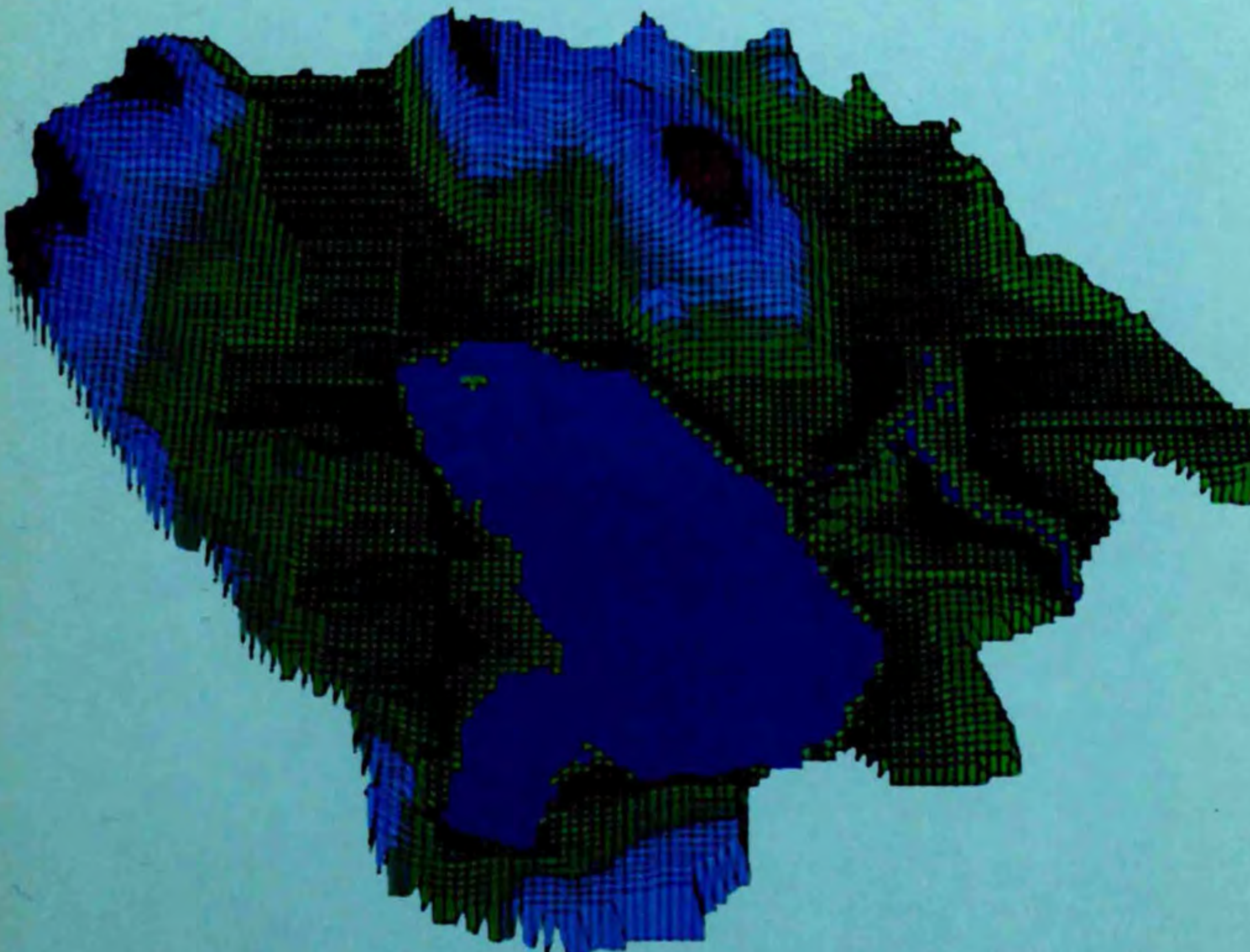
1996

Land Use Patterns in Relation to Lake Water Quality in the North Pond Watershed

Problems in Environmental Science course (Biology 493), Colby College

Colby Environmental Assessment Team, Colby College

LAND USE PATTERNS IN RELATION TO LAKE WATER QUALITY IN THE NORTH POND WATERSHED



BI 493
Problems in Environmental Science
Colby College
Waterville, ME 04901

1997

MEMO

DATE: May 12, 1997

TO: Report recipients

FROM: Professors David Firmage and Russell Cole

RE: Class report on North Pond and its watershed

We make this report available in the hope that the work contained herein may be of interest or help to others interested in the problem addressed. We realize that some areas of the study could and perhaps should be expanded. We feel confident of the quality of the work done and only wish the time had been available so that the students could fulfill their desire to conduct a more comprehensive study.

This report is the work of students enrolled in the Problems in Environmental Science course (Biology 493) taught at Colby College during the fall semester of 1996. The course is taken by seniors who are majoring in Biology with a concentration in Environmental Science. The students work as though they were an environmental consulting firm. The object of the course is to teach the students how to approach a problem, how to develop a workplan, and what is necessary to implement the plan successfully. As part of this learning process the students use methods and tools they have learned in other courses and they are also introduced to new methodology as needed. Standard methods of analysis are used as well as state of the art instrumentation for any of the original analysis done. The methods used were those approved by EPA and the DEP. However, there are time constraints involved in the study since all requirements for the course must be completed within the fall semester. These constraints mean that most of the new data can only be gathered during the months of September through early November and, typically, that extensive analysis can not be done. Some of the water quality data were gathered during the previous summer and made available to the class for analysis in addition to their fall sampling. Also, in order to teach various techniques and to have the students consider a problem from a number of angles, the project is expanded to more areas than a group might normally take on for a short term project. This means that in some areas we sacrifice some depth for more breadth.

While the class was constrained by time, they have managed to accomplish an amazing amount of work during that period and we are very pleased with the quality of that work! We hope that you find it useful.

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This study of the North Pond watershed was conducted by the students of the Biology 493 : Problems in Environmental Science class at Colby College, Waterville, Maine. The students were:

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Introduction

General Nature of the Study

Lakes are natural resources which have many effects on the land surrounding them. They support adjacent communities by providing water and regulating temperatures, helping to define the surrounding ecosystem, and serving as sources of drinking water and recreation. The prolonged presence of human activity in a watershed can disturb the physical and chemical cycles of the lake and its surrounding ecosystems (Henderson-Sellers and Markland 1987).

Over time, lakes undergo a process called eutrophication, a natural aging process during which the nutrient levels increase and dissolved oxygen levels decrease (Smith 1992). As the lake ages or becomes more eutrophic, organic material gradually collects in the lake basin. For a period of time the increased organic matter raises the nutrient level in the lake and causes higher productivity. As the lake becomes more eutrophic, dissolved oxygen (DO) levels fall because of the high levels of organic material decomposing in the water. Organisms which cannot live under low dissolved oxygen levels begin to die. Over time the diversity and overall health of the lake decrease until only a few highly tolerant species remain (Henderson-Sellers and Markland 1987).

Human activity within the watershed can greatly accelerate the eutrophication process by increasing the rate at which nutrients such as phosphorus and nitrogen enter the lake (Fernandez et al. 1992). Increased nutrient loading causes dramatic increases in algal populations resulting in algal blooms. Many New England lakes develop a greenish tint because of algal blooms during early summer or early fall. Populations of bacteria which feed on organic material rise because of increased food supply. Bacterial activity decreases the level of dissolved oxygen in the lake (Henderson-Seller and Markland 1987). A sharp decrease in dissolved oxygen levels can cause massive death of many lake fauna especially fish, a process known as fish kill. While this process is not yet occurring at North Pond or Little Pond, it could occur in the future depending on the activity of local residents.

North Pond and Little Pond include the communities of Smithfield, Mercer, Rome and Norridgewock as shown on United States Geological Survey topographical maps. They are located in the Belgrade Lakes region of south-central Maine. The watershed is approximately 487400 acres. More than half of the watershed (55%) is found in Smithfield. Mercer comprises 30% and Rome is slightly more than 10% of the watershed. Norridgewock only contains 1% of the watershed.

North Pond and Little Pond receive nutrient inputs from many different sources both natural and manmade. Natural sources such as the Serpentine, Pattee Brook, Leech Brook and Bog Stream carry nutrients from their surroundings to the lake on suspended particles and dissolved in the water. Activities and developments such as roads, construction, logging, and human waste disposal in subsurface waste disposal systems have negative effects on water quality. They contribute unnaturally high levels of nutrients and suspended particles which will carry nutrients to the lake or its tributaries and eventually empty into the lake. The lake is also used for recreational swimming, boating, fishing, hunting and as a source of drinking water. A gravel pit, several tree farms and an airfield are also located within the watershed.

Historically, North Pond has not suffered from algal blooms like East Pond which has seasonal algal blooms because of high nutrient levels (BI493 1991). However if human activity is not monitored and development carefully controlled, North Pond's nutrient cycle could be accelerated resulting in algal blooms, poor water quality, and fish kills.

The major purpose of this study is to assess the current land use patterns and their influences on the water quality of North Pond and Little Pond, including biotic and abiotic parameters which are involved. Additionally several other parts of the study are:

- Assess the potential for nutrient loading from road runoff, tributaries, residential areas, and other human activities within the watershed
- Determine the influence of current and historical land use patterns on the lake water quality. Calculate flushing rate and water budget for North Pond and Little Ponds.
- Use gathered information to construct phosphorus and nutrient level equation which will allow projections of future condition of water quality considering specific changes in human practices surrounding the lake.
- Make recommendations to North Pond Lake Association, Maine Department of Environmental Protection, and the towns of Mercer, Smithfield, Norridgewock, and Rome based on findings.

The water quality and land use assessment of the North Pond watershed was completed by the Colby Environmental Assessment Team (CEAT) during the fall of 1996.

Background

LAKE CHARACTERISTICS

Distinction Between Lakes and Ponds

Lakes and ponds are natural and man-made inland bodies of water (Niering 1985). Environmental conditions may vary from lake to pond, but there are certain characteristics that are shared between the two (Smith 1992).

The amount of light that is able to penetrate a pond's or lake's surface water is an important feature of both. Ponds tend to be smaller and have larger littoral zones (shallow area of the water body where light reaches the bottom) than lakes. It is primarily surface area and depth that distinguishes between the two types of water bodies (Niering 1985).

Temperature, which changes with the seasons and depth, is an important factor in both pond and lake ecosystems (Smith 1992). Because water is most dense at approximately 4°C, many species are able to survive in an aquatic environment throughout the year, since ice remains on the surface and prevents most lakes from freezing solid. During the summer, lake water stratifies according to temperature, establishing an upper, warm water layer called the epilimnion, and a lower cold water layer called the hypolimnion. Between the epilimnion and the hypolimnion is an area of rapid temperature change called the metalimnion. Thermal stratification prevents mixing of oxygen and nutrients within a lake. Ponds, due to their shallow waters, do not thermally stratify during the summer months. Although North Pond and Little Pond are considered lakes, they do not thermally stratify (Bouchard, pers. comm.). The shallow depth of both lakes does not allow effective turnover, and therefore the lake doesn't experience changes in dissolved oxygen (DO) associated with depth. Variations in oxygen and temperature strongly influence the adaptations for life and the buffering capabilities for pollutants in ponds and lakes (Smith 1992).

General Characteristics of Maine Lakes

Lakes are a vital natural resource in Maine (Davis et al. 1978). They provide fresh water for swimming, fishing, drinking, livestock and agriculture. The aesthetic beauty of Maine's lakes draw many tourists throughout the year and are important habitats for wildlife. Nine percent of Maine's approximately 5700 lakes have areas greater than 5.59 mi^2, and there has been relatively little research conducted with regard to their systems and potential (Davis et al. 1978).

The majority of Maine lakes were formed during the most recent glaciation (Wisconsin) of the Pleistocene period (about 10,000 years ago) (Davis et al. 1978). Most lake substrates are dominated by glacial till, bedrock, and glaciomarine clay-silt because Maine was once covered by glaciers. Generally these deposits and the underlying bedrock (typically granitic) are of an "infertile" nature. This characteristic helps account for the fact that few lakes in Maine are naturally eutrophic or even mesoeutrophic.

The movement of the glaciers in Maine was predominantly southeasterly explaining the orientation of many of Maine's lakes. They are often long and relatively narrow in the southeastern direction (Davis et al. 1978). This feature of a lake is important to consider, particularly with reference to the seasonal changes which take place in the water body. Surface area and shape play a fundamental role, for instance, in the effect of wind on the water body, a critical function of its turnover effectiveness.

With few exceptions, lakes in Maine are located in lowland areas among hills (Davis et al. 1978). They are generally frozen on the surface 4 to 5 months out of the year. While Davis et al. noted that much of the state's lake watersheds were forested, these stands have recently come under increasing pressure from the timber industry. Residential development of watersheds and increased construction of lake recreation facilities have also posed a significant threat to the water quality of many of Maine's lakes and ponds. These projects can result in significant disturbances if they are in close proximity to the shoreline, they can significantly impact the aquatic ecosystems. In watersheds where agricultural practices have been less significant, both residential development and forestry practices may be the most acute causes of anthropogenic, or human caused, nutrient loading.

The level of dissolved matter (including sodium ions, potassium ions, phosphorus and organic matter) in lakes act as a standard measure of lake water quality. In Maine, several factors exist which serve as a function of water quality: proximity to the ocean, location within the state, residence time of water within the soil, wetland influences, and bedrock chemistry (Davis et al. 1978). Physical factors also play a critical role in the water quality. Particular terrestrial and aquatic vegetation, as well as unique habitat types, will also affect the water quality. Also, lake morphometry, as mentioned above, (e.g., depth and surface area) can function to change the lake's temperature, nutrient cycles, and effective turnover.

Lake Basin Characteristics

The physical properties of the lake basin drastically affect the biological and chemical processes of the lake. The morphometry, hydrologic cycles, and sediments of a basin contribute to the processes which affect the nutrient cycling and seasonal changes in the lake ecosystem. Most temperate lakes illustrate a degree of turnover, and lakes that turnover completely in both the spring and fall are referred to as dimictic (BI493 1994).

Stratification is such a vital component in lake ecosystem functioning, its principles should be understood. Water has the unique property of maximum density at 3.94° C, whereas all other substances increase their densities with a decrease in temperatures. Therefore ice, which freezes at 0° C, actually floats in water which is above the freezing point. The process of stratification is created by the different densities in lake water due to differences in temperature. This stratification follows a seasonal pattern in conjunction with the changes in solar radiation received by the lake water.

Direct radiation of the upper levels of the water column warms that layer of water forming the epilimnion (Figure 1). While usually no deeper than about 7 m to 8 m in northeastern lakes, the

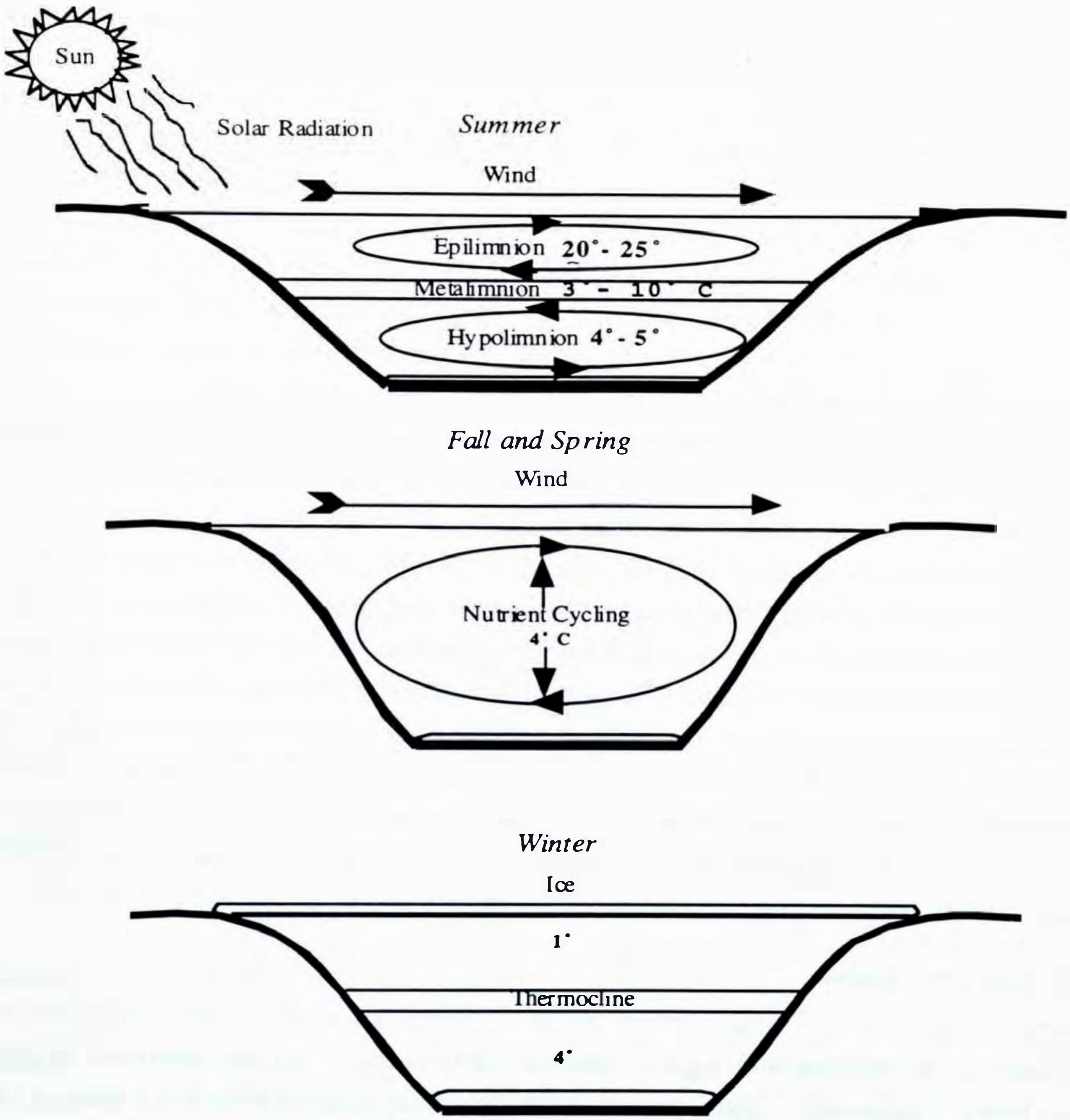

Figure 1. Mixing by means of lake turnover in dimictic lakes. During the summer, lakes are stratified into three layers (epilimnion, mitalimnion, and hypolimnion). During the fall and spring, the isothermal temperature and density facilitate the lake turnover and redistribution of nutrients. In the winter, the lake is again stratified, with the slightly warmer water on the bottom of the lake and the ice at the surface.

epilimnion hosts the most abundant floral communities (Davis et al. 1978). This creates an oxygen rich stratum due to the photosynthetic capacities of these communities. Nutrients in the epilimnion, however, get depleted by algal populations growing in the water column (Cole, pers. comm.), and may remain depleted until the turnover of early fall (BI493 1994).

Below the epilimnion is a layer of sharp temperature decline, known as the metalimnion (Smith 1992). Within this stratum is the greatest temperature gradient in the lake, called the thermocline, which tends to decrease approximately 1° C per meter depth (Smith 1992). This thermocline separates the epilimnion from the hypolimnion, the lowest layer of a lake. The hypolimnion is beyond the depth to which sufficient light can penetrate in order to facilitate effective photosynthesis. It is an area in which most decomposition of organic material takes place through both aerobic and anaerobic biological processes. While aerobic (requiring oxygen) bacteria break down organic matter more quickly, they also significantly deplete the oxygen at these depths (Davis et al. 1978).

Both the spring and fall turnovers serve to reoxygenate the lower depths, and mix the nutrients throughout the upper strata. These turnovers are a function of several factors which include the geographic position and shape of the lake, seasonal changes in temperatures, the interaction of the wind and water surface, and the depth of the lake (Davis et al. 1978). The cold water near the surface can hold high levels of oxygen and the demand on the oxygen supply is also considerably less due to decreased activities of aquatic organisms at these temperatures (Smith 1992). A snow cover, however, will affect the photosynthetic processes during the winter months by blocking solar radiation. In the later winter months, oxygen levels may become so depleted as to cause substantial fish kills (Cole, pers. comm.). As the winter passes, and the ice layer melts, the upper layers of the lake begin to warm once more and wind begins to mix the lake. Oxygen may be carried down the water column while nutrients pervade the epilimnion. As late spring approaches, solar radiation increases and stratification will again become evident, and the temperature profiles return to that of the summer (Smith 1992).

Trophic Status of Lakes

There are many ways of characterizing a lake, and each way has its limitations. One of the most useful biological classifications was originally proposed by Thienemann and later elaborated by others (Maitland 1990). Thienemann's characterization is based primarily on the nutrient levels within a lake. Lakes are generally divided into three major categories: oligotrophic, eutrophic, and dystrophic (Table 1). Young or oligotrophic lakes are usually lacking in nutrients, while eutrophic lakes are nutrient rich (Niering 1985). Oligotrophic lakes tend to be deep and oxygen rich with steep-sided basins. There is a low surface to volume ratio. They are characterized as nutrient deficient, even though they may be high in nitrate levels. They are primarily deficient in phosphorus, which is the limiting nutrient for plant productivity in most freshwater ecosystems. The shape of a lake can also determine its productivity. Steep-sided oligotrophic lakes do not allow extensive growth of rooted vegetation; there is no extensive, shallow margin for attachment. Eutrophic lakes, partially due to sediment loading over years, tend to be relatively shallow and bowl shaped, which allows for the productivity of rooted plants (Table 1).

Table 1. Generalized characteristics of oligotrophic, eutrophic, and dystrophic lakes (Adapted from Maitland 1990).

Character	Oligotrophic	Eutrophic	Dystrophic
Basin shape	Narrow and deep	Broad and shallow	Small and shallow
Lake shoreline	Stony	Weedy	Stony or peaty
Water transparency	High	Low	Low
Water color	Green or blue	Green or yellow	Brown
Dissolved solids	Low, deficient in N	High, especially in N and Ca	Low, deficient in Ca
Suspended solids	Low	High	Low
Oxygen	High	High at surface, deficient under ice and thermocline	High
Phytoplankton	Many species, low numbers	Few species, high numbers	Few species, low numbers
Macrophytes	Few species, rarely abundant, yet found in deeper water	Many species, abundant in shallow water	Few species, some species are abundant in shallow water
Zooplankton	Many species, low numbers	Few species, high numbers	Few species, low numbers
Zoobenthos	Many species, low numbers	Few species, high numbers	Few species, low numbers
Fish	Few species, salmon and trout characteristic	Many species, especially minnows	Extremely few species, often none

Eutrophic lakes are nutrient enriched (Chapman 1992) and typically have a relatively high surface to volume ratio (Maitland 1990). These lakes are generally rich in phytoplankton, which is supported by the increased availability of dissolved nutrients (Table 1). A eutrophic lake supports a tremendous amount of planktonic algae and is usually low in dissolved oxygen. Low dissolved oxygen levels at the bottom of the lake lead to the release of phosphorus and other nutrients from the bottom sediments, resulting in their eventual recycling through the water column (Chapman 1992). This stimulates even further growth of phytoplankton (Smith 1992). There is relatively little biotic diversity in a highly eutrophic lake, except for the phytoplankton and the decomposers that maintain the low levels of oxygen.

Lakes that receive large amounts of organic matter from the surrounding land, particularly in the form of humic (dead organic) materials, are termed dystrophic lakes (Smith 1992). The large quantity of humic materials stains the water brown. Dystrophic lakes generally have highly productive littoral zones (shallow area along the lake basin where light penetrates to the bottom). The littoral zone allows submergent, floating, and emergent vegetative growth.

High oxygen levels, high macrophyte productivity, and low phytoplankton amounts are characteristic of dystrophic lakes (Table 1). Eventually the invasion of rooted aquatic macrophytes chokes the aquatic habitat with plant growth, and the lake basin is filled in, resulting in the development of a terrestrial ecosystem (Goldman and Home 1983).

Over time, lakes tend to be enriched by introduced nutrients and eventually become eutrophic (Niering 1985). No matter how a lake basin originated, the lake will show succession (Goldman and Home 1983). Nutrient enrichment and the filling in of lakes are a natural phenomena. These processes, however, can be greatly affected by anthropogenic activities which increase the rate at which nutrient loading occurs and the amounts of nutrients going into the lake. The United States Environmental Protection Agency (USEPA) characterizes the process of eutrophication by the following criteria:

1) Decreasing hypolimnetic dissolved oxygen concentrations;
2) Increasing nutrient concentrations in the water column;
3) Increasing suspended solids, especially organic material;
4) Progression from a diatom population to a population dominated by blue-green algae and/or green algae;
5) Decreasing light penetration (e.g., increasing turbidity);
6) Increasing phosphorus concentrations in the sediments (Henderson-Sellers and Markland 1987).

As a lake ages, it continues to fill up through the deposition of dead organic matter and sediment from various inputs. Lakes may also receive mineral nutrients from streams, groundwater, and runoff. As nutrient availability increases, so does primary productivity. Increased productivity leads to more dead organic material which accumulates in lentic ecosystems (pertaining to standing water, as lakes and ponds). Lakes are created and destroyed by biological and geological processes. In time, lakes will fill in, decrease in size, and may finally be replaced by a terrestrial community (Smith 1992).

Phosphorus and Nitrogen Cycles

In a freshwater lake, phosphorus and nitrogen are the two major nutrients that are important for the growth of algae and macrophytes. Each nutrient has its own complex chemical cycle within the lake (Overcash and Davidson 1980). It is necessary that we understand these cycles so that we may devise better techniques to control high levels of these nutrients.

Phosphorus is generally considered the most important nutrient in lakes because it is the limiting nutrient for plant growth in freshwater systems (Maitland 1990). Phosphorus naturally occurs in lakes in minute quantities (measured in ppb), however this is all that is needed for plant growth due to the high efficiency with which plants can assimilate phosphorus (Maitland 1990). There are multiple external sources that contribute phosphorus to a lake (Williams 1992), but a large source is also within the lake itself (Henderson-Sellers and Markland 1987). The cycle of phosphorus in a lake is extremely complex, with some models including up to seven different forms of phosphorus (Frey 1963). For the purposes of this study, it is only necessary to understand that there are two broad categories of phosphorus in a lake: dissolved phosphorus (DP), and particulate phosphorus (PP). The basic cycle that these forms of phosphorus follow in a stratified lake is summarized in Figure 2. DP is an inorganic form of phosphorus which is readily available for plant use in primary production; it is this form of phosphorus which is limiting to plant growth. PP is phosphorus which is incorporated into organic matter such as plant and animal tissues. DP is converted into PP through the process of primary production, which occurs in the epilimnion. Much of this PP then gradually settles into the hypolimnion in the form of dead organic matter. If there is oxygen present, PP will be converted to DP through decomposition by aerobic bacteria. When there is little or no oxygen present, which is often the case in the sediments of a stratified lake, anaerobic bacterial decomposition will result in the conversion of PP to DP (Lerman 1978).

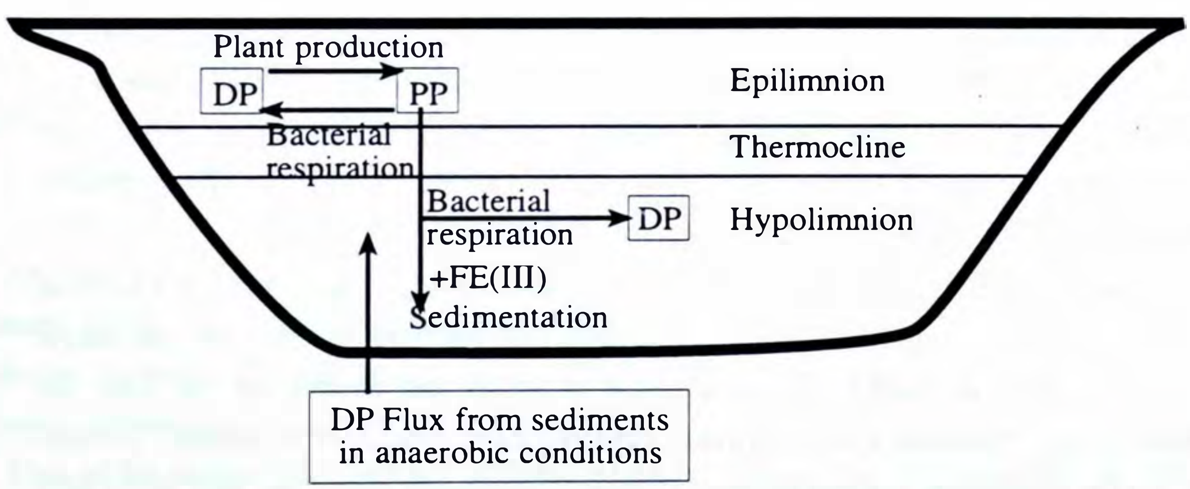

Figure 2. A model of the cycle of the major forms of phosphorus, dissolved (DP) and particulate (PP), within a lake ecosystem. The sedimentation of DP through complexation with Fe (III) contributes to the build-up of DP in the sediments. Note the production of DP in the hypolimnion due to bacterial decomposition as well as from the release of DP from the Fe complex in the sediments during anaerobic conditions. The fact that the thermocline prevents DP from mixing between the surface and bottom water is critical to the cycle because it can allow for build up of DP in bottom waters (Adapted from Lerman 1978).

In oxygenated water an important reaction occurs which involves DP and the oxidized form of iron, Fe(III) (Chapman 1992). This form of iron can bind with DP to form an insoluble complex, ferric phosphate, which can effectively tie up large amounts of phosphorus as it settles into the bottom sediments. Upon decreasing the oxygen levels at the sediment-water interface, such as after extended periods of stratification, the Fe(III) will be reduced to Fe(II) which results in the release of DP. The ferric phosphate complex, combined with the anaerobic bacterial conversion of PP to DP, can lead to a significant build-up of DP in anoxic sediments. In fact, the sediments of a lake can have phosphorus concentrations of 50-500 times the phosphorus concentration of the water (Henderson-Sellers and Markland 1987). This allows a lake's sediment to be an even larger source of phosphorus than external inputs. Because nutrients are inhibited from mixing into the epilimnion during the summer by stratification processes, DP concentrations that are formed in the sediments and lower hypolimnion waters can build up until fall turnover.

The fall turnover results in a large flux of nutrients to the region of the lake where plant growth can occur, creating the potential for algal blooms. If an algal bloom does occur, DP will be converted to PP in the form of algal tissues. The algae will die as winter approaches and the dead organic matter will settle to the bottom where PP will be converted back to DP and build up again, allowing for another large nutrient input to surface waters during spring overturn (Chapman 1992).

The other major plant nutrient, nitrogen, is not usually the limiting factor for plant growth in a lake (Chapman 1992). However, it is still important to understand its cycle because high concentrations can lead to algal blooms in the presence of phosphorus. Also, levels greater than 10 ppm can lead to the development of the condition in infants known as methemoglobinemia, if the water is used as a source of drinking water (Greenberg et al. 1992). Available nitrogen exists in lakes in three major chemical forms: nitrates (NO_3-), nitrites (NO_2-), and ammonia (NH_3). Their relative positions in the nitrogen cycle are summarized in Figure 3.

The majority of free nitrogen in a lake exists in the form of nitrates (Maitland 1990). This form of nitrogen is directly available for assimilation by algae and macrophytes (Figure 3). In eutrophic lakes, there may be so much algae and macrophyte growth that most of the nitrates of the lake are incorporated into their tissues (Maitland 1990). Nitrites, however, cannot be used by plants. Nitrate-forming bacteria in aerobic conditions, convert nitrites to nitrates. Ammonia enters the lake ecosystem as a product of the decomposition of plant and animal tissues and their waste products. It can follow one of three paths. First, many macrophytes can assimilate ammonia directly into their tissues. Alternatively, in aerobic conditions, certain bacteria will convert the ammonia directly to the more usable form of nitrogen, nitrates. Finally, in the case of anaerobic decomposition, which commonly occurs in the sediments of stratified lakes, nitrates can be reduced to nitrites. If these anaerobic conditions persist, the nitrites can be entirely broken down to elemental nitrogen (N_2). This form is not available to any plants without the aid of nitrogen-fixing bacteria, as only bacteria have the capability to convert nitrogen to nitrates through nitrogen fixation (Overcash and Davidson 1980). The underlying pattern that is evident from this cycle is that whatever form of nitrogen is added to the lake

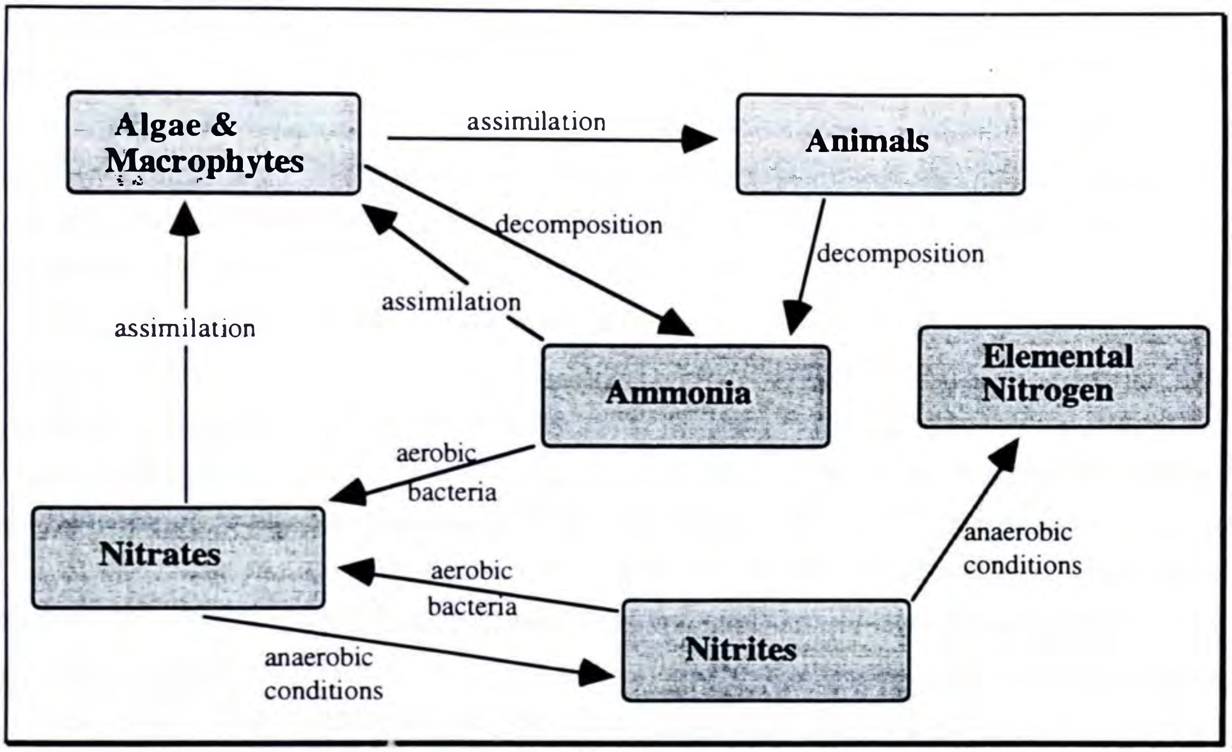

Figure 3. A diagram of the various forms of nitrogen that occur in the nitrogen cycle within a lake ecosystem. It is important to note that in aerobic conditions both ammonia and nitrites are converted to nitrates which are available for use by plants.

it will eventually become available for plant use. In order to understand the amount of this nutrient available for plant growth, one must take into account not only the various forms of nitrogen, but also the oxygen concentrations (aerobic and anaerobic conditions) of the water.

Several in-lake mitigation techniques exist to deal with the problem of excessive nutrients once they are present in the lake (Henderson-Sellers and Markland 1987). All of these techniques take advantage of the information we have explaining how phosphorus cycles in a lake. None of these techniques are without disadvantages, but for lakes with serious algal growth problems they may be necessary (Henderson-Sellers and Markland 1987).

One of the easiest methods used to eliminate excessive nutrients is to decrease the lake water level rapidly (Henderson-Sellers and Markland 1987). For example, if dams are used to control the outflow of the lake, opening these widely, so that the lake loses a large volume of water in a short period of time, may cause many of the nutrients located in the epilimnion to be flushed from the lake. This is a relatively simple technique, however in cases where the lake drains into another lake or significant water body, the problem of an overload of nutrients may not be eliminated, but simply shifted to another site. Additionally this may only be a temporal solution because the source of nutrients from the hypolimnion will not be affected; thus it will continue to supply nutrients to the rest of the lake.

Another approach of nutrient reduction involves removing the nutrient rich hypolimnetic water. By inserting a large pipe into the hypolimnion and pumping the water out in such a way that it would not go directly back into the lake, the nutrient levels in the water would be reduced (Henderson-Sellers and Markland 1987).

Chemical precipitation is a relatively simple technique which requires some expensive equipment. It is based on the natural process of iron complexing with phosphorus. Adding salt to the water will complex the DP to form an insoluble compound that will immobilize the P (Henderson-Sellers and Markland 1987). This is an effective technique but, due to the cost, is not practical for very large lakes. Furthermore, the P will eventually be released from this complex, requiring reapplication after several years.

Aeration of the hypolimnion is a process that requires some expensive machinery to perform. It operates on the principle that an increase in the oxygen levels in the lower strata of the hypolimnion will reduce the amount of DP released from the sediments. If there is oxygen present where the sediment and water interface, there will be no conversion of iron to its reduced form, so there will be no DP released from the ferric phosphate complex (Henderson-Sellers and Markland 1987).

Another approach, in lakes with large macrophyte production, is to harvest the plants. This method can be expensive due to the cost of equipment used and the frequency with which the harvesting must be performed. This procedure removes all the nutrients that are tied up in the plants at the time of the harvest and prevents them from re-entering the lake cycle (as long as the harvested plants are not stored on shore, allowing the nutrient rich water in the plants to flow back into the lake). There is some debate over the effectiveness of this method, because plants also act as a sink for nutrients. At the time of removal, the nutrients that would normally have been taken up by the plants will be available to algae, perhaps resulting in an algal bloom (BI493 1995). On the other hand, if only the foliage of the plants is harvested, then the plants will still be able to fulfill their role of taking up nutrients from the water.

One final management option is to remove the source of nutrients from the sediments by removing the sediments themselves. This is known as dredging, and although it is effective, it is extremely expensive due to the large cost of equipment needed (Henderson-Sellers and Markland 1987). Also, there is some question as to ecologically disruptive effects that actions such as this may have on the lake ecosystem.

In terms of eliminating nutrients once they have built up in a lake, it is evident from these less-than-ideal techniques that it is a very challenging task especially due to the complexity of the cycling within the lake. The ideal method for controlling nutrients in a lake is to limit the input levels so that the natural processes of the lake will be able to compensate levels without large accumulations over time.

Freshwater Wetlands

Wetlands are important transitional areas between aquatic and terrestrial ecosystems. They support a wide range of biotic species (MLURC 1976). Table 2 gives descriptions of fresh inland wetlands. More importantly, they are useful for the balance of an aquatic ecosystem because of their efficiency in nutrient uptake by vegetation. Wetlands have the potential to reduce heavy metals and nutrients from various sources including mine drainage, sewage, and industrial wastes (Smith 1990). Agricultural runoff adds excess nitrogen and phosphorus, the primary limiting agents in a lake ecosystem, into the lake. Wetlands are able to absorb some of these nutrients, thereby improving the overall water quality, and store the nutrients in sediment which can later be used by the surrounding plant life (Niering 1985).

Usually, wetlands have a water table near, at, or above the level of the land. Wetland soil is periodically or perpetually saturated, and contains non-soil substrates such as peat. Wetlands also contain hydrophyte vegetation which is adapted for life in saturated and anaerobic soils (Chiras 1991).

In the North Pond watershed, there are several wetlands located around various water sources (see Analytical Procedures and Findings: Land Use Results and Discussion - Figure 40).

WATERSHED LAND USE

Land Use Types

A watershed is defined by the total land area that contributes water to a particular lake. It is bounded by the highest points surrounding the lake and its tributaries. The assessment of land use within this area is essential in determining factors that may affect the lake water quality. Different types of land use have varying effects on nutrient loading to lakes (BI493 1994). Nutrients can bind to soil, and if eroded, this soil can add to the nutrient load. Nutrients from anthropogenic sources have had a substantial effect on water quality in numerous Maine lakes (MDEP 1992b).
Areas that have been cleared for agricultural, residential, or urban uses can contribute to nutrient loading. The combination of removing vegetation and compacting soil may result in a significant increase in surface runoff. Surface runoff can increase erosion of sediments and various wastes of human origin. Products such as fertilizers, pesticides, and herbicides associated with human activity can contain nitrogen, phosphorus, other plant nutrients, and miscellaneous chemicals (MDEP 1992a). These sediments can have adverse effects on water quality.

Natural areas, such as forested land, offer better protection against soil erosion and surface runoff. The canopy provides a cover over the soil, lessening the impact of rain, and reducing soil erosion. The root systems of the trees further reduce soil erosion and slow the rate of runoff, allowing water to percolate into the soil. Forested areas act as buffering systems by absorbing the nutrients when they are located between sources of nutrients and water bodies. Forests cover much of Maine, therefore expansion of residential areas usually results in forest clearing. By clearing forested areas, erosion, and therefore nutrient loading, can increase with subsequent decline in lake water quality in an area that previously acted as a buffer zone. Also, the resulting development provides impervious surfaces that increase the amount of surface runoff. A study concerning phosphorus loading in Augusta, Maine revealed that a residential area produced ten times more phosphorus than an adjacent forested area (Dennis 1986; Figure 4).

Table 2. Descriptions of site characteristics and plant populations of different types of fresh inland wetlands (Smith 1990).

Type	Site characteristics	Plant populations
Seasonally flooded basins or flats	Soil covered with water or waterlogged during variable periods, but well drained during much of the growing season; in upland depressions and bottomlands	Bottomland hardwoods to herbaceous growth
Fresh meadows	Without standing water during growing season; waterlogged to within a few inches of surface	Grasses, sedges, broadleaf plants, rushes
Shallow fresh marshes	Soil waterlogged during growing season; often covered with 15 cm or more of water	Grasses, bullrushes, spike rushes, cattails, arrowhead, pickerel weed
Deep fresh marshes	Soil covered with 15 cm to 1 m of water	Cattails, bullrushes, reeds, spike rushes, wild rice
Open freshwater	Water less than 3 m deep	Bordered by emergent vegetation such as pondweed, wild celery, water lily
Shrub swamps	Soil waterlogged; often covered with 15 cm of water	Alder, willow, buttonbush, dogwoods
Wooded swamps	Soil waterlogged; often covered with 0.3 m of water; along sluggish streams, flat uplands, shallow lake basins	Tamarack, arbor vitae, spruce, red maple, silver maple
Bogs	Soil waterlogged; spongy covering of mosses	Heath shrubs, sphagnum moss, sedges

Residential areas are separated into shoreline and nonshoreline homes that can be either permanent or seasonal residences (see Analytical Procedures and Findings: Roads and Residential Areas). Residential areas in a watershed generally contain lawns, driveways, parking areas, rooftops, and other impervious surfaces that reduce percolation, thereby causing runoff accumulation. Since year-round homes produce more phosphorus through extended use of septic systems, they may pose more of a threat to nutrient loading than seasonal homes.

The use of household products in and around the home is also potentially harmful to water quality (BI493 1993). Due to their proximity to the lakes, shoreline homes can provide direct sources of nutrients to the lake. Products used in the household (e.g., detergents and soaps) contain phosphorus. Lawns and gardens are maintained with fertilizers that are high in phosphorus. These products used around the home can leak into the groundwater and subsequently enter the lake. Storms can also carry away these high nutrient products due to increased surface runoff near residences. The nutrients enter the water column and lead to lake eutrophication. In addition, when improperly designed or used, septic systems found at year round or seasonal homes can potentially be large sources of nutrients (EPA 1980).

Commercial uses of forested land, such as logging and tree harvesting, remove the cover of the canopy, thereby exposing the soil to direct rainfall, which facilitates erosion. Skid trails may pose a problem when they run adjacent to or through streams (Hahnel, pers. comm.). Shoreland zoning ordinances have established that a 75 ft strip of vegetation be maintained between a skid trail and the normal high water line of a water body or upland edge of a wetland to alleviate the potential impact harvesting may have on a water body (MDEP 1990). Two studies by the Land Use Regulation Commission on tree harvesting sites noted that erosion and sedimentation problems occurred on 50% of the active and 20% of the inactive logging sites selected (MDC 1983).

Roads can also provide excessive surface runoff if poorly designed or maintained. Their contribution also depends on regulations enforced by local governments. Roads are divided into four main types (state, municipal, dirt, and fire roads) and can have varying degrees of nutrient loading potential. Roads and driveways leading down to shoreline areas or streams provide easy access to the lake for runoff and can contribute large amounts of nutrients if they are not well constructed or maintained (KCSWCD 1992).

Land use is an important determinant of lake water quality. Before new development can occur it is important to identify particular considerations such as soil type or the phosphorus loading coefficient. These considerations need to be taken into account and shared with developers as guidelines to minimize impact on the lake. To maintain water quality there must be state and local regulations in place that moderate nutrient loading from various land uses. Investigation of impacts from land use practices and possible future development will help preserve a healthy lake system.

Buffer Strips

Buffer strips are important for control of nutrients entering the lake (MDEP 1990). Increased levels of nutrients can promote algal growth and increase the lake's eutrophication rate. According to the Belgrade Shoreline Zoning Ordinance, one should have "a strip of land extending 100 ft, horizontal distance, inland from the nonnal high-water line of a great pond or a river flowing to a great pond, and 75 ft, horizontal distance, from any other water body, tributary stream, or the upland edge of a wetland" as a buffer strip (Belgrade 1991). An example of an ideally buffered home is shown in Figure 5. This home has a winding path down to the water. Runoff is diverted into the woods where nutrients will be absorbed by the forest litter. The house is set back from the water 100 ft, and has a buffer strip between it and the water consisting of a large canopy which can absorb nutrients and break the impact of precipitation hitting the ground (MDEP 1990). The driveway curves down to the house.

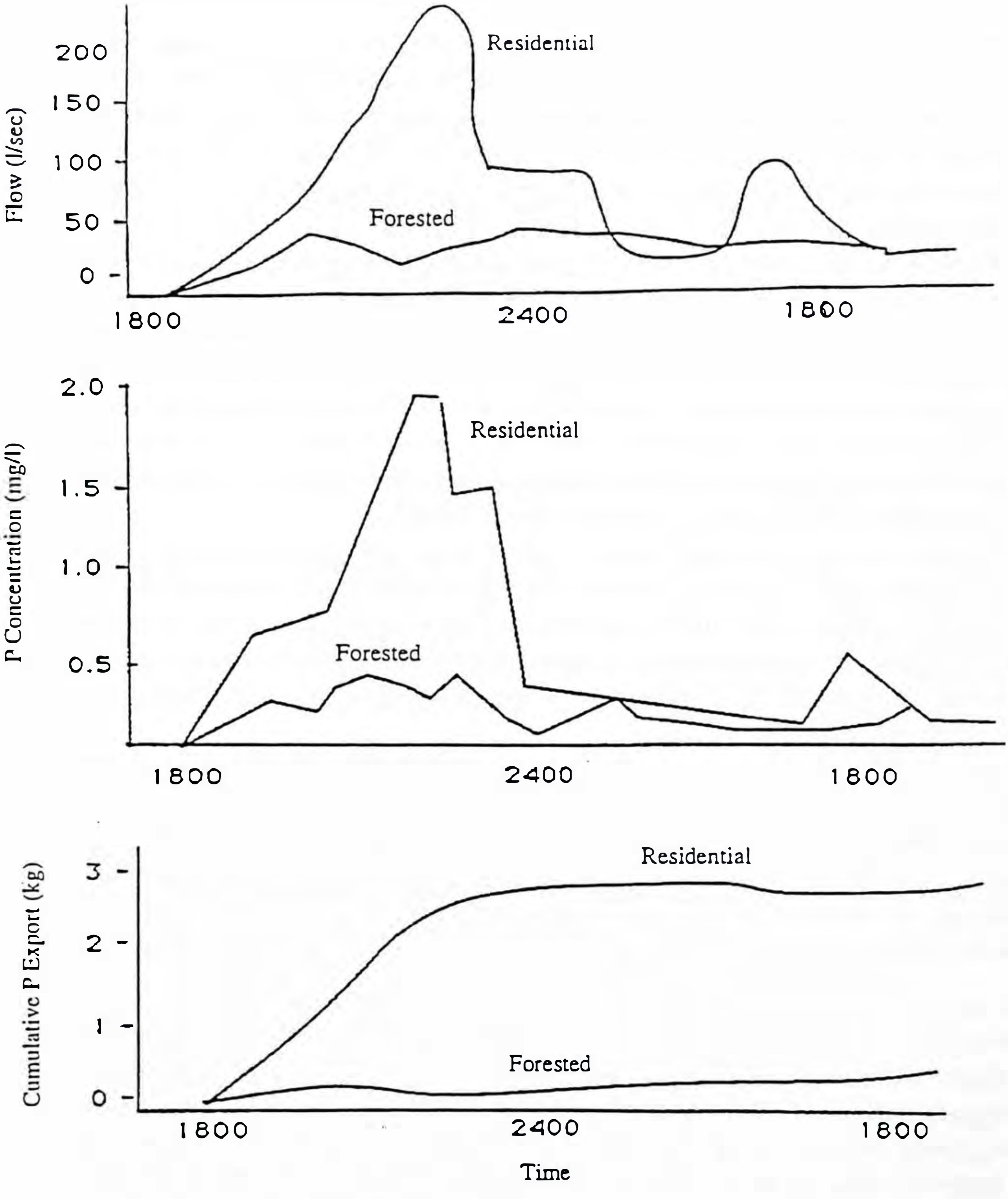

Figure 4. Comparisons of runoff after an April rain storm in two neighboring watersheds near Augusta, ME. Top: volume of immediate runoff over a 12 hour period; Middle: phosphorus concentration in the runoff; Bottom: total amount of phosphorus exported into local streams and lakes from the storm (Dennis 1986).

