0	-99	-99	-99	0.90	3
05/05/92	9	6.53	-99.0	26.70	4.000	-99.00	-99.0	-99	-99	-99	0.13	0
05/05/92	10	6.67	-99.0	41.00	20.000	-99.00	-99.0	-99	-99	-99	0.98	0
05/05/92	11	6.30	-99.0	43.80	21.000	-99.00	-99.0	-99	-99	-99	1.20	38
05/05/92	12	6.36	-99.0	27.60	11.000	-99.00	-99.0	-99	-99	-99	0.42	0
05/05/92	13	5.46	-99.0	32.60	26.000	-99.00	-99.0	-99	-99	-99	0.90	2
05/05/92	14	6.55	-99.0	29.30	21.000	-99.00	-99.0	-99	-99	-99	0.65	2
05/05/92	15	6.16	-99.0	25.90	25.000	-99.00	-99.0	-99	-99	-99	0.86	0
05/28/92	1	-99.0	-99.0	-99.00	0.000	0.000	0.00	-99	0	0.0	-99.0	0
05/28/92	1	-99.0	-99.0	-99.00	54.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	2	-99.0	-99.0	-99.00	26.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	3	-99.0	-99.0	-99.00	32.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	4	-99.0	-99.0	-99.00	30.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	5	-99.0	-99.0	-99.00	14.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	6	-99.0	-99.0	-99.00	23.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	7	-99.0	-99.0	-99.00	9.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	8	-99.0	-99.0	-99.00	99.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	9	-99.0	-99.0	-99.00	35.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
05/28/92	10	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	11	-99.0	-99.0	-99.00	30.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	12	-99.0	-99.0	-99.00	18.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	13	-99.0	-99.0	-99.00	40.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	14	-99.0	-99.0	-99.00	37.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	15	-99.0	-99.0	-99.00	29.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	17	-99.0	-99.0	-99.00	34.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	18	-99.0	-99.0	-99.00	25.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	19	-99.0	-99.0	-99.00	33.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	20	-99.0	-99.0	-99.00	69.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	21	-99.0	-99.0	-99.00	29.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/28/92	22	-99.0	-99.0	-99.00	25.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/02/92	1	6.74	-99.0	28.50	36.000	-99.00	-99.0	-99	-99	-99	1.40	29
06/02/92	2	6.63	-99.0	28.30	31.000	-99.00	-99.0	-99	-99	-99	1.00	54
06/02/92	3	6.75	-99.0	32.40	25.000	-99.00	-99.0	-99	-99	-99	1.40	2
06/02/92	4	6.88	-99.0	42.50	33.000	-99.00	-99.0	-99	-99	-99	1.70	36
06/02/92	5	6.71	-99.0	44.00	14.000	-99.00	-99.0	-99	-99	-99	0.60	14
06/02/92	6	6.44	-99.0	57.30	19.000	-99.00	-99.0	-99	-99	-99	1.00	117
06/02/92	7	5.98	-99.0	129.80	10.000	-99.00	-99.0	-99	-99	-99	0.40	254
06/02/92	8	6.70	-99.0	160.30	95.000	-99.00	-99.0	-99	-99	-99	1.60	68
06/02/92	9	6.74	-99.0	31.00	5.000	-99.00	-99.0	-99	-99	-99	0.30	0
06/02/92	10	6.69	-99.0	43.60	38.000	-99.00	-99.0	-99	-99	-99	1.00	3
06/02/92	11	6.71	-99.0	46.60	38.000	-99.00	-99.0	-99	-99	-99	1.70	47
06/02/92	12	6.54	-99.0	28.10	14.000	-99.00	-99.0	-99	-99	-99	0.80	62
06/02/92	13	5.54	-99.0	33.80	36.000	-99.00	-99.0	-99	-99	-99	1.20	14
06/02/92	14	6.68	-99.0	32.60	49.000	-99.00	-99.0	-99	-99	-99	1.60	24
06/02/92	15	6.17	-99.0	32.80	25.000	-99.00	-99.0	-99	-99	-99	1.30	4
06/26/92	1	-99.0	-99.0	-99.00	39.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	2	-99.0	-99.0	-99.00	47.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	3	-99.0	-99.0	-99.00	25.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	4	-99.0	-99.0	-99.00	38.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	5	-99.0	-99.0	-99.00	9.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	6	-99.0	-99.0	-99.00	28.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
06/26/92	7	-99.0	-99.0	-99.00	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	8	-99.0	-99.0	-99.00	87.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	9	-99.0	-99.0	-99.00	2.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	10	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	11	-99.0	-99.0	-99.00	43.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	12	-99.0	-99.0	-99.00	17.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	13	-99.0	-99.0	-99.00	43.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	14	-99.0	-99.0	-99.00	32.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	15	-99.0	-99.0	-99.00	31.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/06/92	1	6.70	9.90	30.50	42.000	0.810	0.02	150	3	-99	2.50	5
07/06/92	2	6.70	9.50	34.30	39.000	0.340	0.07	65	1	-99	1.00	22
07/06/92	3	6.70	10.60	39.00	28.000	0.270	0.08	48	1	-99	0.90	61
07/06/92	4	6.80	13.50	46.70	43.000	0.470	0.03	80	1	-99	2.70	23
07/06/92	5	6.80	7.20	52.70	9.000	0.230	0.04	19	5	-99	0.50	88
07/06/92	6	6.70	6.80	38.90	52.000	0.440	0.11	65	3	-99	2.20	200
07/06/92	7	6.50	9.00	116.40	16.000	0.190	0.02	22	24	-99	0.30	200
07/06/92	8	6.80	19.20	175.00	100.00	0.650	0.09	48	37	-99	1.80	1
07/06/92	9	6.70	8.20	40.10	5.000	0.100	0.02	8	1	-99	0.40	22
07/06/92	10	6.50	4.30	44.60	15.000	0.290	0.06	28	6	-99	0.60	73
07/06/92	11	6.70	6.70	49.00	29.000	0.440	0.03	70	7	-99	0.60	6
07/06/92	12	6.60	7.30	33.00	18.000	0.260	0.05	55	6	-99	2.00	40
07/06/92	13	5.50	2.30	34.80	42.000	0.630	0.05	90	6	-99	1.20	0
07/06/92	14	6.60	8.10	32.80	28.000	0.420	0.07	55	1	-99	0.50	3
07/06/92	15	6.30	6.00	29.70	26.000	0.530	0.02	60	1	-99	0.60	1
07/22/92	1	-99.0	-99.0	-99.00	37.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	2	-99.0	-99.0	-99.00	43.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	3	-99.0	-99.0	-99.00	31.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	4	-99.0	-99.0	-99.00	39.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	5	-99.0	-99.0	-99.00	8.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	6	-99.0	-99.0	-99.00	31.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	7	-99.0	-99.0	-99.00	14.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	8	-99.0	-99.0	-99.00	87.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	9	-99.0	-99.0	-99.00	47.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
07/22/92	10	-99.0	-99.0	-99.00	18.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	11	-99.0	-99.0	-99.00	30.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	12	-99.0	-99.0	-99.00	22.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	13	-99.0	-99.0	-99.00	47.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	14	-99.0	-99.0	-99.00	38.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/22/92	15	-99.0	-99.0	-99.00	44.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/11/92	1	6.90	-99.0	29.50	36.000	-99.00	-99.0	-99	-99	-99	1.30	40
08/11/92	2	6.60	-99.0	31.40	94.000	-99.00	-99.0	-99	-99	-99	2.40	2
08/11/92	3	6.80	-99.0	34.60	28.000	-99.00	-99.0	-99	-99	-99	1.00	22
08/11/92	4	6.70	-99.0	41.80	32.000	-99.00	-99.0	-99	-99	-99	1.60	76
08/11/92	5	6.90	-99.0	45.60	8.000	-99.00	-99.0	-99	-99	-99	0.50	14
08/11/92	6	6.80	-99.0	48.60	25.000	-99.00	-99.0	-99	-99	-99	1.90	70
08/11/92	7	6.40	-99.0	124.60	11.000	-99.00	-99.0	-99	-99	-99	0.40	129
08/11/92	8	7.00	-99.0	180.00	81.000	-99.00	-99.0	-99	-99	-99	1.20	27
08/11/92	9	-99.0	-99.0	-99.00	-99.00	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/11/92	10	6.80	-99.0	42.00	19.000	-99.00	-99.0	-99	-99	-99	1.30	66
08/11/92	11	6.70	-99.0	41.80	24.000	-99.00	-99.0	-99	-99	-99	0.50	45
08/11/92	12	6.90	-99.0	32.40	19.000	-99.00	-99.0	-99	-99	-99	1.50	10
08/11/92	13	5.40	-99.0	31.70	49.000	-99.00	-99.0	-99	-99	-99	1.90	0
08/11/92	14	6.60	-99.0	29.10	55.000	-99.00	-99.0	-99	-99	-99	1.70	200
08/11/92	15	6.20	-99.0	28.30	36.000	-99.00	-99.0	-99	-99	-99	1.00	4
08/25/92	1	-99.0	-99.0	-99.00	25.000	-99.00	-99.0	-99	-99	-99	-99.0	10
08/25/92	2	-99.0	-99.0	-99.00	33.000	-99.00	-99.0	-99	-99	-99	-99.0	10
08/25/92	3	-99.0	-99.0	-99.00	30.000	-99.00	-99.0	-99	-99	-99	-99.0	70
08/25/92	4	-99.0	-99.0	-99.00	40.000	-99.00	-99.0	-99	-99	-99	-99.0	80
08/25/92	5	-99.0	-99.0	-99.00	8.000	-99.00	-99.0	-99	-99	-99	-99.0	20
08/25/92	6	-99.0	-99.0	-99.00	27.000	-99.00	-99.0	-99	-99	-99	-99.0	140
08/25/92	7	-99.0	-99.0	-99.00	10.000	-99.00	-99.0	-99	-99	-99	-99.0	20
08/25/92	8	-99.0	-99.0	-99.00	68.000	-99.00	-99.0	-99	-99	-99	-99.0	10
08/25/92	9	-99.0	-99.0	-99.00	-99.00	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/25/92	10	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	10
08/25/92	11	-99.0	-99.0	-99.00	30.000	-99.00	-99.0	-99	-99	-99	-99.0	10
08/26/92	32	6.82	-99.0	43.40	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
09/21/92	1	-99.0	-99.0	-99.00	48.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/25/92	12	-99.0	-99.0	-99.00	22.000	-99.00	-99.0	-99	-99	-99	-99.0	10
08/25/92	13	-99.0	-99.0	-99.00	48.000	-99.00	-99.0	-99	-99	-99	-99.0	10
08/25/92	14	-99.0	-99.0	-99.00	43.000	-99.00	-99.0	-99	-99	-99	-99.0	120
08/25/92	15	-99.0	-99.0	-99.00	38.000	-99.00	-99.0	-99	-99	-99	-99.0	10
08/25/92	17	-99.0	-99.0	-99.00	37.000	-99.00	-99.0	-99	-99	-99	-99.0	40
08/25/92	18	-99.0	-99.0	-99.00	23.000	-99.00	-99.0	-99	-99	-99	-99.0	20
08/25/92	19	-99.0	-99.0	-99.00	33.000	-99.00	-99.0	-99	-99	-99	-99.0	30
08/25/92	21	-99.0	-99.0	-99.00	42.000	-99.00	-99.0	-99	-99	-99	-99.0	10
08/25/92	22	-99.0	-99.0	-99.00	27.000	-99.00	-99.0	-99	-99	-99	-99.0	130
08/25/92	23	-99.0	-99.0	-99.00	93.000	-99.00	-99.0	-99	-99	-99	-99.0	10
09/10/92	2	6.80	-99.0	31.00	33.000	-99.00	-99.0	-99	-99	-99	0.70	21
09/10/92	3	6.80	-99.0	34.60	35.000	-99.00	-99.0	-99	-99	-99	0.90	4
09/10/92	4	6.60	-99.0	43.80	43.000	-99.00	-99.0	-99	-99	-99	2.00	15
09/10/92	5	6.90	-99.0	44.10	8.000	-99.00	-99.0	-99	-99	-99	0.50	5
09/10/92	6	6.90	-99.0	38.80	34.000	-99.00	-99.0	-99	-99	-99	2.10	200
09/10/92	8	6.80	-99.0	203.00	61.000	-99.00	-99.0	-99	-99	-99	1.40	2
09/10/92	10	6.60	-99.0	40.50	22.000	-99.00	-99.0	-99	-99	-99	0.80	2
09/10/92	11	6.60	-99.0	40.50	22.000	-99.00	-99.0	-99	-99	-99	0.50	17
09/10/92	12	6.80	-99.0	31.80	24.000	-99.00	-99.0	-99	-99	-99	2.50	49
09/10/92	13	5.70	-99.0	33.40	44.000	-99.00	-99.0	-99	-99	-99	1.40	8
09/10/92	14	6.70	-99.0	29.50	48.000	-99.00	-99.0	-99	-99	-99	1.30	28
09/10/92	15	6.30	-99.0	27.20	35.000	-99.00	-99.0	-99	-99	-99	0.90	1
08/26/92	33	6.56	-99.0	43.10	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/26/92	34	6.02	-99.0	45.60	18.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/26/92	35	6.78	-99.0	43.70	7.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/26/92	36	6.59	-99.0	43.90	8.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/09/92	32	6.77	-99.0	43.00	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/09/92	33	6.66	-99.0	43.00	7.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/09/92	34	5.99	-99.0	47.20	31.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/09/92	35	6.80	-99.0	-99.00	43.700	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/09/92	36	6.60	-99.0	44.20	6.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	2	-99.0	-99.0	-99.00	22.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
09/21/92	3	-99.0	-99.0	-99.00	27.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	4	-99.0	-99.0	-99.00	47.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	5	-99.0	-99.0	-99.00	7.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	6	-99.0	-99.0	-99.00	20.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	8	-99.0	-99.0	-99.00	45.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	10	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	11	-99.0	-99.0	-99.00	23.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	12	-99.0	-99.0	-99.00	26.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	13	-99.0	-99.0	-99.00	38.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	14	-99.0	-99.0	-99.00	28.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/21/92	15	-99.0	-99.0	-99.00	29.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/07/92	32	6.60	4.90	45.40	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/07/92	33	6.50	-99.0	44.70	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/07/92	34	6.20	-99.0	46.40	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/07/92	35	6.80	4.60	45.10	9.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/07/92	36	6.67	-99.0	43.70	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/26/92	32	6.88	4.30	44.70	14.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/26/92	33	6.47	-99.0	44.70	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/26/92	34	6.12	-99.0	46.00	14.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/26/92	35	7.02	4.40	44.40	25.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
05/26/92	36	6.42	-99.0	44.50	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/10/92	32	6.70	3.80	43.90	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/10/92	33	6.30	-99.0	46.00	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/10/92	34	6.00	-99.0	46.00	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/10/92	35	6.90	4.30	43.50	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/10/92	36	6.50	-99.0	43.10	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	32	6.23	-99.0	44.50	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	33	6.29	-99.0	44.40	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	34	5.92	-99.0	45.40	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	35	6.85	-99.0	44.70	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
06/26/92	36	6.38	-99.0	44.60	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/07/92	32	6.70	-99.0	45.90	9.000	-99.00	0.02	-99	6	4.0	-99.0	-99
07/07/92	33	6.40	-99.0	45.90	13.000	-99.00	0.02	-99	6	4.0	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
07/07/92	34	5.90	-99.0	46.30	19.000	-99.00	0.02	-99	7	4.0	-99.0	-99
07/07/92	35	6.90	-99.0	45.50	13.000	-99.00	0.02	-99	7	4.0	-99.0	-99
07/07/92	36	6.40	-99.0	45.50	16.000	-99.00	0.13	-99	7	4.0	-99.0	-99
07/21/92	32	6.80	5.70	43.20	13.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/21/92	33	6.30	-99.0	45.20	11.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/21/92	34	5.90	-99.0	45.40	15.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/21/92	35	6.80	6.00	44.20	9.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
07/21/92	36	6.40	-99.0	45.80	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/03/92	32	6.80	-99.0	44.20	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/03/92	33	6.50	-99.0	45.10	10.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/03/92	34	5.90	-99.0	47.00	24.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/03/92	35	7.01	-99.0	44.80	7.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
08/03/92	36	6.45	-99.0	45.80	37.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
09/22/92	32	6.70	4.50	43.50	7.000	-99.00	-99.0	12	-99	-99	-99.0	-99
09/22/92	33	6.50	-99.0	44.10	10.000	-99.00	-99.0	20	-99	-99	-99.0	-99
09/22/92	34	6.10	-99.0	47.70	27.000	-99.00	-99.0	65	-99	-99	-99.0	-99
09/22/92	35	6.80	5.70	44.70	6.000	-99.00	-99.0	12	-99	-99	-99.0	-99
09/22/92	36	6.70	-99.0	44.60	8.000	-99.00	-99.0	14	-99	-99	-99.0	-99
10/05/92	2	6.20	-99.0	30.40	47.000	-99.00	-99.0	-99	-99	-99	1.50	3
10/05/92	3	6.70	-99.0	36.00	26.000	-99.00	-99.0	-99	-99	-99	1.50	2
10/05/92	4	6.50	-99.0	45.10	57.000	-99.00	-99.0	-99	-99	-99	3.30	9
10/05/92	5	6.90	-99.0	44.40	8.000	-99.00	-99.0	-99	-99	-99	0.70	5
10/05/92	6	6.80	-99.0	32.50	94.000	-99.00	-99.0	-99	-99	-99	4.00	11
10/05/92	8	6.80	-99.0	206.00	68.000	-99.00	-99.0	-99	-99	-99	2.30	3
10/05/92	10	6.80	-99.0	41.70	37.000	-99.00	-99.0	-99	-99	-99	1.00	2
10/05/92	11	6.70	-99.0	42.90	35.000	-99.00	-99.0	-99	-99	-99	1.40	10
10/05/92	12	6.70	-99.0	30.80	21.000	-99.00	-99.0	-99	-99	-99	1.60	2
10/05/92	13	5.70	-99.0	35.10	50.000	-99.00	-99.0	-99	-99	-99	1.50	0
10/05/92	14	6.80	-99.0	30.10	37.000	-99.00	-99.0	-99	-99	-99	0.60	3
10/05/92	15	6.30	-99.0	27.10	24.000	-99.00	-99.0	-99	-99	-99	1.10	33
10/12/92	30	6.70	-99.0	43.90	9.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/12/92	31	6.28	-99.0	53.20	43.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/12/92	35	6.65	-99.0	43.30	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99

Pawtuckaway Lake Raw Chemistry Data

Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
10/12/92	36	6.68	-99.0	44.20	7.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	1	-99.0	-99.0	-99.00	18.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	2	-99.0	-99.0	-99.00	34.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	3	-99.0	-99.0	-99.00	20.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	4	-99.0	-99.0	-99.00	35.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	5	-99.0	-99.0	-99.00	8.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	6	-99.0	-99.0	-99.00	17.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	7	-99.0	-99.0	-99.00	16.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	8	-99.0	-99.0	-99.00	45.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	10	-99.0	-99.0	-99.00	24.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	11	-99.0	-99.0	-99.00	20.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	12	-99.0	-99.0	-99.00	12.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	13	-99.0	-99.0	-99.00	28.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	14	-99.0	-99.0	-99.00	23.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	15	-99.0	-99.0	-99.00	24.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	17	-99.0	-99.0	-99.00	25.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	18	-99.0	-99.0	-99.00	21.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	19	-99.0	-99.0	-99.00	19.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	20	-99.0	-99.0	-99.00	61.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	21	-99.0	-99.0	-99.00	25.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	22	-99.0	-99.0	-99.00	19.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	23	-99.0	-99.0	-99.00	74.000	-99.00	-99.0	-99	-99	-99	-99.0	-99
10/21/92	27	-99.0	-99.0	-99.00	342.00	-99.00	-99.0	-99	-99	-99	-99.0	-99
11/09/92	30	6.50	-99.0	45.40	16.000	-99.00	-99.0	55	-99	-99	-99.0	-99
11/09/92	31	6.43	-99.0	45.70	18.000	-99.00	-99.0	60	-99	-99	-99.0	-99
11/09/92	35	6.69	-99.0	44.40	11.000	-99.00	-99.0	42	-99	-99	-99.0	-99
11/09/92	36	6.74	-99.0	44.30	9.000	-99.00	-99.0	42	-99	-99	-99.0	-99
11/24/92	1	6.47	12.60	37.50	20.000	0.370	0.02	65	3	-99	2.00	2
11/24/92	2	6.54	6.60	28.30	31.000	0.320	0.02	49	3	-99	1.30	12
11/24/92	3	6.44	4.20	33.20	18.000	0.210	0.04	32	3	-99	2.70	23
11/24/92	4	6.67	6.40	43.10	24.000	0.290	0.02	55	4	-99	2.50	2
11/24/92	5	6.73	5.30	44.00	13.000	0.250	0.05	17	6	-99	0.80	3
11/24/92	6	5.91	2.30	28.60	17.000	0.370	0.02	65	4	-99	1.40	3

Pawtuckaway Lake Raw Chemistry Data

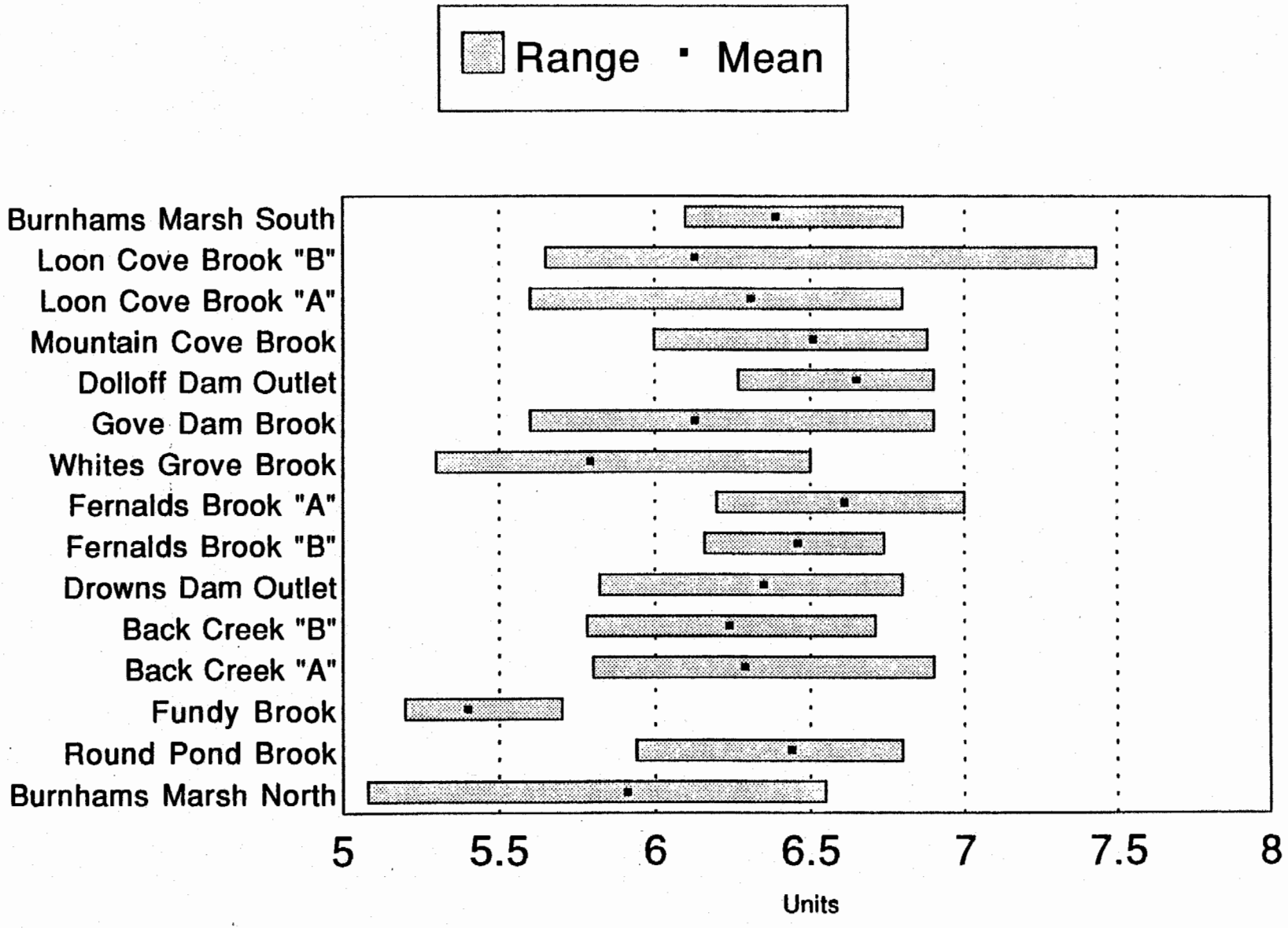
Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
11/24/92	7	5.96	4.00	115.70	16.000	0.210	0.02	43	28	-99	1.00	22
11/24/92	8	6.67	9.60	172.90	72.000	0.540	0.02	65	41	-99	2.50	14
11/24/92	9	6.38	3.40	33.60	6.000	0.100	0.02	21	3	-99	0.90	3
11/24/92	10	6.47	4.00	42.10	25.000	0.410	0.12	45	6	-99	1.30	0
11/24/92	11	6.10	3.20	44.30	21.000	0.410	0.02	100	8	-99	1.40	52
11/24/92	12	6.28	4.10	27.40	17.000	0.250	0.02	39	3	-99	1.70	2
11/24/92	13	5.36	1.30	32.80	18.000	0.570	0.02	100	6	-99	1.10	5
11/24/92	14	6.52	6.30	27.60	56.000	0.830	0.02	60	3	-99	1.60	12
11/24/92	15	5.85	2.80	22.80	19.000	0.480	0.02	80	3	-99	1.70	4
03/30/93	3	5.60	-99.0	24.10	39.000	-99.00	-99.0	-99	-99	-99	2.70	2
03/30/93	4	6.00	-99.0	32.90	33.000	-99.00	-99.0	-99	-99	-99	4.90	2
03/30/93	5	6.30	-99.0	53.50	20.000	-99.00	-99.0	-99	-99	-99	1.60	2
03/30/93	6	5.60	-99.0	30.00	86.000	-99.00	-99.0	-99	-99	-99	7.00	1
03/30/93	7	5.30	-99.0	80.20	55.000	-99.00	-99.0	-99	-99	-99	6.50	14
03/30/93	8	6.20	-99.0	97.20	199.00	-99.00	-99.0	-99	-99	-99	6.10	200
03/30/93	11	5.90	-99.0	41.60	41.000	-99.00	-99.0	-99	-99	-99	3.30	19
03/30/93	12	5.80	-99.0	23.60	32.000	-99.00	-99.0	-99	-99	-99	2.20	1
04/07/93	1	5.65	-99.0	27.60	15.000	-99.00	-99.0	-99	-99	-99	0.76	0
04/07/93	2	6.10	-99.0	25.50	14.000	-99.00	-99.0	-99	-99	-99	2.00	0
04/07/93	3	6.05	-99.0	26.30	15.000	-99.00	-99.0	-99	-99	-99	0.30	0
04/07/93	4	6.26	-99.0	37.20	15.000	-99.00	-99.0	-99	-99	-99	0.71	0
04/07/93	5	6.27	-99.0	43.30	21.000	-99.00	-99.0	-99	-99	-99	0.90	2
04/07/93	6	5.91	-99.0	39.10	12.000	-99.00	-99.0	-99	-99	-99	1.20	0
04/07/93	7	5.54	-99.0	105.10	12.000	-99.00	-99.0	-99	-99	-99	2.00	6
04/07/93	8	6.48	-99.0	169.50	168.00	-99.00	-99.0	-99	-99	-99	2.50	62
04/07/93	9	6.16	-99.0	24.90	6.000	-99.00	-99.0	-99	-99	-99	0.40	0
04/07/93	10	5.82	-99.0	35.20	15.000	-99.00	-99.0	-99	-99	-99	1.00	0
04/07/93	11	5.78	-99.0	41.20	19.000	-99.00	-99.0	-99	-99	-99	0.40	4
04/07/93	12	5.97	-99.0	26.80	9.000	-99.00	-99.0	-99	-99	-99	1.00	0
04/07/93	13	-99.0	-99.0	37.40	15.000	-99.00	-99.0	-99	-99	-99	0.50	1
04/07/93	14	5.94	-99.0	26.50	11.000	-99.00	-99.0	-99	-99	-99	0.50	0
04/07/93	15	5.08	-99.0	22.40	17.000	-99.00	-99.0	-99	-99	-99	0.70	1
04/08/94	27	-99.0	-99.0	511.00	3.900	-99.00	-99.0	-99	-99	-99	15.30	-99

Pawtuckaway Lake Raw Chemistry Data

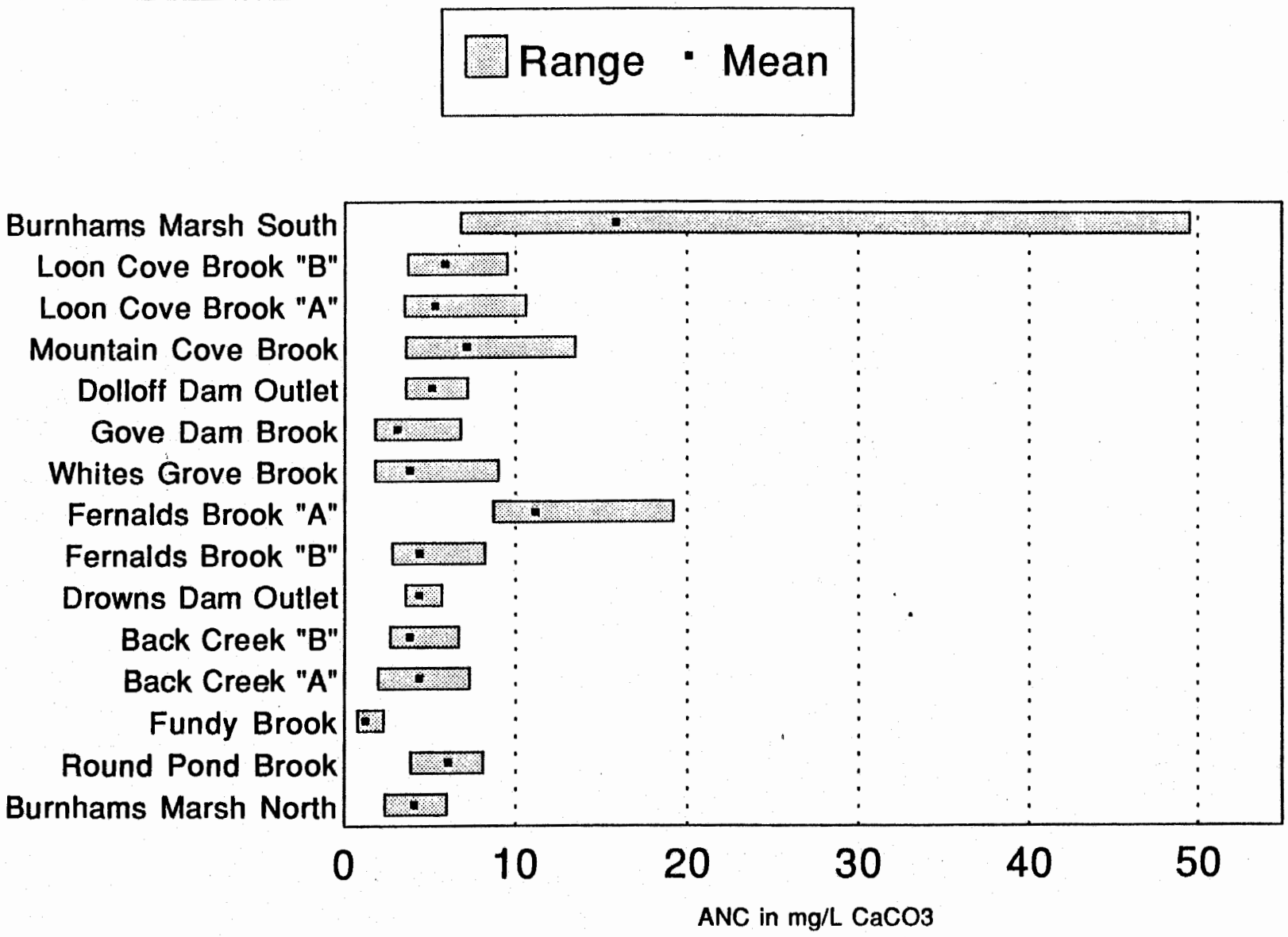
Date	Station	Ph	Anc	Cond	Tp	Tkn	Nitrates	Color	Cl	So4	Turb	Ecoli
03/30/93	27	-99.0	-99.0	-99.00	0.520	-99.00	-99.0	-99	-99	-99	-99.0	1700
02/26/92	27	-99.0	-99.0	-99.00	0.725	-99.00	-99.0	-99	-99	-99	-99.0	200
12/31/93	27	-99.0	-99.0	208.00	0.120	-99.00	-99.0	-99	-99	-99	5.00	15000
05/05/92	27	-99.0	-99.0	-99.00	1.870	-99.00	-99.0	-99	-99	-99	-99.0	-99

APPENDIX V-4

Pawtuckaway Lake
Tributary pH Range

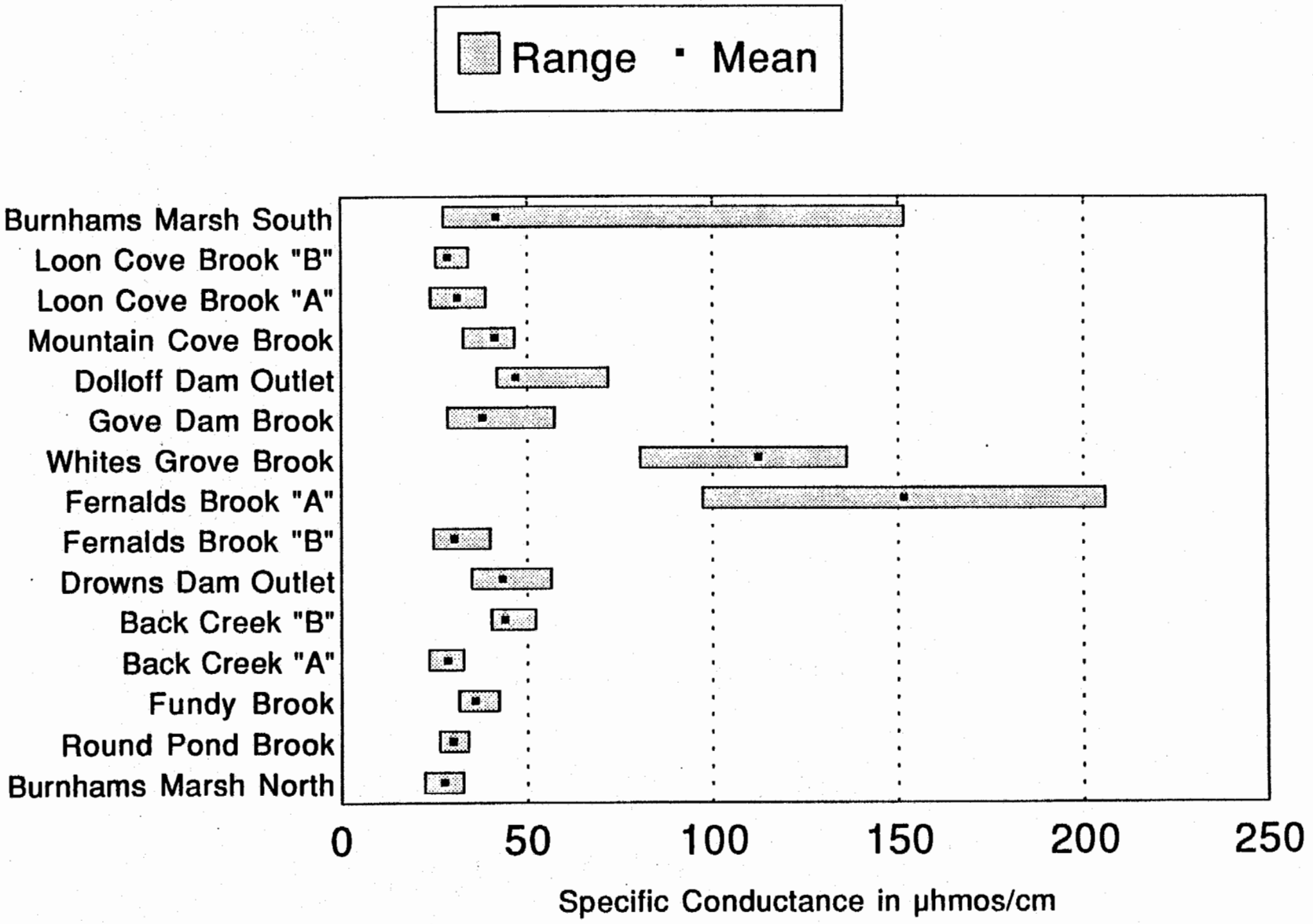


Pawtuckaway Lake
Tributary ANC Range

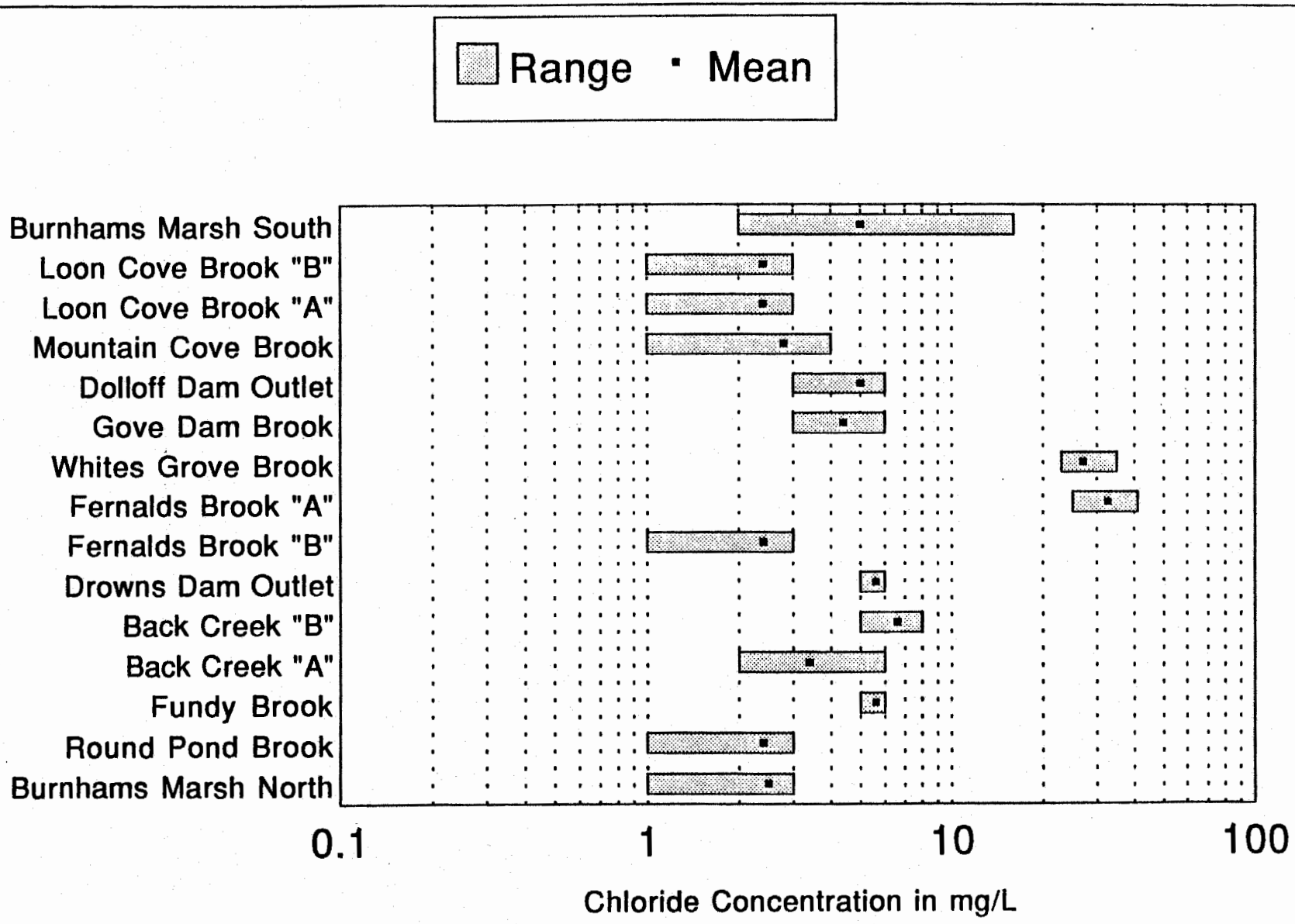


Pawtuckaway Lake

Tributary Specific Conductivity Range

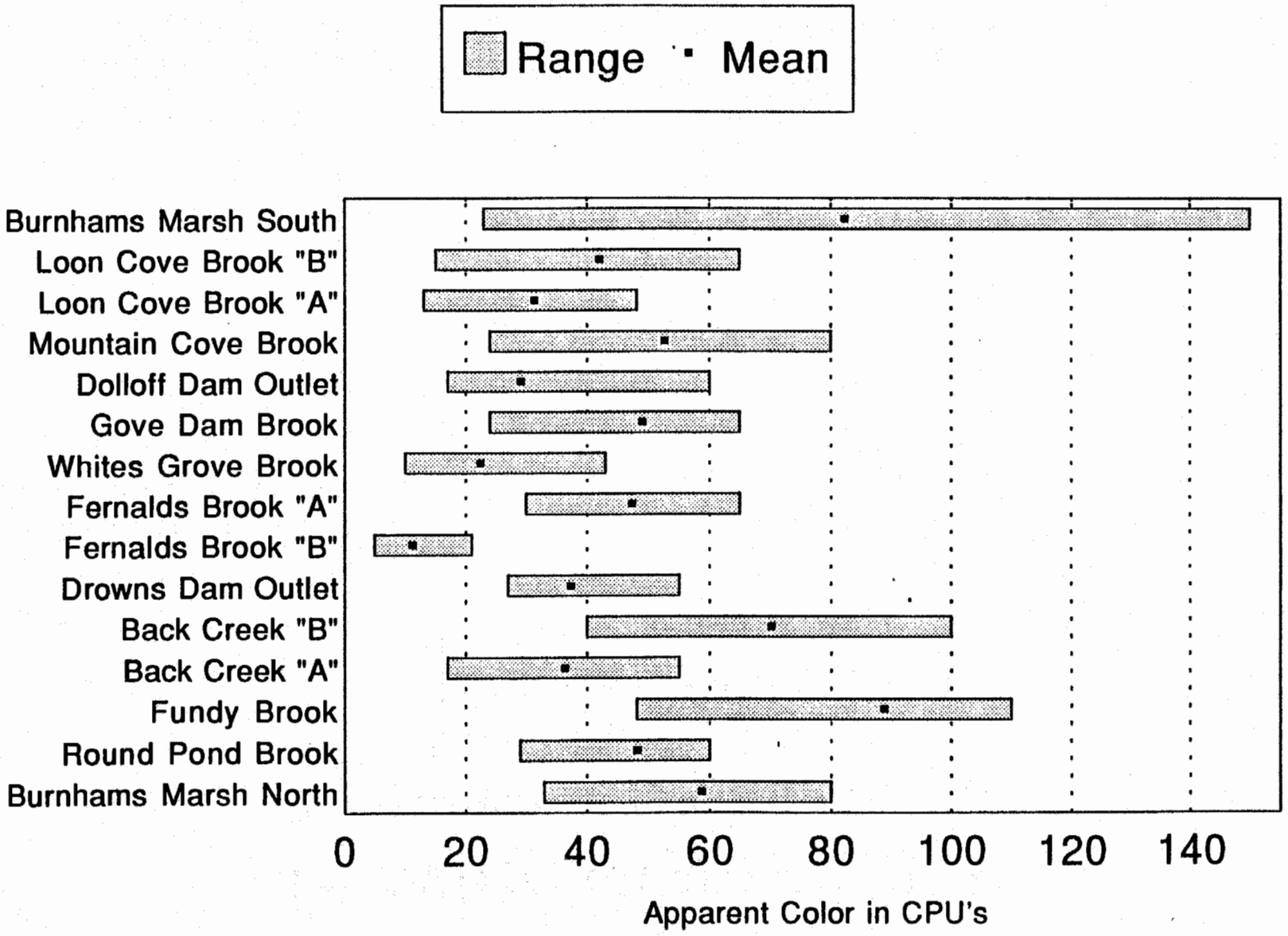


Pawtuckaway Lake
Tributary Chloride Ranges

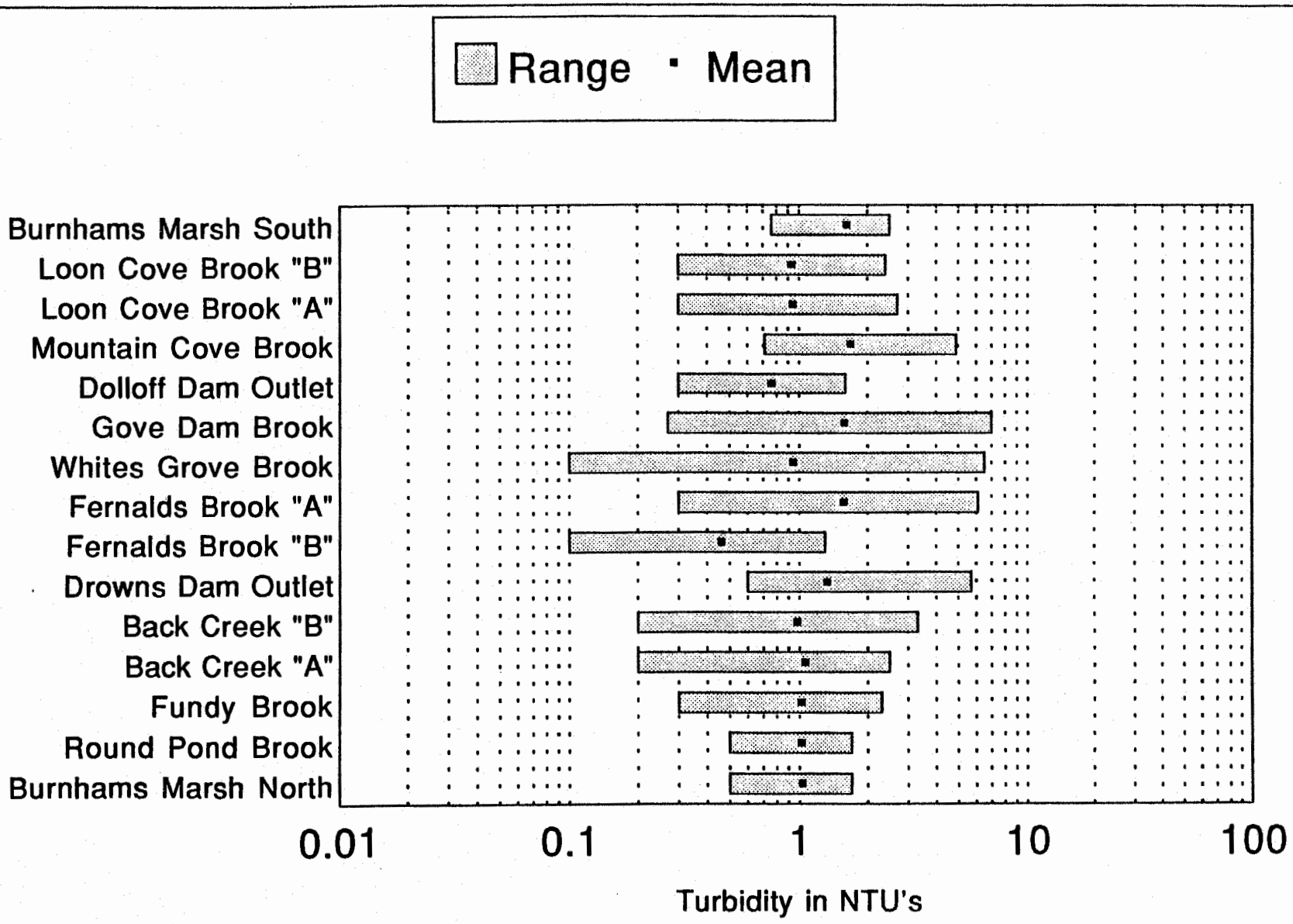


Pawtuckaway Lake

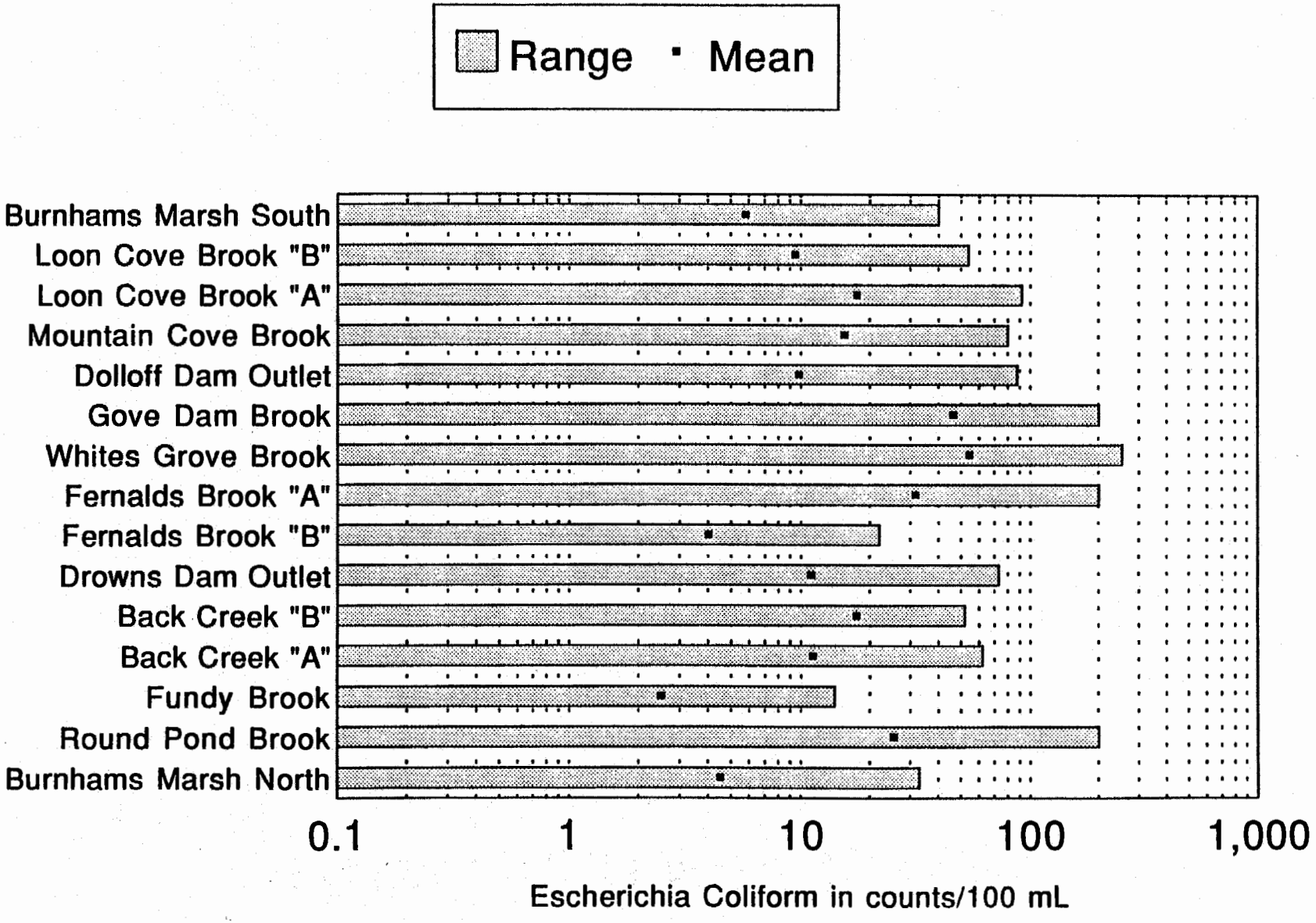
Tributary Apparent Color



Pawtuckaway Lake
Tributary Turbidity Range

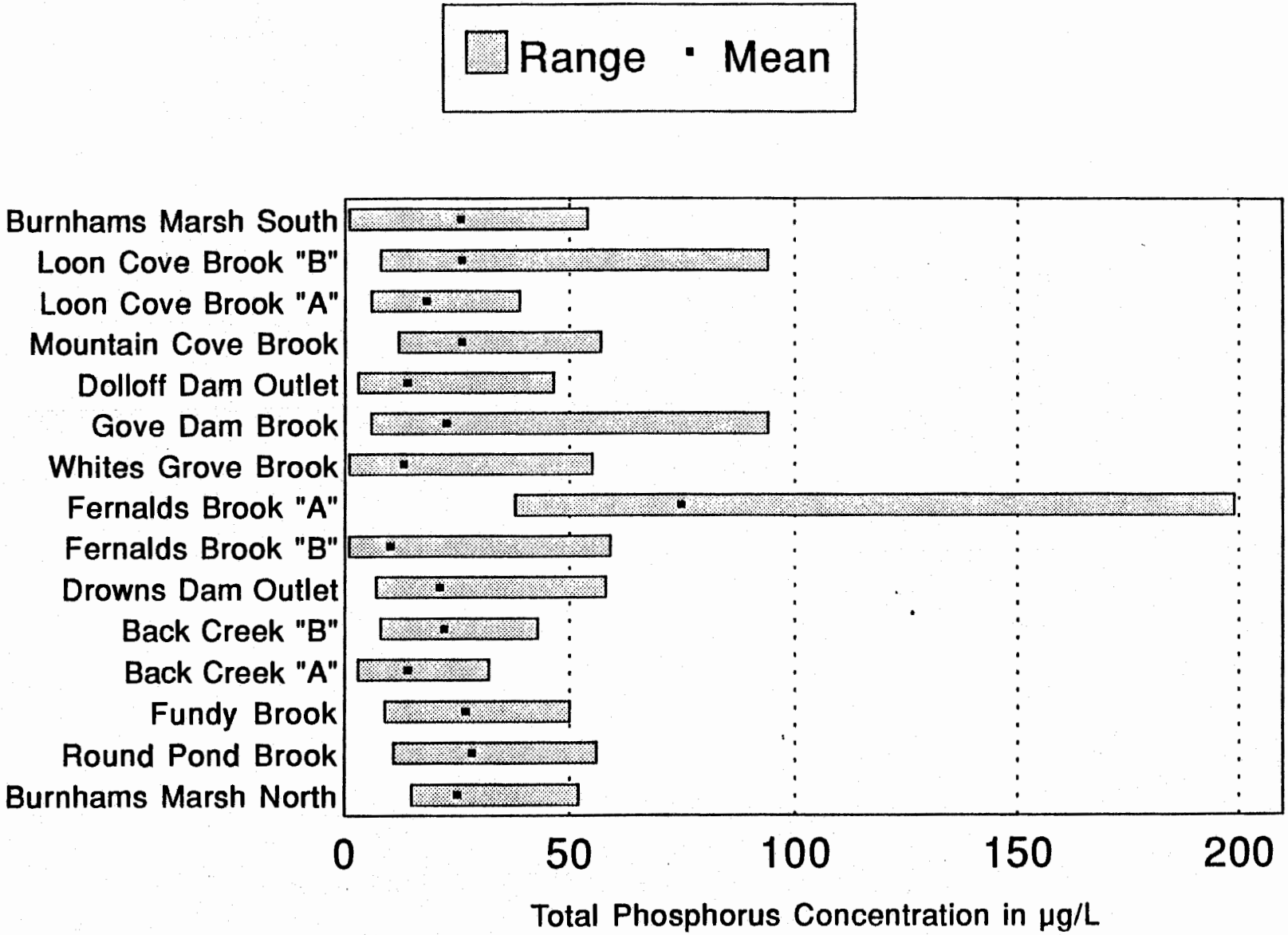


Pawtuckaway Lake
Tributary E.coli Range

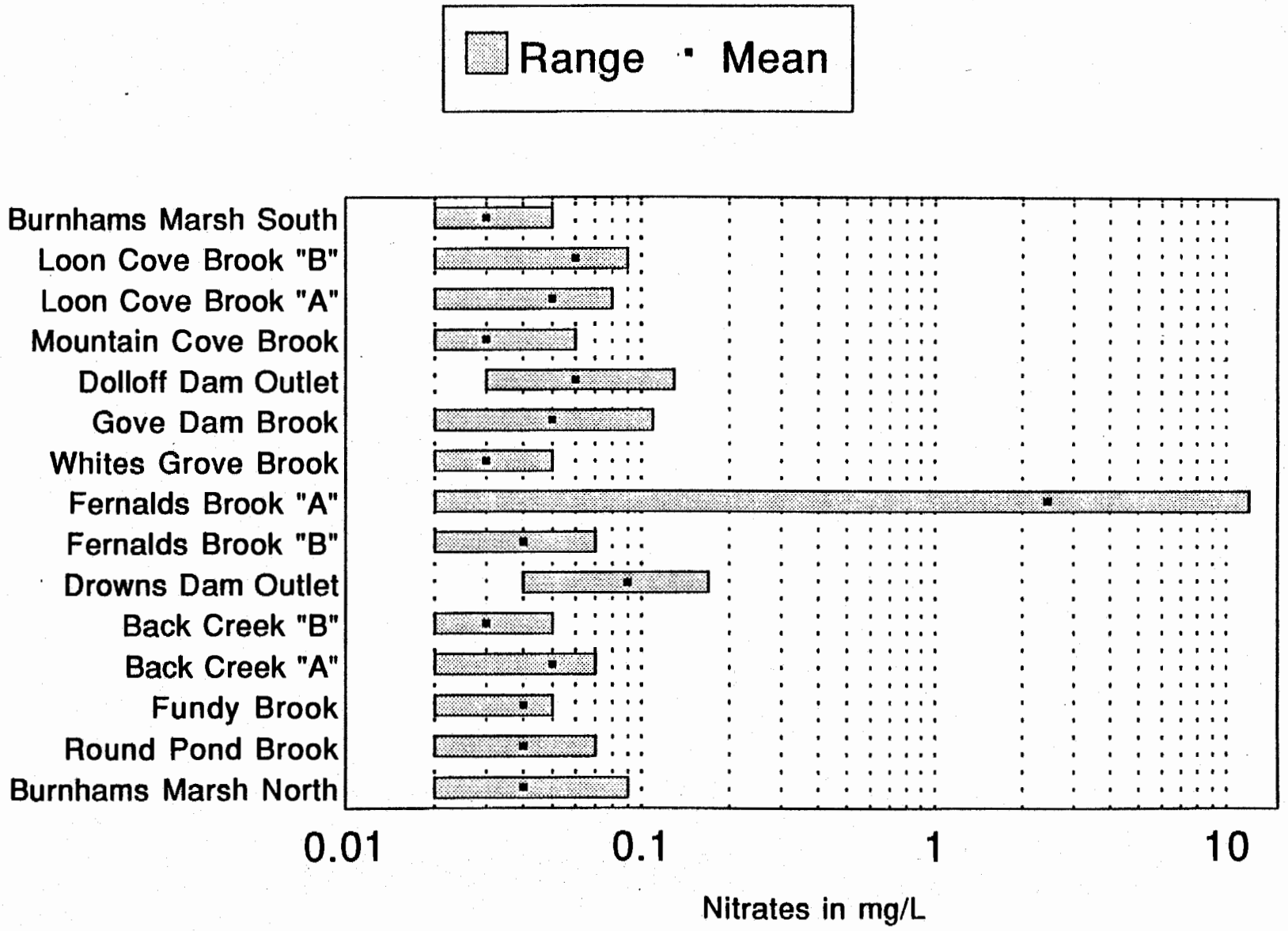


Pawtuckaway Lake

Tributary Total Phosphorus Range

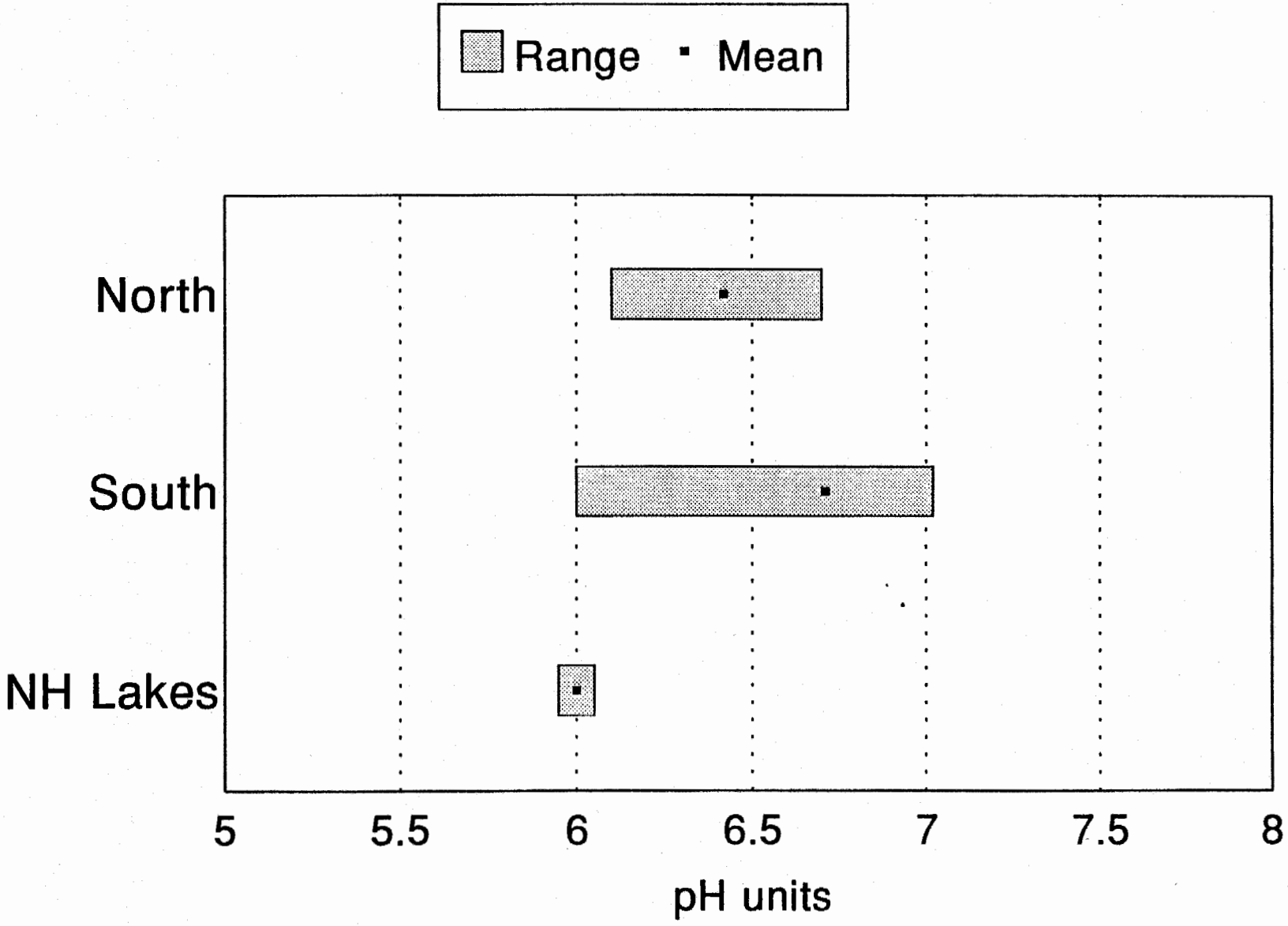


Pawtuckaway Lake
Tributary Nitrate Range



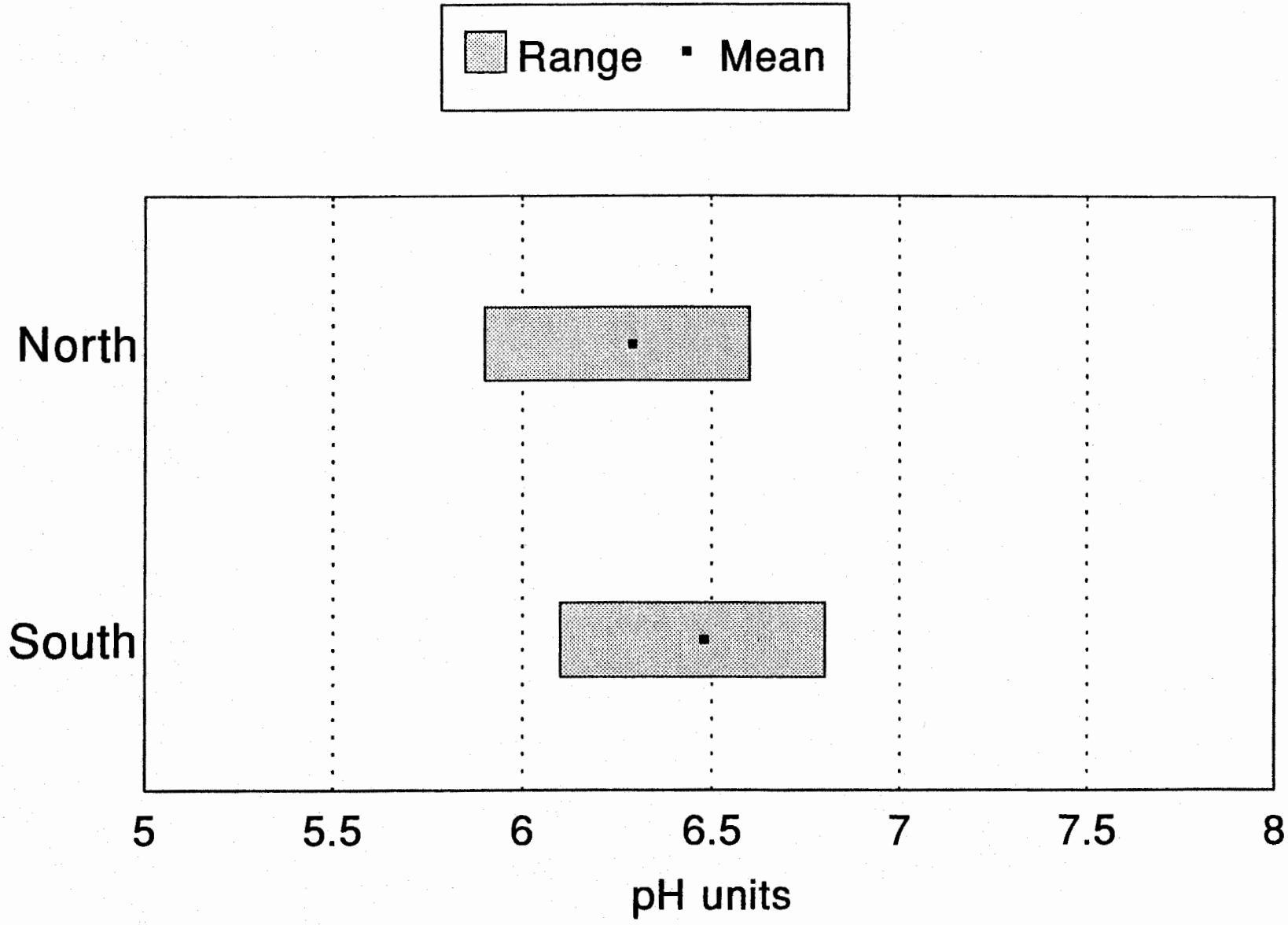
APPENDIX V-5

Pawtuckaway Lake
Epilimnetic pH Range



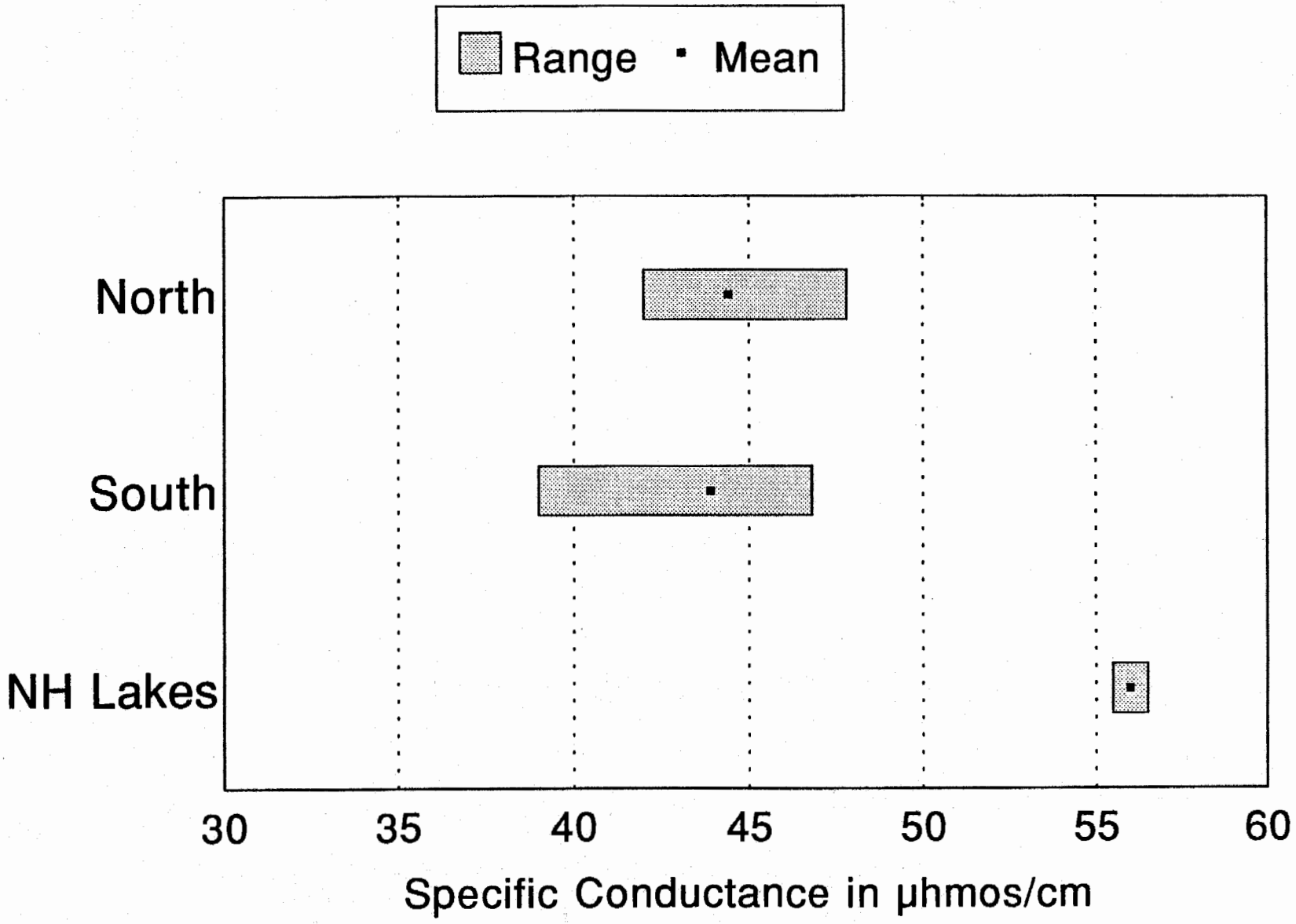
Pawtuckaway Lake

Hypolimnetic pH Range



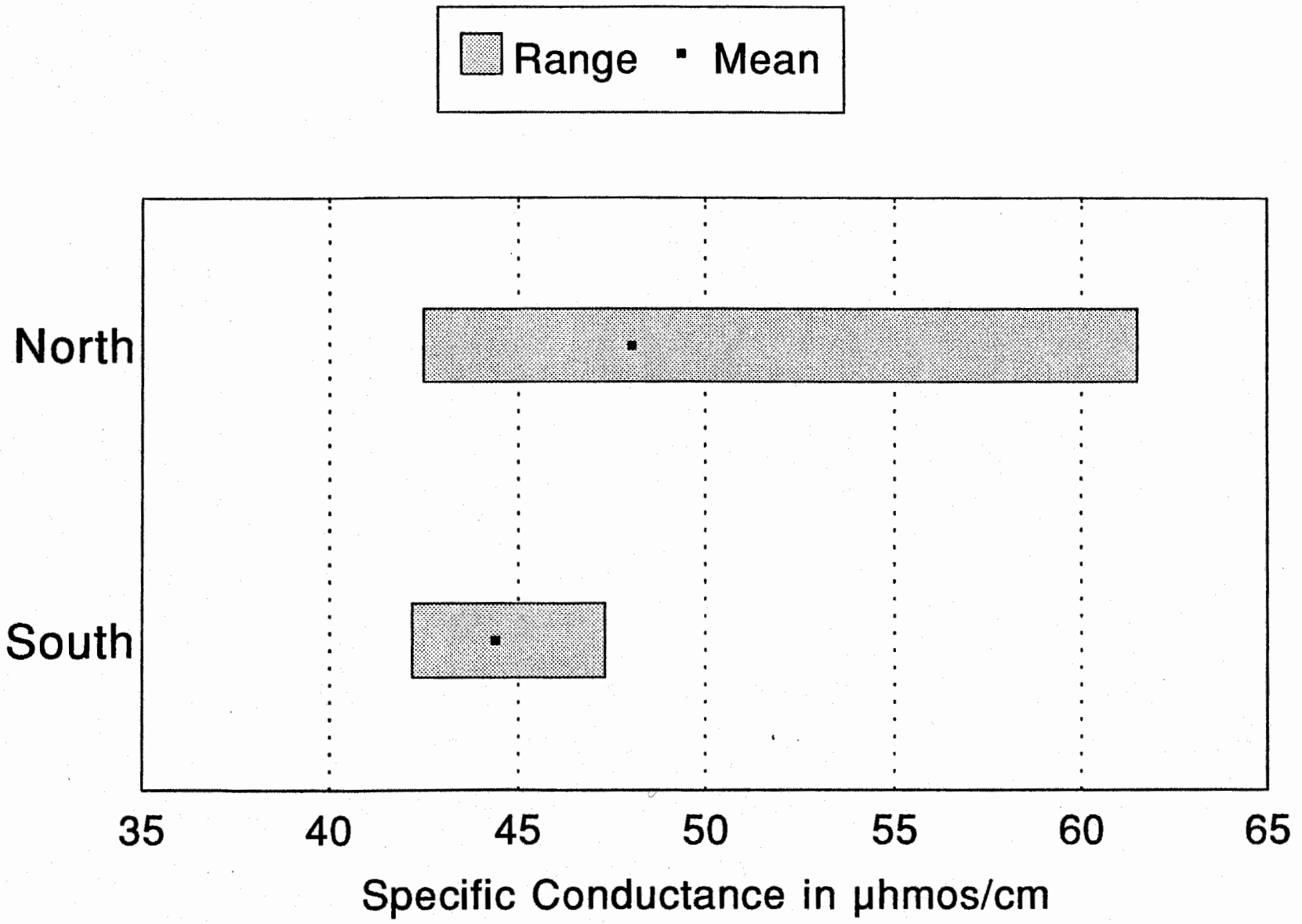
Pawtuckaway Lake

Epilimnetic Specific Conductance Range



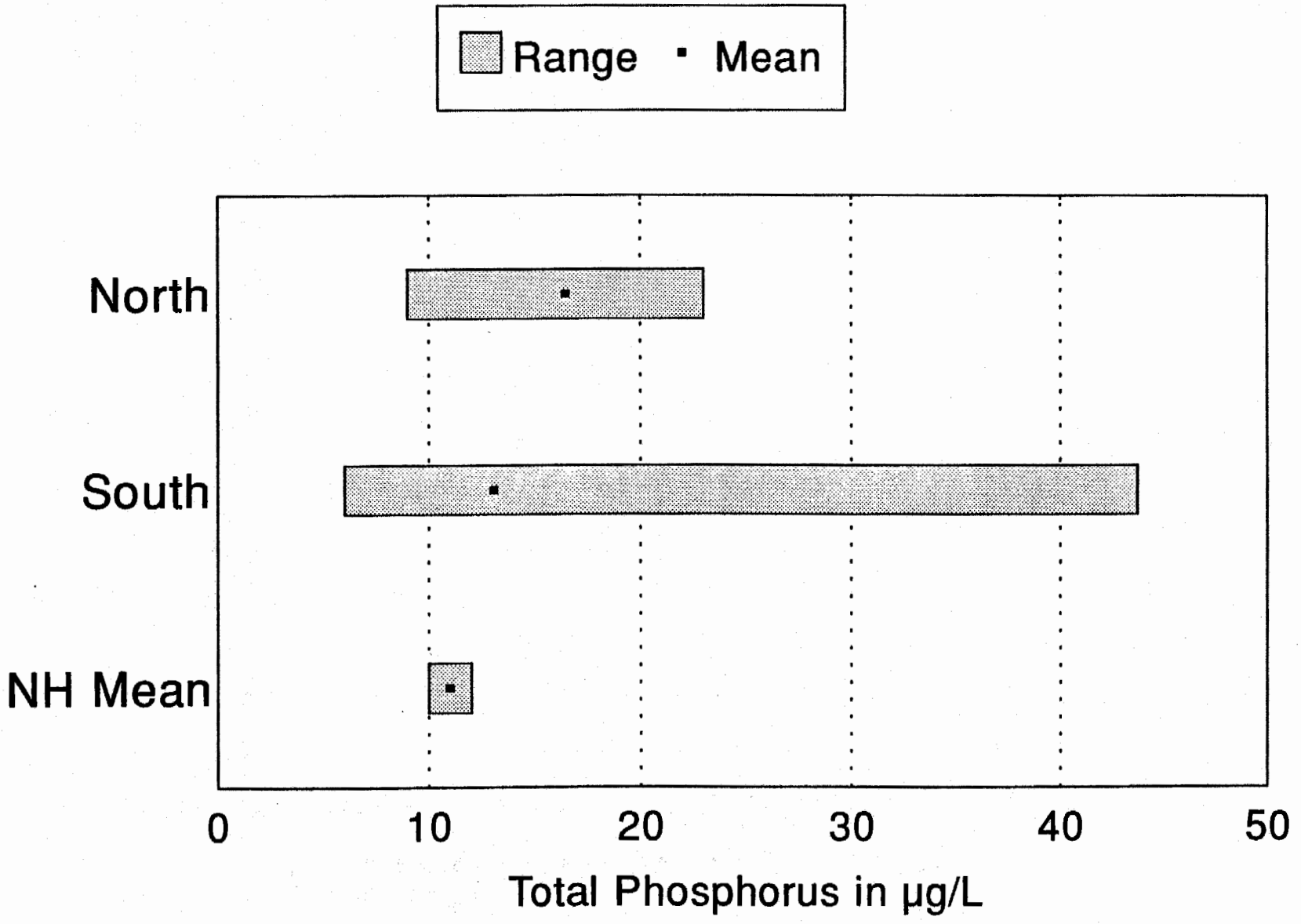
Pawtuckaway Lake

Hypolimnetic Specific Conductance Range



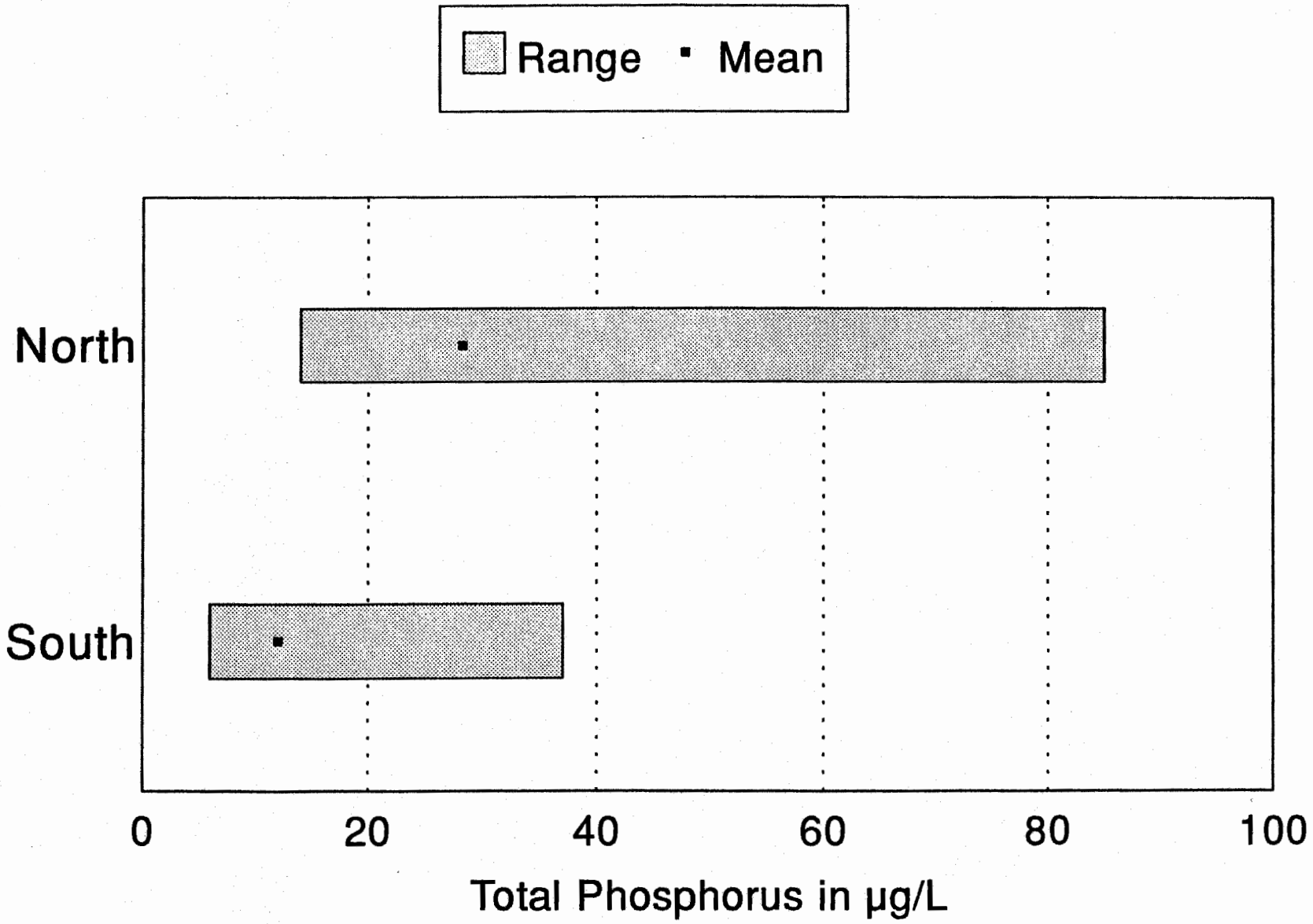
Pawtuckaway Lake

Epilimnetic Total Phosphorus Range



Pawtuckaway Lake

Hypolimnetic Total Phosphorus Range



APPENDIX VI-1

Pawtuckaway Lake Raw Biology Data

Date	Station	Chl-a	Secchi	Dominant Phytoplankton	%	Dominant Zooplankton	Cells/ml
10/15/91	NORTH	2.44	3.2	Coelosphaerium	57	Polyarthra	45.2
				Asterionella	16	Kellicottia	20.3
10/15/91	SOUTH	2.42	4.2	Asterionella	32	Kellicottia	9.4
				Coelosphaerium	28		
				Uroglenopsis	16		
11/12/91	NORTH	-99.00	2.3	Asterionella	74	Polyarthra	21.8
						Kellicottia	20.3
						Calanoid copepod	17.2
11/12/91	SOUTH	-99.00	3.5	Asterionella	56		
				Coelosphaerium	31		
12/16/91	NORTH	-99.00	-99.0	Asterionella	94	Codonella	74.1
						Keratella	21.8
						Nauplius larva	13.1
04/14/92	NORTH	-99.00	-99.0	Asterionella	96	Nauplius larva	38.1
						Keratella	23.1
						Kellicottia	15.0
01/14/92	SOUTH	-99.00	-99.0	Asterionella	90	Nauplius larva	27.2
02/14/92	NORTH	-99.00	-99.0	Asterionella	99	Nauplius larva	27.3
						Keratella	7.6

Pawtuckaway Lake Raw Biology Data

Date	Station	Chl-a	Secchi	Dominant Phytoplankton	%	Dominant Zooplankton	Cells/ml
02/14/92	SOUTH	-99.00	-99.0	Asterionella	75	Nauplius larva	50.9
						Kellicottia	12.7
04/16/92	NORTH	10.46	2.0	Asterionella	84	Keratella	63.2
						Nauplius larva	48.0
						Polyarthra	30.5
04/16/92	SOUTH	6.34	3.0	Dinobryon	63	Polyarthra	69.8
				Asterionella	34	Keratella	37.1
						Kellicottia	30.5
05/07/92	NORTH	2.43	4.7	Dinobryon	86	Nauplius larva	36.0
						Kellicottia	18.0
						Keratella	11.0
05/07/92	SOUTH	2.92	5.2	Dinobryon	69	Kellicottia	79.2
						Cyclopoid copepod	64.8
						Nauplius larva	43.2
05/26/92	NORTH	6.19	3.5	Asterionella	67	Kellicottia	50.1
				Tabellaria		Calanoid copepod	34.9
						Nauplius larva	26.2
05/26/92	SOUTH	5.83	4.3	Asterionella	87	Kellicottia	50.1
				Tabellaria		Polyarthra	13.1
						Nauplius larva	13.1
06/10/92	NORTH	5.97	3.0	Asterionella	59	Kellicottia	10.9
				Tabellaria	32	Calanoid copepod	10.9
				Dinobryon	24	Nauplius larva	8.7

Pawtuckaway Lake Raw Biology Data

Date	Station	Chl-a	Secchi	Dominant Phytoplankton	%	Dominant Zooplankton	Cells/ml
06/10/92	SOUTH	5.39	3.4	Asterionella	34	Kellicottia	32.7
				Stephanodiscus	19		
				Tabellaria	17		
06/26/92	NORTH	3.36	4.4	Tabellaria	44	Kellicottia	48.0
				Asterionella	18	Polyarthra	8.7
				Anabaena	12	Daphnia	6.5
06/26/92	SOUTH	4.55	4.4	Tabellaria	38	Kellicottia	37.1
				Gleocapsa	24	Nauplius larva	8.5
				Stephanodiscus	20		
07/07/92	NORTH	2.35	4.9	Tabellaria	30	Kellicottia	13.1
				Coelosphaerium	28	Daphnia	8.7
						Calanoid copepod	6.5
07/07/92	SOUTH	2.89	4.7	Gleocapsa	64	Daphnia	8.7
						Kellicottia	4.4
						Calanoid copepod	4.4
07/21/92	NORTH	6.92	3.9	Gleocapsa	80	Nauplius larva	6.5
07/21/92	SOUTH	6.09	4.4	Gleocapsa	81	Conochilus	30.5
						Nauplius larva	4.4
08/03/92	NORTH	4.19	3.7	Anabaena	51	Colotheca	39.2
				Gleocapsa	18	Nauplius larva	30.5
						Conochilus single	17.4

Pawtuckaway Lake Raw Biology Data

Date	Station	Chl-a	Secchi	Dominant Phytoplankton	%	Dominant Zooplankton	Cells/ml
08/03/92	SOUTH	4.17	4.2	Anabaena	64	Conochilus	19.6
				Gleocapsa	15	Nauplius larva	19.6
						Colotheca	17.4
08/26/92	NORTH	3.77	4.6	Anabaena	36	Nauplius larva	21.8
				Filamentous spp	16	Keratella	18.2
						Calanoid copepod	10.9
08/26/92	SOUTH	3.41	4.3	Anabaena	46	Tiny ciliate	96.5
				Filamentous spp	24	Synchaeta	20.0
						Nauplius larva	12.7
09/09/92	NORTH	3.80	5.3	Microcystis	30	Nauplius larva	8.8
				Filamentous spp	23		
09/09/92	SOUTH	2.37	6.1	Anabaena	24	Daphnia	7.3
				Microcystis	16	Nauplius larva	5.5
						Kellicottia	5.5
09/22/92	NORTH	3.08	5.0	Coelosphaerium	20	Nauplius larva	15.2
				Merismopedia	19	Kellicottia	3.5
				Microcystis	18	Keratella	2.3
09/22/92	SOUTH	2.89	5.2	Microcystis	23	Nauplius larva	10.9
				Merismopedia	20	Daphnia	6.2
						Conochilus	4.7
10/12/92	NORTH	2.92	4.7	Coelosphaerium	30	Daphnia	18.2
				Microcystis	17	Kellicottia	5.5
				Anabaena	15	Nauplius larva	5.5