This curving allows the water to be diverted into the woods and then filtered by the forest litter. The runoff is allowed time to be naturally filtered by the surrounding forest rather than running directly into the lake. Most buffer strips on North Pond, Little Pond and the Serpentine, are not in accordance with the above shoreline zoning ordinance and may provide insufficient nutrient absorption. Some houses surrounding the lake have natural woodland buffer strips, however, there are many houses in the south basin of North Pond which are surrounded by large green lawns. Such lawns do not provide adequate nutrient uptake before runoff enters the lake.

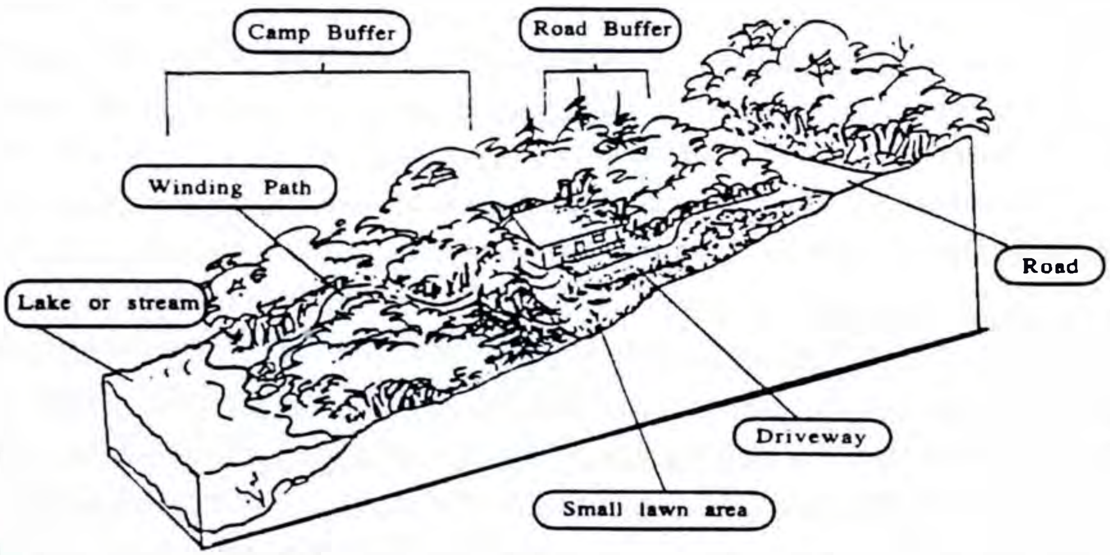

Figure 5. Diagram of an ideally buffered home.

Nutrient Loading

Nutrient loading into a lake can be affected by both natural and anthropogenic processes (Hem 1970). Human activity, however, usually accelerates the loading of nutrients and sediments into a lake. The water quality can be adversely affected in a short period of time. Clearing away forests and constructing roads and buildings with flat impervious surfaces increase runoff, carrying nutrients from agricultural, residential, and industrial products and uses (such as detergent, fertilizer, and sewage) into the lake. Since phosphorus and nitrogen are the limiting nutrients in algal growth, and algal growth affects the trophic state of a lake, increases of phosphorus and nitrogen from these sources can lead to a decrease in lake water quality and eventually varying degrees of eutrophication.

Total phosphorus loading to a lake can be determined using a phosphorus loading model (see Analytical Procedures and Findings: Phosphorus Loading). This model takes into account the various aspects upon which the phosphorus concentration in the lake basin is dependent, such as lake size, volume, flushing rate, and land use patterns within the watershed (Cooke et al. 1986). This model is useful because it allows for the projection of the impacts that various factors may have on phosphorus loading. It enables predictions of lake responses to changes in land use to be made. The accuracy of the predictions is based on the accuracy of the assumptions (EPA 1990).

Soil Types

Nutrient loading in lake ecosystems is a function of the soil types and their respective characteristics (BI493 1994). Both their physical features, such as permeability, depth, particle size, organic content, and the presence of an impermeable layer (hardpan), as well as the natural features (slope, average depth of the water table, and depth to the bedrock) which influence them, are important to consider in deciphering the nutrient loading functions (USDA 1978). These factors can determine appropriate land uses such as forestry, agriculture, and residential or commercial development. The soils most capable of accommodating such disturbances, by preventing extreme erosion and runoff of both dissolved and particulate nutrients, are those which have medium permeability, moderate slopes, deep water tables, low rockiness and organics, and no impermeable layer (USDA 1992). Soils that do not meet all of these criteria must be considered carefully before implementing a development, forestry, or agricultural plan.

Zoning and Development

The purpose of zoning and development ordinances are to maintain safe, healthful conditions, control water pollution, protect wildlife and freshwater wetlands, control building and placement of structures as well as other types of land use, conserve rural nature, and anticipate the impacts of development (Belgrade 1991). Shoreland zoning ordinances regulate development along the shoreline in a manner that reduces the deterioration of lake water quality. Uncontrolled development along the shoreline within sensitive areas can result in a severe drop in water quality that is not easily corrected. In general, these regulations have become more stringent as increased development has caused water quality to decline in many watersheds (MDEP 1992b). If no comprehensive plan or town ordinances have been enacted, the state regulations are used by default.

Shoreline Residential Areas

Shoreline residential areas are of critical importance to water quality due to their proximity to the lake. Any nutrient additives from households (such as detergents) have only short distances to travel to reach the lake. Buffer strips along the shore are essential in acting as a sponge for the nutrients flowing from residential areas to the lake (Woodard 1989). These buffer zones consist of an area of natural vegetation growing between a structure and the body of water in question. Town ordinances in Belgrade and Rome regulate buffer strip widths, thereby influencing phosphorus loading to the lake (see Background, Watershed Land Use: Buffer Strips).

Households that have lawns leading directly down to the shore have no obstacles to run off, and movement of phosphorus can pass easily into the lake. Buffer strips, when used in conjunction with appropriate setback laws for house construction, can dramatically reduce the proximity effects of the shoreline homes (MDEP 1992b).

Maine seasonal residences, located on or near the shoreline in a cluster, can contribute disproportionately to phosphorus loading into the lake ecosystem. Such clusters of camps usually exist because they have been grandfathered, and thus do not follow shoreland zoning laws. Although seasonal, they may involve large numbers of people. Therefore, phosphorus export from these areas is likely to increase during this time because of their concentrated use. In the North Pond, Little Pond, and the Serpentine watershed, there are some specific areas that contain multiple residences per lot. These can be found on the North and East sides of North Pond. The effects of these plots on nutrient loading depend on factors such as septic system location and condition (see Background, Watershed Land Use: Sewage Disposal Systems).

Nonshoreline Residential Areas

Although not as important in phosphorus loading as shoreline areas, inland areas can also have an impact on nutrient loading. Runoff, carrying the phosphorus from soaps, detergents, and fertilizers usually filters through buffer strips consisting of forested areas several acres wide, rather than a few feet wide (as with shoreline buffers). In these cases, phosphorus has the opportunity to be absorbed into the soils and vegetation. The majority will not reach the lake directly, but will simply enter the forest's nutrient cycle.

However, houses located up to one half mile away from the lake can supply the lake with phosphorus almost directly when badly constructed roads persist. Runoff collected on roofs and driveways may travel unhindered down roads to the lake. Although nonshoreline homes are not as threatening as shoreline homes, watersheds having large residential areas with improper drainage can have a significant effect on phosphorus loading.

Tributaries can make inland homes nutrient loading hazards in a similar way that shoreline homes. Phosphorus washed from residential lawns without buffer strips can enter into a stream and eventually into the lake. Even when far from the shoreline, a house can have a significant impact, especially if it is near a stream which leads into the lake. Therefore, similar restrictions and regulations as those for shoreline homes apply to nonshoreline homes that are located along streams.

Sewage Disposal Systems

Subsurface wastewater disposal systems are defined in the State of Maine Subsurface Wastewater Disposal Rules as: "a collection of treatment tank(s), disposal area(s), holding tank(s), alternative toilet(s), or other devices and associated piping designed to function as a unit for the purpose of disposing of wastewater in the soil" (MDHS 1988). These systems are generally found in areas with no municipal disposal systems, such as sewers. Examples of these subsurface disposal systems include pit privies and septic systems, both of which are found in the watershed of North Pond, Little Pond, and the Serpentine.

Pit Privy

Pit privies are also known as outhouses. Most privies are found in areas with low water pressure systems. They are simple disposal systems consisting of a small, shallow pit or trench. Human excrement and paper are the only wastes that are able to be decomposed and treated. Little water is used with pit privies. Therefore chances of contamination of ground water are reduced. Contamination may occur if the privy is located too close to a body of water due to infiltration of waste into the upper soil levels (BI493 1994).

Holding Tank

Holding tanks are watertight, airtight chambers, usually with an alarm, that hold waste for periods of time. The tanks are durable and made of either concrete or fiberglass (MDHS 1988). The minimum capacity for a holding tank is 1500 gallons. These must be pumped or else they could back up into the structure or may leak into the ground, causing contamination. According to Bob Martin (pers. comm.), the plumbing inspector for Belgrade, holding tanks are, "the system of last resort." The reason for his opinion may be that although purchasing a holding tank is inexpensive, the owner is then required to continually pay to have that holding tank pumped.

Septic System

Septic systems are the most widely used subsurface disposal system. They are also the most complex system for wastewater disposal. The system includes a building sewer, treatment tank, effluent line, disposal area, distribution box, and occasionally, a pump. The pump enables the effluent to be moved to a more suitable location if the location of the treatment tank is unsuitable for a leaching field (MDHS 1983). Figure 6 shows the basic layout of the components of a typical septic system. They are an efficient and economical alternative to a sewer system, provided they are properly installed. Unfortunately, many septic systems that are not installed properly may lead to nutrient loading and groundwater contamination. The location of the systems and the soil characteristics determine the effectiveness of the system.

The distance between a septic system and a body of water should be sufficient so that there is no contamination of the water. The shoreline regulations in Belgrade and Rome state that septic systems need to be at least 100 ft away from a lake and 75 ft away from streams (Rome 1990, Belgrade 1991). Unfortunately, many parcels of land are grandfathered, which means their septic systems were installed before the passage of current regulations. Therefore, those systems may be closer to the shore than is currently permitted. However, any replacement systems in these grandfathered areas must reflect the new regulations. Replacement systems can either be completely relocated, or an effluent pump installed on the outside of the existing treatment tank can be used to move the sewage uphill to a new disposal area that is away from the pond (MDHS 1983).

Human waste and gray water can be transferred from the house through the building sewer to the treatment tank. There are two kinds of treatment tanks, aerobic and septic (MDHS 1983). The aerobic tanks rely on aerobic bacteria, which are more active. Unfortunately, they are also more susceptible to condition changes. These tanks also require energy to pump in fresh air, more maintenance, and are more expensive. For these reasons, the septic tank is preferable. Septic tanks rely on anaerobic bacteria. Both tanks are water-tight, durable, and usually made of concrete or fiberglass. Raw materials are held until they are more suitable for discharge (MDHS 1983).

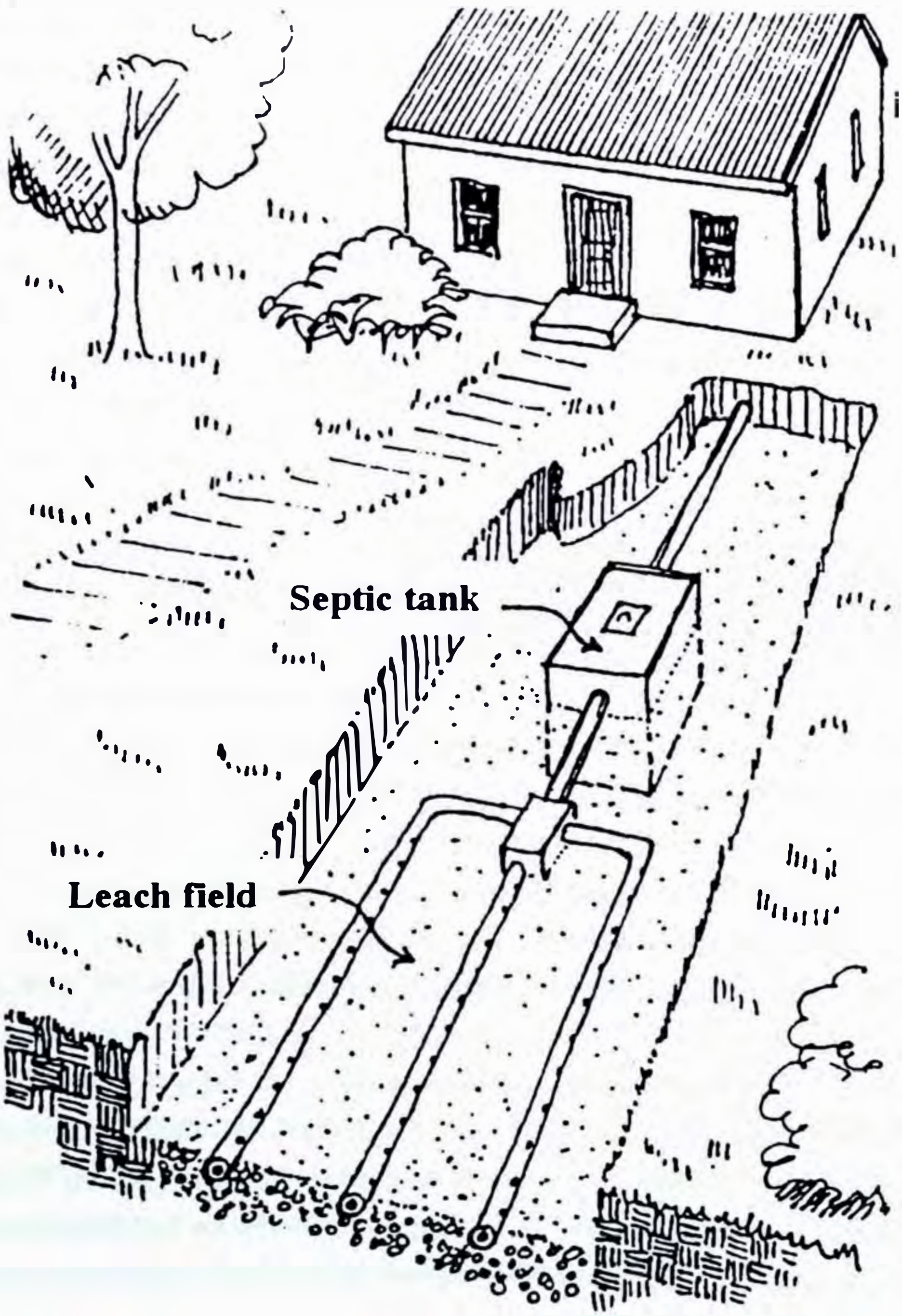

Figure 6. The layout of a typical septic system (Williams 1992).

As the physical, chemical, and biological breakdowns occur, scum and sludge are separated from the effluent. Figure 7 shows the cross section of a typical treatment tank. Scum is the layer of grease, fats, and other particles that are lighter than water and move to the top of the treatment tank. Scum is caught in the baffles so that it cannot escape into the disposal area. Sludge is composed of the solids that sink to the bottom of the tank. Over time, much of the scum and sludge is broken down by anaerobic digestion. The effluent, which has received a primary treatment, then travels through the effluent line to the disposal area.

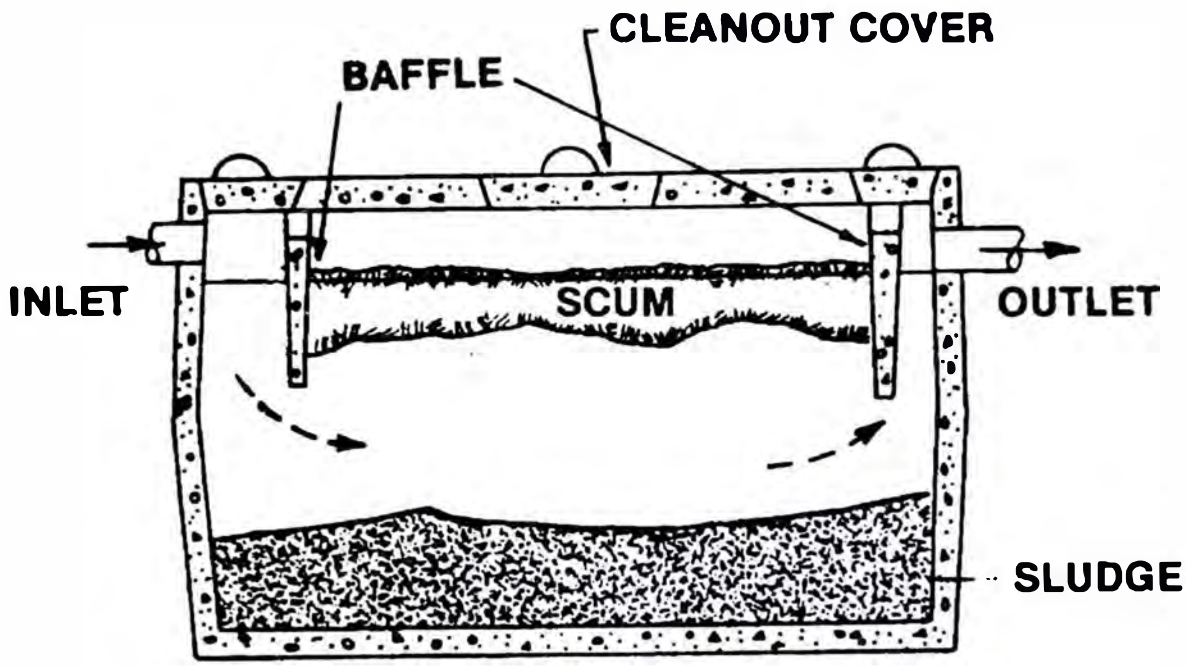

Figure 7. The cross-section of a typical treatment tank showing the movement of effluent through the tank as well as the separation of the scum and sludge (MDHS 1983).

The purpose of a disposal area is to provide additional treatment of the waste water. The disposal area can be one of three types: bed, trench, or chamber (MDHS 1983). Beds are wider than trenches, and usually require more than one distribution line; typically, beds need a distribution box. Chambers are made of pre-cast concrete. The size of the disposal area depends on the volume of water and soil characteristics. The soils in the disposal area serve to distribute and absorb effluent, provide microorganisms and oxygen for treatment of bacteria, and remove nutrients from the wastewater through chemical and cation exchange reactions (MDHS 1983). Effluent is anaerobic as it leaves the treatment tank, therefore will need to be treated aerobically in the disposal field to kill the anaerobic bacteria before treatment is considered complete. If the effluent is not treated completely, it can be a danger to the water body and the organisms within it, as well as to human health. Three threats to lakes include organic particulates which increase biological oxygen demand (BOD), nutrient loading, and water contamination through the addition of viruses and bacteria (MDHS 1983).

BOD is the oxygen demanded by decomposers to break down organic waste in water (BI493 1994). Organic matter will increase if there is contamination from human and animal wastes. As the amount of organic material increases, BOD increases. If the BOD exceeds dissolved oxygen, species within the lake may begin to die. If the flushing rate is low, dissolved oxygen content and increasing organic matter could become problematic.

The three major types of wastes that travel into the septic system include garbage disposal wastes, black water, and gray water. The garbage disposal wastes can easily back up the septic system and therefore should not be added to the septic system. Black water and gray water are significant contributors of phosphorus. Black water also contributes nitrogen, toilet wastes, and microorganisms. Gray water brings in chemicals and nutrients. Once a system is clogged or a leak develops, humans are exposed to potential bacterial and viral contamination (MDHS 1983).

Reducing the chances of clogging will allow septic systems to be the most efficient. Year-round residents should have their septic tanks pumped every two to three years, or when the sludge level fills half the tank (Williams 1992). Seasonal residents should pump their septic tanks every five to six years to prevent clogging from occurring in the disposal field. Garbage disposals place an extra burden on a septic system (Williams 1992). Cigarette butts, sanitary napkins, and paper towels are not easily broken down by the microorganisms and end up filling the septic tank too quickly. The disposal of chemicals, such as pouring bleach or paint down the drain, may also affect septic systems by killing microorganisms. Water conservation slows the flow through the septic system and allows more time for bacteria to treat the water. By decreasing the amount of water passing through the disposal field, the septic system can work more effectively and recover after heavy use (Williams 1992). Odors, extra green grass around the septic cover, and slow drainage are symptoms of a septic system that has been used heavily, and is now having problems.

When constructing a septic system, it is important to determine the best place on the lot for the system based on soil characteristics and topography. An area with a gradual slope (10 to 20%) that allows for gravitational pull is necessary for proper sewage treatment (MDHS 1988). Too little a slope causes stagnation, while too steep a slope drains the soil too quickly. Time for treatment is cut short and water is not treated properly. Adding or removing soils to decrease or increase the slope can solve this problem.

Soil containing loam, sand, and gravel allows the proper amount of time for runoff and purification (MDHS 1983). Table 3 shows the soil conditions and types that are needed to install an effective septic system. Soil cannot be too porous, otherwise water runs through too quickly and is not sufficiently treated. Depth of bedrock is another important consideration. If the bedrock is too shallow, the waste will not be able to sink and will rise back up to the surface of the soil. Clays and thin (fine) soils do not allow for water penetration and again water will run along the surface untreated. A solution to this would be to add loam and sand to improve the permeability (BI493 1994). If a soil drains too quickly, loam, and clay can be added to slow the movement down (BI493 1994).

Federal, state, and local laws are established to protect the land and water quality. The federal government sets the minimum standards for subsurface waste disposal systems. The states then can make these rules more strict. The states set new minimums according to the federal laws. Examples include minimum setback for septic systems and no new septic systems on a flood plain (MDHS 1983). Maine's Comprehensive Land Use Plan sets the standard regulations that each city and town must follow. Each town can set up their own land use plan, according to the state regulations, but many just develop local ordinances that consider specific things such as shoreline zoning. The MDEP,

Table 3. **Soil characteristics that determine the soil suitability for a septic system (MDHS 1983).**

Parent Material	Soil Profile	Textural Classification and Descriptions	Soil Conditions: Shallow to Bedrock A, Bedrock I (less than 10")	Shallow to Bedrock A, Bedrock II (10" to 15")	Shallow to Bedrock A, Bedrock III (between 15"-48")	Drainage B: Well Drained (Ground Water Table greater than 48")	Drainage C: Moderately Well Drained (Ground Water Table between 48" to 15")	Drainage D: Somewhat Poorly Drained (Ground Water Table between 15" to 7")	Drainage E: Very Poorly Drained (Ground Water Table less than 7")	Disposal Area Rating Sec. 12
Glacial Till	1	Silt loam soils which tend to become more compact with depth. [illegible] Angular coarse fragments may be present.		4	2	1	1	3	4	LARGE
Glacial Till	2	Loam to sandy loam soils which do not have a [illegible] layer. Angular coarse fragments may be present.		4	2	1	1	3	4	MEDIUM LARGE
Glacial Till	3	Loam, sandy loam to loamy sand soils with a restrictive layer. Angular coarse fragments may be present.		4	2	1	1	3	4	MEDIUM LARGE
Glacial Till	4	Sandy loam to loamy sand overlying loamy sand soils derived from ablation till. Coarse fragments (angular to rounded) may be present. No restrictive layer throughout profile.		4	2	1	1	3	4	MEDIUM
Stratified Drift	5	Loam to sandy loam soils overlying stratified fine and medium sands. Rounded coarse fragments may be present.		4	2	2	2	3	4	MEDIUM
Stratified Drift	6	[illegible] and gravel. Round coarse [illegible] may be present.		4	2	2	2	3	4	SMALL
Mixed Origin	7	Loamy sand to sand overlying a restrictive layer of silt to silty clay which occurs at a depth of 15 inches or greater. Coarse fragments may be present in upper horizons but usually absent in lower horizons.		4	2	1	1	3	4	MEDIUM LARGE
Lacustrine Marine	8	Loam to fine sand overlying firmer silt loam to silt. A restrictive layer may be present. Coarse fragments usually absent. Stratified lenses of very fine sand, silts and clays may be present in the substratum.		4	2	1	1	3	4	LARGE
Lacustrine Marine	9	Silt loam soils overlying firm silt loams to silty clays exhibiting a restrictive layer. Coarse fragments are usually absent.		4	2	1	1	3	4	EXTRA LARGE
Organic	10	Soils composed of organic materials in various stages of decomposition.								
Alluvial, Dune, Beach	11	Variable in texture. Exhibiting very little weathering. Deposited in flood plain, sand dune or beach environment.				5	5			SEC. 11.F 11.G

Legend	Description	Notes
Blank	ALL SYSTEMS PERMITTED	Note 1: See 11 C.2.a.i for Separation Distances. Note 2: See 11 C.2.a.ii and 11 C.2.b for Separation Distances.
Vertical lines	Severe Limitations. REPLACEMENT SYSTEMS MAY BE PERMITTED (Sec. 15)	Note 3: See Sec. 15 for Replacement System Variance by LPI. See 11 C.2.a & 11 C.2.b for Separation Distances.
Grid	Very Severe Limitations. REPLACEMENT SYSTEMS MAY BE PERMITTED if no alternative. NEW SYSTEMS NOT PERMITTED.	Note 4: See Sec. 15 for Replacement System Variance with Department Review. See 11.C.2. for Separation Distances.
Shaded	Extremely Severe Limitations. SYSTEMS NOT PERMITTED	Note 5: See Sec. 11.F for Coastal Sand Dune limitations. See Sec. 11.G for Flood Plain limitations.

the Department of Conservation, and local Code Enforcement Officers are responsible for overseeing the enforcement of these laws.

Since 1974, state mandates have prevented septic systems from being installed without a site evaluation, or within 100 ft from the high water mark. Other regulations state that there must be no less than 300 ft between a septic system disposal field and a well that uses more than 2000 gallons per day and no systems can be built any less than 100 ft away from any well when the septic system uses less than 2000 gallons per day (MDHS 1988). Also, 20% is the maximum slope of the original land that can support a septic system. These regulations are in place for the safety of the people living in the North Pond and Little Pond watershed as well as for the ecosystem within the lake. By following these mandates, safe and efficient septic systems can be installed and used.

Roads

Roads can greatly contribute to water quality deterioration by adding to phosphorus loading within the watershed. They do this by creating an easy access route for runoff from the land into the lake. This is especially prevalent for roads that lead directly down to the water. Besides adding phosphorus, they may allow easy access for runoff of other nutrients and organic pollutants into the lake via improperly constructed culverts and ditches. Improper construction and maintenance can increase the nutrient input caused by roads.

Proper drainage of roads is very important when trying to control phosphorus loading within a watershed. Construction materials, such as pavement, dirt, or gravel, may influence the amount and rate of runoff (Woodard 1989). The inevitable erosion of these building materials due to road traffic causes deterioration of the road surface. Storm events help to deteriorate the road even more rapidly by dislodging particles from the road surface and carrying them away. These particles may then runoff as sediment into the lake, carrying a large amount of phosphorus with them. Roads may therefore be a large source of phosphorus loading to a lake if poor construction, maintenance, and/or erosion control practices occur (KCSWCD 1992).

Road construction should try to achieve the following long-term goals: minimize the surface area covered by the road, minimize runoff and erosion with proper drainage and the placement of wetponds and catch basins (as well as culverts and ditches), and maximize the lifetime and durability of the road (MDEP 1990). Thus, a well constructed road should allow surface water to run off away from the road and divert road surface waters to prevent excessive amounts of surface runoff, phosphorus, and other nutrients from entering the lake. This may be done by considering the following items before road construction begins: road location, road area, road surface material, road cross section, road drainage (ditches, diversions, and culverts), and road maintenance (MDEP 1992a).

The location of a road is typically determined by the area in which homes are built, although the State of Maine has set guidelines to control the location of roads (MDEP 1990). All roads must be set back at least 100 ft from the shoreline of a lake if they are for residential use, and 200 ft for industrial, commercial, or other non-residential uses involving one or more buildings (MDEP 1991). Along with this limit, a new road in Rome or Belgrade should not be built with a grade of more than 10%, except for short segments of less than 200 ft (Belgrade 1991 and Rome 1990).

The surface area that a road occupies can also lead to an increased potential for erosion and runoff, and therefore must be limited. Thus, it is very important to design a road with its future use in mind. For instance, a road should be constructed no longer than is absolutely necessary. A particular road should not be extended past the last structure that is to be serviced by that road. The width of a road, which is often based upon the maintenance capabilities of the area, must also be considered (Cashat 1984). If a group is not able to maintain the proposed road because of maintenance costs, it should build a road that is not as wide so that maintenance costs will be lower. Proper planning for maintenance is typically a more effective, practical, and less expensive way to develop the road area (Woodard 1989).

Road surface material is another important factor to consider when building a road. Studies have shown that phosphorus washes off a road at a higher rate from a paved surface than it does from a sand and gravel surface (Lea et al. 1990). On the other hand, sand and gravel roads erode more quickly and therefore have the potential for emptying more sediment, and therefore more nutrients, into a water body. Consequently, pavement is chosen for roads with a high volume of traffic, while sand and gravel roads are typically used for low traffic areas or seasonal use patterns. Both types of roads need proper maintenance and road surfaces should be periodically replaced and properly graded so that a stable base may be maintained and road surface erosion will be minimized.

The road cross section is another important factor to consider when planning to build a road. A crowned road cross section allows for proper drainage to take place and helps in preventing deterioration of the road surface (MDOT 1986). This means that if the road is pictured in cross section, it will slope downward from the middle, towards the outer edges. The crown should have a slope of 1/8 to 1/4 inches per foot of width for asphalt and 1/2 in to 3/4 in per foot of width for dirt roads (KCSWCD 1992). This slope allows the surface water to run off down either side of the road as opposed to running over its whole length. Road shoulders should also have a slightly steeper cross slope than the road itself so that runoff can flow into a ditch or buffer zone (KCSWCD 1992).

The drainage of a road must also be considered when constructing it. Both ditches and culverts are used to help drain roads into buffer zones so that runoff will not enter the lake directly and buffer strips will absorb some of the nutrients from the road. These measures are also used in situations for handling runoff that may be blocked by road construction. Ditches are necessary along wide or steep stretches of road to divert water flow off the road and away from a body of water. They are ideally parabolic in shape with a rounded bottom and are of a sufficient depth, not exceeding a depth to width ratio of 2:1. The ditch should also be clean and free of debris, and covered with abundant vegetation to reduce erosion (KCSWCD 1992). These ditches must also be constructed of proper soil that will not erode easily from the velocity of waters passing through them.

Culverts are hollow pipes that are installed beneath roads to channel water in proper drainage patterns. The most important factor to consider when installing a culvert is its size. It must be large enough to handle the expected amount of water which will pass through it. If this is not the case, water will tend to flow over and around the culvert and wash out the road. This may increase the amount of erosion that is occurring on the road and possibly increase the sediment load that may enter the lake. The culvert must be set in the ground at a 30° angle down slope with a pitch of 2% to 4% (KCSWCD 1992). A pitch greater than 4% can lead to rapid velocity of water flowing through. An increase in velocity can cause erosion to fill the culvert and result in washout on the low side below the road. It is also important to have a proper crown above the culvert to avoid creating a low center point in the culvert. The standard criteria for crowning above culverts is one inch of crown for every 10 ft of culvert length (KCSWCD 1992). The spacing of culverts is based upon the road grade.

Diversions allow water to be channeled away from the road surface into wooded or grassy areas. These are important along sloped roads, especially those leading towards a lake. By diverting the water into wooded or grassy areas, natural buffers are used to filter sediment and decrease volume through infiltration before the water reaches the lake, along with preventing the water from gaining velocity (KCSWCD 1992). Efficient installation and spacing of diversions can also eliminate the use of culverts (KCSWCD 1992).

Maintenance is very important to keep a road in good working condition as well as to prevent it from causing problems for the lake. Over time, extensive use and wear will cause a road to deteriorate. These problems will only become worse if ignored and will therefore cost more money in the long run to repair. Roads should be periodically graded, ditches and culverts inspected and cleaned, and regularly inspected to assess any problems that may develop. These practices will help to preserve the water quality of the lake and will add to its aesthetic value.

Agriculture and Livestock

Agriculture can cause many problems within the watershed of a lake. Tilling of soil and livestock grazing areas are potential sources of erosion, which could carry sediments and nutrients to the lake and have an adverse effect on the water quality (Williams 1992). To minimize these problems there are ordinances that prohibit new tilling of soil and new grazing areas within 100 ft of a lake or river. Problems can still exist, however, with areas that were in use before these ordinances were passed by the State of Maine in 1990. According to the Shoreline Zoning Act, these areas can be maintained as they presently exist and therefore may result in decreased water quality and increased erosion (MDEP 1990). Additional solutions to the problems related to tilling of soil are to plow with the contour lines (across as opposed to up and down a slope) and to strip crop.

Another potential agricultural impact on water quality is manure from livestock. Manure becomes a problem when it is spread as a fertilizer, which is a common agricultural practice. Manure spreading can lead to nutrient loading, especially in the winter when the ground is frozen and the nutrients do not have a chance to filter into the soil. These problems become worse with the tendency to over fertilize. To help prevent these problems the state has passed zoning ordinances which prohibit the storage of manure within 100 ft of a lake or river (MDEP 1990). Another solution may be to avoid spreading manure in the winter. The town may provide subsidies as an incentive if the problem is large enough. These solutions, though, do not address the problem of livestock that defecate close to water bodies when they may be near them to drink (BI493 1994). One solution for this may be to put up grazing fences to keep the cattle away from the water. Runoff from the use of artificial fertilizers and pesticides is another way in which nutrients and other pollutants may end up in the lake. These problems can be minimized by only fertilizing during the growing season and not before a storm. Other methods besides pesticides are available for pest control, such as biological control or inter-cropping.

Forestry

Forestry is another area of development that can contribute to nutrient loading through erosion and runoff. The creation of logging roads and skidder trails may direct runoff into the lake. The combination of erosion, runoff, and pathways can therefore have a large impact on the water quality of a lake (Williams 1992). Again there are shoreline zoning ordinances which relate to these specific problems to minimize the damage done to a lake. For example, timber harvesting equipment, such as skidders, cannot use streams as travel routes unless they are frozen or cause no ground movement (MDEP 1990). There is also an ordinance which prohibits clear-cutting within 100 ft of the shoreline of the lake or river running to the lake. At distances greater than 100 ft, harvest operations cannot create clear-cut openings greater than 10,000 ft^2 in the forest canopy, and if they exceed 500 ft^2, they have to be at least 100 ft apart. These regulations are intended to minimize erosion (MDEP 1990). In order for these laws to be effective they have to be enforced. This may be a difficult task for most towns since they do not have the budgets necessary to regulate these areas. Therefore, illegal forestry techniques may occur and negatively impact lake water quality.

Tree farms are also an important component of many watersheds, including North Pond, Little Pond, and the Serpentine. These farms can be managed privately or federally. A problem may occur here depending on the purposes of the farm. For example, a tree farm may have been purchased to conserve the area, in which case there would be limited runoff. This is because forests have the ability to act as a natural buffer for the nutrients going into a lake, if left undisturbed. On the other hand, most tree farms are used for economic reasons, namely to harvest the trees. This use may be a problem if the farmer does not consider the value of the forest, other than timber production, before clear-cutting the area (Clawson 1975). These areas can be a source of fertilizers and pesticides and, therefore, logging practices and tree farming are important issues in considering water quality. A number of logging areas and a tree farm are located in the North Pond, Little Pond, and Serpentine subwatersheds.

Cleared Land

Cleared land also presents problems of erosion and nutrient runoff due to the large areas that have been cleared of trees and other vegetation which act as natural filters. Sediments from these cleared areas could create a problem because they carry large amounts of nitrogen, phosphorus, other plant nutrients, and chemicals to the lake. Without a buffer from the vegetation these problems are made even worse (BI493 1994). Since pasture land is created by the replacement of natural vegetation with forage crops, it is included in this category. Also included in this category are large grassy areas, for example, lawns or parks.

The MDEP (1990) has established some guidelines for cleared land. For example, there can be no cleared openings greater than 250 ft^2 in the forest canopy within 100 ft of a lake or river. Where there are cleared lands, some solutions to minimize erosion may be to build terraces, which would decrease the flow of storm water down a slope allowing the nutrients to settle out before they get to the lake. Plowing parallel to the contour lines, as suggested for agricultural uses, will decrease the flow of storm water. These two solutions may prevent erosion by breaking up large areas of tilled soil.

Wetlands

There are different types of wetlands that may be found in a watershed. A bog, which is dominated by sphagnum moss, sedges and spruce, has a high water table (Nebel 1987). Fens are open wetland systems that are nutrient rich and may include such species as sedges, sphagnum moss, and bladderwort. Marshes have variable water levels and may include cattails and arrowheads (Nebel 1987). Swamps are waterlogged soils and can either be of woody or shrub types. Shrub swamps consist of alder, willow, and dogwoods while woody swamps are dominated by hemlock, red maple, and eastern white cedar (Nebel 1987). Furthermore, wetlands are important because they contain a variety of wildlife, such as waterfowl and invertebrates (Nebel 1987).

The type of wetland and its location in a watershed are important factors when determining whether the wetland is a nutrient sink or source, that is, whether it prevents nutrients from going into the lake or contributes nutrients to the lake. It is also important to note that one wetland may be both a source and a sink for different nutrients. This characteristic may vary with the season as well, depending on the amount of input to the wetland. Vegetation is important because different flora take up different nutrients. For example, willow and birch store more nitrogen and phosphorus than sedges and leatherleaf (Nebel 1987). This indicates that shrub swamps are a better nutrient sink than the other types of wetlands. Also, if nutrient sink wetlands are located closer to the lake, they will act more as a buffer, as opposed to ones further back in the watershed. Wetlands that do filter out nutrients are an important factor in controlling the water quality of a lake. These wetlands also help moderate the impact of erosion near the lake. Unfortunately, there is not enough encouragement or regulations to protect these areas (SFI 1991). Without these regulations, water quality in some areas may decrease.

Although there are regulations controlling wetland use, there has been a trend to destroy them through development due to lack of enforcement of these regulations. These areas should be protected by the Resource Protection Districts, which limit development to 250 ft away from the wetland. Wetlands, however, may be found in desirable areas, such as near a lake, which increases the likelihood of development on them even though these regulations exist (Nebel 1987). Therefore, the decrease of wetlands and the increase of development on wetlands will most likely have negative effects on the water quality of a lake due to runoff, erosion, and a decrease of natural buffering.

Study Area - North Pond and Watershed

NORTH POND CHARACTERISTICS

Historical Perspective

Communities have gradually developed around Little Pond and North Pond. Nearly seventy years ago a few camps were nestled on the northern shore of North Pond and one fishing camp without any road access was on the southern side (Joly pers. comm.). Now roads encircle the lake and houses perch precariously on the edge of the water. Many activities such as saw mills, logging, and waterslides have centered around the lake. Dams which were built by Central Main Power in 1927 regulate the flow of water to improve electrical generation and reduce seasonal stresses. After years of human presence the growing surrounding population can be seen to have some negative effects on the health of the water body.

Biological Perspective

North Pond and Little Pond are warm polymictic, marginally eutrophic lakes. The shallow depth of polymictic lakes eliminates seasonal stratification (Chapman 1996). The trophic status of a lake is based mainly upon the amount of primary production, defined as the conversion of light or chemical energy into organismal tissue (Davis et al 1978). There are several ways to determine the trophic status of lakes (see Background: Trophic Status of Lakes). Common indicators of trophic status are transparency, chlorophyll a, and total phosphorus concentrations in the water column. Transparency is a measure of the amount of suspended solids and phytoplankton, and it is commonly measured with a Secchi disk. Lower transparencies indicate higher primary productivity levels which are characteristic of eutrophic lakes (Figure 8).

The concentration of chlorophyll a and total phosphorus reflects the extent of primary production. Sharp increases in the amount of primary production, such as algal blooms, can turn lakes an unnatural color or even make the water poisonous for animals to drink (Reid 1961). North Pond and Little Pond, like most Maine lakes, have moderate primary production (NKRPC 1990).

Another important characteristic of lakes is their buffering capacity, the ability of a lake to neutralize acid. The alkalinity of a lake determines its ability to buffer acid. Alkalinity is a measure of calcium carbonate in the water (Pearsall 1991). As a pH buffer and inorganic carbon reserve, calcium carbonate affects the water's capacity to support algal growth and other aquatic life. Lakes with an alkalinity of less than 4 ppm of calcium carbonate can be damaged by acid rain. Lakes with an alkalinity higher than 10 ppm can endure acid rain and maintain a stable environment for their inhabitants. Maine lakes range from 4 ppm to 20 ppm calcium carbonate (Pearsall 1991) with a mean value of 12.2 ppm as reported by the MDEP based on a sample size of 533 lakes (Figure 9).

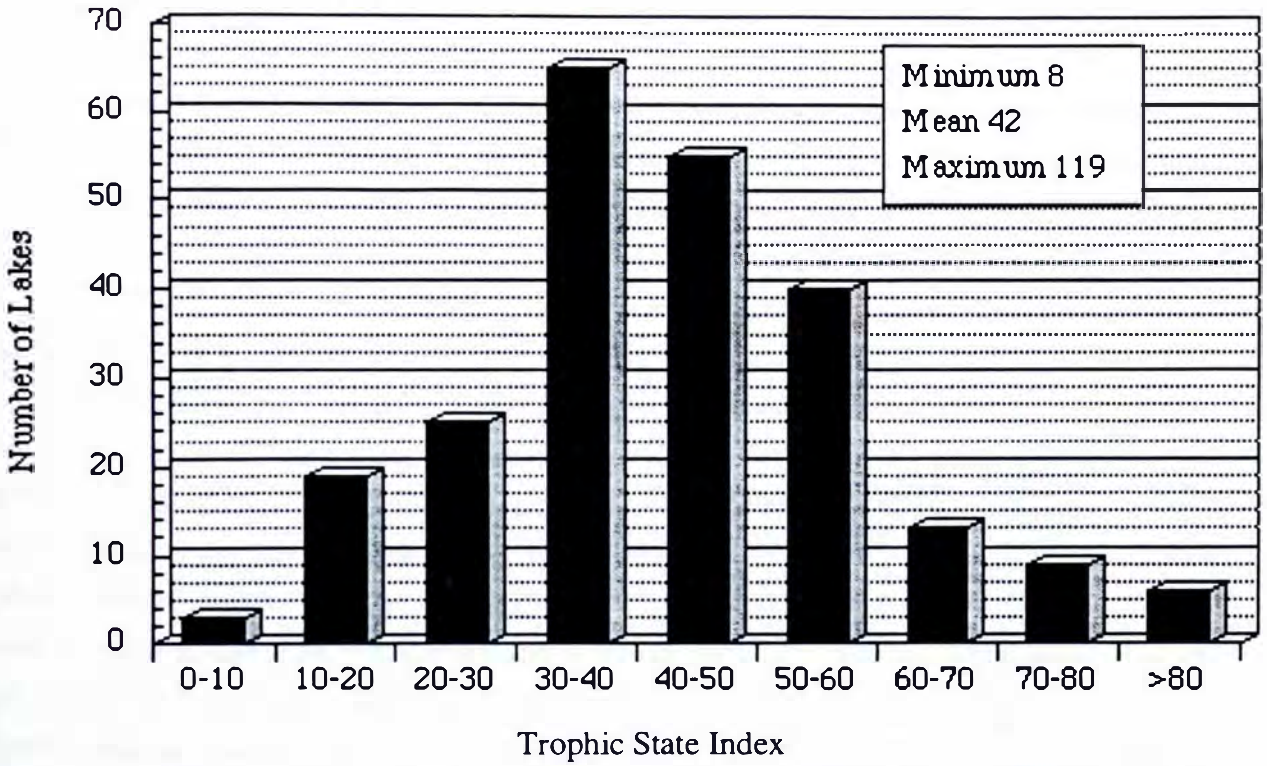

Figure 8. Distribution of lakes among Trophic State Index categories in 239 Maine lakes sampled as reported by DEP in 1991 (BI493 1994).

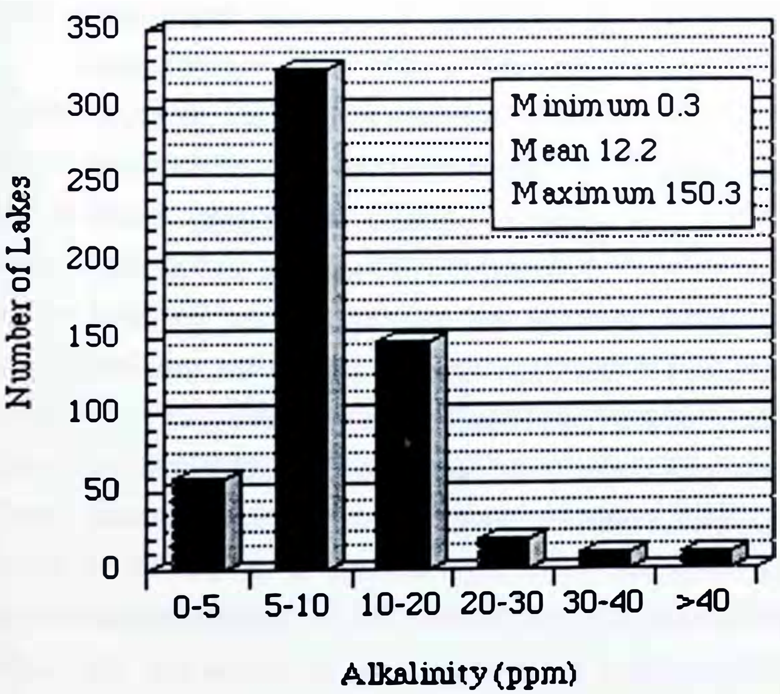

Figure 9. Alkalinity values for 533 Maine lakes sampled as reported by DEP in 1991 (BI493 1994)

Problems with excessively low pH or alkalinity are not evident in the average Maine lake (Stauffer 1990). By neutralizing acid, the lake maintains a relatively constant pH. The pH reflects the concentration of hydrogen ions in the water. The pH of Maine lakes typically range from 6.1 to 6.8 (Davis et al. 1978) with a mean of 6.7 (MDEP 1994a) (Figure 10).

Plants and animals are sensitive to changes in pH, and some species have narrow ranges in which they can exist. Increased acidity decreases the viability of some aquatic organisms and can lead to local extinction of a species (Pearsall 1991). pH levels of 6.0 or lower cause the death of snails and crustaceans; a pH of 5.5 kills salmon and whitefish; at 5.0 perch and pike die; and pH levels of 4.5 have an effect on eel and brook trout. Slight variations in the trophic status or pH of a lake can cause drastic changes in the composition of local and surrounding ecosystems.

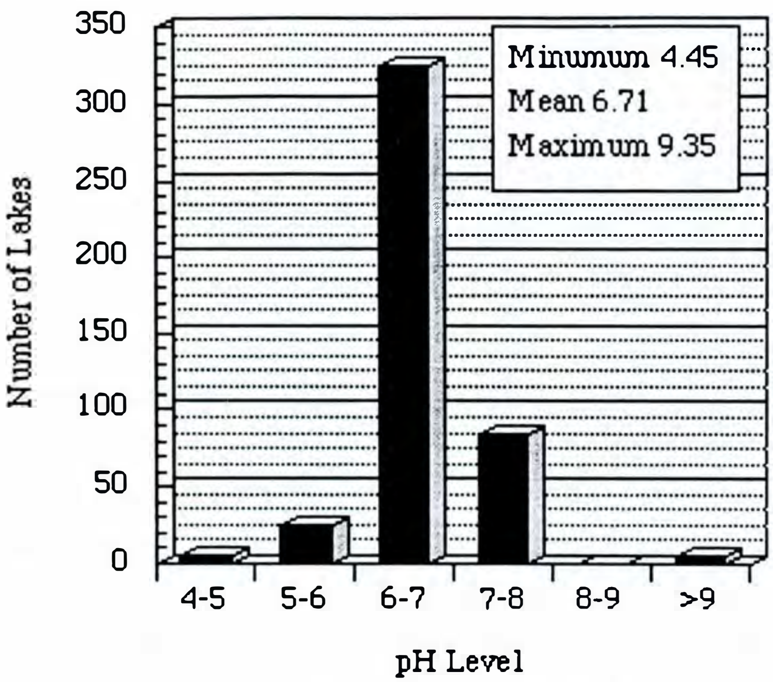

Figure 10. pH values for 453 Maine lakes sampled as reported by DEP in 1991 (BI 493 1994)

Lakes define and influence surrounding habitats. The boundaries of local habitats have highly characteristic zonation and stratification (Smith 1992). North Pond and Little Pond support a wide variety of habitats ranging from the surface film and open water to the bottom and littoral zones and the surrounding wetlands which support many different species (see Introduction: Freshwater Wetlands) (MLURC 1976). Autotrophic organisms such as bacteria, protists, and plants form the base of the food chain. Nutrients and energy move through both the grazing and detrital food chains (Smith 1992). Primary producers take inorganic nutrients and solar energy and fix them in organic molecules. Grazers feed off the primary producers and carnivores in turn eat the grazers. Detritivores recycle nutrients tied up in dead organic material and return them to the nutrient pool.