Pawtuckaway Lake Raw Biology Data

Date	Station	Chl-a	Secchi	Dominant Phytoplankton	%	Dominant Zooplankton	Cells/ml
10/12/92	SOUTH	4.15	4.2	Microcystis	18	Daphnia	1.8
				Cryptomonas	14	Nauplius larva	1.8
						Cyclopoid copepod	1.8
11/09/92	SOUTH	2.54	5.6	Dinobryon	67	Kellicottia	3.1
				Cryptomonas	23	Cyclopoid copepod	3.1
11/09/92	NORTH	3.35	2.4	Chroomonas		Kellicottia	
				Coelosphaerium		Cyclopoid copepod	
				Cryptomonas			
01/14/92	NORTH	-99.00	-99.0	ASTERIONELLA	96	NAUPLIUS LARVA	38.1

APPENDIX VI-2

Pawtuckaway Lake Raw Inverted Microscope Phytoplankton Counts

Date	Dominant Phytoplankton	Cells/ml	GROUP DENSITIES							
			Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
10/15/91	Chroomonas	462.2	34.6	90.7	0.0	4.3	21.6	531.4	8.6	0.0
	Cryptomonas	69.1								
	Schroderia	47.5								
	TOTAL DENSITY	738.7								
10/15/91	Chroomonas	570.2	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
	Schroderia	99.4	34.6	194.4	0.0	21.6	0.0	604.8	0.0	30.2
	Tiny Flagellate	43.2								
	TOTAL DENSITY	885.6								
11/12/91	Chroomonas	181.4	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
	Schroderia	86.4	13.0	129.6	0.0	0.0	8.6	207.4	0.0	17.3
	Closteriopsis	25.9								
	TOTAL DENSITY	375.8								
11/12/91	Chroomonas	250.6	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
	Schroderia	194.4	17.3	263.5	4.3	0.0	30.2	263.5	0.0	60.5
	Mallamonas	60.5								
	TOTAL DENSITY	639.4								
06/26/92	Chroomonas	194.4	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
	Cyclotella/Stephano.	151.2	64.8	177.1	13.0	0.0	155.5	246.2	0.0	0.0
	TOTAL DENSITY	656.6								
06/26/92	Cyclotella/Stephano.	449.3	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
	Chroomonas	155.5	86.4	190.1	4.3	0.0	457.9	185.8	0.0	4.3
	TOTAL DENSITY	928.8								

Pawtuckaway Lake Raw Inverted Microscope Phytoplankton Counts

Date	Dominant Phytoplankton	Cells/ml	GROUP DENSITIES							
			Blue-Greens	Greens	Desmids	Euglen-oids	Diatoms	Crypto-monads	Dinoflag-ellates	Chryso-phytes
04/16/92	Chroomonas	203.0	4.3	237.6	8.6	13.0	112.3	285.1	8.6	116.6
	Ankistrodesmus	159.8								
	Dinobryon	116.6								
	TOTAL DENSITY	786.2								
05/07/92	Chroomonas	380.2	Blue-Greens	Greens	Desmids	Euglen-oids	Diatoms	Crypto-monads	Dinoflag-ellates	Chryso-phytes
	Schroderia	164.2	38.9	341.3	13.0	0.0	25.9	470.9	0.0	73.4
	Tiny Flagellates	99.4								
	TOTAL DENSITY	963.4								
05/17/92	Chroomonas	125.3	Blue-Greens	Greens	Desmids	Euglen-oids	Diatoms	Crypto-monads	Dinoflag-ellates	Chryso-phytes
	Mallamonas	103.7	4.3	194.4	8.6	0.0	64.8	190.1	0.0	112.3
	Schroderia	103.7								
	TOTAL DENSITY	570.2								
06/10/92	Cyclotella/Stephano.	565.9	Blue-Greens	Greens	Desmids	Euglen-oids	Diatoms	Crypto-monads	Dinoflag-ellates	Chryso-phytes
	Chroomonas	492.5	21.6	302.4	21.6	0.0	574.6	522.7	0.0	51.8
	Schroderia	211.7								
	TOTAL DENSITY	1494.7								
07/29/92	Chroomonas	149.0	Blue-Greens	Greens	Desmids	Euglen-oids	Diatoms	Crypto-monads	Dinoflag-ellates	Chryso-phytes
	Cryptomonas	77.8	118.8	84.2	0.0	8.6	6.5	226.8	0.0	34.6
	Merismopedia	60.5								
	TOTAL DENSITY	479.5								
05/26/92	Cyclotella/Stephano.	583.2	Blue-Greens	Greens	Desmids	Euglen-oids	Diatoms	Crypto-monads	Dinoflag-ellates	Chryso-phytes
	Chroomonas	337.0	13.0	159.8	4.3	0.0	591.8	354.2	0.0	21.6
	TOTAL DENSITY	1144.8								

Pawtuckaway Lake Raw Inverted Microscope Phytoplankton Counts

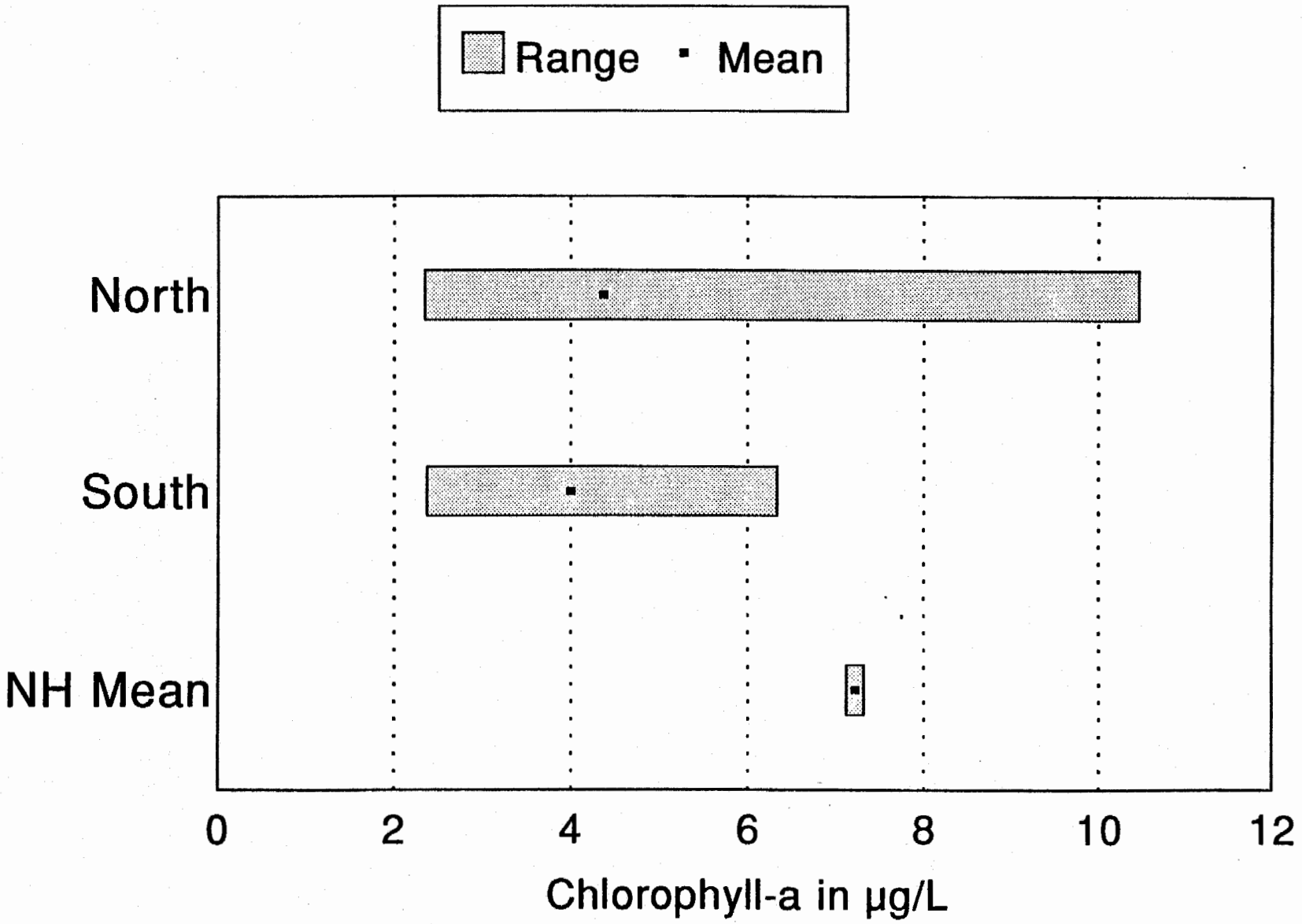
Date	Dominant Phytoplankton	Cells/ml	GROUP DENSITIES							
			Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
06/10/92	Cyclotella/Stephano.	***.*	25.9	229.0	0.0	17.3	1426	293.8	0.0	51.8
	TOTAL DENSITY	2043.4								
04/16/92	Chroomonas	501.1	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
	Tiny Flagellates	203.0	17.3	306.7	0.0	17.3	73.4	665.3	8.6	30.2
	Cryptomonas	164.2								
	TOTAL DENSITY	1118.9								
08/26/92	Merismopedia	159.8	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
	Chroomonas	142.6	306.7	146.9	4.3	4.3	8.6	194.4	0.0	8.6
	Aphanotheca	103.7								
	TOTAL DENSITY	673.9								
05/26/92	Cyclotella/Stephano.	505.4	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
	Chroomonas	375.8	8.6	168.5	25.9	0.0	514.1	410.4	0.0	60.5
	Mallamonas	60.5								
	TOTAL DENSITY	1188.0								
10/12/92	Croomonas	267.8	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
			90.7	103.7	4.3	0.0	4.3	337.0	0.0	21.6
	TOTAL DENSITY	561.6								
10/12/92	Chroomonas	203.0	Blue-Greens	Greens	Desmids	Euglenoids	Diatoms	Cryptomonads	Dinoflagellates	Chrysophytes
	Cryptomonas	82.1	34.6	64.8	4.3	0.0	0.0	285.1	0.0	51.8
	TOTAL DENSITY	440.6								

Pawtuckaway Lake Raw Inverted Microscope Phytoplankton Counts

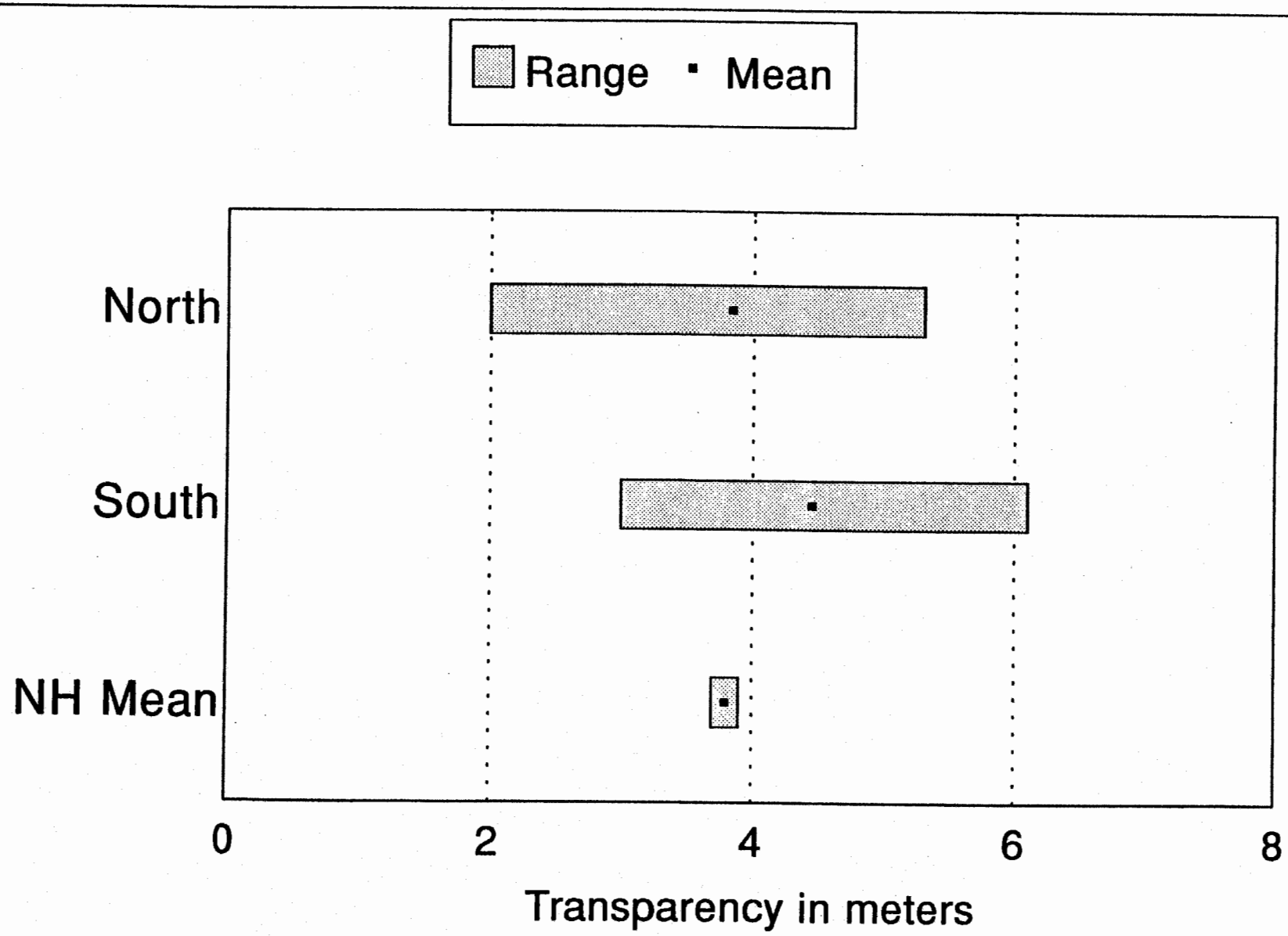
Date	Dominant Phytoplankton	Cells/ml	GROUP DENSITIES							
			Blue-Greens	Greens	Desmids	Euglen-oids	Diatoms	Crypto-monads	Dinoflag-ellates	Chryso-phytes
11/09/92	Chroomonas	712.8	21.6	220.3	0.0	0.0	8.6	794.9	4.3	43.2
	TOTAL DENSITY	1093.0								
11/09/92	Chroomonas	289.4								
	Tiny Flagellates	185.8								
		.	Blue-Greens	Greens	Desmids	Euglen-oids	Diatoms	Crypto-monads	Dinoflag-ellates	Chryso-phytes
			21.6	250.6	0.0	4.3	38.9	362.9	4.3	34.6
	TOTAL DENSITY	717.1								

APPENDIX VI-3

Pawtuckaway Lake
Chlorophyll-a Range



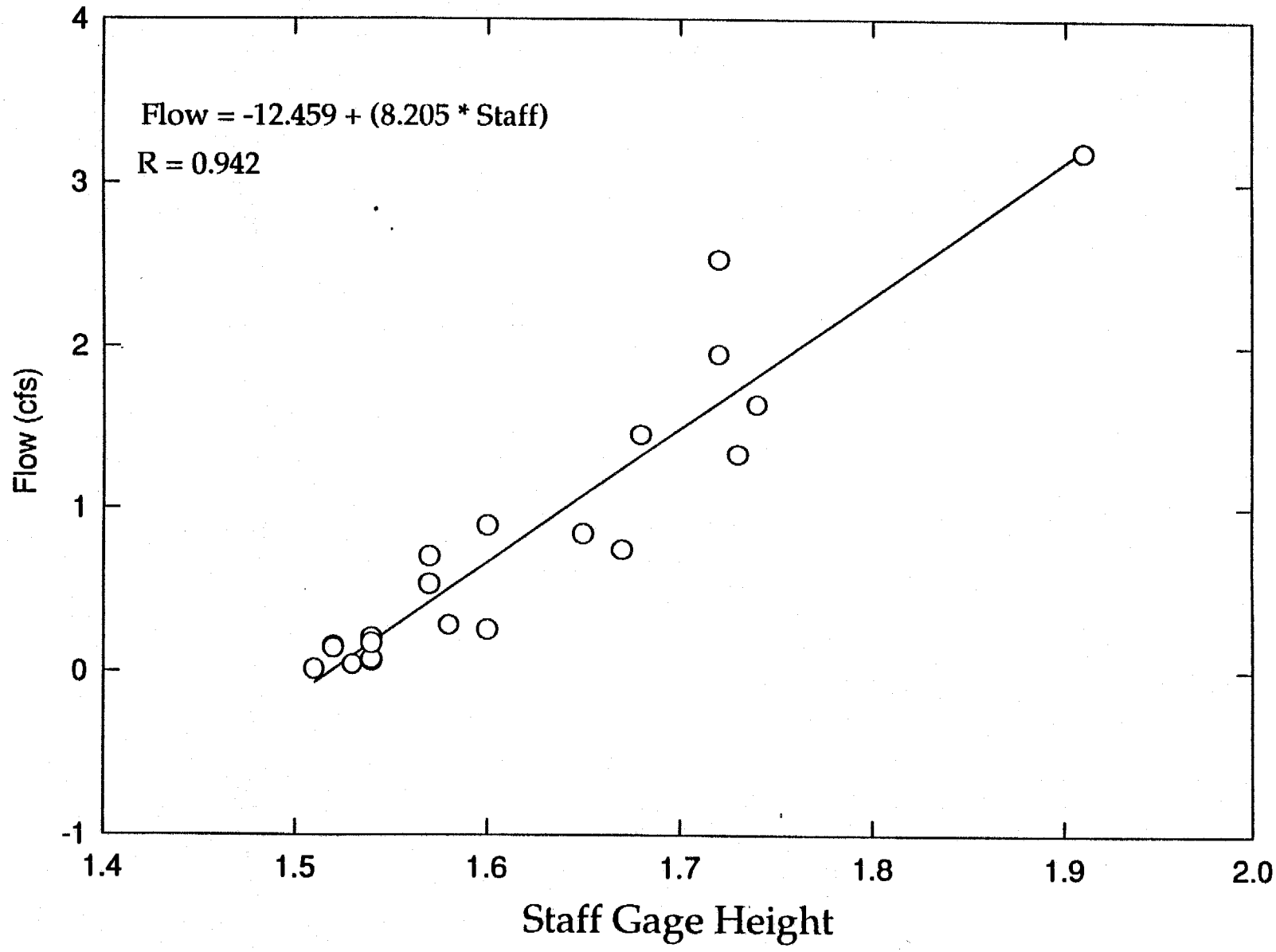
Pawtuckaway Lake
Transparency Range



APPENDIX VII-1

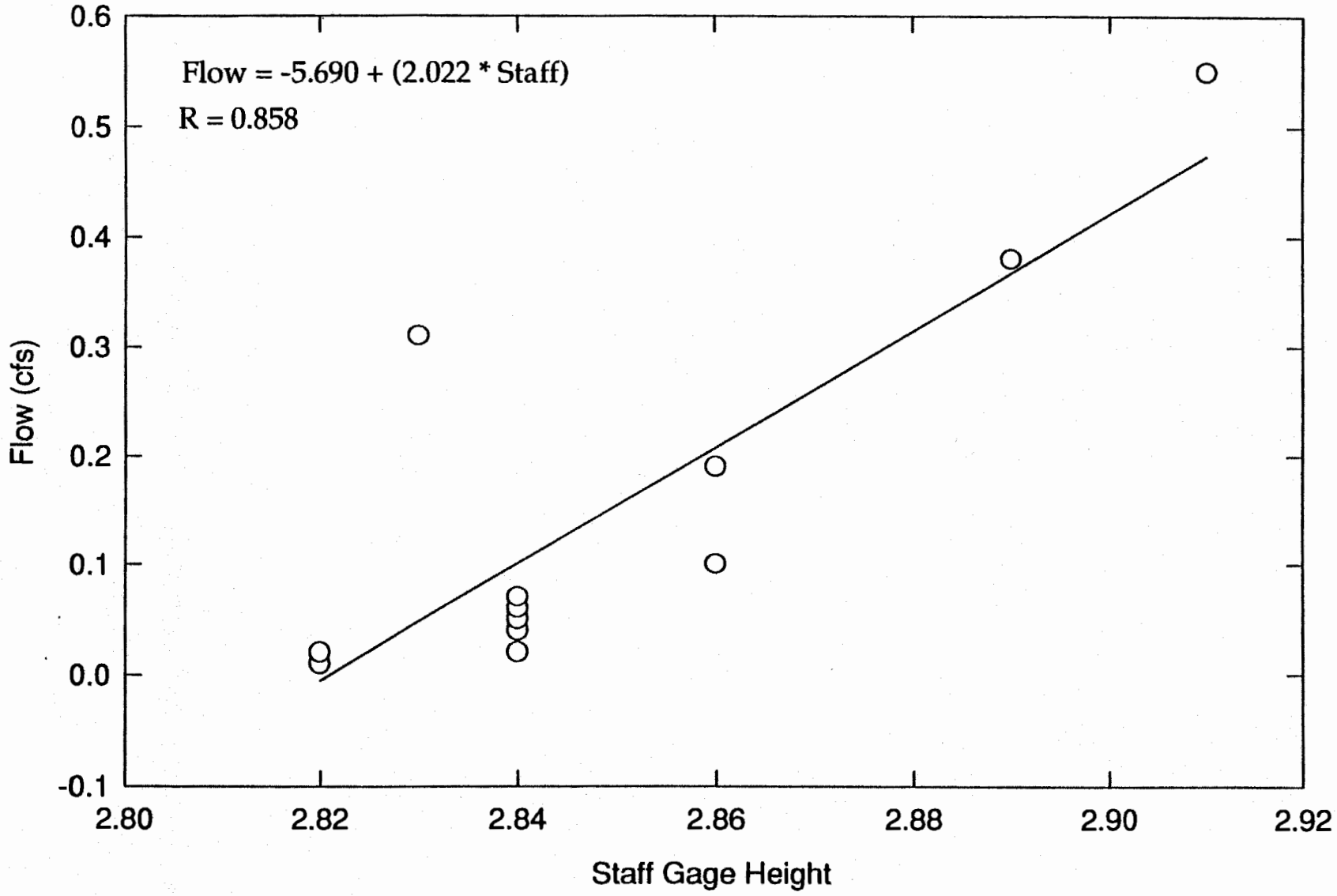
Station 1A*

Burnham's Marsh Outlet (South)



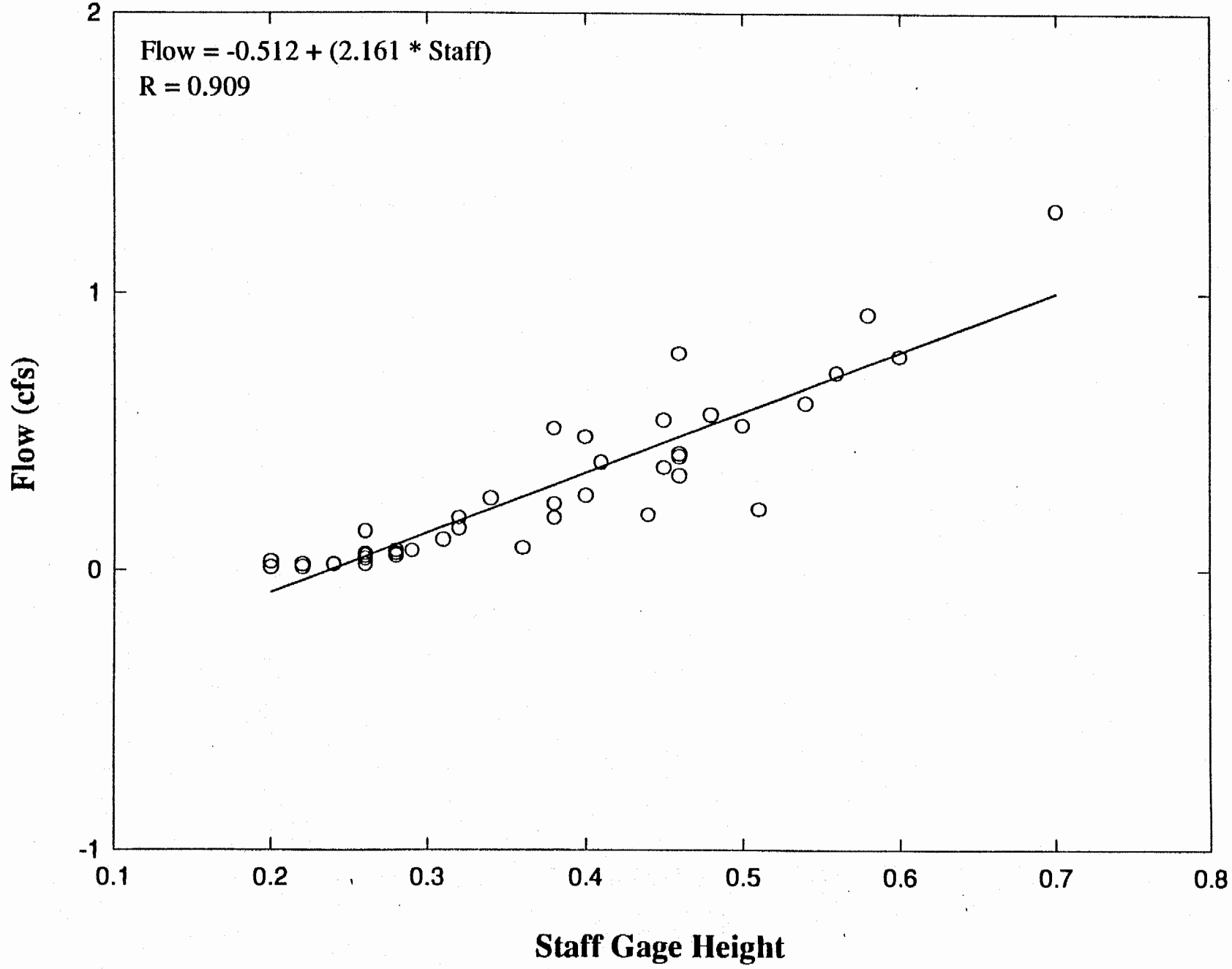
* Boards out 10-91 to 4-26-92

Station 1B*
Burnham's Marsh Outlet (South)

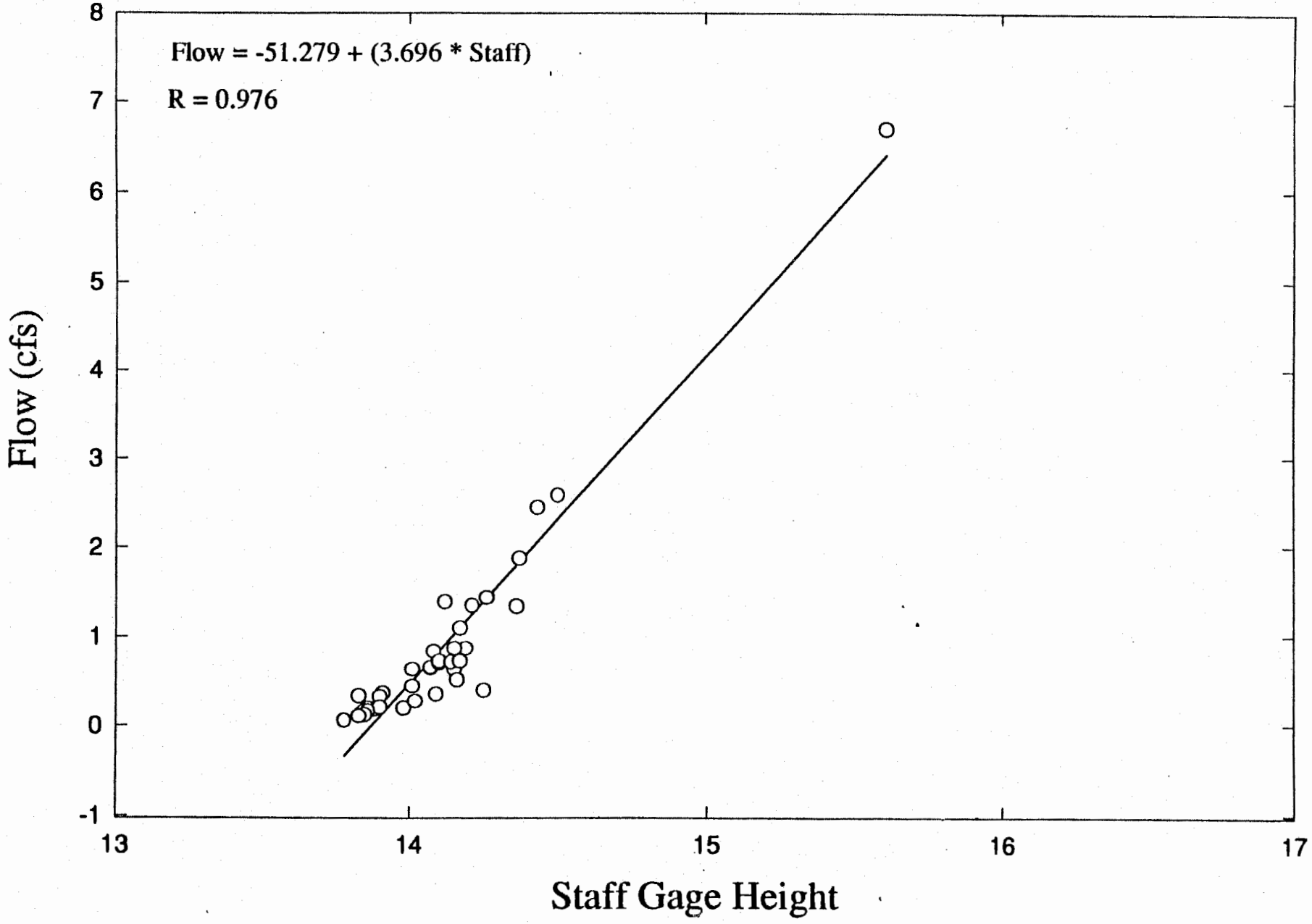


* Boards in

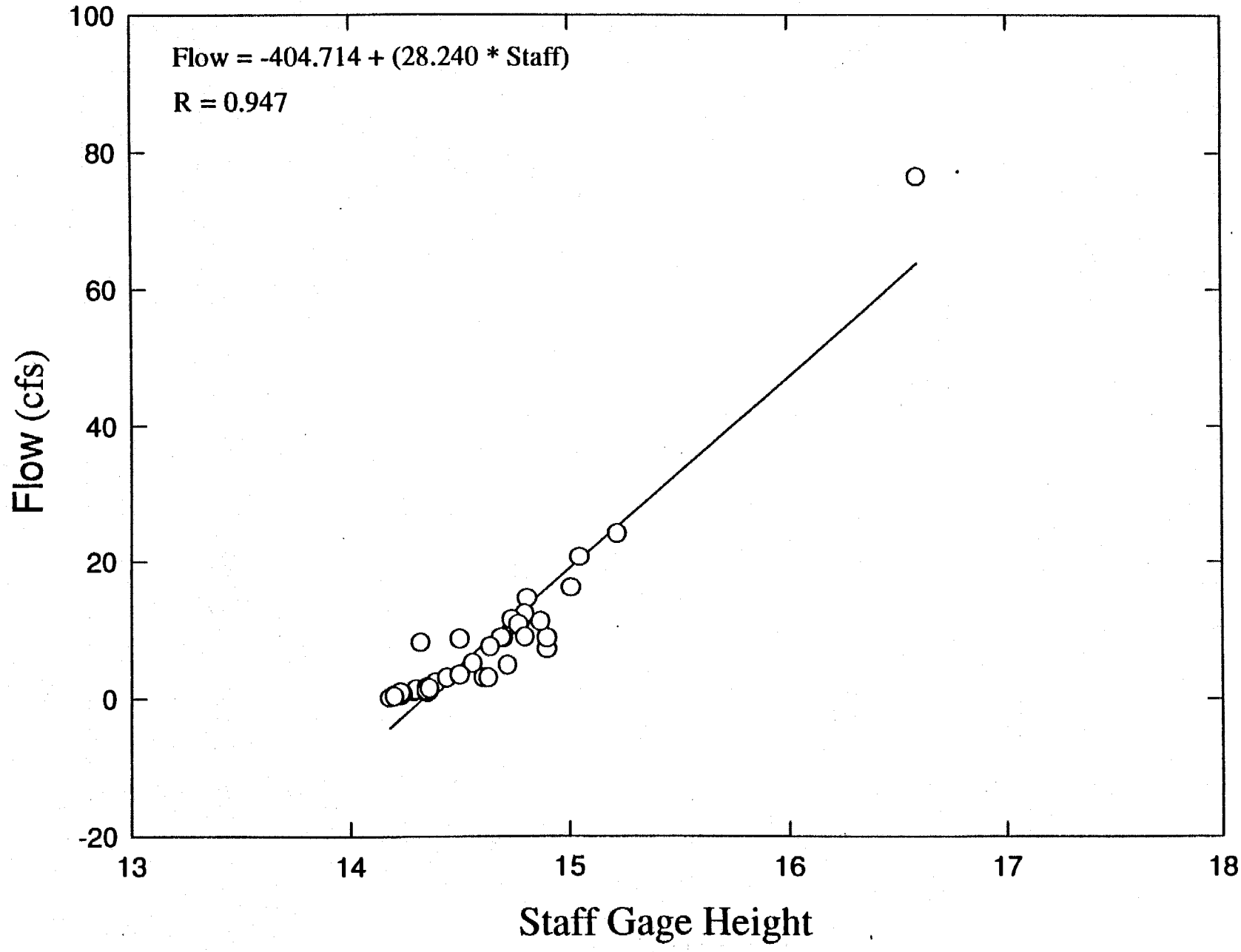
Station 2
Loon Cove Brook "B"



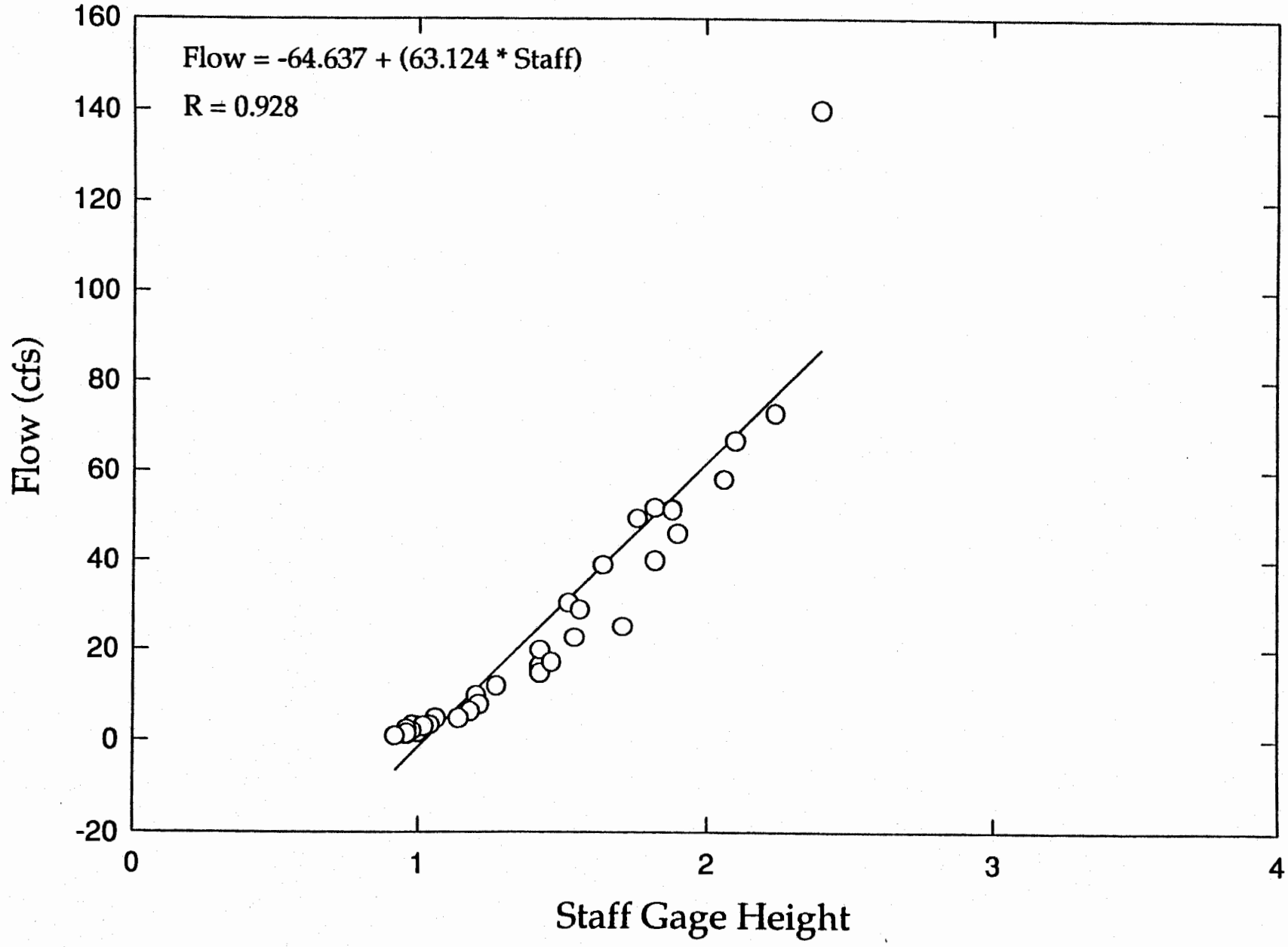
Station 3
Loon Cove Brook "A"



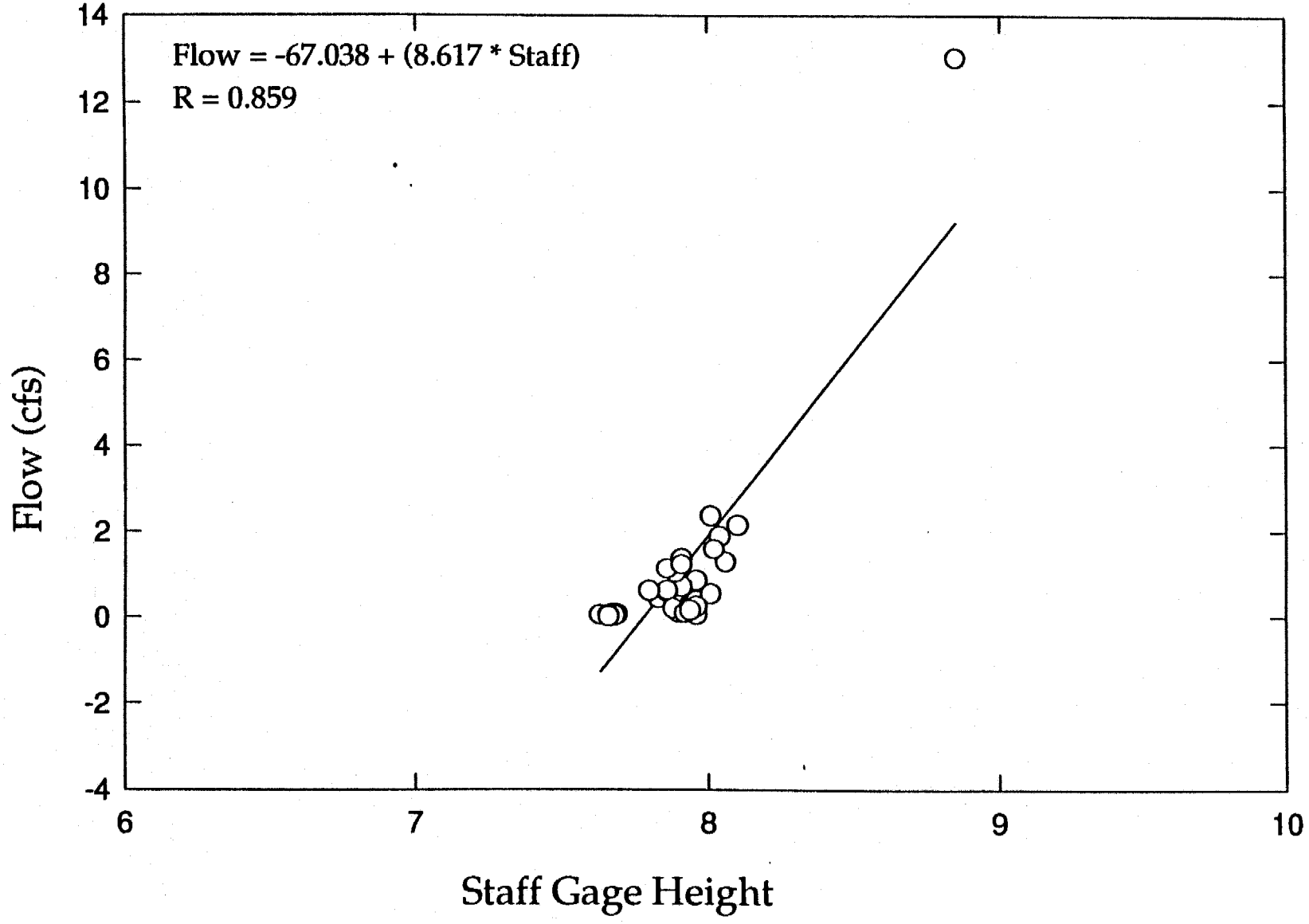
Station 4
Mountain Cove Brook



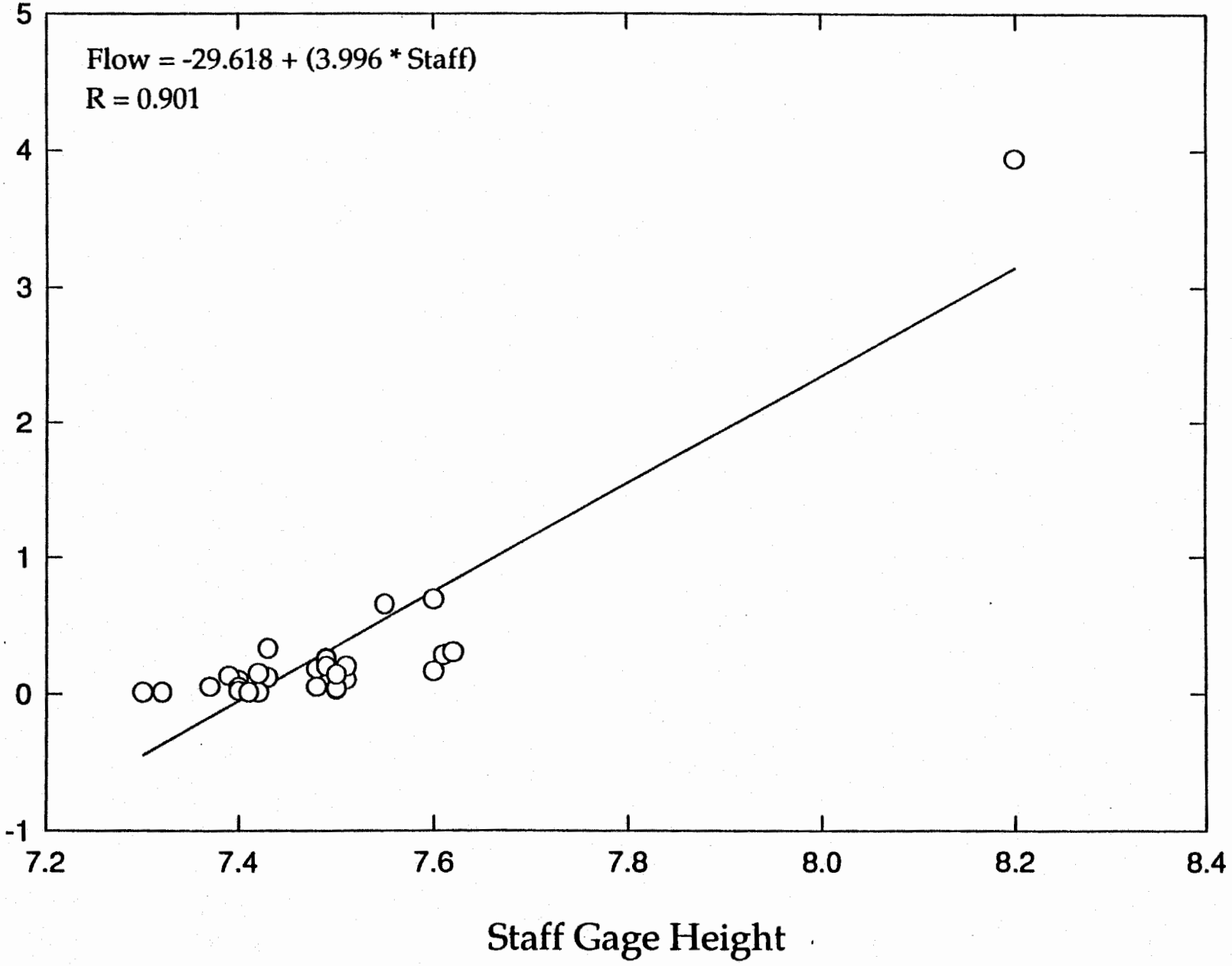
Station 5
Dolloff Dam



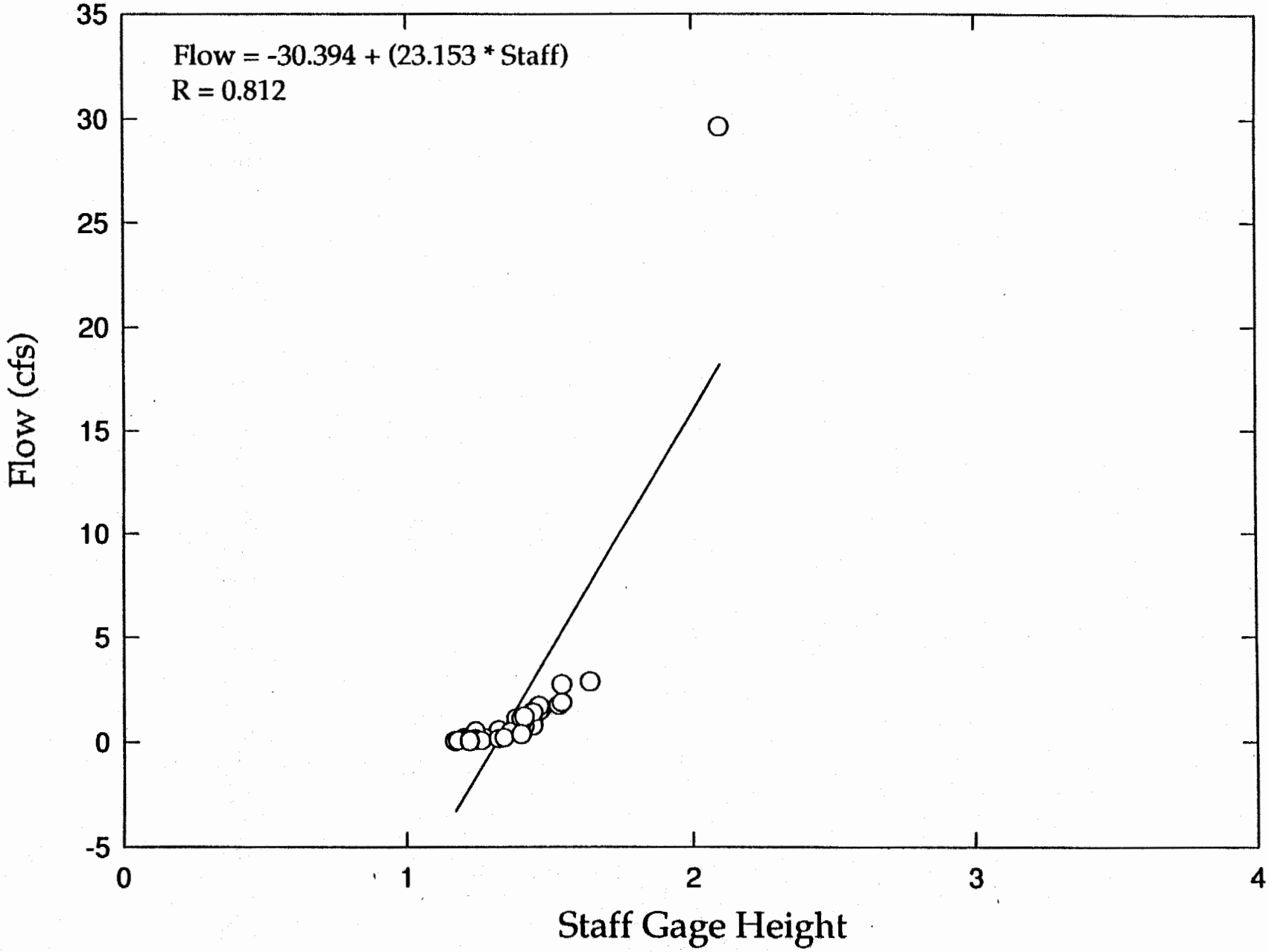
Station 6
Gove Dam Brook



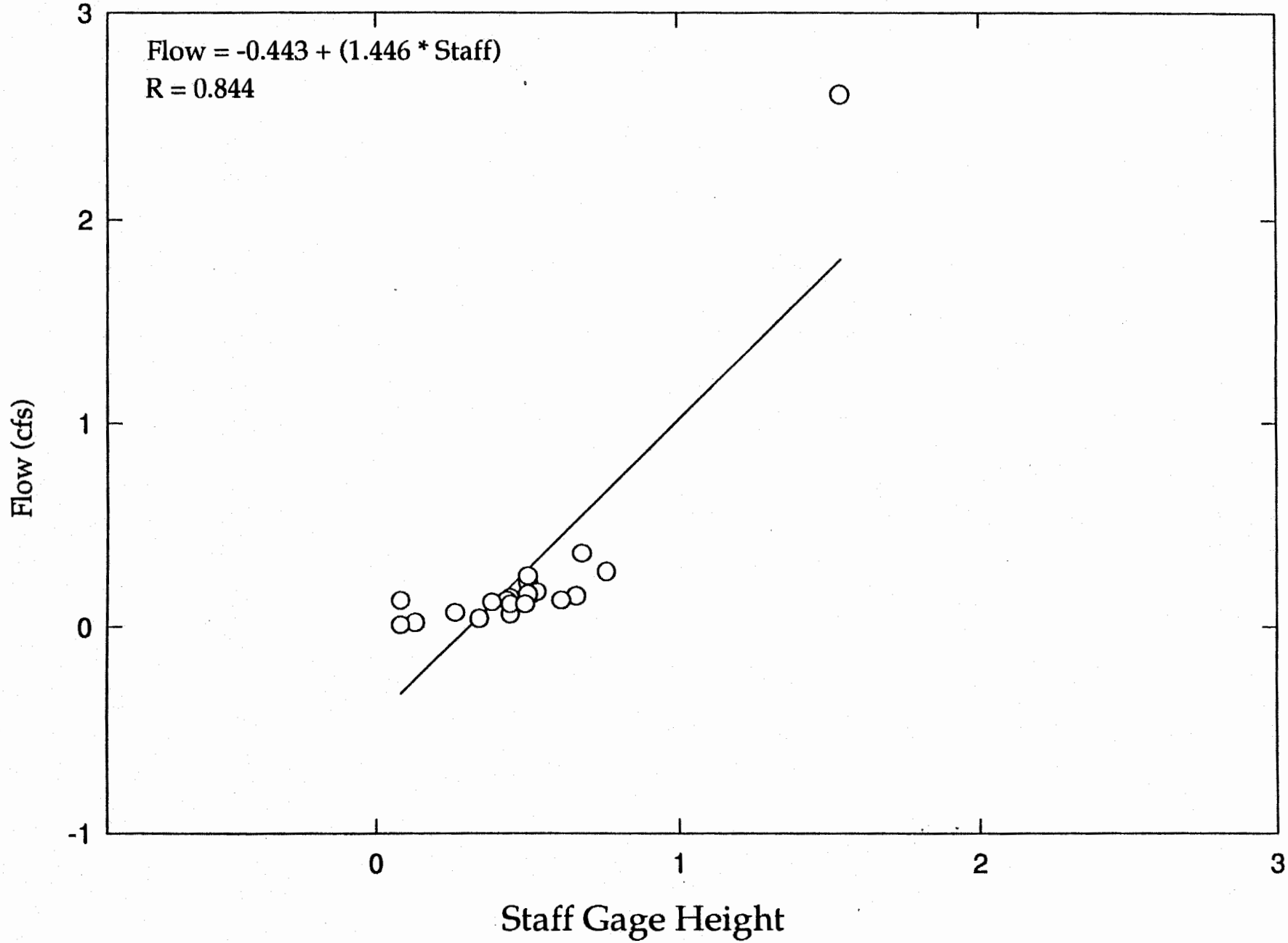
Station 7
White's Grove Brook



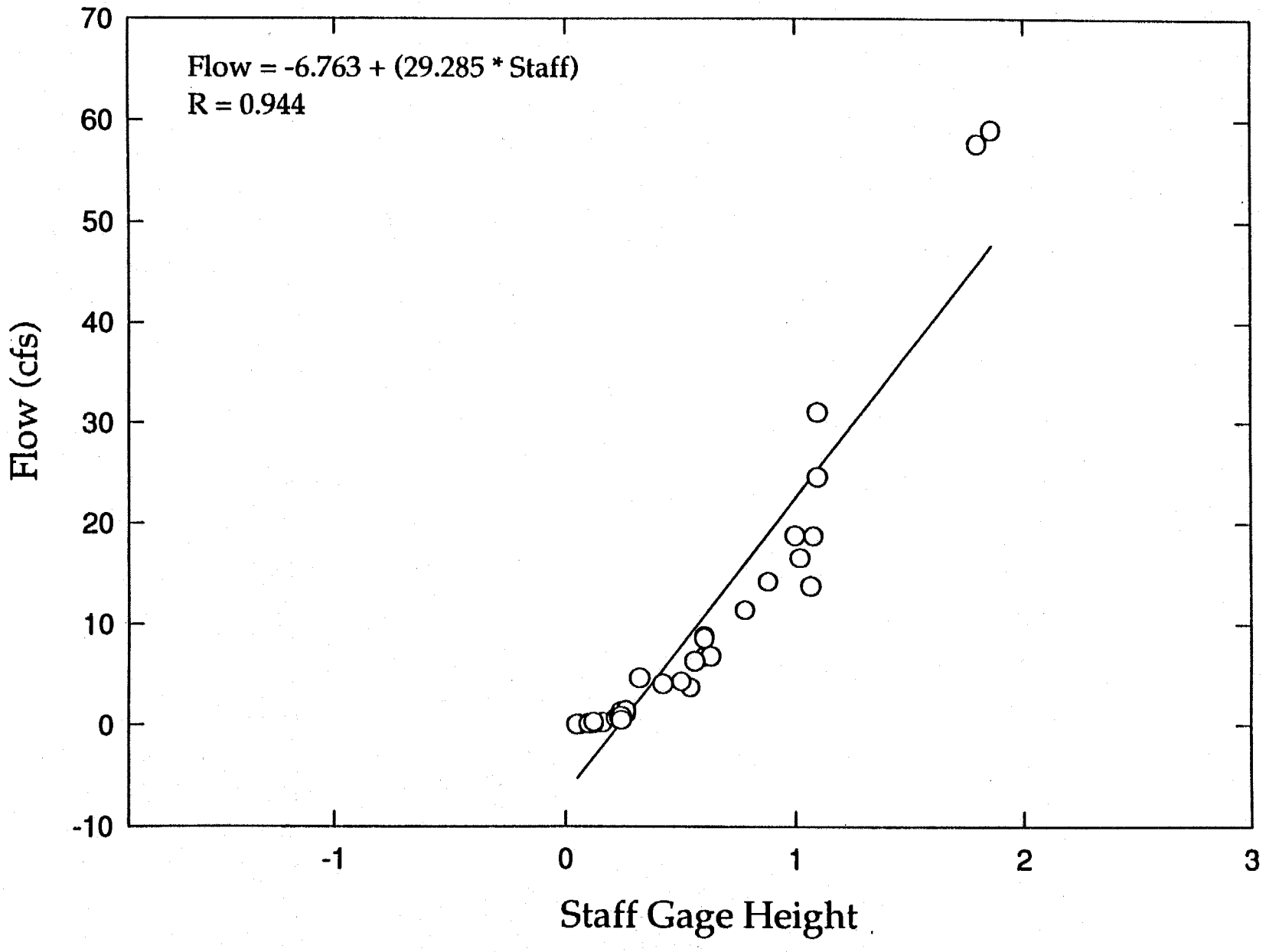
Station 8
Fernald's Brook "A"



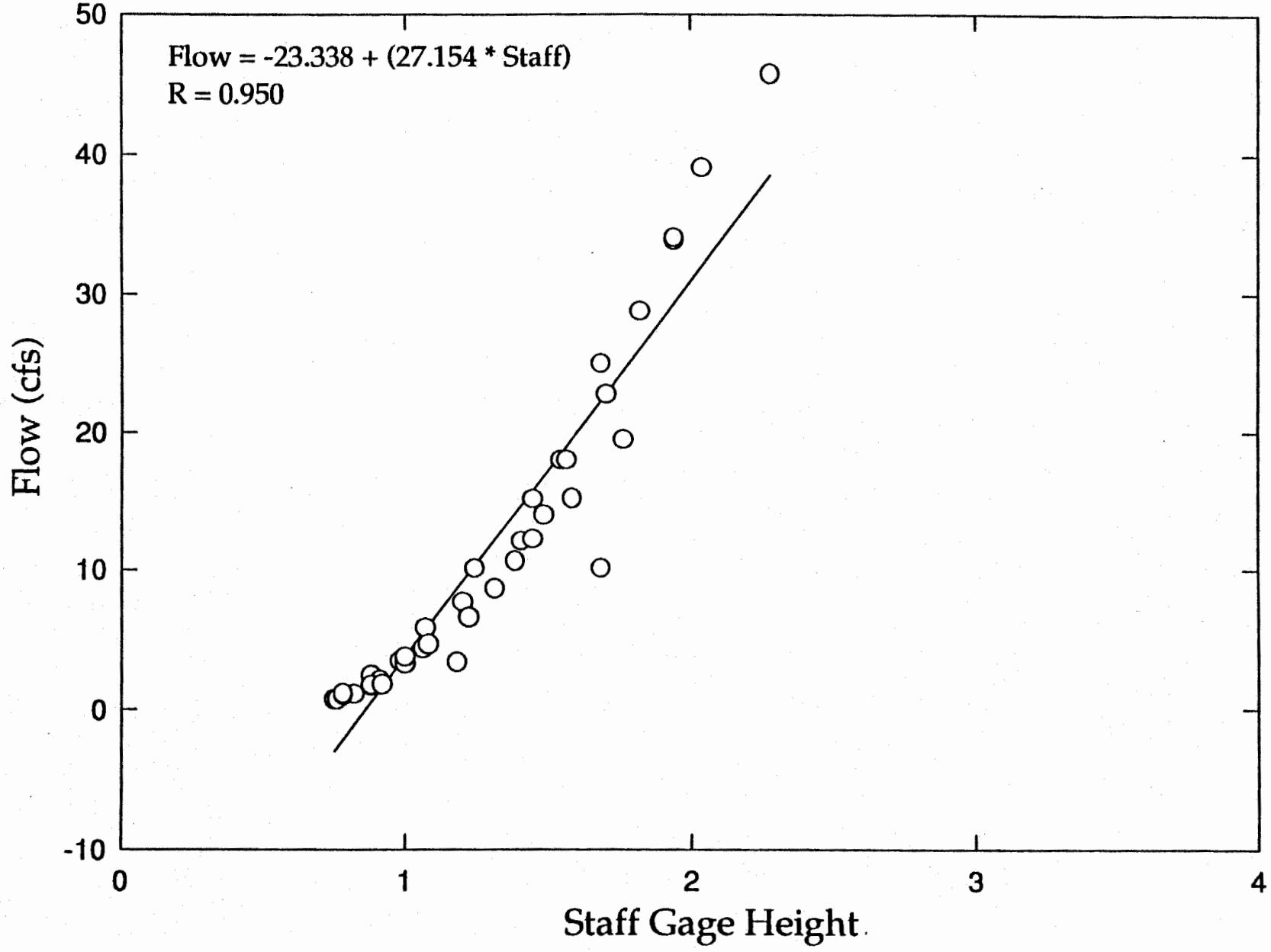
Station 9
Fernald's Brook "B"



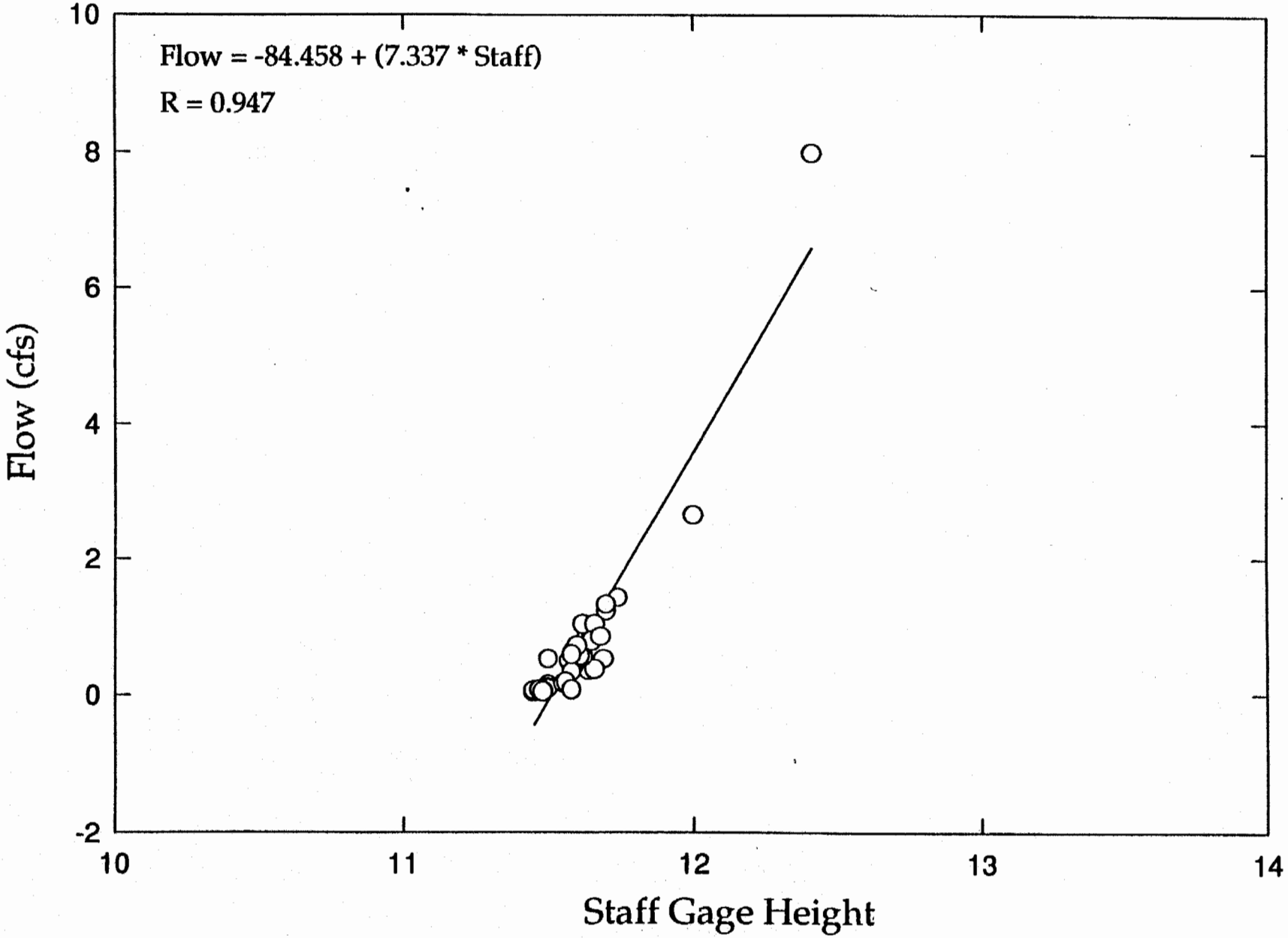
Station 10
Drown's Dam



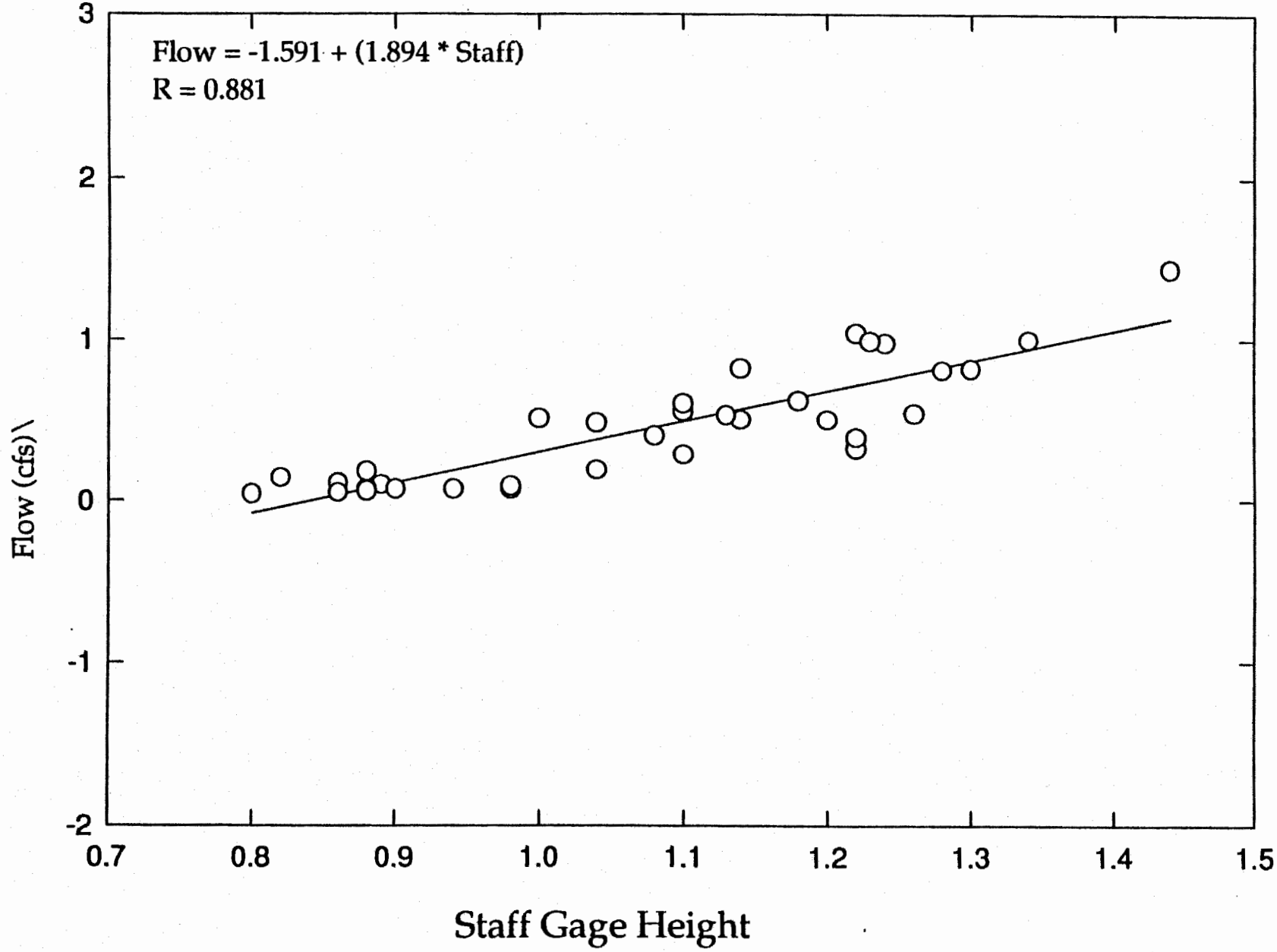
Station 11
Back Creek "B"



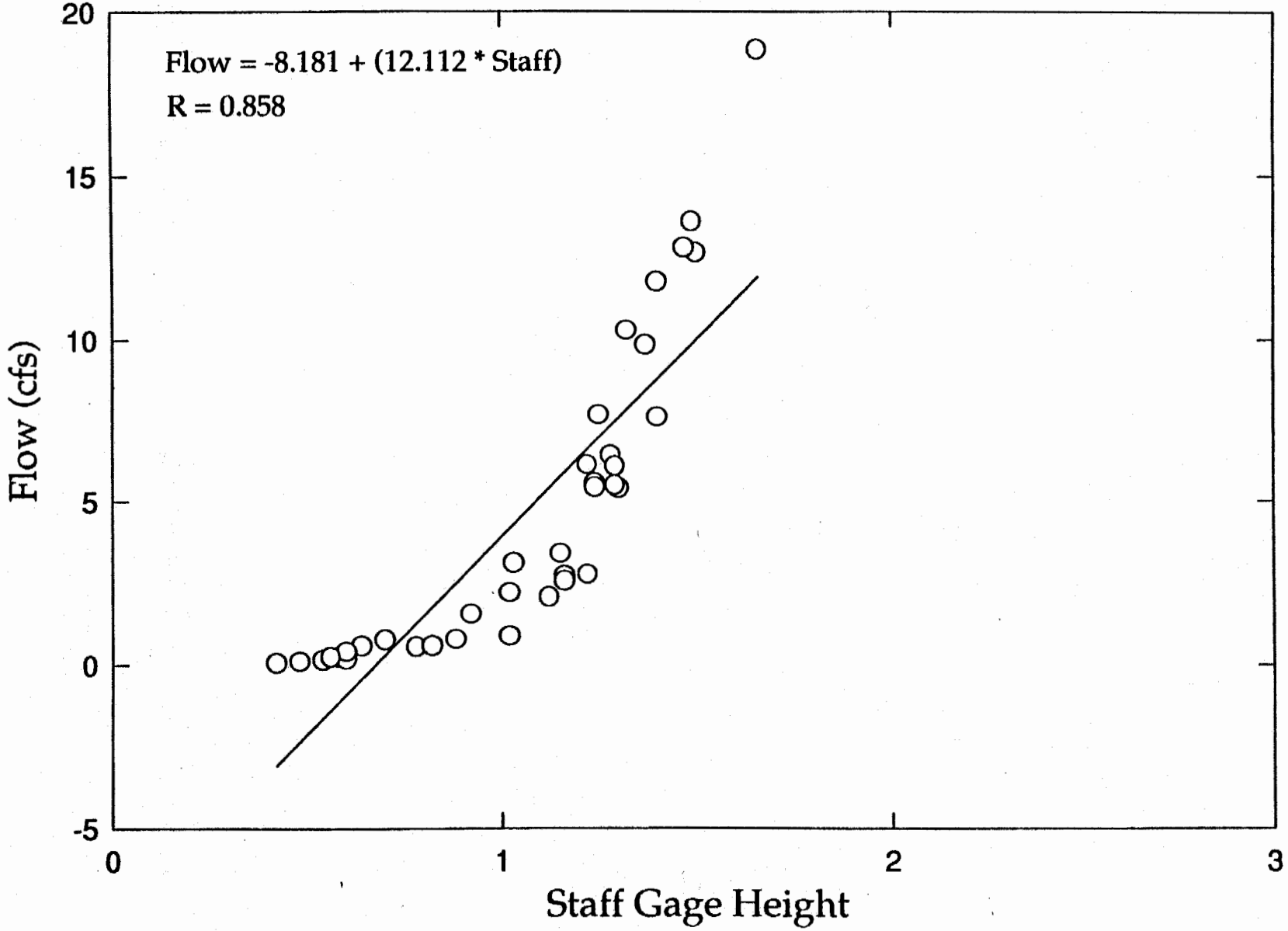
Station 12
Back Creek "A"



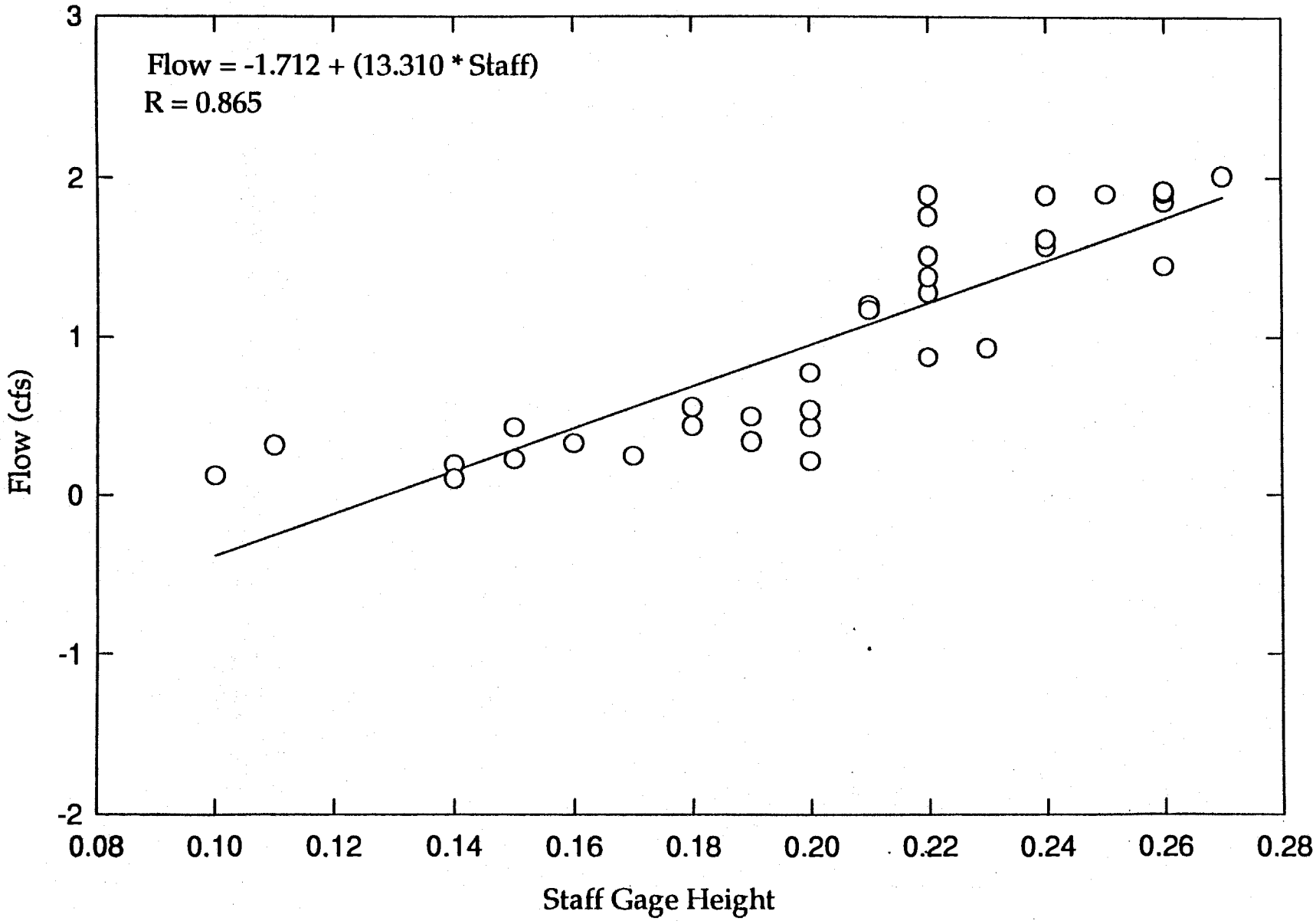
Station 13
Fundy Brook



Station 14
Round Pond Brook



Station 15
Burnham's Marsh Outlet (North)



APPENDIX VII-2

Pawtuckaway Lake Raw Staff Gage and Flow

Station 1

Date	Staff	Flow	Status	Comment
10/03/9	7.20	0.14	BOTH	
10/10/9	0.60	0.22	BOTH	NEW STAFF GAGE INSTALLED.
10/15/9	-99.0	-99.0	GAGE	PULLED OUT BOARDS ON
10/22/9	1.54	0.06	BOTH	NEW GAGE INSTALLED.
10/29/9	1.51	0.01	BOTH	
11/05/9	1.53	0.04	BOTH	ONE BOARD IN.
11/19/9	1.58	0.28	BOTH	
11/26/9	1.91	3.19	BOTH	
12/05/9	1.74	1.64	BOTH	
12/10/9	1.67	0.74	BOTH	
12/18/9	1.73	1.33	BOTH	
01/07/9	1.65	0.84	BOTH	
02/20/9	1.61	-99.0	GAGE	
02/26/9	1.61	-99.0	GAGE	
03/12/9	1.72	1.95	BOTH	
03/17/9	1.57	0.70	BOTH	
03/24/9	1.57	0.53	BOTH	
03/31/9	1.72	2.53	BOTH	
11/02/9	1.52	-99.0	GAGE	PLIA READINGS; AFTER 3
11/09/9	1.49	-99.0	GAGE	PLIA READINGS; AFTER DRY
11/16/9	1.53	-99.0	GAGE	PLIA READINGS; AFTER SOME
11/23/9	2.06	-99.0	GAGE	PLIA READINGS; AFTER
11/30/9	1.78	-99.0	GAGE	PLIA READINGS; AFTER SOME
12/07/9	1.68	-99.0	GAGE	PLIA READINGS; AFTER 2 -3
12/14/9	1.72	-99.0	GAGE	PLIA READINGS; RAIN.
12/21/9	1.72	-99.0	GAGE	PLIA READINGS; SNOWY.
12/28/9	1.58	-99.0	GAGE	PLIA READINGS;
01/04/9	1.59	-99.0	GAGE	PLIA READINGS
01/11/9	1.60	-99.0	GAGE	PLIA READINGS.
02/01/9	1.56	-99.0	GAGE	PLIA READINGS
02/08/9	1.54	-99.0	GAGE	PLIA READINGS; FLURRIES.
02/15/9	1.53	-99.0	GAGE	PLIA READINGS; THIN ICE
02/22/9	1.56	-99.0	GAGE	PLIA READINGS
02/29/9	1.60	-99.0	GAGE	PLIA READINGS
12/27/9	1.59	-99.0	GAGE	DES READINGS
12/31/9	1.68	-99.0	GAGE	DES READINGS
01/17/9	1.60	-99.0	GAGE	DES READINGS
03/10/9	1.57	-99.0	GAGE	DES READINGS
04/08/9	1.52	0.15	BOTH	DES FLOWS AND READINGS BY
04/14/9	1.54	0.20	BOTH	DES FLOWS AND GAGES. DD
03/07/9	1.61	-99.0	GAGE	PLIA GAGE READINGS DURING
03/14/9	1.65	-99.0	GAGE	PLIA GAGE READINGS;
03/21/9	1.56	-99.0	GAGE	PLIA GAGE READINGS; CLEAR
03/28/9	1.66	-99.0	GAGE	PLIA GAGE READINGS;
04/04/9	1.60	-99.0	GAGE	PLIA GAGE READINGS; CLEAR

Pawtuckaway Lake Raw Staff Gage and Flow

Station 1

Date	Staff	Flow	Status	Comment
04/11/9	1.53	-99.0	GAGE	PLIA GAGE READINGS; SLEET
01/21/9	1.56	-99.0	GAGE	DES GAGE READINGS.
01/28/9	1.57	-99.0	GAGE	DES GAGE READINGS.
02/03/9	1.56	-99.0	GAGE	DES GAGE READINGS
02/13/9	1.52	-99.0	GAGE	DES GAGE READINGS
04/21/9	1.60	0.25	BOTH	
04/18/9	1.64	-99.0	GAGE	PLIA GAGE READINGS
05/05/9	2.89	0.38	BOTH	UNIFORM DEPTH ACROSS
04/25/9	1.55	-99.0	GAGE	PLIA GAGE READINGS; COOL
05/02/9	2.88	-99.0	GAGE	PLIA GAGE READINGS; FOGGY
05/12/9	2.86	0.10	BOTH	DES flows and gages.
05/20/9	2.84	-99.0	GAGE	DES GAGES
05/28/9	2.82	-99.0	G	DES GAGES AND UPSTREAM
06/02/9	2.88	-99.0	G	DES GAGES
06/08/9	2.86	0.19	B	DES FLOWS AND GAGES
06/16/9	2.84	0.04	BOTH	
06/25/9	2.84	0.05	BOTH	
06/30/9	2.82	0.01	BOTH	
07/04/9	2.82	-99.0	GAGE	PLIA readings; raining.
07/06/9	2.84	0.06	BOTH	
07/17/9	2.84	0.07	BOTH	
05/09/9	2.88	-99.0	GAGE	PLIA readings; rainy.
05/16/9	2.88	-99.0	GAGE	PLIA readings; showers.
05/23/9	2.82	-99.0	GAGE	PLIA readings; hot and
05/30/9	2.81	-99.0	GAGE	PLIA readings; sunny and
06/06/9	3.02	-99.0	GAGE	PLIA readings; heavy rain
06/13/9	2.85	-99.0	GAGE	PLIA; dry.
06/20/9	2.89	-99.0	GAGE	PLIA; sunny.
06/27/9	2.82	-99.0	GAGE	PLIA; cloudy.
07/22/9	2.84	0.02	BOTH	
07/28/9	2.82	0.02	BOTH	
08/05/9	2.83	0.31	BOTH	
08/11/9	2.84	-99.0	GAGE	
09/02/9	2.76	-99.0	GAGE	no water over boards
08/19/9	2.88	-99.0	GAGE	
07/11/9	2.83	-99.0	GAGE	PLIA readings; dry and
07/18/9	2.85	-99.0	GAGE	PLIA readings; hot and
07/25/9	2.84	-99.0	GAGE	PLIA readings; warm
08/25/9	2.82	-99.0	GAGE	upstream flows not valid
09/10/9	2.82	-99.0	GAGE	Insignificant flow over
09/14/9	2.80	-99.0	GAGE	No flow; insignificant
09/21/9	2.82	-99.0	GAGE	gages only, flow meter
08/01/9	2.84	-99.0	GAGE	PLIA readings, mild with
08/08/9	2.82	-99.0	GAGE	PLIA; warm and sunny.
08/15/9	2.84	-99.0	GAGE	PLIA READINGS; cool and

Pawtuckaway Lake Raw Staff Gage and Flow

Station 1

Date	Staff	Flow	Status	Comment
08/22/9	2.82	-99.0	GAGE	PLIA READINGS; WARM AND
09/29/9	2.84	-99.0	GAGE	Flow over boards is from
10/05/9	2.82	-99.0	GAGE	
08/29/9	2.82	-99.0	GAGE	plia readings; early
09/05/9	2.84	-99.0	GAGE	plia; clear and cool
09/12/9	2.82	-99.0	GAGE	plia; foam at site,
09/19/9	2.82	-99.0	GAGE	plia; clear.
09/26/9	2.82	-99.0	GAGE	
10/03/9	2.82	-99.0	GAGE	plia, sunny.
10/13/9	2.84	0.54	BOTH	rain over weekend
10/21/9	1.57	-99.0	GAGE	flow meter dies, boards
10/10/9	2.94	-99.0	GAGE	plia readings; wet and
10/17/9	2.85	-99.0	GAGE	plia readings; cool and
10/20/9	1.56	-99.0	GAGE	gages only; video trib
10/28/9	1.52	0.14	BOTH	FLOWS BY SL AND MB;
11/02/9	1.54	0.07	BOTH	
10/24/9	1.50	-99.0	GAGE	PLIA READINGS
10/31/9	1.52	-99.0	GAGE	PLIA READINGS
11/13/9	1.56	-99.0	GAGE	
11/18/9	1.54	0.17	BOTH	
11/24/9	1.60	0.89	BOTH	Rain two days previous.
11/08/9	1.56	-99.0	GAGE	PLIA READINGS; OVERCAST.
11/14/9	1.56	-99.0	GAGE	PLIA READINGS; SUNNY AND
11/21/9	1.54	-99.0	GAGE	PLIA READINGS; OVERCAST.
11/28/9	1.62	-99.0	GAGE	plia gage readings
04/06/9	1.68	1.45	BOTH	SPRING RUNOFF; SL/MB

Pawtuckaway Lake Raw Staff Gage and Flow

Station 2

Date	Staff	Flow	Status	Comment
10/03/9	0.50	0.52	BOTH	
10/10/9	0.38	0.24	BOTH	
10/15/9	0.34	-99.0	GAGE	
10/22/9	0.34	0.26	BOTH	
10/29/9	0.31	0.11	BOTH	
11/05/9	0.32	0.15	BOTH	
11/19/9	0.38	0.51	BOTH	
11/26/9	0.56	0.71	BOTH	
12/05/9	0.46	0.78	BOTH	
12/10/9	0.45	0.54	BOTH	
12/18/9	0.51	0.22	BOTH	
01/07/9	0.46	0.42	BOTH	
02/20/9	0.46	-99.0	GAGE	
02/26/9	0.46	-99.0	GAGE	
03/12/9	0.60	0.77	BOTH	
03/17/9	0.44	0.20	BOTH	
03/24/9	0.40	0.27	BOTH	
03/31/9	0.58	0.92	BOTH	
11/02/9	0.31	-99.0	GAGE	
11/09/9	0.31	-99.0	GAGE	
11/16/9	0.44	-99.0	GAGE	
11/23/9	0.95	-99.0	GAGE	BEAVER DAM BETWEEN SITE
11/30/9	0.49	-99.0	GAGE	
12/07/9	0.44	-99.0	GAGE	
12/14/9	0.66	-99.0	GAGE	
12/21/9	0.53	-99.0	GAGE	
12/28/9	0.41	-99.0	GAGE	
01/04/9	0.43	-99.0	GAGE	
01/11/9	0.43	-99.0	GAGE	
02/01/9	0.42	-99.0	GAGE	
02/08/9	0.38	-99.0	GAGE	
02/15/9	0.38	-99.0	GAGE	
02/22/9	0.39	-99.0	GAGE	
02/29/9	0.50	-99.0	GAGE	SOLID ICE
12/27/9	0.40	-99.0	GAGE	
12/31/9	0.50	-99.0	GAGE	
01/17/9	0.53	-99.0	GAGE	
03/10/9	0.46	-99.0	GAGE	
04/08/9	0.41	0.39	BOTH	
04/14/9	0.40	0.48	BOTH	
03/07/9	0.49	-99.0	GAGE	
03/14/9	0.50	-99.0	GAGE	
03/21/9	0.42	-99.0	GAGE	
03/28/9	0.59	-99.0	GAGE	
04/04/9	0.47	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 2

Date	Staff	Flow	Status	Comment
04/11/9	0.40	-99.0	GAGE	
01/21/9	0.40	-99.0	GAGE	
01/28/9	0.58	-99.0	GAGE	
02/03/9	0.40	-99.0	GAGE	
02/13/9	0.42	-99.0	GAGE	
04/21/9	0.48	0.56	BOTH	
04/18/9	0.54	-99.0	GAGE	
04/27/9	0.46	0.41	BOTH	
05/05/9	0.45	0.37	BOTH	
04/25/9	0.44	-99.0	GAGE	
05/02/9	0.40	-99.0	GAGE	
05/12/9	0.38	0.19	BOTH	
05/20/9	0.32	-99.0	GAGE	
05/28/9	0.26	-99.0	G	
06/02/9	0.34	-99.0	G	
06/08/9	0.46	0.34	B	
06/16/9	0.28	0.06	BOTH	
06/25/9	0.26	0.04	BOTH	
06/30/9	0.24	0.02	BOTH	
07/06/9	0.26	0.05	BOTH	
07/17/9	0.26	0.02	BOTH	
05/09/9	0.41	-99.0	GAGE	
05/16/9	0.35	-99.0	GAGE	
05/23/9	0.30	-99.0	GAGE	
05/30/9	0.26	-99.0	GAGE	
06/06/9	0.70	-99.0	GAGE	
06/13/9	0.33	-99.0	GAGE	
06/20/9	0.26	-99.0	GAGE	
06/27/9	0.28	-99.0	GAGE	
07/22/9	0.26	0.06	BOTH	
07/28/9	0.22	0.02	BOTH	
08/05/9	0.26	0.14	BOTH	
08/11/9	0.24	-99.0	GAGE	
08/19/9	0.34	-99.0	GAGE	
07/04/9	0.25	-99.0	GAGE	
07/11/9	0.25	-99.0	GAGE	
07/18/9	0.28	-99.0	GAGE	
07/25/9	0.24	-99.0	GAGE	
08/25/9	0.24	-99.0	GAGE	
09/02/9	0.20	0.01	BOTH	
09/10/9	0.22	0.01	BOTH	
09/14/9	0.20	0.03	BOTH	
09/21/9	0.20	-99.0	GAGE	
08/01/9	0.26	-99.0	GAGE	
08/08/9	0.26	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 2