The major groups of freshwater algae are green algae, euglenoids, dinoflagellates and diatoms (Reid 1987). Cyanobacteria are also present (Firmage, pers. comm.). Two species of cyanobacteria, *Aphani zomenon* flos-aqua and *Anabaena planktonica*, were part of the algal blooms of the 1970's in Salmon Lake (Nichols et al. 1984). Diatoms often account for the majority of the phytoplankton community in Maine lakes (Dennis 1975). While phytoplankton populations peak in middle and late summer, they decrease during winter and spring (Davis et al. 1978). Fungi, liverworts and mosses also inhabit freshwater areas. Many species of vascular plants are associated with lakes. Common lake flora are discussed in the Wetlands Section of the Introduction of this report. Freshwater areas also support animal inhabitants. These include the simplest unicellular organisms, sponges, hydroids and worms, and the more commonly seen animals such as arthropods (insects and crayfish), snails, clams, and mussels. Vertebrates, such as fish, amphibians, reptiles, birds and mammals, are also found near or in lakes.

Geological and Hydrological Perspective

The majority of the surficial geology in the North Pond watershed is comprised of a heterogeneous till mixture of sand, silt, clay, and stones (Weddle 1987). This mixture was deposited directly by glacial ice. The heterogeneous till is characterized by a low permeability. Therefore, little groundwater is found flowing through this soil (Doss, pers. comm.).

Comprising a significantly smaller amount of the watershed are swamp and tidal marsh deposits formed by an accumulation of sediments and other organic material in depressions and poorly drained areas (Weddle 1987). They consist of peat, silt, clay, and sand which lead to poor drainage. These deposits are scattered throughout the watershed and are mainly located to the north of North Pond along Bog Stream and around the Serpentine and Clark Brook. There are also small pockets of these soils found south of Beech Hill along the western edge of the watershed, west of North Pond, south of Little Pond on the southern edge of the watershed, directly south of the Narrows, and along the northern shoreline of Little Pond continuing north to Birch Point.

Glacial-marine deposits comprised of silt, clay, and sand are also found in small amounts in the western region of the watershed. They are generally a clayey silt, but with an abundance of sand at the surface in some areas. These clay deposits are relatively impermeable and, like the till deposits, allow little groundwater flow (Doss, pers. comm.).

There are also small areas of glacial-stream deposits in the watershed comprised of sand and gravel (Weddle 1987). They have good drainage and are moderately to highly permeable. They are found north of North Pond between Beech Hill and Oak Hill, the northeast corner of the watershed, and in the Serpentine subwatershed around Smith Pond. Of all the deposits found in the watershed, these are the only types through which a significant amount of groundwater flows (Doss, pers. comm.).

There are only two areas along the shoreline of North Pond that consist of soils that could contribute a significant amount of groundwater to the lake (Weddle 1987). One area is located on a stretch of land along the northern shoreline slightly east of Pomleau Island between Oak Hill and Mt. Tom. The second area is a smaller stretch along the eastern shoreline south of the Serpentine and the center of Smithfield. There are only two areas of North Pond which are probably influenced by ground water. They are located in the northern part and a very small amount of the eastern part of the lake.

In the North Pond watershed, bedrock is exposed mainly in the northern region around Mt. Tom, Oak Hill, and Beech Hill (Weddle 1987). It is mainly crystalline and does not dissolve easily (Doss, pers. comm.). Any surficial deposits that may be covering this bedrock are till.

Soil Types

Soils have been divided into series based on different geological and hydrological characteristics (USDA 1972, 1978). These series are based on particle size, organic matter, permeability and depth to bedrock. Recognizing the soil series and knowledge of their characteristics can aid in the determination of appropriate land use.

In the North Pond watershed the primary soil is Berkshire. This soil is generally stony, well drained, deep, and slightly sloping (USDA 1972). Permeability of Berkshire soil is moderate and the available water capacity is high. The Berkshire series is located throughout the watershed and occupies approximately 35% of it. The next most common soil group found in the watershed is associated with peat and muck. Peat and muck associated soils occupy approximately 19% of the watershed and are found mainly on the northwest shore of the lake continuing north along Bog Stream. They are hydric soils with a relatively high water table. Peru and Paxton series occupy approximately 16% of the watershed and are moderately well drained soils with fine sandy loams. These soils are located in small areas of the western side of watershed.

Regional Land Use Trends

Nutrient loading, especially of phosphorus, can influence water quality within a watershed by contributing to the eutrophication rate in lakes (see Background: Nutrient Loading). A variety of land use types have characteristics which may contribute to or help prevent the eutrophication of a lake. Two main causes of nutrient loading are point and nonpoint sources. A point source is a site where pollution is directly emptied into the water, such as a pipe. Non-point sources are sources of pollution that enter the water indirectly as in runoff. Large point sources from industrial areas are not a frequent occurrence on the shores of most Maine lakes, although small point sources such as pipes coming from shoreline camps are often prevalent (Davis et al. 1978). Common to Maine's watersheds are land use types that provide nonpoint sources of pollution such as agricultural, forested, and residential areas.

Farming in Maine appears now to be less prevalent than it was historically (Davis et al. 1978); the increase in reverting land (agricultural land left to regrow) in the North Pond watershed is representative of this trend (see Analytical Procedures and Findings: Cleared Land). While the tendency for land to be cleared for agriculture seems to be diminishing, regional areas of land have been continuously cleared for residential development, including houses and lawns (BI493 1996; Table 4). Associated with residential land is the construction of roads which often become sources of increased nutrient loading due to runoff (see Background: Roads). Logging is another prevalent land use type in Maine that can have negative implications for the quality of water within a watershed, especially if the area logged is on sloped land where runoff can easily bring excess nutrients into the water. Land use anywhere in the watershed has the potential to effect the water quality in streams, rivers and lakes. It is therefore important to study the impact of all the individual land types and their associated activities, especially as they change over time, to determine how land types will affect water quality in the future (Pearsall 1991).

Table 4. Comparison of changes in land use types for North Pond and East Pond watersheds from 1965 to 1991. The values are percentages of the total land area in the watershed (BI493 1991).

Land Use	North Pond 1965/66	North Pond 1991	East Pond 1965	East Pond 1991
Wetlands	7	7	3	3
Mature Forest	78	75	78	77
Regenerating Area	<1	<1	†	†
Cleared Land	12	10	*	*
Agricultural Land	*	*	4	2
Reverting Area	<1	2	3	2
Residential Area	2	3	10	14
Municipal/Industrial	<1	1	‡	‡
Road Area	<1	1	2	2

*Cleared land in the East Pond study is referred to as agricultural land.
†Regenerating area was not differentiated from forested area in the East Pond study.
‡Muncipal/Industrial area was not included in the East Pond study.

The trends that have occurred in nearby watersheds can be used to make predictions for the North Pond water-shed. Because East Pond empties into the North Pond through the Serpentine and is a relatively shallow lake, the trends occurring within it's watershed may tend to be similar to the trends within the North Pond water-shed (BI493 1991). A comparison of the East Pond and North Pond land use types as they changed over time showed similarities suggesting that the changes in the North Pond watershed may have similar ramifications as those in East Pond watershed (Table 4). Smithfield Planning Board projected that approximately 56% of the land within the East Pond watershed will be developed within the next 50 years. This estimate serves as a possible indication of the levels of development that could occur within the North Pond watershed. This projection further suggests that continued development, which may be responsible for the degradation of East Pond's water, will indirectly affect North Pond.

Bathymetry

Bathymetry is the measurement of underwater topography. North Pond and Little Pond have very similar bathymetric characteristics. The bathymetric data used in this study was made available by Roy Bouchard, MDEP. Individual depth recordings were connected to make topographic lines. When the lines were all entered on the data layer the basin was completely modeled. MacGIS software allowed for the depiction of these bathymetric intervals (see Analytical Procedures and Findings: General GIS Methodology).

The basin slopes of both North and Little Ponds are gradual (Figure 11). The steepest slope of the North Pond basin is located on the northeast quadrant of the lake. The orientation of North Pond's

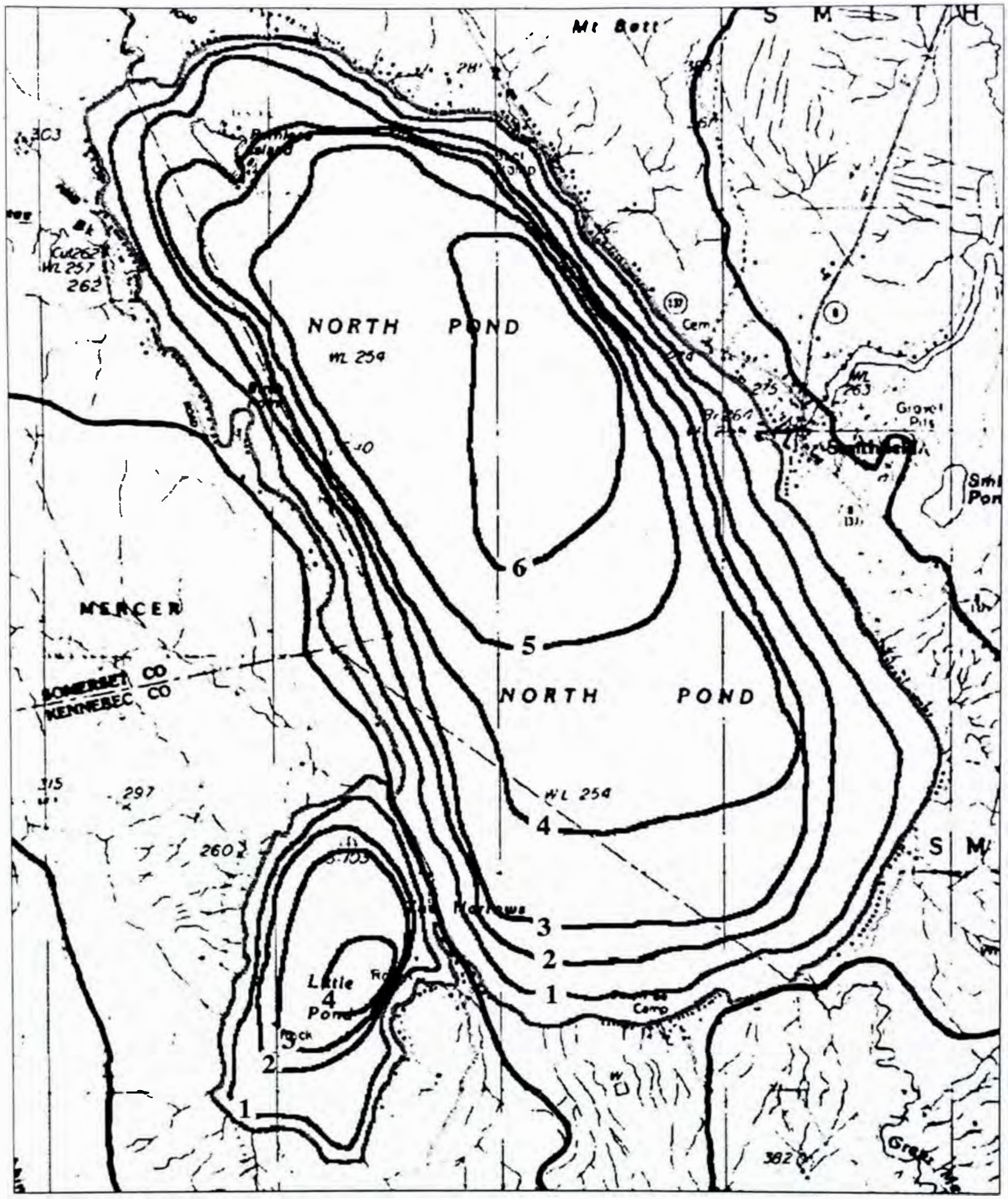

Figure 11. Lake bathymetry showing depth of North Pond and Little Pond in meters. North Pond reaches a maximum depth of over six meters while Little Pond is over four meters deep. The scale on the map is approximately 1.0 inch equal to 0.39 mi (0.63 km).

central axis runs the length of the lake from northwest to southeast. This is important when the predominant wind patterns are taken into account. The normal direction for the wind in the North Pond area is from northwest to southeast (Bouchard, pers. comm.). The fact that the lake situation and the bearing of the predominant wind patterns have the same orientation contributes to the high level of mixing. The basins of North and Little Ponds are different in scale but similar in shape; Little Pond is only rotated approximately 45° in a clockwise direction. The steepest slope in North Pond is in the northeast portion, while the steepest slope in Little Pond is located on the east perimeter of the lake. North and Little Ponds reaching their greatest depths at just over six and four meters respectively.

Lake Level Management

There are two dams which control the water flow in the North Pond watershed. One controls the flow of water from the Serpentine into North Pond and the other from North Pond through Great Meadow Stream and into Great Pond. The flow of water into North Pond from the Serpentine is controlled by Bob Joly of Smithfield. The dam on the Serpentine is approximately 650 ft from North Pond. It was built in 1927 by Central Maine Power to control water for generating power (Joly, pers. comm.). The dam consists of three cement pillars, one in the middle of the stream and one on each bank of the stream. The cement pillar in the middle is in the shape of a T and the two on the stream banks have slots facing upstream. The significance of the T shape and the slots are that they allow for wooden boards to be put in the stream to hold back water from East Pond. The wooden boards are the major form of flow control for water entering North Pond from the Serpentine.

The Great Meadow Stream dam was built more recently. Water from North Pond to Great Pond is controlled by Bill Grove of Smithfield. It consists of five steel I-beams anresembles the letter H. Two beams stand upright, one on each stream bank. Two other beams lay horizontal, one on top of the other, and connect to the ones on the stream banks. The final I-beam is in the stream bed, the top of which is visible just above the sediment in the stream. The flow of water is controlled by raising or lowering the two I-beams that cross the river. When there is no restriction on flow, the beams are held up by steel pins that are inserted into the two upright beams along the banks of the stream.

The state has regulations that determine when the dams must be opened in the fall and closed in the spring (Grove, pers. comm.). Dams must be opened no later than October 15 in the fall and remain open until April. In April the dams are allowed to be closed. The decision to open and close the dams during the remainder of the season, from April through September, is done using common sense (Joly, pers. comm.).

Changing the level of the lake can have many different effects on the water quality. The greatest amount of lake level change takes place in the fall and spring. Water level drawdown has been shown to have large effects on the water quality, both positive and negative (Cooke et al. 1986). Due to the drying out and freezing of the roots of aquatic plants, one of the largest effects can be the decrease in the amount of macrophytes seen on the periphery of the lake. Decreasing the lake level also allows for the repair of docks, dredging of sediments, and the improvement of other shoreline features. These are all positive aspects of water level drawdown because most of them benefit the water quality of the lake.

Negative aspects of water level drawdown are not as well documented, but there has been some indication that algal blooms occur after a drawdown when water again floods the lake (Cooke et al. 1986). Algal blooms are thought to be caused by the increase in oxygen in the lake sediment which is released when the water level increases during reflooding of the lake. Another negative aspect of water level drawdown is the decrease in the amount of invertebrate species and size of insect populations. Presence of invertebrate species may decrease due to the decrease in habitat when aquatic plant species begin to die (Cooke et al. 1986). Common invertebrate, insect populations may also decline because of the lack of habitat created by the vegetation loss. This decrease in insects could also cause a decrease in the fish populations of the lake. The drawdown might also cause the fish population to drop due to a lack of oxygen in the water. However, some experiments have shown that the level of oxygen can increase from the water-level drawdown (EPA 1983).

Lake level management is an important aspect in water quality control. It has both positive and negative aspects that could cause an acceleration in the eutrophication of lakes, if not properly managed.

Resource Protection

Resources are viewed as components of the environment that are of potential value to humans. Resource protected zones occur where development would negatively affect the biological characteristics, such as water quality or habitat, of the natural areas (MDEP 1994b). Each town has their own zoning maps, located in the town offices, that display where resource protected areas can be found. The most common areas of resource protection are wetlands, streams, and shoreline areas. Areas where rare animal species are found could also be protected from future development in order to ensure a biologically diverse region.

Wetlands are a particularly important area for protection. One of the greatest values of wetlands is their biological diversity (WWF 1992). Other reasons wetlands are protected include water quality control, erosion prevention, and recreation. Streams need to be protected from development to ensure that water quality of both the streams and the bodies of water they empty into do not become degraded. Building or development too close to a stream will not only affect the stream, but also the downstream areas.

In Smithfield, a majority of the land falls into one of the categories mentioned above. There are numerous wetland areas, such as the area around Bog Stream or the Serpentine, that are protected (Smithfield 1996). Also, there are a number of streams that are protected, such as Sucker Brook or Leech Brook. Areas around North Pond can be zoned as resource protection areas or limited residential areas, and this will prevent degradation of water quality from building. The areas that are protected are mostly wetlands.

Mercer is similar to Smithfield in the types of areas that are protected. Residential development is limited along shoreline regions of the lake due to resource protection. Riparian areas in this town, like those in Smithfield, are also protected. An example of a protected stream area is Pattee Brook. In Mercer, the Bog Stream region is an example of a protected wetland.

Rome also has stream protected zones, wetland protected areas, and limited residential zones. The area around the mouth of Great Meadow stream is an example of a protected wetland area. Areas around Little Pond are limited to residential development.

Two other important protected areas found in the North Pond watershed are deer wintering areas and waterfowl and wading bird habitat. These areas are not necessarily protected from future development, however the waterfowl and wading bird habitats are found in wetlands and therefore must be protected from future development (Dumont, pers. comm.). Deer wintering areas can be found almost anywhere in the watershed. Development could take place in one of these areas but it would have to be approved by the state first.

Study Objectives

WATER QUALITY ASSESSMENT

Lake Body

The water quality of the North Pond watershed was assessed by evaluating several physical and chemical parameters that included total phosphorus, total nitrogen, alkalinity, conductivity, pH, dissolved oxygen (DO), turbidity, transparency, and hardness. Each of these parameters may contribute in varying degrees to the eutrophication of the lake.

A complete evaluation of the lake body also included water samples from Little Pond which is connected via the Narrows to North Pond. The sampling sites throughout North Pond and the adjacent Little Pond consisted of characterization sites and spot sites. Characterization sites were chosen to represent the overall water quality of the lake, while spot sites were chosen as potential sources of increased external phosphorus loading. All sites were selected during a reconnaissance field survey, based on potential environmental and human related variables, such as land use and recreation practices, that may impact lake water quality (see Analytical Procedures and Findings: Water Quality Study Sites). Some of these considerations included steep land grades, sedimentation, hydrology, human activity and population density. Results from this water quality analysis were used to generate recommendations regarding appropriate lake management and future development of the North Pond watershed.

Tributaries

The water quality of the lake body is also greatly influenced by variable nutrient inputs from associated subwatersheds. Streams and tributaries, in particular, are important mechanisms of nutrient transport. Water samples were taken from several tributary sites which were selected during a reconnaissance field survey. Tributary sampling sites were chosen based on land use patterns that may contribute to nutrient loading, including proximity to roads and development.

In addition to the water samples collected during periods of normal flow, water samples were also gathered during a storm event. Increased precipitation generally causes accumulated nutrients to be flushed from the soil through runoff (Cole, pers. comm.). Streams and tributaries then transport and eventually deposit the nutrients into the lake body where they impact productivity levels. Typically, periods of intense or prolonged rainfall lead to sediment loading and a greater concentration of nutrients in the tributaries and streams and ultimately the lake body.

EFFECT OF LAND USE PATTERNS ON PHOSPHORUS LEVELS

The areas of each land use pattern in the watershed were determined in order to estimate the phosphorus input of each into North Pond. The analysis of phosphorus levels for each land use served as an indicator for problem areas that could be controlled or monitored in the future. A phosphorus budget was then created for North Pond.

The watershed is shared by the towns of Smithfield, Rome, Mercer, and Norridgewock and development is, therefore, subject to each town's ordinances. The four towns share responsibility for the water quality of North Pond. The objective of this study was to understand the effects of each town's ordinances on water quality. This component of the study included not only the analysis of shoreline and nonshoreline residences in the watershed, but also septic systems, roads, mature forested land, cleared land, agricultural land, wetlands, and municipal/industrial land.

The number of shoreline and nonshoreline residences was counted (shoreline was defined as being within 200 ft of the water body and nonshoreline was defined as being more than 250 ft from the water body), and key characteristics were determined. The condition and type of waste disposal systems were determined through communication with plumbing inspectors from towns within the watershed. The degree of use of septic systems was determined by identifying seasonal and year-round residences. Taking into account the condition and type of waste disposal system, degree of use, and location of residences, recommendations were made for maintenance of septic systems in existing residential areas in the watershed, as well as for future development.

A road survey was also conducted to determine the condition and maintenance level needed for each of the roads in the watershed. The area of these roads was calculated to determine the impact of runoff from dirt, paved, and camp roads on phosphorus loading. Problem roads which would increase future phosphorus loading were identified for repair.

Cleared land, including large tracts of farmland for agriculture or livestock, is important in determining phosphorus loading. Runoff and its additional characteristics of nutrient and sediment loading into the lakes and their tributaries is increased by the presence of cleared land. By comparing 1965/1966 and 1991 aerial photos, changes in land types were identified.

By taking all of these land use factors into account, recommendations were made regarding problem areas and maintenance of present sources of phosphorus loading into North Pond.

Analytical Procedures and Findings

Water Quality Study Sites

Eighteen sites were chosen for water quality sampling in the North Pond watershed (Figure 12). These sites were divided into characterization, spot, and tributary sites. All sites were chosen after an initial lake and watershed reconnaissance on 09-SEP-96 by CEAT. Assignment of sites was based on lake morphology, hydrology, and topography of the surrounding land. Other factors contributing to the possible eutrophication of the lake were also considered, including surface runoff from municipal land, state and camp roads, seasonal and year-round residential development, agriculture, forestry, and commercial gravel operations. Sampling of sites was conducted from late September through early October 1996. Site 1 was also sampled during the summer of 1996 to obtain data from an additional season.

Characterization sites were sites that were chosen to represent the overall water quality of each water body. Therefore, they were subject to all applicable chemical and physical tests designated by CEAT in order to fully characterize the water body and compare sites (see Water Quality Methodology: Lake and Tributary Water Quality). The Characterization Sites were 1 and 5 in North Pond, 7 in Little Pond and 15 in the Serpentine. Site 1 was located in the deepest portion of North Pond, Site 5 was in the middle of the north end of North Pond, and Site 7 was in the deepest portion of Little Pond. Site 15 was located in the northeast branch of the Serpentine

Spot sites, located in areas of the lakes where high nutrient input was likely, were sampled in order to examine the impact of certain watershed land uses. Spot Sites 2, 3, 4, 6, and 8 included point sources such as pipes as well as nonpoint sources such as boat launch ramps, areas of shoreline with concentrated development, the major inlet and the major outlet of the lake.

Tributary sites were located in all major tributaries of North Pond. They consisted of Sites 9 through 18 and were used to investigate the contribution of nutrients from land use practices in the North Pond watershed such as municipal roads and nonshoreline agricultural development.

Storm sites were tributary sites that were resampled in order to compare the physical and chemical qualities of the tributaries when the input of water was at a particularly high level due to rainfall. They consisted of Tributary Sites 9, 11, 12, and 17 and were sampled at half hour intervals over an eight hour period during the storm event on 21-OCT-96.

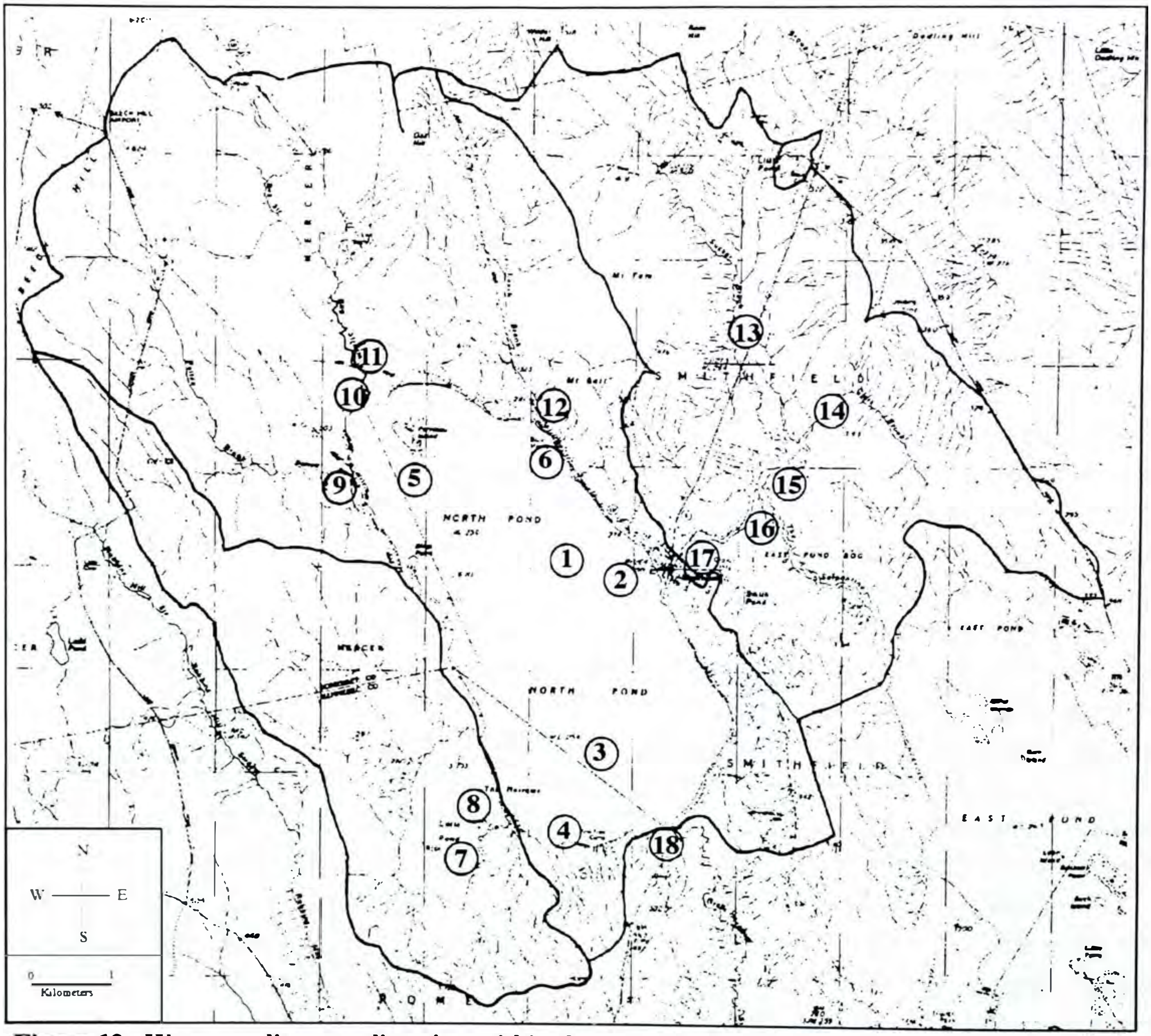

Figure 12. Water quality sampling sites within the watersheds of North Pond, Little Pond, and the Serpentine

North Pond Study Sites

SITE 1: MDEP Characterization Site

Located slightly north of the Serpentine outlet in Smithfield on the eastern side of the lake, 500 ft from shore. This site is in the deepest portion of the lake at a depth of approximately 6.1 m (20 ft), and has been sampled by the MDEP in past years. This site was chosen to serve as an indication of the general health of the water body and so that comparisons could be made with the data from past years.

SITE 2: Outlet of the Serpentine

Located 150 ft off shore from the outlet of the Serpentine. This site was chosen to investigate the water quality of the lake where it mixes with the water from East Pond that is carried by the Serpentine.

SITE 3: South End of North Pond

Located in the southern end of the lake, at a depth of approximately 3.7 m (12 ft). The site is 800 ft from the southern shore, between the mouth of Great Meadow Stream and Pine Tree Camp. This site was chosen to assess water quality in the southern portion of the lake for comparison with sample sites in the northern portion of the lake.

SITE 4: Pipe at Pine Tree Camp

Located at Pine Tree Camp, where a small pipe comes from under the western end of the lawn near the volleyball court and empties onto the beach. This site was chosen to investigate the possible input of phosphorus or other chemicals from the pipe.

SITE 5: Characterization Site in North End of North Pond

Located in the northern end of the lake 500 ft south of Pomleau Island and 500 ft from the western shore north of Birch Point, at approximately 4.5 m (15 ft) depth. This site was chosen to assess water quality in the northern portion of the lake and serve as an indicator of the general health of the water body.

SITE 6: Boat Launch Ramp

Located 75 ft off shore from an asphalt boat launch ramp that enters the water from Route 137 in the northeastern portion of the lake. This site was sampled to determine whether water quality was affected by runoff from the road.

Little Pond Study Sites

SITE 7: Little Pond Characterization Site

Located in the southern end of the lake, 200 ft from the southern shore and halfway between the east and western shores. It is in the deepest portion of the lake at approximately 4.5 m (15 ft) depth. This site was chosen to characterize the water quality in the deepest area of Little Pond and where the shoreline is moderately developed.

SITE 8: Southeastern Shore Near Developments

Located in the small cove adjacent to the Narrows in the southeastern portion of the lake, 75 ft from a red A-frame house on the shore and at a depth of approximately 1.3 m (4.3 ft). This site was chosen because the surrounding shoreline is highly developed.

Tributary Study Sites

SITE 9: Pattee Brook

Located where Pattee Brook flows through three large culverts under Pond Road. Pattee Brook flows into the northwestern portion of North Pond. The sample was taken immediately upstream of the culverts. This site was chosen to investigate the quality of water coming from the portion of the watershed drained by Pattee Brook.

SITE 10: Bog Stream

Located in Bog Stream, halfway between the mouth of the stream and its intersection with North Shore Drive. A large volume of water enters the lake from Bog Stream. This site was chosen to investigate the quality of water coming from the portion of the watershed that is drained by Bog Stream.

SITE 11: Bog Stream at Intersection of North Shore Drive

Located 25 ft downstream from where Bog Stream flows under North Shore Drive through a culvert. There is a public boat launch ramp adjacent to the road on the downstream side of the bridge. This site was chosen to examine the impact of runoff from the road and boat launch ramp on water quality.

SITE 12: Leech Brook

Located on the downstream side of the intersection of Leech Brook and Route 137 north of Smithfield on the eastern side of the lake. Leech Brook has been heavily rip-rapped (lined with stones) in this area. This site was chosen to investigate the quality of water coming from the portion of the watershed drained by Leech Brook.

SITE 13: Sucker Brook

Located where Route 8 crosses over Sucker Brook. This stream is very small and often difficult to find. The samples were taken immediately upstream from the culvert. This site was chosen to investigate the quality of water coming from the portion of the watershed drained by Sucker Brook.

SITE 14: Mouth of Clark Brook Tributary

Located where a small bridge crosses Clark Brook, which flows into the Northeast Branch of the Serpentine. The samples were taken from a canoe just downstream from the bridge. This site was chosen to investigate the quality of water coming from the portion of the watershed drained by Clark Brook.

SITE 15: Characterization Site in Northeast Branch of Serpentine

Located in the bog of the Serpentine where the southeast and northeast branches converge. The site is 250 ft north of the confluence of the two branches in the northeast branch. This site was chosen to characterize the water quality of the Serpentine in an area that is not influenced by water from East Pond.

SITE 16: Southeast Branch of Serpentine

Located in the bog of the Serpentine where the southeast and northeast branches converge. The site is 250 ft south of the confluence of the two branches in the southeast branch. This site was chosen to investigate the quality of water entering from East Pond.

SITE 17: Serpentine

Located in Smithfield where the Serpentine crosses under Route 8/137 at Sunset Camps. The sample was taken upstream of the bridge. This site was chosen to investigate the Serpentine water quality as it flows through the highly developed area of Smithfield and into North Pond.

SITE 18: Outlet of North Pond: Great Meadow Stream

Located in Great Meadow Stream 100 ft downstream from its mouth. The samples were taken in the center of the stream. The site is accessible by boat or Fire Road S12. This site was chosen to determine the quality of water as it leaves the North Pond basin.

Water Quality Methodology

Water quality is influenced by three major factors; physical, chemical, and biological factors. To study physical factors, measurements were taken of depth, temperature, dissolved oxygen, transparency, and conductivity. Chemical analyses included total phosphorus, nitrates, total nitrogen, alkalinity, hardness, color and pH. Biological measurements included coliform bacteria and macrophyte growth. Measurements and tests differed depending on the site (Appendix A). Each sample site was selected according to criteria listed above in the Water Quality Study Sites. Details of the analytical procedures used for each chemical test are located in the respective chemical test section (see Water Quality Methodology: Lake and Tributary Water Quality).

All water data were collected by the CEAT on 16-SEP-1996, 23-SEP-1996 and 30-SEP-1996 (Appendix A). Collection was carried out from 2:00 PM - 5:30 PM on those days. Data from the Storm Event was taken between about 7:00 PM and 3:30 AM on 20-OCT-96 at approximately half hour intervals during the storm (see Water Quality Methodology: Tributary Storm Event). Measurements of transparency, water depth, DO, temperature and pH were conducted on site while all others except coliform were performed in the Colby Environmental Laboratory. All samples were analyzed within the prescribed holding times for each test according to standard methods. One coliform sample was taken at Site 12 on 23-SEP-96 and delivered within 24 hours to Northeast Labs in Winslow, Maine for analysis. Water sampling procedures all followed the standards described in the Quality Assurance Guidelines (Appendix B). The results of all chemical and physical tests, including the storm event, are located in Appendix C.

Water collection techniques included grab sampling and core sampling. Grab samples were taken at three levels: 0.5 m below the surface, mid-depth in the water column, and 1 m above the bottom. The first level was collected by hand while middle and bottom samples were collected using the alpha water sampler. Core samples were used to collect a composite sample from the entire water column and used only for total phosphorus testing. Samples were taken at Site 1, Site 5, and Site 7 and analyzed accordingly on 30-SEP-96 (Appendix A).

Phosphorus samples were collected in polyethylene bottles, triple rinsed with a 1:1 hydrochloric acid (HCL) and water solution. Some samples were preserved or filtered in the field as described within individual test sections (see Water Quality Methodology: Lake and Tributary Water Quality). Samples were chilled on ice in the field and refrigerated in the Colby Environmental Laboratory until they were analyzed. Bottles were labeled according to test site, stratification, collection date, and bottle number.

NORTH POND & LITTLE POND WATER QUALITY ASSESSMENT

Lake and Tributary Water Quality

Physical Measurements

CEAT conducted six physical measurements to evaluate the lake and tributary water quality of the North Pond watershed: tributary flow rates, lake depth, dissolved oxygen content, transparency, turbidity, and conductivity. The physical measurements provide insight into the general health of the lake and associated tributaries, as well as establish a preliminary study as basis for further studies.

Tributary Flow Rates

Flow rate is a measure of how much water passes a certain point over time, which is necessary for determining the amount of water a stream carries into a lake and the relative impact the stream has on the lake. Typically, a tributary carries a significant amount of nutrients such as phosphorus into a lake. Consequently, elevated flow increases the amount of nutrient loading in the lake (Pearsall, pers. comm.).

Methods

The instrument used to measure flow rate was a Marsh-McBirney, Inc. Flow Mate flow meter. First, the stream was divided into sections, as described in the Quality Assurance Guidelines (Appendix B). Sections were based on the topography of the stream bed. The flow meter was inserted and read at the center of each section, or cell, where flow disturbance was minimal and measurements were combined to determine overall stream flow. Total stream width was recorded as well as the distance from each point to the bank. Flow in each cell was then calculated by using the following formula:

Stream flow per cell (ft^3/s) = [length of cell (ft)] x [average depth of cell (ft)] x [average cell velocity (ft/s)]

Average depth and velocity were determined from the observed values in the middle of each cell. Finally, flows for each of the cells were added up along the transect to calculate the total flow for the tributary. Flow rates were measured at Sites 10 and 18 on 23-SEP-96 and at Sites 9, 12, 13, 14, and 17 on 23-SEP-96. Sites 9, 11, 12, and 17 were measured on 20-OCT-96, during the storm event (Appendix A).

An alternative method was used to measure flow rate at Great Meadow Stream (Site 18). Flow rate was instead determined by measuring the time it took for a float to travel a measured distance. To reduce the chance of wind blowing the bottle away, the float was partially filled with water. However, wind was very minimal on 23-SEP-96. This procedure was repeated twice and the mean flow rate was calculated.

Results and Discussion

The flow rates calculated for the North Pond tributaries are relatively similar (Table 5). Great Meadow Stream (Site 18) is the major outlet draining into Great Pond. The large value may be skewed because the North Pond dam was opened for the winter on 03-SEP-96 (Grove, pers. comm.). The Serpentine (Site 17) had a flow of 1.18 ft^3/s. The East Pond dam was opened before Labor Day; but the flow rate had diminished by the time of measurement (Joly, pers. comm.).

Table 5. Flow rate (ft^3/s) measurements for tributary sites in North Pond watershed. Samples taken on 23-SEP-96 and 30-SEP-96. See Figure 12 for location of sites.

Site	23-SEP-96	30-SEP-96
9	--	0.38
10	3.52	--
12	--	0.98
13	--	8.47
14	--	2.46
17	--	1.18
18	87.90	--

The drainage basin of the tributaries and topography of the subwatersheds were used as indicators of potential flow. The Serpentine (Site 17) is the primary contributor to the North Pond watershed. Its drainage area, which includes Sucker Brook (Site 13) and Clark Brook (Site 14), is 4249 acres. Under normal circumstances, the outlet flows from East Pond into North Pond. However, during storms with precipitation greater than 2.50 in, the rain accumulates within the subwatershed and causes the normal flow to backflush and drain into East Pond (BI493 1991). The northern region of North Pond has three primary tributaries; Pattee Brook (Site 9), Bog Stream (Site 10), and Leech Brook (Site 12). All three tributaries drain areas of relatively high relief and have drainage basins of 1326, 1793, and 694 acres, respectively.

The diameter of culverts is another indicator of potential runoff and heavy flow in the surrounding drainage basins. Site 17 in the Serpentine did not have a culvert but, rather, had a bridge that spanned 22 ft across its width. Also, all three tributary sites located in the northern region of North Pond have culverts that are greater than 4 ft with a range of 4 ft to 6 ft. Tributaries with large culverts indicate areas where flow, at least seasonally, is expected to be high. The culverts are designed to accommodate the expected peak flow at any point over the course of a year (BI493 1996).

Numerous factors affect the daily flow rate of the North Pond tributaries, including precipitation, topography, soil type, and the regulation of the North and East Pond dams. Although there is seasonal variation in flow, Pattee Brook (Site 9), Bog Stream (Site 10), Leech Brook (Site 12), and the Serpentine (Site 17) appear to be the major contributors to North Pond. Their respective relief and size of their drainage, as well as their culvert diameters indicate significant importance to North Pond.

Lake Depth

The depth of a water body affects oxygen content and temperature which influence such factors as volume, mixing, dilution ability, and aquatic life. Shallow lakes tend to be more biologically productive than deep lakes because of the large area of bottom sediments relative to the volume of water (North American Lake Management Society 1988).

Methods

Two methods of depth measurement were used. One method involved using a dropline, a marked rope with a weight on the end. Once in the water, the pre-marked meter line was pulled taut and depth of the water column read at the water surface. A second method for recording depth involved the use of a Humminbird depth finder (Appendix B).

Depths were measured in North Pond, Little Pond, the Serpentine and other surrounding tributaries on 23-SEP-96 and 30-SEP-96 in conjunction with water sampling activities. Depth measurements were taken at all sites except Site 4, a terrestrial site where a small pipe runs from the lawn down to the beach (Appendix A).

Results and Discussion

Sites 1 through 8 had a range of 1.3 m to 5.2 m and the Tributary Sites 9 through 18 had a range of 0.1 m to 2.7 m (Table 6).

The mean depth of North Pond is 4.1 m. This is shallow in comparison with other Belgrade Lakes (MDEP 1994a). The surrounding lakes, consisting of Long Pond, Messalonskee Lake, Salmon Lake, Great Pond, and East Pond have mean depths of 11.0, 10.0, 7.0, 6.0, and 5.0 m, respectively (MDEP 1994a). North Pond has a relatively uniform depth throughout most of the basin (Figure 11). In comparing the MDEP characterization sites of North Pond (Site 1) and Long Pond, the maximum depth varied from 5.2 m in North Pond to 27.7 m in Long Pond.

Table 6. Water depths (m) for the study sites on North Pond, Little Pond, and Serpentine subwatersheds. Measurements taken on 23-SEP-96 and 30-SEP-96. See Figure 12 for location of sites.

Subwatershed	Site	23-SEP-96	30-SEP-96
North Pond	1	--	5.2
	2	--	2.4
	3	--	3.7
	5	--	4.4
	6	--	1.6
	9	0.5	--
	10	--	1.3
	11	--	1.2
	12	0.1	--
	18	1.6	--
Little Pond	7	--	4.7
	8	--	1.3
Serpentine	13	2.1	--
	14	--	2.0
	15	2.2	--
	16	1.8	--
	17	2.7	--

Lake Dissolved Oxygen and Temperature

Dissolved oxygen and temperature are important indicators of the general health and productivity of a water body. Unhealthy lakes with high levels of organic matter have a low DO content, while healthy lakes have a high DO content (Potvin and Bacon 1993).

A temperature profile of the water column can be used to assess DO levels relative to depth. Temperature data is also significant for other reasons. Warm temperatures generally increase biological activity such as algal production, fish growth, and biological decay (Potvin and Bacon 1993). An increase in biological decay leads to a decrease in DO levels. Dead organic matter, or detritus, settles from the surface layer onto the substrate and is decomposed by oxygen dependent microorganisms, thereby decreasing the DO.

Dissolved oxygen levels typically are low prior to lake turnover. Lakes with a mean depth greater than 4.57 m usually undergo a turnover in the spring and fall during which the oxygen-poor bottom waters are replenished by the oxygen rich top waters (Potvin and Bacon 1993). However, due to shallow depths, turnover is not a factor for North Pond and Little Pond (see Introduction: Lake Basin Characteristics). Without adequately high DO levels, biological diversity declines as oxygen-dependent aquatic life begins to die. Very low oxygen levels also may cause anoxia and contribute to internal phosphorus loading.

Methods

DO and temperature measurements were taken at North Pond Sites 1, 3, 5, and 6, Little Pond Sites 7, and 8, and at Tributary Site 18 on 30-SEP-96. Measurements at Site 2 were taken on 16-SEP-96. An Orion model 840 Oxygen DO meter was used to measure dissolved oxygen and temperature at each of the sites. Measurements were made at one meter intervals from the surface to bottom. Surface DO and temperature readings were also taken at all other lake sites on 30-SEP-96 (Appendix A).

Results and Discussion

The dissolved oxygen content and temperature measurements at Characterization Sites 1, 5, and 7 did not indicate significant variations in dissolved oxygen content or temperature throughout the water column. Characterization Site 5 showed a slight decrease in dissolved oxygen content while temperature remained constant with increasing depth (Figure 13). All profiles conducted by CEAT in the fall of 1996 indicated that the lakes were well mixed.

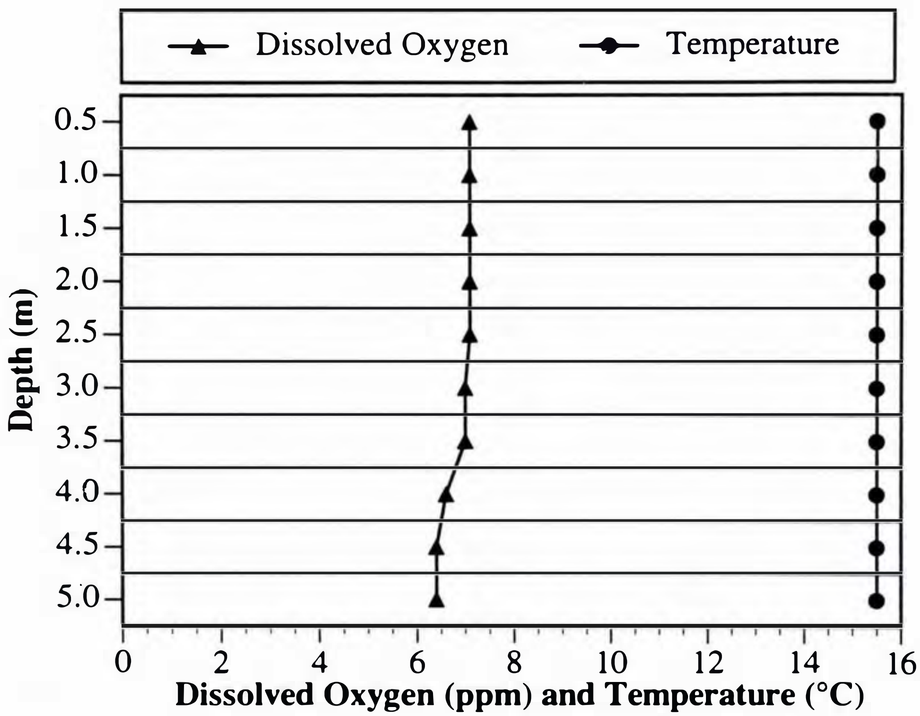

Figure 13. The dissolved oxygen (ppm) and temperature (°C) profile from North Pond Characterization Site 5 on 30-SEP-96. See Figure 12 for location of the site.

The dissolved oxygen and temperature profiles recorded in the past by MDEP in North Pond at Character-ization Site 1 generally followed the same pattern as the measurements obtained by CEAT. MDEP profiles from 1978 to 1995 showed little year round stratification (MDEP 1994a). The data from this study indicates that the water was predominantly well mixed. Slight decreases in dissolved oxygen and temperature have occurred with increasing depth from 1978 to 1995, as on 11-JUL-91 (Figure 14). However, stratification did not occur to the same extent in North Pond as it did in nearby lakes similar to North Pond (BI493 1995, 1996). The mixing of the water cannot be attributed to fall turnover since the water at Characterization Site 1 was found to be well mixed on 10-JUL-96 and 30-SEP-96. The shallowness of North Pond and Little Pond probably promotes mixing throughout the water column year round. Wind and the movement of water in and out of the lakes facilitate the mixing of the water column (EPA 1988).

In addition, North Pond does not undergo the seasonal variations in dissolved oxygen levels that deeper Maine lakes do because the shallow depths of North and Little Ponds allow for even circulation of water (Bouchard, pers. comm.).

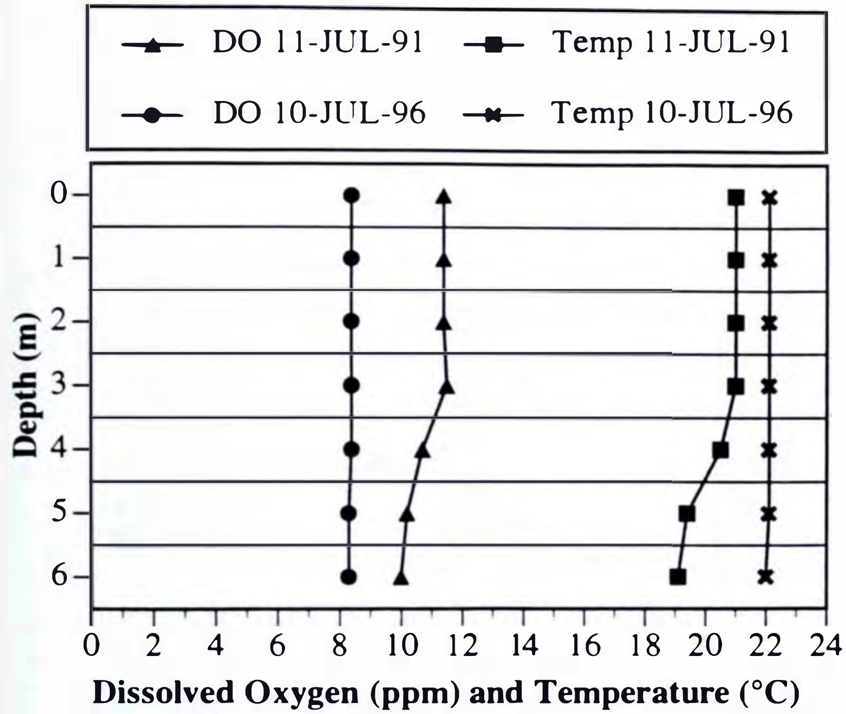

Figure 14. Comparison of dissolved oxygen (ppm) and temperature (°C) profiles from North Pond Characterization Site 1 sampled on 10-JUL-91 (MDEP) and 11-JUL-96 (CEAT). See Figure 12 for location of the site.

In addition to the stratification of the water column, depleted levels of dissolved oxygen are also of concern. Standards have been developed to assess the negative impacts of low dissolved oxygen levels in lakes. Dissolved oxygen levels less than 5 ppm have been found to harm freshwater fish (Novotny and Olem 1994). Another consequence of depleted dissolved oxygen levels arises in periods after anoxia when internal cycling of phosphorus from the sediment redistributes phosphorus in the lake (EPA 1988). The resuspension of phosphorus in the water contributes to internal phosphorus loading and promotes algal blooms. The dissolved oxygen measurements taken at three characterization sites and surface readings in the lakes or tributaries do not indicate depleted dissolved oxygen levels that would negatively affect the productivity of the lake or create an unhealthy environment for many biological processes.