Date	Staff	Flow	Status	Comment
08/15/9	0.24	-99.0	GAGE	
10/05/9	0.20	0.01	BOTH	
08/22/9	0.28	-99.0	GAGE	
09/29/9	0.24	0.02	BOTH	
08/29/9	0.24	-99.0	GAGE	
09/05/9	0.24	-99.0	GAGE	
09/12/9	0.24	-99.0	GAGE	
09/19/9	0.24	-99.0	GAGE	
09/26/9	0.24	-99.0	GAGE	
10/03/9	0.22	-99.0	GAGE	
10/13/9	0.32	0.19	BOTH	
10/21/9	0.29	0.07	BOTH	
10/10/9	0.46	-99.0	GAGE	
10/17/9	0.30	-99.0	GAGE	
10/20/9	0.30	-99.0	GAGE	
10/28/9	0.28	0.05	BOTH	
11/02/9	0.28	0.07	BOTH	
10/24/9	0.28	-99.0	GAGE	
10/31/9	0.30	-99.0	GAGE	
11/13/9	0.38	-99.0	GAGE	
11/18/9	0.36	0.08	BOTH	
11/24/9	0.54	0.60	BOTH	
11/08/9	0.34	-99.0	GAGE	
11/14/9	0.38	-99.0	GAGE	
11/21/9	0.34	-99.0	GAGE	
11/28/9	0.58	-99.0	GAGE	
04/06/9	0.70	1.30	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 3

Date	Staff	Flow	Status	Comment
10/03/9	14.15	0.63	BOTH	
10/10/9	14.19	0.86	BOTH	
10/15/9	14.09	-99.0	GAGE	
10/22/9	14.07	0.64	BOTH	
10/29/9	14.01	0.63	BOTH	
11/05/9	13.98	0.19	BOTH	
11/19/9	14.07	0.65	BOTH	
11/26/9	14.37	1.87	BOTH	
12/05/9	14.15	0.86	BOTH	
12/10/9	14.12	1.38	BOTH	
12/18/9	14.25	0.39	BOTH	TWO DEGREES OUT.
01/07/9	14.16	0.51	BOTH	
02/20/9	14.10	-99.0	GAGE	
02/26/9	14.07	-99.0	GAGE	
03/12/9	14.43	2.44	BOTH	
03/17/9	14.08	0.83	BOTH	
03/24/9	14.01	0.44	BOTH	
03/31/9	14.36	1.33	BOTH	
11/02/9	14.00	-99.0	GAGE	
11/09/9	13.95	-99.0	GAGE	
11/16/9	14.14	-99.0	GAGE	
11/23/9	14.95	-99.0	GAGE	
11/30/9	14.21	-99.0	GAGE	SOME FOAM.
12/07/9	14.10	-99.0	GAGE	
12/14/9	14.44	-99.0	GAGE	
12/21/9	14.20	-99.0	GAGE	
12/28/9	14.03	-99.0	GAGE	
01/04/9	14.07	-99.0	GAGE	
01/11/9	14.07	-99.0	GAGE	
02/01/9	14.02	-99.0	GAGE	
02/08/9	13.90	-99.0	GAGE	HEAVY DUTY ICE
02/15/9	13.90	-99.0	GAGE	MUCH ICE
02/22/9	14.03	-99.0	GAGE	
02/29/9	15.42	-99.0	GAGE	SOLID ICE
12/27/9	14.07	-99.0	GAGE	
12/31/9	14.19	-99.0	GAGE	
01/17/9	14.41	-99.0	GAGE	
03/10/9	14.14	-99.0	GAGE	
04/08/9	14.10	0.70	BOTH	
04/14/9	14.10	0.72	BOTH	
03/07/9	14.11	-99.0	GAGE	
03/14/9	14.20	-99.0	GAGE	
03/21/9	14.04	-99.0	GAGE	
03/28/9	14.40	-99.0	GAGE	
04/04/9	14.20	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 3

Date	Staff	Flow	Status	Comment
04/11/9	14.09	-99.0	GAGE	
01/21/9	14.20	-99.0	GAGE	
01/28/9	14.22	-99.0	GAGE	
02/03/9	14.10	-99.0	GAGE	
02/13/9	-99.0	-99.0	GAGE	FROZEN SOLID.
04/21/9	14.26	1.43	BOTH	
04/18/9	14.25	-99.0	GAGE	
04/27/9	14.17	1.09	BOTH	
05/05/9	14.14	0.71	BOTH	
04/25/9	14.17	-99.0	GAGE	
05/02/9	14.03	-99.0	GAGE	
05/12/9	14.02	0.27	BOTH	
05/20/9	13.98	-99.0	GAGE	
05/28/9	13.91	0.36	B	
06/02/9	13.91	-99.0	G	
06/08/9	14.17	0.72	B	
06/16/9	13.90	0.32	BOTH	
06/25/9	13.88	0.18	BOTH	
06/30/9	13.84	0.13	BOTH	gage almost out of water
07/06/9	13.86	0.19	BOTH	
07/17/9	13.90	0.20	BOTH	
05/09/9	14.06	-99.0	GAGE	
05/16/9	14.00	-99.0	GAGE	
05/23/9	13.96	-99.0	GAGE	
05/30/9	13.87	-99.0	GAGE	
06/06/9	14.20	-99.0	GAGE	
06/13/9	13.97	-99.0	GAGE	
06/20/9	13.90	-99.0	GAGE	
06/27/9	13.88	-99.0	GAGE	
07/22/9	13.85	0.16	BOTH	
07/28/9	-99.0	0.08	FLOW	
08/05/9	13.83	0.33	BOTH	gage dry, read at stream
08/11/9	13.86	-99.0	GAGE	
08/19/9	13.95	-99.0	GAGE	
07/04/9	13.86	-99.0	GAGE	
07/11/9	13.85	-99.0	GAGE	
07/18/9	13.88	-99.0	GAGE	
07/25/9	13.84	-99.0	GAGE	gage dry; 13.84 or 13.80
09/02/9	-99.0	0.06	FLOW	gage dry
09/10/9	-99.0	0.08	FLOW	gage dry
09/14/9	13.78	0.05	BOTH	
09/21/9	-99.0	-99.0		Dry
08/01/9	14.85	-99.0	GAGE	
08/08/9	13.80	-99.0	GAGE	dry
08/15/9	13.83	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 3

Date	Staff	Flow	Status	Comment
08/22/9	13.88	-99.0	GAGE	
09/29/9	-99.0	0.04	FLOW	GAGE DRY
10/05/9	-99.0	0.04	FLOW	
08/29/9	13.78	-99.0	GAGE	dry
09/05/9	13.86	-99.0	GAGE	
09/12/9	13.80	-99.0	GAGE	
09/19/9	13.80	-99.0	GAGE	
09/26/9	13.76	-99.0	GAGE	
10/03/9	13.80	-99.0	GAGE	dry
10/13/9	14.94	0.33	BOTH	
10/21/9	13.86	0.16	BOTH	
10/10/9	14.08	-99.0	GAGE	
10/17/9	13.86	-99.0	GAGE	
10/20/9	13.85	-99.0	GAGE	
10/28/9	13.85	0.12	BOTH	
11/02/9	13.83	0.10	BOTH	
10/24/9	13.82	-99.0	GAGE	
10/31/9	13.87	-99.0	GAGE	
11/13/9	14.05	-99.0	GAGE	
11/18/9	14.09	0.35	BOTH	
11/24/9	14.21	1.34	BOTH	
11/08/9	14.05	-99.0	GAGE	
11/14/9	14.12	-99.0	GAGE	
11/21/9	13.96	-99.0	GAGE	
03/30/9	15.61	6.70	BOTH	SPRING RUNOFF EVENT; ONLY
04/06/9	14.50	2.58	BOTH	
04/06/9	14.50	2.58	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 4

Date	Staff	Flow	Status	Comment
10/03/9	14.50	8.63	BOTH	
10/10/9	14.90	7.12	BOTH	BEAVER ACTIVITY
10/15/9	14.79	-99.0	GAGE	
10/22/9	14.72	4.86	BOTH	
10/29/9	14.61	2.98	BOTH	
11/05/9	14.63	2.98	BOTH	
11/19/9	14.90	8.79	BOTH	
11/26/9	15.50	18.42	BOTH	
12/05/9	14.78	11.18	BOTH	
12/10/9	14.76	11.38	BOTH	
12/18/9	14.87	11.15	BOTH	
01/07/9	14.75	10.48	BOTH	
02/20/9	14.65	-99.0	GAGE	
02/26/9	14.64	-99.0	GAGE	
03/12/9	15.05	20.61	BOTH	
03/17/9	14.69	8.69	BOTH	
03/24/9	14.56	5.12	BOTH	
03/31/9	15.01	16.15	BOTH	
11/02/9	14.62	-99.0	GAGE	
11/09/9	14.58	-99.0	GAGE	
11/16/9	14.88	-99.0	GAGE	
11/23/9	15.57	-99.0	GAGE	
11/30/9	14.95	-99.0	GAGE	
12/07/9	14.72	-99.0	GAGE	
12/14/9	14.60	-99.0	GAGE	
12/21/9	14.80	-99.0	GAGE	
12/28/9	14.64	-99.0	GAGE	
01/04/9	14.66	-99.0	GAGE	
01/11/9	14.66	-99.0	GAGE	
02/01/9	14.63	-99.0	GAGE	
02/08/9	14.49	-99.0	GAGE	
02/15/9	14.49	-99.0	GAGE	
02/22/9	14.54	-99.0	GAGE	
02/29/9	14.54	-99.0	GAGE	
12/27/9	14.65	-99.0	GAGE	
12/31/9	14.76	-99.0	GAGE	
01/17/9	14.65	-99.0	GAGE	
03/10/9	14.67	-99.0	GAGE	
04/08/9	14.70	8.69	BOTH	
04/14/9	14.69	8.85	BOTH	
03/07/9	14.70	-99.0	GAGE	
03/14/9	14.84	-99.0	GAGE	
03/21/9	14.62	-99.0	GAGE	
03/28/9	15.00	-99.0	GAGE	
04/04/9	14.78	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 4

Date	Staff	Flow	Status	Comment
04/11/9	14.68	-99.0	GAGE	BEAVER DAM HAS BREACHED
01/21/9	14.59	-99.0	GAGE	
01/28/9	14.65	-99.0	GAGE	
02/03/9	14.55	-99.0	GAGE	
02/13/9	14.45	-99.0	GAGE	
04/21/9	14.81	14.57	BOTH	
04/18/9	14.86	-99.0	GAGE	
04/27/9	14.80	12.27	BOTH	
05/05/9	14.74	11.46	BOTH	
04/25/9	14.80	-99.0	GAGE	
05/02/9	14.72	-99.0	GAGE	
05/12/9	14.64	7.52	BOTH	
05/20/9	14.48	-99.0	GAGE	
05/28/9	14.36	1.78	B	
06/02/9	14.80	-99.0	G	
06/08/9	14.77	10.74	B	
06/16/9	14.39	2.32	BOTH	
06/25/9	14.35	1.45	BOTH	
06/30/9	14.29	0.99	BOTH	
07/06/9	14.30	1.33	BOTH	
07/17/9	14.36	1.20	BOTH	
05/09/9	14.68	-99.0	GAGE	
05/16/9	14.58	-99.0	GAGE	
05/23/9	14.44	-99.0	GAGE	
05/30/9	14.30	-99.0	GAGE	
06/06/9	14.80	-99.0	GAGE	
06/13/9	14.46	-99.0	GAGE	
06/20/9	14.32	-99.0	GAGE	
06/27/9	14.30	-99.0	GAGE	
07/22/9	14.35	0.93	BOTH	
07/28/9	14.23	0.44	BOTH	
08/05/9	14.32	8.12	BOTH	
08/11/9	14.35	-99.0	GAGE	
08/19/9	14.56	-99.0	GAGE	
07/04/9	14.24	-99.0	GAGE	
07/11/9	14.82	-99.0	GAGE	
07/18/9	14.40	-99.0	GAGE	
07/25/9	14.26	-99.0	GAGE	
08/25/9	14.24	-99.0	GAGE	
09/02/9	14.18	0.17	BOTH	
09/10/9	14.24	0.67	BOTH	
09/14/9	14.20	0.52	BOTH	
09/21/9	14.18	-99.0	GAGE	
08/01/9	14.30	-99.0	GAGE	
08/08/9	14.24	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 4

Date	Staff	Flow	Status	Comment
08/15/9	14.24	-99.0	GAGE	
08/22/9	14.32	-99.0	GAGE	
09/29/9	14.23	0.95	BOTH	
10/05/9	14.20	0.36	BOTH	
08/29/9	14.24	-99.0	GAGE	
09/05/9	14.28	-99.0	GAGE	
09/12/9	14.22	-99.0	GAGE	
09/19/9	14.20	-99.0	GAGE	
09/26/9	14.19	-99.0	GAGE	
10/03/9	14.24	-99.0	GAGE	
10/13/9	14.44	3.01	BOTH	
10/21/9	14.35	1.62	BOTH	
10/10/9	14.52	-99.0	GAGE	
10/17/9	14.38	-99.0	GAGE	
10/28/9	14.35	1.22	BOTH	
10/20/9	14.34	-99.0	GAGE	
11/02/9	14.36	1.48	BOTH	
10/24/9	14.32	-99.0	GAGE	
10/31/9	14.37	-99.0	GAGE	
11/13/9	14.58	-99.0	GAGE	
11/18/9	14.50	3.44	BOTH	
11/24/9	14.80	8.94	BOTH	
11/08/9	14.54	-99.0	GAGE	
11/14/9	14.60	-99.0	GAGE	
11/21/9	14.48	-99.0	GAGE	
11/28/9	14.94	-99.0	GAGE	
03/30/9	16.59	76.39	BOTH	
04/06/9	15.22	24.07	BOTH	
03/30/9	15.61	6.70	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 5

Date	Staff	Flow	Status	Comment
10/03/9	1.52	30.33	BOTH	
10/10/9	1.64	38.84	BOTH	
10/15/9	1.52	-99.0	GAGE	
10/22/9	2.06	58.05	BOTH	FLOW RECORDED AT
10/29/9	1.71	24.95	BOTH	
11/05/9	1.60	-99.0	GAGE	FLOW METER DIES AT THIS
11/19/9	1.82	51.74	BOTH	
11/26/9	2.40	139.9	BOTH	
12/05/9	2.12	-99.0	GAGE	
12/10/9	1.88	51.42	BOTH	
12/18/9	2.10	66.60	BOTH	
01/07/9	1.88	51.20	BOTH	
02/20/9	1.58	-99.0	GAGE	
02/26/9	0.40	-99.0	GAGE	LAKE GAGE ON DAM = 19.80
03/12/9	1.20	9.63	BOTH	
03/17/9	1.42	16.32	BOTH	
03/24/9	1.42	19.72	BOTH	
03/31/9	1.90	45.93	BOTH	
11/02/9	1.80	-99.0	GAGE	
11/09/9	1.80	-99.0	GAGE	
11/16/9	2.08	-99.0	GAGE	
11/23/9	3.35	-99.0	GAGE	
11/30/9	2.20	-99.0	GAGE	
12/07/9	2.02	-99.0	GAGE	
12/14/9	1.95	-99.0	GAGE	
12/21/9	2.00	-99.0	GAGE	
12/28/9	1.75	-99.0	GAGE	
01/04/9	1.68	-99.0	GAGE	
01/11/9	1.78	-99.0	GAGE	
02/01/9	1.70	-99.0	GAGE	
02/08/9	1.50	-99.0	GAGE	
02/15/9	0.98	-99.0	GAGE	
02/22/9	1.28	-99.0	GAGE	
02/29/9	1.20	-99.0	GAGE	
12/27/9	1.75	-99.0	GAGE	
12/31/9	1.82	-99.0	GAGE	
01/17/9	1.82	-99.0	GAGE	
03/10/9	1.04	-99.0	GAGE	LAKE GAGE = 20.89
04/08/9	1.76	49.36	BOTH	
04/14/9	1.42	14.67	BOTH	GAGE ON DAM READS: 23.00.
03/07/9	1.00	-99.0	GAGE	
03/14/9	1.30	-99.0	GAGE	
03/21/9	1.40	-99.0	GAGE	
03/28/9	1.59	-99.0	GAGE	
04/04/9	1.82	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 5

Date	Staff	Flow	Status	Comment
04/11/9	1.36	-99.0	GAGE	
01/21/9	1.64	-99.0	GAGE	
01/28/9	1.82	-99.0	GAGE	
02/03/9	1.58	-99.0	GAGE	
02/13/9	1.40	-99.0	GAGE	
04/21/9	1.21	7.74	BOTH	GAGE AT DAM = 23.80 AND
04/18/9	1.10	-99.0	GAGE	
04/27/9	1.06	4.80	BOTH	
05/05/9	1.18	6.22	BOTH	LAKE GAGE= 25.20
04/25/9	1.08	-99.0	GAGE	
05/02/9	1.08	-99.0	GAGE	
05/12/9	1.27	11.82	BOTH	
05/20/9	1.14	-99.0	GAGE	
05/28/9	0.96	-99.0	G	
06/02/9	1.09	-99.0	G	
06/08/9	1.54	22.57	B	
06/16/9	1.00	2.95	BOTH	
06/25/9	0.95	1.31	BOTH	
06/30/9	0.96	1.17	BOTH	
07/06/9	0.98	3.13	BOTH	
07/17/9	1.00	1.67	BOTH	
05/09/9	1.30	-99.0	GAGE	
05/16/9	1.26	-99.0	GAGE	
05/23/9	1.10	-99.0	GAGE	
05/30/9	0.96	-99.0	GAGE	
06/06/9	1.36	-99.0	GAGE	
06/13/9	1.16	-99.0	GAGE	
06/20/9	0.96	-99.0	GAGE	
06/27/9	0.98	-99.0	GAGE	
07/22/9	1.06	4.62	BOTH	
07/28/9	1.04	3.23	BOTH	
08/05/9	1.02	2.97	BOTH	
08/11/9	1.04	-99.0	GAGE	
08/19/9	1.16	-99.0	GAGE	
07/04/9	1.00	-99.0	GAGE	
07/11/9	1.02	-99.0	GAGE	
07/18/9	1.06	-99.0	GAGE	
07/25/9	1.06	-99.0	GAGE	
08/25/9	1.00	-99.0	GAGE	
09/02/9	0.96	2.25	BOTH	
09/10/9	0.98	1.94	BOTH	
09/14/9	0.96	2.39	BOTH	
09/21/9	0.96	-99.0	GAGE	
08/01/9	1.08	-99.0	GAGE	
08/08/9	1.02	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 5

Date	Staff	Flow	Status	Comment
08/15/9	1.08	-99.0	GAGE	
08/22/9	1.08	-99.0	GAGE	
09/29/9	0.96	1.39	BOTH	
10/05/9	0.92	0.80	BOTH	
08/29/9	1.02	-99.0	GAGE	
09/05/9	0.98	-99.0	GAGE	
09/12/9	1.00	-99.0	GAGE	
09/19/9	1.00	-99.0	GAGE	
09/26/9	0.98	-99.0	GAGE	
10/03/9	0.96	-99.0	GAGE	
10/13/9	1.14	4.64	BOTH	
10/21/9	1.56	28.77	BOTH	
10/10/9	1.02	-99.0	GAGE	
10/17/9	1.56	-99.0	GAGE	
10/20/9	1.26	-99.0	GAGE	
10/28/9	1.82	39.83	BOTH	FLOWED FROM SPILLWAY.
11/02/9	1.46	17.08	BOTH	
10/24/9	1.28	-99.0	GAGE	
10/31/9	1.60	-99.0	GAGE	
11/13/9	1.40	-99.0	GAGE	
11/18/9	2.24	72.65	BOTH	boards pulled yesterday.
11/24/9	1.98	-99.0	GAGE	
11/08/9	1.50	-99.0	GAGE	
11/14/9	1.42	-99.0	GAGE	
11/21/9	1.98	-99.0	GAGE	
11/28/9	2.98	-99.0	GAGE	
03/30/9	2.50	-99.0	GAGE	
04/06/9	2.50	-99.0	GAGE	
03/30/9	2.50	-99.0	GAGE	
04/06/9	2.50	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 6

Date	Staff	Flow	Status	Comment
10/03/9	7.95	0.68	BOTH	
10/10/9	7.94	0.28	BOTH	
10/15/9	7.91	-99.0	GAGE	
10/22/9	7.93	0.18	BOTH	
10/29/9	7.90	0.10	BOTH	
11/05/9	7.91	-99.0	GAGE	
11/19/9	7.96	0.36	BOTH	
12/05/9	8.00	-99.0	GAGE	
12/10/9	8.01	0.53	BOTH	
12/18/9	8.06	1.28	BOTH	
01/07/9	7.96	0.85	BOTH	
02/20/9	8.00	-99.0	GAGE	
02/26/9	8.03	-99.0	GAGE	
03/12/9	8.04	1.88	BOTH	
03/17/9	7.91	0.70	BOTH	
03/24/9	7.83	0.44	BOTH	
03/31/9	8.01	2.36	BOTH	
11/02/9	7.94	-99.0	GAGE	
11/09/9	7.92	-99.0	GAGE	
11/16/9	8.00	-99.0	GAGE	
11/23/9	8.50	-99.0	GAGE	
11/30/9	7.99	-99.0	GAGE	FOAMY
12/07/9	7.99	-99.0	GAGE	CHIPPED ICE OUT.
12/14/9	8.10	-99.0	GAGE	
12/21/9	7.95	-99.0	GAGE	
12/28/9	7.92	-99.0	GAGE	
01/04/9	7.90	-99.0	GAGE	
01/11/9	8.00	-99.0	GAGE	LOTS OF ICE.
02/01/9	7.92	-99.0	GAGE	
02/08/9	7.81	-99.0	GAGE	
02/15/9	7.75	-99.0	GAGE	
02/22/9	7.95	-99.0	GAGE	CLEARED ICE
02/29/9	8.00	-99.0	GAGE	
12/27/9	7.90	-99.0	GAGE	
12/31/9	8.12	-99.0	GAGE	
01/17/9	7.90	-99.0	GAGE	
03/10/9	7.92	-99.0	GAGE	
04/08/9	7.86	0.58	BOTH	
04/14/9	7.86	0.62	BOTH	
03/07/9	7.90	-99.0	GAGE	
03/14/9	8.12	-99.0	GAGE	
03/21/9	7.86	-99.0	GAGE	
03/28/9	8.05	-99.0	GAGE	
04/04/9	7.90	-99.0	GAGE	
04/11/9	7.85	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 6

Date	Staff	Flow	Status	Comment
01/21/9	7.89	-99.0	GAGE	
01/28/9	7.85	-99.0	GAGE	
02/03/9	7.90	-99.0	GAGE	
02/13/9	7.92	-99.0	GAGE	
04/21/9	7.91	1.36	BOTH	SEPTIC REPAIRS UNDERWAY
04/18/9	7.98	-99.0	GAGE	
04/27/9	7.89	1.04	BOTH	
05/05/9	7.86	1.12	BOTH	
04/25/9	7.98	-99.0	GAGE	
05/02/9	7.87	-99.0	GAGE	
05/12/9	7.80	0.61	BOTH	
05/20/9	7.74	-99.0	GAGE	
05/28/9	7.67	0.05	B	
06/02/9	7.79	-99.0	G	
06/08/9	7.91	1.22	B	
06/16/9	7.69	0.06	BOTH	
06/25/9	7.68	0.04	BOTH	
06/30/9	7.60	0.00	BOTH	
07/06/9	7.68	0.06	BOTH	
07/17/9	7.68	0.04	BOTH	
05/09/9	7.86	-99.0	GAGE	
05/16/9	7.82	-99.0	GAGE	
05/23/9	7.72	-99.0	GAGE	
05/30/9	7.66	-99.0	GAGE	
06/06/9	8.20	-99.0	GAGE	
06/13/9	7.74	-99.0	GAGE	
06/20/9	7.66	-99.0	GAGE	
06/27/9	7.65	-99.0	GAGE	
07/22/9	7.68	0.03	BOTH	
07/28/9	7.62	-99.0	GAGE	
08/05/9	7.63	0.04	BOTH	
08/11/9	7.69	-99.0	GAGE	
08/19/9	7.84	-99.0	GAGE	
07/04/9	7.59	-99.0	GAGE	
07/11/9	7.68	-99.0	GAGE	
07/18/9	7.70	-99.0	GAGE	
07/25/9	7.68	-99.0	GAGE	
08/25/9	7.66	-99.0	GAGE	
09/02/9	7.61	-99.0	GAGE	insignificant flow
09/10/9	7.66	0.04	BOTH	
09/14/9	7.66	0.02	BOTH	
09/21/9	7.60	-99.0	GAGE	
08/01/9	7.73	-99.0	GAGE	
08/08/9	7.62	-99.0	GAGE	
08/15/9	7.66	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 6

Date	Staff	Flow	Status	Comment
08/22/9	7.74	-99.0	GAGE	
09/29/9	7.66	0.03	BOTH	
10/05/9	7.66	0.01	BOTH	
09/05/9	7.74	-99.0	GAGE	
10/13/9	7.88	0.20	BOTH	
10/21/9	7.92	0.09	BOTH	
10/10/9	7.90	-99.0	GAGE	
10/17/9	7.90	-99.0	GAGE	
10/20/9	7.92	-99.0	GAGE	
10/28/9	7.96	0.05	BOTH	
11/02/9	7.96	0.24	BOTH	
10/24/9	7.92	-99.0	GAGE	
10/31/9	7.96	-99.0	GAGE	
11/13/9	8.06	-99.0	GAGE	
11/18/9	7.94	0.15	BOTH	
11/24/9	8.02	1.58	BOTH	
11/08/9	7.97	-99.0	GAGE	
11/14/9	8.00	-99.0	GAGE	
11/21/9	7.92	-99.0	GAGE	
11/28/9	8.06	-99.0	GAGE	
03/30/9	8.85	13.03	BOTH	
04/06/9	8.10	2.14	BOTH	
03/30/9	8.85	13.03	BOTH	
04/06/9	8.10	2.14	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 7

Date	Staff	Flow	Status	Comment
10/03/9	7.37	0.05	BOTH	
10/10/9	7.42	0.10	BOTH	
10/15/9	7.41	-99.0	GAGE	
10/22/9	7.48	0.05	BOTH	
10/29/9	7.50	0.03	BOTH	
11/05/9	7.50	-99.0	GAGE	
11/19/9	7.51	0.10	BOTH	
11/26/9	7.61	0.28	BOTH	
12/05/9	7.54	-99.0	GAGE	
12/10/9	7.62	0.30	BOTH	
12/18/9	7.60	0.16	BOTH	
01/07/9	7.43	0.33	BOTH	
02/20/9	-99.0	0.11	FLOW	GAGE FROZEN IN.
02/26/9	-99.0	0.64	FLOW	GAGE FROZEN.
03/12/9	7.51	0.20	BOTH	
03/17/9	7.43	0.12	BOTH	
03/24/9	7.41	0.05	BOTH	
03/31/9	7.55	0.65	BOTH	
11/02/9	7.53	-99.0	GAGE	
11/09/9	7.48	-99.0	GAGE	
11/16/9	7.50	-99.0	GAGE	
11/23/9	7.88	-99.0	GAGE	
11/30/9	7.54	-99.0	GAGE	CLEARED ICE.
12/07/9	7.52	-99.0	GAGE	CLEARED ICE OUT.
12/14/9	7.54	-99.0	GAGE	
12/21/9	7.44	-99.0	GAGE	
12/28/9	7.37	-99.0	GAGE	
01/04/9	7.38	-99.0	GAGE	
01/11/9	7.40	-99.0	GAGE	
02/01/9	7.92	-99.0	GAGE	
02/08/9	8.58	-99.0	GAGE	PROBABLY READ ICE LEVEL.
02/15/9	8.60	-99.0	GAGE	PROBABLY READ ICE LEVEL.
02/22/9	8.20	-99.0	GAGE	PROBABLY READ ICE LEVEL
02/29/9	7.42	-99.0	GAGE	CHIP OUT ICE
12/27/9	7.44	-99.0	GAGE	
12/31/9	7.42	-99.0	GAGE	
01/17/9	7.63	-99.0	GAGE	
03/10/9	7.48	-99.0	GAGE	
04/08/9	7.49	0.26	BOTH	
04/14/9	7.48	0.18	BOTH	
03/07/9	7.42	-99.0	GAGE	
03/14/9	7.43	-99.0	GAGE	
03/21/9	7.42	-99.0	GAGE	ICY.
03/28/9	7.55	-99.0	GAGE	
04/04/9	7.50	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 7

Date	Staff	Flow	Status	Comment
04/11/9	7.46	-99.0	GAGE	
01/21/9	7.89	-99.0	GAGE	BACKED UP WITH ICE.
01/28/9	8.37	-99.0	GAGE	
02/03/9	-99.0	-99.0	GAGE	ICED IN; MUST FLOW
02/13/9	-99.0	-99.0	GAGE	FROZEN SOLID LIKE A FISH
04/21/9	7.49	0.25	BOTH	
04/18/9	7.54	-99.0	GAGE	
04/27/9	7.49	0.20	BOTH	
05/05/9	7.42	0.15	BOTH	
04/25/9	7.55	-99.0	GAGE	
05/02/9	7.50	-99.0	GAGE	
05/12/9	7.40	0.10	BOTH	
05/20/9	7.36	-99.0	GAGE	
05/28/9	7.32	0.01	B	
06/02/9	7.42	-99.0	G	PILE OF SAND ON BEACH
06/08/9	7.39	0.13	B	
06/16/9	7.26	0.00	BOTH	
06/25/9	7.30	0.00	BOTH	
06/30/9	-99.0	-99.0	BOTH	bone dry
07/06/9	7.30	0.01	BOTH	
07/17/9	7.24	0.13	BOTH	
05/09/9	7.44	-99.0	GAGE	
05/16/9	7.42	-99.0	GAGE	
05/23/9	7.32	-99.0	GAGE	
05/30/9	7.32	-99.0	GAGE	
06/06/9	7.70	-99.0	GAGE	
06/13/9	7.28	-99.0	GAGE	
06/20/9	7.25	-99.0	GAGE	
06/27/9	7.28	-99.0	GAGE	
07/22/9	7.30	0.01	BOTH	
07/28/9	7.25	-99.0	GAGE	
08/11/9	7.32	-99.0	GAGE	
08/19/9	7.38	-99.0	GAGE	
07/11/9	7.30	-99.0	GAGE	
07/18/9	7.32	-99.0	GAGE	
07/25/9	7.30	-99.0	GAGE	
09/02/9	-99.0	-99.0		dry
09/10/9	-99.0	-99.0		dry
09/14/9	7.24	-99.0	GAGE	Insignificant flow
09/21/9	-99.0	-99.0		DRY
08/01/9	7.35	-99.0	GAGE	
08/08/9	7.26	-99.0	GAGE	
08/15/9	7.30	-99.0	GAGE	
08/22/9	7.30	-99.0	GAGE	
09/29/9	7.30	-99.0	GAGE	INSIGNIFICANT FLOW

Pawtuckaway Lake Raw Staff Gage and Flow

Station 7

Date	Staff	Flow	Status	Comment
09/05/9	7.30	-99.0	GAGE	
10/13/9	7.40	0.05	BOTH	
10/21/9	7.40	0.02	BOTH	
10/10/9	7.52	-99.0	GAGE	
10/17/9	7.38	-99.0	GAGE	
10/20/9	7.40	-99.0	GAGE	
10/28/9	7.42	0.01	BOTH	
11/02/9	7.41	0.01	BOTH	
10/24/9	7.40	-99.0	GAGE	
10/31/9	7.44	-99.0	GAGE	
11/13/9	7.60	-99.0	GAGE	
11/18/9	7.50	0.04	BOTH	
11/24/9	7.50	0.14	BOTH	
11/08/9	7.52	-99.0	GAGE	
11/14/9	7.54	-99.0	GAGE	
11/21/9	7.50	-99.0	GAGE	
11/28/9	7.45	-99.0	GAGE	
03/30/9	8.20	3.94	BOTH	
04/06/9	7.60	0.69	BOTH	
03/30/9	8.20	3.94	BOTH	
04/06/9	7.60	0.69	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 8

Date	Staff	Flow	Status	Comment
10/03/9	1.42	1.09	BOTH	
10/10/9	1.44	0.77	BOTH	
10/15/9	1.42	-99.0	GAGE	
10/22/9	1.40	0.57	BOTH	
10/29/9	1.40	0.72	BOTH	
11/05/9	1.43	-99.0	GAGE	
11/19/9	1.41	0.74	BOTH	
11/26/9	0.80	0.30	BOTH	
12/05/9	1.42	-99.0	GAGE	
12/10/9	1.47	1.55	BOTH	
12/18/9	1.44	1.44	BOTH	
01/07/9	1.46	1.45	BOTH	
02/20/9	1.40	-99.0	GAGE	
02/26/9	1.46	-99.0	GAGE	
03/12/9	1.53	1.74	BOTH	
03/17/9	1.38	0.95	BOTH	
03/24/9	1.40	0.87	BOTH	
03/31/9	1.54	2.72	BOTH	
11/02/9	1.46	-99.0	GAGE	
11/09/9	1.38	-99.0	GAGE	
11/16/9	1.45	-99.0	GAGE	
11/23/9	2.08	-99.0	GAGE	
11/30/9	1.44	-99.0	GAGE	SOME ODOR.
12/07/9	1.36	-99.0	GAGE	CLEARED ICE.
12/14/9	1.58	-99.0	GAGE	LARGE BEAVER DAM
12/21/9	1.42	-99.0	GAGE	
12/28/9	1.33	-99.0	GAGE	
01/04/9	1.38	-99.0	GAGE	
01/11/9	1.38	-99.0	GAGE	
02/01/9	1.34	-99.0	GAGE	
02/08/9	1.28	-99.0	GAGE	
02/15/9	1.24	-99.0	GAGE	
02/22/9	1.35	-99.0	GAGE	
02/29/9	1.38	-99.0	GAGE	
12/27/9	1.34	-99.0	GAGE	
12/31/9	1.44	-99.9	GAGE	
01/17/9	1.46	-99.0	GAGE	
03/10/9	1.44	-99.0	GAGE	
04/08/9	1.38	1.11	BOTH	
04/14/9	1.40	1.12	BOTH	
03/07/9	1.34	-99.0	GAGE	
03/14/9	1.42	-99.0	GAGE	
03/21/9	1.35	-99.0	GAGE	
03/28/9	1.58	-99.0	GAGE	
04/04/9	1.42	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 8

Date	Staff	Flow	Status	Comment
04/11/9	1.38	-99.0	GAGE	
01/21/9	1.38	-99.0	GAGE	
01/28/9	1.32	-99.0	GAGE	
02/03/9	1.31	-99.0	GAGE	
02/13/9	1.45	-99.0	GAGE	
04/21/9	1.46	1.70	BOTH	
04/18/9	1.50	-99.0	GAGE	
04/27/9	1.44	1.39	BOTH	
05/05/9	1.40	1.11	BOTH	
04/25/9	1.48	-99.0	GAGE	
05/02/9	1.40	-99.0	GAGE	
05/12/9	1.32	0.54	BOTH	
05/20/9	1.24	-99.0	GAGE	
05/28/9	1.20	-99.0	G	
06/02/9	1.34	-99.0	G	
06/08/9	1.41	1.18	B	
06/16/9	1.20	0.17	BOTH	
06/25/9	1.20	0.13	BOTH	
06/30/9	1.17	0.01	BOTH	
07/06/9	1.22	0.12	BOTH	
05/09/9	1.36	-99.0	GAGE	
05/16/9	1.30	-99.0	GAGE	
05/23/9	1.22	-99.0	GAGE	
05/30/9	1.20	-99.0	GAGE	
06/06/9	1.50	-99.0	GAGE	
06/13/9	1.24	-99.0	GAGE	
06/20/9	1.18	-99.0	GAGE	
06/27/9	1.20	-99.0	GAGE	
07/22/9	1.27	0.17	BOTH	7 inches of sand in
07/28/9	1.18	0.05	BOTH	
08/05/9	1.24	0.49	BOTH	
07/17/9	1.24	0.13	BOTH	2.5 inches of sand in
08/11/9	1.26	-99.0	GAGE	7.5" of sand in culvert
08/19/9	1.38	-99.0	GAGE	8-20"of sand at mouth of
07/04/9	1.17	-99.0	GAGE	
07/11/9	1.20	-99.0	GAGE	
07/18/9	1.21	-99.0	GAGE	
07/25/9	1.24	-99.0	GAGE	
08/25/9	1.24	-99.0	GAGE	5.75" of sand in culvert.
09/02/9	-99.0	0.03	FLOW	gage dry and 6" of sand
09/10/9	1.22	0.07	BOTH	
09/14/9	1.24	0.06	BOTH	
09/21/9	1.22	-99.0	GAGE	
08/01/9	1.28	-99.0	GAGE	
08/08/9	1.20	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 8

Date	Staff	Flow	Status	Comment
08/15/9	1.20	-99.0	GAGE	
08/22/9	1.28	-99.0	GAGE	
09/29/9	1.26	0.04	BOTH	
10/05/9	1.22	0.03	BOTH	
09/05/9	1.26	-99.0	GAGE	
10/13/9	1.36	0.44	BOTH	7 INCHES OF SAND IN
10/21/9	1.32	0.14	BOTH	
10/10/9	1.44	-99.0	GAGE	
10/17/9	1.30	-99.0	GAGE	
10/20/9	1.30	-99.0	GAGE	
10/28/9	1.34	0.18	BOTH	
11/02/9	1.34	0.12	BOTH	20 to 26" of sand at
10/24/9	1.32	-99.0	GAGE	.
10/31/9	1.32	-99.0	GAGE	
11/13/9	1.46	-99.0	GAGE	
11/18/9	1.40	0.35	BOTH	
11/24/9	1.54	1.84	BOTH	
11/08/9	1.43	-99.0	GAGE	
11/14/9	1.44	-99.0	GAGE	
11/21/9	1.35	-99.0	GAGE	
11/28/9	1.56	-99.0	GAGE	
03/30/9	2.10	29.62	BOTH	
04/06/9	1.64	2.86	BOTH	
03/30/9	2.10	29.62	BOTH	
04/06/9	1.64	2.86	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 9

Date	Staff	Flow	Status	Comment
10/03/9	0.44	0.14	BOTH	
10/10/9	0.51	0.16	BOTH	
10/15/9	0.44	-99.0	GAGE	
10/22/9	0.44	0.06	BOTH	
10/29/9	0.34	0.04	BOTH	
11/05/9	0.31	-99.0	GAGE	
11/19/9	0.43	0.13	BOTH	
11/26/9	1.54	2.60	BOTH	
12/05/9	0.58	-99.0	GAGE	
12/10/9	0.66	0.15	BOTH	
12/18/9	0.76	0.27	BOTH	
01/07/9	0.61	0.13	BOTH	
02/20/9	1.47	-99.0	GAGE	
02/26/9	0.68	-99.0	GAGE	
03/12/9	0.50	0.22	BOTH	
03/17/9	0.44	0.11	BOTH	
03/24/9	0.38	0.12	BOTH	
03/31/9	0.68	0.36	BOTH	
11/02/9	0.36	-99.0	GAGE	
11/09/9	0.30	-99.0	GAGE	
11/16/9	0.50	-99.0	GAGE	
11/23/9	1.30	-99.0	GAGE	
11/30/9	0.68	-99.0	GAGE	FRESH BEAVER ACTIVITY.
12/07/9	0.57	-99.0	GAGE	SILTY
12/14/9	1.01	-99.0	GAGE	
12/21/9	0.72	-99.0	GAGE	
12/28/9	0.54	-99.0	GAGE	
01/04/9	0.58	-99.0	GAGE	
01/11/9	0.59	-99.0	GAGE	
02/01/9	0.51	-99.0	GAGE	
02/08/9	0.42	-99.0	GAGE	
02/15/9	0.30	-99.0	GAGE	
02/22/9	0.35	-99.0	GAGE	
02/29/9	0.41	-99.0	GAGE	
12/27/9	0.56	-99.0	GAGE	
12/31/9	0.58	-99.0	GAGE	
01/17/9	0.48	-99.0	GAGE	
03/10/9	0.42	-99.0	GAGE	
04/08/9	0.53	0.17	BOTH	
04/14/9	0.50	0.16	BOTH	
03/07/9	0.40	-99.0	GAGE	
03/14/9	0.45	-99.0	GAGE	
03/21/9	0.42	-99.0	GAGE	
03/28/9	0.58	-99.0	GAGE	
04/04/9	0.61	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 9

Date	Staff	Flow	Status	Comment
04/11/9	0.50	-99.0	GAGE	
01/21/9	0.44	-99.0	GAGE	
01/28/9	0.46	-99.0	GAGE	
02/03/9	0.42	-99.0	GAGE	
02/13/9	-99.0	-99.0	GAGE	SOLID ICE
04/21/9	-99.0	0.23	FLOW	
04/18/9	0.60	-99.0	GAGE	
04/27/9	0.50	0.25	BOTH	
05/05/9	0.49	0.11	BOTH	
04/25/9	0.72	-99.0	GAGE	
05/02/9	0.60	-99.0	GAGE	
05/12/9	0.38	0.12	BOTH	
05/20/9	0.32	-99.0	GAGE	
05/28/9	0.19	-99.0	G	
06/02/9	0.26	-99.0	G	
06/08/9	0.26	0.07	B	
06/16/9	0.08	0.01	BOTH	
06/25/9	0.13	0.02	BOTH	
06/30/9	0.04	0.00	BOTH	gage almost out of water
07/06/9	0.08	0.01	BOTH	
07/17/9	-99.0	0.00	FLOW	gage dry
05/09/9	0.53	-99.0	GAGE	
05/16/9	0.41	-99.0	GAGE	
05/23/9	0.20	-99.0	GAGE	
06/06/9	1.20	-99.0	GAGE	
06/13/9	0.14	-99.0	GAGE	
06/20/9	0.06	-99.0	GAGE	
06/27/9	0.06	-99.0	GAGE	
07/22/9	-99.0	-99.0	BOTH	
07/28/9	-99.0	-99.0	BOTH	
08/19/9	-99.0	-99.0	GAGE	gage dry
07/11/9	0.04	-99.0	GAGE	
07/18/9	0.02	-99.0	GAGE	
09/02/9	-99.0	-99.0		dry
08/01/9	-99.0	-99.0		dry
08/08/9	-99.0	-99.0		dry
08/15/9	-99.0	-99.0		dry
08/22/9	-99.0	-99.0		dry
10/13/9	-99.0	0.02	FLOW	
10/10/9	0.22	-99.0	GAGE	
11/24/9	0.08	0.13	BOTH	
05/30/9	0.16	-99.0	GAGE	
04/06/9	0.36	0.51	BOTH	
04/06/9	0.36	0.51	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 10

Date	Staff	Flow	Status	Comment
10/03/9	1.02	16.56	BOTH	
10/10/9	1.08	18.72	BOTH	
10/15/9	0.62	-99.0	GAGE	
10/22/9	1.86	59.00	BOTH	
10/29/9	1.07	13.76	BOTH	
11/05/9	0.99	-99.0	GAGE	
11/19/9	0.60	6.73	BOTH	
11/26/9	0.54	3.68	BOTH	
12/05/9	0.09	-99.0	GAGE	
12/10/9	0.06	0.02	BOTH	
12/18/9	0.10	0.08	BOTH	
01/07/9	0.05	0.01	BOTH	
02/26/9	0.12	-99.0	GAGE	
03/12/9	0.16	0.14	BOTH	
03/17/9	0.16	0.19	BOTH	
03/24/9	0.12	0.09	BOTH	
03/31/9	0.10	0.07	BOTH	
11/02/9	1.22	-99.0	GAGE	
11/09/9	0.57	-99.0	GAGE	
11/16/9	0.84	-99.0	GAGE	
11/23/9	0.43	-99.0	GAGE	
11/30/9	0.14	-99.0	GAGE	
12/07/9	0.08	-99.0	GAGE	
12/14/9	0.10	-99.0	GAGE	
12/21/9	0.06	-99.0	GAGE	
12/28/9	0.14	-99.0	GAGE	
01/04/9	0.02	-99.0	GAGE	
01/11/9	0.03	-99.0	GAGE	
02/01/9	0.02	-99.0	GAGE	ICED IN.
02/08/9	0.02	-99.0	GAGE	SOLID ICE
02/15/9	0.88	-99.0	GAGE	
02/22/9	0.30	-99.0	GAGE	
02/29/9	1.10	-99.0	GAGE	
03/10/9	0.15	-99.0	GAGE	
04/08/9	0.07	-99.0	GAGE	NO SIGNIFICANT FLOW; ONLY
04/14/9	0.06	-99.0	GAGE	LEAKING THRU BOARDS ONLY.
03/07/9	0.14	-99.0	GAGE	
03/14/9	0.19	-99.0	GAGE	
03/21/9	0.12	-99.0	GAGE	
03/28/9	0.12	-99.0	GAGE	
04/04/9	0.06	-99.0	GAGE	
04/11/9	0.08	-99.0	GAGE	
01/17/9	-99.0	-99.0	GAGE	DRY
01/21/9	-99.0	-99.0	GAGE	DRY
01/28/9	-99.0	-99.0	GAGE	DRY

Pawtuckaway Lake Raw Staff Gage and Flow

Station 10

Date	Staff	Flow	Status	Comment
02/03/9	-99.0	-99.0	GAGE	DRY
02/13/9	-99.0	-99.0	GAGE	SOLID ICE
04/18/9	0.12	-99.0	GAGE	
04/27/9	0.12	0.26	BOTH	
05/05/9	0.88	14.17	BOTH	WATER OVER SPILLWAYS AND
04/25/9	0.13	-99.0	GAGE	
05/02/9	0.41	-99.0	GAGE	
05/12/9	1.00	18.79	BOTH	
05/20/9	0.78	-99.0	GAGE	
05/28/9	0.46	-99.0	G	
06/02/9	0.76	-99.0	G	TWO DUMPTRUCKS UNLOADING
06/16/9	0.60	8.80	BOTH	
06/25/9	0.42	4.02	BOTH	
06/30/9	0.24	1.26	BOTH	
07/06/9	0.22	0.64	BOTH	
07/22/9	0.60	8.54	BOTH	
07/17/9	0.50	4.30	BOTH	gage was .48 at beginning
05/09/9	1.10	-99.0	GAGE	
05/23/9	0.58	-99.0	GAGE	
05/16/9	0.88	-99.0	GAGE	
06/06/9	1.12	-99.0	GAGE	
06/13/9	0.74	-99.0	GAGE	
06/20/9	0.48	-99.0	GAGE	
06/27/9	0.28	-99.0	GAGE	
07/28/9	0.24	0.77	BOTH	
08/05/9	0.32	4.64	BOTH	
08/11/9	0.56	-99.0	GAGE	
08/19/9	0.80	-99.0	GAGE	
07/04/9	0.18	-99.0	GAGE	
07/11/9	0.36	-99.0	GAGE	
07/18/9	0.50	-99.0	GAGE	
07/25/9	0.41	-99.0	GAGE	
08/25/9	0.52	-99.0	GAGE	
09/02/9	0.26	1.04	BOTH	
09/10/9	0.26	1.37	BOTH	
09/14/9	0.23	0.75	BOTH	
09/21/9	0.24	-99.0	GAGE	
08/01/9	0.26	-99.0	GAGE	
08/08/9	0.44	-99.0	GAGE	
08/15/9	0.34	-99.0	GAGE	
08/22/9	0.64	-99.0	GAGE	
09/29/9	0.24	0.86	BOTH	skip rock championships
10/05/9	0.24	0.44	BOTH	
08/29/9	0.26	-99.0	GAGE	
09/05/9	0.25	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 10

Date	Staff	Flow	Status	Comment
09/12/9	0.24	-99.0	GAGE	
09/19/9	0.24	-99.0	GAGE	
09/26/9	0.23	-99.0	GAGE	
10/13/9	0.63	6.76	BOTH	
10/03/9	0.23	-99.0	GAGE	
10/21/9	1.80	57.65	BOTH	
10/10/9	0.30	-99.0	GAGE	
10/17/9	1.54	-99.0	GAGE	
10/20/9	1.40	-99.0	GAGE	
10/28/9	1.10	24.55	BOTH	
11/02/9	0.78	11.33	BOTH	
10/24/9	1.38	-99.0	GAGE	
10/31/9	0.89	-99.0	GAGE	
11/13/9	0.74	-99.0	GAGE	
11/18/9	0.56	6.28	BOTH	
11/24/9	0.14	-99.0	GAGE	
11/08/9	0.78	-99.0	GAGE	
11/14/9	0.68	-99.0	GAGE	
11/21/9	0.18	-99.0	GAGE	
11/28/9	0.40	-99.0	GAGE	
12/27/9	-99.0	-99.0	GAGE	ICED IN
05/30/9	0.31	-99.0	GAGE	
04/06/9	1.10	31.06	BOTH	
04/06/9	1.10	31.06	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 11

Date	Staff	Flow	Status	Comment
10/03/9	1.48	13.98	BOTH	
10/10/9	1.54	17.99	BOTH	
10/15/9	1.30	-99.0	GAGE	
10/22/9	1.31	8.64	BOTH	
10/29/9	1.18	3.38	BOTH	
11/05/9	1.17	-99.0	GAGE	
11/19/9	1.40	12.10	BOTH	
11/26/9	2.04	39.10	BOTH	
12/05/9	1.68	25.00	BOTH	
12/10/9	1.58	15.17	BOTH	
12/18/9	1.76	19.48	BOTH	
01/07/9	1.70	22.80	BOTH	
02/20/9	1.56	-99.0	GAGE	
02/26/9	1.42	-99.0	GAGE	
03/12/9	2.28	45.76	BOTH	HIGH FLOWS ON THIS DATE
03/17/9	1.44	12.24	BOTH	
03/24/9	1.20	7.67	BOTH	
03/31/9	1.94	33.83	BOTH	
11/02/9	1.20	-99.0	GAGE	
11/09/9	1.10	-99.0	GAGE	
11/16/9	1.61	-99.0	GAGE	
11/23/9	2.90	-99.0	GAGE	
11/30/9	1.71	-99.0	GAGE	
12/07/9	1.51	-99.0	GAGE	
12/14/9	1.95	-99.0	GAGE	
12/21/9	1.60	-99.0	GAGE	
12/28/9	1.38	-99.0	GAGE	
01/04/9	1.44	-99.0	GAGE	
01/11/9	1.47	-99.0	GAGE	
02/01/9	1.32	-99.0	GAGE	
02/08/9	1.11	-99.0	GAGE	
02/15/9	1.04	-99.0	GAGE	
02/22/9	1.36	-99.0	GAGE	
02/29/9	1.44	-99.0	GAGE	
12/27/9	1.40	-99.0	GAGE	
12/31/9	1.90	-99.0	GAGE	
01/17/9	1.40	-99.0	GAGE	
03/10/9	1.52	-99.0	GAGE	
04/08/9	1.38	10.63	BOTH	
04/14/9	1.44	15.14	BOTH	
03/07/9	1.27	-99.0	GAGE	
03/14/9	1.76	-99.0	GAGE	
03/21/9	1.26	-99.0	GAGE	
03/28/9	2.09	-99.0	GAGE	
04/04/9	1.70	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 11

Date	Staff	Flow	Status	Comment
04/11/9	1.32	-99.0	GAGE	
01/21/9	1.42	-99.0	GAGE	
01/28/9	1.34	-99.0	GAGE	
02/03/9	1.20	-99.0	GAGE	
02/13/9	1.08	-99.0	GAGE	
04/21/9	1.82	28.78	BOTH	
04/18/9	1.64	-99.0	GAGE	
04/27/9	1.56	17.99	BOTH	
05/05/9	1.68	10.09	BOTH	
04/25/9	1.60	-99.0	GAGE	
05/02/9	1.32	-99.0	GAGE	
05/12/9	1.22	6.56	BOTH	
05/20/9	0.98	-99.0	GAGE	
05/28/9	0.78	1.02	B	
06/02/9	1.26	-99.0	G	
06/16/9	0.88	2.41	BOTH	
06/25/9	0.91	2.13	BOTH	
06/30/9	-99.0	1.31	BOTH	
07/06/9	0.88	1.72	BOTH	
07/17/9	0.98	3.47	BOTH	
05/09/9	1.34	-99.0	GAGE	
05/16/9	1.08	-99.0	GAGE	
05/23/9	0.90	-99.0	GAGE	
05/30/9	0.76	-99.0	GAGE	
06/06/9	1.56	-99.0	GAGE	
06/13/9	1.52	-99.0	GAGE	
06/20/9	0.85	-99.0	GAGE	
06/27/9	0.88	-99.0	GAGE	
07/22/9	1.00	3.24	BOTH	
07/28/9	0.88	1.76	BOTH	
08/05/9	0.92	1.78	BOTH	
08/11/9	0.91	-99.0	GAGE	
08/19/9	1.22	-99.0	GAGE	
07/04/9	0.82	-99.0	GAGE	
07/18/9	0.96	-99.0	GAGE	
07/25/9	0.90	-99.0	GAGE	
08/25/9	0.88	-99.0	GAGE	
09/02/9	0.75	0.73	BOTH	
09/10/9	0.82	1.10	BOTH	
09/14/9	0.76	0.72	BOTH	
09/21/9	0.76	-99.0	GAGE	
08/01/9	0.93	-99.0	GAGE	
08/08/9	0.84	-99.0	GAGE	
08/15/9	0.86	-99.0	GAGE	
08/22/9	1.01	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 11

Date	Staff	Flow	Status	Comment
09/29/9	0.78	1.07	BOTH	
10/05/9	0.78	1.14	BOTH	
08/29/9	0.84	-99.0	GAGE	
09/05/9	0.84	-99.0	GAGE	
09/12/9	0.78	-99.0	GAGE	
09/19/9	0.78	-99.0	GAGE	
09/26/9	0.76	-99.0	GAGE	
10/03/9	0.80	-99.0	GAGE	
10/13/9	1.07	5.81	BOTH	
10/21/9	1.00	3.76	BOTH	
10/10/9	1.06	-99.0	GAGE	
10/17/9	1.00	-99.0	GAGE	
10/20/9	1.00	-99.0	GAGE	
10/28/9	1.06	4.35	BOTH	
11/02/9	1.08	4.64	BOTH	
10/24/9	1.00	-99.0	GAGE	
10/31/9	1.00	-99.0	GAGE	
11/13/9	1.26	-99.0	GAGE	
11/18/9	1.24	10.09	BOTH	
11/24/9	1.94	34.04	BOTH	
11/08/9	1.30	-99.0	GAGE	
11/14/9	1.36	-99.0	GAGE	
11/21/9	1.18	-99.0	GAGE	
11/28/9	1.84	-99.0	GAGE	
03/30/9	-99.0	194.0	FLOW	GAGE REMOVED BY ICE FLOW
03/30/9	-99.0	194.0	FLOW	spring runoff
04/06/9	-99.0	50.75	FLOW	GAGE FOUND ON STREAM BED

Pawtuckaway Lake Raw Staff Gage and Flow

Station 12

Date	Staff	Flow	Status	Comment
10/03/9	11.64	0.35	BOTH	
10/10/9	11.69	0.52	BOTH	
10/15/9	11.66	-99.0	GAGE	
10/22/9	11.66	0.37	BOTH	
10/29/9	11.59	0.65	BOTH	
11/05/9	11.54	-99.0	GAGE	
11/19/9	11.59	0.42	BOTH	
11/26/9	11.70	1.23	BOTH	
12/05/9	11.63	0.80	BOTH	
12/10/9	11.65	0.84	BOTH	
12/18/9	11.65	1.00	BOTH	
01/07/9	11.62	0.55	BOTH	
02/20/9	11.67	-99.0	GAGE	
02/26/9	11.73	-99.0	GAGE	
03/12/9	11.74	1.42	BOTH	
03/17/9	11.60	0.63	BOTH	
03/24/9	11.58	0.37	BOTH	
03/31/9	11.70	1.32	BOTH	
11/02/9	11.68	-99.0	GAGE	
11/09/9	11.56	-99.0	GAGE	
11/16/9	11.59	-99.0	GAGE	
11/23/9	11.52	-99.0	GAGE	
11/30/9	11.65	-99.0	GAGE	
12/07/9	11.60	-99.0	GAGE	
12/14/9	11.88	-99.0	GAGE	
12/21/9	11.62	-99.0	GAGE	
12/28/9	11.56	-99.0	GAGE	
01/04/9	11.59	-99.0	GAGE	
01/11/9	11.59	-99.0	GAGE	
02/01/9	11.58	-99.0	GAGE	
02/08/9	11.55	-99.0	GAGE	
02/15/9	11.52	-99.0	GAGE	
02/22/9	11.60	-99.0	GAGE	
02/29/9	11.60	-99.0	GAGE	
12/27/9	11.57	-99.0	GAGE	
12/31/9	11.61	-99.0	GAGE	
01/17/9	11.59	-99.0	GAGE	
03/10/9	11.61	-99.0	GAGE	
04/08/9	11.61	0.56	BOTH	
04/14/9	11.62	1.03	BOTH	
03/07/9	11.70	-99.0	GAGE	
03/14/9	11.62	-99.0	GAGE	
03/21/9	11.60	-99.0	GAGE	
03/28/9	11.78	-99.0	GAGE	
04/04/9	11.66	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 12

Date	Staff	Flow	Status	Comment
04/11/9	11.61	-99.0	GAGE	
01/21/9	11.56	-99.0	GAGE	
01/28/9	11.64	-99.0	GAGE	
02/03/9	11.55	-99.0	GAGE	
02/13/9	11.54	-99.0	GAGE	
04/21/9	11.66	1.03	BOTH	
04/18/9	11.68	-99.0	GAGE	
04/27/9	11.65	0.78	BOTH	
05/20/9	11.54	-99.0	GAGE	
05/05/9	11.60	0.71	BOTH	
04/25/9	11.68	-99.0	GAGE	
05/02/9	11.62	-99.0	GAGE	
05/12/9	11.57	0.49	BOTH	
05/28/9	11.50	-99.0	G	
06/02/9	11.59	-99.0	G	
06/16/9	11.50	0.14	BOTH	
06/25/9	11.48	0.05	BOTH	
06/30/9	11.48	0.03	BOTH	
07/06/9	11.50	0.10	BOTH	
07/17/9	11.50	0.09	BOTH	
05/09/9	11.60	-99.0	GAGE	
05/16/9	11.58	-99.0	GAGE	
05/23/9	11.52	-99.0	GAGE	
05/30/9	11.50	-99.0	GAGE	
06/06/9	11.88	-99.0	GAGE	
06/13/9	11.99	-99.0	GAGE	
06/20/9	11.57	-99.0	GAGE	
06/27/9	11.50	-99.0	GAGE	
07/22/9	11.50	0.09	BOTH	
07/28/9	11.46	0.06	BOTH	
08/05/9	11.50	0.52	BOTH	
08/11/9	11.52	-99.0	GAGE	
08/19/9	11.58	-99.0	GAGE	
09/29/9	11.48	0.06	BOTH	
07/04/9	11.48	-99.0	GAGE	
07/11/9	11.48	-99.0	GAGE	
07/18/9	11.48	-99.0	GAGE	
07/25/9	11.40	-99.0	GAGE	
08/25/9	11.48	-99.0	GAGE	
09/02/9	11.45	0.03	BOTH	
09/10/9	11.45	0.06	BOTH	
09/14/9	11.47	0.07	BOTH	
09/21/9	11.46	-99.0	GAGE	
08/01/9	11.48	-99.0	GAGE	
08/08/9	11.48	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 12

Date	Staff	Flow	Status	Comment
08/15/9	11.48	-99.0	GAGE	
08/22/9	11.52	-99.0	GAGE	
10/05/9	11.48	0.04	BOTH	
08/29/9	11.47	-99.0	GAGE	
09/05/9	11.48	-99.0	GAGE	
09/12/9	11.48	-99.0	GAGE	
09/19/9	11.46	-99.0	GAGE	
09/26/9	11.46	-99.0	GAGE	
10/03/9	11.48	-99.0	GAGE	
10/13/9	11.58	0.33	BOTH	
10/21/9	11.55	0.16	BOTH	
10/10/9	11.62	-99.0	GAGE	
10/17/9	11.56	-99.0	GAGE	
10/20/9	11.55	-99.0	GAGE	
10/28/9	11.56	0.18	BOTH	
11/02/9	11.58	0.07	BOTH	
10/24/9	11.54	-99.0	GAGE	
10/31/9	11.58	-99.0	GAGE	
11/13/9	11.66	-99.0	GAGE	
11/18/9	11.58	0.58	BOTH	
11/24/9	11.68	0.85	BOTH	
11/08/9	11.58	-99.0	GAGE	
11/14/9	11.58	-99.0	GAGE	
11/21/9	11.56	-99.0	GAGE	
11/28/9	11.68	-99.0	GAGE	
03/30/9	12.41	7.99	BOTH	
04/06/9	12.00	2.65	BOTH	
03/30/9	12.41	7.99	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 13

Date	Staff	Flow	Status	Comment
10/03/9	1.04	0.48	BOTH	
10/10/9	1.04	0.19	BOTH	
10/15/9	1.10	-99.0	GAGE	
10/22/9	1.20	0.50	BOTH	
10/29/9	1.19	0.02	BOTH	
11/05/9	1.21	-99.0	GAGE	
11/19/9	1.22	0.32	BOTH	
11/26/9	1.28	0.81	BOTH	
12/05/9	1.22	1.04	BOTH	
12/10/9	1.24	0.98	BOTH	
12/18/9	1.23	0.99	BOTH	
01/07/9	1.22	0.39	BOTH	
02/20/9	1.22	-99.0	GAGE	
02/26/9	1.28	-99.0	GAGE	
03/12/9	1.34	1.00	BOTH	
03/17/9	1.14	0.50	BOTH	
03/24/9	1.10	0.55	BOTH	
03/31/9	1.26	0.54	BOTH	
11/02/9	1.20	-99.0	GAGE	
11/09/9	1.14	-99.0	GAGE	
11/16/9	1.18	-99.0	GAGE	
11/23/9	1.42	-99.0	GAGE	
11/30/9	1.20	-99.0	GAGE	
12/07/9	1.17	-99.0	GAGE	
12/14/9	1.30	-99.0	GAGE	
12/21/9	1.22	-99.0	GAGE	
12/28/9	1.14	-99.0	GAGE	
01/04/9	1.12	-99.0	GAGE	
01/11/9	1.15	-99.0	GAGE	
02/01/9	1.10	-99.0	GAGE	
02/08/9	1.05	-99.0	GAGE	
02/15/9	1.02	-99.0	GAGE	
02/22/9	1.14	-99.0	GAGE	
02/29/9	1.15	-99.0	GAGE	
12/27/9	1.16	-99.0	GAGE	
12/31/9	1.24	-99.0	GAGE	
01/17/9	1.21	-99.0	GAGE	
03/10/9	1.20	-99.0	GAGE	
04/14/9	1.08	0.40	BOTH	
03/07/9	1.18	-99.0	GAGE	
03/14/9	1.21	-99.0	GAGE	
03/21/9	1.12	-99.0	GAGE	
03/28/9	1.38	-99.0	GAGE	
04/04/9	1.14	-99.0	GAGE	
04/11/9	1.06	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 13

Date	Staff	Flow	Status	Comment
01/21/9	1.11	-99.0	GAGE	
01/28/9	1.12	-99.0	GAGE	
02/03/9	1.08	-99.0	GAGE	
02/13/9	1.14	-99.0	GAGE	
04/21/9	1.18	0.62	BOTH	
04/18/9	1.23	-99.0	GAGE	
04/27/9	1.14	0.82	BOTH	
05/05/9	1.13	0.53	BOTH	
04/25/9	1.17	-99.0	GAGE	
05/02/9	1.10	-99.0	GAGE	
05/12/9	1.10	0.60	BOTH	
05/20/9	0.96	-99.0	GAGE	
05/28/9	0.92	-99.0	G	
06/02/9	0.98	-99.0	G	
06/16/9	0.89	0.10	BOTH	
06/25/9	0.86	0.11	BOTH	
06/30/9	0.82	0.14	BOTH	
07/06/9	0.86	0.05	BOTH	
07/17/9	0.88	0.06	BOTH	
05/09/9	1.10	-99.0	GAGE	
05/16/9	1.06	-99.0	GAGE	
05/23/9	0.96	-99.0	GAGE	
05/30/9	0.92	-99.0	GAGE	
06/06/9	1.22	-99.0	GAGE	
06/13/9	0.92	-99.0	GAGE	
06/20/9	0.85	-99.0	GAGE	
06/27/9	0.86	-99.0	GAGE	
07/22/9	0.90	0.07	BOTH	
07/28/9	0.88	0.07	BOTH	
08/11/9	0.94	-99.0	GAGE	
08/19/9	1.02	-99.0	GAGE	
07/04/9	0.88	-99.0	BOTH	
07/11/9	0.86	-99.0	GAGE	
07/18/9	0.88	-99.0	GAGE	
07/25/9	0.86	-99.0	GAGE	
08/25/9	0.86	-99.0	GAGE	
09/02/9	0.80	0.04	BOTH	
09/10/9	0.88	0.07	BOTH	
09/14/9	0.90	-99.0	GAGE	
09/21/9	0.84	-99.0	GAGE	
08/01/9	0.87	-99.0	GAGE	
08/08/9	0.90	-99.0	GAGE	
08/15/9	0.90	-99.0	GAGE	
08/22/9	0.88	-99.0	GAGE	
09/29/9	0.88	0.18	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 13

Date	Staff	Flow	Status	Comment
10/05/9	0.88	0.06	BOTH	
08/29/9	0.86	-99.0	GAGE	
09/05/9	0.88	-99.0	GAGE	
09/12/9	0.85	-99.0	GAGE	
09/19/9	0.86	-99.0	GAGE	
09/26/9	0.84	-99.0	GAGE	
10/03/9	0.86	-99.0	GAGE	
10/13/9	1.00	0.51	BOTH	
10/21/9	0.94	0.07	BOTH	
10/10/9	1.08	-99.0	GAGE	
10/17/9	1.02	-99.0	GAGE	
10/20/9	0.98	-99.0	GAGE	
10/28/9	0.98	0.07	BOTH	
11/02/9	0.98	0.09	BOTH	
10/24/9	0.98	-99.0	GAGE	
10/31/9	1.06	-99.0	GAGE	
11/13/9	1.22	-99.0	GAGE	
11/18/9	1.10	0.28	BOTH	
11/24/9	1.30	0.82	BOTH	
11/08/9	1.08	-99.0	GAGE	
11/14/9	1.14	-99.0	GAGE	
11/21/9	1.08	-99.0	GAGE	
11/28/9	1.28	-99.0	GAGE	
04/06/9	1.44	1.44	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 14

Date	Staff	Flow	Status	Comment
10/03/9	1.25	7.65	BOTH	
10/10/9	1.30	5.39	BOTH	
10/15/9	1.18	-99.0	GAGE	
10/22/9	1.12	2.06	BOTH	
10/29/9	1.15	3.40	BOTH	
11/05/9	1.02	0.87	BOTH	
11/19/9	1.03	3.10	BOTH	
11/26/9	1.49	13.61	BOTH	
12/05/9	1.28	6.39	BOTH	
12/10/9	1.22	2.75	BOTH	
12/18/9	1.40	7.59	BOTH	
01/07/9	1.29	5.48	BOTH	
02/20/9	1.23	-99.0	GAGE	
02/26/9	1.19	-99.0	GAGE	
03/12/9	1.50	12.65	BOTH	
03/17/9	1.24	5.54	BOTH	
03/24/9	1.16	2.70	BOTH	
03/31/9	1.47	12.81	BOTH	
11/02/9	1.08	-99.0	GAGE	
11/09/9	1.04	-99.0	GAGE	
11/16/9	1.18	-99.0	GAGE	
11/23/9	1.88	-99.0	GAGE	
11/30/9	1.30	-99.0	GAGE	
12/07/9	1.18	-99.0	GAGE	
12/14/9	1.50	-99.0	GAGE	
12/21/9	1.32	-99.0	GAGE	
12/28/9	1.16	-99.0	GAGE	
01/04/9	1.19	-99.0	GAGE	
01/11/9	1.17	-99.0	GAGE	
02/01/9	1.18	-99.0	GAGE	
02/08/9	1.08	-99.0	GAGE	
02/15/9	1.02	-99.0	GAGE	
02/22/9	1.16	-99.0	GAGE	
02/29/9	1.22	-99.0	GAGE	
12/27/9	1.16	-99.0	GAGE	
12/31/9	1.30	-99.0	GAGE	
01/17/9	1.24	-99.0	GAGE	
03/10/9	1.30	-99.0	GAGE	
04/08/9	1.24	5.42	BOTH	
04/14/9	1.22	6.10	BOTH	
03/07/9	1.18	-99.0	GAGE	
03/14/9	1.35	-99.0	GAGE	
03/21/9	1.20	-99.0	GAGE	
03/28/9	1.50	-99.0	GAGE	
04/04/9	1.36	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 14

Date	Staff	Flow	Status	Comment
04/11/9	1.22	-99.0	GAGE	
01/21/9	1.14	-99.0	GAGE	
01/28/9	1.22	-99.0	GAGE	
02/03/9	1.16	-99.0	GAGE	
02/13/9	1.04	-99.0	GAGE	
04/21/9	1.38	-99.0	GAGE	
04/18/9	1.40	-99.0	GAGE	
04/27/9	1.37	9.82	BOTH	
05/05/9	1.40	11.76	BOTH	
04/25/9	1.40	-99.0	GAGE	
05/02/9	1.27	-99.0	GAGE	
05/12/9	1.32	10.27	BOTH	
05/20/9	1.19	-99.0	GAGE	
05/28/9	0.76	-99.0	G	
06/02/9	0.91	-99.0	G	
06/08/9	1.29	6.06	B	
06/16/9	0.70	0.75	BOTH	
06/25/9	0.54	0.14	BOTH	
06/30/9	0.58	0.24	BOTH	
07/06/9	0.64	0.58	BOTH	
07/17/9	0.78	0.54	BOTH	
05/09/9	1.17	-99.0	GAGE	
05/16/9	1.06	-99.0	GAGE	
05/23/9	0.98	-99.0	GAGE	
05/30/9	0.72	-99.0	GAGE	
06/06/9	1.12	-99.0	GAGE	
06/13/9	0.82	-99.0	GAGE	
06/20/9	0.60	-99.0	GAGE	
06/27/9	0.65	-99.0	GAGE	
07/22/9	0.88	0.77	BOTH	
07/28/9	0.60	0.18	BOTH	
08/11/9	0.74	-99.0	GAGE	
08/19/9	1.08	-9.90	GAGE	
07/04/9	0.60	-99.0	GAGE	
07/11/9	0.82	-99.0	GAGE	
07/18/9	0.72	-99.0	GAGE	
07/25/9	0.64	-99.0	GAGE	
08/25/9	0.64	-99.0	GAGE	
09/02/9	0.42	0.05	BOTH	
09/10/9	0.60	0.40	BOTH	
09/14/9	0.54	-99.0	GAGE	
09/21/9	0.42	-99.0	GAGE	
08/01/9	0.60	-99.0	GAGE	
08/08/9	0.51	-99.0	GAGE	
08/15/9	0.51	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 14

Date	Staff	Flow	Status	Comment
08/22/9	0.80	-99.0	GAGE	
09/29/9	0.56	0.24	BOTH	
10/05/9	0.48	0.10	BOTH	
08/29/9	0.56	-99.0	GAGE	
09/05/9	0.61	-99.0	GAGE	
09/12/9	0.58	-99.0	GAGE	
09/19/9	0.50	-99.0	GAGE	
09/26/9	0.49	-99.0	GAGE	
10/03/9	0.44	-99.0	GAGE	
10/13/9	1.02	2.20	BOTH	
10/21/9	0.78	-99.0	GAGE	
10/10/9	1.02	-99.0	GAGE	
10/17/9	0.94	-99.0	GAGE	
10/20/9	0.76	-99.0	GAGE	
10/28/9	0.82	0.58	BOTH	
11/02/9	0.92	1.55	BOTH	
10/24/9	0.88	-99.0	GAGE	
10/31/9	0.86	-99.0	GAGE	
11/13/9	1.18	-99.0	GAGE	
11/18/9	1.16	2.55	BOTH	
11/24/9	1.46	-99.0	GAGE	
11/08/9	1.14	-99.0	GAGE	
11/14/9	1.16	-99.0	GAGE	
11/21/9	1.08	-99.0	GAGE	
11/28/9	1.50	-99.0	GAGE	
04/06/9	1.66	18.84	BOTH	ST. PARK 3-WHEEL ACCESS

Pawtuckaway Lake Raw Staff Gage and Flow

Station 15

Date	Staff	Flow	Status	Comment
11/05/9	0.19	0.49	BOTH	NEW STATION AND NEW GAGE
11/19/9	0.24	1.57	BOTH	
11/26/9	2.70	2.25	BOTH	
12/05/9	0.26	1.85	BOTH	
12/10/9	0.26	1.91	BOTH	
12/18/9	0.26	1.92	BOTH	
01/07/9	0.25	1.90	BOTH	
02/20/9	0.21	-99.0	GAGE	
02/26/9	0.22	-99.0	GAGE	
03/12/9	0.24	1.89	BOTH	
03/17/9	0.22	1.51	BOTH	
03/24/9	0.21	1.20	BOTH	
03/31/9	0.22	1.89	BOTH	
11/09/9	0.20	-99.0	GAGE	
11/16/9	0.22	-99.0	GAGE	
11/23/9	0.31	-99.0	GAGE	
11/30/9	0.27	-99.0	GAGE	
12/07/9	0.26	-99.0	GAGE	
12/14/9	0.30	-99.0	GAGE	
12/21/9	0.26	-99.0	GAGE	
12/28/9	0.26	-99.0	GAGE	
01/04/9	0.25	-99.0	GAGE	
01/11/9	0.25	-99.0	GAGE	
02/01/9	0.22	-99.0	GAGE	
02/08/9	0.20	-99.0	GAGE	
02/15/9	0.20	-99.0	GAGE	
02/22/9	0.22	-99.0	GAGE	
02/29/9	0.22	-99.0	GAGE	
12/27/9	0.25	-99.0	GAGE	
12/31/9	0.26	-99.0	GAGE	
01/17/9	0.24	-99.0	GAGE	
03/10/9	0.22	-99.0	GAGE	
04/08/9	0.22	1.28	BOTH	
04/14/9	0.22	1.38	BOTH	
03/07/9	0.22	-99.0	GAGE	
03/14/9	0.22	-99.0	GAGE	
03/21/9	0.22	-99.0	GAGE	
03/28/9	0.22	-99.0	GAGE	
04/04/9	0.24	-99.0	GAGE	
04/11/9	0.22	-99.0	GAGE	
01/21/9	0.23	-99.0	GAGE	
01/28/9	0.23	-99.0	GAGE	
02/03/9	0.20	-99.0	GAGE	
02/13/9	0.20	-99.0	GAGE	
04/21/9	0.24	1.62	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 15

Date	Staff	Flow	Status	Comment
04/18/9	0.24	-99.0	GAGE	COOL AND OVERCAST
04/27/9	0.22	1.76	BOTH	cleared debris around
05/05/9	0.26	1.45	BOTH	
04/25/9	0.22	-99.0	GAGE	
05/02/9	0.25	-99.0	GAGE	
05/12/9	0.22	0.87	BOTH	
05/20/9	0.22	-99.0	GAGE	SNAPPING TURTLE AND WATER
05/28/9	0.19	-99.0	G	
06/02/9	0.20	0.77	B	
06/08/9	0.23	0.93	B	
06/16/9	0.20	0.21	BOTH	
06/25/9	0.20	0.42	BOTH	
06/30/9	0.16	0.32	BOTH	
07/06/9	0.18	0.43	BOTH	
07/17/9	0.20	0.53	BOTH	
05/09/9	0.25	-99.0	GAGE	
05/16/9	0.22	-99.0	GAGE	
05/23/9	0.20	-99.0	GAGE	
05/30/9	0.20	-99.0	GAGE	
06/06/9	0.29	-99.0	GAGE	
06/13/9	0.23	-99.0	GAGE	
06/20/9	0.20	-99.0	GAGE	
06/27/9	0.16	-99.0	GAGE	
07/22/9	0.19	0.33	BOTH	
07/28/9	0.16	3.65	BOTH	
08/05/9	0.18	7.56	BOTH	
08/11/9	0.19	-99.0	GAGE	
08/19/9	0.21	-99.0	GAGE	
07/04/9	0.16	-99.0	GAGE	
07/11/9	0.20	-99.0	GAGE	
07/18/9	0.20	-99.0	GAGE	
07/25/9	0.18	-99.0	GAGE	
08/25/9	0.18	-99.0	GAGE	
09/02/9	0.10	0.12	BOTH	
09/10/9	0.14	0.19	BOTH	
09/14/9	0.12	-99.0	GAGE	
09/21/9	0.13	-99.0	GAGE	
08/01/9	0.19	-99.0	GAGE	
08/08/9	0.17	-99.0	GAGE	
08/15/9	0.18	-99.0	GAGE	
08/22/9	0.19	-99.0	GAGE	
09/29/9	0.14	0.10	BOTH	
10/05/9	0.11	0.31	BOTH	
08/29/9	0.15	-99.0	GAGE	
09/05/9	0.16	-99.0	GAGE	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 15

Date	Staff	Flow	Status	Comment
09/12/9	0.14	-99.0	GAGE	
09/19/9	0.16	-99.0	GAGE	
09/26/9	0.14	-99.0	GAGE	
10/03/9	0.12	-99.0	GAGE	
10/13/9	0.18	0.55	BOTH	
10/21/9	0.15	-99.0	GAGE	
10/10/9	0.20	-99.0	GAGE	
10/17/9	0.18	-99.0	GAGE	
10/20/9	0.15	-99.0	GAGE	
10/28/9	0.15	0.42	BOTH	
11/02/9	0.15	0.22	BOTH	
10/24/9	0.16	-99.0	GAGE	
10/31/9	0.14	-99.0	GAGE	
11/13/9	0.18	-99.0	GAGE	
11/18/9	0.17	0.24	BOTH	
11/24/9	0.21	1.17	BOTH	
11/08/9	0.16	-99.0	GAGE	
11/14/9	0.14	-99.0	GAGE	
11/21/9	0.16	-99.0	GAGE	
11/28/9	0.24	-99.0	GAGE	
04/06/9	0.27	2.01	BOTH	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 16

Date	Staff	Flow	Status	Comment
02/20/9	-99.0	0.26	FLOW	SEASONAL TRIBUTARY
02/26/9	-99.0	0.87	FLOW	SEASONAL FLOW.
04/27/9	-99.0	0.15	FLOW	

Pawtuckaway Lake Raw Staff Gage and Flow

Station 17

Date	Staff	Flow	Status	Comment
02/20/9	-99.0	0.41	FLOW	UPSTREAM STATION FOR (#3)
05/28/9	-99.0	0.22	F	UPSTREAM OF #3
10/21/9	-99.0	0.11	FLOW	upstream of 4

Pawtuckaway Lake Raw Staff Gage and Flow

Station 18

Date	Staff	Flow	Status	Comment
02/20/9	-99.0	5.89	FLOW	UPSTREAM STATION FOR
05/28/9	-99.0	1.75	F	UPSTREAM OF #4
10/21/9	-99.0	0.50	FLOW	upstream of 2

Pawtuckaway Lake Raw Staff Gage and Flow

Station 19

Date	Staff	Flow	Status	Comment
05/28/9	-99.0	0.02	F	UPSTREAM OF #6
10/21/9	-99.0	0.07	FLOW	upstream of 6

Pawtuckaway Lake Raw Staff Gage and Flow

Station 20

Date	Staff	Flow	Status	Comment
02/20/9	-99.0	0.04	FLOW	UPSTREAM STATION FOR #7,
05/28/9	-99.0	0.00	F	UPSTREAM OF #7
10/21/9	-99.0	0.01	FLOW	upstream of 7

Pawtuckaway Lake Raw Staff Gage and Flow

Station 21

Date	Staff	Flow	Status	Comment
02/20/9	-99.0	19.25	FLOW	UPSTREAM STATION OF BACK
05/28/9	-99.0	0.64	F	UPSTREAM OF #11 AT
10/21/9	-99.0	2.80	FLOW	upstream of 11

Pawtuckaway Lake Raw Staff Gage and Flow

Station 22

Date	Staff	Flow	Status	Comment
02/20/9	-99.0	3.84	FLOW	UPSTREAM OF BACK B (#11)
05/28/9	-99.0	0.57	F	UPSTREAM OF #11 AT BRIDGE
10/21/9	-99.0	3.29	FLOW	upstream of 11

Pawtuckaway Lake Raw Staff Gage and Flow

Station 23

Date	Staff	Flow	Status	Comment
04/21/9	-99.0	4.36	FLOW	UPSTREAM TRIB OF ROUND
10/21/9	-99.0	0.06	FLOW	upstream of 14

Pawtuckaway Lake Raw Staff Gage and Flow

Station 24

Date	Staff	Flow	Status	Comment
04/27/9	-99.0	0.11	FLOW	FUNDY A

Pawtuckaway Lake Raw Staff Gage and Flow

Station 25

Date	Staff	Flow	Status	Comment
04/27/9	-99.0	0.12	FLOW	FUNDY B

Pawtuckaway Lake Raw Staff Gage and Flow

Station 26

Date	Staff	Flow	Status	Comment
04/27/9	-99.0	0.03	FLOW	FUNDY C

Pawtuckaway Lake Raw Staff Gage and Flow

Station 27

Date	Staff	Flow	Status	Comment
10/21/9	-99.0	0.04	FLOW	upstream of 8

APPENDIX VII-3

Pawtuckaway Lake Raw Seepage Meter Data

Station	Date	Total Time (min)	Total Volume (ml)	Rate (L/m2)	Comment
1	06/26/9	96	40	2.35	only 1-6 meters today
1	07/14/9	71	140	11.13	
1	07/21/9	95	320	19.01	
1	07/27/9	104	320	17.37	
1	08/03/9	108	210	10.98	
1	08/13/9	69	215	17.59	
1	08/18/9	61	320	29.61	
1	08/26/9	109	375	19.42	
1	09/03/9	64	100	8.82	
1	09/11/9	68	70	5.81	RAIN
1	09/16/9	160	75	2.65	SL AND WALT
1	09/22/9	129	40	1.75	
1	09/30/9	84	55	3.70	wicked cold
1	10/06/9	109	45	2.33	
1	10/12/9	187	145	4.38	rain on 10/10 and 10/12
2	06/26/9	92	95	5.83	
2	07/14/9	68	150	12.45	
2	07/21/9	99	310	17.68	
2	07/27/9	107	175	9.23	
2	08/03/9	109	150	7.77	
2	08/13/9	66	465	39.77	
2	08/18/9	66	170	14.54	
2	08/26/9	106	415	22.10	
2	09/03/9	63	120	10.75	
2	09/11/9	66	80	6.84	
2	09/16/9	155	110	4.01	
2	09/22/9	130	185	8.03	
2	09/30/9	86	85	5.58	
2	10/06/9	103	125	6.85	
2	10/12/9	183	100	3.08	
3	07/14/9	69	225	18.41	
3	07/21/9	99	265	15.11	control meter
3	07/27/9	101	185	10.34	
3	08/03/9	109	265	13.72	control meter
3	08/13/9	66	280	23.95	
3	08/18/9	66	230	19.67	
3	08/26/9	105	225	12.10	
3	09/03/9	63	140	12.54	CONTROL METER
3	09/11/9	66	115	9.84	CONTROL
3	09/16/9	155	100	3.64	CONTROL

Pawtuckaway Lake Raw Seepage Meter Data

Station	Date	Total Time (min)	Total Volume (ml)	Rate (L/m2)	Comment
3	09/22/9	130	110	4.78	CONTROL
3	09/30/9	87	170	11.03	
3	10/06/9	104	190	10.31	
3	10/12/9	183	90	2.78	
4	06/26/9	90	30	1.88	
4	07/14/9	67	370	31.17	
4	07/21/9	92	455	27.92	
4	07/27/9	95	380	22.58	
4	08/03/9	110	185	9.49	
4	08/13/9	66	185	15.82	
4	08/18/9	61	250	23.14	
4	08/26/9	106	320	17.04	
4	09/03/9	67	60	5.06	
4	09/11/9	69	55	4.50	
4	09/16/9	154	75	2.75	
4	09/22/9	135	95	3.97	
4	09/30/9	93	75	4.55	
4	10/06/9	99	45	2.57	
4	10/12/9	181	110	3.43	
5	06/26/9	66	35	2.99	
5	07/14/9	66	45	3.85	
5	07/21/9	91	250	15.51	
5	07/27/9	91	565	35.05	
5	08/03/9	110	285	14.63	
5	08/13/9	66	175	14.97	
5	08/18/9	60	245	23.05	
5	08/26/9	103	380	20.83	
5	09/03/9	69	90	7.36	
5	09/11/9	70	60	4.84	
5	09/16/9	153	70	2.58	
5	09/22/9	130	125	5.43	
5	09/30/9	88	110	7.06	
5	10/06/9	97	90	5.24	
5	10/12/9	177	110	3.51	
6	06/26/9	65	50	4.34	
6	07/14/9	64	590	52.04	
6	07/21/9	89	755	47.89	
6	07/27/9	78	205	14.84	
6	08/03/9	109	285	14.76	
6	08/13/9	63	145	12.99	

Pawtuckaway Lake Raw Seepage Meter Data

Station	Date	Total Time (min)	Total Volume (ml)	Rate (L/m2)	Comment
6	08/18/9	60	240	22.58	
6	08/26/9	105	550	29.57	
6	09/03/9	69	90	7.36	
6	09/11/9	71	115	9.14	
6	09/16/9	147	110	4.22	
6	09/22/9	140	170	6.85	
6	09/30/9	87	110	7.14	
6	10/06/9	89	95	6.03	
6	10/12/9	175	345	11.13	
7	07/14/9	65	0	0.00	
7	07/21/9	90	25	1.57	
7	07/27/9	81	8	0.56	
7	08/03/9	110	15	0.77	
7	08/13/9	63	170	15.23	control = 45ml at 63
7	08/18/9	60	130	12.23	
7	08/26/9	103	345	18.91	7A 610 mL at 103 mins.
7	09/03/9	68	1	0.08	7A IS 8 mL AT 68 MINS.
7	09/11/9	70	25	2.02	7A IS 10 mL AT 70 MINS.
7	09/16/9	149	-2	-0.08	7A IS 12mL AT 149 mins.
7	09/22/9	139	105	4.26	7A IS 15 AT 139 mins.
7	09/30/9	86	220	14.44	7a is 100 mL at 86
7	10/06/9	92	25	1.53	7A is 40 ml at 93 mins.
7	10/12/9	176	65	2.08	7A is 20 ml at 176
8	07/14/9	76	185	13.74	
8	07/21/9	83	115	7.82	
8	07/27/9	76	10	0.74	
8	08/03/9	70	10	0.81	
8	08/13/9	61	6	0.56	
8	08/18/9	63	10	0.90	
8	08/26/9	80	5	0.35	meter looked high in
8	09/03/9	63	0	0.00	
8	09/11/9	69	-10	-0.82	
8	09/16/9	145	-10	-0.39	
8	09/22/9	140	0	0.00	
8	09/30/9	87	-4	-0.26	
8	10/12/9	174	0	0.00	
9	07/14/9	75	5	0.38	
9	07/21/9	83	265	18.02	
9	07/27/9	70	110	8.87	
9	08/03/9	71	75	5.96	

Pawtuckaway Lake Raw Seepage Meter Data

Station	Date	Total Time (min)	Total Volume (ml)	Rate (L/m2)	Comment
9	08/13/9	62	20	1.82	
9	08/18/9	63	375	33.60	
9	08/26/9	82	230	15.83	
9	09/03/9	63	85	7.62	
9	09/11/9	60	85	8.00	
9	09/16/9	144	80	3.14	
9	09/22/9	139	35	1.42	
9	09/30/9	88	60	3.85	
9	10/06/9	85	80	5.31	
9	10/12/9	173	85	2.77	
10	07/14/9	76	215	15.97	
10	07/21/9	83	335	22.78	
10	07/27/9	65	135	11.72	
10	08/03/9	71	165	13.12	
10	08/13/9	73	145	11.21	
10	08/18/9	65	355	30.83	
10	08/26/9	80	255	17.99	
10	09/03/9	60	60	5.65	
10	09/11/9	64	120	10.58	
10	09/16/9	143	30	1.18	
10	09/22/9	108	55	2.87	
10	09/30/9	88	30	1.92	
10	10/06/9	85	90	5.98	
10	10/12/9	173	65	2.12	
11	07/14/9	70	390	31.45	
11	07/21/9	85	690	45.82	
11	07/27/9	60	405	38.10	
11	08/03/9	70	405	32.66	
11	08/13/9	60	225	21.17	
11	08/18/9	60	260	24.46	
11	08/26/9	81	520	36.24	
11	09/03/9	60	65	6.12	
11	09/11/9	84	60	4.03	
11	09/16/9	144	65	2.55	
11	09/22/9	78	50	3.62	
11	09/30/9	87	65	4.22	
11	10/06/9	77	60	4.40	
11	10/12/9	172	80	2.63	
12	07/14/9	73	420	32.48	
12	07/21/9	87	450	29.20	

Pawtuckaway Lake Raw Seepage Meter Data

Station	Date	Total Time (min)	Total Volume (ml)	Rate (L/m2)	Comment
12	07/27/9	61	690	63.85	
12	08/03/9	68	475	39.43	
12	08/13/9	62	315	28.68	meter upended and
12	08/18/9	61	310	28.69	
12	08/26/9	82	405	27.88	
12	09/03/9	60	130	12.23	
12	09/11/9	85	170	11.29	
12	09/16/9	143	65	2.57	
12	09/22/9	83	70	4.76	
12	09/30/9	86	170	11.16	
12	10/06/9	80	55	3.88	
12	10/12/9	127	165	7.33	
13	07/14/9	72	375	29.40	
13	07/21/9	88	500	32.07	
13	07/27/9	61	340	31.46	
13	08/03/9	68	565	46.90	
13	08/13/9	60	175	16.46	
13	08/18/9	62	395	35.96	
13	08/26/9	79	470	33.58	
13	09/03/9	60	90	8.47	
13	09/11/9	83	75	5.10	
13	09/16/9	143	65	2.57	
13	09/22/9	98	40	2.30	
13	09/30/9	84	70	4.70	
13	10/06/9	77	60	4.40	
13	10/12/9	128	80	3.53	
14	07/14/9	71	105	8.35	
14	07/21/9	86	165	10.83	
14	07/27/9	60	145	13.64	
14	08/03/9	68	55	4.57	
14	08/13/9	60	135	12.70	
14	08/18/9	63	205	18.37	
14	08/26/9	79	80	5.72	
14	09/03/9	60	140	13.17	
14	09/11/9	83	120	8.16	
14	09/16/9	147	110	4.22	
14	09/22/9	85	40	2.66	
14	09/30/9	84	70	4.70	
14	10/06/9	74	45	3.43	
14	10/12/9	129	110	4.81	

APPENDIX VIII-1

Sanitary Survey Form

For:

Date: Property Address:

Owner: Owner's Address:

Person Interviewed: Owner: Tenant:

Interviewer: Date:

SEWAGE DISPOSAL SYSTEM

Septic Tank and Leach Field or Trench ☐ Chemical Toilet ☐

Cesspool ☐ Gas Toilet ☐

Sealed Holding Tank ☐ Privy ☐

Other:

Comments:

AGE OF SYSTEM: years Date System Built:

SYSTEM LOADING

Number of Bedrooms: Year Round ☐

System Capacity (G.P.D.): Seasonal ☐

Average No. of Occupants: Spring
Summer
Fall
Winter

SYSTEM MAINTENANCE

Repairs:

Replacement:

Date of Latest Septic Tank Pumping:

Average Frequency of Tank Pumping:

CONDITION OF SYSTEM: Problems?