Lake Transparency

Transparency is a measurement of water clarity and indicates how much algal matter is suspended in the water. A low transparency reading suggests a large amount of biological activity within the water column. The lake is considered productive if a transparency reading is below 4 m. If it is between 4 to 7 m, it is considered moderately productive, and above 7 m, unproductive. Most Maine lakes have a transparency ranging from 3 to 7 m (Pearsall 1991).

Methods

To conduct a transparency measurement a black and white circular disk, or Secchi disk, was used. To obtain a trial reading, the disk was lowered into the water on a calibrated cable until it was no longer visible through an Aqua-Scope (Appendix B). The depth at this level was recorded. The disk was then lowered one meter further and then brought back up until it was visible again. This depth was recorded and then averaged with the first one. The final transparency measurement represents an average of three trials. One transparency measurement was made at the MDEP Characterization Site 1 on 10-JUL-96, and again on 16-SEP-96. Sites 3, 5, 7, and 10 were measured on 23-SEP-96, while Sites 15 and 16 were measured on 30-SEP-96 (Appendix A).

Results and Discussion

The transparency readings taken on 16-SEP-96 and 30-SEP-96 in the North Pond and Little Pond subwatersheds have a mean of 3.5 ± 0.2 m (Figure 15). The Secchi depth measurement taken in July was 1.1 m greater than the measurement taken in September. The difference in depth may signify the result of a late summer and early fall algal bloom. According to Roy Bouchard from the MDEP (pers. comm.), the local standard for transparency associates algal blooms with Secchi readings of 2.0 m or below. Other studies, however, have linked readings below 4.0 m with algal blooms (Pearsall 1991).

The tributary sites had markedly lower transparency readings than the lake characterization sites. These measurements were taken in bog sites; therefore, the water is discolored by decomposition products. Site 10, sampled on 30-SEP-96, had a reading of 0.8 m, while Characterization Site 15 and Site 16, sampled on 23-SEP-96, had the same reading of 1.2 m. These tributaries may contribute to phosphorus loading which can lead to algal blooms in North Pond.

Maine lakes have a transparency range of 3.0 m to 7.0 m and a mean of 5.6 ± 0.2 m. The historic mean of North Pond from 1970 to 1994 is 4.0 ± 0.1 m (MDEP 1994a). In comparison to the other Belgrade Lakes, the historic mean of North Pond is low. East Pond had a mean of 4.6 ± 0.1 m, Salmon Lake a mean of 5.1 ± 0.2 m, Messalonskee Lake a mean of 5.9 ± 0.3 m, Great Pond a mean of 6.6 ± 0.1 m, and Long Pond a mean of 6.8 ± 0.1 m. All the lakes fall within Maine's transparency range; however the readings for North Pond fringe on the border between high and moderate biological activity.

North Pond is marginally eutrophic (Bouchard, pers. comm.). The lake does not experience extreme algal blooms, such as an emerald coloration, floating masses of dead algae or an unpleasant odor. However, it does undergo a rapid increase in algal mass during the summer months. The transparency values taken in June, July, and August from the years 1970 to 1995 reflect the high algal production (MDEP 1996). Two periods were selected due to sample sizes; 1970 through 1985, and 1986 through 1995. The transparency values were then statistically analyzed. Transparency for July and August show a significant decrease between the two periods (t-test, n=12, p=0.02 and n=14, p=0.01, respectively). Although not statistically significant, the mean values for June in the two periods show a decreasing trend (t-test, n=13, p=0.09). Thus transparency has decreased since the period 1970 through 1985. These results may forecast more pronounced algal blooms in the future.

Turbidity

Turbidity is a measure of the amount of scattering and absorption of light by particles suspended in water (Chapman 1992). Turbidity differs from transparency which is the limitation of visibility in

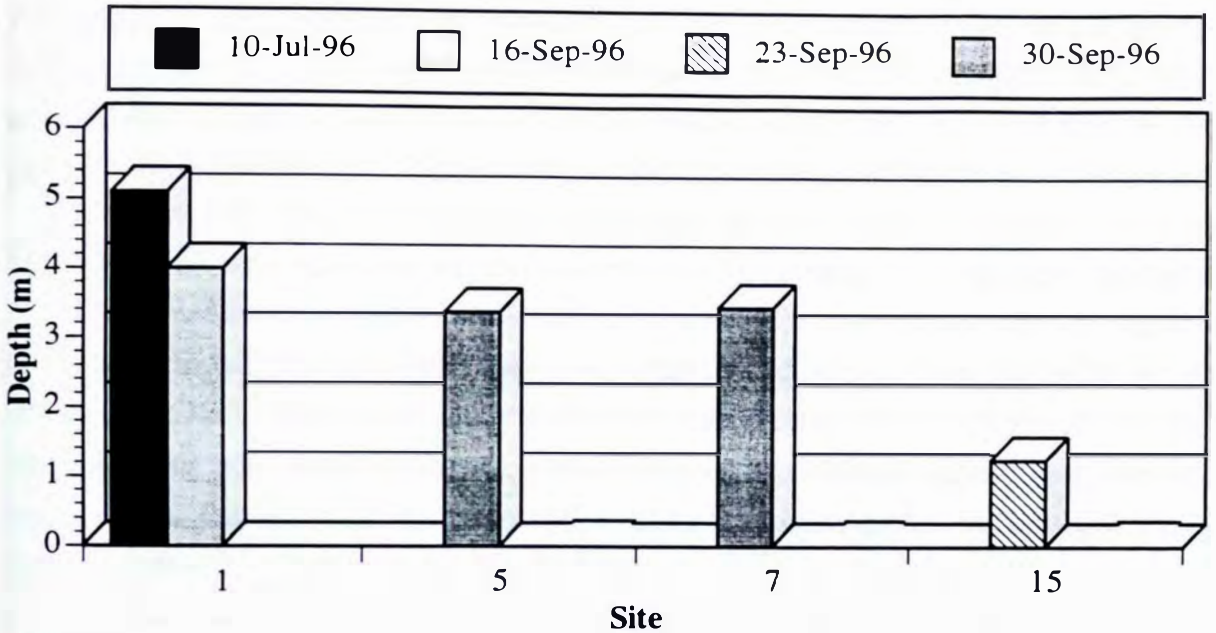

Figure 15. Secchi disk transparency readings for the characterization sites in North Pond (Site 1 and Site 5), Little Pond (Site 7), and Serpentine (Site 15). Measurements taken on 10-Jul-96, 16-SEP-96, 23-SEP-96, and 30-SEP-96. See Figure 12 for location of sites.

the water. Materials contributing to turbidity may include silt, clay, fine organic and inorganic particles, plankton, and other organisms. One source of these particles may be biological activity within the lake (McKee and Wolf 1963). Another source may be terrestrial input from runoff which can be affected by land use patterns. Turbidity is important in terms of the water chemistry of a lake because phosphorus is often associated with suspended particles. In addition to indicating higher phosphorus loads, high turbidity may modify a lake's temperature structure, decrease fish production, or interfere with light penetration and inhibit photosynthesis. According to the United States Public Health Service (USPHS) Drinking Water Standards, acceptable drinking water should not exceed 5 turbidity units (McKee and Wolf 1963).

Methods

CEAT collected samples from all sites except Sites 3 and 4 (Appendix A). Sampling was done on 23-SEP-96, 30-SEP-96, and 20-OCT-96. Samples were kept on ice until they could be refrigerated in the Colby Environmental Laboratory. All samples were analyzed within a 48 hour maximum holding period (Clesceri et al. 1989). The Absorptometric Method for Turbidity was used in analyzing the samples with readings measured in Formazin Turbidity Units (FTU) (Hach 1991). At North Pond Characterization Sites 1 and 5, and Little Pond Characterization Site 7, samples were taken from the surface, mid-depth, and bottom, while at all other sites samples were taken only at the surface.

Color may interfere with turbidity measurements, so most samples were analyzed in such a way that took color into account (Hach 1991). However, incorrect methodology was used and some samples were not analyzed in this manner. Therefore a color correction factor was calculated and applied to the readings. In order to calculate a color correction factor, the readings that accounted for color had to be compared with readings from the same site that did not account for color. The only sites with sufficient data for this were the four tributary sites sampled in the storm event (see North Pond and Little Pond Water Quality Assessment: Tributary Storm Event). The storm event measurements did account for color, whereas the measurements of previously collected samples from the corresponding sites did not. In order to minimize the effect of rainfall on the readings, the earliest data from the storm event was used, which was before any significant rain had fallen. The mean difference was calculated between the measurements that accounted for color, and the measurements that did not. This number indicated how skewed the measurements were if color was not accounted for. This number became the color correction factor. Readings that did not take color into account were multiplied by the correction factor to obtain an adjusted reading.

Results and Discussion

Turbidity readings ranged from 2.00 FTU at Sites 2 and 6 to 3.75 FTU at the Little Pond Characterization Site 7. The mean turbidity for the surface samples taken from North Pond and Little Pond Pond Sites was 2.79 ± 0.28 FTU (mean ± 1 SE; n=6). At Sites 1, 5, and 7 there were no significant differences among samples taken at the surface, mid-depth, and bottom of the lake (ANOVA, n=9, p=0.8697; Figure 16). These data suggest that the lake is uniform in turbidity, which may parallel uniformity in other measurements of water quality. This is supported by the dissolved oxygen and temperature profiles (see Lake and Tributary Water Quality - Lake Dissolved Oxygen and Temperature). The fact that there is little variation among the sites indicates that substantial mixing occurs horizontally in addition to vertically. The turbidity of all North Pond and Little Pond sites is below the USPHS drinking water limit of 5 turbidity units. The mean turbidity of the lake sites is also lower than the mean for East Pond which was 5.00 FTU (BI493 1991). North Pond and Little Pond Sites have only slightly higher turbidity than Salmon Lake (2.00 FTU; BI493 1994) and Long Pond, South Basin (2.30 FTU; BI493 1996).

Tributary turbidity readings ranged from 2.00 FTU at Bog Stream (Site 11) to 19.00 FTU at the mouth of Clark Brook (Site 14). Tributary sites had a mean turbidity of 8.97 ± 1.59 FTU (n=10). Despite their high variability, tributary sites had significantly higher turbidity than lake sites at the surface (t-test, n=16, p =0.01; Figure 17). This finding suggests that the tributaries carry more suspended materials, some of which probably settle out when the water reaches the lake. This settling accounts for the lower turbidity in North Pond and Little Pond than in the tributaries, and also suggests that many of the tributaries are sources of the suspended particles that are present in the lake (see Lake and Tributary Water Quality - Macrophytes). This has implications for phosphorus loading since phosphorus is often associated with suspended particles (see Lake and Tributary Water Quality -

Phosphorus). In addition, Clark Brook may be a significant contributor of suspended material to the Serpentine due to its high turbidity. The Serpentine, in turn, may contribute significant amounts of suspended material to North Pond, as it has a turbidity reading of 9.00 FTU at Site 17. For the most part, the tributary sites are above the 5 FTU limit set by the USPHS.

Conductivity

Conductivity is a physical measurement of the ability of water to convey an electric current and is directly related to the dissolved ions (charged particles) and the solids that are present in water (Chapman 1992). Water with high ion concentrations can be analyzed further to determine the specific ions that affect the water quality (BI493 1996). Conductivity is also directly related to turbidity because a high amount of sediment typically results in a high amount of dissolved ions, which increases conductivity (Chapman 1992).

Methods

Surface samples were collected on 30-SEP-96 at North Pond Characterization Sites 1, 5 and Spot Sites 2 and 6 and also at Little Pond Characterization Site 7 and Spot Site 8 (Figure 18). Mid-depth and bottom samples were also collected at Characterization Sites 1, 5, and 7.

Surface samples were collected on 23-SEP-96 at Tributary Sites 9, 11, 12, 13, 14, 16, 17, and 18 (Figure 19), as well as at the Serpentine Characterization Site 15. On 30-SEP-96 a sample was collected at Tributary Site 10.

All samples were analyzed within 24 hours from the sampling time and were kept refrigerated prior to testing (Clesceri et al. 1989). The conductance values were measured using a Model 31A YSI Conductance Bridge at the Colby Environmental Laboratory. Results are expressed in micromhos per centimeter (μmhos/cm) (Stednick 1991).

Results and Discussion

The conductivity values for Maine lakes are generally low with a mean range between 20 μmhos/cm and 40 μmhos/cm and are considered within the "clean lake" range (Pearsall 1991). Conductivity measurements correlate well with other factors affecting lake water quality and, therefore, can be used by fishery biologists to calculate fish yield estimates.

Conductivity measurements for all lake surface samples ranged from 21.0 μmhos/cm to 31.0 μmhos/cm with a mean of 27.3 ± 1.8 μmhos/cm (Figure 18). The range for North Pond Sites 1, 2, 5, and 6 was 30.0 μmhos/cm to 31.0 μmhos/cm with a mean of 30.3 ± 0.25 μmhos/cm. The range for Little Pond Sites 7 and 8 was 21.0 μmhos/cm to 22.0 μmhos/cm with a mean of 21.5 μmhos/cm. The mean values between North Pond and Little Pond were significantly different (t-test, $n=6$, $p=.0001$). Lower conductivity values recorded for Little Pond could be a result of fewer tributaries flowing into Little Pond as compared to North Pond. With fewer tributaries there would be less sediment delivered into Little Pond keeping the conductivity values lower. The low values at Sites 7 and 8 also suggest less mixing of sediments from the bottom of the lake at these sites.

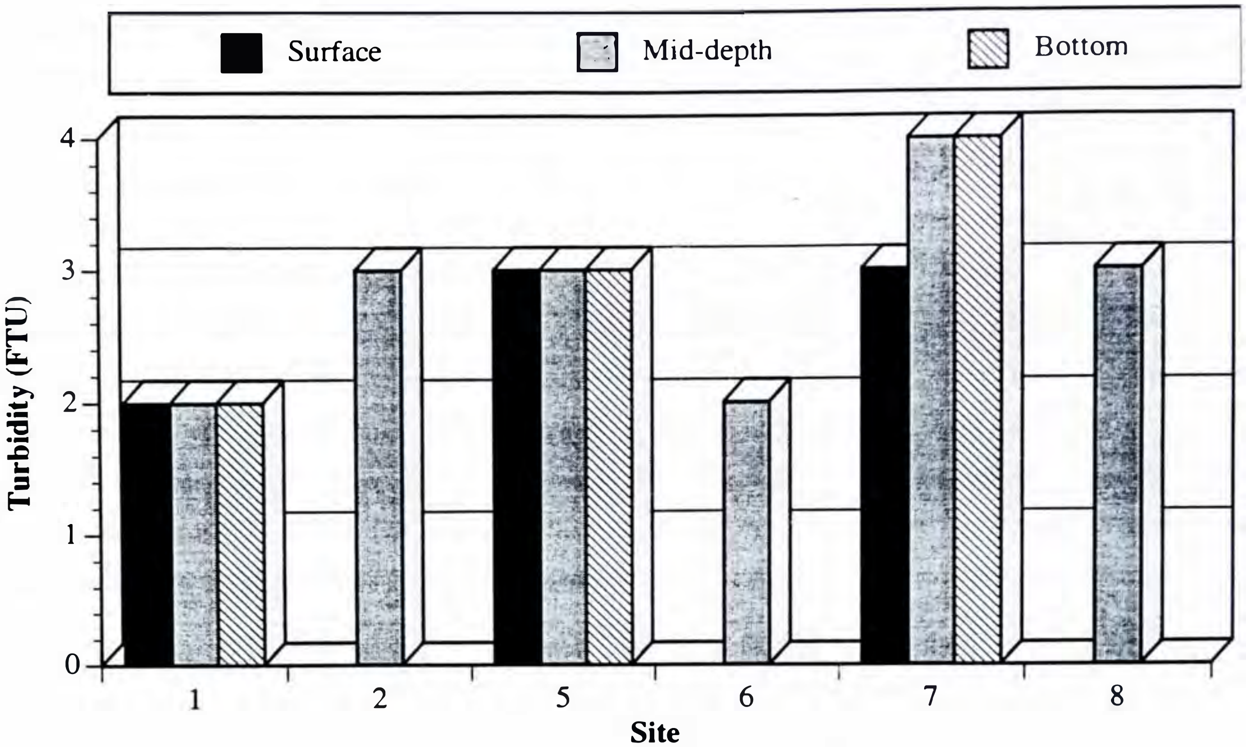

Figure 16. Turbidity in formazin turbidity units (FTU) of samples taken on 30-OCT-96 from surface, mid-depth and bottom samples at the North Pond (Sites 1, 2, 5 and 6) and Little Pond (Sites 7 and 8) characterization sites. See Figure 12 for location of sites.

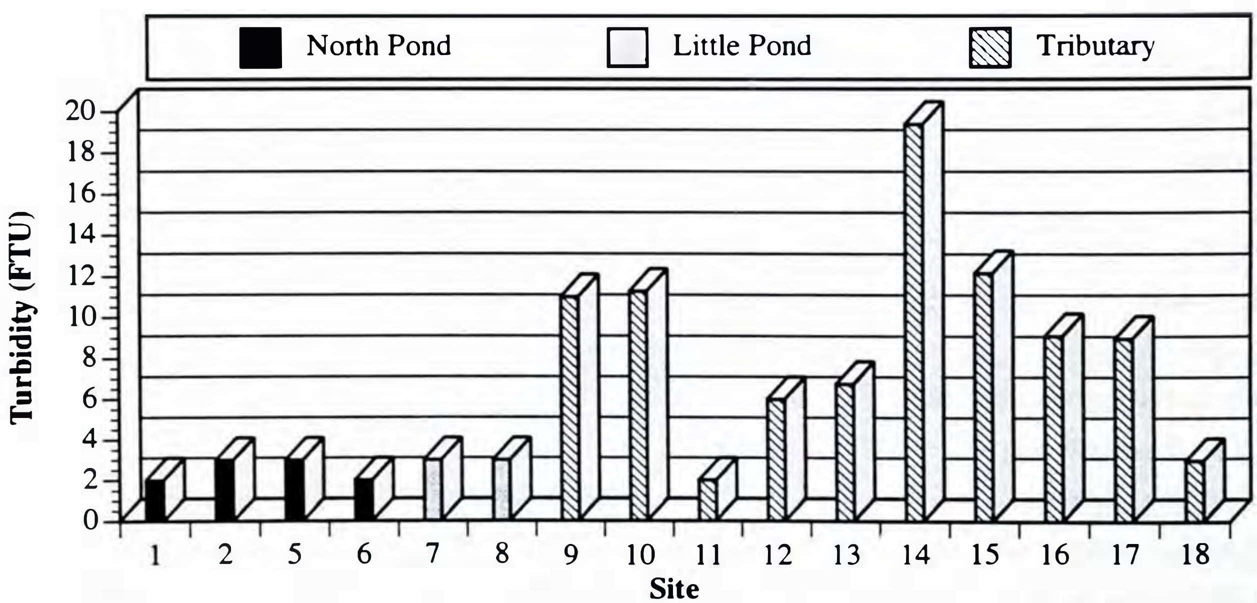

Figure 17. Turbidity in formazin turbidity units (FTU) of surface samples taken on 23-SEP-96 and 30-SEP-96 at North Pond (Sites 1, 2, 5 and 6), Little Pond (Sites 7 and 8), and Tributaries (Sites 9 to 18) . See Figure 12 for location of sites.

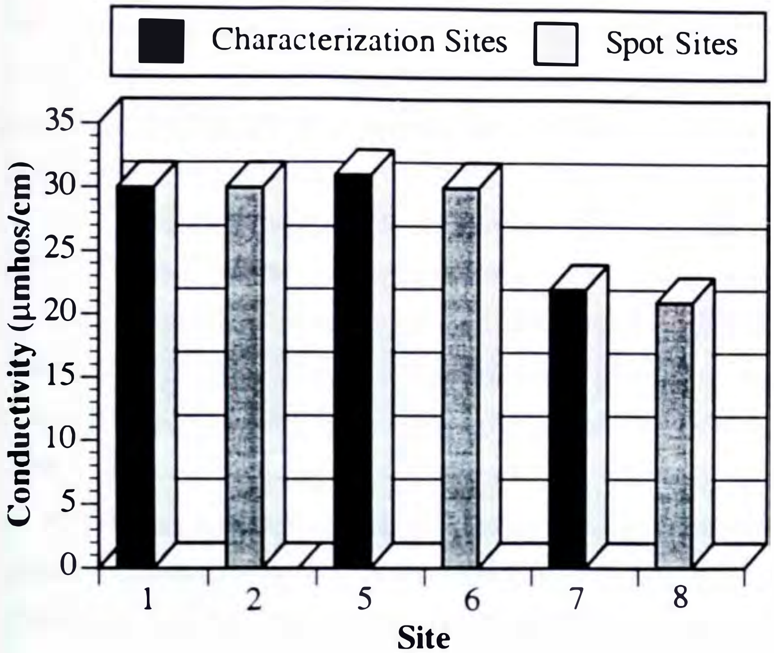

Figure 18. Conductivity measurements (µmhos/cm) for surface samples taken from North Pond (Sites 1, 2, 5 and 6) and Little Pond (Sites 7 and 8) on 30-SEP-96. See Figure 12 for location of sites.

Surface, mid-depth, and bottom samples were collected at Sites 1, 5, and 7 (Table 7). The results from these tests suggests that there was little difference between conductivity and depth at the time of this study. North Pond Spot Sites 2 and 6 showed no increase in conductivity values compared to the Characterization Sites. Site 2 (150 ft off shore from the outlet of the Serpentine) and Site 6 (75 ft off shore from an asphalt boat launch ramp) both had surface values of 30.0 µmhos/cm. These relatively low values suggests that there is not sediment rich water flowing into these areas from the Serpentine or from the road. A low turbidity value of 3 FTU at Site 2 and 2 FTU at Site 6 supports this conclusion.

The conductivity results for North fall within the "clean lake" range (Pearsall 1991). North Pond's conductivity values ranged from 21.0 µmhos/cm to 31.0 µmhos/cm with a mean of 27.3 ± 1.8 µmhos/cm. Historical evidence from a study done from 1971 to 1974 on Maine lakes indicated that North Pond's conductivity values had a range of 31.0 µmhos/cm to 43.0 µmhos/cm with a mean of 33.0 µmhos/cm (Davis et al. 1978). East Pond, which eventually flows into North Pond by means of the Serpentine, had a mean conductivity value of 29.0 µmhos/cm in 1991 for all of the sites at all of the levels (BI493 1991).

Conductivity values for the tributaries ranged from 22.0 µmhos/cm to 64.0 µmhos/cm (Figure 19) with a mean of 31.4 ± 4.2 µmhos/cm.

Site 12 had the highest conductivity value at 64.0 µmhos/cm, which was well above normal. It also had a notably higher conductivity value compared to the other samples taken on the same day. This may be a result of the relatively slow flow of the water at Site 12 which allowed ions to accumulate in the water. The longer water remains in contact with mineral or rock fragments the higher the resulting dissolved ion levels (Davis et al. 1978). There also could have been a sampling error; sediments could have been stirred up in the water prior to sampling. The next highest conductivity value came from Site 10 (Bog Stream) with a value of 40.0 µmhos/cm, suggesting that this tributary has a high level of ion delivery. A study done on Long Pond, North Basin Watershed showed that ions may be exported from wetlands (BI493 1995). In this study, the tributaries that flowed through wetlands had higher conductivity values. Bog Stream flows through a bog which may

Table 7. Conductivity measurements for North Pond and Little Pond samples taken on 30-SEP-96.

Location	Site	Conductivity (µmhos/cm)
surface	1	30.0
mid-depth	1	35.0
bottom	1	35.0
surface	5	31.0
mid-depth	5	30.0
bottom	5	30.0
surface	7	22.0
mid-depth	7	21.0
bottom	7	22.0

be exporting increased concentrations of Mg^{2+} and Ca^{2+} ions that are then carried into the lake, resulting in a higher conductivity value at Site 10. Site 18 at the outlet of North Pond had the lowest conductivity value of 22.0 µmhos/cm for the tributary sites. This southern most point of North Pond could have a lower value than the upper tributary points because open water acts as a dilution basin for ions and dissolved solids (BI493 1995).

The mean value for the tributary sites was 31.4 µmhos/cm which was slightly higher than the mean conductivity values for the lake sites (27.3 µmhos/cm). Tributaries tend to have increased sediment delivery rates but conductivity levels for most of the tributary sites did not increase by a significant amount (t-test, n=10, p=.4843). This suggests that the majority of the North Pond tributaries do not contain a lot of suspended sediment in the fall. Increased amounts of suspended sediment in the tributaries probably occurs during storms and the period of spring runoff.

Chemical Analyses

CEAT conducted seven chemical analyses to evaluate the lake and tributary water quality of North Pond. The tests for total phosphorus and nitrate/nitrogen concentrations were critical

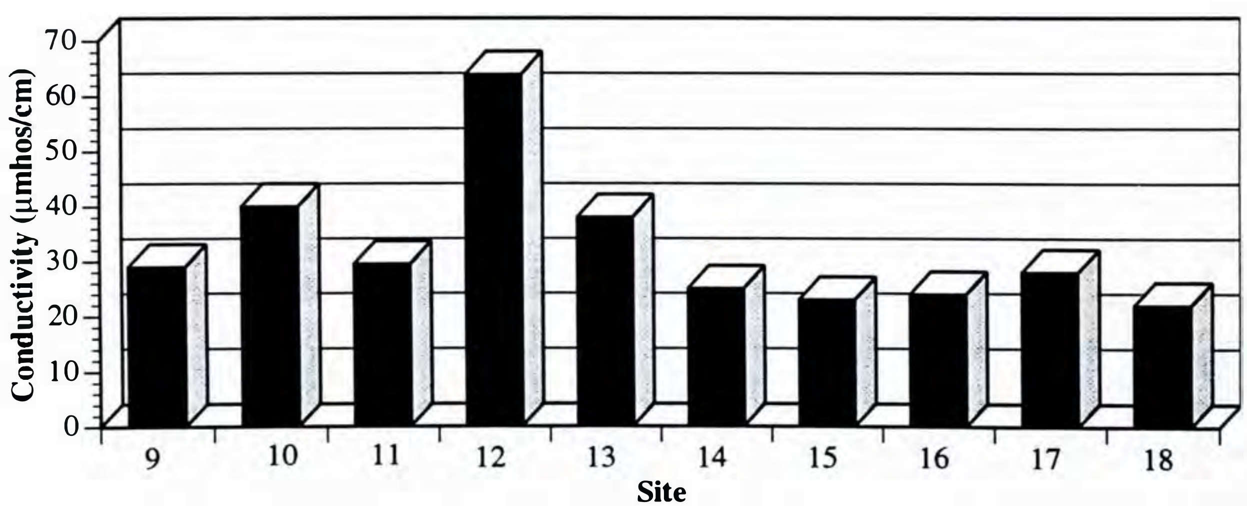

Figure 19. Conductivity measurements (µmhos/cm) for surface samples from tributary sites flowing into North Pond except for Site 18 which flows out of North Pond. All samples were taken on 30-SEP-96 except Site 10 which was sampled on 23-SEP-96. See Figure 12 for location of sites.

components of this study because they enabled CEAT to assess the current stage of eutrophication of North Pond. These tests combined with other analyses of hardness, color, pH, and alkalinity provided insight into the general health of North Pond and established a foundation for future studies into this region.

Phosphorus

Eutrophication is primarily controlled by the amount of total phosphorus found in bodies of water (Stednick 1991). Phosphorus is a major limiting nutrient for algae and plant growth because it controls the primary productivity, the rate at which energy is stored by photosynthetic activity (Smith 1990). Increases in the concentration of phosphorus cause an increased rate of eutrophication, leading to visible changes in water quality, such as algal blooms. Phosphorus is found in two forms, dissolved phosphorus and particulate phosphorus, and occurs naturally as a result of the weathering of phosphorus bearing rocks and the decomposition of organic matter in the body of water (see Introduction: Phosphorus and Nitrogen Cycles). Though phosphorus is found naturally in fresh water bodies, it is the increased concentrations of phosphorus due to human influence that cause the most concern as this speeds up the eutrophication process. The minimum phosphorus concentration needed to sustain a hazardous algal bloom or other plant infestation is 15 ppb (Pearsall 1991).

Methods

The North Pond study focused on the total phosphorus concentrations (both dissolved and particulate phosphorus) at sites in North Pond, Little Pond, and certain tributaries within the watershed. The sites in North and Little Pond which were analyzed for total phosphorus concentration were Sites 1, 3, 4, 5, 6, 7, and 8. The Characterization Sites (1, 5, and 7) and the Spot Sites (3, 4, 6, and 8) were taken in North and Little Pond during sampling on 23-SEP-96 and 30-SEP-96. A quality assurance guideline was followed with the use of splits, spikes, and duplicates of 10% of the total water samples analyzed (see Appendix B). The particulate phosphorus was first converted to dissolved phosphorus through digestion. Digestion was done by lowering the pH of the sample using 1 ml of 11N sulfuric acid and autoclaving at 15 psi for 30 minutes. After the dissolved phosphorus had cooled, the solution was neutralized using 1 ml of 11N sodium hydroxide. The dissolved phosphorus sample was then analyzed using the Ascorbic Acid total phosphorus method (Clesceri et al. 1989) and Milton Roy Spectronic 1001+ Spectrophotometer.

Results and Discussion

The three characterization sites in North and Little Pond had total phosphorus concentrations below the critical 15 ppb limit and the range of surface grab to bottom grab samples was comparatively small (8.9 ppb to 11.6 ppb). At Site 1 a surface and a mid-depth grab were taken on 30-SEP-96 and had total phosphorus concentrations of 8.9 ppb and 9.2 ppb, respectively. This characterization site in

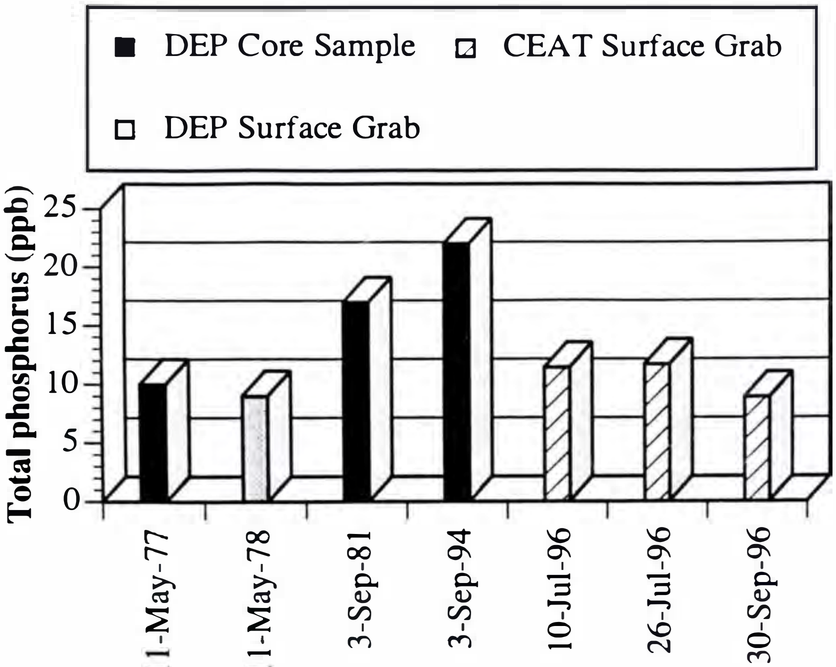

Figure 20. Total phosphorus concentrations (ppb) from surface grabs and core samples at the North Pond DEP Characterization Site 1, during the period 1977 to 1996 (MDEP 1996, BI 493 1996). See Figure 12 for location of the site.

North Pond has been studied since 1977 by the MDEP and the results of their sampling, along with the CEAT data taken 10-JUL-96, 26-JUL-96, and 30-SEP-96, are shown in Figure 20.

The core samples taken by the MDEP on 03-SEP-81 and 03-SEP-94 show high concentrations of total phosphorus, greater than 15 ppb (Figure 20). These results are difficult to explain considering the rapid increase in total phosphorus concentration over a short period of time (an increase of approximately 8 ppb in just over three years and then the decline CEAT recorded). It is possible that an error could have been made when estimating the depth of the site. Given this scenario, when sampling occurred, particulate from the bottom could have been taken into the core sample causing the marked increase in total phosphorus concentrations. All concentrations were within a limited range well below the critical 15 ppb limit with the exception of the samples taken on 03-SEP-81 and 03-SEP-94 (Figure 20). The total phosphorus concentrations from the MDEP and from samples collected this fall by CEAT do not indicate any real trends over time. The concentrations for surface, mid-depth, and bottom samples at Site 1 were compared between the late summer and late fall sampling dates (Figure 21). The concentrations indicate the occurrence of a natural phosphorus cycle with values following the seasonal variations expected during these time periods. There was a limited range of concentrations among all three respective sampling dates: 11.2 ppb to 12.2 ppb on 10-JUL-96, 11.3 ppb to 12.2 ppb on 26-JUL-96, and 8.9 ppb to 9.2 ppb on 30-SEP-96. This indicates complete mixing between the layers and a lack of stratification even in the deepest part of the lake.

The second characterization site, Site 5, was sampled on 30-SEP-96. In comparison to the other characterization sites, it had the highest concentrations of total phosphorus, 11.6 ppb at the surface (Figure 22). Though the values for phosphorus concentration were higher at this site, the range in values was approximately 3 ppb, an acceptable amount given that the maximum concentration was slightly less than 12 ppb. The lower core concentration, 8.5 ppb, and higher grab concentrations, 9.9 ppb to 11.6 ppb, could indicate a slight sampling error. However, the values are within an acceptable range and thus show no significant problem with the sampling or analytical techniques.

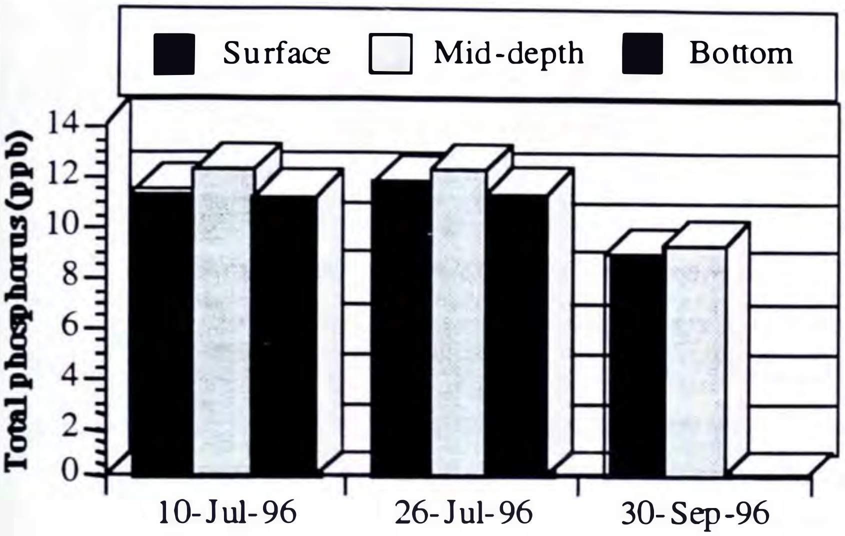

Figure 21.Total phosphorus concentrations (ppb) for surface, mid-depth and bottom samples taken from North Pond DEP Characterization Site 1. The average of two values was taken for the middle and bottom 10-JUL-96 and the surface for 26-JUL-96. Figure 12 for location of the site.

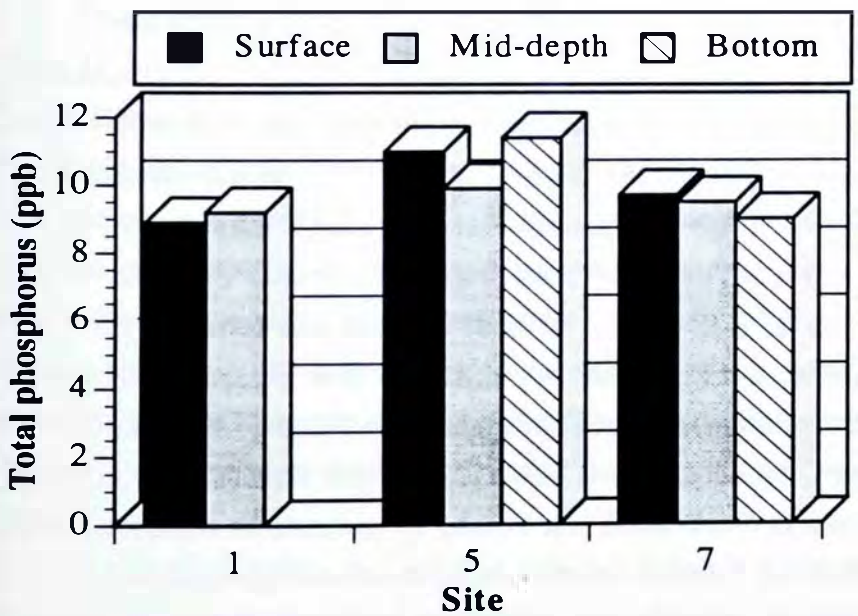

Figure 22. Total phosphorus concentrations (ppb) for surface, mid-depth, and bottom samples. North Pond Site 5 is an average of two values. All samples taken from North and Little Ponds on 23-SEP-96 and 30-SEP-96. See Figure 12 for location of sites.

The final characterization site, Site 7, was located in the deepest part of Little Pond. The concentrations of the surface, mid-depth, and bottom grabs taken on 30-SEP-96 at this site are shown in Figure 22. The total phosphorus concentrations are all quite low (9.1 to 9.7 ppb) indicating active mixing between the layers. The core sample taken at Site 7 had a concentration of 31.8 ppb. Because this core sample value was much higher than any of the grab samples at the same site, it is believed that contamination may have occurred. Perhaps some of the sediments at the bottom of the site were taken into the core, which could have increased the concentration value when analyzed, or the bottles used during the sampling or analysis could have been contaminated. Since the total phosphorus concentrations of the three grab sites were all close (9.0 ppb to 9.7 ppb), it can be assumed that the correct core value should in fact be closer to these values.

The three characterization sites in North and Little Ponds all have total phosphorus concentrations well below the 15 ppb limit for sustaining algal blooms. As an assessment of overall water quality for North Pond, the lake appears to be well mixed throughout and shows no effects of stratification between the layers. In analyzing data obtained from the MDEP and samples taken over the summer of 1996, there do not seem to be any significant trends of increasing or decreasing phosphorus concentrations other than the normal fluctuations in the phosphorus cycle of a lake. However, it is important to note that the data from the MDEP is limited and those samples which were taken occurred at uneven intervals over a 17 year period. This makes it difficult to determine any trends in North and Little Ponds.

Along with the three characterization sites sampled, there were four other spot sites sampled on 23-SEP-96 and 30-SEP-96 in North and Little Ponds. A summary of the surface grabs from these four sites and the three North and Little Pond characterization sites are shown in Figure 23. In general, none of the spot sites showed problem areas with high concentrations of total phosphorus. Except for the low concentration at Site 4, the range in values was within 3.0 ppb, with the maximum concentration less than 12.0 ppb.

The surface grab at Site 3 had a total phosphorus concentration of 10.6 ppb, the highest surface grab. The low concentration value from the sample taken at Site 4 came from a pipe which empties onto the beach of Pine Tree Camp at the southern shore of the lake. The pipe originates in the forest behind the camp. Therefore it is most likely that nutrients such as phosphorus were absorbed by the biota in the vicinity instead of running into the water body. The third spot site, Site 6, was chosen due to its vicinity to a potential phosphorus loading site, an asphalt boat launch ramp off of Route 137 in the northeastern part of the lake. This site did not have an elevated total phosphorus concentration (9.2 ppb) (Figure 23). The final spot site was in Little Pond, and was chosen due to its proximity to shoreline residential development. The concentration here was 9.7 ppb, again low enough to avoid immediate problems.

As was the case with the characterization sites, the spot sites indicated no problem areas in North Pond. Even in locations where it appeared that there was a distinct possibility of having an increased phosphorus loading problem, none was detected. Although the samples taken by CEAT indicate no current total phosphorus problem sites in North and Little Ponds, there are important considerations to take into account. The data taken by the MDEP on 03-SEP-81 and 03-SEP-94 does not completely coincide with CEAT's data. If the data was accurate it may be a cause for concern. It is also difficult to gauge trends over time with so little data available from MDEP on North and Little Ponds. Finally, the concentrations of total phosphorus,although they are all currently below the 15 ppb threshold, are approaching this critical limit. With lakes as shallow as North and Little Ponds, all precautions need to be taken to ensure that the concentrations do not rise any further. Future increases in total phosphorus concentrations have the potential to increase the primary productivity of the lake and sustain a viable algal bloom.

There are several factors that may have influenced the tributary sites at the time CEAT conducted this study. Increased flow rates of the tributaries that resulted from high levels of rain in August and September may have flushed phosphorus from surrounding areas into the streams. The increased flow may have also elevated the amount of particulate matter in the stream, or in the case of wetland systems, may have mobilized the retained phosphorus by sediment scour and resuspension (Reddy

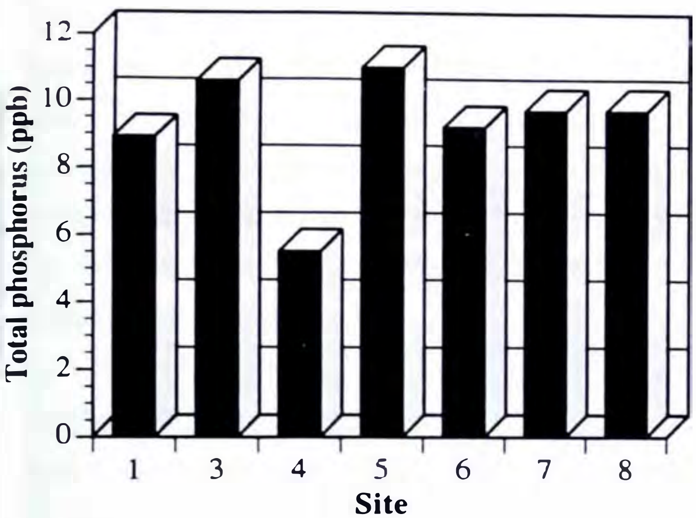

Figure 23. Total phosphorus concentrations (ppb) from surface grabs taken at North Pond (Sites 1 to 6) and Little Pond (Sites 7 and 8). North Pond Site 5 is an average of two values taken along with all other samples on 23-SEP-96 and 30-SEP-96. See Figure 12 for site locations.

et al. 1996). Since this study was conducted in the fall, the effects of the temporary release of phosphorus from above ground aquatic vegetation due to senescence (loss of leaves), seasonal growth patterns (more phosphorus is utilized during higher periods of growth), and decomposition of detrital tissue which rapidly releases phosphorus back into the water column, need to be taken into account. For many freshwater macrophytes, phosphorus release during the decay of detrital tissue is rapid, with up to 80% of the phosphorus released in two to three weeks (Reddy et al. 1996). Also, the relief of an area influences sediment runoff into streams. Elevated slope increases the loss of phosphorus from the land because there is a greater amount of particulate runoff (Harper 1992). For example, a rise in slope from 8 degrees to 20 degrees can enhance the loss of phosphorus by 360% or greater.

There were twelve sites chosen from ten major tributaries in the watershed of North Pond.

Sites 12 and 18

Leech Brook (Site 12) and Great Meadow Stream (Site 18, the outlet of North Pond leading to Great Pond) appear to have little effect on phosphorus loading into North Pond during the fall. Both sites had phosphorus levels lower than those observed in North Pond characterization sites (Figure 24). The low total phosphorus level in Leech Brook may be because it flows through a sparsely developed forested area, a sink for nutrients, into which much of the phosphorus is absorbed. Great Meadow Stream has a slightly lower phosphorus value than the characterization sites in North Pond which is representative of the water quality of the lake. These low levels at the outlet are demonstrative of the dilution power of large water bodies and macrophyte absorption of shallow areas.

Sites 9 to 11

Pattee Brook (Site 9) and Bog Stream (Site 11) had total phosphorus levels above the 15 ppb threshold and were identified as problem sites (Figure 24). Pattee Brook's high total phosphorus level could possibly be attributed to the proximity of the brook sampling site to Pond Road and the dense shoreline development, both of which may cause an increase in dissolved and particulate phosphorus.

Bog Stream also contributes to the phosphorus loading of North Pond. The high values at Site 11 may reflect the phosphorus loading from the boat ramp, North Shore Drive, weather conditions, and seasonal changes. Site 10, half way between the road and the mouth of the stream, approached but did not exceed levels of 15 ppb. This may be due to the fact that wetlands tend to lessen

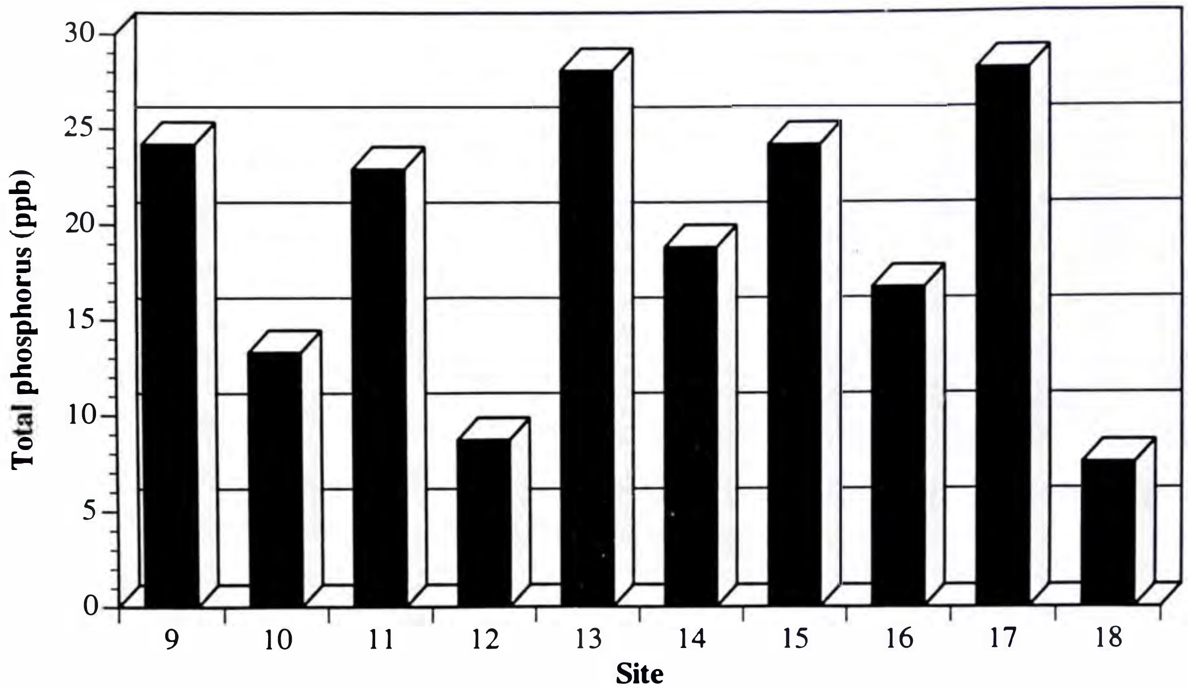

Figure 24. Total phosphorus concentrations (ppb) in the major tributaries flowing into North Pond and the outlet (Site 18, Great Meadow Stream) from North Pond. See Figure 12 for location of sites.

phosphorus loading because of their decreased flow rate, which allows sediments to settle out and large amounts of phosphorus to be absorbed by macrophytes. Bog Stream's impact on North Pond is shown by the one time reconnaissance reading of total phosphorus of 17.2 ppb, taken 50 m offshore from the mouth of the stream, as well as the increased growth of macrophytes around the mouth. The higher level at the mouth than at Site 10 may be accounted for by the different sampling dates, seasonal differences and/or detrital decomposition.

Sites 13 to 17

All sites in Sucker Brook (Site 13), Clark Brook (Site 14), and the Serpentine (Sites 15 to 17), had values that exceeded the 15 ppb threshold (Figure 24), and were identifiable problem sites. The values ranged from 16.2 ppb to 28.2 ppb. Sucker Brook registered the second highest total phosphorus level for a major tributary. Sucker Brook is influenced by the amount of sediment runoff and vegetation of Mt. Tom, an area of relatively high relief to the northeast of North Pond. Phosphorus is loaded into this brook from Route 8 and several dirt roads, as well as from a farm which is located adjacent to the brook. The farm also consists of large amounts of pasture lands, and livestock were observed in and around the stream. Phosphorus loading from permanent pasture lands is higher than from forests by up to two times depending on the soil type in the region (Harper 1992). Plowed farm lands may also contribute greater amounts of phosphorus because of the increased loss of topsoil due to poor cultivation practices, increased silt runoff, and waterlogging which makes phosphorus more soluble. Sucker Brook feeds into the northeast branch of the Serpentine and affects the water quality of the Serpentine.

Clark Brook joins the northern end of the Serpentine. Phosphorus levels and flow rates in this brook are lower than those observed in Sucker Brook. This implies that Clark Brook's impact on the water quality of the Serpentine is less then that of Sucker Brook. However, Clark Brook still contributes water greater than the threshold of 15 ppb. This can be primarily attributed to runoff from roads or seasonal influences because the sparse development in this area would have very little affect on the water quality (see Watershed Land Use: Zoning and Development Patterns and Roads and Residential Areas).

Sites 15, 16 and 17 in the Serpentine show a gradient of phosphorus levels. As noted above, the northeast branch of this water body is greatly influenced by Sucker and Clark Brooks. At Site 15 the total phosphorus level was 24.2 ppb which implies dilution of phosphorus levels by the larger volume of water in the Serpentine and sediment settling out due to the slower flow rate. Total phosphorus levels exceeded the 15 ppb threshold in the stream and dense algal mats were observed between Smithfield and the convergence of the northeast and southeast branches. Site 16 carries water from East Pond and surrounding wetlands into the Serpentine. Phosphorus levels are lower in this branch, possibly because of the ability of the wetlands to decrease phosphorus levels and the fact that there are fewer nonpoint sources in this area (see Watershed Land Use: Zoning and Development Patterns and Roads and Residential Areas).

At Site 17, where the Serpentine crossed Route 8 in the Smithfield township, the total phosphorus levels were the highest of all major tributaries. The high relief to the south of Smithfield, the gravel pit, low flow rate, municipal and dirt roads, and the heavy development around this site may all have a great influence on the water quality. These factors may combine to bring about high levels of total phosphorus.

At the mouth of the Serpentine (Site 2), approximately 150 ft offshore, 7.3 ppb was recorded, which is characteristic of North Pond. This shows the dilution power of North Pond, and the low flow of the Serpentine.

There were higher values of total phosphorus, with a mean of 53.25 ppb, observed in the Serpentine in 1990 (BI493 1991). This may be attributed to discrepancies in the sample locations of the two different studies, the differing laboratory techniques practiced in the analysis, or the fact that total phosphorus levels have been declining in the Serpentine over the past six years.

Little Pond Tributaries

A single reconnaissance sampling was done around the perimeter of Little Pond and three tributaries were sampled. Tributary Sites 1 and 2 in Little Pond had high levels of phosphorus and Tributary Site 3 had an extremely low level of phosphorus (Figure 25). The high levels at Tributary Sites 1 and 2 may be due to the presence of stagnant waters and the seasonal release of phosphorus into the water column. The low value at Tributary Site 3 could either be a discrepancy in analysis or could be due to absorption of nutrients by the surrounding vegetation. These tributaries have a greater seasonal

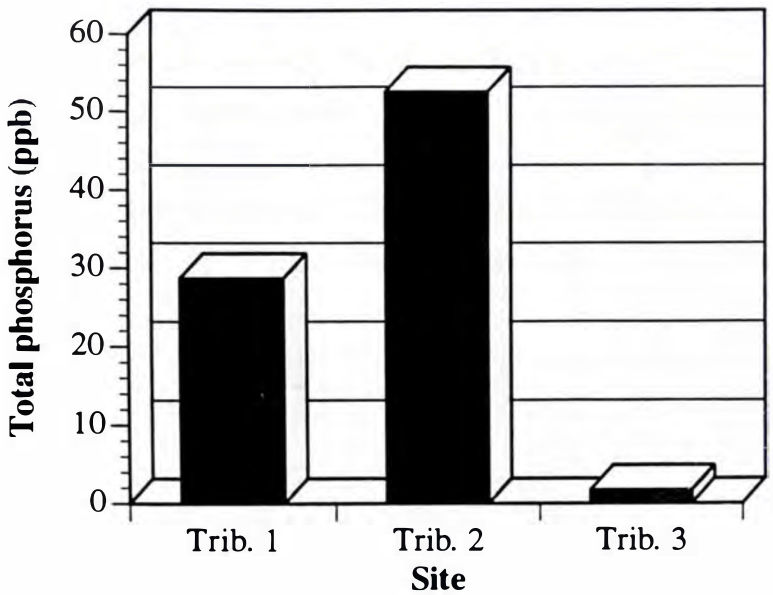

Figure 25. Total phosphorus concentrations (ppb) for the three tributaries flowing into Little Pond. See Figure 12 for location of sites.

influence on the water quality during storms and spring runoff because they generally have extremely low flow rates throughout much of the year.

Nitrates

Nitrate is the predominant form of available nitrogen in a lake (Chapman 1992). It is an essential nutrient in the growth of algae. Consequently, lack of nitrates may limit algal growth, while a surplus may contribute to an algal bloom. However, it is the amount of phosphorus in a lake that usually controls the level of algal productivity and the possibility of an algal bloom. It is still important to measure nitrate concentrations to determine if phosphorus is indeed the limiting nutrient for algae. In addition, high nitrate concentrations can be indicative of agricultural or industrial runoff, especially when found in tributaries. Natural sources of nitrate include rainwater, soil leaching through runoff, and the activity of blue-green algae and other microbiota in the water (Stednick 1991). The amount of nitrate derived from soil leaching is often magnified by certain land uses within a watershed. In addition, other forms of nitrogen may enter a lake and be converted into nitrate. Natural levels of nitrate in lakes rarely exceed 0.100 ppm; levels of 0.200 ppm or greater can often stimulate algal growth (Chapman 1992). The maximum allowable level of nitrate in drinking water is 45 ppm (Stednick 1991).

Methods

CEAT collected samples at all sites except Site 4 (the pipe at Pine Tree Camp, where not all tests were conducted) on 23-SEP-96 and 07-OCT-96 (Appendix A). The samples were kept on ice while in the field, and then refrigerated in the Colby Environmental Laboratory until they were analyzed. The analysis was conducted within 48 hours after sampling, using the low-range cadmium reduction method with a Hach DR/3000 spectrophotometer (Hach 1991).

Results and Discussion

The range of nitrate concentration for sites in North Pond and Little Pond was from 0.030 ppm at Site 2 and Site 8, to 0.065 ppm at Site 7. The mean nitrate concentration for all lake sites was 0.046 ± 0.005 ppm (n=7). This is higher than East Pond (BI493 1991) and Salmon Lake (BI493 1994), which had concentrations of 0.030 ppm and 0.020 ppm, respectively. However, the nitrate concentration in Long Pond, South Basin was 0.050 ppm, which is slightly higher than North Pond (BI493 1996). All lake sites were below the 0.200 ppm concentration, at which algal growth may be stimulated, as well as below the maximum natural nitrate level of 0.100 ppm (Figure 26). However, because nitrates are quickly incorporated into algal material, these low nitrate readings do not necessarily indicate there is little input to the lake. If high levels of nitrates were entering the lake and being used by algae, little would be left unassimilated in the water. Therefore, it is important to look at the levels of total nitrogen, as some of the nitrogen may be in forms largely unusable by algae and thus be able to indicate the actual amount of nitrogen in the lake (see Lake and Tributary Water Quality - Total Nitrogen).

The range of tributary nitrate concentration was from 0.030 ppm at Site 9 and Site 17 to 0.110 ppm at Site 11. The mean nitrate concentration for tributary sites was 0.058 ± 0.025 ppm (n=10). Tributary sites did not have significantly higher nitrate concentrations than lake sites (t-test, n=17, p=0.255). However, certain tributary sites such as Bog Stream (Sites 10 and 11), were obviously higher than any lake site (Figure 26). This suggests that although still below the 0.200 ppm required to stimulate algal growth, Bog Stream may be the highest source of nitrate to North Pond. Great Meadow Stream (Site 18), which is the outlet of North Pond, had a nitrate concentration of 0.055 ppm. By comparing this number to the 0.058 ppm mean for all tributaries, it can be seen that nitrate concentrations at the inflow and outflow are fairly close. Although these concentrations are similar, they do not indicate whether the total mass of nitrate entering the lake is similar to the mass leaving, which is important in terms finding out if North Pond is a source or a sink of nitrate. To determine this, discharge data are necessary for the tributaries and Great Meadow Stream so that the total mass can be calculated.

Total Nitrogen

Although nitrate is the most usable form of nitrogen for plants, other forms of nitrogen are important because they can be converted into nitrate and used by plants. This is accomplished by certain microorganisms or by the assimilation of nitrogen by macrophytes and their subsequent

decomposition (Stednick 1991). Therefore, under certain conditions, total nitrogen can be seen as potential nitrate. In addition, when there is high primary productivity in a lake and nitrates are quickly assimilated, the levels of total nitrogen can be used as a better indicator of the nitrogen level in the water. It is important to monitor total nitrogen in both the lake and tributaries because the concentration of total nitrogen in tributaries reflects the amount being carried into the lake. This affects how much total nitrogen is put into the lake for conversion into nitrate and used in algal production. For water to be suitable for most beneficial uses, such as drinking, total nitrogen levels must be less than 10 ppm (McKee and Wolf 1963).

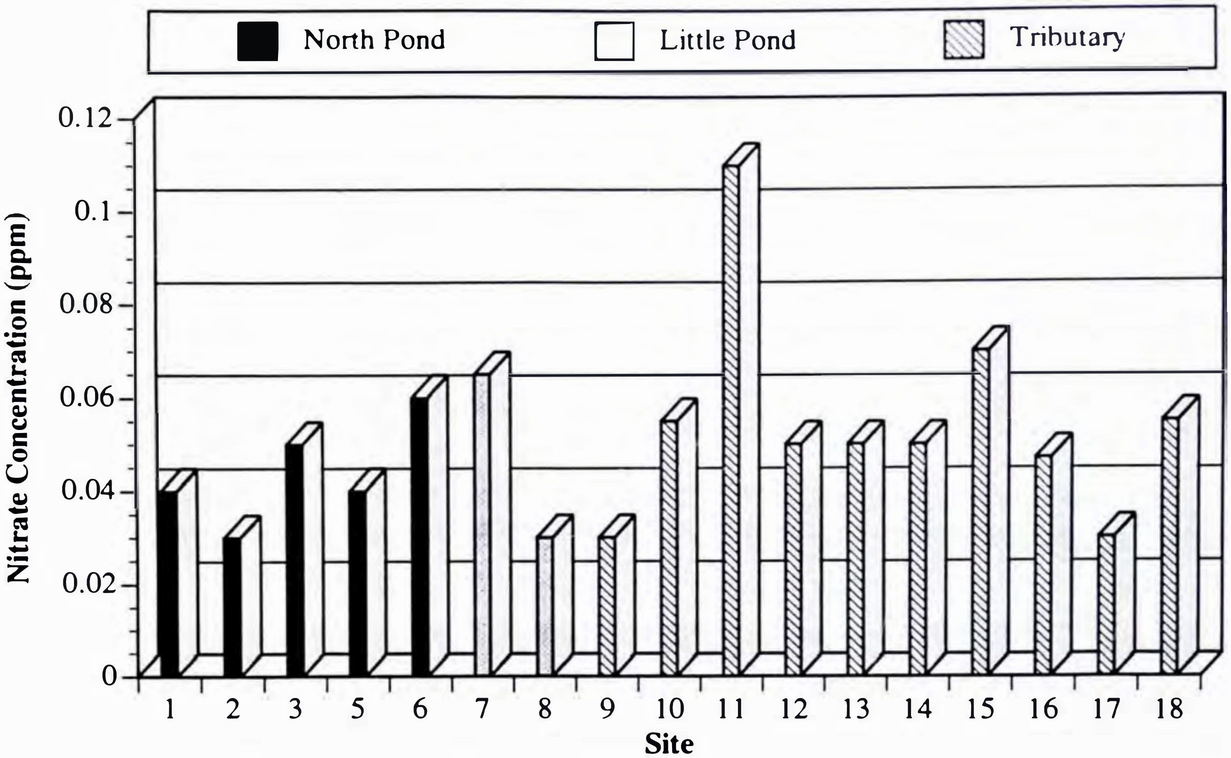

Figure 26. Nitrate concentration (ppm) of surface samples taken on 23-SEP-96 and 07-OCT-96 at North Pond (Sites 1 to 6), Little Pond (Sites 7 and 8), and Tributaries (Sites 9 to 18). See Figure 12 for location of sites.

Methods

CEAT collected samples on 30-SEP-96 at Sites 3, 5, 7, and 15, and acidified with sulfuric acid (Appendix A). They were kept on ice while in the field, and then refrigerated in the Colby Environmental Laboratory until analyzed. All samples were analyzed in the Colby Environmental Laboratory within a 28 day maximum holding period (Clesceri et al. 1989). The Digestion and Nesslerization Method for Total Kjeldahl Nitrogen was used (Hach 1991). This was done with a Hach Digesdahl® Digestion Apparatus and a Hach DR/3000 Spectrophotometer.

Results and Discussion

Total nitrogen concentration from lake sites ranged from 0.25 ppm at Site 7 to 1.25 ppm at Site 5. These levels are well below 10 ppm suggesting that there are no significant concentrations of total nitrogen at North Pond or Little Pond sites. Nitrate made up the highest percentage of total nitrogen at Little Pond Characterization Site 7, and the lowest percentage at Characterization Site 5 (Table 8). However, it is difficult to determine if this range of percentages is due to differences in the rate of biotic uptake of nitrate or differences in the actual amount of nitrate at each site. Sawyer et al. (1952) reported that for most algae the optimum nitrogen to phosphorus ratio ranges from 15:1 to 30:1. The only site that had a nitrogen to phosphorus ratio within this range was Site 7. Since this site is located in Little Pond, it may be somewhat isolated from the rest of the lake in terms of water currents. This may be related to the higher nitrogen to phosphorus ratio there. However, because the ratio at Site 7 was at the upper end of the range, and the rest of the sites were well above it, it appears that algal growth in North Pond as a whole is limited by phosphorus concentration rather than nitrogen concentration.

Table 8. Total nitrogen concentrations and related calculations from samples collected on 30-SEP-96 at North Pond and Little Pond sites. See Figure 12 for location of sites.

Site	Total Nitrogen Concentration (ppm)	Total Nitrogen in the Form of Nitrate (%)	Nitrogen to Phosphorus Ratio
3	0.50	10.0	47:1
5	1.25	3.2	114:1
7	0.25	26.0	26:1

The tributary sample, which was taken from the Serpentine at Site 15, had a concentration of 0.75 ppm. This value is close to the mean for the samples taken at the lake sites (0.67 ± 0.30 ppm, n=3). There seemed to be no substantial difference between the total nitrogen concentration of the lake sites and that of Site 15. However, due to the very small sample size, these results are not conclusive. The 0.75 ppm reading for Site 15 is well below 10 ppm suggesting that the Serpentine has sufficiently low concentrations of total nitrogen and does not contribute substantial amounts to North Pond.

Hardness

The hardness of natural water is related to the presence of dissolved calcium and magnesium salts (Chapman 1992). Hardness measures the amount of dissolved calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions that are present in water and is expressed as parts per million calcium carbonate (ppm $CaCO_3$). Water containing $CaCO_3$ within a range of 0 ppm to 60 ppm is considered to be soft (Stednick 1991). Soft water is beneficial for fish growth, but it may make the fish more susceptible to toxic elements such as copper (Cu) and zinc (Zn). Hardness in water can be caused by the natural accumulation of salts from contact with soil and geological formations, or it can be a result of direct pollution (McKee and Wolf 1963). Calcium dissolves from almost all rocks and soils, but limestone, dolomite and gypsum are the greatest contributors (Stednick 1991). Magnesium is dissolved from all rocks, but most readily from dolomitic rocks.

Methods

Hardness samples were taken at North Pond Sites 1, 3, and 5 and Little Pond Site 7 on 30-SEP-96. All samples were refrigerated until analyzed, and were all analyzed within the maximum holding time of six months (Clesceri et al. 1989). Surface water samples from these sites were analyzed for hardness at the Colby Environmental Laboratory using the EPA approved HACH Titration Method adapted from the EDTA Titrimetric Method (Hach 1992).

Results and Discussion

The values for hardness were similar for each surface sample site within North Pond and Little Pond. The mean was 10.1 ± 0.4 ppm and the range was 9.0 ppm to 11.0 ppm. The north end of North Pond (Site 5) was 10.0 ppm and the south end (Site 3) was 10.5 ppm. This shows there was no increase in Ca^{2+} and Mg^{2+} ions from the north to the south ends. In Long Pond, North Basin, a nearby lake, hardness values were between 12.1 ppm and 13.9 ppm for surface sites in 1995 (BI493 1995). A lake study done on Salmon Lake in 1994 also showed values in the soft range (BI 493 1994). The two ponds that make up Salmon Lake, McGrath Pond and Ellis Pond, had mean hardness values of 26.5 ppm and 24.5 ppm, respectively. These other studies indicate that the low levels of hardness that characterize the surface water of North Pond in this study are normal.

Most lakes in Maine are soft water lakes (Davis et al. 1978). The soft water of North Pond suggests that if certain mineral toxins were to be introduced at some point in the future, aquatic life in North Pond may be more sensitive to these toxins (Chapman 1992).

Alkalinity

Alkalinity is the measurement of the water's ability to neutralize acids (its capacity to buffer against the addition of acids) (McKee and Wolf 1963). The presence of several substances, primarily carbonates, bicarbonates, and hydroxides, and the conditions of the water such as pH and hardness contribute to the degree of alkalinity of a water body (McKee and Wolf 1963; Stednick 1991). Water with a relatively neutral pH tends to have a low alkalinity. Low alkaline water is less able to resist pH changes. Therefore bodies of water with greater alkalinity values (higher than 10 ppm $CaCO_3$) can endure the effects of acid rain for longer periods of time (Pearsall 1991). Alkalinity of water in the New England area is generally low, but in some locations may be increased by the addition of sewage and industrial waste (McKee and Wolf 1963). In general, the alkalinity of Maine lakes ranges from 4 ppm $CaCO_3$ to 20 ppm $CaCO_3$ (Pearsall 1991; Figure 9).

Methods

Surface and bottom samples were collected from Characterization Sites 1 and 5 and surface, middle, and bottom samples were collected from Characterization Site 7 in little Pond on 23-SEP-96. The samples were put on ice immediately after collection and refrigerated in the Colby Environmental Laboratory until analyzed. The samples were analyzed on 06-OCT-96 in the Colby Environmental Laboratory using the potentiometric titration method (Clesceri et al. 1989).

Results and Discussion

The alkalinity values of the three sites at all levels sampled are shown in Figure 27. The highest alkalinity was found at Characterization Site 5 in the bottom stratum with a value of 13.3 ppm $CaCO_3$. The lowest value was in the bottom layer of Characterization Site 1 (3.3 ppm $CaCO_3$). This is an extremely low alkalinity and could be an incorrect value that was due to sampling or testing error. At

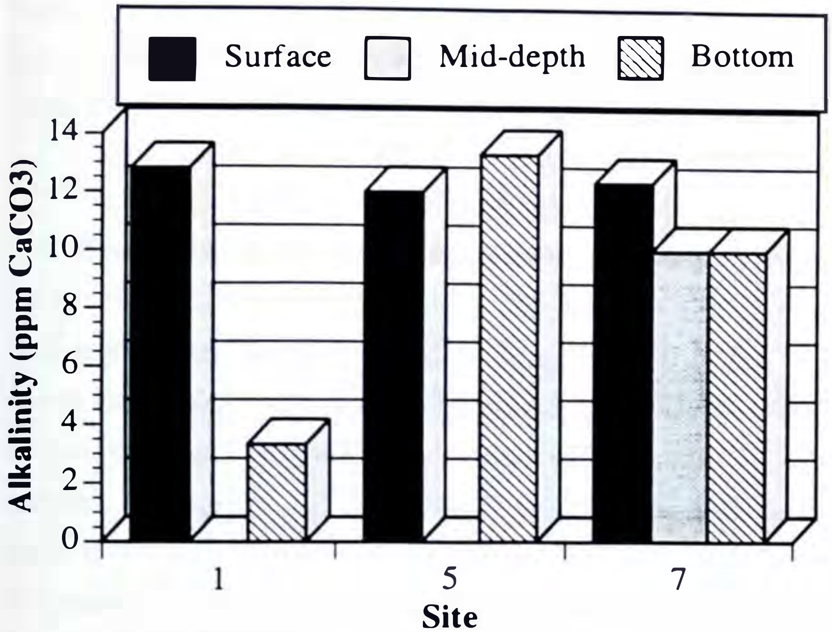

Figure 27. Alkalinity measurements (ppm CaCO3) for North Pond (Site 1 and 5) and Little Pond (Site 7) sites. Measurements taken on 23-SEP-96. See Figure 12 for location of sites.

Sites 5 and 7 there was little differentiation in alkalinity between the water depths. The mean alkalinity of the surface samples was 12.4 ± 0.2 ppm $CaCO_3$.

The historical data show the alkalinity of North Pond to be slightly lower than the results from this study. MDEP data from 09-AUG-83 gave an alkalinity of 7.15 ppm $CaCO_3$. In 1978, surface measurements ranged from 8.0 ppm $CaCO_3$ to 10.0 ppm $CaCO_3$ with a mean of 8.6 ppm $CaCO_3$ and bottom samples ranged from 6.0 ppm $CaCO_3$ to 11.0 ppm $CaCO_3$ with a mean of 8.8 ppm $CaCO_3$ (Davis et al. 1978). The alkalinity measurements obtained by CEAT for North Pond and Little Pond are slightly higher than these historical values.

The alkalinity values for other lakes in this area were also lower than those found in North Pond and Little Pond. In Long Pond, South Basin, the alkalinity ranged from 8.0 ppm $CaCO_3$ to 9.6 ppm $CaCO_3$ with a mean of 8.8 ppm $CaCO_3$ (BI493 1996). Long Pond, North Basin was found to have alkalinity values ranging from 6.0 ppm $CaCO_3$ to 12.0 ppm $CaCO_3$ and a mean of 9.3 ppm $CaCO_3$ (Davis, et al. 1978). Another study done in 1995 resulted in a comparable value of 7.0 ppm $CaCO_3$ for Long Pond, North Basin (BI493 1995).

Although the present alkalinity of North Pond is somewhat higher than historical data, the values are still within a fairly normal range for Maine lakes (see Introduction: Biological Perspective). The slightly higher measurements obtained in this study compared to the historical data could be caused by pollution originating from wastes discharged into the lake. However, the increase in alkalinity is minimal and is not strong evidence that North and Little Ponds are unhealthy.

pH

The pH is a measure of the concentration of free hydrogen ions (H^+) in a solution. The pH is measured on a scale from zero to 14, with zero being very acidic and 14 very alkaline. A pH of 7 represents a neutral condition (Chapman 1992). Many biological and chemical processes within a water body are influenced by pH. For instance, the types of plants or animals living around a lake can be influenced by the acidic or basic condition of the water (Pearsall 1991).

Typically, the pH of lakes in the northeastern United States is neutral to slightly acidic. This is not surprising as rainfall in the northeastern United States is characterized as slightly acidic. Maine fits into this category with pH for its lakes ranging between 6.1 and 6.8 (Charles 1991). Highly acidic rainfalls will increase the acidity (lower the pH) of a lake or other water body due to an increase in runoff which carries acidic particles via tributaries into the surrounding lakes. Under natural conditions, such as an unpolluted lake, pH is controlled by carbon dioxide, carbonate, and bicarbonate ions, along with other natural compounds (Chapman 1992). The higher the pH, the richer a water body usually is in these carbohydrates, bicarbonates, and associated salts. However, the presence of industrial effluents or an increase in atmospheric deposition of acid-forming substances can also cause changes in the natural acid-base balance of a water body. Thus, the overall level of pH helps to make predictions about the overall quality of the water body (Stednick 1991).

Methods

All pH measurements obtained in the field were taken using the Horiba Compact pH meter, B-213. Sites 9 and 11 through 17 were tested on 23-SEP-1996 while Sites 1, 3, 5, 7, 10, and 18 were all tested for pH on 30-SEP-1996. All pH values were taken in the field with the exception of Site 5 and Site 11, due to a malfunction with the pH meter. These samples were assessed immediately upon return to the Colby Environmental Laboratory.

Results and Discussion

The mean pH value for the North Pond characterization sites was 7.07 ± 0.05 and 6.73 for the Little Pond Characterization Site 7. Mean pH values for both lakes occurred within the pH value range of 5.5 to 7.4 set by the U.S. Fish and Wildlife Service for lakes in the United States (Cowardin 1979). The mean pH value recorded at North Pond exceeded the 6.10 to 6.80 range for mean pH values for Maine lakes, while the Little Pond mean pH fell within the set standards (Pearsall 1991). The mean pH value for Characterization Site 1 in North Pond fell within the historical range of 6.40 to 7.15 for data measured by MDEP from 1978 to 1983 (MDEP 1994a). The pH data suggest that the quality of the lake water is near neutral and not harmful to some of the biological processes which take place in the lakes.

The mean pH for all tributary sites was 6.29 ± 0.25. The pH values recorded at Sites 9, 11, 12, 14, 15, and 16 all occurred outside the 6.10 to 6.80 range for mean pH values of Maine lakes (Pearsall 1991). In addition, several pH values were higher than the historical range of 6.40 to 7.15 for data taken from Characterization Site 1 in North Pond from 1978 to 1983 (MDEP 1996). The Bog Stream sites were slightly acidic, but reasonable given the amount of decomposition which takes place in a bog setting. There was a gradient ranging from very acidic water in Clark Brook (pH=4.82) to normal at Site 17 (pH=6.44) in the Serpentine. Data collected at Clark Brook for the East Pond study indicated a pH value of 4.20 suggesting this site has remained acidic for at least the past six years (BI493 1991). As in Bog Stream, the acidity of Clark Brook may be attributed to decomposition which occurs in the marsh alongside Clark Brook. Also the water that drains into Clark Brook comes from a mixed forest. The conifers in the forest may contribute to the acidification of Clark Brook. The areas of high acidity, Clark Brook and the upper Serpentine, are regions that could be harmful to some biological processes.

Color

True color is the measurement of substances in solution after the suspendoids have been taken out by filtration or centrifugation. The color in areas that contain a substantial amount of vegetation, such as bogs and marshes, tends to be higher due to the compounds added from the decomposition of plants (Pearsall 1991). Specifically, the substances which are responsible for true color are plant-derived compounds such as tannins, lignins, and humic acid, and inorganic materials such as natural minerals (Chapman 1992). The true color measurement is important because primary production of algae is dependent upon the degree to which the water is colored. If the water is highly colored, the transmission of light through the water will be reduced, thereby hindering photosynthesis of submerged plants and algae. Color may also be associated with and be indicative of higher phosphorus levels and lower transparency readings. As a lake becomes more eutrophic, the color generally increases (McKee and Wolf 1963).

Methods

For the lake sites, samples were taken at Sites 1, 2, 5, and 6-8 on 23-SEP-96 and 30-SEP-96. At Characterization Sites 1 and 5 in North Pond and Characterization Site 7 in Little Pond, mid-depth and bottom samples were also taken on 30-SEP-96. Samples were taken for Tributary Sites 9 and 11 through 18 on 23-SEP-96 and for Site 10 on 30-SEP-96. All of these samples were kept on ice immediately after collection and during transport. They were then analyzed in the Colby Environmental Laboratory on the date of their collection.

True color was measured using the Platinum-Cobalt method and the protocol was adapted from the HACH DR/3000 Spectrophotometer Manual (Hach 1991). The samples were analyzed using the DR/3000 spectrophotometer. Color values are expressed in Standard Platinum Units (SPU) which are equivalent to parts per million. Samples with values of 25 SPU or less are considered to be uncolored and those with measurements of 26 SPU or greater are colored (Pearsall 1991).

Results and Discussion

The surface measurements ranged from 10.0 SPU at Characterization Site 1 to a high of 24.0 SPU at Site 8 in Little Pond (Figure 28). The mean surface value for these sites was 16.7 ± 2.2 SPU. Four of these values are within the range of the color found in North Pond in previous years by MDEP (15 to 25 SPU), while Sites 1 and 5 had measurements which were lower (MDEP 1996). The MDEP results show that color has increased over time (Table 9). North Pond was also sampled by Davis et al. (1978), who found that the mean color from the seven samples taken was 25.0 SPU. The most recent sample previous to this study was taken by MDEP on 03-SEP-94 and was 25.0 SPU (Table 9).

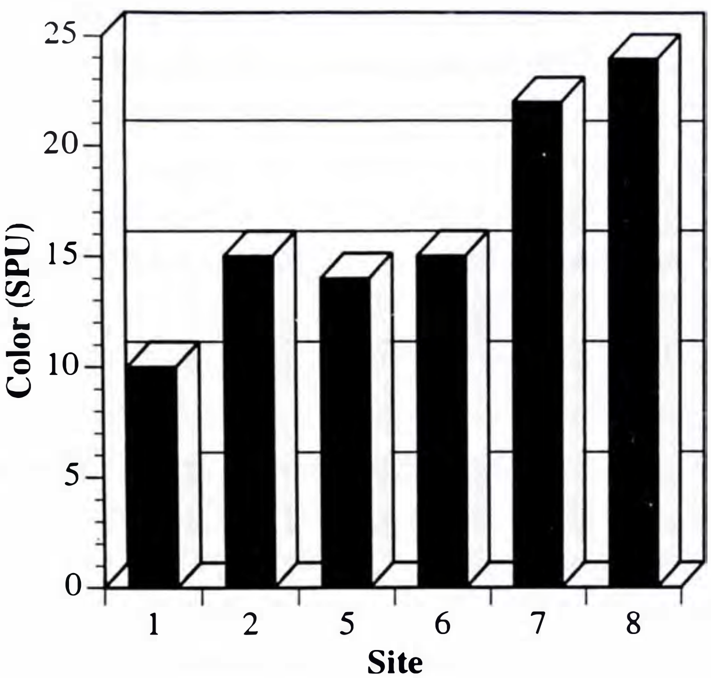

Figure 28. Surface color measurements (SPU) from sites in North Pond (Sites 1, 2, 5 and 6) and Little Pond (Sites 7 and 8). Measurements taken on 30-SEP-96. See Figure 12 for location of sites.

All of the color results for these North Pond and Little Pond sites fell below 25.0 SPU and therefore the water can be considered to be uncolored.

The mean color for North Pond Sites 1, 2, 5, and 6 was 13.5 ± 1.2 SPU and that of Little Pond Sites 7 and 8 was 23.0 ± 1.0 SPU. The mean color in Little Pond is significantly higher (t-test, n=6, p=0.01) than in North Pond. The size of the water body, the amount of wetlands surrounding Little Pond in relation to its small size, and topography could all be factors influencing color of the water. Little Pond had several wetland areas containing macrophytes which probably contributed color-causing substances to the water upon decomposition. Compounds such as tannins, lignins, humic acids, along with other inorganic materials like minerals would be less dilute in this smaller area. The surrounding topography of Little Pond is steep so that runoff would wash directly into the lake, carrying minerals and other substances.

Table 9. MDEP color data (MDEP 1994) for North Pond Characterization Site 1.

Sample Date	Color (SPU)
30-AUG-78	15
30-AUG-78	15
03-SEP-81	15
09-AUG-83	20
03-SEP-94	25

There was little variation in color at different depth levels at Sites 1, 5, and 7 (Figure 29). At Sites 1 and 7 the variation from top to bottom was 3.0 SPU and 2.5 SPU, respectively. The surface and bottom samples of Site 5, 14.0 and 15.0 SPU, respectively, were higher than similar measurements at Sites 1 and 7. However, the mid-depth sample at Site 5, 8.0 SPU, fell within range of the other site values. Because Little Pond is shallow, the water is probably well mixed leading to little variation at different depths.

Overall, the true color values in North Pond and Little Pond are fairly low and indicate that photosynthesis would not be obstructed by color. The water is relatively free of substances in solution that would impede primary productivity.

The highest value recorded was at Clark Brook (Site 14), with a value of 310.0 SPU (Figure 30). Clark Brook had a significant amount of vegetation and the high color values were probably a

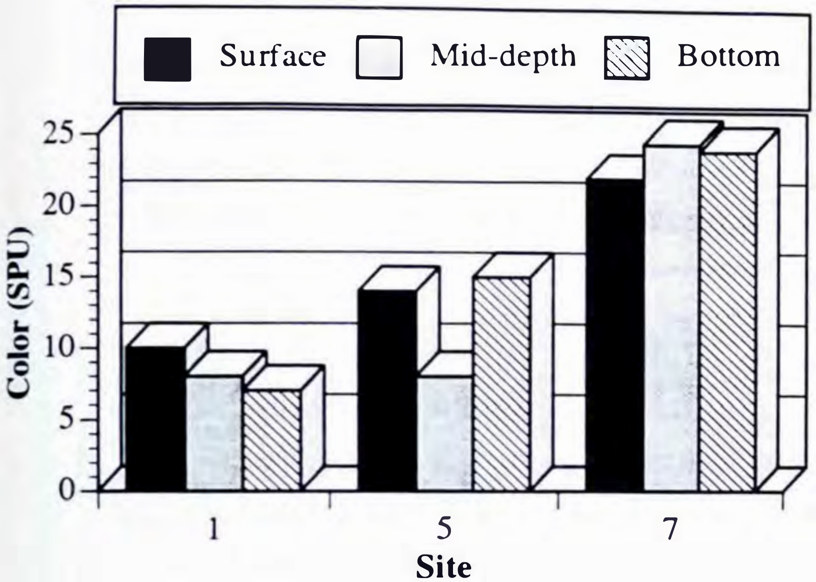

Figure 29. Color measurements (SPU) at different depths at North Pond (Sites 1 and 5) and Little Pond (Site 5) characterization sites. Measurements taken on 30-SEP-96. See Figure 12 for location of sites.

result of plant decomposition products such as tannins and lignins. The only two tributaries which were uncolored (25.0 SPU or less) were Sites 12 and 18.

Site 12 (Leech Brook) had a color value of 18.0 SPU and Site 18 (Great Meadow Stream) was 19.0 SPU. At Site 12, the relatively low value is probably due to less abundant plant life in this stream. Site 18 is the outlet of North Pond and the low color values probably occurred because this water had not passed through any marshy areas where color-causing compounds would have been added. The sample taken at Site 18 was expected to have similar color measurements as the characterization sites within North Pond. The color measurement at Tributary Site 18 of 19.0 SPU, is not a great deal higher than the mean color

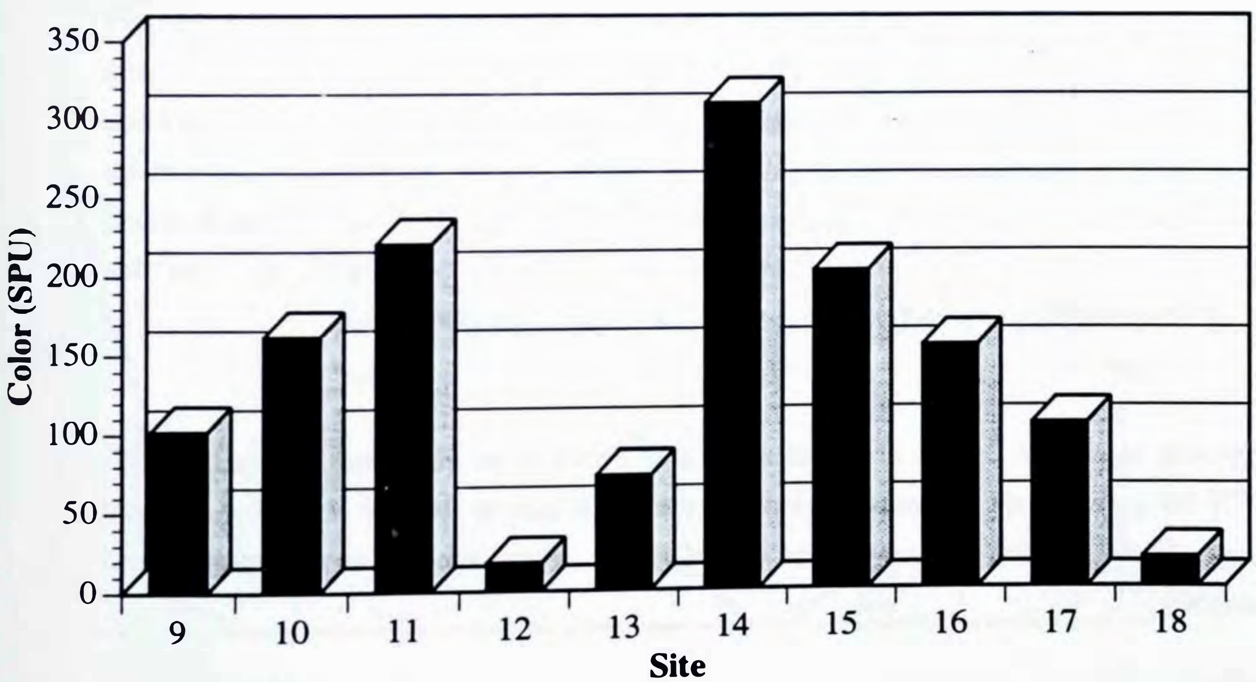

Figure 30. Surface color measurements (SPU) from tributary sites at North Pond. Measurements were taken on 23-SEP-96 except the measurement for Site 10 which was taken on 30-SEP-96. See Figure 12 for location of sites.

value for North Pond of 13.5 ± 1.2 SPU.

In all cases, except Tributary Sites 12 and 18, the tributaries were considerably higher in color than the lake sites. This was probably because there tended to be more vegetation in and around the streams and therefore more decomposition. Tributaries also have less area in which the color-causing compounds could be diluted. The low color values in the characterization sites of the lakes also indicate that the impact of the color from the tributaries is relatively low.

Biotic Measurements

Biotic components of a lake consist of all living organisms in and around the water body, such as aquatic plants in the water, terrestrial vegetation along the shoreline, and fauna living in sediments or in the water column. These species are of interest because their presence and growth patterns may be indicators of the health of a lake (Cole, pers. comm.). The health of a lake often reflects land use patterns in the watershed. For instance, the presence of coliform bacteria in the water can indicate feces that may have been carried into the lake via runoff from agricultural land or residential development. In addition, growth of macrophytes may signal areas of high sedimentation from runoff. High runoff indicates high phosphorus loading potential. The biotic measurements made during this study include surveys of macrophytes and buffer strips as well as testing for the presence of coliform bacteria where deemed appropriate.

Macrophytes

Macrophytes are aquatic plants, both floating and rooted, that grow in shallow, protected water areas rich in sediments and nutrients. They deter shoreline erosion by minimizing wave impact and their root systems aid in stabilizing sediments. Macrophytes also play a role in slowing eutrophication because they absorb nutrients such as phosphorus (Williams 1992). Since macrophytes depend on phosphorus and other nutrients for growth, their presence near the mouth of a tributary or major runoff area can be indicative of high sedimentation rates, and therefore high phosphorus loading. For this reason it is useful to investigate patterns of macrophyte development in the water body.

Methods

Macrophyte growth along the shores of North and Little Ponds was observed by boat on 07-OCT-96 and 30-OCT-96 respectively. Areas of concentrated macrophyte growth were located and lettered A-E on a map of the lakes for the purpose of identification. Plant species were identified and indicated where possible.

Results and Discussion

In North Pond, areas of concentrated macrophyte growth were located primarily along the developed northern and eastern shorelines and near tributary inlets (Figure 31). In the northeast corner of the lake, in the area between Pomleau Island and the shoreline around the mouth of Bog Stream (Site A), there was thick growth of floating macrophytes, particularly tape grass (*Vallisneria*

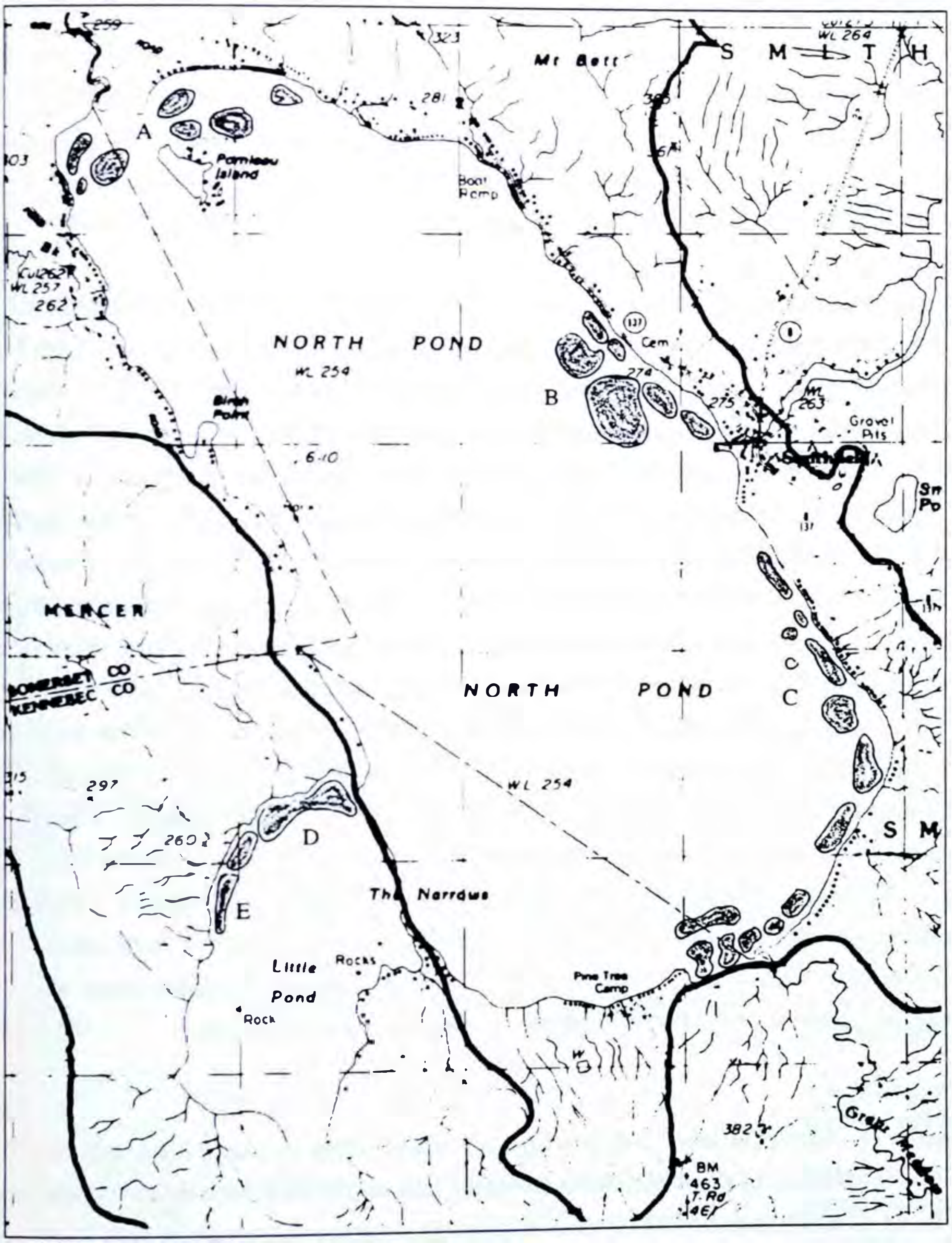

Fig. 31. Areas of concentrated macrophyte growth in North Pond and Little Pond.

americana) and scented pond lily (*Nymphaea odorata*). In the shallow water area just north of Smithfield where Rt. 137 runs parallel to the eastern shoreline (Site B) there was a high concentration of bullrushes (*Scirpus* species) and some pickerel weed (*Pontederia cordata*) growing in a patchy distribution. The shoreline from just south of Smithfield to the outlet at Great Meadow Stream (Site C) was dominated by growth of bullrush and some pickerel weed. The western shore of the lake was found to have relatively little growth of macrophytes compared with the rest of the shoreline. In Little Pond, particularly high concentrations of macrophytes, primarily bullrushes and pickerel weed, were found in shallow water areas in the north end, where the lake borders a large marsh (Site D). Similarly, macrophytes were found in high concentrations along the western shore of Little Pond (Site E), which is also relatively marshy.

The patterns of observed macrophyte growth are probably the combined result of several factors and may suggest areas of high phosphorus loading into the lake. Water depth is a determining factor in the growth of macrophytes; correspondingly, all macrophytes in both lakes were found in the shallowest areas, such as the north end of both lakes and the east side and southeastern end of North Pond. In deeper portions of the lakes, like the western shore of North Pond and the southern end of Little Pond, few or no macrophytes were observed. The western shore of North Pond along the Narrows is very rocky, which is generally not conducive to plant growth (Cowardin et al. 1979). The pattern of macrophyte growth in North Pond suggests that developed shoreline contributes more to nutrient input and sedimentation than nondeveloped shoreline because of greater erosion and runoff due to poor or absent buffer strips. For instance, the thick growth of macrophytes on the eastern shore of North Pond where Rt. 137 runs very close to the water could be due to the steep bank on that side of the road, which facilitates runoff of sediment and nutrients such as phosphorus. Tributaries, especially if they run through developed areas, can be a major source of nutrients and sediments which facilitate macrophyte growth. Water flow in a tributary slows when it comes in contact with the lake, and sediments settle out of the water column (see Lake Tributary Water Quality - Turbidity). This could explain why macrophytes were found near the mouths of most major tributaries in both lakes. In addition, the presence of macrophytes where the lakes border wetlands suggest that these areas are rich in nutrients and sediments as a result of constant flushing of material from the marsh.

Buffer Strips

Buffer strips are bands of vegetation located downslope of cleared areas or along lake, stream, and wetland shorelines which function to filter and store sediment and nutrients from surface runoff before it reaches a water body (Dennis et al. 1989). Buffer vegetation consists of an organic duff layer (pine needles and leaves), trees and bushes, whose roots stabilize the soil layer. This vegetation can be of undisturbed natural origin or replanted with naturally occurring species (Factsheet #5: Cumberland County SWCD and Portland Water District). As surface runoff flows through a buffer area, it is slowed so that it can infiltrate and be stored in spaces between soil particles, where nutrients such as phosphorus are utilized by vegetation (Dennis et al. 1989). Typically, lawns hinder the ability of the soil to absorb water because of the thick mat of grass. Therefore it is necessary to buffer lawns from the shoreline.

To complete the survey of land uses and their impacts on water quality it was necessary to characterize the quality of buffer strips in each section of the shoreline so that the effectiveness of phosphorus and sediment absorption could be assessed. Buffer strips must have a slope no steeper than 30% grade (Dennis et al. 1989) and a minimum width of 100 ft to be fully effective in filtration and footpaths accessing the water should be winding and no greater than 10 ft wide as measured between tree trunks (MDEP 1994b).

Methods

The extent of development and corresponding quality of buffer strips along the shoreline of North Pond was assessed by boat on 07-OCT-96; the shoreline reconnaissance of Little Pond was conducted on 30-SEP-96. The shoreline was divided into sections of similar buffer strip ranking. These sections were of variable length and were evaluated individually. A total of 67 buffer strips were assessed according to guidelines that assign a numerical rating of one to five, with one being the ideal condition of a buffer strip and five being a very poor or absent buffer zone (Table 10). Since individual residences varied in buffer strip quality, the shoreline was divided into sections that received an average buffer strip rating so that an overall idea of what areas were in good condition or particularly in need of improvement could be ascertained.

Table 10. Guidelines for characterizing buffer strip quality along the North Pond shoreline (adapted from BI493 1996).

Quality of Buffer Strip	Rating	Width (ft)*	Slope (%)†	Overstory	Understory
Excellent	1	>100	<30	many, deep-rooted, large trees	very thick layer of shrubs, saplings, etc.
Very Good	2	75-100	<30	deep-rooted, large trees	thick layer of shrubs, saplings
Good	3	50-75	30	scattered trees	thin, scattered shrubs, saplings
Substandard	4	25-50	>30	scattered, spindly trees	little to none; sparse grasses
Poor	5	<25	>30	none/lawn	none/lawn

*distance from shoreline to residences
†slope from shoreline to residences

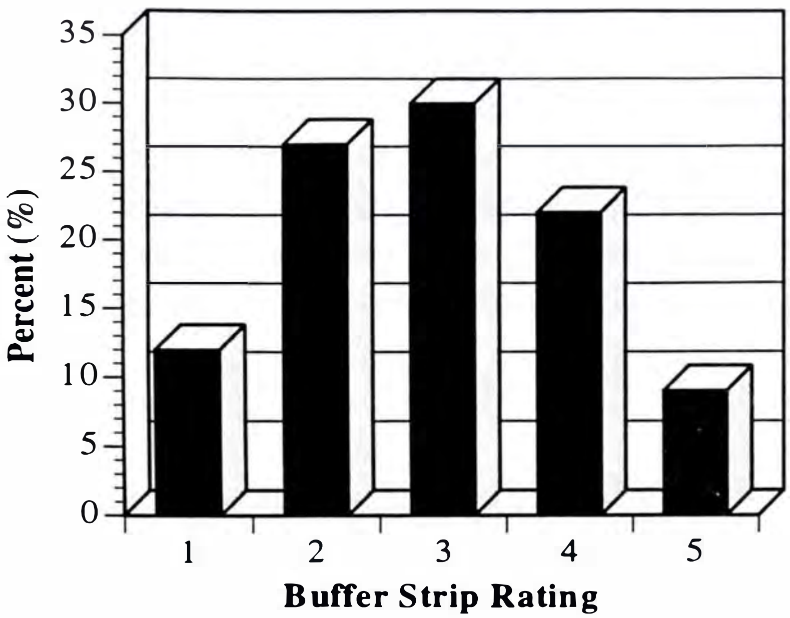

Figure 32. Percent of buffer strips along the North Pond shoreline falling within categories 1-5 as described in Table 3. Range of ratings is from 1 (best) to 5 (worst).

Results and Discussion

In general, more buffer strips were in ideal to average condition as defined by the parameters in Table 10 than were in poor to bad condition (Figure 32). The greatest percentage (30%) of buffer strips along the shoreline of North Pond were found to be in average, or good, condition, while approximately 25% of buffer strips were in very good condition, and 12% were excellent. Substandard buffer strips comprised 22% of the total shore sites assessed while 9% fell under the worst category. The shoreline of North Pond was divided into six sections characterized by an average buffer strip quality. The section of shoreline along Rt. 137 between Smithfield and the intersection with North Shore Drive, where there are numerous summer camps, received an average rating of 3.5 and had several residences where buffer strips were in great need of improvement. The road parallels the water very closely in this area, there is a steeply sloped bank from the road, and many house decks extend over the water. Buffering vegetation along this stretch of shoreline is limited to a few scattered trees. There is also a boat launch ramp in this area which consists of a deteriorating asphalt driveway leading directly from the road into the water. The shoreline between Bog Stream and the intersection of Rt. 137 with North Shore Dr. received an average buffer strip rating of 3. In this vicinity, there are summer residences concen-trated close to the shoreline, beaches with no buffer vegetation, driveways and lawns running down to the water, and erosion off of steep slopes into the lake.