Owner comments:

Interviewer Comments:
(Visual Inspection for surface flow, leaking fixtures, odors, etc.)

Inspection Evaluation: ☐ Ok ☐ Failed ☐ Evidence of Problems

WATER SUPPLY SOURCE

Town System	☐	Lake	☐
Drilled Well	☐	Dug or Surface Well	☐
Off-Lot Well/Spring	☐	Bottled Water	☐

WATER CONSUMPTIVE APPLIANCE DATA

Number of Toilets:

Number of Showers: Indoor Outdoor

Number of Wash Basins:

Dishwasher: Yes ☐ No ☐

Clothes Washer: Yes ☐ No ☐

Garbage Disposal: Yes ☐ No ☐

CONFORMANCE WITH FOUR-FOOT RULE

Estimated elevation of bottom of leach bed above SHWT feet.

Estimated elevation of system (bottom of leach bed, chambers, etc.) above lake level feet.

Distance to nearest ledge outcropping feet.

Interviewer Comments:

PROPERTY DATA

Lake Frontage feet

Lot Size acres

Soil Type

Sketch of Buildings, set-back distances of each to lake shore, distance of sewage disposal system to nearest surface water and lake, including tank, leach field, etc.

APPENDIX VIII-2

Pawtuckaway Lake Sanitary Survey Raw Data

Number	System Type	Age	# of Occup.	Problem	Months Occup.	Appliances Wash.	Dish.	G.D.	Distance to Lake	Slope	Evaluation
1	STL		3	N	4				400	MS	
2	STL	2	4	N	12	*	*		400	MS	New System Unfinished House
3	STL	5	4	N	12	*	*		100	MS	
4	STL	8	2	N	12	*	*		95	MS	
5	STL	39	3	P	12	*			75	MS	New Tank in 1987
6	DW		3	N	1				150	MS	
7	STL	40	4	P	1				400	MS	
8	STL	40	4	P	12	*			200	MS	New Tank in 1983
9	STL		2	N	12				75	MS	New Tank in 1990
10	STL	29	6	N	12	*	*	*	125	MS	Updated since 1965
11	STL		2	P	12	*	*		150	MS	
12	STL	16	1	N	12	*	*		200	MS	
13	STC	10	3	N	12	*	*		200	MS	Non-Pump System
14	STC	6	2	N	12	*	*	*	250	MS	
15	STL	27	2	P	9				65	MS	
16	STC	5	2	N	4				100	MS	
17	STL	17	2	N	12	*	*		100	MS	
18	STL	2	3	N	12				150	MS	New System
19	STL	27	2	N	6				125	MS	Chem toilet in winter
20	STL	6	2	N	12	*	*	*	75	MS	
21	STL	40	3	P	2				2000	MS	Never Pumped
22	STC	4	2	N	7	*			110	MS	
23	STL	17	1	N	12	*	*		175	MS	New Pump in 1989
24	STL	5	3	N	12	*	*		75	MS	
25	STL	26	2	N	12	*			150	MS	Repairs in 1988
26	STL	20	4	Y	2				35	MS	Proximity to Lake
27	STL	10	3	N	12	*	*		175	MS	
28	STL		3	P	12	*	*		70	MS	New Tank
29	STL	16	1	N	12	*	*		100	MS	
30	STL	26	3	P	2	*			95	MS	Pumped in 1984
31	STL	40	3	P	2				1100	MS	
32	STL	32	1	Y	1				70	MS	Age and Proximity to Lake
33	STL	25	6	P	2	*		*	50	MS	Pumped in 1989
34	STL	22	4	N	5				300	L	Pumped in 1990
35	STL	25	3	Y	6				50	L	Pumped once in 1991

Pawtuckaway Lake Sanitary Survey Raw Data

Number	System Type	Age	# of Occup.	Problem	Months Occup.	Appliances Wash.	Dish.	G.D.	Distance to Lake	Slope	Evaluation
36	STL	30	4	P	9				50	L	Not Occupied
37	STL	19	2	N	12	*	*		90	L	Pumped every year
38	STL	25	2	P	4				85	L	
39	DW	43	1	P	2				75	L	Replaced pipes
40	Cess	42	2	Y	4				50	L	Pumped in 1990
41	STL	12	4	P	2					L	Never Pumped
42	STL	40	1	Y	12				25	L	Pumped in 1992
43	STL	7	2	N	12	*	*		75	L	Upgraded 1950's system in 1987
44	STL	5	2	N	12	*	*		400	L	Never Pumped
45	STL	4	2	N	6					L	
46	STC	27	2	P	6				98	L	Pumped in 1993
47	STL	19	2	N	6				100	L	Pumped in 1990
48	Out	40	2	N	2				100	L	Undeveloped lot
49	STL	18	2	N	6	*			500	L	Pumped in 1982
50	STL	24	4	Y	12	*				L	750 gal dry well for grey
51	STL	27	3	P	12	*		*	200	L	Pumped in 1992
52	STL	22	2	P	4				130	L	Pumped in 1989
53	STL	6	2	N	12	*	*		75	L	Pumped every 2 years
54	STL	24	2	P	12	*	*	*	100	L	
55	STC	7	3	N	12	*	*		400	MS	Replaced pumps
56	STL	7	4	N	5				200	MS	
57	STC	10	3	N	12	*	*	*	500	MS	Pumped in 1991
58	STL	30	4	Y	6				60	L	Pumped in 1991
59	STL	23	2	P	12	*	*	*	400	L	Pumped in 1990
60	STL	20	2	P	12	*			185	L	Pumped in 1987
61	STL	8	3	N	12	*	*		75	L	Pumped every year
62	STL	7	2	N	12	*	*		75	MS	Pumped in 1990
63	STL	22	4	P	3	*			80	MS	Pumped in 1989
64	STL	24	2	P	12	*	*	*	100	MS	Pumped every 2 years
65	STC	9	5	P	12	*	*	*	75	MS	Ledge surrounds system
66	STL	22	2	P	9				80	MS	Ledge
67	STC	3	4	N	12	*	*		80	MS	
68	STC	3	3	N	12	*			110	MS	
69	STC	15	2	Y	12	*	*		65	MS	Age and distance to lake
70	STL	12	5	N	12	*	*		75	MS	Pumped every year

Pawtuckaway Lake Sanitary Survey Raw Data

Number	System Type	Age	# of Occup.	Problem	Months Occup.	Appliances Wash.	Dish.	G.D.	Distance to Lake	Slope	Evaluation
71	STL	12	5	N	3				75	MS	
72	STL	33	2	P	3				75	MS	Ledge
73	STL	12	2	N	12	*	*		100	MS	Steep with bedrock outcrops
74	STL	20	3	N	12		*	*	200	MS	
75	STC	22	2	P	12	*	*	*	100	MS	Chambers installed in 1984
76	STL	22	2	P	1				100	MS	First pumped in 1992
77	STL	27	2	P	12	*	*		95	MS	
78	STL	17	3	N	12	*	*		215	MS	Pumped in 1989
79	STL	16	2	N	12	*	*	*	500	MS	
80	STL	27	2	P	12	*	*		75	MS	Pumped in 1990
81	STL	12	2	N	9		*	*	75	MS	
82	STL	10	3	N	3	*	*		75	MS	Steep slopes
83	STL	6	2	N	12	*	*	*	100	MS	
84	Cess	26	2	P	3				150	MS	
85	STC	29	3	Y	3				150	MS	Iron tank, never pumped
86	STL	17	2	N	12	*	*		100	MS	New pump
87	STC	30	2	P	3				200	MS	Replaced baffles
88	STL	17	2	N	1				120	MS	
89	STL	17	4	N	3				100	MS	Pumped in 1991
90	STL	5	3	P	12	*	*		150	MS	Never pumped
91	STL	12	4	N	12	*			75	MS	Pumped in 1992
92	STL	32	3	P	4	*	*		75	MS	
93	STL	8	5	P	3				70	L	Replaced failed cesspool
94	STC	6	5	N	2	*	*		80	L	
95	STL	12	2	N	9	*	*		75	L	Replaced cesspool
96	STL	27	1	P	12	*			96	L	
97	STL	22	5	P	9				125	L	Pumped in 1988
98	STL	6	2	N	12	*	*		75	L	
99	STL	32	5	P	4				75	L	
100	STL	12	2	N	12	*	*	*	80	L	Replaced leachfield in 1982
101	STL	8	2	N	3	*			75	L	
102	Cess	31	3	P	4				70	L	Pumped 5 times since built
103	STL	14	2	N	12	*	*		2500	MS	Never pumped
104	STL	15	5	Y	12	*	*		60	MS	Distance to lake
105	STL	12	2	N	12	*			300	MS	Pumped every year

Pawtuckaway Lake Sanitary Survey Raw Data

Number	System Type	Age	# of Occup.	Problem	Months Occup.	Appliances Wash.	Dish.	G.D.	Distance to Lake	Slope	Evaluation
106	STL	36	3	P	9				85	MS	
107	STL	18	2	N	12	*			180	MS	
108	STL	5	2	N	6				115	MS	Replaced 30 yr old system
109	STL	32	1	P	12	*			75		
110	STL	30	2	P	12	*	*	*	75	MS	Grey water bypasses into sep
111	STL	37	2	P	12				75	MS	Repaired lines
112	HT	30	2	P	6				140	MS	No repairs
113	STL	21	2	Y	12	*	*	*	100	MS	Never pumped
114	STL	12	3	N	4				100	MS	Never pumped
115	STL	22	3	N	4				75	MS	Pumped every year
116	Cess	12	4	Y	12				50	MS	Distance to lake
117	STL	29	2	P	5	*			75	L	Inspected in 1990
118	STL	4	3	N	5	*			200	L	
119	STL	23	2	P	4				100	L	
120	HT	20	2	N	2				75	L	Pumped every year
121	STL	10	2	Y	1				30	L	Never pumped
122	STL	23	1	P	12	*			75	L	Never pumped
123	STL	16	4	N	12				140	L	
124	STL	4	2	N	12				75	L	Never pumped
125	STL	10	2	N	5		*		90	L	Never pumped
126	STL	58	5	N	6				300	L	New leach field in 1987
127	Out	30	1	N	2				100	L	
128	STC	6	4	N	12	*	*		75	L	16 chamber system
129	STL	32	7	Y	1				70	L	Never pumped
130	STC	22	4	P	5				110	L	Pumped in 1986
131	STL	23	2	P	4	*			105	L	Pumped every 4 years
132	STL	32	2	P	12				75	L	Replaced stone around tank in
133	STC	31	2	Y	3				50	L	Distance to lake
134	STL	9	4	Y	12	*	*		50	L	Distance to lake
135	DW	19	3	P	9				100	L	1,000 gal seepage tank
136	STL	29	2	N	6	*			75	L	New leach field in 1988
137	STC	42	2	P	6	*	*		75	L	No repairs
138	STL	28	2	P	12				75	L	Pumped every 5 years
139	STL	19	2	N	12	*	*		125	L	Pumped in 1991
140	STL	15	2	N	12	*			85	L	New tank in 1985

Pawtuckaway Lake Sanitary Survey Raw Data

Number	System Type	Age	# of Occup.	Problem	Months Occup.	Appliances Wash.	Dish.	G.D.	Distance to Lake	Slope	Evaluation
141	STL	27	2	Y	4				50	L	Pumped every 5 years
142	STL	20	2	P	4		*		90	L	Never pumped
143	STL	17	4	Y	3				40	L	
144	STL	36	1	Y	12	*			65	L	Pumped in 1988
145	STL	5	2	N	12	*	*	*	500	L	Pumped every two years
146	STL	14	4	N	12	*			120	L	
147	STL	5	2	Y	12	*	*		50	L	Never pumped
148	STL	27	2	P	4				100	L	
149	Cess	38	2	Y	3	*			33	L	Pumped once. Grey water
150	STC	5	3	N	12	*	*	*	75	L	Upgraded
151	Cess	25	5	P	2				100	L	Never pumped
152	HT	12	4	N	4				100	L	Original system built in
153	STL	5	4	N	12	*	*		200	L	Pumped every year
154	STL	25	2	N	12				450	L	Pumped in 1991
155	STL	17	2	N	12	*	*		75	L	
156	STL	15	6	N	4				75	L	
157	STL	7	6	N	4				100	L	New tank in 1989
158	STL	25	6	P	4				200	L	Never pumped
159	STC	3	4	P	12	*	*		90	L	Grey water bypass into drywell
160	HT	17	4	Y	4	*			20	L	
161	HT	10	2	N	2				75	L	
162	STL	34	2	Y	8				50	L	Pumped every 5 years
163	Chem		3	N	4				100	L	BFI rental
164	STL	24	2	Y	12	*	*		70	L	Pumped every 2 years
165	STL	50	6	Y	2				25	L	Pumped in 1991, no repairs
166	STL	10	5	N	9				100	L	Repairs in 1986
167	Chem		4	N	9				100	L	BFI rental
168	STL	47	8	N	3				100	L	Rebuilt in 1987
169	Chem		4	N	3				200	L	BFI rental
170	STL	20	5	P	3				100	L	Never pumped or repaired
171	STL	20	3	P	4				85	L	Pumped every 2 years
172	STC	4	2	N	4	*	*		75	L	

APPENDIX XI-1

CHAPTER 483-B

COMPREHENSIVE SHORELAND PROTECTION ACT

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483-B:3 Consistency Required
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July 1994

CHAPTER 483-B

COMPREHENSIVE SHORELAND PROTECTION ACT

483-B:1 Purpose. The general court finds that:

I. The shorelands of the state are among its most valuable and fragile natural resources and their protection is essential to maintain the integrity of public waters.

II. The public waters of New Hampshire are valuable resources held in trust by the state. The state has an interest in protecting those waters and has the jurisdiction to control the use of the public waters and the adjacent shoreland for the greatest public benefit.

III. There is great concern throughout the state relating to the utilization, protection, restoration and preservation of shorelands because of their effect on state waters.

IV. Under current law the potential exists for uncoordinated, unplanned and piecemeal development along the state's shorelines, which could result in significant negative impacts on the public waters of New Hampshire.

483-B:2 Minimum Standards Required. To fulfill the state's role as trustee of its waters and to promote public health, safety, and the general welfare, the general court declares that the public interest requires the establishment of standards for the subdivision, use, and development of the shorelands of the state's public waters. The development standards provided in this chapter shall be the minimum standards necessary to protect the public waters of the state of New Hampshire. These standards shall serve to:

I. Further the maintenance of safe and healthful conditions.

II. Provide for the wise utilization of water and related land resources.

III. Prevent and control water pollution.

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IV. Protect fish spawning grounds, aquatic life, and bird and other wildlife habitats.

V. Protect buildings and lands from flooding and accelerated erosion.

VI. Protect archaeological and historical resources.

VII. Protect commercial fishing and maritime industries.

VIII. Protect freshwater and coastal wetlands.

IX. Control building sites, placement of structures, and land uses.

X. Conserve shoreline cover and points of access to inland and coastal waters.

XI. Preserve the state's lakes, rivers, estuaries and coastal waters in their natural state.

XII. Promote wildlife habitat, scenic beauty, and scientific study.

XIII. Protect public use of waters, including recreation.

XIV. Conserve natural beauty and open spaces.

XV. Anticipate and respond to the impacts of development in shoreland areas.

XVI. Provide for economic development in proximity to waters.

483-B:3 Consistency Required.

I. All state agencies shall perform their responsibilities in a manner consistent with the intent of this chapter. State and local permits for work within the protected shorelands shall be issued only when consistent with the policies of this chapter.

II. When the standards and practices established in this chapter conflict with other local or state laws and rules, the more stringent standard shall control.

III. All agricultural activities and operations in the state as defined in RSA 21:34-a and as governed by RSA 430, including the use of animal manure, lime, wood ash, irrigation and the clearing of land for agricultural utilization, and other agricultural technologies, shall be exempt from the provisions of this chapter, provided such activities and operations are in conformance with the

most recent best management practices determined by the United States Department of Agriculture Soil Conservation Service, the United States Department of Agriculture Cooperative Extension Service and the department of agriculture. Persons carrying out such agricultural activities and operations in the protected shoreland shall work directly with the local representatives of the above agencies for their particular property.

483-B:4 Definitions. In this chapter:

I. "Abutter" means any person whose property is located in New Hampshire and adjoins or is directly across the street or stream from the land under consideration by the local land use board. For purposes of receiving testimony only, and not for purposes of notification, the term "abutter" shall include any person who is able to demonstrate that his land will be directly affected by the proposal under consideration.

II. "Accessory structure" means a structure detached from the primary building on the same lot and customarily incidental and subordinate to the primary building or use, such as a pump house, gazebo or woodshed.

III. "Basal area" means the cross sectional area of a tree measured at a height of 4-1/2 feet above the ground, usually expressed in square feet per acre for a stand of trees.

IV. "Commissioner" means the commissioner of the department of environmental services or designee.

V. "Department" means the department of environmental services.

VI. "Disturbed area" means an area in which natural vegetation is removed, exposing the underlying soil.

VII. "Ground cover" means any herbaceous plant which normally grows to a mature height of 4 feet or less.

VIII. "Lot of record" means a parcel, the plat or description of which has been recorded at the registry of deeds for the county in which it is located.

IX. "Major project" [Repealed 1994, eff. July 1, 1994]

X. "Municipality" means a city, town, village district if specifically authorized to zone by the legislature, or county in respect to unincorporated towns or unorganized places or any combination thereof pursuant to RSA 53-A.

XI. "Natural woodland buffer" means a forested area consisting of various species of trees, saplings, shrubs, and ground covers in any combination and at any stage of growth.

XI-a. "Ordinary high water mark" means the line on the shore, running parallel to the main stem of the river, established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the immediate bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas. Where the ordinary high water mark is not easily discernible, the ordinary high water mark may be determined by the department of environmental services.

XII. "Person" means a corporation, company, association, society, firm, partnership or joint stock company, as well as an individual, a state, and any political subdivision of a state or any agency or instrumentality thereof.

XIII. "Primary building line" means a setback from the reference line.

XIV. "Primary structure" means a structure other than one which is used for purposes wholly incidental or accessory to the use of another structure on the same premises.

XV. "Protected shoreland" means, for natural, fresh water bodies without artificial impoundments, for artificially impounded fresh water bodies, and for coastal waters and rivers, all land located within 250 feet of the reference line of public waters.

XVI. "Public waters" shall include:

(a) All fresh water bodies listed in the official list of public waters published by the department pursuant to RSA 271:20, II, whether they are great ponds or artificial impoundments.

(b) Coastal waters, being all waters subject to the ebb and flow of the tide, including the Great Bay Estuary and the associated tidal rivers.

(c) Rivers, meaning all year-round flowing waters of fourth order or higher, as shown on the now current version of the U.S. Geological Survey 7 1/2' topographic maps. Stream order shall be determined using the Strahler method, whereby the highest year-round streams in a watershed are first order streams, their juncture yields second order streams, the juncture of second order streams yields third order streams, et seq. A listing of the streams of fourth order and higher shall be prepared and maintained by the office of state planning and delivered to the commissioner 30 days after the effective date of this act.

XVII. "Reference line" means:

(a) For natural fresh water bodies without artificial impoundments, the natural mean high water level as determined by the division of water resources of the department.

(b) For artificially impounded fresh water bodies, the waterline at full pond as determined by the elevation of the top of the impoundment structure.

(c) For coastal waters, the highest observable tide line, which means a line defining the furthest landward limit of tidal flow, not including storm events, which can be recognized by indicators

such as the presence of a strand line of flotsam and debris, the landward margin of salt tolerant vegetation, or a physical barrier that blocks further flow of the tide.

(d) For rivers, the ordinary high water mark.

XVIII. "Removal or removed" means cut, sawed, pruned, girdled, felled, pushed over, buried, burned, killed, or otherwise destructively altered.

XIX. "Residential unit" means a structure, or portion thereof, providing complete and independent living facilities, including permanent facilities for living, sleeping, eating, cooking, and sanitation which are used in common by one or more persons.

XX. "Sapling" means any woody plant which normally grows to a mature height greater than 20 feet and has a diameter less than 6 inches at a point 4-1/2 feet above the ground.

XXI. "Shrub" means any multi-stemmed woody plant which normally grows to a mature height of less than 20 feet.

XXII. "Structure" means anything built for the support, shelter or enclosure of persons, animals, goods, or property of any kind, as well as anything constructed or erected with a fixed location on or in the ground, exclusive of fences.

XXIII. "Subdivision" means subdivision as defined in RSA 672:14.

XXIV. "Tree" means any woody plant which normally grows to a mature height greater than 20 feet and which has a diameter of 6 inches or more at a point 4-1/2 feet above the ground.

XXV. "Urbanization" means the concentrated development found in the sections of towns or cities where there has been an historic pattern of intensive building for commercial or industrial use, or mixed residential, commercial, and industrial use.

483-B:5 Enforcement by Commissioner; Duties; Woodland Buffer.

I. The commissioner, with the advice and assistance of the office of state planning, department of resources and economic development and department of agriculture, shall enforce the provisions of this chapter.

II. The commissioner or his designee may, for cause, enter upon any land or parcel at any reasonable time to perform oversight and enforcement duties provided for in this chapter.

III. Relative to Forest Inventory Plans [Repealed 1994, eff. July 1, 1994]

IV. To encourage coordination of state and local enforcement measures, the commissioner shall notify, at the time of issuance or filing, the local governing body of enforcement action undertaken by the state in respect to protected shoreland within the municipality by sending it copies of relevant administrative orders issued and pleadings filed.

V. The commissioner may issue an order to any person in violation of this chapter, of rules adopted under this chapter, or of any condition of a permit issued under this chapter.

483-B:6 Prior Approval; Permits.

I. Within the protected shoreland, any person intending to:

(a) Engage in any earth excavation activity shall obtain all necessary local approvals in compliance with RSA 155-E.

(b) Construct a water dependent structure as described in RSA 483-B:9, II(c) shall obtain approval and all necessary permits pursuant to RSA 482-A.

(c) Install a septic system as described in RSA 483-B:9, V(b)(1)-(3) shall obtain all permits pursuant to RSA 485-A:29.

(d) Conduct an activity resulting in a contiguous disturbed area exceeding 50,000 square feet shall obtain a permit pursuant to RSA 485-A:17.

(e) Subdivide land for residential or non-residential development as described in RSA 483-B:9 V(d) and (e) shall obtain approval pursuant to RSA 485-A:29.

II. In applying for these approvals and permits, such persons shall demonstrate to the satisfaction of the department that the proposal meets or exceeds the development standards of this chapter. The department shall grant, deny, or attach reasonable conditions to a permit listed in subparagraphs I(a)-(e), to protect the public waters or the public health, safety or welfare. Such conditions shall be related to the purposes of this chapter.

483-B:7 Reporting; On-Site Inspections; Local Participation. The department may devise a system whereby municipal officials may voluntarily assist with the permitting process under RSA 483-B:6 and the subsequent enforcement of permit conditions, by performing certain reporting functions relative to on-site inspections. Utilization of such reports shall be at the department's discretion, but may, when appropriate, obviate the need for further on-site review by department staff.

483-B:8 Municipal Authority.

I. Municipalities may adopt land use control ordinances relative to all protected shorelands which are more stringent than the minimum standards contained in this chapter.

II. Municipalities are encouraged to adopt land use control ordinances for the shorelands of water bodies and water courses other than public waters.

III. Municipalities in which protected shoreland is situated may enforce the provisions of this chapter by issuing cease and desist orders and by seeking injunctive relief or civil penalties as provided in RSA 483-B:18, III(a) and (b). Civil penalties and fines collected by the court shall be remitted within 14 days to the treasurer of the municipality prosecuting said violations, for the use

of the municipality. Any municipality electing to enforce the provisions of this chapter shall send copies of any pleading to the attorney general at the time of filing.

IV. The authority granted to municipalities under this chapter shall not be interpreted to extend to RSA 430:28-48.

V. Municipalities bordering the same water body are encouraged to employ jointly a single code enforcement officer to monitor compliance.

483-B:9 Minimum Shoreland Protection Standards.

I. The standards in this section are designed to minimize shoreland disturbance so as to protect the public waters, while still accommodating reasonable levels of development in the protected shoreland. Development outside the protected shoreland shall conform to local zoning and local ordinances and shall not be subject to standards established in this chapter.

II. Within the protected shoreland the following restrictions shall apply:

(a) The establishment or expansion of salt storage yards, automobile junk yards, and solid or hazardous waste facilities shall be prohibited.

(b) Primary structures shall be set back behind the primary building line. This line shall initially be set back 50 feet from the reference line. Upon the establishment of a shoreland building setback by a municipality, that standard, whether greater or lesser than 50 feet, shall define the primary building line in that municipality.

(c) A water dependent structure, meaning one which is a dock, wharf, pier, breakwater, or other similar structure, or any part thereof, built over, on, or in the waters of the state, shall be constructed only as approved by the wetlands board pursuant to RSA 482-A.

(d) No fertilizer, except lime and wood ash, shall be used on lawns or areas with grass on residential properties.

III. Public water supply facilities, including water supply intakes, pipes, water treatment facilities, pump stations, and disinfection stations shall be permitted by the commissioner as necessary, consistent with the purposes of this chapter and other state law. Private water supply facilities shall not require a permit.

IV. The placement and expansion of public water and sewage treatment facilities shall be permitted by the commissioner as necessary, consistent with the purpose of this chapter and other state law.

IV-a. Hydro electric facilities, including, but not limited to, dams, dikes, penstocks, and powerhouses, shall be recognized as water dependent, and shall be permitted by the commissioner as necessary, consistent with the purposes of this chapter and other state law.

IV-b. Public utility lines and associated structures and facilities shall be permitted by the commissioner as necessary, consistent with the purposes of this chapter and other state law.

IV-c. An existing solid waste facility which is located within 250 feet of the reference line of public waters under this chapter may continue to operate under an existing permit, provided it does not cause degradation to an area in excess of that area under permit.

IV-d. No solid waste facility shall place solid waste within 250 feet of the reference line of public waters under this chapter except as expressly permitted under RSA 483-B:9, IV-c. However, any solid waste facility may be allowed, subject to permitting conditions under RSA 149-M:10, to erect accessory structures and conduct other activities consistent with the operation of the facility within 250 feet of the reference line of public waters under this chapter, such as filling, grading and installing monitoring wells and other drainage structures as is consistent with its solid waste permit as issued by the department of environmental services. Under no circumstances shall the toe of any slope encroach within 150 feet of the reference line.

V. The following minimum standards shall apply to the protected shoreland provided that forestry, involving water supply reservoir water management or agriculture conducted in accordance with best management practices, shall be exempted from the provisions of this chapter:

(a) Natural woodland buffer.

(1) Where existing, a natural woodland buffer shall be maintained within 150 feet of the reference line. The purpose of this buffer shall be to protect the quality of public waters by minimizing erosion, preventing siltation and turbidity, stabilizing soils, preventing excess nutrients and chemical pollution, maintaining natural water temperatures, maintaining a healthy tree canopy and understory, preserving fish and wildlife habitat, and respecting the overall natural condition of the protected shoreland.

(2) Within the natural woodland buffer of the protected shoreland under conditions defined in RSA 483-B:9, V the following prohibitions and limitations shall apply:

(A) Not more than a maximum of 50 percent of the basal area of trees, and a maximum of 50 percent of the total number of saplings shall be removed for any purpose in a 20-year period. A healthy, well-distributed stand of trees, saplings, shrubs and ground covers and their living, undamaged root systems shall be left in place. Replacement planting with native or naturalized species may be permitted to maintain the 50 percent level.

(B) Relative to pre-project inventory and forest inventory plans. [Repealed 1992, eff. Jan. 1, 1993].

(C) Trees, saplings, shrubs and ground covers which are removed to clear an opening for building construction, accessory structures, septic systems, roadways, pathways, and parking areas shall be excluded when computing the percentage limitations under subparagraph (a)(2)(A).

(D) Dead, diseased, unsafe, noxious or fallen trees, saplings, shrubs, or ground covers may be removed. Their removal shall not be used in computing the percentage limitations under subparagraph (a)(2)(A).

(E) Stumps and their root systems which are located within 50 feet of the reference line shall be left intact in the ground.

(F) Dead and living trees that provide dens and nesting places for wildlife are encouraged to be preserved.

(G) Planting efforts that are beneficial to wildlife are encouraged to be undertaken.

(b) Septic systems.

(1) All new lots, including those in excess of 5 acres, created within the protected shoreland are subject to subdivision approval by the division of water supply and pollution control, subsurface systems bureau under RSA 485-A:29.

(2) The following conditions, based on the characteristics of the receiving soil as they relate to U.S. Department of Agriculture, soil conservation service drainage classes, shall dictate the setback requirements for all new leaching portions of new septic systems, as follows:

(A) Adjacent to ponds, lakes, estuaries and the open ocean.

(i) Where the receiving soil downgradient of the leaching portions of a septic system is a porous sand and gravel material with a percolation rate faster than 2 minutes per inch, the setback shall be at least 125 feet from the reference line;

(ii) For soils with restrictive layers within 18 inches of the natural soil surface, the setback shall be at least 100 feet from the reference line; and

(iii) For all other soil conditions, the setback shall be at least 75 feet from the reference line.

(B) Adjacent to rivers the setback shall be no less than 75 feet, and may be greater if approved by the commissioner.

(3) The placement of all septic tanks and leaching portions of septic systems for replacement systems shall comply with the requirements of subparagraph (b)(2), to the maximum extent feasible.

(c) Erosion and siltation.

(1) All new structures within protected shoreland shall be designed and constructed in accordance with rules adopted by the department pursuant to 541-A, relative to terrain alteration under RSA 485-A:17, for controlling erosion and siltation of public waters, during and after construction.

(2) New structures within the protected shoreland shall be designed and constructed to prevent the release of surface runoff across exposed mineral soils.

(3) A permit pursuant to RSA 485-A:17, I shall be required for improved, developed, or subdivided land within the protected shoreland whenever there is a contiguous disturbed area exceeding 50,000 square feet.

(d) Minimum lots and residential development. In the protected shoreland:

(1) The minimum size for new lots in areas dependent upon on-site septic systems shall be determined by soil type lot size determinations, as established by the water supply and pollution control division.

(2) For projects in areas dependent upon on-site sewage and septic systems, the total number of residential units in the protected shoreland, whether built on individual lots or grouped as cluster or condominium development, shall not exceed one unit per 150 feet of shoreland frontage.

(3) Lots in areas serviced by municipal sewers shall conform to municipal minimum lot standards, and shall not be subject to any shoreland frontage requirement, except as provided by municipal standards.

(4) Lots and residential units outside of the protected shoreland shall not be subject to this chapter.

(e) Minimum lots and non-residential development. In the protected shoreland:

(1) The minimum size for new non-residential lots in areas dependent upon on-site septic systems shall be determined by soil type lot size determinations, as set forth under rules adopted pursuant to RSA 541-A.

(2) Non-residential development requiring on-site water and sewage shall not be constructed on lots less than 150 feet in width.

(3) Non-residential lots in areas serviced by municipal sewers shall conform to municipal minimum lot standards.

(4) Non-residential lots outside of the protected shoreland shall not be subject to this chapter.

(f) Common owners and residential or non-residential development. In the protected shoreland, waterfront parcels held in common by one or more owners of contiguous interior parcels may be developed but only in a manner consistent with the provisions of this chapter. Care shall be taken for the adequate provision of parking, toilet facilities, and related support systems to minimize the project's impact on the public waters.

(g) The commissioner shall have the authority to grant variances from the minimum standards of this section. Such authority shall be exercised subject to the criteria which govern the grant of a variance by a zoning board of adjustment under RSA 674:33, I(b).

483-B:10 Nonconforming Lots of Record. Nonconforming, undeveloped lots of record that are located within the protected shoreland shall comply with the following restrictions, in addition to any local requirements:

I. Except when otherwise prohibited by law, present and successive owners of an individual undeveloped lot may construct a single family residential dwelling on it, notwithstanding the provisions of this chapter. Conditions may be imposed which, in the opinion of the commissioner, more nearly meet the intent of this chapter, while still accommodating the applicant's rights.

II. Building on nonconforming lots of record shall be limited to single family residential structures and related facilities, including, but not limited to docks, piers, boathouses, boat loading ramps, walkways, and other water dependent structures, consistent with state law.

483-B:11 Nonconforming Structures.

I. Except as otherwise prohibited by law, pre-existing non-conforming structures located within the protected shoreland may be repaired, improved, or expanded. An expansion that increases the sewerage load to an on-site septic system, for example, additional bedrooms, shall require approval by the department. Between the primary building line and the reference line, no alteration shall extend the structure closer to the public water, except that the addition of an open deck or porch is permitted up to a maximum of 12 feet towards the reference line.

II. When reviewing requests for variances involving the redevelopment of sites that currently contain nonconforming structures, the commissioner shall review proposals which are more nearly conforming than the existing structures, and may waive some of the existing standards, so long as

the net effect represents an improvement in the overall degree of protection provided to the public waters.

483-B:12 Shoreland Exemptions.

I. The governing body of a municipality may, in its discretion, request the commissioner to exempt all or a portion of the protected shoreland within its boundaries from the provisions of this chapter if the governing body finds that special local urbanization conditions exist in the protected shoreland for which the exemption is sought.

II. If the governing body of a municipality requests such an exemption, it shall submit evidence of existing and historical patterns of building and development in the protected shoreland. Such evidence shall address:

(a) Current and past building density.

(b) Commercial or industrial uses.

(c) Municipal or other public utilities.

(d) Current municipal land use regulations which affect the protected shoreland.

(e) Any other information which the commissioner may reasonably require.

III. With the advice of the office of state planning, the commissioner shall approve or deny the request for an exemption and shall issue written findings in support of his decision. A request for an exemption shall be approved only if the municipality demonstrates, using the evidence required under paragraph II, that special conditions of urbanization exist along the portion of shoreland to be exempted.

IV. The state port authority may request an exemption under this section for all or a portion of and land purchased, leased, or otherwise acquired by it pursuant to RSA 271-A.

483-B:13 Public Hearing and Notice to Abutter. [Repealed 1992, eff. Jan. 1, 1993]

483-B:14 Rehearings and Appeals. Where the requirements of this chapter amend the existing statutory authority of the department or other agencies relative to certain established regulatory programs and shall be enforced under these established regulatory programs, the existing procedures governing contested cases and hearings and appeals regarding these requirements shall apply. Where requirements of this chapter are new and do not amend existing statutory authority relative to any established regulatory programs, the procedures set forth in RSA 541-A:31 for contested cases shall apply.

483-B:15 Gifts, Grants and Donations. The department is authorized to solicit, receive, and expend any gifts, grants, or donations made for the purposes of this chapter. Gifts of land or easements shall be assigned to the department of resources and economic development for management or assignment to another state agency or other public body, as appropriate.

483-B:16 Assistance to Municipalities; Office of State Planning. The office of state planning may assist municipalities with the implementation of local ordinances under this chapter, upon the request of an individual municipality.

483-B:17 Rulemaking. The commissioner shall adopt rules, pursuant to RSA 541-A, relative to:

I. The content and structure of all forms, applications and permits to be received or issued by the department under this chapter, including information and other materials to be submitted by an applicant.

II. Procedures for filing and review of requests for urbanized shoreland exemptions and standards for granting urbanized shoreland exemptions, including the time frames for decisions.

III. Enforcement of the minimum shoreland standards, including methods and timing of inspection and coordination with municipalities.

IV. Procedures and criteria for the placement of small accessory structures such as storage sheds and gazebos, the size, placement, and construction of which is consistent with the intent of this chapter, between the reference line and the primary building line.

V. Criteria governing the assessment of administrative fines.

483-B:18 Penalties.

I. The following shall constitute a violation of this chapter:

(a) Failure to comply with the provisions of this chapter.

(b) Failure to obey an order of the commissioner or a municipality issued relative to activities regulated or prohibited by this chapter.

(c) Misrepresentation by any person of a material fact made in connection with any activity regulated or prohibited by this chapter.

II. Any person who violates this chapter and any person who purchases land affected by a violation of this chapter who knew or had reason to know of the violation shall be liable for remediation or restoration of the land affected.

III. Persons violating the provisions of this chapter shall be subject to the following:

(a) Upon petition of the attorney general or of the municipality in which the violation occurred, the superior court may levy upon any person violating this chapter a civil penalty in an amount not to exceed $20,000 for each day of continuing violation. The superior court shall have jurisdiction to restrain a continuing violation of this chapter, and to require remediation.

(b) Any person who knowingly violates any provision of this chapter, or any rule adopted or order issued under this chapter or any condition of any permit issued under this chapter shall be guilty of a misdemeanor if a natural person, or guilty of a felony if any other person, and, notwithstanding RSA 651:2, may in addition to any sentence of imprisonment, probation or

conditional discharge, be fined not more than $20,000 for each violation if found guilty pursuant to this section. Each day of violation shall constitute a separate offense.

(c) The commissioner, after notice and hearing pursuant to RSA 541-A, may impose an administrative fine of up to $5,000 for each offense upon any person who violates this chapter. Rehearings and appeals relating to such fines shall be governed by RSA 541. Imposition of an administrative fine under this section shall not preclude the imposition of further civil or criminal penalties under this chapter.

483-B:19 Applicability. The provisions of this chapter shall not apply to any applicant whose land is in a municipality that has adopted a shoreland protection ordinance under RSA 674:16, the provisions of which are at least as stringent as similar provisions in this chapter. The director of the office of state planning shall certify to the commissioner that the provisions of a local ordinance are at least as stringent as similar provisions in this chapter.

483-B:20 Designated Rivers. The provisions of this chapter shall not apply to rivers or river segments designated by the general court and approved for management and protection under RSA 483 prior to January 1, 1993.

History

General Court Review of Rivers Exemption. 1992, 235:27: "In the event that the local river management advisory committees do not fulfill their responsibilities prescribed in RSA 483:8-a, III(c) or that the cities and towns along designated rivers or segments thereof do not adopt the proposals made by their local river management advisory committees, the house and senate shall re-examine the exemption provided in RSA 483-B:20 and propose minimum standards as defined by this act."

APPENDIX XI-2

PAWTUCKAWAY LAKE WATER QUALITY PROJECT
BEST MANAGEMENT PRACTICES

FERNALD DAIRY FARM
NOTTINGHAM, NH
FEBBRUARY 9, 1995

Table of Contents:

Rationale for Sizing Manure Pit.....Pgs. 1 and 2
Plan View Manure Storage Facility.....Pg. 3
Manure Storage and Heavy Use Area Cross Sections.....Pg. 4
Concrete Push-Off Wall Detail and Steel Schedule.....Pg. 5
Standard Design for Concrete Slab.....Pg. 6
Volume of Earth Fill Calculations.....Pg. 7
Plan View of Suspended Roof Gutter System.....Pg. 8
Roof Runoff Calculations.....Pgs. 9 and 10
Hydrology Used For Sizing Sod Waterway.....Pgs. 11 and 12
Sod Waterway Design Calculations.....Pg. 13
Plan View of Sod Waterway.....Pg. 14
Bill of Materials and Itemized Cost Estimate.....Pg. 15

NH-Ver 1.2

US Department of Agricult
Soil Conservation Service

A SOLID WASTE STORAGE DESIGN

prepared for

Dave Fernald

in

Rockingham County, New Hampshire

Designed by : SJH — Checked by : _____
Date : 01/10/93 — Date : _____

THE RECOMMENDED DIMENSIONS ARE:

Shape	=	Rectangular
Top dimensions	=	80 x 122 ft.
Bottom Dimensions	=	54 x 96 ft.
Sideslopes	=	2.0 :1
Actual depth	=	6.5 ft.
Design depth	=	6.0 ft.
Depth when 1/2 full	=	3.5 ft.
Depth when 3/4 full	=	4.8 ft.

THIS FACILITY IS DESIGNED FOR THE FOLLOWING CONDITIONS:

180	Days storage
100	heifers/replace, w/ ave. weight of 800 lbs, producing 1.4 cu.ft./1000 lbs/animal/day.
42	inches of annual rainfall.
5.2	inches of rainfall for a 25 yr.- 24 hr. event.
300	lbs./day of Sawdust bedding @ 12.0 lbs./cu.ft. (ratio of volume stored to volume used = 0.5)
.5	foot of freeboard.

When full, this facility will contain 43056 cu.ft.(322058 gal) of waste.

EARTHEN PIT - 6' WALLS

* ASSUMING TOTAL CONFINEMENT

PROS OF 6' WALL
SMALLER PUSHOFF WALL
WOULD NOT DO CONC. RETAINING WALL 8' HIGH W/BLOCKS
RAMP WOULD BE 15% OR STEEPER
3' WALL WOULD REQUIRE 9' CUT - ON SITE LEDGE MAN PROHIBIT THIS

NH-Ver 1.2

US Department of Agriculture
Soil Conservation Service

A SOLID WASTE STORAGE DESIGN

prepared for

Dave Fernald

in

Rockingnam County, New Hampshire

Designed by : SJH Checked by : _____
Date : 01/10/93 Date : _____

THE RECOMMENDED DIMENSIONS ARE:

Shape	=	Rectangular
Top dimensions	=	80 x 94 ft.
Bottom Dimensions	=	46 x 60 ft.
Sideslopes	=	2.0 :1
Actual depth	=	8.5 ft.
Design depth	=	8.0 ft.
Depth when 1/2 full	=	4.9 ft.
Depth when 3/4 full	=	6.6 ft.