The section of shoreline from Bog Stream to Birch Point received an average buffer strip rating of 2.5. This area had buffer strips in relatively good condition, with the exception of two beaches bordering the water. The section of shoreline from Birch Point to the northern point of the Narrows had the best quality of buffer strips, receiving a rating of 1.8. This area is also the most undeveloped section of shoreline in North Pond. The section from the southern point of the Narrows to Pine Tree Camp was also in relatively good condition, with the exception of some lawns bordering the water. The section of shoreline between Pine Tree Camp and Smithfield received an average buffer strip rating of 3. The primary problem in this area was the presence of multiple beaches.

Little Pond was less developed, with its entire northern and western shorelines relatively undisturbed. Houses were scattered along the southern shore and increasingly concentrated on the eastern shore, especially in the cove formed by the Narrows. In general the southern end of Little Pond had well developed buffer zones. In the more crowded area of the cove formed by the Narrows, buffer strips were in average to worse condition, with much more development such as lawns and beaches bordering the shore.

According to Maine state shoreline zoning ordinances, all new development including principal and accessory structures, roads and driveways, must be at least 100 ft from the normal high water line of the lake (MDEP 1994b). In addition, state ordinances specify that a buffer strip of no less than 100 ft wide shall be left undisturbed along the shoreline. Selective cutting of trees in the buffer zone is allowed as long as a viable, evenly distributed stand of trees and other vegetation is preserved. A point system is used to define a "well-distributed stand of trees and other vegetation", with a rating score of 12 or higher in a 25 ft by 25 ft square (625 ft^2) area being sufficient to maintain the adequate buffer strip. According to this rating system, trees with a diameter of 2 in to 3 in at 4.5 ft above the ground earn 1 point, trees with a diameter measuring greater than 4 in to 12 in earn 2 points and trees with diameter greater than 12 in earn 3 points. State ordinances also specify no removal of vegetation under 3 ft in height, pruning of branches on the bottom third of the tree only, and replacement of native tree species that fall or must be cut because of storm damage, death, or disease. The areas of North Pond shoreline that do not comply with these zoning ordinances and therefore have insufficient buffer strips were probably grandfathered, but should receive attention.

Coliform

The most widely used indicator for fecal water contamination is the coliform group of bacteria present in the gastrointestinal tract of warm-blooded animals (Brock et al. 1994). Scientists have suggested the sole use of *E. coli* as an indicator of fecal pollution, since it can be easily distinguished from other members of the coliform group (Britton 1994). Most coliform bacteria are pathogenic with respect to humans which necessitates monitoring and regulating coliform levels in water sources. Faulty septic systems and runoff from neighboring farms and pasture areas are the primary sources of animal excrement contamination in a lake system. Feces-polluted waters not only create a public health concern, but they also contribute to the overall eutrophication process by loading concentrated amounts of phosphorus into the lake (Chapman 1992).

Methods

Coliform sampling sites were chosen on the basis of potential fecal pollution from neighboring land areas. Sampling was not done in the North or Little Pond subwatersheds because there was little evidence for contamination. Little Pond subwatershed lacks substantial shoreline residences and livestock pastures while North Pond does include a fairly concentrated residential area in Smithfield which could contribute to fecal loading via improper septic devices. However, shoreline surveys demonstrated that there were few, if any, apparent problems with septic systems in the Smithfield area (see Watershed Land Use: Roads and Residential Areas).

The Serpentine subwatershed in the past has been known to load high levels of fecal contaminants into the Serpentine from agricultural and livestock areas in the northern end of the watershed, specifically after high rainfall levels (BI493 1991). Cattle were observed grazing in or at the waters edge near the confluence of Sucker and Clark Brooks in 1991 (Cole, pers. comm.). Cattle were observed grazing adjacent to the confluence in the fall of 1996 (Christensen pers. comm.).

Due to the past history of high coliform counts in the Serpentine subwatershed, Site 15, just south of the Sucker-Clark confluence, was designated as the coliform sampling site for the Serpentine. On 23-SEP-96, water from Site 15 was collected by CEAT and brought to Northeast Laboratory within 24 hours of collection for coliform analysis. The fecal coliform membrane filter technique with Endobroth media was used by Northeast Laboratory to ascertain a coliform count (Clesceri et al. 1989). Results were measured in the number of colonies per 100 ml of water.

Results and Discussion

Site 15 yielded a coliform count of 7 colonies per 100 ml. This level is well below the EPA's guidelines of 1000 colonies per 100 ml for safe recreational use of the water. *E. coli* was found to be present which means that recent fecal contamination had occurred, most likely due to defecation from livestock. Improperly managed septic systems are not a factor in determining coliform levels at Site 15 since there are no nearby residences and since most of the residential areas are located in the North Pond subwatershed, rather than in the Serpentine.

The coliform count at Site 15 has declined over the years. At approximately the same time of year in 1991, a count of 12 colonies per 100 ml was noted at the confluence of Sucker and Clark brooks (BI493 1991). This trend may be explained by several factors. A difference in coliform levels may be due to random variation in the samples, or perhaps agricultural and livestock activity has either declined over time or farmers in the area have switched to techniques that lessen the impact of fecal pollution on water quality. Examples of these techniques are fencing in cattle from water bodies and maintaining proper manure storage facilities.

Given that most of the excrement pollution occurs by leaching of animal and human wastes, rainfall and soil types have a large impact on fecal loading rates into a lake. At the confluence of Sucker and Clark Brooks, a coliform count of 2640 colonies per 100 ml was recorded in 1991 immediately after a storm event (BI493 1991). These data show that high levels of precipitation can dramatically affect the potential fecal contamination of a lake. Since the coliform test for the North Pond study was not analyzed after a substantial rainfall, there is a possibility that 7 colonies per 100 ml at Site 15 may be misrepresentative of the true runoff potential that can exist after a storm. If this is the case, severe runoff could contribute a high level of excrement pollution to the North Pond lake system.

Tributary Storm Event

A storm event measures the amount of nutrients added to tributaries during and after a period of rainfall. It is an essential part of a water quality testing program since the amount can often exceed normal tributary inputs (EPA 1988). Eventually, these nutrients reach the lake and promote eutrophication.

A heavy rain can wash large amounts of sediment into a tributary. This input of sediment will alter the turbidity levels and nutrient budget of the stream. Areas which drain into these tributaries are often susceptible to erosion due to development and agricultural activity. Stream beds that suffer from erosion contribute more sediment than a stream bed with little erosion. An analysis of flow, turbidity, rainfall, and phosphorus input is necessary to assess the effect of erosion and runoff upon tributary and lake water quality.

Physical Measurements

Flow Rate

Tributary flow rates during and after rainfall give an indication of the amount of water entering the tributary via runoff and direct precipitation. By comparing the change in flow rates with respect to precipitation levels at each site, a direct relationship between runoff potential and rainfall may be derived.

Methods

Flow rate measurements for the 20/21-OCT-96 storm event were taken at Tributary Sites 9, 11, 12, and 17 using a Marsh McBirney, Inc. Flowmate flow meter to assess the amount of water flowing into North Pond as a result of rainfall. At each site, a transect perpendicular to the flow of the tributary was assigned and divided into two or three sections depending on the width and contour of the stream (see North Pond and Little Pond Water Quality Assessment: Lake and Tributary Water Quality - Tributary Flow Rates). Large streams with an uneven stream bottom were generally assigned three sections while small streams with a relatively uniform bottom were generally assigned two sections (Appendix B). At each section, flow (ft^3/sec), depth (ft), and width (ft) were measured at approximately half hour intervals during the storm event. Sites 9, 11, 12, and 17 were measured for 6.83 hrs, 6.5 hrs, 6.7 hrs, and 8.0 hrs respectively.

Calculations involving total flow at each sampling site were derived in previous sections (see North Pond and Little Pond Water Quality Assessment: Lake and Tributary Water Quality - Tributary Flow Rates). The sum of the flow of the individual cells is equal to the overall flow of the tributary for each time interval.

Results and Discussion

The total accumulation of rainfall for each storm site was slightly less than one inch and the majority of the rainfall occurred during the last hours of the storm event. This trend was evident for Site 11 and Site 12 (Figure 33). When precipitation increased over the last two hours, the flow rate increased dramatically. However, Site 9 and Site 17 did not show a clear relationship between rainfall and flow. The flow patterns for these sites seemed to be random fluctuations that did not correspond

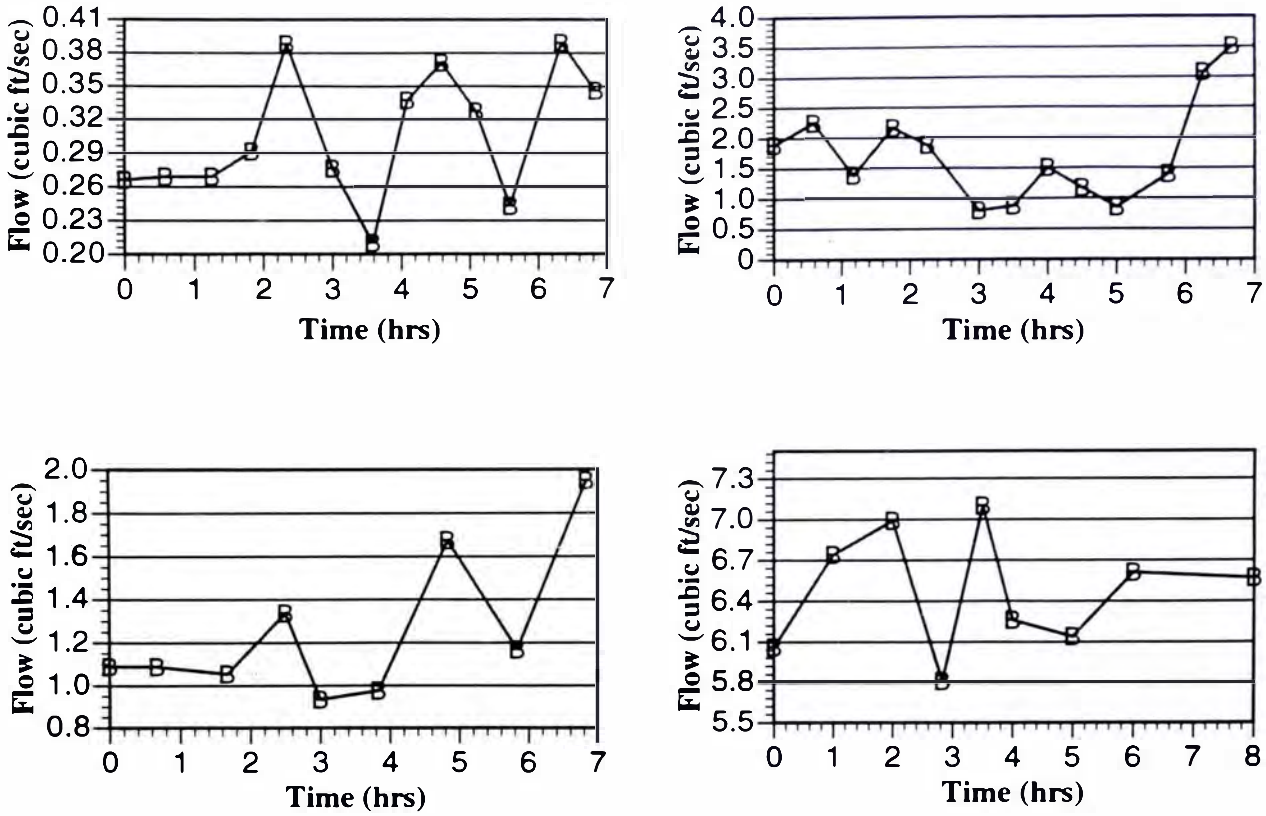

Figure 33. Flow rate measurements (cubic ft/sec) of Sites 9, 11, 12, and 17 during the storm event of 20-OCT-96. See Figure 12 for location of sites.

with precipitation levels. Different types of soils with different saturation coefficients could have caused these varied flow rates. Rainfall may have differed over different drainage areas as well. It is also probable that the flow meter was not placed in the exact transect position for every sampling period. A regression analysis was conducted on the relationship between flow and precipitation to assess the validity of the storm event (see Tributary Storm Event - Precipitation). Storms increase the amount of runoff flowing into a watershed. This relationship explains why Site 9 and Site 12 experienced an increase in flow as rainfall increased. Bog Stream (Site 9) is a relatively large stream in comparison to other tributaries in the watershed, but its flow is quite slow. Leech Brook (Site 12), located in the northeastern corner of the lake, flows directly into North Pond, but is smaller in width and depth than Bog Stream. However, the flow during the storm event did correlate with rainfall (see Tributary Storm Event - Precipitation). In effect, both large and small streams in the watershed show strong correlations with rainfall. There are several reasons why Pattee Brook (Site 11) and the Serpentine (Site 17) showed little response to rainfall. Pattee Brook is a relatively small stream with a bowl-like basin. It was noted during the storm event sampling of Pattee Brook that debris was blocking some of the culverts, restricting flow. This observation sheds light on the unresponsiveness of flow patterns to rainfall since overall flow was restricted by a barrier. The Serpentine has been shown to exhibit flow reversal, creating a backflush into East Pond during and right after large storms

(BI493 1991). However, it was noted that backflushing generally occurred with precipitation greater than 2.6 in. The entire storm event for North Pond accumulated roughly one inch of rainfall. Backflushing probably did not occur during the storm event since the extensive wetlands that border the Serpentine act as sponges and do not respond quickly to sporadic bursts of precipitation (Firmage, pers. comm.).

Flow values during the storm event ranged from 7.10 ft^3/sec (Site 17) to 0.80 ft^3/sec (Site 11). The higher flow rates can be attributed to the Serpentine's (Site 17) larger land area drained as compared to the other sites. Normal flow and storm flow (maximum values) were compared across Sites 9, 12, and 17. Site 12 and Site 17 both displayed significantly larger flow values during the storm event (1.95 ft^3/sec and 7.10 ft^3/sec respectively) than in the absence of rain (0.98 ft^3/sec and 1.20 ft^3/sec respectively). The storm flow of Site 9 (0.39 ft^3/sec) barely surpassed its normal flow (0.38 ft^3/sec). Flow rates normally increase after a storm event since water in the form of runoff is being added to the stream, increasing the velocity and depth of the basin.

Turbidity

Turbidity measures the amount of suspended material in the water column. An increase in flow normally leads to an increase in turbidity levels (Chapman 1992). Sediment from runoff and from the bottom of the tributary is stirred up and suspended in the water column due to an increase in velocity of the stream. Sediment carried by streams is usually deposited directly into the lake, forming deltas, or mounds of sediment. This process is due to a decrease in the overall flow at the mouth of the tributary which causes sediment particles to precipitate out of the water column.

Methods

Turbidity (FTU), like flow, was also measured for Storm Sites 9, 11, 12, and 17. Surface grabs were taken every half hour for the 20/21-OCT-96 storm event. Samples were taken in the middle of the tributary along the transect line. The turbidity samples were then analyzed in the Colby Environmental Laboratory using the HACH DR/3000 Spectrophotometer Absorptometric method for turbidity (Clesceri et al. 1989).

Results and Discussion

Turbidity showed a definite correlation with rainfall. As the rainfall level increased over the last hours of the storm event, Site 9 and Site 12 showed expected increases in turbidity levels. However, Site 11 and Site 17 fluctuated without respect to the precipitation patterns. Trends in normal turbidity measurements on 23-SEP-96 were compared with maximum storm event levels on 20/21-OCT-96 (Figure 34). Site 11 and 12 were the only tributaries that showed greater turbidity values during the storm than in the absence of rain. At these sites, turbidity levels increased as a result of sediment input from erosion. Site 9 and 17, however, showed surprisingly lower turbidity values during the storm event than without rainfall. Site 9 displayed relatively equal levels of turbidity for both storm and normal sampling dates. The shallow slope and mixture of sandy and fine loams in the drainage area of this tributary sieve out sediment particles during rainfall periods that would otherwise reach the lake. Sediment loading through erosion at this site, therefore, is probably minimal. At Site 19, the high levels of turbidity (14 FTU) in the absence of rain may be attributed to the observation that the dam controlling outflow from the Serpentine into North Pond was open at the sampling date 23-SEP-96 (see North Pond and Little Pond Water Quality Assessment: Lake and Tributary Water Quality - Tributary Flow Rates). Sediment on the basin floor could have been stirred up into the water column since the dam was open, increasing turbidity levels. However, during the storm event, the dam was open and turbidity readings were lower (8 FTU) for the Serpentine. The difference in turbidity levels may be attributed to the dam being opened long enough so that some sediment was already flushed out, leaving less sediment to flush.

Precipitation

Rainfall determines the amount of runoff that collects in a stream bed over time. Precipitation is an essential parameter in a storm event, and may influence flow and turbidity levels of tributaries.

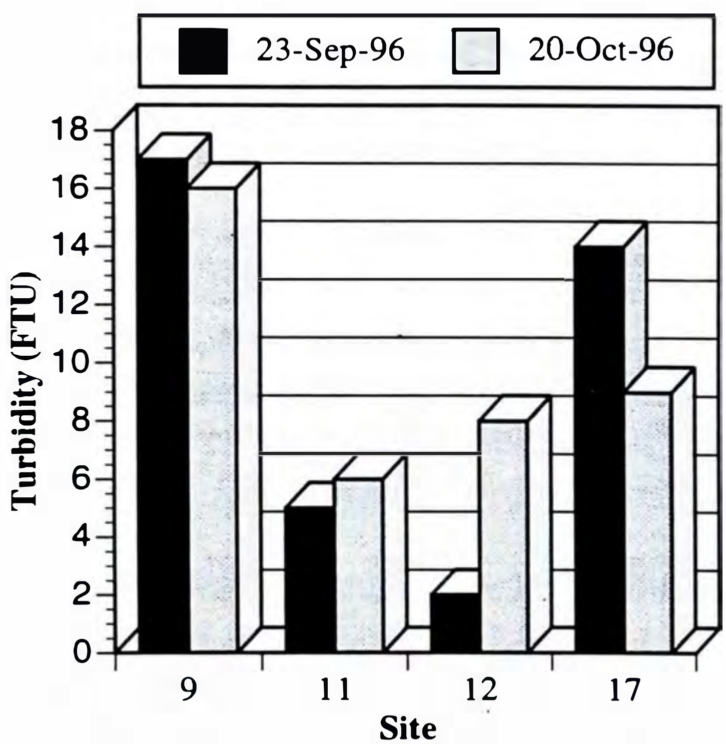

Figure 34. A comparison of turbidity (FTU) measurements from tributary Sites 9, 11, 12, and 17 on 23-SEP-96 and the storm event of 20-OCT-96. Maximum values of the storm event were used. See Figure 12 for location of sites.

Methods

Precipitation was measured every half hour during the storm event. A rain gauge was placed at all four sites to measure variation in rain across storm sites. Rainfall was recorded as total accumulation in inches.

Results and Discussion

Total accumulation of rainfall varied among storm sites. Sites 9, 11, 12, and 17 recorded total rainfall values of 1.02 in, 0.92 in, 0.70 in, and 0.70 in, respectively. Usually storm events that receive over an inch of rainfall are considered valid as soil becomes saturated and can no longer absorb the precipitation (Firmage, pers. comm.).

It was necessary to assess

the validity of the storm event through simple regression analysis. Only one of the sites surpassed this minimum one inch level and rainfall was fairly sporadic. A regression measures the degree of predictability that an independent variable, such as rainfall, has over a dependent variable, such as flow. If the dependent variable y can be determined by a straight line relationship from the independent variable x, then y is totally dependent on x and receives an r-value equal to one. However, if there is no relationship between x and y, then the r-value should equal zero. A r-value of -1 means that an inverse relationship exists between the two variables: as x increases, y decreases. However, most regression analyses normally fall between one and negative one.

Both flow and turbidity, dependent variables, were measured against rainfall, the independent variable, over time for each site using simple regression analysis (Table 11). Of the four sites, Leech Brook (Site 12) had the highest dependency on rainfall for flow (r=0.744, p=0.0267). Pattee Brook (Site 11) showed less of a relationship, but still displayed significance (r=0.523, p=0.022). The remaining Sites 9 and 17 did not show a significant relationship between rainfall and flow. Leech Brook may respond to changes in rainfall levels quicker than the larger tributary sites because of its small size and steep slopes of 9% to 30% in the drainage basin (see Watershed Land Use: Slopes in Watershed). A lag time between rainfall and flow response may exist for larger tributaries with larger basin areas, such as the Serpentine (Site 17). If this is the case, then the regressions may be inaccurate measurements for flow depending upon precipitation since the lag time is not taken into account.

Table 11. Regression analysis of the 20-OCT-96 storm event measuring the dependency of turbidity (FTU) and flow (ft^3/sec) on rainfall (in) recorded at each site. See Figure 12 for site locations.

Storm site	Flow vs rainfall		Turbidity vs rainfall	
	r-value	p-value	r-value	p-value
9	0.397	0.1788	0.865	0.0001*
11	0.523	0.0012*	0.331	0.3004
12	0.744	0.0216*	0.671	0.0477*
17	0.076	0.8454	0.017	0.7400

* significant difference in slope of regression line (p<0.05)

When comparing turbidity versus rainfall, Pattee Brook (Site 9) showed the greatest dependency on rainfall (r=0.865, p=0.0001) while Leech Brook (Site 12) followed close behind with a significant regression (r=0.671, p=0.048). A similar trend in turbidity occurred where response to rainfall was only seen in the small tributaries while Bog Stream (Site 11) and the Serpentine (Site 17) showed relatively no response to rainfall when lag times were not taken into account. Thus, the validity of the storm event may only hold for small tributary sites.

Chemical Analyses

Phosphorus

Bound up in soil and organic matter, phosphorus is released into the surrounding environment when the sediment is disturbed (MDEP 1989). Human development and natural events such as rainstorms can disrupt the cohesion of the sediment and flush significant amounts of phosphorus into surrounding tributaries. Since incoming tributaries have a direct impact on lake water quality, the concentration of phosphorus in tributaries greatly influences the degree of eutrophication occurring in the lake body. During periods of prolonged rainfall, the soil can become supersaturated and additional precipitation becomes runoff, transporting phosphorus bound to soil particles into nearby streams (MDEP 1992). The input of large volumes of water from runoff consequently increases tributary flow rate and turbidity levels. One large storm event may produce a nutrient income equal to several months of income during normal flow (EPA 1988). The relative degree of phosphorus loading during and following a storm event is the product of several factors including development patterns around the tributary site, frequency, length, and intensity of the storm.

Methods

Water samples were taken throughout the storm event from four tributary sites. The sites, all located in the northern half of the watershed, included Site 9 (Pattee Brook), Site 11 (Bog Stream), Site 12 (Leech Brook), and Site 17 (Serpentine). During the eight hour storm event period, surface grab water samples were collected approximately every half hour from each of the four tributary sites. The water samples were then packed in ice and returned to the Colby Environmental Laboratory for total phosphorus analysis (see North Pond and Little Pond Water Quality Assessment: Lake and Tributary Water Quality - Phosphorus). The samples were analyzed for total phosphorus on 24-OCT-96.

Composite samples of all four sites were analyzed to estimate the average amount of phosphorus added by each tributary site throughout the duration of the storm event. Each 50 ml composite sample was made up of water that was a mixture of all the water samples taken at an individual site throughout the duration of the storm event. The proportion of each sample added to the composite was based on the flow rate of the tributary measured at the time the sample was taken. The sum of the flow rates at each sampling time interval was calculated for each site in order to determine the total water flow during the storm event for individual sites. The individual flow rates for each sampling time interval were then divided by the total storm event water flow for that site to derive a percentage. That percentage corresponded to the proportion of sample volume to be added to the 50 ml composite sample for each site.

The first water sample at Pattee Brook (Site 9) was collected at 8:10 PM and had a total phosphorus concentration of 10.5 ppb (Figure 35). Total phosphorus concentrations generally increased over the eight hour period, however, the slope was neither constant nor consistent. The peak concentration of 30.7 ppb was reached at 1:15 AM after a series of lesser peaks associated with lower total phosphorus levels.

The first phosphorus sample for Leech Brook (Site 12) was collected at 7:40 PM and had a total phosphorus concentration of 16.1 ppb (Figure 36). After a brief lag period, phosphorus concentration reached its peak at 9:20 PM at a concentration of 26.6 ppb. Subsequently there was a general trend of decreasing phosphorus levels during the next five hours with the exception of two minor peaks at 11:30 PM of 23.2 ppb and 1:30 AM at 15.3 ppb.

The Serpentine (Site 17) had a relatively high initial reading at 7:00 PM of 19.1 ppb, which was the peak concentration at the Serpentine during that sampling period (Figure 37). Total phosphorus levels remained fairly constant until 10:30 PM when phosphorus levels were at their lowest concentration of 9.9 ppb. Over the next 2.5 hours, total phosphorus concentrations increased gradually. Toward the end of the sampling period, total phosphorus concentrations dropped slightly.

The composite analysis showed Site 9 to have an average total phosphorous concentration of 11.3 ppb (Figure 38). Sites 12 and 17 had composite concentrations of 12.3 ppb and 12.7 ppb, respectively, and Site 11 exhibited a composite concentration of 12.0 ppb.

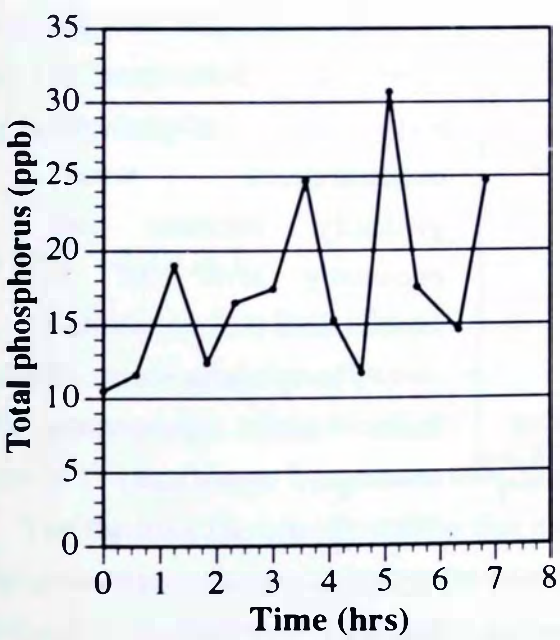

Figure 35. Total phosphorus concentrations (ppb) for Pattee Brook (Site 9) during the eight hour tributary storm event sampling on 21 and 22-OCT-96.

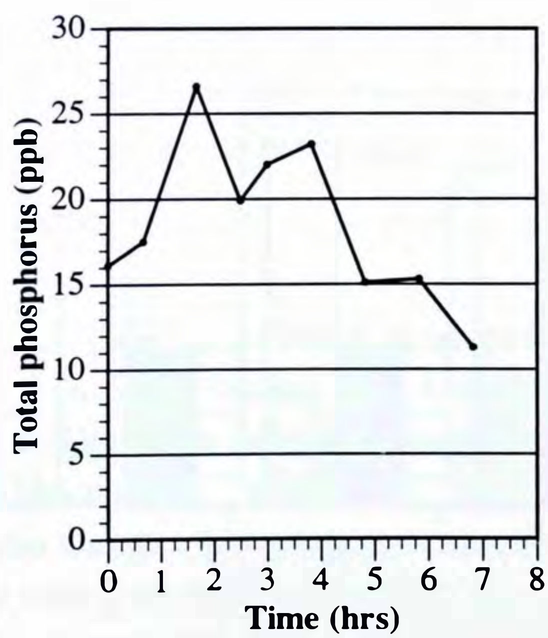

Figure 36. Total phosphorus concentrations (ppb) for Leech Brook (Site 12) during the eight hour tributary storm event sampling on 21 and 22-OCT-96.

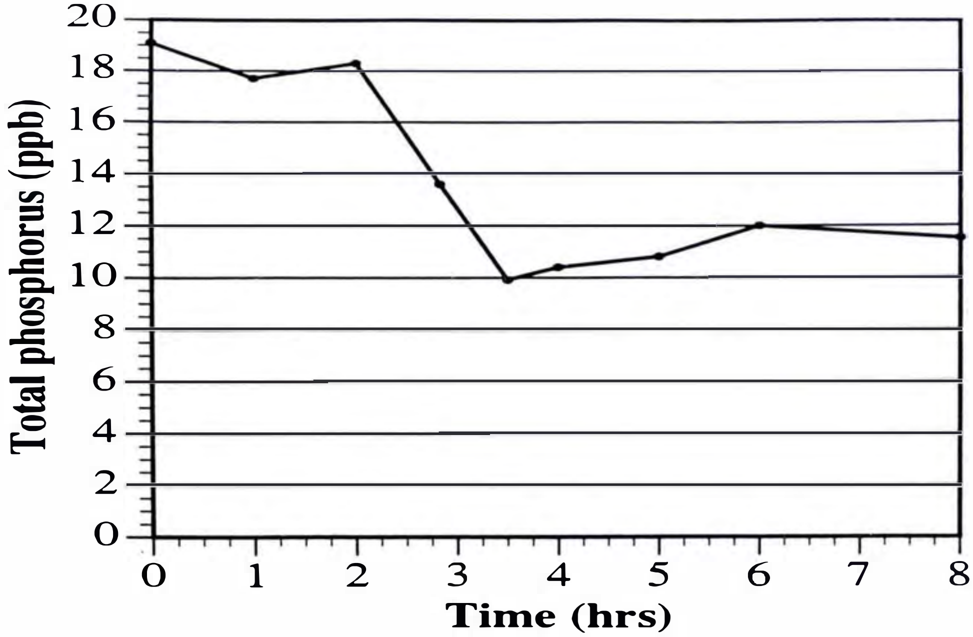

Figure 37. Total phosphorus concentrations (ppb) for the Serpentine (Site 17) during the eight hour tributary storm event sampling on 21 and 22-OCT-96.

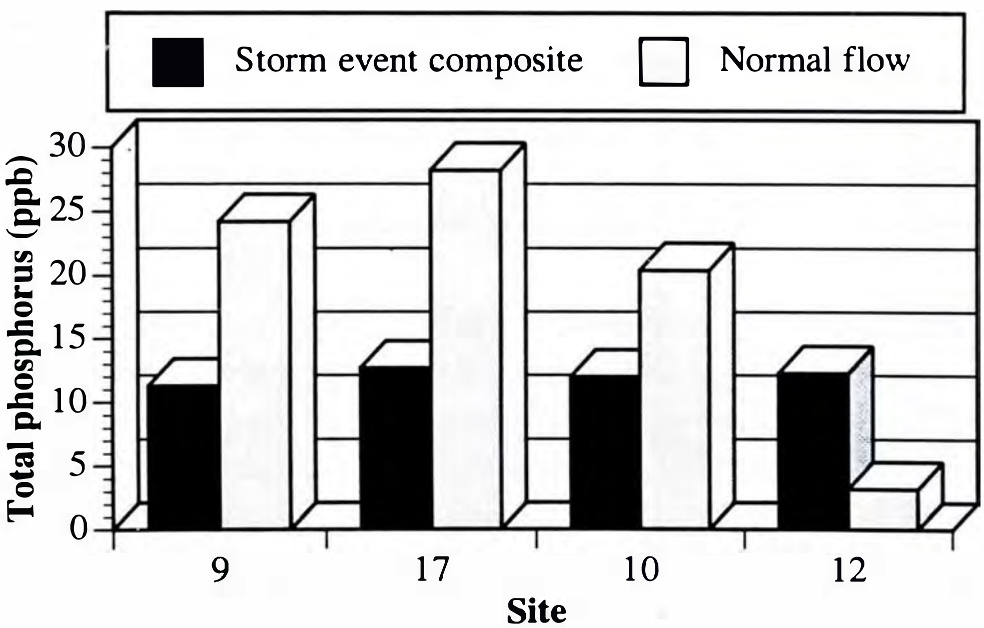

Figure 38. Total phosphorus concentrations (ppb) for storm event composite samples and for samples taken during periods of normal flow at four tributary sites during the eight hour storm event on 21 and 22-OCT-96.

Initial storm event predictions were based on tributary dynamics and phosphorus loading trends as well as storm event data from a survey of Long Pond, South Basin (BI493 1996). Storm event total phosphorus concentrations were expected to follow a general pattern that included an initial lag period prior to soil saturation. The lag period, exhibiting normal flow total phosphorus levels, would be followed by the peak phosphorus concentration once the accumulated phosphorus reservoir started to flush from the sediment into the tributary. Subsequently, total phosphorus concentrations would gradually decrease and eventually level off at normal flow concentrations.

The sporadic nature of these total phosphorus readings, specifically at Sites 9 and 12, may be attributed to the sporadic rainfall pattern (see Tributary Storm Event - Precipitation). High total phosphorus concentrations may correspond to periods following heavy precipitation, while low points may have occurred following periods of little to no precipitation. Overall precipitation levels did not reach the minimum necessary for there to be a significant impact. These results do not coincide with the predicted pattern and seem to contradict expectations that a storm event would increase total phosphorus concentrations in the tributary.

Site 9, however, generally has a very low flow rate, and water tends to accumulate and stagnate. In such a stagnant environment, total phosphorus levels would naturally be high. In the event of a storm, the tributary would become diluted by precipitation and phosphorus would begin to be flushed downstream, thus accounting for lower total phosphorus concentrations. Site 17 showed concentrations that were the most consistent with the predictions described earlier.

The composite reading for Site 9 was 11.3 ppb. However, normal flow readings measured prior to the storm were significantly higher with phosphorus concentrations at 24.2 ppb. The composite analysis also showed higher phosphorus concentrations at Sites 17 and 10 during periods of normal flow (28.2 ppb and 20.4 ppb, respectively) than during the storm event when their phosphorus levels averaged 12.7 ppb and 12.0 ppb, respectively. Site 12 was the only site that demonstrated a lower phosphorus concentration prior to the storm.

The results of the phosphorus analyses from the storm event do not suggest a significant input of additional phosphorus into the tributaries leading into North Pond. However, possible discrepancies between expected results and the actual results may be the product of sampling error, variable tributary conditions, and insufficient rainfall. If sediment had been picked up during water sampling, phosphorus concentrations may have potentially been inflated due to contamination, and would therefore give an inaccurate representation of total phosphorus levels. In sites such as Bog Stream (Site 11), high phosphorus concentrations may be due to high levels of decomposition and its stagnant, marshy environment which is capable of trapping large masses of sediment.

WATER BUDGET

The water budget for a lake yields the net input (I_{net}) of water to the lake from terrestrial runoff, tributaries, upstream lakes or ponds, and precipitation, as well as the flushing rate. A water budget is useful in assessing a lake's sensitivity or susceptibility to algal blooms and eutrophication (Cole, pers. comm.). The I_{net} shows how much water flows into a lake system.

The flushing rate measures how fast input is cycled through a lake ecosystem. Specifically, the flushing rate is the number of times the total volume of water in the lake is replaced in a year. The I_{net} is defined as the net volume of water that enters a lake through precipitation and runoff, minus the volume of water lost through evaporation. The general equation for net input (units in square meters) is as follows:

$$I_{net} = (\text{Runoff} \times \text{Land Area}) + (\text{Precipitation} \times \text{Lake Area}) - (\text{Evaporation} \times \text{Lake Area})$$

Values used in the North Pond I_{net} are as follows:

Runoff = 0.622 m/yr

Precipitation = 1.01 m/yr

Evaporation = 0.56 m/yr

North Pond surface area = 9,123,000 m^2

North Pond watershed area = 30,920,000 m^2

Average Depth = 4.07 m

The North Pond watershed and lake areas were calculated using ZIDAS. North Pond watershed and subwatershed boundaries were obtained from a MDEP topographical map (see Watershed Land Use: Land Use Methodology). The runoff constant is a ten-year average for runoff in the Kennebec River Basin from 1958 to 1967 (BI493 1995). The evaporation constant was taken from a study in the lower Kennebec River Basin (Prescott 1969). The average depth was calculated from unpublished bathymetric data obtained from MDEP. The precipitation average was a ten-year average of monthly rainfall data from two NOAA weather stations, located in Augusta and Waterville (NOAA 1985 to 1995). These stations were chosen because North Pond is roughly equidistant between the two. Each station measured precipitation on a daily basis by collecting rain and snow in an 8 in rain gauge.

The flushing rate is influenced by inputs from upstream lakes, as well as tributaries within the watershed. East Pond, Little Pond, and the Serpentine contribute to the flushing rate of North Pond. The surface areas for Little Pond and the Serpentine were obtained using ZIDAS methodology. The I_{net} values for Little Pond and the Serpentine were then calculated in the same manner as described above for North Pond. The land and lake areas for East Pond were obtained from a previous study (BI493 1991). The current ten-year precipitation average, runoff constant, and evaporation constant were then used to calculate the I_{net} for East Pond.

The flushing rate is equal to the sum of the upstream I_{net} values and the Q value of North Pond divided by the total volume of the lake basin. Q is the I_{net} of North Pond plus the volume of water lost through evaporation in one year. The flushing rate for North Pond was calculated as follows:

$$\textbf{Flushing Rate} = \frac{\text{Q North Pond} + I_{net}\text{ East Pond} + I_{net}\text{ Little Pond} + I_{net}\text{ Serpentine}}{\text{North Pond Surface Area x Average Depth}}$$

The I_{net} for North Pond was calculated to be 23,296,582 m^3/year (Appendix D). The flushing rate of North Pond is 1.36 flushes per year. This is a relatively slow flushing rate for a lake of this size (Bouchard, pers. comm.). The slower a flushing rate is, the more time it takes for water to move through the lake basin, giving the nutrients more time to collect in the water column. The longer nutrients are suspended in the water column, the higher the productivity of the lake and the higher the risk of eutrophication. If the nutrient loading rate increases in North Pond, the low flushing rate for this lake would facilitate higher productivity and increase the risk of an algal bloom and possible eutrophication.

The MDEP calculated a flushing rate of 1.00 flushes per year for North Pond (MDEP 1994a). The difference between this value and the value calculated in this study is most likely due to variations in methodology for measuring lake and land area. The values reported in this study were calculated using a current ten-year average for precipitation and land areas were digitized ten times to account for variability in tracing. MDEP data is collected mostly through volunteer monitoring programs. They observe and monitor numerous lakes and, therefore, use a simpler methodology for calculating the water budget. MDEP also does not use a current ten-year precipitation average. Both values are slow flushing rates in comparison with other lakes and suggest an increased sensitivity to nutrient loading and algal blooms.

The other lakes in the Belgrade chain have low flushing rates, with the exception of Messalonskee Lake and Long Pond, North and South Basins (MDEP 1994a, BI493 1995, BI493 1996; Table 12). The location of Long Pond near the end of the Belgrade chain means that this lake receives all of the input from upstream lakes. A high flushing rate for a lake in this location is therefore not surprising. The lowest flushing rate was found in East Pond (BI493 1991), followed by Great Pond (MDEP 1994a), the largest lake, and Salmon Lake (BI493 1994a), located at one of the heads of the chain. Salmon Lake has the smallest lake surface area of the chain and, consequently, has the smallest volume of water which results in a slow flushing rate. North Pond and Messalonskee Lake (MDEP 1994a) have similar flushing rates which are slightly higher than East Pond, Great Pond, and Salmon Lake's rates. North Pond is located at one of the heads of the chain, as is Salmon Lake; but North Pond has a relatively large watershed, resulting in a larger volume of water flowing through the North Pond system. Messalonskee Lake is the bottom of the Belgrade chain, but it is the second largest lake after Great Pond. The flushing rate for Long Pond, North and South Basins are higher, even though both lakes are located at the bottom of the chain. The faster flushing rate of these two ponds can be attributed to their location, as they are the source of inflow of water into the lake chain.

East Pond comprises 18% of the total volume of water that passes through North Pond (Figure 39). Data suggest that the presence of industrial and human developments put East Pond at risk for high phosphorus concentrations and algal blooms (BI493 1991). In 1987, East Pond experienced a severe algal bloom, which resulted in a loss of clarity and an increase in chlorophyll a and biomass. There have been regular blooms in recent years, but currently East Pond is improving (Joly, pers. comm.). A slow flushing rate, however, inhibits a rapid recovery for this lake (Table 12). Water clarity for East Pond has been as low as 1.4 m. At present, water clarity is 3.8 m. A 1994 epicore sample of total phosphorus was measured at 21 ppb, while a surface grab yielded 18 ppb (MDEP 1994a). Due to the high nutrient content of East Pond's water, the large percentage of water contributed from East Pond to North Pond increases North Pond's risk of algal blooms and eutrophication.

Table 12. Comparison of water budget characteristics of lakes in the Belgrade Lakes region.

Lake	Watershed Area (m^2)	Lake Surface Area (m^2)	Volume (m^3)	I_{net} (m^3/yr)	Flushing Rate (flushes/yr)
North Pond[a]	30,920,000	9,123,000	37,148,856	23,296,582	1.36
East Pond[b]	10,949,000	6,769,624	33,848,120	9,880,216	0.29
Great Pond[c]	-----	33,130,000	240,649,445	-----	0.43
Salmon Lake/ McGrath Pond[d]	23,126,300	4,657,500	28,410,750	16,480,434	0.58
Messalonskee Lake[c]	-----	14,190,000	136,209,103	-----	1.59
Long Pond, North Basin[e]	24,164,589	5,212,900	46,276,529	17,167,676	2.80
Long Pond, South Basin[f]	33,700,000	5,220,000	46,980,000	23,273,902	4.50

a. See Appendix D.
b. BI493 1991
c. MDEP 1994
d. BI493 1994
e. BI493 1995
f. BI493 1996

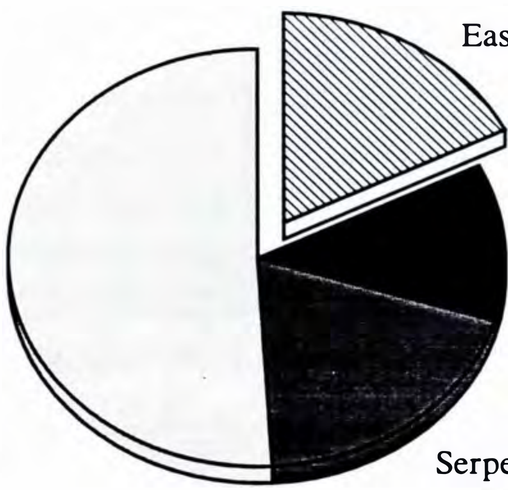

Figure 39. Percent composition of the total water budget for the North Pond watershed, including inputs from Little Pond, the Serpentine, and East Pond.

Watershed Land Use

Phosphorus loading is the addition of phosphorus to a body of water and is due to both natural causes and human activity. Human induced phosphorus loading is typically much larger than natural loading (BI493 1996). The addition of phosphorus can have not only environmental, but also economic and recreational impacts (Moore 1992). The lake or pond may lose its appeal to swimmers, boaters and property owners along the shoreline due to algal blooms. Several seemingly harmless activities can together lead to phosphorus overloads (see Introduction: Phosphorus and Nitrogen Cycles).

This study attempted to examine land use patterns in the North Pond watershed and to identify specific sources of concern. Land use was quantified and used to calculate phosphorus loading capabilities to determine areas for future monitoring or maintenance. Within this study, an investigation of residential areas and the effects of zoning and town ordinances was used, as well as an examination of soil types and erodibility with regard to land use.

The area for each land use type in the North Pond watershed and their respective characteristics were used in a phosphorus loading model to calculate present and predict future levels of phosphorus loading into the lake. This model established phosphorus contributions for each land use which were then used to make recommendations concerning their maintenance and control.

ZONING AND DEVELOPMENT PATTERNS

Each town in the watershed of North Pond has any of three zones along their shorelines: limited residential recreation zone, stream protection zone, and resource protection zone (MDEP 1994b). Smithfield also has a limited commercial zone in the town's center. The purposes of these zones are to control water pollution, to protect wildlife and freshwater wetlands, to control building sites and placement of structures and land uses, to conserve the functionality and beauty of the shore and its cover, and to respond to the impacts of development. Generally speaking, the zoning ordinances state that resources such as wetlands, bogs, or streams cannot be developed. Smithfield, Mercer, and Norridgewock have each made small adjustments to the State of Maine Guidelines for Municipal Shoreland Zoning Ordinances to create their own ordinances. The ordinances specify that lots must be a minimum size, 40,000 ft^2 in Rome and Mercer, and 80,000 ft^2 in Smithfield. The shoreland zoning ordinances are effective within 250 ft of the shoreline of the lakes, and 75 ft of the tributary streams in the watershed. They stipulate that in limited residential zones a distance of 100 ft must exist between the high-water line of the lakes and any new buildings, and 75 ft must exist between the high-water line of streams and any new buildings in stream protection zones (MDEP 1994b). Each town's ordinances also specify a minimum shore frontage to avoid overcrowding along the shore.

Rome, because it has not created its own shoreline ordinance, uses the state's ordinance by default. Smithfield and Mercer have developed their own shoreland zoning ordinances, though they vary only slightly from the state's ordinance. Norridgewock, though it has its own ordinance, does not have any shoreline property in the North Pond watershed area.

During the development process in residential zones, extensive areas of soil are exposed and the erosion of large areas of unstabilized soil can be a significant threat to the water quality of the lakes (MDEP 1992b). Many properties in the North Pond watershed have been grandfathered, meaning that they have pre-existed changes in zoning laws, and are therefore not required to follow current ordinances. It is important to note that ordinances can be amended at any time and, in some cases, they have not remained in force for even a year and therefore may not be an effective means of protecting lake water quality (Fortier et al. 1990).

Shoreland Results and Discussion

The goals of the shoreland zoning ordinances in Smithfield, Mercer, and Rome are to aid in the maintenance of good water quality and natural resource status. The wetland areas at the mouth of Bog Stream and at the head of Great Meadow Stream are covered under resource protection, as shown on the official zoning maps located in each of the town's offices. Generally speaking, the rest of North Pond's and Little Pond's shoreline is open to residential development, though some areas are currently impractical for development due to high relief or inaccessiblity.

Because the shoreline residential lots are so close to the bodies of North Pond and Little Pond, it is obvious that they will have a strong affect on water quality. Runoff from houses travels a short distance before reaching the lakes and adds potentially significant amounts of nutrients, particularly phosphorus to the lake. Runoff from developed shoreland lots could contain gray water (water from sinks and showers, which may include phosphorus containing detergents), any fertilizers or chemicals used on lawns, unabsorbed septic matter, or sediments released from general development. Buffer strips, which were generally determined to be of average quality for the shoreline houses, act as a sponge. They absorb nutrients in runoff, thereby preventing them from entering the lake water (Introduction: Buffer Strips). Buffer strips should be encouraged on all developed shoreland lots.

Many of the residences along the shoreline, including tightly clustered residences that have been grandfathered through more recent zoning ordinances, are seasonal. During the summer months they undergo a dramatic increase in use and are then likely to contribute to phosphorus export into the lakes. There are areas along Route 137 where houses come extremely close to the water's edge and where summer use can be expected to contribute greatly to phosphorus loading of North Pond, depending on such factors as septic quality (see Land Use Results and Discussion: Subsurface Waste Water Disposal Systems) and buffering. The same is true for tightly clustered summer camps like Sunset Camps and Pine Tree Camps. In addition, there are a few houses, one on North Shore Drive, and several old seasonal residences on Birch Point, which are in need of repair. The erosion from these may contribute sediment to the lakes.

Generally speaking, it was found that approximately two-thirds of the shoreline of North Pond was developed with seasonal residences. The western shore had the most dense development, particularly where Route 137 runs close to the shoreline. Other areas of significant development included the northwestern shore along Pond Road up to Birch Point, the northern shore along North Shore Drive, the southeastern area near Pine Tree Camp, and the southern Narrows area.

Nonshoreline Results and Discussion

Although their role in phosphorus loading is not as direct as shoreline residences, nonshoreline residences can still impact water quality. This is especially true if they are located near a tributary. Stream protection zones exist in each town and specify a minimum distance between development and tributary streams. They are a good measure to insure the preservation of clean stream water. Runoff from nonshoreline houses will usually have the chance to be absorbed by miles of forest flora, causing the phosphorus to enter the forest's nutrient cycle rather than be emptied into the lakes. The forest is, essentially, a giant buffer strip. However, badly constructed roads that lead to the water's edge, such as McNulty Road in Rome, can conduct runoff from populated nonshoreline areas directly into the lakes and can have a significant effect on phosphorus loading (see Land Use Results and Discussion: Roads and Residential Areas).

Nonshoreline residences are subject to many of the same restrictions and regulations as shoreline residences. If a nonshoreline residence is built in the proximity of a stream without an adequate buffer strip, phosphorus can be drained off the lawn, into the stream, and then directly into the lakes. The existence and observance of stream protection zones is a good way to reduce this hazard.

LAND USE METHODOLOGY

The Zeiss Interactive Digital Analysis System (ZIDAS) was used to determine the areas of land use types in the North Pond, Little Pond and Serpentine subwatersheds. Aerial photographs from 1965/1966 and 1991 were obtained from the United States Department of Agriculture High Altitude Photography Program. The photos were covered with a sheet of clear, plastic mylar and arranged in a mosaic to show the entire watershed of North Pond. Using a transparency of a topographical map, the watershed, subwatershed, and town boundaries were projected onto the mosaic and traced with permanent marker (U.S.G.S. Quadrangles: Rome, Mercer, Norridgewock, Belgrade). The North Pond watershed and East Pond, Serpentine, and Little Pond subwatershed boundaries were acquired from the MDEP.

Seven straight road segments with distinct landmarks visible on the photographs were measured during a field reconnaissance on 28-OCT-1996 to scale the aerial photographs. The road segments were measured on the photographs using a map wheel. The map wheel values were then compared to the reconnaissance distances to determine the scale for each photograph. The scale for the 1965/1966 photographs was 1 in:1528 ft. The scale for the 1991 photographs with codes NAPP 3952-74/75 and NAPP 3952-13 was 1 in:3308 ft. The scale for the 1991 photographs with codes NAPP 3955-55/56 was 1 in:2981 ft. The scales were entered into the ZIDAS computer when the corresponding photograph was analyzed, yielding values in square feet as opposed to unspecified map units.

Six different categories of land uses for the North Pond watershed were recorded from both the photographs and the field reconnaissances on 21-OCT-1996 and 28-OCT-1996. The categories were wetlands, municipal and industrial land, cleared land, mature forested land, roads, and residential areas. Cleared land was further divided into recently cleared land, including lawns and agricultural fields, and reverting fields. Reverting fields were defined as lots cleared in the past for either agricultural or residential purposes. They have begun succession, with small trees and shrubs growing instead of simply grasses, herbaceous perennials, or specific agricultural crops. The distinction is important in that cleared land will contribute more phosphorus than will reverting fields. Reverting fields will break up the rainfall and enhance water percolation into the soil, allowing nutrient uptake and preventing increased erosion and runoff. A thick, matted lawn, however, would prevent percolation into the soil and facilitate runoff. A field that has been recently plowed or has bare soil will increase erosion, as there is no vegetation to hold the rainfall.

Forested land was divided into mature forest and regenerating forest. Regenerating forest was defined as lots which were clear-cut or selectively harvested for timber and are now regrowing. The canopies are open and regeneration is patchy. Mature forest was defined as a closed canopy.

Residential areas were separated into shoreline and nonshoreline residences. House counts from field reconnaissances were used to determine the number of nonshoreline and shoreline residences. The MDEP average lot sizes for shoreline and nonshoreline residences, one-half acre and one acre respectively, were used to determine the total residential area in the watershed (Bouchard, pers. comm.). The total number of shoreline residences were multiplied by the average shoreline lot size to obtain the total residential shoreline area. The same procedure was used for nonshoreline residences. These classifications of land use types are important because each type will contribute a different amount of phosphorus to the watershed.

The watershed, subwatershed, and town boundaries were digitized from the topographic maps to obtain their areas. Land use types were then determined on the photographs using a Topcon stereoscope. Outlines of all land use types except mature forested land were traced on the 1991 photographs with different colored overhead transparency markers. The outlined areas in each category were traced ten times using ZIDAS to acquire an average. Ten repetitions were sufficient to account for variability in tracing. The average values were then subtracted from the total land area of the watershed to obtain the area of mature forested land. The average values were then used in the water budget calculation (Appendix D) and the phosphorus-loading equation (Appendix E).

The 1965/1966 photographs were analyzed for apparent differences. Cleared land, municipal/industrial land, regenerating land, and reverting land were measured using ZIDAS methods as described above. Road area was calculated by using a map wheel to measure the length of visible roads in each town and subwatershed on the 1965/1966 photos. The length of road segments were then multiplied by average widths obtained from 1996 field reconnaissances. Many camp roads may not have been counted as they were not visible on the aerial photographs. Shoreline and nonshoreline residences were obtained by counting houses by subwatershed and towns on a 1956 topographic map from the Colby Geology Department. As a result, the number of residences may be under-represented in this model for the years 1965/1966. The total shoreline and nonshoreline residences were then multiplied by the standard MDEP value of one-half acre for shoreline and one acre for nonshoreline. Mature forested land was calculated by subtracting all other land types from the total land area of the watershed. The area left over was assumed to be mature forested land. Average values for land use types from 1965/1966 were then compared with average values from 1991 to establish trends in land use development and phosphorus loading for the North Pond watershed.

LAND USE RESULTS AND DISCUSSION

The North Pond watershed is 14,384 acres. The Little Pond subwatershed is 2494 acres while the North Pond subwatershed is 7641 acres. The Serpentine subwatershed is 4249 acres. Eighteen percent of the North Pond watershed is covered by water. North Pond and Little Pond are 2254 and 290 acres respectively. The Serpentine is 72 acres.

The four towns in the North Pond watershed are Smithfield, Mercer, Rome, and Norridgewock. Smithfield is the largest town, occupying 6398 acres. Mercer is 3719 acres and Rome is 1551 acres. Norridgewock represents a small portion of the watershed, measuring only 102.5 acres.

North Pond watershed is composed of several different land use types (Figure 40). Mature forest is the largest land type in the watershed, comprising over 75% of the watershed in both 1965/1966 and 1991 photographs (Figure 41). Cleared land was the second largest land type in the watershed, occupying approximately 10% in both 1965/1966 and 1991 aerial photographs. Wetlands comprised 7% of the watershed in both 1965/1966 and 1991 aerial photographs.

As the area of land use types fluctuate over time, it is important to note the impact on water quality, specifically on the rates of phosphorus loading (see Phosphorus Loading). Comparing changes in the forested and cleared areas from 1965/66 to 1991 and determining what land use type the changed areas may have become is useful for speculating on how the agricultural, logging, and developmental practices have and will continue to effect the water quality of North Pond and Little Pond. The aerial photographs provided an idea of how land types changed over 26 years; today, five years after the 1991 photographs, the changes that have continued to arise are useful for predicting the situation of the watershed in the future.

Forestry and Logging

The forested land of North Pond watershed was divided into mature forest and regenerating forest (see Land Use Methodology). Mature forests were characterized as areas with a high density of canopy. This method was used instead of the height of trees because the changing topography made it difficult to determine relative height on the aerial photographs. Also, because a variety of forest communities are located within the watershed, mature trees have different heights in different areas. Regenerating forest was distinguished as areas of patchy woodland or areas with evidence of previous logging (such as skidder trails, strip cutting, and clearcutting).

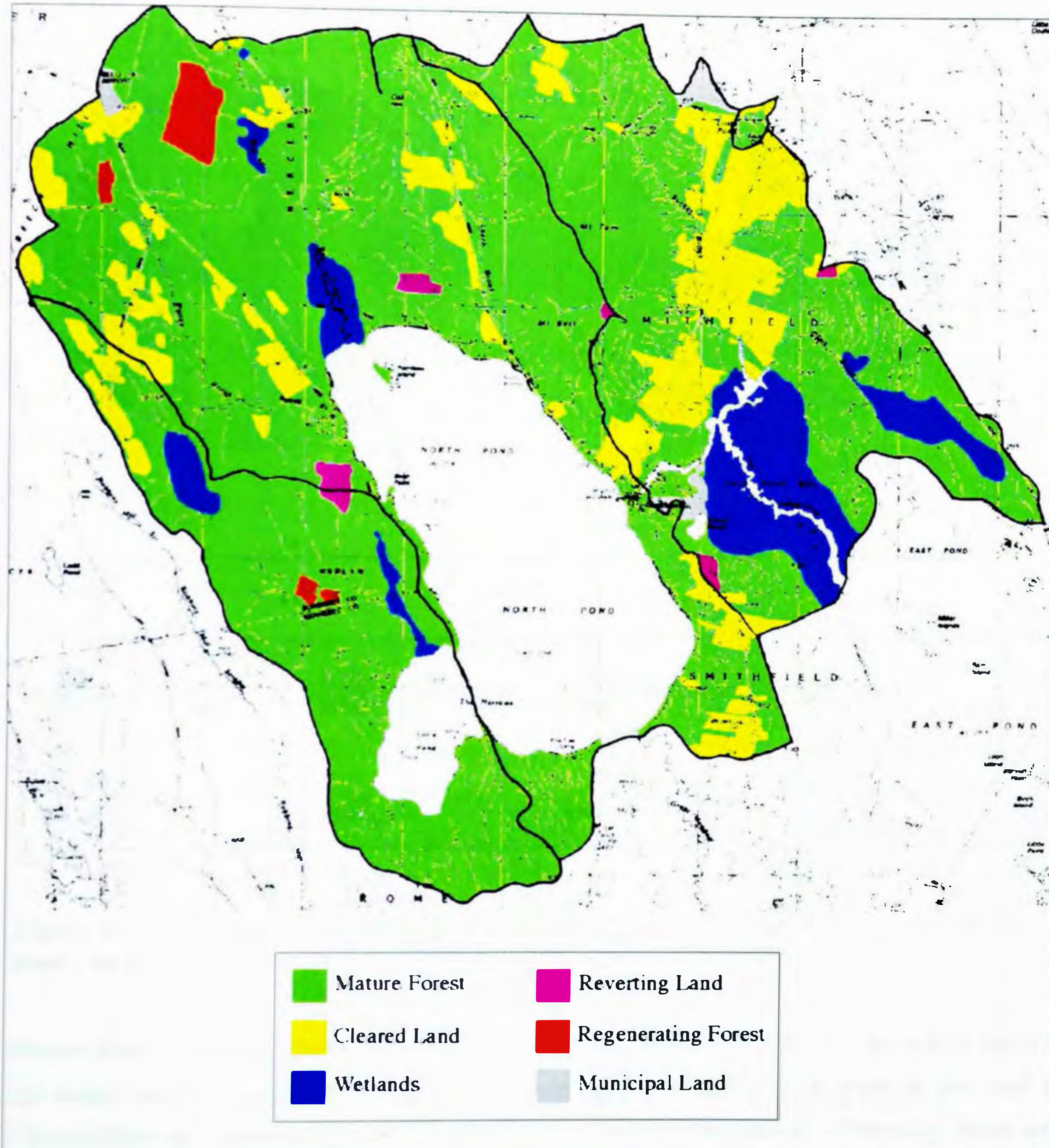

Figure 40. Location of land use types in the North Pond watershed based on 1991 aerial photographs (scale 1:71,500). The scale on the map is approximately 0.5 inches equal to 0.55 mi (0.89 km).

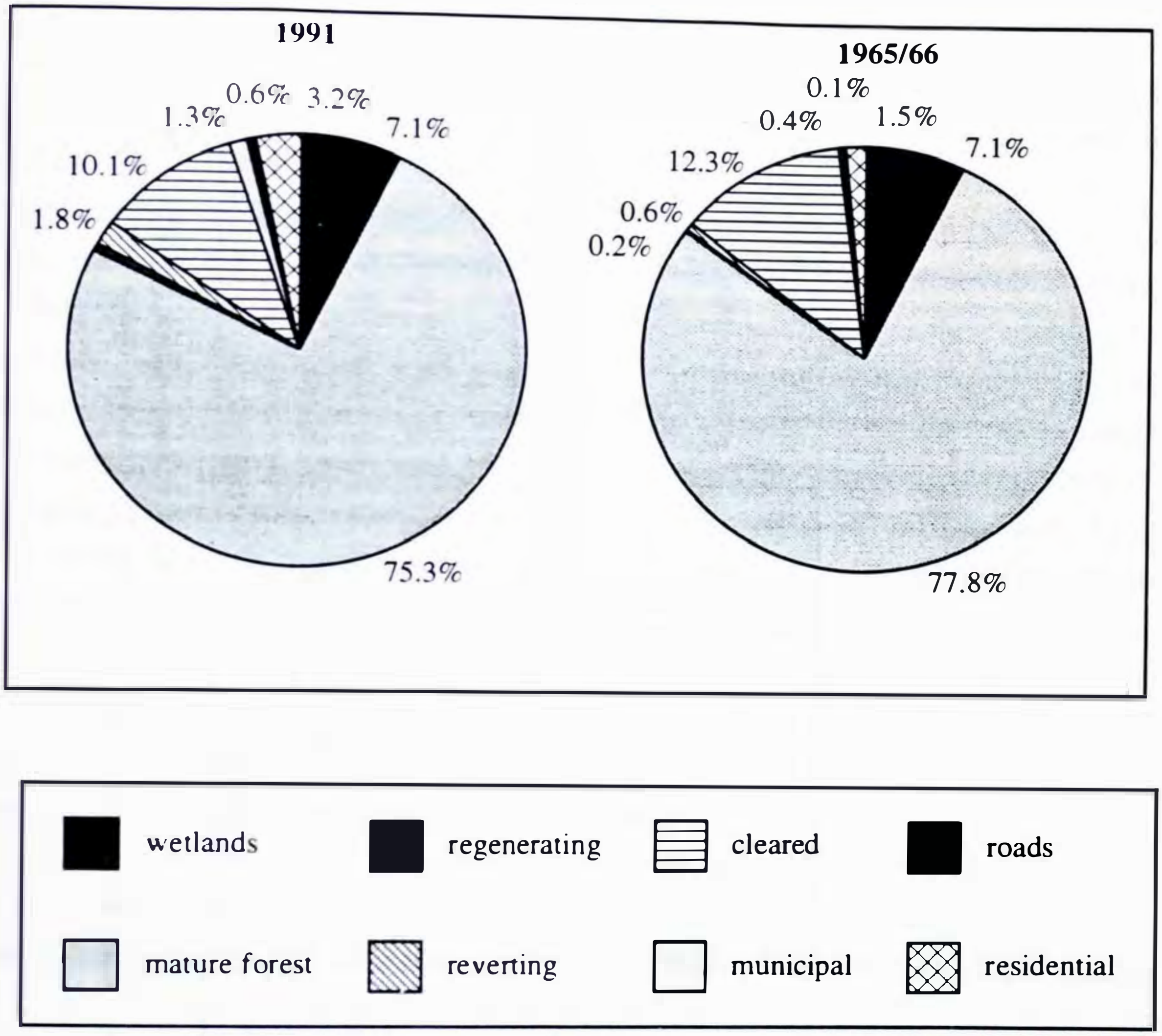

Figure 41. Land use types comprising the total land area of the North Pond watershed based on 1991 and 1965/1966 aerial photographs.

Mature forests generally have a positive impact on water quality within a watershed, but they also represent areas that may be susceptible to future logging. Therefore, an increase in the total area of mature forest does not necessarily imply better water quality in the future. Presently, there are large amounts of mature forest susceptible to logging in the North Pond watershed. There are many influences that can predict future logging trends. For example, logging has the potential to increase in this watershed if there is a rise in timber prices (Cole, pers. comm.).

In Smithfield, Mercer, and Rome the amount of mature forested land decreased from 1965/66 to 1991 by 122.8, 35.8, and 2.3 acres respectively (Table 13). In Norridgewock, the forested land increased by 13.3 acres.

The 122.8 acre decrease in Smithfield's mature forest may be partly represented by the fact that municipal land expanded, increasing by 117.1 acres (Table 13). Roads and residential areas which also increased could represent the remaining area that was once forested. Regenerating land in Smithfield increased by 36.7 acres and represents logging in the past.

Table 13. Area (acres) of land use types in Smithfield, Mercer, Rome, and Norridgewock for the years 1965/66 and 1991.

Land Use	Smithfield		Mercer		Rome		Norridgewock	
	1965/66	1991	1965/66	1991	1965/66	1991	1965/66	1991
Wetlands	657.0	657.0	146.9	146.9	36.3	36.3	0.0	0.0
Mature Forest	4419.6	4296.8	3171.9	3136.1	1471.3	1469.0	82.7	96.0
Regenerating Area	17.4	54.1	0.0	11.1	0.0	0.0	0.0	0.0
Cleared Land	1126.7	897.6	302.3	285.6	10.1	0.0	17.4	2.8
Reverting Land	10.3	82.1	60.1	13.7	0.0	0.0	0.0	0.0
Shoreline Residential	82.0	94.0	11.0	38.5	21.0	21.0	0.0	0.0
Nonshoreline Residential	42.0	142.0	11.0	61.0	8.0	18.0	2.0	2.0
Municipal/Ind ustrial	10.4	127.5	0.0	20.4	0.0	0.0	0.0	0.0
Road Area	32.5	46.9	15.8	19.5	3.8	6.8	0.4	1.7

The forested land in Mercer decreased 35.8 acres from 1965/66 to 1991 (Table 13). Because both reverted and cleared land decreased also, it can be suggested that the decrease in forested land went, not to agricultural practice, but to development such as expansion of municipal/industrial, residential, and road areas. Indeed, there were 81.2 additional acres of residential land and roads and 20.4 more acres of municipal/industrial area in 1991 than in 1965/66.

The mature forest in Rome decreased by only 2.3 acres from 1965/66 to 1991 (Table 13). There was no increase in shoreline residential area, possibly because it had already reached its full capacity. On the other hand, nonshoreline residential area did increase by 10 acres suggesting that all of the forest that was lost could have gone to residential development. Both residential and road expansion may have also occurred on agricultural land (see Land Use Results and Discussion: Cleared Land).

Norridgewock was the only town in the North Pond watershed that experienced an increase in acres of mature forest. It appeared that the forest arose from cleared land as cleared land was the only land type that decreased (see Land Use Results and Discussion: Cleared Land).

There was no evidence of active logging in the aerial photographs for 1965/66 or 1991. However, CEAT found in 1996 that some land in Rome had been selectively cut. One particular area, Black Horse Acres, was near McNulty Road on Rome's Little Pond shoreline. The area was selectively logged in 1995 and is now being left to regrow.

Logging in this area may have important implications for future water quality because of the area's steep slope and shoreline location. There is also a large amount of mature forest that remains susceptible to future logging in Rome and the entire North Pond watershed. In addition to Black Horse Acres, there was further evidence of logging in Rome near Foss Hill Road and Pine Tree Camp Road (Moreau, pers. comm.). As a result, there is probably some regenerating land in Rome today that was not included in the data obtained from the aerial photographs. Further suggesting that logging may increase in the future is the fact that regenerating land in the North Pond watershed increased from 1965/66 to 1991. Regenerating forest represents past logging. The fact that there was more regenerating forest in 1991 suggests that logging was more prevalent in the time period between 1965/66 and 1991 than it was previous to 1965/66. The evidence of logging today supports the notion that this trend may be continuing, meaning there may be more logging in the future.

Municipal and Industrial

During field reconnaissances, CEAT located a municipal airport, as well as two gravel pits within the North Pond watershed. Municipal and industrial land area was determined from 1965/1966 and 1991 aerial photographs using ZIDAS (see Land Use Methodology). The total municipal/industrial area was calculated to be 10.4 and 147.9 acres in 1965/1966 and 1991 respectively (Table 13). The total municipal/industrial area for 1991 constitutes 1.3% of the North Pond watershed land area (Figure 41).

The airport comprises 20.4 acres in the 1991 photographs (Table 13). It was not visible in the 1965/1966 aerial photographs. It is a very small airport located in the northwest corner of the watershed in the town of Mercer (Figure 40). Only part of the airport is within the watershed boundary. Information about the frequency of use of this airport was not obtained for this study.

The two gravel pits are both in the town of Smithfield and occupy 127.5 acres (Table 13). One is located in the northeast section of the watershed in the town of Smithfield and is 41.3 acres (Figure 40). This gravel pit did not appear on the 1965/1966 aerial photographs, but it did appear outside the North Pond watershed boundaries on a 1983 topographic map (see Land Use Methodology). Between 1983 and 1991, the gravel pit expanded west and south into the North Pond watershed. Whether or not this gravel pit was being actively mined at the time of this study was not determined.

The second gravel pit is located in downtown Smithfield, near the Serpentine, Smith Pond, and East Pond Bog (Figure 40). It was measured to be 86.2 acres from the 1991 photographs. This is a marked increase from the 1965/1966 photographs, where the same gravel pit was measured to be 10.4 acres (Table 13). This constitutes a 62.3% increase in circumference for the gravel pit. The relative depth of the gravel pit could not be determined from the photographs. This gravel pit is currently active, based on observations during field reconnaissances. In addition, during field reconnaissance of the area it was observed that the gravel pit had expanded across Route 8/137. The land bordering North Pond was being mined. This recent operation could not be seen on the 1991 aerial photographs.

Municipal/industrial land uses in the North Pond watershed need to be monitored closely. The gravel pit in the center of Smithfield is close to both the East Pond Bog and North Pond. Gravel pits are a potential source of phosphorus loading, due to the fact that they are essentially open pit mines with bare soil. There is no vegetation to combat erosion, keep particulate matter from being stirred into the air, or prevent sediments from leaching into lakes and streams. If the gravel pits expand any further, phosphorus loading for North Pond may increase. This may result in a decline in water quality of North Pond (see Introduction: Nutrient Loading).

Cleared Land

Cleared land in the North Pond watershed was segregated into agricultural uses and lawns. Agricultural area was distinguished as cultivated fields with visible crop rows and pastures without visible rows. The amount of cleared land in a watershed can be significant for the water quality of lakes (see Introduction: Cleared Land). The two predominant types of agriculturally cleared land, cultivated and pastured, can both contribute to increased phosphorus in the water. The presence of lawns is most likely associated with residential development and therefore can also impact water quality.

The location and type of cleared land provides evidence of the trends that are occurring throughout the watershed area. Overall, cleared land from 1965/66 to 1991 in the entire watershed decreased by 18.6%; in contrast to 1965/66, a large proportion of the cleared area in 1991 appeared as cultivated land rather than pastures (Figure 41, Table 13)

The area that was reverted in 1991 was considered to be part of the area that was agriculturally cleared in 1965/66. In Smithfield, cleared land decreased by 229.1 acres, 71.8 acres of which may be accounted for by the increase in reverting land area (Table 13). The fact that mature forest also decreased suggests that the remaining cleared land has not grown back to mature forest, but may have been developed residentially, municipally/industrially, or made into roads as each of these land types increased from 1965/66 to 1991. The actual amounts that each land type may have contributed to the decrease is difficult to precisely calculate because not all of each land type may have been distinguished on the photos.

In Mercer, both cleared and reverted land decreased by 16.7 acres and 46.4 acres, respectively. This suggests that the land that was cleared has gone to other land types such as residential, municipal/industrial, or roads which all increased in Mercer (Table 13).

Rome was similar to Mercer in that both cleared and reverting land decreased from 1965/66 to 1991. The difference in Rome is that shoreline residential area did not change. The shoreline residential area, which was calculated from a 1956 topographic map house count, may have been fully developed or increases may have been present that were undetected by CEAT during field reconnaissance in 1996. Therefore, nonshoreline residential areas and roads may have been developed on the previously cleared land.

Cleared land in Norridgewock decreased by 14.6 acres. Mature forest and roads in Norridgewock increased by 13.3 acres and 1.3 acres respectively (Table 13). This indicates that all the cleared land was converted to roads or reverted to mature forest. The decreased cleared land in Norridgewock was exactly compensated for by the increase in mature forest and road area.

Wetlands

Wetlands were determined using topographical maps, aerial photographs from both 1965/1966 and 1991, and field reconnaissances (see Land Use Methodology). A wetland is usually found near a water body, such as a river or lake, or at a low elevation, such as a basin or kettlehole, into which runoff from the surrounding land can drain (BI493 1996).

There are 840.2 acres of wetland in the North Pond watershed. This constitutes approximately 7.1% of the land area of the watershed (Figure 41). The area of wetlands was constant from 1965/1966 to 1991, most likely due to the difficulty of developing this type of land. Compared to other watersheds in the Belgrade Lakes region, wetlands in North Pond watershed make up a larger percentage of total watershed than East Pond (3.0%), Salmon Lake (1.0%), and Long Pond, North Basin (4.9%) (BI493 1991, BI493 1994, BI493 1995). Wetlands in Long Pond, South Basin were 8.3% of the watershed land area, but this represents 687.2 acres which is 152.0 acres smaller than the wetlands in North Pond (BI493 1996).

Smithfield had the largest area of wetland, 657.0 acres (Table 13). There were three main areas of wetland in Smithfield. East Pond Bog, located near the gravel pit, is the largest of the three wetland areas with an area of 445.1 acres (Figure 40). The second wetland area in Smithfield is located near Clark Brook in the southeastern corner of the North Pond watershed. It was measured to have an area of 159.4 acres. Both of these wetland areas fall within the boundaries of the Serpentine subwatershed.

The third wetland area in Smithfield was located in the North Pond subwatershed on the east shore of Bog Stream. It was calculated to be 52.4 acres in size.

Mercer had the second largest area of wetland with 146.9 acres. There were four separate wetland areas in this town. The largest of the wetland areas in Mercer, 52.4 acres, is located at the north end of North Pond on the west shore of Bog Stream. There are two inland areas of wetland in Mercer, both located to the northwest of North Pond near Route 137. Together they measure 22.2 acres. The fourth wetland area in Mercer is located near the western shore of North Pond and extends south to Little Pond. Part of this wetland, 24.2 acres, is located in Mercer. The section is located in Rome and was determined to be 36.3 acres.

Each wetland area is unique in hydrogeologic and biologic composition (see Introduction: Wetlands). As a result, determining the significance of wetlands in external phosphorus loading would require an examination of each individual wetland's pH, soil nutrient levels, and vegetation types (BI493 1996). For example, a wetland with dense vegetation will slow the flow of water and allow the plants and sediment to absorb more nutrients. This type of wetland is, in effect, a nutrient sink. Conversely, a wetland with a high rate of evapotranspiration would result in a higher nutrient concentration. This type of wetland will not absorb more nutrients from runoff and will act as a concentrated nutrient source, rather than a sink. CEAT did not conduct these wetland investigations due to time constraints. Therefore, the wetland areas in this study were not differentiated according to their hydrogeologic composition.

Roads and Residential Areas

Road Characteristics and Contributions to Phosphorus Loading

One of the major goals of completing the road survey was to determine the amount of phosphorus loading from the roads in the North Pond watershed. Soil and atmospheric particles containing phosphorus found on roads are carried into lakes via rainfall. In an undisturbed environment, phosphorus is bound to soil particles and in organic matter for use by plants. The land's ability to retain phosphorus decreases once this environment is disturbed (Dennis 1989). Erosion due to disturbed land patterns increases the amount of phosphorus that is likely transported by water. It is estimated that phosphorus runoff from roads and ditch erosion may range from 500 ppb to 1000 ppb (Williams 1992).

A major factor influencing phosphorus loading into a waterbody is the quality of roads within the surrounding watershed. Problems often stem from poor construction of roads as well as poor maintenance. Sound sedimentation and erosion controlling measures are required to prevent soil and phosphorus migration during construction (Lea et. al.1990). In determining the extent of phosphorus loading, several characteristics of roads must be considered: crowning, diversions, culverts, cracking and gullying, ditches, and surface constituents. By constructing roads in a manner that meets the highest standards for each of these categories, the amount of phosphorus loading can be limited.

The objective of crowning is to drain a road as fast as possible thus limiting the time rainwater is in contact with the road surface. Typically, paved roads are scraped or graded by bringing material from the edges of the road to the center to create a crown. Special attention must be paid to avoid leaving a berm, or ridge, on the side of the road which would then act as a barrier to prevent water from running off the road and into a ditch (Michaud 1992; Figure 42).

Acting as an impediment to runoff, diversions carry rainwater flowing down roads to areas where phosphorus can be readily absorbed such as forest or shrub. Diversions may be constructed of wood, are placed in a cross section of a road, and act as a catchment for water (Michaud 1992). Setting up diversions may be especially difficult in highly populated areas such as Smithfield due to the lack of undeveloped land where phosphorus can be absorbed (Williams 1992).

The installation of culverts is another tool to minimize erosion. Culverts are large pipes that direct water to drainage basins, forest or shrub areas where phosphorus can be filtered. Most often culverts are made of metal, but they can also be constructed from wood, plastic, or concrete (Michaud 1992).

Cracking and gullying of the road surface can be a direct result of heavy rainfall and can deter

Figure 42. A berm ridge on the side of a dirt road which prevents the drainage of water off the road.

swift drainage from a road surface. Increased erosion is the major problem caused by cracking and gullying because it leads to more particles being swept away (Michaud 1992). Cracking and gullying is also a predecessor to potholes which collect water and make drainage more difficult.

The presence and quality of ditches is one of the most important indicators of phosphorus loading potential from roads. Designing ditches with the highest potential of water flow in mind is critical so that they can work correctly in storm situations to keep erosion at a minimum. In terms of the shape of a ditch, a wide, flat channel that is vegetated is most desirable (Figure 43). Additionally, a wider, flatter ditch slows the velocity of flow while vegetation or stones provide stability (Michaud 1992). When water flow is greater than what the ditch is designed to handle, erosion often occurs and sediment with phosphorus is directly washed from the ditches (Lea et. al. 1990). Proper ditches must be maintained to keep phosphorus loading to a minimum. When ditches become filled with sediment and debris, they should be cleaned to prevent additional erosion from the road (Williams 1992). A variety of stabilization techniques such as seeding, sodding, or rip-rapping aid in controlling erosion in ditches (Lea et. al. 1990). Rip-rapping means lining a ditch with stones where stone size is dependent on the expected flow (Michaud 1992).

The surface constituents of a road are extremely crucial since different types of roads have different effects on phosphorus loading. As studies have indicated, phosphorus is washed from paved surfaces at a faster rate than permeable surfaces (Lea et. al. 1990). Sand and/or gravel roads erode more quickly than paved roads and thus have the potential to empty more sediment and nutrients, especially phosphorus, into a water body. Therefore, roads tend to be paved and sanded in high usage areas or graveled in seasonal usage areas (BI493 1996).

Figure 43. An example of a well maintained ditch. Runoff is being properly drained from the road surface.

General Road Methods

A comprehensive field survey of paved, dirt and camp roads in the North Pond watershed was conducted on 30-SEPT-96, 02-OCT-96 and 07-OCT-96. The survey was conducted in order to assess the quality of the roads to evaluate their impact on water quality through potential phosphorus loading. Camp road surveys were separate from dirt and paved road surveys. Camp roads were defined as vehicle accessible roads which led to more than one house on the direct perimeter of the lake. Though camp roads are not necessarily dirt, all camp roads surveyed by CEAT were dirt roads. Paved and dirt roads consisted of the roads which did not lead directly to the lake. None of the driveways in the watershed were surveyed. The dirt and paved road survey was prepared by CEAT, and the camp road survey forms were modified from forms obtained from MDEP (Appendix G). Widths and road segment lengths were evaluated with a measuring wheel, and total road length was measured with vehicle odometers. Slope values were measured with a clinometer.

Camp Road Survey

Methods

The camp road survey included a general description of road quality which included length in miles, average width in feet, overall slope in percent, total number of water diversions, number of missing water diversions, number of missing culverts needed, and size of culverts needed. A specific assessment of slope, ditching, culvert condition, water diversions, and road surfaces was also completed for each camp road (Appendix G).

A *Ditch Total Index* was calculated to determine the overall quality of camp road ditches. Each tenth of a mile section of road was evaluated based on ditch need, depth, width, vegetation, sediments, and shape. Each category was rated on a scale from "good" to "big problem," and an average score was assigned to each category. Each segment was also given a percentage value which summarized the ditch condition; a value of 100% denoted a road with good ditches or a road where no ditches were needed, and 0% was a road where no ditches were present but needed. The product of the ditch condition value and the category total yielded the *Ditch Total Index* value (Appendix G). If a ditch is cleaned and shaped properly, it will effectively collect subsurface and rain water. If water is not diverted from the road surface, it may cause structural problems or erosion of the road base due to deterioration of the pavement (Michaud 1992; Figure 44).

The quality of culverts was assessed through calculation of the *Culvert Total Index*. A summary evaluation of the entire road was analyzed by the following criteria: need, wear, size, insides, and covering material. The interior of culverts was evaluated by the presence or absence of material such as silt, rocks, or water; an ideal culvert is clean. The rating scale ranged from "good" to "big problem", and was used to determine a percentage value associated with the overall culvert condition (Appendix G). A properly installed culvert will divert water flowing from a brook or stream under a

Figure 44. The effects of erosion where a ditch has not been properly maintained.

road without penetrating the surface of the road or the bed of the road underneath. As with ditches, if no culvert is present, a road can incur severe damage (Figure 45).

A summary evaluation of water diversions was also completed for the *Water Diversions Total Index*. The quality of water diversions was judged on need and where the water was diverted. If water was observed heading directly off a road into the lake, it received a "big problem" designation (Appendix G). Diversions were considered "good" if they channeled water into wooded areas well before the shoreline. Since water diversions also serve to divert water away from roadways, they can be used in place of culverts (Joly 1987).

Road surfaces were also evaluated in tenth of a mile segments. Crowning, surface, edge and road material were scored under the standard grading system of "good" to "big problem."

Dry and wet surfaces were evaluated separately. Road material consists of surface constituents, including gravel, sand, dirt, and clay. Seasonal or year-round usage was also noted, as well as a percentage value summarizing surface condition. This value described the road based on a percentage scale ranging from zero to 100% good. The *Surface Total Index* was calculated as the product of surface, usage, and condition scores (Appendix G).

The final evaluation of the road was calculated by summing of the *Ditches, Culverts, Water Diversions, and Surface Total Indices* for the *Road Total Index*. Lower scores indicate better roads, and higher scores indicate roads in need of work (Appendix G). In this instance, surveys can be reevaluated to determine where to focus road repair.

The overall slope was calculated from a gradient analysis of segments from each road. A segment is defined as a length of camp road which has a relatively continuous angle of incline or percent grade. A score was assigned to each segment based on the segment length multiplied by the percent grade. Scores for each segment were summed for a road segment total which was used to identify problematic roads. The soil erosion potential or phosphorus loading potential was calculated by multiplying set erosion potential coefficients by the number of segments with a particular length and percent grade (Appendix G).

Twenty-three vehicle accessible camp roads were surveyed in the North Pond watershed, accounting for a total area of 375,013 ft^2 (Appendix M). Camp roads that were not surveyed were either overgrown or had closed gates blocking the road entrance. It is believed that the vast majority of the camp roads in the watershed were accounted for in this report.

Camp roads were organized into four different quality classes according to their *Road Total Index* values (Table 14 and Figure 46). Lower *Road Total Index* values indicate better roads and higher *Road Total Index* values indicate poor roads. Class 1 includes *Road Total Index* values between 0 and 100, Class 2 includes values between 101 and 200, Class 3 includes 201 to 300, Class 4 includes 301 and higher values (Figure 46).

Figure 45. A poorly placed culvert in a dirt road which has not been properly maintained. This culvert should have been placed further below the road surface.

There is a relatively even distribution of roads in each class, revealing a wide range in the quality of camp roads. More than 50% of the roads scored in Class 1 and 2. The largest number of roads are found in Class 2, accounting for 30% of all camp roads. The highest *Road Total Index* value (697) was given to Fire Lane 1 located on the western side of North Pond. RVFD 225-1A1A achieved the best score of 41. There does not appear to be any overall geographical correlation with road quality; good and poor roads exist throughout the watershed. However, roads displaying similar quality appear to be clustered in certain areas. RVFD 225-1A1A, RVFD 225-1A1C and RVFD 225-1A1D all

Table 14. Surface Total, Ditch Total, Culvert Total, and Road Total Indicies, The Road Segment Average and the Total Road Value for camp roads within the North Pond watershed. These indicies and values were calculated from values obtained using the camp road survey.

Camp Road	Road Surface	Ditches	Culverts	Diversions	Road Total Index	Road Segment Average	Total Road Value*
RVFD 225-1A1A	16.0	8.0	16.0	1.0	41.0	21.5	881.5
RVFD 225-1A1C	30.0	54.0	16.0	9.5	109.5	13.5	1478.3
RVFD 225-1A1D	16.0	32.0	5.0	2.0	55.0	7.0	385.0
S-1	52.0	190.0	5.0	15.0	262.0	12.0	3144.0
S-3	84.0	81.0	17.0	0.0	182.0	21.4	3894.8
S-5	82.3	57.0	12.5	15.0	166.8	9.0	1501.2
S-7	57.0	160.0	21.0	15.0	253.0	15.8	3997.4
S-11	18.0	64.0	8.0	0.0	90.0	15.8	1422.0
S-12	175.0	83.8	6.5	0.0	265.3	13.4	355.0
McNulty Rd.	72.0	110.0	23.7	8.0	231.7	8.6	1837.8
N-3	95.0	36.0	8.0	2.0	141.0	13.7	1931.7
W-5	260.0	200.0	5.0	15.0	480.0	8.5	4080.0
W-6	40.0	120.0	5.0	15.0	180.0	12.0	2160.0
W-7	100.0	180.0	5.0	15.0	300.0	12.0	3600.0
W-9	48.0	200.0	5.0	15.0	268.0	8.0	2144.0
W-12	56.0	90.0	5.0	2.0	153.0	12.0	1863.0
Fire Ln. 1	475.0	200.0	17.0	5.0	697.0	8.5	5924.5
Fire Ln. 2	280.0	200.0	27.0	2.0	509.0	12.0	6108.0
Fire Ln. 3	450.0	200.0	5.0	2.0	657.0	12.0	7884.0
Fire Ln. 4	350.0	200.0	21.0	2.0	573.0	8.5	4870.5
Sunset Camp Rd. A	65.0	110.0	5.0	15.0	195.0	12.0	2340.0
Sunset Camp Rd. B	24.0	10.0	27.0	15.0	76.0	12.0	912.0
Pine Tree Camp Rd.	4.5	37.0	17.6	3.7	62.8	16.2	1017.3

* Road Total Value is the product of the Road Total Index and Road Segment Average values.

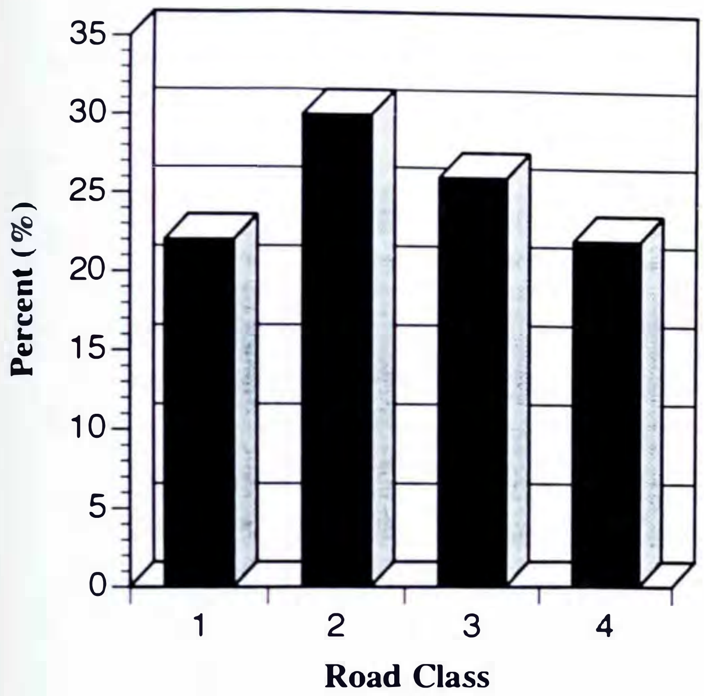

Figure 46. Percentage of camp roads within four road classes based on Total Road Index values. Class 1 demonstrates the best quality roads.

received scores lower than 1 10 and are all located in the same vicinity on the eastern shore of Little Pond. This suggests that this area may be newly developed, or has had consistent road maintenance.

The town of Smithfield had the largest percentage of road area in the watershed, at 62%. This value includes 7% of the camp road area in the watershed, among fifteen roads. Of these roads, only one scored in category four, indicating that the overall quality of roads in Smithfield is good. Additionally, 75% of the camp roads in Rome scored in category 1 or 2, and also displayed good quality. The four camp roads in Mercer, Fire Lanes 1,2,3 and 4 indicated the most work needed (Table 14).

In order to compare values from studies completed in the Long Pond and Salmon Lake watershed, CEAT categorized those values using the same scale used for this report. In comparison to road surveys completed in the South Basin of Long Pond (BI493 1996), the North Pond watershed had a greater percentage of poor quality roads, and a lower percentage of good quality roads, according to the *Road Total Index*. This investigation also revealed that 20% of the roads from the Salmon Lake watershed would be category 4, compared to 22% from North Pond's watershed (BI493 1994). These results suggest that the roads surrounding North Pond are slightly poorer than in other areas.

The *Total Road Value* was computed in order to combine the results of gradient analysis from the Road Segment Average and the road quality assessment from *Road Total Index* (Table 14). This value assesses the combined effect of slope and road quality. As with the *Road Total Index*, a lower *Total Road Value* indicates a better road. The values were organized into four classes to comparatively rate the data with the categories formed with the *Road Total Index* values. Class 1 included values 0 to 2000, Class 2 included 2001 to 4000, Class 3 included 4001 to 6000, and Class 4 included 6001 to 8000. The same basic trends existed for *Total Road Value* that were shown by the *Road Total Index*. Although slope does not affect the overall quality of a road, it does affect the potential amount of phosphorus loading.

Many of the camp roads in the North Pond watershed need repair. Though complete structural repair may be costly, many individual roads may only require minor work. For reference purposes, the camp roads in the North Pond watershed have been organized by *Road Total Index* class to determine where future repair should be considered (Appendix K).

Paved and Dirt Road Survey

Methods

The paved and dirt roads were evaluated in terms of general measurements as well as specific road surface descriptions. General measurements consisted of the road's length in miles, the average width in feet, and the average slope in percent. Average values for width and slope were calculated from three randomly selected measurements along the road. Road surface descriptions were evaluated with a rating system of three values; 0, 0.5, or 1.0 (zero signifying poor quality and one the highest quality). The scores were obtained from observations at three equal road segments. The final score was an average of the observations which was used to form a composite view of each road. The roads were scored on the following categories: Crowning, Culverts, Ditches, Water Diversions, Cracking, and Gullying. Scores for each category (0-1) were summed for a road total value which ranged from zero to five. A score of five indicated a perfect road. One evaluation form was completed for each road (Appendix G).

Results and Discussion

The North Pond watershed incorporates 2,886,622 ft^2 of dirt and paved roads which are vehicle accessible (Appendix M). Of all dirt and paved roads surveyed, RVFD 225-2 was the only road which received a perfect score of five, with all aspects of road quality in good condition (Figure 47). The CEAT studies revealed that all other paved and dirt roads in the North Pond watershed could use repair on at least one aspect of road quality. When scores for all dirt and paved roads were totaled, crowning received the lowest score overall. This suggests that road crowning is an aspect of road maintenance which is ignored. This is most likely attributed to the high cost of crowning a road, though an early investment in road maintenance could save future expenses due to cracking and gullying. The total score for cracking and gullying was also low, suggesting that many roads were in poor condition. Maine winters can be particularly taxing on roads, contributing to frost heaves and general road deterioration. Salt and sand which are spread on road surfaces during the winter, combined with snow plowing causes continued damage which is not easily avoided. It is important to consider that dirt and paved roads are important contributors to phosphorus loading through surface runoff. If problems associated with road quality can be controlled at a significant distance from the lake, the water quality of the lake will be less affected by potential phosphorus loading (Lea et al. 1990).

Routes 8 and 137, including the section of road where the two routes merge south of Smithfield, all received index scores of 4 as relatively good paved roads (Figure 47). These roads receive adequate attention and funding because they are state owned (Balgooyen, pers. comm.). Since these routes provide the only access to most of the other roads in the watershed, they probably receive the most

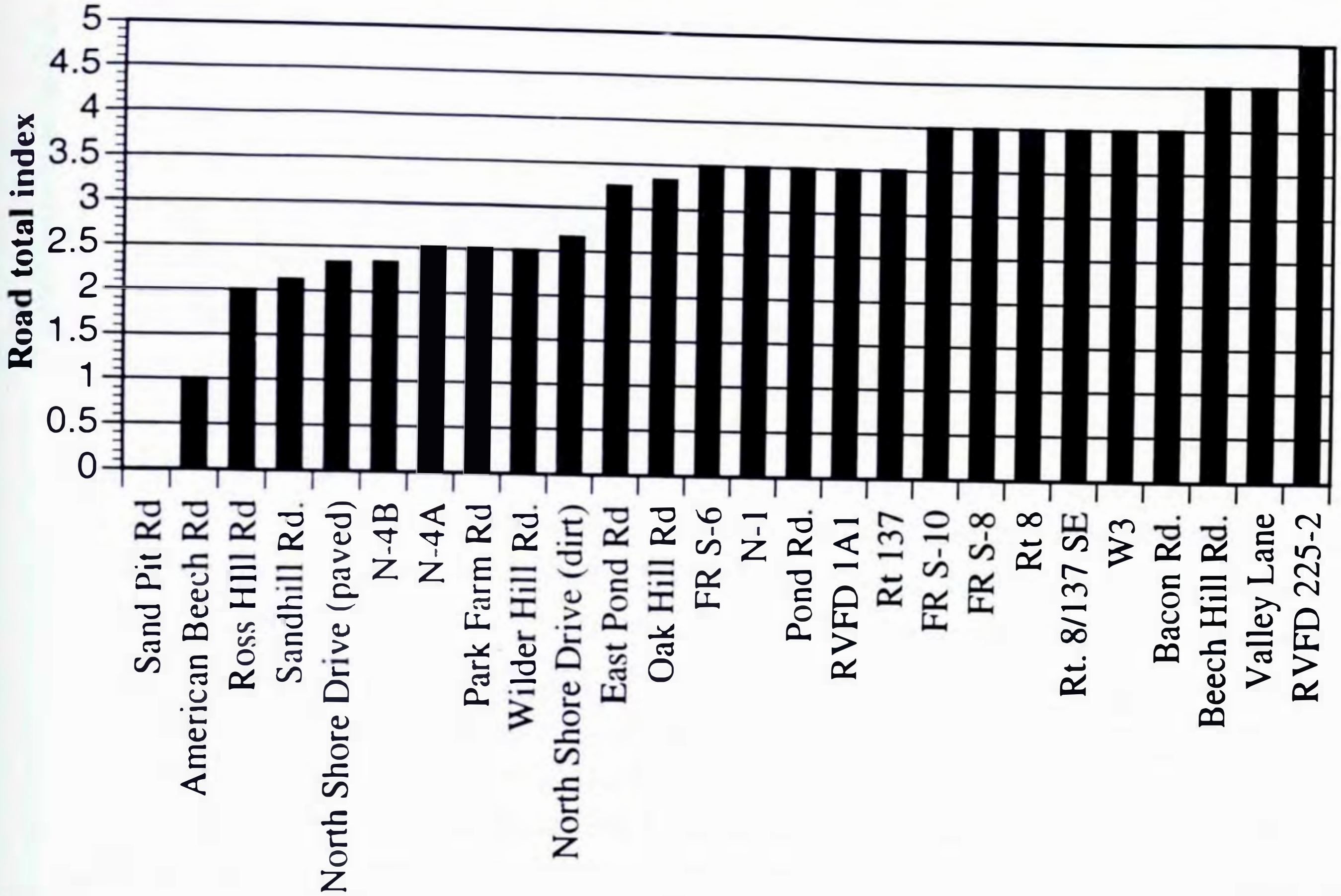

Figure 47. Road total indices for paved and dirt roads in the North Pond watershed based on crowning, culverts, ditches, diversions, cracking, and gullying. A higher score indicates a better road.

traffic and greatest impact. To maintain the present quality of roads, they should be regularly monitored and repaired when necessary. The Maine Department of Transportation has organized a program to aid volunteer road crews to help maintain state and municipally owned roads (Williams 1992).

Sand Pit Road which is located at the northern corner of the watershed, should be investigated separately because it leads to several mounds of sand and gravel. While under investigation, mining operations were in progress which accelerated the movement of particles and aerial fallout on the road surface. Based on observations, Sand Pit Road received a score of zero for all parameters of road quality (Figure 47). The effect of sand and gravel pits on lake water quality can be compared to that of construction sites since both contribute an excess of concentrated and course sediments to surface runoff. The comprehensive plan for the town of Smithfield provided by the Smithfield Planning Board recommends the installment of hay bales and fabric fences down slope of construction sites, in order to filter and divert sediments from the site before they enter potential runoff (Joly 1987).

A relationship exists among the following roads: Sandhill Road, Wilder Hill Road, Ross Hill Road, Park Farm Road, N 4-A, and N 4-B are all dirt roads located in the northeastern section of the

North Pond watershed, and all received a score less than three (Figure 47). All roads exhibited low scores for crowning, ditches, cracking and gullying, which suggests that this particular area is more neglected than others. Upon survey of these roads, local residents commented that the scraping of some roads in the area was funded by municipal budgets (Balgooyen, pers. comm.). Though these roads may appear to be far from North Pond, they are included in the watershed and should not be overlooked. It is the responsibility of land and homeowners in the area to contact town officials concerning ongoing road maintenance. Local residents also suggested that ditches lining Oak Hill and Sand Hill Roads were exaggerated in depth and width to the extent of causing deterioration of the road and forested areas adjacent to the road. If ditches are not properly constructed, they may cause more harm than benefit. It is the responsibility of residents and municipal maintenance workers to monitor and correct these problems depending on if the road is privately or municipally owned.

Slope can be used as an indicator of potential phosphorus loading from roads, but there is little that can be done about existing steep roads. For future growth, the Smithfield Planning Board recommends that development be avoided on slopes with a grade greater than 20% (Joly 1987). Using this criteria, none of the paved or dirt roads surveyed in the North Pond would be considered too steep for development.

Overall, 68% of the dirt and paved roads in the North Pond watershed scored a 3 or higher, indicating that most roads are in decent to good condition. In the future, efforts should be focused on upgrading existing roads and continuing a high standard of road maintenance for future roads.