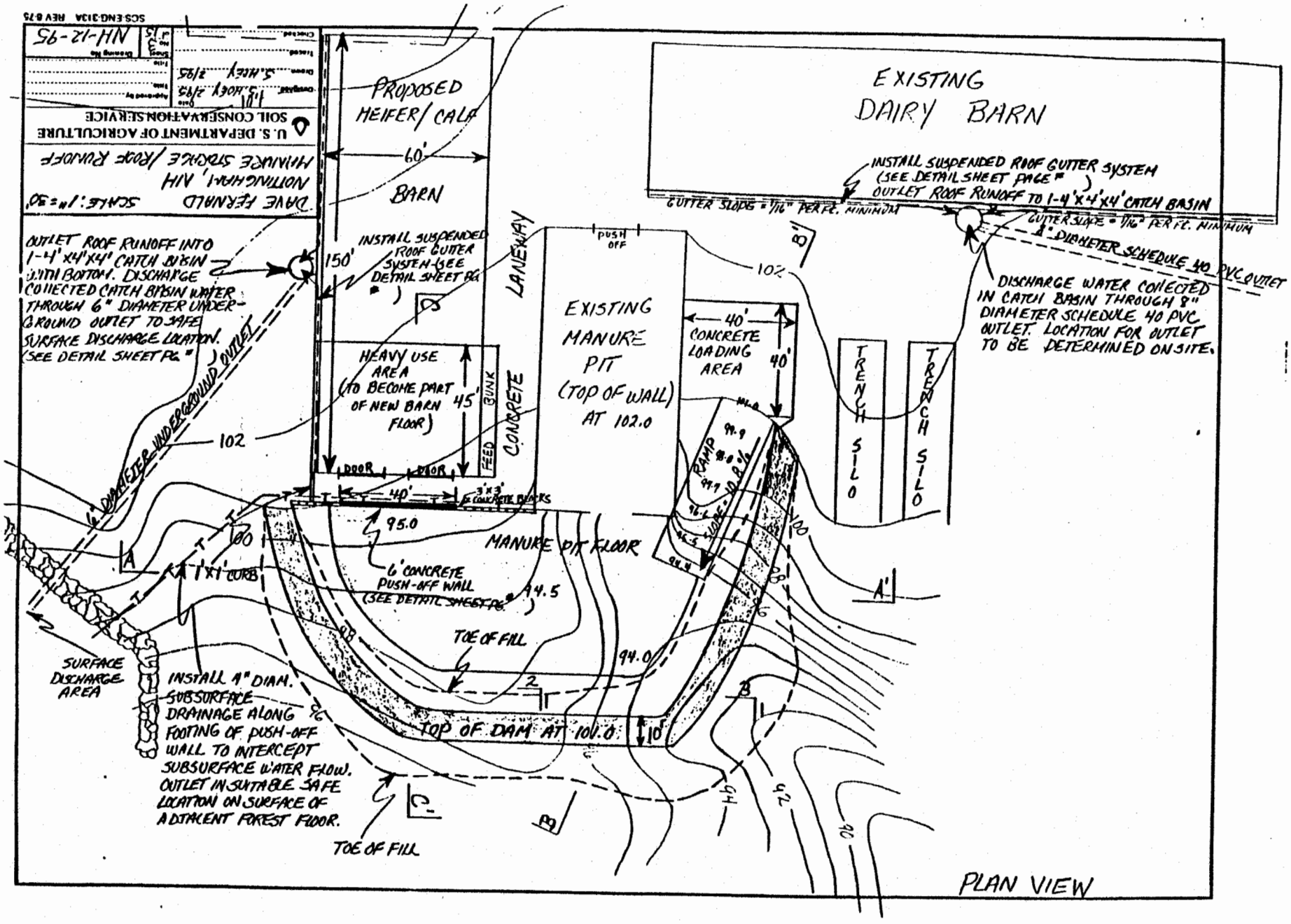
THIS FACILITY IS DESIGNED FOR THE FOLLOWING CONDITIONS:

180	Days storage
100	heifers/replace, w/ ave. weight of 800 lbs, producing 1.4 cu.ft./1000 lbs/animal/day.
42	inches of annual rainfall.
5.2	inches of rainfall for a 25 yr.- 24 hr. event.
300	lbs./day of Sawdust bedding @ 12.0 lbs./cu.ft. (ratio of volume stored to volume used = 0.5)
.5	foot of freeboard.

When full, this facility will contain 38378 cu.ft.(287067 gal) of waste.

EARTHEN PIT - 8' WALLS

* ASSUMING TOTAL CONFINEMENT

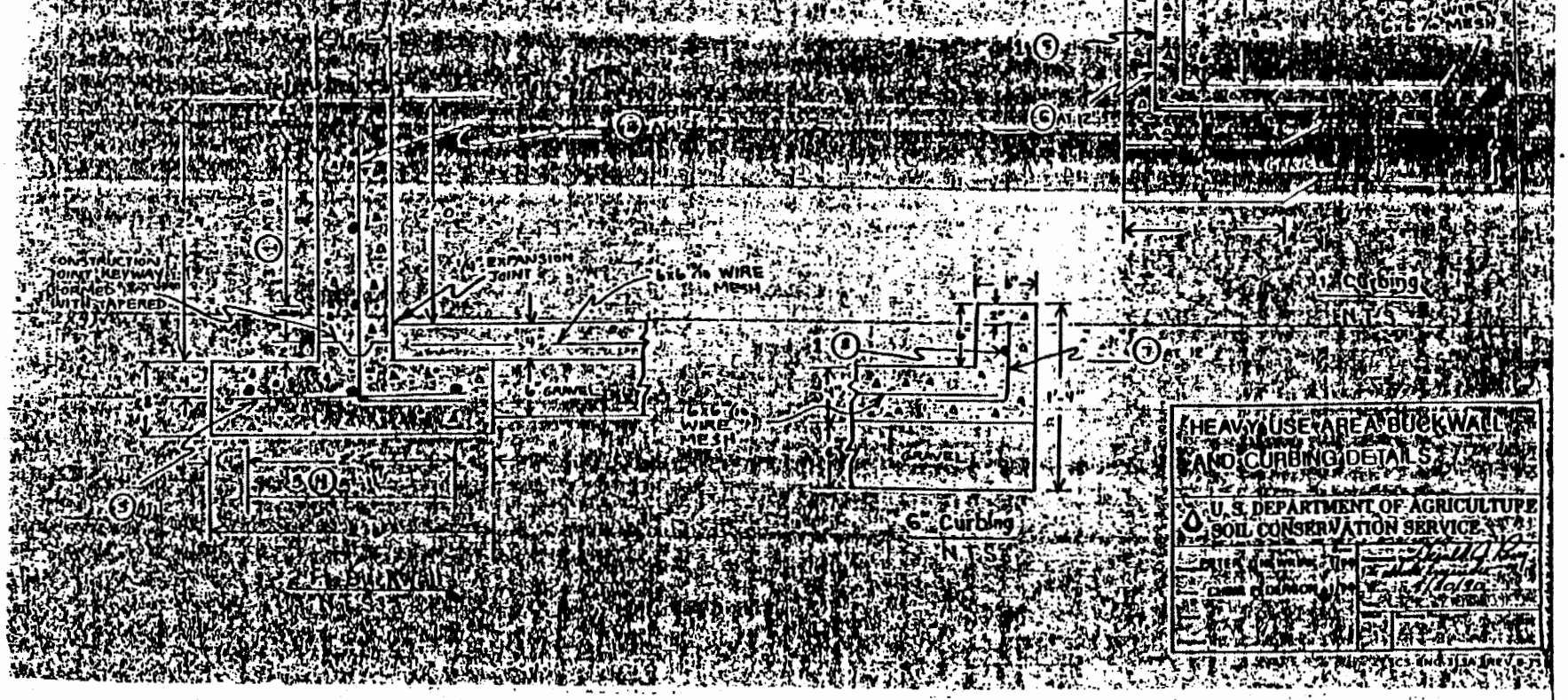


EXISTING DAIRY BARN
INSTALL SUSPENDED ROOF GUTTER SYSTEM (SEE DETAIL SHEET PAGE #)
OUTLET ROOF RUNOFF TO 1-4'X4'X4' CATCH BASIN
GUTTER SLOPE = 1/16" PER FT. MINIMUM
8" DIAMETER SCHEDULE 40 PVC OUTLET
DISCHARGE WATER COLLECTED IN CATCH BASIN THROUGH 8" DIAMETER SCHEDULE 40 PVC OUTLET. LOCATION FOR OUTLET TO BE DETERMINED ON SITE.
PROPOSED HEIFER/CALF BARN
60'
150'
INSTALL SUSPENDED ROOF GUTTER SYSTEM (SEE DETAIL SHEET PG #)
OUTLET ROOF RUNOFF INTO 1-4'X4'X4' CATCH BASIN WITH BOTTOM. DISCHARGE COLLECTED CATCH BASIN WATER THROUGH 6" DIAMETER UNDERGROUND OUTLET TO SAFE SURFACE DISCHARGE LOCATION. (SEE DETAIL SHEET PG #)
6" DIAMETER UNDERGROUND OUTLET
HEAVY USE AREA (TO BECOME PART OF NEW BARN FLOOR)
45'
BUNK
FEED
CONCRETE
LANEWAY
DOOR
DOOR
40'
3'X3' CONCRETE BLOCKS
EXISTING MANURE PIT (TOP OF WALL) AT 102.0
PUSH OFF
40'
CONCRETE LOADING AREA
40'
TRENCH SILO
TRENCH SILO
RAMP
SLOPE = 10.8%
102
95.0
MANURE PIT FLOOR
6' CONCRETE PUSH-OFF WALL (SEE DETAIL SHEET PG #)
94.5
94.0
TOE OF FILL
TOP OF DAM AT 101.0
10'
1'X1' CURB
SURFACE DISCHARGE AREA
INSTALL 4" DIAM. SUBSURFACE DRAINAGE ALONG FOOTING OF PUSH-OFF WALL TO INTERCEPT SUBSURFACE WATER FLOW. OUTLET IN SUITABLE SAFE LOCATION ON SURFACE OF ADJACENT FOREST FLOOR.
TOE OF FILL
A
A'
B
B'
C
C'
PLAN VIEW
DAVE FERNALD
NOTTINGHAM, NH
MANURE STORAGE/ROOF RUNOFF
SCALE: 1" = 30'
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NH-12-95

	MARK	SIZE	TYPE	QUANT.	LENGTH	DIMENSIONS A	DIMENSIONS B	TOTAL LENGTH
2 FT. BUCKWALL	1	#5	St.	3				
	2	#5	1		3'-6"	2'-6"	1'-0"	
	3	#4	St.		2'-2"			
	4	#4	St.	3				
6" CURB	5	#4	St.	1				
	6	[illegible]	[illegible]	[illegible]	2'-0"	1'-0"	1'-0"	
	7	[illegible]	[illegible]	[illegible]	1'-0"	0'-6"	0'-6"	
	8	[illegible]	[illegible]	[illegible]	[illegible]			

CONSTRUCTION NOTES

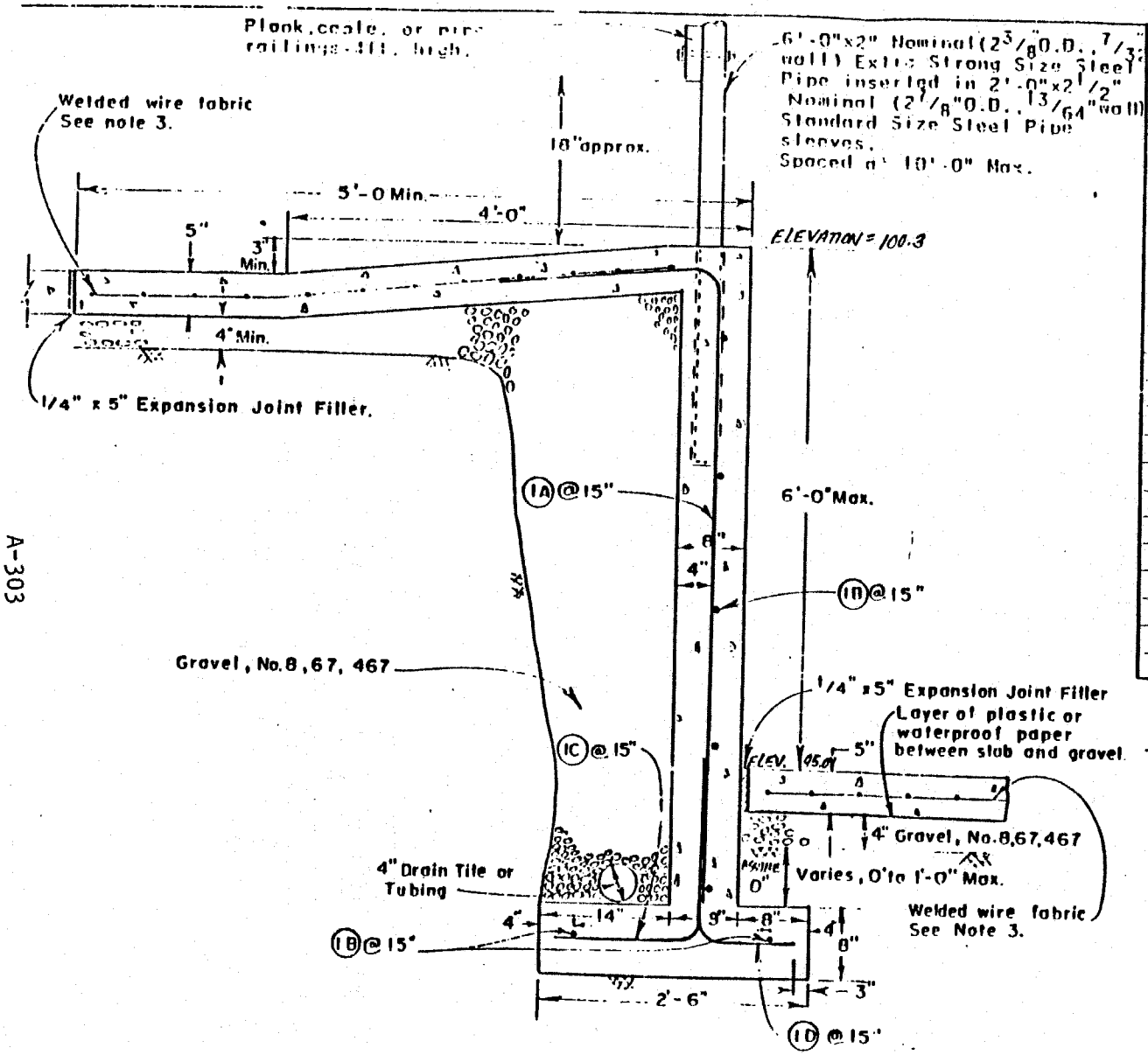
1) USE CONSTRUCTION SPECIFICATIONS # 32 AND # 34 AND MATERIAL SPECIFICATIONS # 535 AND # 536
2) SCS FIELD OFFICE STAFF SHALL BE CONTACTED BEFORE EACH PHASE OF CONSTRUCTION
3) CONCRETE SHALL BE CLASS 4,000
4) EXPANSION JOINTS SHALL BE PROVIDED AT A MAXIMUM SPACING OF 30' IN SLABS AND WALLS
5) PREFORMED EXPANSION JOINT FILLER SHALL BE SPONGE RUBBER TYPE I OR BITUMINOUS



HEAVY USE AREA BUCKWALL AND CURBING DETAILS

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

DAVE FERNALD
NH-12-95
R6.5



TYPE I PUSH-OFF WALL-6 FT. MAX.

A-303

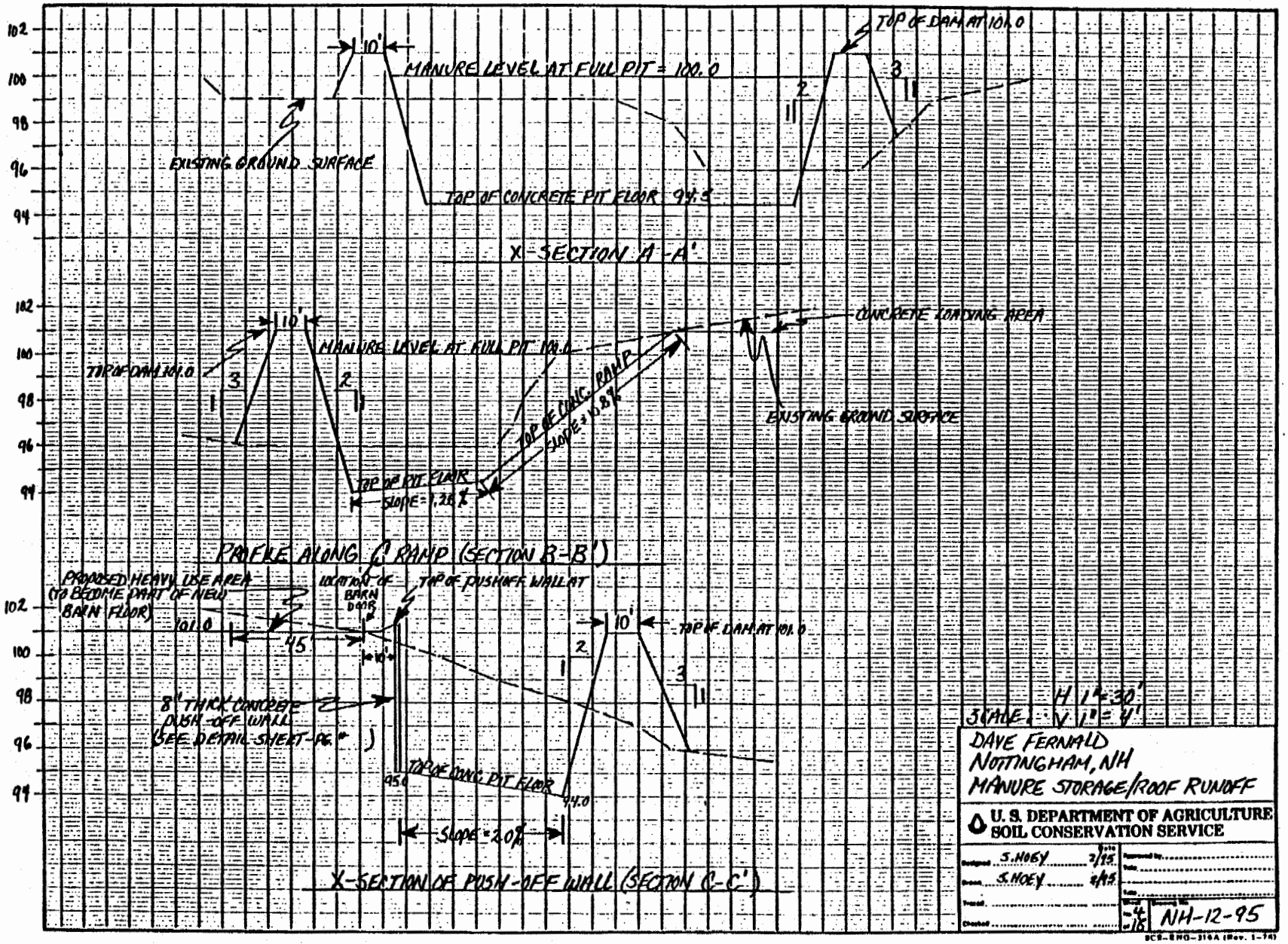
STEEL SCHEDULE

Mark	Size	Length	Quan.	Type	A	B	C	Tot. Leng
1A	5	9'0"	32	22		2'-0"	2"	
1B	5	39'6"	6	1				
1C	5	2'-10"	32	23	-	1'-11"	1'-3"	
1D	5	2'-4"	32	23	-	1'-11"	9"	
2A	5			22	-	2'0"	2"	
2B	5			1				
2C	8			1				
2D	8			23	-		3'6"	
2E	8			23	-		2'1"	
2F	5	6'-1"		23	-	4'-1"	2'-1"	
3A	6		7	1				
3B	6	6'-6"	14	1				
3C	6	4'-2"	2	24	3-2	1'-0"	-	
3D	4	9'-6"	4	23	6"	8'-6"	6"	
3E	4	8'-6"		1				
3F	5			1				
3G	5			1				
3H	5	3'-9"		23	-	2'-0"	1'-9"	
4A	5			1				
4B	5			1				
4C	5			23	-	1'-11"	1'3"	

BAR TYPES

GENERAL NOTES:

1. Expansion joints shall be provided at intervals not exceeding 30 feet in each direction. Joint filler shall be 1/4 in. thick and shall be preformed; bituminous, sponge rubber, cork, or expanded cork as described in ASTM Designation D-1751, or D-1752.
2. Where watertightness is essential, copper or PV waterstops shall be used in the wall and/or fl expansion joints, together with the expansion joint filler.
3. Unless otherwise shown, all floor steel shall l 6"x6" x6/6 welded wire fabric or 3 (3/8") bars 18" spacing.


TOP OF DAM AT 101.0
10'
MANURE LEVEL AT FULL PIT = 100.0
EXISTING GROUND SURFACE
TOP OF CONCRETE PIT FLOOR 94.5
X-SECTION A-A'
CONCRETE LOADING AREA
MANURE LEVEL AT FULL PIT 100.0
TOP OF DAM 101.0
TOP OF CONC. RAMP
SLOPE = 8.8%
EXISTING GROUND SURFACE
TOP OF PIT FLOOR
SLOPE = 1.28%
PROFILE ALONG ℄ RAMP (SECTION B-B')
PROPOSED HEAVY USE AREA (TO BECOME PART OF NEW BARN FLOOR)
101.0
45'
LOCATION OF BARN DOORS
TOP OF PUSHOFF WALL AT
10'
TOP OF DAM AT 101.0
8" THICK CONCRETE PUSH-OFF WALL (SEE DETAIL SHEET-PG.
95.0
TOP OF CONC. PIT FLOOR
94.0
SLOPE = 2.0%
X-SECTION OF PUSH-OFF WALL (SECTION C-C')
SCALE: H 1"=30'
V 1"= 4'
DAVE FERNALD
NOTTINGHAM, NH
MANURE STORAGE/ROOF RUNOFF
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed S.HOEY 7/95
Drawn S.HOEY 8/95
Traced
Checked
Approved by
Date
Date
Sheet No. 4 of 18
NH-12-95

VOLUME OF FILL REQUIRED FOR DAM

TOP OF DAM WIDTH = 10'

Table 11-6. Sample volume computations using "sum of end areas" method

Station	Ground Elevation	Fill Height (feet)	End Area 1/ (sq.ft.)	Sum of End Areas (sq.ft.)	Distance (feet)	Double Volume (cu.ft.)
0+00	101	0	0			
				13	15	195
0+15	100	1	13			
				43	15	645
0+30	99	2	30			
				82	15	1230
0+45	98	3	52			
				132	37	4884
0+82	97	4	80			
				160	33	5280
1+35	97	4	80			
				192	8	1536
1+43	96	5	112			
				262	13	3406
1+56	95	6	150			
				343	14	4802
1+70	94	7	193			
			=	386	35	13510
2+05	94	7	193			
				343	10	3430
2+15	95	6	150			
				262	7	1384
2+22	96	5	112			
				192	6	1152
2+28	97	4	80			
				132	9	1188
2+37	98	3	52			
				82	9	738
2+46	99	2	30			
				43	9	387
2+55	100	1	13			
				13	25	325
2+80	101	0	0			
					Total 2/	44092

1/ End areas based on 12-foot top width and 3 to 1 slopes on both sides.
2/ Double volume in cu.ft. is divided by 54 to obtain volume in cu.yds.

$\frac{44092}{54} = 816\ yd^3$

816 cu. yds.

Allowance for settlement (20)% = 163 cu. yds.

Total Volume (FILL) = ±980 cu. yds.

TOTAL EXCAVATED VOL. = ±945 yd^3

EXCAVATED VOLUME = $V = \frac{(A+4B+C)}{6} \times \frac{D}{2:1}$

A = AREA TOP
B = " " MID
C = " " BOTTO
D = AV. DEPTH (4')

$V = yd^3$

PIT DEPTH = 6' - BUT SURFACE OF PIT IS NOT AT GROUND SURFACE ACROSS ENTIRE AREA USED AVG. DEPTH 4'

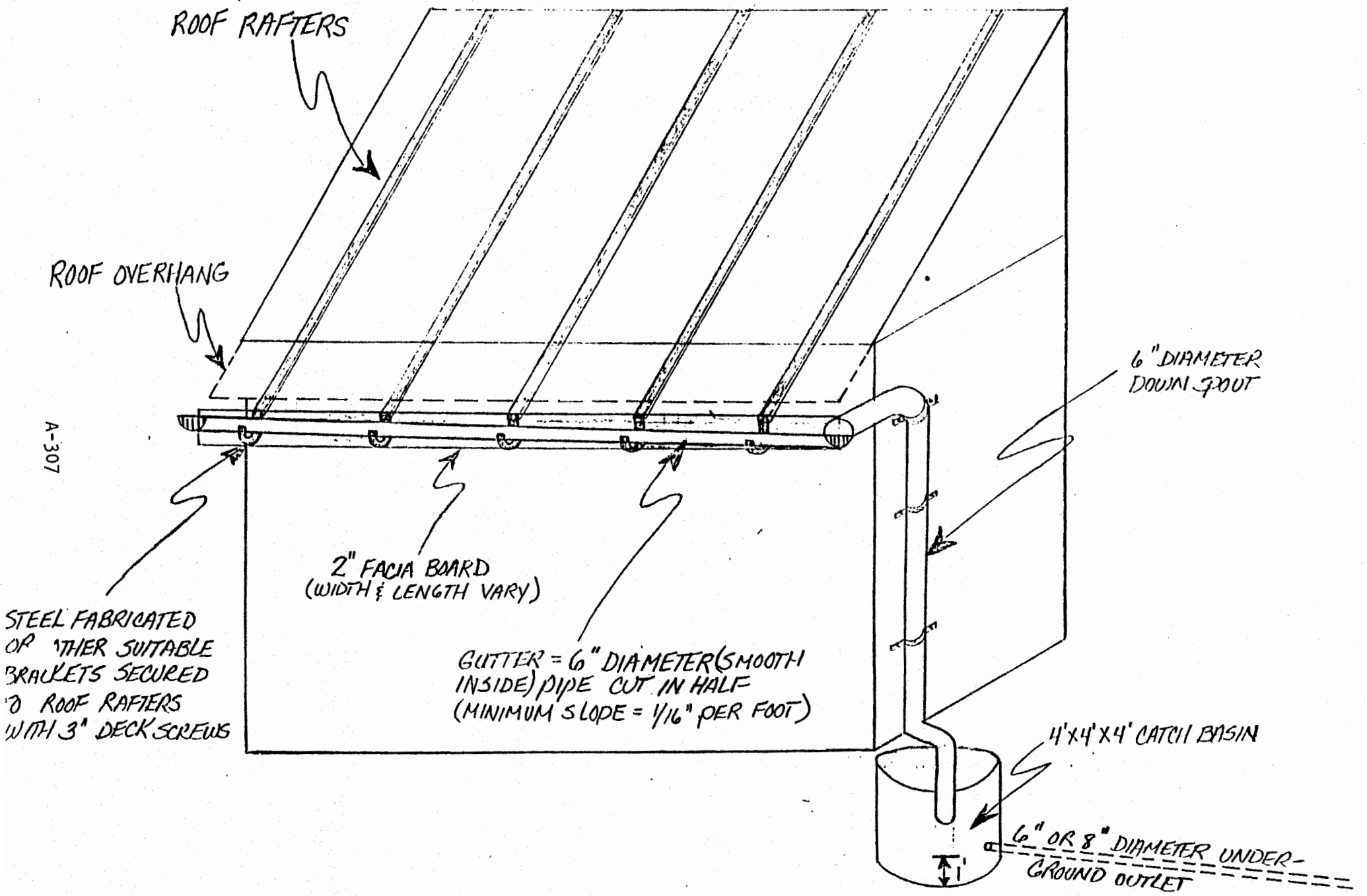
BOTTOM LENGTH = 100
BOTTOM WIDTH = 55
SIDESLOPES = 0:1 ON BARN SIDE & 2:1 ELSEWHERE

TOP LENGTH = 4 (2)(2) + 100 = 116'
TOP WIDTH = 4 (2) + 55 = 63'
TOP AREA = 7308 ft^2

MID LENGTH = 2(2)(2) + 100 = 108'
MID WIDTH = 2(2) + 55 = 59'
MID AREA = 6372 ft^2

BOTTOM AREA = 5500 ft^2

$V = \frac{(7308 + 25488 + 5500)}{6} \times 0.148 = \pm 945\ yd^3$



A-307

PLAN VIEW OF SUSPENDED ROOF GUTTERS (NO SCALE)

DESIGN WORKSHEET
for
Pipe Flow Formula Solution

prepared for

Dave Fernald

in

Rockingham County, New Hampshire

Designer : S. Hoey
Date : 01/17/93

Checker _____
Date _____

****

MAIN DAIRY BARN - ROOF RUNOFF OUTLET
- CALCULATIONS FOR 8" DIAMETER UNDERGROUND OUTLET -

Mannings Coefficient (n)	0.013
Entrance Coefficient (Ke)	0.20
Diameter of pipe	8 inch.
Head on pipe	3.0 feet.
Length of pipe	400 feet.
Pipe Capacity	1.0 cfs ← O.K.
Velocity in pipe	2.9 ft/sec
Friction Cofficient (Kp)	0.0538
Max allowable fall in pipe when outlet is not submerged	2.8 ft.

RUNOFF FROM MAIN DAIRY BARN ROOF: (FOR 25 YR. 5 MINUTE RAIN)
220' X 54' X 0.000167 Ft/SEC = 1.8 CFS (1/2 OF THIS PER BLDG. SIDE) OR 0.9

DOWNSPOUT CAPACITY: (ASSUMING 6" DIAMETER CIRCULAR DOWNSPOUT AND 1/2 OF A 6" DIAMETER WATER & SEWER PIPE AS THE GUTTER)

USING ORIFICE FLOW: $Ca\sqrt{2gh} = Q$

C = CONSTANT 0.6
a = DOWNSPOUT AREA IN in^2 (OR 28.26 in^2)
g = 32.2 ft/SEC
h = HEAD AT DOWNSPOUT (OR 3")

$17\sqrt{193.2} = \pm$ 236 GALLONS/MIN. OR $\pm$ 0.5 CFS

THEREFORE:
2 - 6" DIAMETER DOWNSPOUTS ARE NEEDED TO CARRY THE 0.9 CFS GENERA
FROM 1/2 OF THE DAIRY BARN ROOF. AN 8" OUTLET PIPE IS NEEDED.

NH-Ver 2.0

US Department of Agriculture
Soil Conservation Service

DESIGN WORKSHEET
for
Pipe Flow Formula Solution

prepared for

Dave Fernald

in

Rockingham County, New Hampshire

Designer : S. Hoey
Date : 01/17/93

Checker _____
Date _____

****

NEW (PROPOSED) BARN - ROOF RUNOFF OUTLET
- CALCULATIONS FOR 6" DIAMETER UNDERGROUND OUTLET -

Mannings Coefficient (n)	0.013
Entrance Coefficient (Ke)	0.20
Diameter of pipe	6 inch.
Head on pipe	3.0 feet.
Length of pipe	180 feet.
Pipe Capacity	0.7 cfs
Velocity in pipe	3.5 ft/sec
Friction Cofficient (Kp)	0.0789
Max allowable fall in pipe when outlet is not submerged	2.8 ft.

O.K.

ROOF RUNOFF FROM NEW (PROPOSED) BARN: (FOR 25 YR. 5 MIN. RAIN)
150' X 60' X 0.000167 Ft/SEC = 1.5 CFS (OR 1/2 PER ROOF SIDE) OR 0.75 CFS

DOWNSPOUT CAPACITY (ASSUMING 6" DIAMETER CIRCULAR DOWNSPOUT AND 1/2 OF A 6" DIAMETER WATER & SEWER PIPE AS GUTTER)

SAME AS CALCULATED FOR DAIRY BARN - SEE PG. #9
OR 0.5 CFS

THEREFORE:
2-6" DIAMETER DOWNSPOUTS ARE NEEDED TO CARRY THE 0.75 CFS GENERATED BY 1/2 OF THE NEW BARN ROOF. A 6" DIAMETER UNDERGROUND OUTLET IS ADEQUATE.

EFM-2 ESTIMATING RUNOFF AND PEAK DISCHARGE VERSION 1.10
Curve Number Computation

Client : Dave Fernald
County : Nottingham State: NH
Practice: Sod Waterway

By: SJH Date: 02-08-95
Checked: ____ Date: _____

COVER DESCRIPTION		Hydrologic Soil Group A	B	C	D
		Acres (CN)			
OTHER AGRICULTURAL LANDS					
Pasture, grassland or range	poor	-	-	1.7(86)	-
	fair	-	-	5.5(79)	-
FULLY DEVELOPED URBAN AREAS (Veg Estab.)					
Impervious Areas					
Paved parking lots, roofs, driveways		0.3(98)	-	-	-
Streets and roads					
Dirt (w/ right-of-way)		-	-	0.5(87)	-
Total Area (by Hydrologic Soil Group)		.3		7.7	

TOTAL DRAINAGE AREA: 8 Acres WEIGHTED CURVE NUMBER: 82

EFM-2 ESTIMATING RUNOFF AND PEAK DISCHARGE VERSION 1.10

Client : Dave Fernald By: SJH Date: 02-08-95
County : Nottingham State: NH Checked: ____ Date: ________
Practice: Sod Waterway

Drainage Area	8 *	Acres
Curve Number	82 *	
Watershed Length	1200	Feet
Watershed Slope	6.2	Percent
Time of Concentration	.231	Hours
Rainfall Type	III	

Storm Number	1	2	3	4	5	6	7
Frequency (yrs)	1	2	5	10	25	50	100
24-Hr Rainfall (in)	2.5	2.97	3.78	4.31	5.14	5.68	6.35
Ia/P Ratio	0.18	0.15	0.12	0.10	0.09	0.08	0.07
Used	0.18	0.15	0.12	0.10	0.10	0.10	0.10
Runoff (in)	1.00	1.36	2.02	2.47	3.20	3.69	4.31
Unit Peak Discharge (cfs/acre/in)	0.802	0.818	0.837	0.845	0.846	0.846	0.846
Peak Discharge (cfs)	6	9	13	17	22	25	29

* - Value(s) provided by CN subroutine (F9)

USE 25YR RETURN TO SIZE WATERWAY

A
PARABOLIC
GRASSED WATERWAY
DESIGN

prepared for

Dave Fernald

in

Rockingham County, New Hampshire

Designer : S. Hoey
Date : 01/17/93

Checker : _____
Date : _____

****

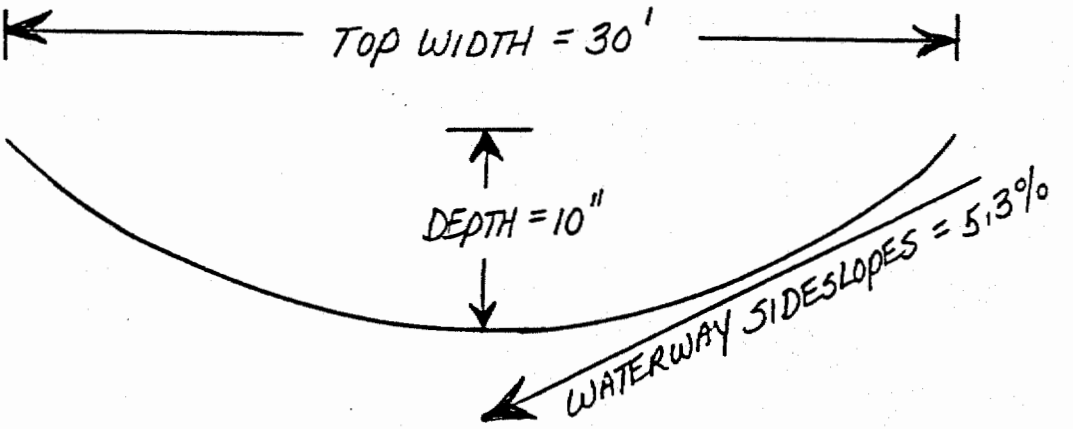
NH-13-95

Reach	RET	Q cfs	Slope %		-Capacity- TW-2 ft	D-2 ft	V-2 fps	-Stability- TW-1 ft	D-1 ft	V-1 fps
0+00 to 4+50	B/D	22	8.40	(10" DEPTH)	30.0	0.8	1.4	22.9	0.4	3.2
0+00 to 4+50	B/D	22	8.40		26.0	0.8	1.6	20.1	0.5	3.5

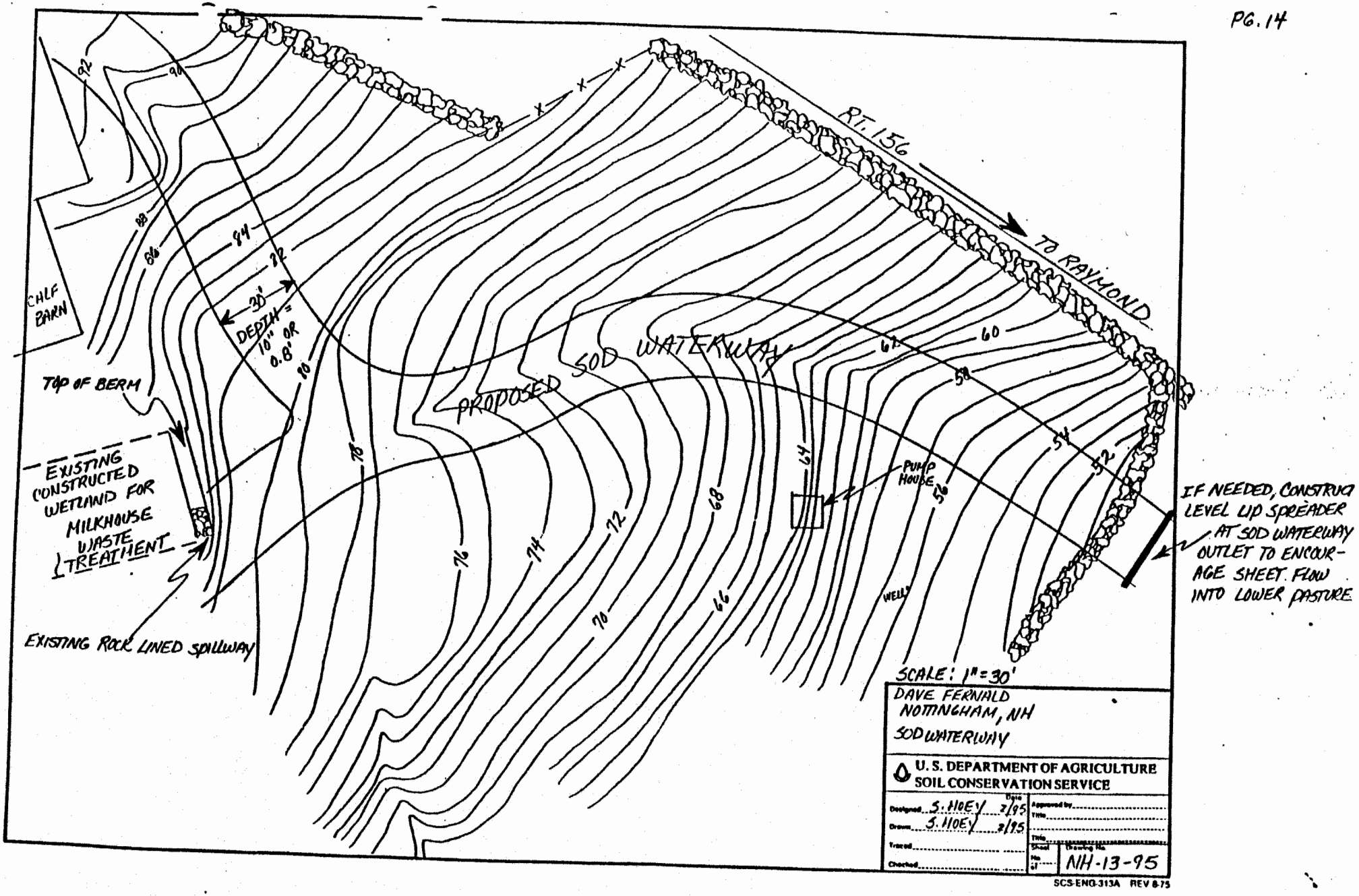
Total Waterway Area = 0.6

*** CAUTION ***
The velocity is less than 1.5 ft/sec in the following reaches: 1

USE 30' TOP WIDTH TO KEEP WATERWAY SIDESLOPES AT 5.3% TO ALLOW EASE OF MOWING.



TYPICAL WATERWAY X-SECTION (NO SCALE)


RT. 156
TO RAYMOND
CHLF BARN
TOP OF BERM
EXISTING CONSTRUCTED WETLAND FOR MILKHOUSE WASTE TREATMENT
EXISTING ROCK LINED SPILLWAY
30' DEPTH = 10" OR 0.8'
PROPOSED SOD WATERWAY
PUMP HOUSE
WELL
IF NEEDED, CONSTRUCT LEVEL UP SPREADER AT SOD WATERWAY OUTLET TO ENCOURAGE SHEET FLOW INTO LOWER PASTURE
SCALE: 1" = 30'
DAVE FERNALD
NOTTINGHAM, NH
SOD WATERWAY
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Designed S. HOEY 2/95
Drawn S. HOEY 2/95
Traced
Checked
Approved by
Title
Sheet No. of
Drawing No. NH-13-95
SCS-ENG-313A REV 8-75

A-313

NH DAVE FERNALD - BMP's

S. HOEY 2/95 NH-12&13-9±

BILL OF MATERIALS & COST ESTIMATE 15 15

1) MANURE STORAGE FACILITY (SIZED FOR 100 - 800 lb. ANIMALS)

CONCRETE (PIT FLOOR) = ± 81 yd³ @ $ 55.00/yd³ = $ 4500.00 ±

CONCRETE (PUSH-OFF WITH FOOTING) = ± 8 yd³ @ $ 55.00/yd³ = $ 440.00 ±

WELDED WIRE FABRIC & REBAR = $ ± 500.00

LABOR (FOR FORMING & POURING CONCRETE) = $ 3000.00 ±

BANK-RUN GRAVEL = 125 yd³ @ $ 7.00/yd³ = $ 875.00 ±

CONCRETE (RAMP & LOADING AREA) = ± 36 yd³ @ $ 55.00/yd³ = $ 1980.00 ±

4" DIAMETER TILE DRAINAGE PIPE = ± 200 LINEAR Ft. @ $ 80.00/250' ROLL = $ 80.00 ±

30 EA. 3'X3'X3' CONCRETE BLOCKS @ $ 35.00/BLOCK = $ 1050.00 ±

SUBTOTAL = $ 12,400 ±

2) HEAVY USE AREA (SIZED FOR 50 ANIMALS)

CONCRETE = ± 60 yd³ @ $ 55.00/yd³ = $ 3300.00 ±

WELDED WIRE FABRIC = $ 300.00 ±

BANK-RUN GRAVEL = ± 70 yd³ @ $ 7.00/yd³ = $ 490.00 ±

LABOR (FOR FORMING & POURING CONCRETE) = $ 2000.00 ±

SUBTOTAL = $ 6100.00

3) SUSPENDED ROOF GUTTERS

(SDR35) 6" DIAMETER PIPE (1/2 SECTION USED FOR ROOF GUTTER AND FULL SECTION USED FOR DOWNSPOUT = ± 600 LINEAR Ft. @ $ 1.90/ft = $ 1140.00 ±

6" DIAMETER SCHED. 40 PVC (FOR UNDERGROUND OUTLETS) = ± 1000 LINEAR Ft. @ $ ± 4.20/ft = $ 4200.00 ±

8" DIAMETER SCHED. 40 PVC (FOR UNDER GROUND OUTLET) = ± 400 LINEAR Ft. @ $ ± 6.80/ft = $ 2720.00 ±

10 EA. 4'X4'X4' DIAMETER CONCRETE CATCH BASINS @ $ ± 200.00 EA. = $ 2000.00 ±

2" X 10" PRESSURE TREATED WOOD (FOR FACIA BOARDS) = $ 2000.00 ±

FABRICATED OR STANDARD BRACKETS = $ 800.00 ±

3" DECK SCREWS = $ 100.00

LABOR (FOR CUTTING PIPE & BUILDING GUTTERS) = $ 1000.00 ±

SUBTOTAL = $ 14,000 ±

4) EQUIPMENT TIME (ALL PRACTICES ESTIMATED TOGETHER)

EXCAVATOR = 8 DAYS @ $ 90.00/hr = $ 5760 ±

BULLDOZER - (D6 OR EQUIVALENT) = 7 DAYS @ $ 75.00/hr = $ 4200.00 ±

SUBTOTAL = $ 9960.00 ±

TOTAL ESTIMATED COST OF INSTALLATION OF ALL BMPS AS DESIGNED

= ± $ 42,500.00