Phosphorus Loading From Roads

Results and Discussion

The road segment mean indices, a measure of erosion potential, indicate that the camp roads in the North Pond watershed are not a serious problem in terms of phosphorus loading. Larger values for segment mean indices are less desirable than smaller values for phosphorus loading potential (Appendix G). RVFD225-1A1A and S-3 have values above 20 indicating that these camp roads have the highest potential for phosphorus loading (Figure 48). With the exception of Pine Tree Camp Road, S-11, and S-7, the remaining camp roads have mean index values below 15. These are all values which indicate that the majority of camp roads in the three subwatersheds are not relatively steep and therefore the potential for phosphorus loading is reduced.

For paved and dirt roads, the potential for phosphorus loading was based on the mean slope of the road. To determine whether a road contributed significantly to phosphorus loading or not, the roads were divided into two groups: one above and one below a slope value of 7%. A slope greater than 7% was considered to be a significant contributor to phosphorus loading while a slope less than 7% was not. W-3, Oak Hill Road, N-1, and Route 137/8 up to the gravel pit are all roads which had mean slopes greater than 7% (Figure 49). The remaining roads all had mean slopes which are less than 7% and can be considered less significant contributors of phosphorus loading.

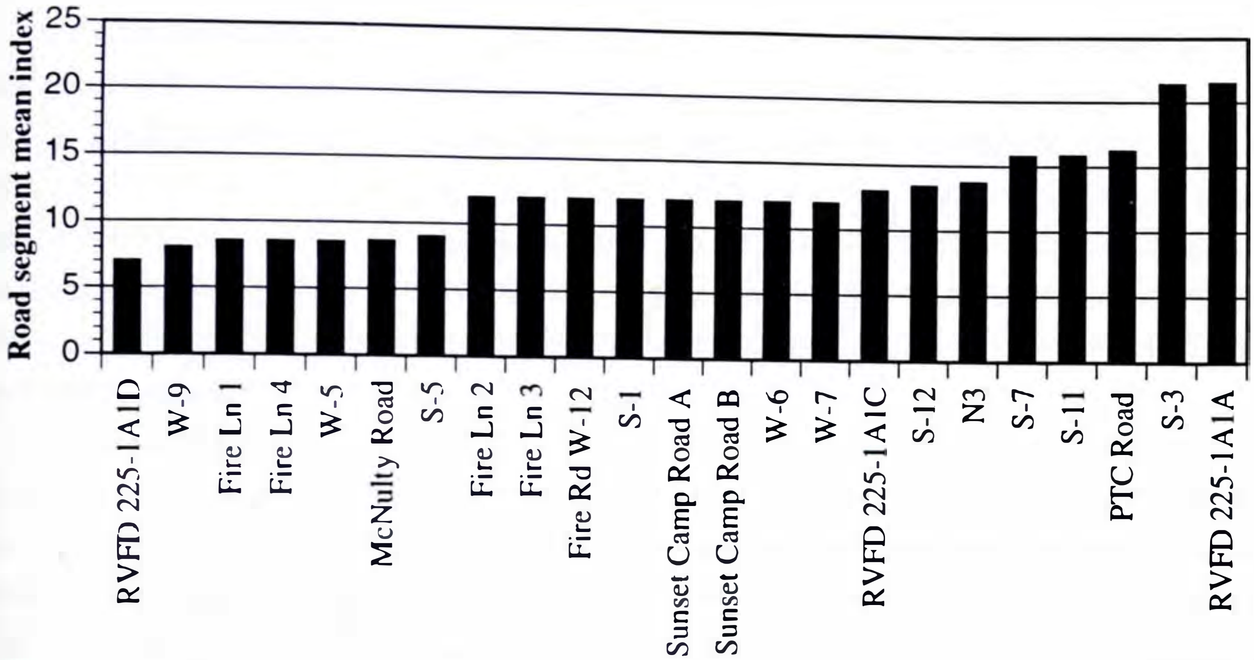

Figure 48. Road segment mean indices indicating the potential for phosphorus loading for camp roads in the North Pond watershed. The road segment mean is the average slope value taken with a clinometer of different road segments.

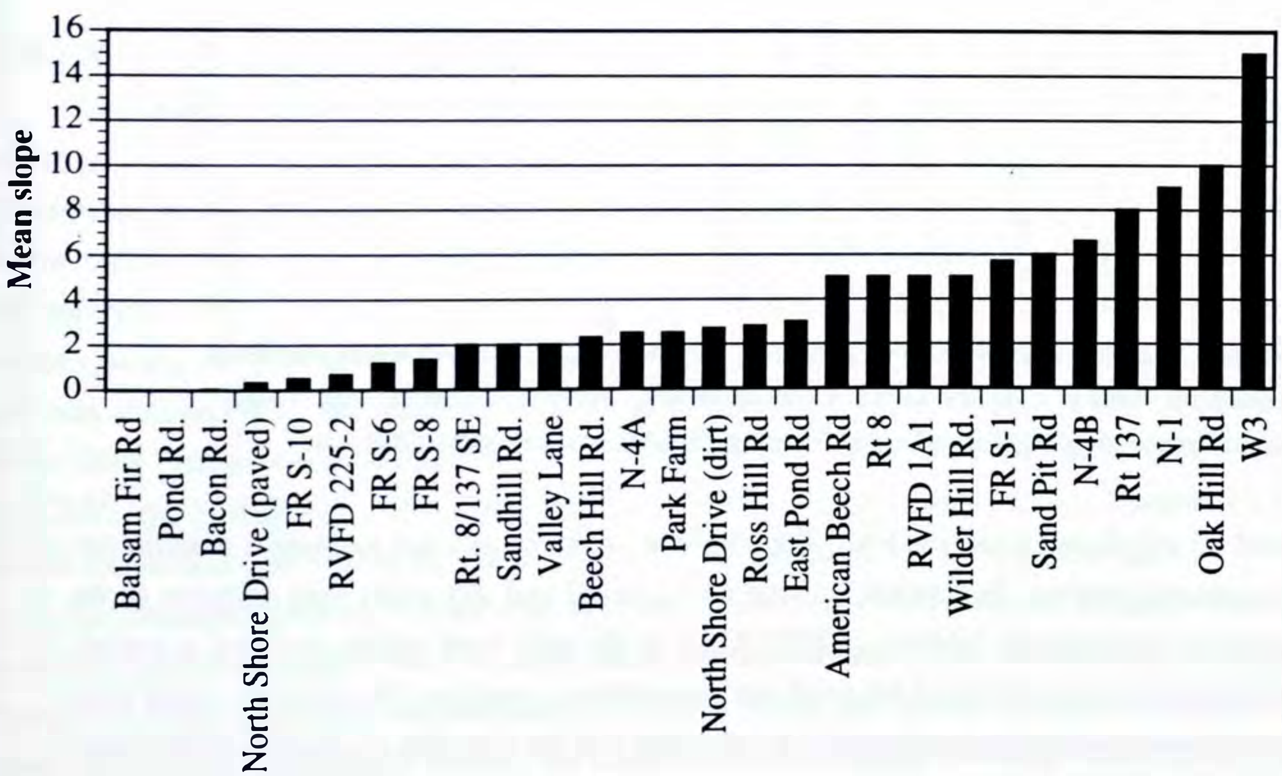

Figure 49. Mean slope of paved and dirt roads in the North Pond watershed based on field surveys. A greater value indicates roads which can potentially contribute more to phosphorus loading.

The Road Total Indices for camp roads suggest which roads are greater contributors to phosphorus loading and are in need of improvements in terms of surface constituents, ditches, culverts, and water diversions. The higher the index value, the poorer the conditions of the road and therefore the greater potential for phosphorus loading from these roads. Fire Lanes 1, 2, 3, and 4 as well as W-5 are the greatest contributors to phosphorus loading (Figure 50). The close proximity of these roads to the pond gives even more reason for alterations in the near future. All other camp roads have Total Index Values less than 300 and are not considered to be large contributors to phosphorus loading.

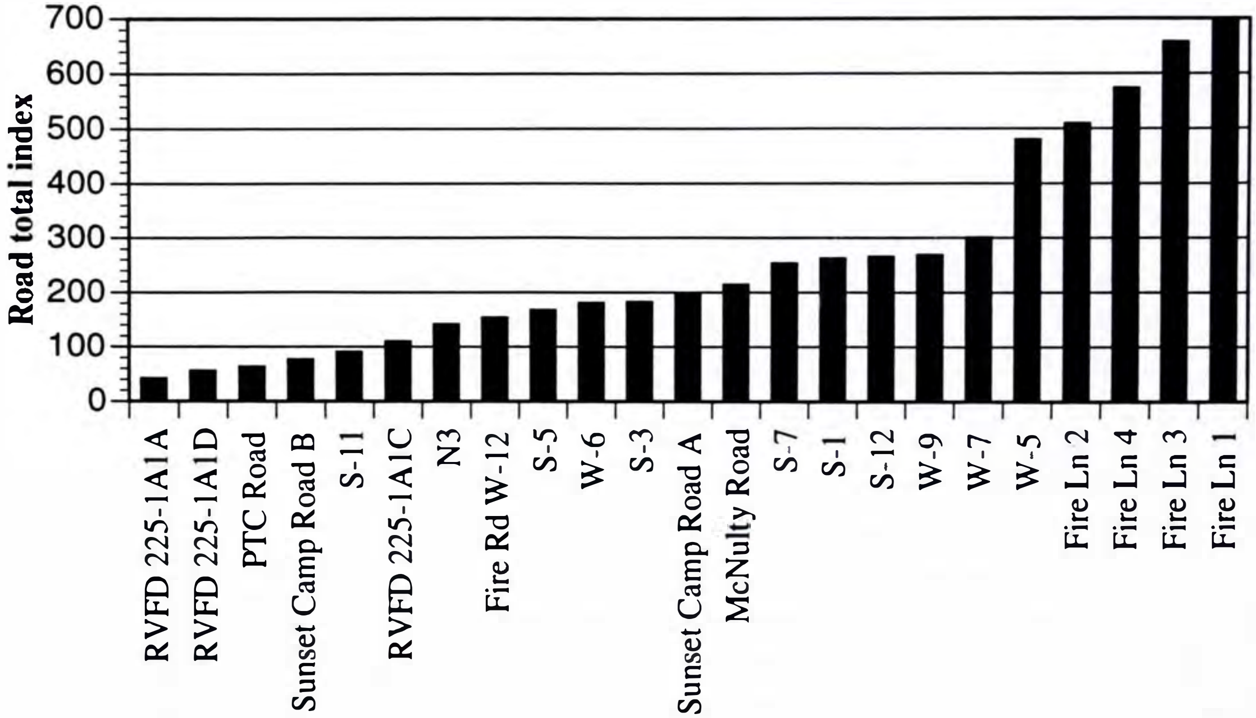

Figure 50. Road total indices for camp roads in the North Pond watershed based on road scores for surface constituents, ditches, culverts, and water diversions. A higher road total index indicates greater potential for

While based on a different scale, the Road Total Indices for paved and dirt roads also indicate the potential for phosphorus loading. In contrast to camp roads, paved and dirt roads with a higher score have less potential for phosphorus loading. RVFD 225-2 is the only road which received a perfect score of five indicating that all aspects of this road are in excellent condition (Figure 47). Only nine paved and dirt roads received scores at or below 2.5 indicating that the majority of paved and dirt roads are in decent condition and, therefore, contribute proportionately less phosphorus to the pond. Of the nine poorer roads, Sand Pit Road received a total score of zero. All aspects of this road surveyed were found unacceptable indicating that potential phosphorus loading is a serious problem. Although this road is near the edge of the watershed, it should not be overlooked since most of the water in the watershed eventually reaches the pond.

While Road Segment Length, Road Slope, and Total Road Indices indicate roads which contribute more to phosphorus loading, the Total Road Value (TRV) combines all aspects of a road and gives a complete indication of which roads contribute the most to phosphorus loading. The TRV is the total road index multiplied by the road segment length for camp roads and by the road slope for paved and dirt roads. S-12 had the lowest TRV suggesting that it is the best overall road in terms of road surface, ditches, culverts, diversions, and slope (Table 14). This indicates that S-12 is the road which contributes the least overall to phosphorus loading. Fire Lane 3 with a TRV of 7884.0 is the greatest contributor to phosphorus loading (Appendix L).

While the total road value takes all characteristics of a road into account, it is interesting to note the difference slope made in characterizing roads with regard to phosphorus loading when the total indices were similar for two roads. S-3 and S-5 have similar road total indices, 182.0 and 166.8 respectively, placing both roads into Class 2 (Appendix K). Conversely, the road total values are very different, 3895 and 1501, and thus each road is then placed in a different classification (Appendix L). This indicates that the slope of each road had a very large impact on its potential for phosphorus loading. Additionally, when discussing phosphorus loading the seasonality of this occurrence should be considered. Most phosphorus loading occurs in the spring when the snow melts and there is a large amount of rainfall (Bouchard, pers. comm.).

Tax Map / Property Card / House Count Methods

Tax maps were obtained from the town offices of Smithfield, Rome, Mercer, and Norridgewock. The approximate boundaries of the North Pond watershed were drawn on the appropriate tax maps in order to exclude all lots not pertinent to the study (lots outside the watershed). The shoreline and nonshoreline lots in the watershed were tallied for each town (Table 15). To obtain the percentage of developed lots for each town, the number of lots was divided by the number of houses, using the assumption that each house occupied a single lot. The percentage of undeveloped lots was assumed to be the percentage that remained when the percent of developed lots was subtracted from 100%. House counts for each town had been previously conducted by visual surveys performed by CEAT on 30-SEP-96, 7-OCT-96, and 21-OCT-96. These counts recorded whether or not the house was within 200 ft from the lakes (shoreline), or outside of 200 ft (nonshoreline).

To obtain the acreage of developed and undeveloped areas, two different methods were used for shoreline and nonshoreline lots. Acreage values for the shoreline were obtained by multiplying the numbers of developed and undeveloped lots by 0.5 acres, the MDEP's standard acreage value for shoreline lots (Bouchard, pers. comm.; see Land Use Methodology). Acreage values for nonshoreline areas were determined in a more complex way. First, the number of developed lots was multiplied by one, the MDEP's acreage value for nonshoreline lots, and the acreage values for municipal or industrial use were added (see Land Use Results and Discussion). This yielded the number of nonshoreline developed acres. To obtain the acreage of undeveloped lots, acreage values for mature forest, cleared land, regenerating areas, and reverting land were summed.

Table 15. The percentages and acreage of developed and undeveloped lots. The percentages of seasonal and year round residences, and percentages of septic system statuses. All information is separated by shoreline and nonshoreline lots for all towns in the North Pond watershed as of SEP-96.

SHORELINE	Smithfield (222 lots)	Mercer (97 lots)	Rome (141 lots)	Norridge. (0 lots)	Total Watershed (460 lots)
Developed Lots					
% Developed	84.7% (188)	79.4% (77)	29.8% (42)	0.0% (0)	66.7% (307)
% Undeveloped	15.3% (34)	20.6% (20)	70.2% (99)	0.0% (0)	33.3% (153)
Acreage					
Developed Acreage on Lots	94.0	38.5	21.0	0.0	153.5
Undeveloped Acreage on Lots	17.0	10.0	49.5	0.0	76.5
Residence Status					
% Seasonal	86.7%	85.7%	100.0%	0.0%	88.3%
% Year Round	13.3%	14.3%	0.0%	0.0%	11.7%
Wastewater Disposal Status for Residences					
% With Septic	70.0%	78.6%	75.0%	0.0%	73.3%
% With Other Than Septic*	15.0%	0.0%	0.0%	0.0%	8.7%
% With No System Indicated	15.0%	21.4%	25.0%	0.0%	18.0%

NONSHORELINE	Smithfield (299 lots)	Mercer (90 lots)	Rome (461 lots)	Norridge. (8 lots)	Total Watershed (858 lots)
Developed Lots					
% Developed	47.5% (142)	67. 8% (61)	3.9% (18)	25.0% (2)	26.0% (223)
% Undeveloped	52.5% (157)	32.2% (29)	96.1% (443)	75.0% (6)	74.0% (635)
Acreage					
Developed Acreage on Lots	269.5	81.4	18.0	2.0	223.0
Undeveloped Acreage on Lots	5330.6	3446.4	1469.0	98.8	10344.8
Residence Status					
% Seasonal	5.6%	18.0%	0.0%	0.0%	8.5%
% Year Round	94.4%	82.0%	100.0%	100.0%	91.5%
Wastewater Disposal Status for Residences					
% With Septic	33.3%	63.6%	100.0%	100.0%	47.5%
% With Other Than Septic*	22.2%	0.0%	0.0%	0.0%	14.3%
% With No System Indicated	44.5%	36.3%	0.0%	0.0%	38.2%

* Other types of septic systems includes pit privies, holding tanks, and cess pools.

Samples of twenty randomly selected property cards, from both shoreline and nonshoreline lots, were taken at the town offices. From these samples, the approximate percentages of residences that had a septic system or had no indication of a septic system (unknown) could be determined, as well as the percentage of residences that had other forms of waste treatment such as a holding tank, pit privy, or cess pool.

The data gathered from tax maps, house counts, and property cards are subject to several sources of error. The lines that were drawn on the tax maps to indicate the watershed boundaries were estimations and may have excluded or included a small number of lots incorrectly. It is possible that during the house counts taken on the above dates, that a small number of residences may have gone unnoticed and uncounted. It is also possible that the extrapolations taken from the property cards may be inaccurate, and that the information on the property cards may have been outdated.

Shoreline Results

Of the lots in Smithfield within the North Pond watershed, 42.6% were on the shoreline, 66.7% of which were developed (Table 15). In Mercer, 41.2% were on the shoreline, as were 70.0% of Rome's lots. Of the developed lots in Smithfield, 57.0% were on the shoreline. In Mercer, 55.8% of the developed lots were on the shoreline, as were 23.4% of Rome's developed lots. None of Norridgewock's lots in the watershed were on the shoreline. For the entire watershed, 35.0% of the lots were on the shoreline, comprising 58.0% of all developed lots.

In Smithfield and Mercer, at least three times as many acres on the shoreline were developed than were undeveloped. In Rome, 21.0 shoreline acres were developed. For the total watershed, 153.5 shoreline acres were developed, comprising 66.7% of the shoreline acreage.

There were 307 residences on the entire shoreline of the North Pond watershed; 188 in Smithfield, 77 in Mercer, 42 in Rome, and zero in Norridgewock (Table 15). In each of the towns, except Norridgewock, at least 85.0% of the shoreline residences were seasonal; Smithfield (86.7%), Mercer (85.7%), Rome (100.0%). Of all the shoreline residences in the watershed, 88.3% of them were seasonal. Based on CEAT's survey, about 73.0% of these residences had septic systems, and about 18.0% had no waste treatment system, and 9.7% had other forms of subsurface wastewater disposal.

Nonshoreline Results

Within the boundaries of the North Pond watershed, 57.4% of Smithfield's lots were nonshoreline, as were 48.1% of Mercer's lots, 76.6% of Rome's lots, and 100% of Norridgewocks's lots. One hundred and forty two (142) of Smithfield's 299 lots were developed (47.5%), 61 of Mercer's 90 were developed (67.8%), 18 of Rome's 461 were developed (3.9%), and 2 of Norridgewock's 8 were developed (25%). Of the 1318 lots in the North Pond watershed, 65.1% were nonshoreline and 26% of these were developed.

In Smithfield, 269.5 acres of nonshoreline lots were developed for residential and municipal or industrial uses, comprising 4.8% of the acreage of the nonshoreline lots. In Mercer and Rome, 2.3%

and 1.2% of the acreage of nonshoreline lots were developed, respectively. About 2.1% of the nonshoreline acreage (223 acres) in the entire watershed was developed.

The survey suggests a greater percentage of nonshoreline residences were year-round than seasonal in the total watershed and in each town. Of all the nonshoreline residences, 91.5% were year-round and 8.5% were seasonal. All of Rome's and Norridgewock's nonshoreline residences had septic systems. 63.6% of Mercer's nonshoreline residences, and 33.3% of Smithfield's, had septic systems. The property cards indicated that approximately half of the nonshoreline residences in Smithfield lacked a waste treatment system.

Discussion of Residences

Residential land use is an important component in determining the phosphorus loading of a lake. The tax maps from each of the towns indicated that approximately two-thirds of the shoreline of the lakes was developed (Table 15). The vast majority of the shoreland zones in the three towns that share the North Pond and Little Pond shoreline are limited residential zones (MDEP 1994b). The shoreline area for approximately one-quarter of a mile on either side of the mouth of the Serpentine is a limited commercial zone, which permits residential uses as well as low intensity business and commercial uses. Generally, anything except the wetland areas around the mouth of Bog Stream and the head of Great Meadow Stream is open to development.

Most of the shoreline lots are small in comparison to nonshoreline lots. Because many developed shoreline lots have been grandfathered, they would not meet the current minimum acreage requirement for their respective towns. Therefore, a high concentration of residences has resulted around the shoreline, many of which lack sufficient buffer strips (see Introduction: Buffer Strips). The value for developed acreage on nonshoreline lots is assumed to be one acre per lot because, on average, only one acre of a nonshoreline lot is developed for residential use, regardless of the size of the lot (Bouchard, pers. comm.). It is important to note that the acreage data are based on best estimations, not actual measurements. Generally, a large percentage of nonshoreline acres are currently undeveloped (Figure 51; Table 15). This means that much of the watershed area could potentially come under development in the future. The large amount of developable land that is currently undeveloped is important in absorbing nonshoreline runoff, and is a valuable natural resource.

The data for Rome may seem somewhat skewed due to the fact that Rome has an unusually high number of lots considering the area it occupies in the watershed (Table 15). Tax maps 29 and 30 show a multitude of small lots which were part of a real estate project in the 1970's (Turner, pers. comm.). There are 580 individual lots on these two maps, approximately 470 of which are in the North Pond watershed. The majority of these lots are currently being purchased and consolidated by a French logging company, the Rome and Carmel Forestry Corporation (Moreau, pers. comm.). Because these lots are close to Little Pond, and because they are located on a very steep slope, it would

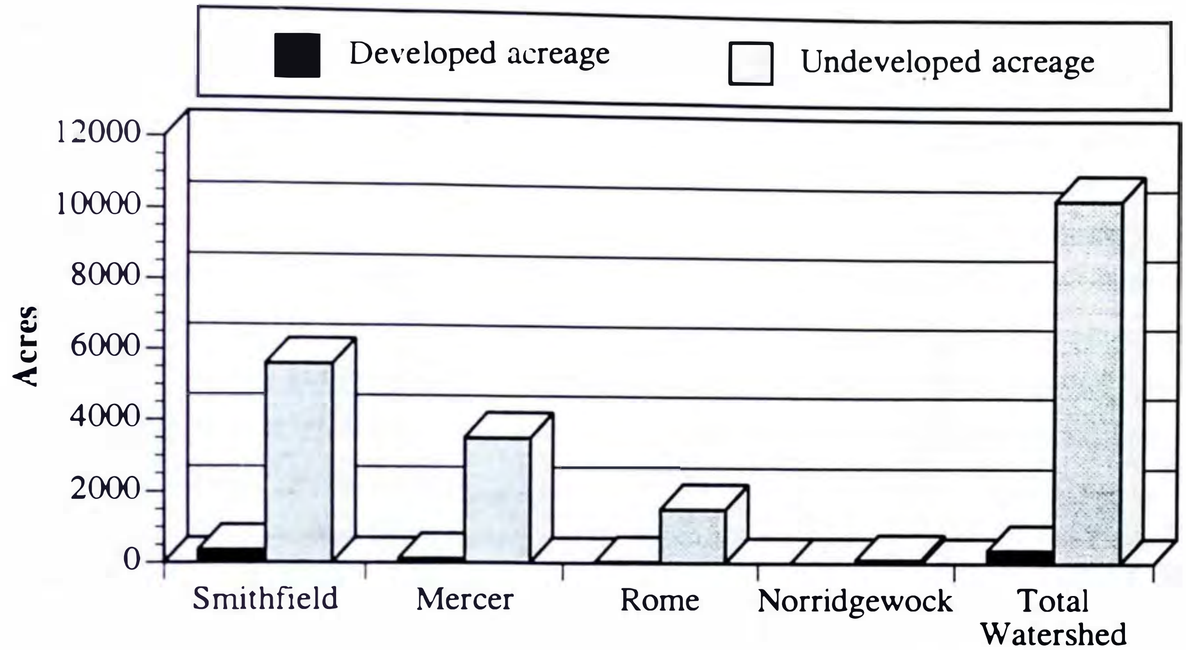

Figure 51. Approximate amounts of developed and undeveloped acreage on lots in the North Pond watershed.

be very threatening to the water quality of the lakes if they were ever developed extensively by logging or by building. Such development does not seem likely since these lots are currently remote and inaccessible by vehicle, but it may be beneficial to consider a moderate resource protection ordinance on this high relief area as additional insurance against sediment and phosphorus runoff caused by development or clearing. The unusually high lot number, however, caused the percentages of developed lots, in both shoreline and nonshoreline areas, to seem deceptively small. Development in Rome, as was clear by visual survey performed by CEAT during reconnaissance, is similar to the development in Smithfield and Mercer.

It is beneficial to consider the status of the North Pond and Little Pond shoreline in relation to other nearby lakes. In 1993, Salmon Lake was found to have 70.0% of its shoreline developed (BI493 1994). Salmon Lake is known to currently suffer algal blooms. In 1994, 63.4% of the shoreline in of Long Pond, North Basin was developed (BI493 1995). In 1995, Long Pond, South Basin had 66.2% of its shoreline developed (BI493 1996). Long Pond's water quality has been regarded as one of the most healthy of the Belgrade Lakes. On the basis of the water qualities of Salmon Lake and Long Pond, it would seem that the percent of developed shoreline has little effect on water quality. However there are many more factors involved in determining water quality, such as depth and flushing rate, which could easily mask the effect of shoreline development.

The survey suggests that North Pond and Little Pond have average development relative to their neighboring Belgrade Lakes, with 66.7% of their shoreline lots developed. Since 88.3% of the developed shoreline lots are seasonal, much of the activity which contributes to phosphorus loading on the shoreline, such as septic system use and heavy recreational use, occurs in the summer months

(Figure 52; Table 15). For the entire watershed 54.7% of the residences were seasonal. This would suggest that the population of the watershed area approximately doubles during the summer months.

In 1995, 86.3% of the Long Pond South Basin shoreline residences had septic systems. In 1988, 90.0% of the residences around East Pond were found to have had septic systems (EPLA, 1989). The sampling methods indicate that 73.6% of the residences in the North Pond watershed have some type of subsurface waste treatment system (Table 15). Each of the towns in the watershed had a high percentage of residences with septic systems and a noticeable percentage of residences whose property cards lacked any information specifying the presence of a septic system (Figure 53). The North Pond watershed has a comparatively substandard septic status, and could contribute to phosphorus loading when coupled with a lack of buffer strips (see Land Use Results and Discussion: Subsurface Waste Water Disposal Systems).

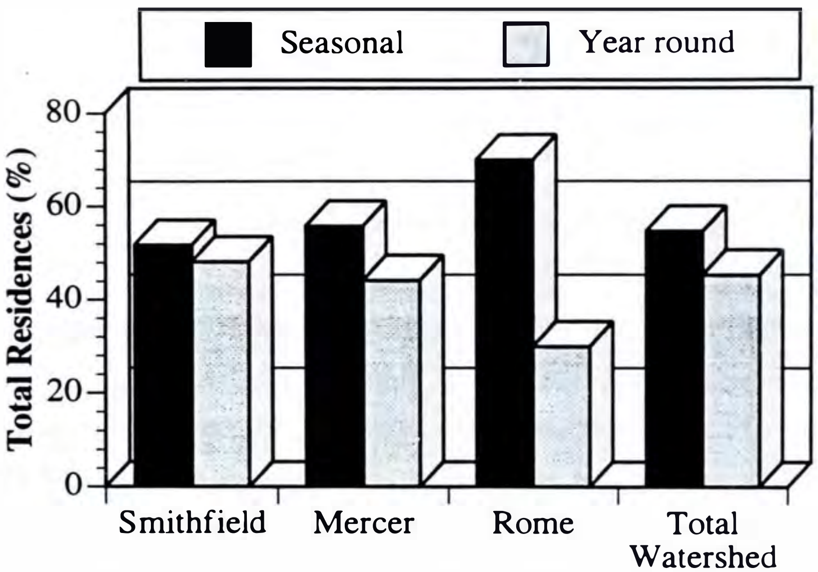

Figure 52. Seasonal and nonseasonal percentages of the residences in each town of the North Pond watershed, as of SEP-96. Norridgewock is not shown individually because it had only two residences in the inland watershed which are year round.

To develop a good idea of the role residences are playing in phosphorus loading of the lake, it is important to summarize the data in general terms. Most of the shoreline lots are developed with few buffer strips, many having grandfathered septic systems, which creates a potentially large phosphorus export into the lakes. However, most of the residences on the shoreline are seasonal, which may lessen their impact on phosphorus loading. Most nonshoreline residences are year-round and are buffered by naturally surrounding vegetation, but may still contribute phosphorus into tributaries. Nonshoreline lots are generally much larger than shoreline lots, and there is a large percentage of these which are currently undeveloped, 74.0% (Table 15), creating a high potential for future development which would contribute to phosphorus loading. An area's potential for future development is dependent upon accessibility by roads, soil suitability, and proper zoning (see Future Projections: Development Trends and Potential).

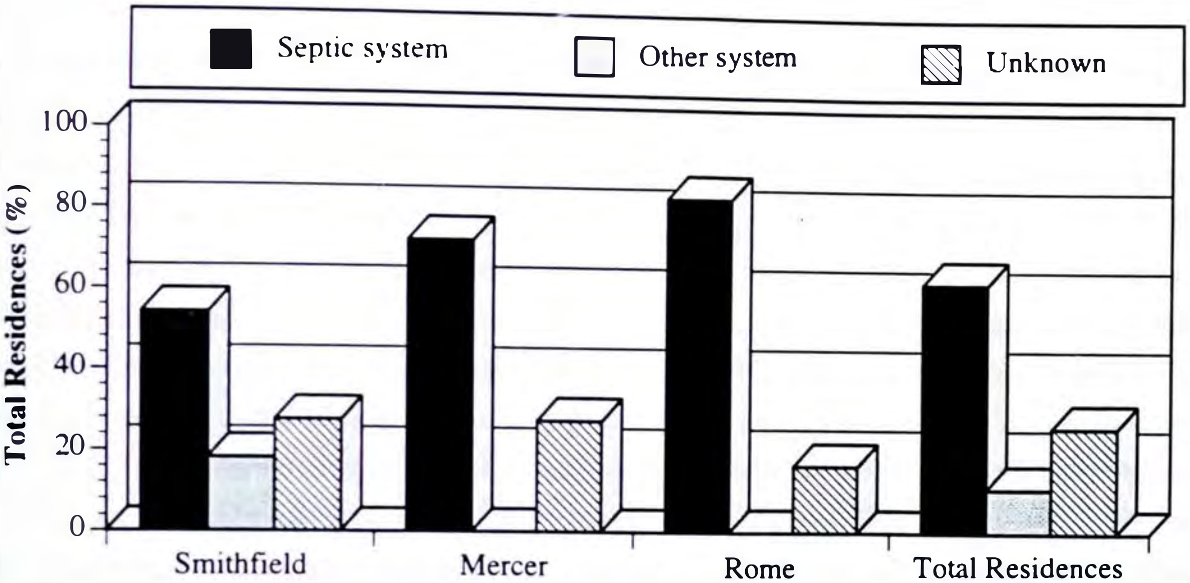

Figure 53. Percentages of septic system status shown by town as of SEP-96. Norridgewock is not shown because it contained only two year round residences in the watershed.

Subsurface Waste Water Disposal Systems

Methods

A general field reconnaissance survey was conducted to study the quality of waste water disposal systems in the North Pond watershed. This included visual observations which provided an idea of the concentration of houses on North Pond and enabled the identification of possible problem areas. Tax maps for each town were consulted to gain information on the size and concentration of lots on the shoreline. For the towns of Mercer, Smithfield, and Rome, 20 shoreline and 20 nonshoreline property cards were sampled to determine the percentage of septic systems used in waste water disposal. The property cards provided information on whether or not a septic system was present for each developed lot (see Land Use Results and Discussion: Roads and Residences, Tax Map/ Property Card/ House Count Methods). Shoreline zoning ordinances were obtained from Smithfield, Mercer, Norridgewock, and Rome. These ordinances explain the rules that each town has adopted concerning subsurface waste water disposal systems. The Maine Subsurface Waste Water Disposal Rules, developed by the Division of Health Engineering of the Maine Department of Human Services, were also obtained. Subsurface waste water disposal applications were sampled for the towns of Smithfield, Mercer, and Rome. From this sample, information was obtained concerning the date a new system was installed; or if the system was a replacement system, the date the system was replaced; the age of the faulty system; and the type of replacement system installed. Personal communications with plumbing inspectors and code enforcement officers gave us overall impressions as well as details concerning the quality of the waste water disposal systems in the North Pond watershed.

Results and Discussion

The status of subsurface waste water disposal systems in the North Pond watershed may have a significant effect on phosphorus loading and lake water quality. These systems, if not properly installed and maintained, can result in damaging phosphorus runoff and nutrient loading to the lake.

The conditions of subsurface waste water disposal systems in North Pond vary in each of the four towns in the watershed. However, the general outlook among local officials is that they are getting better although there is still room for improvement. To understand the conditions of waste water disposal on North Pond some background information is necessary. According to the State of Maine Guidelines for Municipal Shoreline Zoning Ordinances, all subsurface sewage disposal systems must be installed according to the rules set by the state. These rules include a minimum setback of 100 ft from any major water course for new systems, specific instructions concerning the construction of septic systems, and location requirements considering soil types, slope of the land, and other factors (MDHS 1996). In addition to the minimum guidelines set by the state, individual towns are encouraged to develop stronger and more specific rules. However, none of the four towns in the watershed have created their own rules for waste water disposal. They have only used the minimum state code.

It is the job of the plumbing inspector to make sure that all new and replacement systems are built to the standards of the current plumbing code. Old systems that were built before the code was updated, and complied with the rules accepted at the time of installation, are grandfathered and allowed to exist as long as the system continues to function. If the system is not noticeably breaking down, releasing waste and odors on the surface, it is accepted as a working system and is not inspected (Buzzell, pers. comm.). However, some systems on the shoreline may be leaching waste water into the pond without showing noticeable signs of malfunction. These old and potentially failing systems are undoubtedly a cause of pollution in North Pond (Zimmer, pers. comm.). Old, malfunctioning systems may include trenches and other leach fields clogged with waste water, steel drums that have corroded, and cesspools. A cesspool is defined as a porous tank in the ground through which waste water flows and is distributed into the surrounding soil (Landford, pers. comm.). Often waste water flowing from a cesspool is deposited directly into the lake. Cesspools are no longer acceptable in Maine although some still exist in the watershed as grandfathered systems (Buzzell, pers. comm.).

Ideally, all systems will be converted to new functioning systems as soon as possible. The acceptable systems most commonly used on North Pond include septic systems with stone beds, chambers, or trenches and holding tanks (See Introduction: Sewage Disposal Systems). These systems, when correctly managed, will effectively filter waste water.

Each of the acceptable septic systems are good in different situations and the site evaluator will recommend a system for individual properties depending on the soil type, slope of the land, and water table (MDEP 1974). We found that 78.6% of the waste water disposal systems sampled from Mercer shoreline property cards are septic systems with septic tanks and leach fields (Table 15). This figure is close to the percentages found in the other towns. Smithfield has 70.0% septic systems and Rome has 75.0% septic systems on the shoreline. There are only two houses in Norridgwock which are in the watershed and these houses have septic systems. Property cards did not contain age information on individual septic systems, therefore there was no way to tell how many systems were grandfathered. Regardless of the age of the system, it is important to know that the great majority of waste water disposal systems in the area are septic systems and few properties use other methods of disposal. If a developed property does not have a septic system it most likely has a grandfathered cesspool, a holding tank, or a pit privy. Holding tanks can be an effective method of waste disposal when properly used. However pit privies and cesspools frequently break down resulting in runoff of waste into the lake.

The most common system used in Mercer is the chamber septic system. This form of a leach field is at ground level with fill placed on top forming a mound. Mr. Zimmer (pers. comm.) noted that this type of system is useful in North Pond because of the high water table. In our sample of Mercer plumbing applications, we found that most of the systems replaced in the 1990's were malfunctioning cesspools or trenches that were installed in the 1960's. This supports Mr. Zimmer's belief that the systems that are now being replaced are 40 or 50 years old and have most likely been polluting the pond for several years. In Mercer as many as 75% of the septic systems in use today are old systems that have not yet been replaced. These systems are typically corroded steel tanks potentially leaching effluent into the pond. It is important to note that the exact number of old septic systems is not known because inspection of the system and filing of paper work is only conducted on new and replacement systems. There are also some holding tanks and pit privies in Mercer. In Mercer, Smithfield, and Rome there is no incentive for camp owners to convert their pit privies to functioning septic systems because this will result in an increase in taxes due to the addition of plumbing on the property (Springer, pers. comm.).

According to Dale Buzzell (pers. comm.), the Rome plumbing inspector, it is unlikely that Rome has any pit privies or holding tanks in the North Pond watershed. The most common septic systems installed in Rome are stone beds and chambers. Chambers are different from beds because they are made of a series of open concrete boxes instead of an area of crushed stone (MDEP 1974). However, both the chamber and stone bed systems work efficiently to filter waste water. Rome also has a high proportion of grandfathered septic systems. Dale Buzzell, (pers. comm.) noted that in Rome only two systems in the watershed have been replaced over the past four years. However, he mentioned that most of the older systems, built before the updated state rules were implemented, are functioning adequately otherwise they would have been replaced already.

Mike Zarcone (pers. comm.), the plumbing inspector for Smithfield and Norridgewock, has a positive outlook on the quality of the systems in this area. He commented on the improving state of the waste water disposal systems and noted that in the past 20 years most residences of Smithfield and Norridgewock have upgraded their systems. This year six new systems and a holding tank were installed in Smithfield. According to Mr. Zarcone, there are no pit privies in the area. The most common type of septic system used in Smithfield is the stone bed system. However, this system requires adequate space for a large leachfield so that waste can properly filter through. If there is not enough space for the leach field or if it is placed in poor quality soils, the leach field may become clogged and eventually waste water could break through the surface (MDEP 1974). To prevent this condition, in many cases leach fields are set back away from the shoreline or proper soil is brought to the site to act as a liner (MDHS 1996). In Smithfield, there are several properties on the shoreline that may lack the space and soil quality required for some types of septic systems.

Soil quality plays a significant role in determining the location of a septic system and the type of system to be built. Much of the shoreline in Smithfield and the area surrounding Bog Stream are classified as severely and moderately limited for septic system suitability (GIS Results and Discussion: Areas Suitable for Development - see Figure 58). This means that the soils in the area promote phosphorus runoff (see GIS Methodology: Soil Methodology). These sites are also highly developed and the land is undoubtedly saturated with waste water. In these locations it is particularly important to be sure that septic systems are carefully designed by the site evaluator to compensate for poor soil quality. Grandfathered systems that were built on limited soils may not be sufficient to compensate for the severely high or low soil permeability and should be tested and converted if inadequate. Often it is required to modify the sites before the installation of a septic system. The filling, excavating, blasting, or draining necessary on land that has a low septic suitability raises the cost of development in that area (USDA 1989). If development continues in this stressed area, water quality will be at risk. Alternatively, the west side of North Pond, in Mercer, and a section on the south end of North Pond, in Rome, contain large areas of slightly limited soil. These areas are composed of well drained soils ideal for septic systems and will absorb waste water preventing excessive clogging and run off. Future development should occur in these areas rather than the poorly suited areas on the north and east sides of the pond.

The quality of waste water disposal systems in the North Pond watershed seems to vary between the four towns. In general there is a trend toward improvement as each year more systems are converted to meet the up-to-date standards of the state plumbing code. However the status of the septic systems on North Pond is questionable according to Bob Joly (pers. comm.). There may be more old, unsuitable systems than we are aware of and they may be causing alarming damage to the lake water quality of North Pond.

GIS METHODOLOGY

General GIS Methodology

Geographic Information Systems (GIS) allows users to analyze information about environments by categorizing and manipulating data of different geographic characteristics of a specific area. These characteristics can be entered onto a data layer by assigning values to grid cells. The data layer could be thought of as a transparent map that can be overlaid onto other maps. By manipulating these data layers and finding the intersections of imposed maps, new information becomes apparent.

A data layer in macGIS, the program used to create data layers and maps, is composed of grid cells. These cells then make up rows and columns in the initial data layer. Each grid cell is capable of maintaining one characteristic of the watershed and the grid cell defines the resolution and clarity of the map layer. For example, for the many different soils in the watershed, a specific value was assigned to each grid cell to represent the soil found in a particular region. A grid cell size of 8 m^2 was used for all of the maps created by macGIS. This value was assigned because 8 m is the approximate width of the watershed roads which are often major contributors of nutrients into water. This value also provided great clarity and resolution of the maps that were created.

In order to create the initial data layers, a topographical map and a culture and drainage map from the United States Geological Survey (USGS) were each scanned into the application. Grid cell, row, and column values were determined, creating the initial geo-referenced data layer of the North Pond watershed. The referenced layer ensures that the layers created are in the same proportions and same scale as the maps that were scanned into the application.

Maps were created by entering values into every cell of the data layer. For example, peat and muck type soils were given one value, Bangor soil was given another value, and so on until all of the soils were assigned values. Then the areas where the soils were located on the maps created by the United States Department of Agriculture (USDA) for Kennebec and Somerset Counties had the appropriate values assigned on the data layer. A topographic map was created in macGIS by tracing the topographic contour lines. The topographic map consisted of contour lines at 10 ft intervals and bold contour lines at 50 ft intervals. The lines that were traced in macGIS were the bold 50 ft lines and the intervals between were interpolated by the computer.

The program was designed to allow for the manipulation of data layers to produce new useful information. Through specific commands in the program, layers can be imposed upon other layers or changed through mathematical manipulations. The topographic and culture and drainage maps that were scanned into macGIS served as the base for all the maps that were later created. Maps that were produced by macGIS were bathymetry, soil types, slope, land use types, development projections, soil suitability for septic systems, soil erodibility, soil suitability for logging purposes, and soil suitability for agricultural purposes.

Slope Methodology

A data layer showing contour lines was created using a topographic map of the study site created by the USGS (1982). This was mathematically manipulated by the macGIS program to create a slope map in which the watershed was divided into five slope areas: 0% to 3% gradient, 4% to 8% gradient, 9% to 15% gradient, 16% to 30% gradient, and greater than 31% gradient.

Soil Methodology

The North Pond watershed contains twenty-three different soil series (USDA 1972; USDA 1978). These series were categorized into groups according to permeability, composition, and geological location. These new groups were used to determine erodibilty and septic suitability of the soils in the watershed.

A soil type data layer was derived by grouping the twenty-three soil series and entering the new information into a macGIS data layer (Figure 54; see GIS Methodology: General GIS Methodology). The soil groups were categorized by characteristics that are important in determining septic suitability. The group with the highest variety of types consisted of soils associated with wetlands. This group includes peat and muck, Vassalboro, Togus, Rifle, Scantic, Monarda, and Biddeford soil types. Soils in this group were composed of peat with the exception of Scantic, Monarda and Walpole. Scantic and Monarda are low-lying soils located near wetlands. This characteristic causes these two soils to have the same nutrient handling capability as the wetland soils.

The second group consisted of Peru and Paxton soil types. These are both deep, well-drained, and gently sloping soils made of a fine sandy loam series (USDA 1972; USDA 1978). Buxton and Suffield soils are grouped together because they are well-drained sloping soils made of a brown silty loam. Colton and Adams series are two excessively drained sloping soils with sandy loams. Skowhegan and Stetson were grouped together because they consist of moderately well-drained soil with a fine sandy loam. Leicester and Ridgebury are actually the same soils, however since they are named differently in Somerset and Kennebec Counties, we will refer to them as Leicester. The rest of the soils in the watershed remain separate in their own group. Sally Butler of the soil conservation service (pers. comm.), confirmed that the soils were grouped properly. The data layer created from these groups provides a visual representation of the soils in the watershed and served as a tool for data manipulation of other data layers.

Erodibility Methodology

Another data layer was created to examine the erodibility of soils found in the North Pond watershed. This was determined by considering the K-factors of the soil and slope of the area. The K-factor is a measurement of how well the soil particles hold together. It indicates the rate at which a soil will erode and values range from zero to one (Maine Cooperative Extension Service et al. 1975). A soil with a K-factor of zero is nonerodible while a soil with a value of one is extremely erodible. Soils with K-factors greater than 0.32 are severely erodible, 0.24 to 0.31 moderately erodible, and less than 0.24 slightly erodible (Butler, pers. comm.). A data layer was produced dividing the watershed into three areas based on these K-factor groups (Table 16).

Slope is another important characteristic in determining soil erodibility. Soils on steep slopes will allow water to run off faster thereby increasing the erosion potential (see GIS Results and Discussion: Slopes in Watershed). Another data layer showing the slope of the area was then produced. Four groups were created: 0% to 3%, 4% to 8%, 9% to 15%, and greater than 15% slope. Slopes were regrouped this way to facilitate the mathematical manipulation of the data layers for further maps.

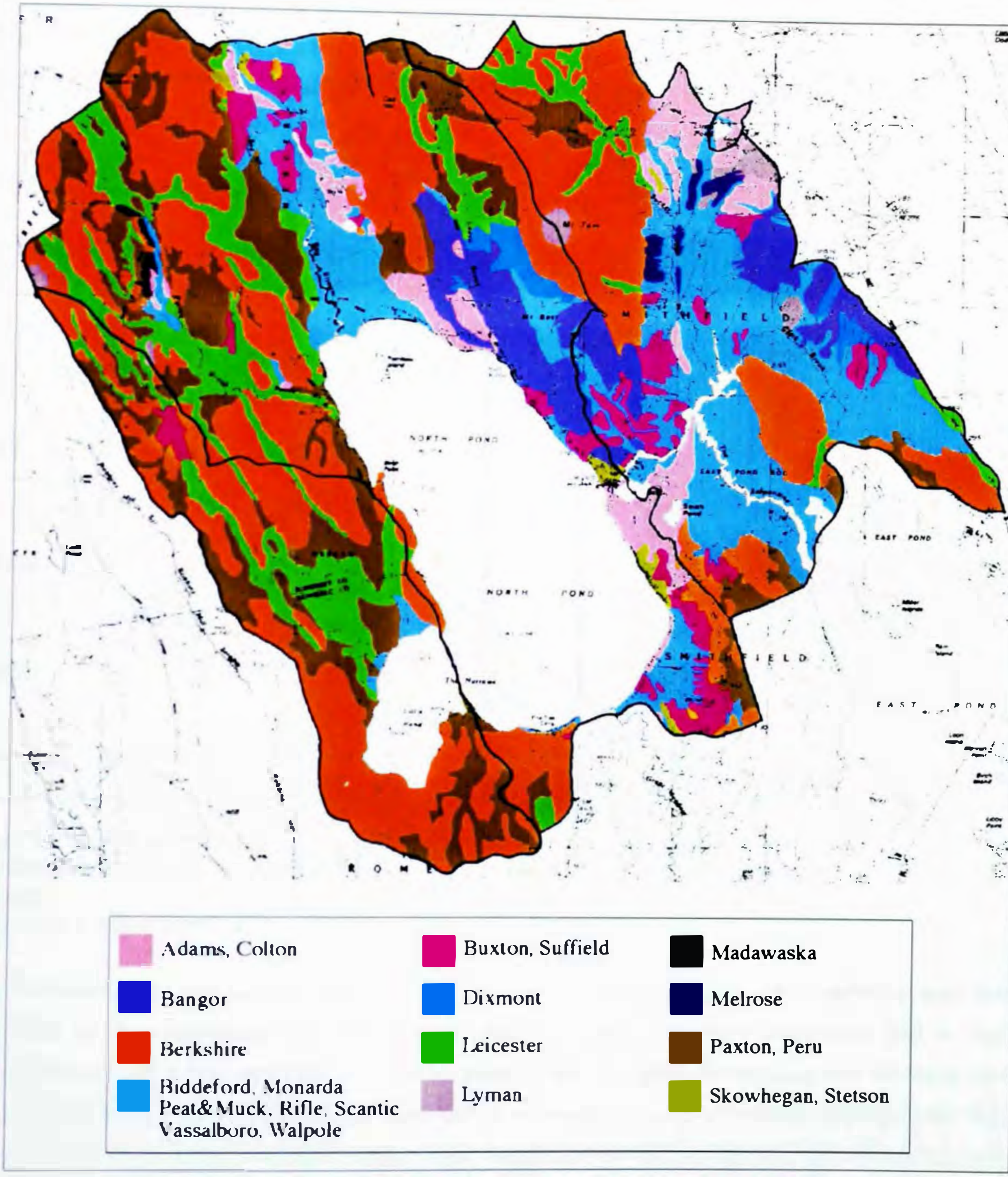

Figure 54. Soils found in the North Pond watershed grouped by permeability and compositional characteristics. The scale on the map is approximately 0.5 inches equal to 0.55 mi (0.89 km).

Table 16. Characteristics of soil types found in North Pond and Little North Pond watershed. Parameters include, water table depth, hydric quality, depth to bedrock, and K-factor (USDA 1992).

Soil Type	Kind	Water Table Depth (in)†	Hydric Y/N	Depth to Bedrock (in)	K Factor*
Adams		> 72	N	>60	0.17
Bangor		> 72	N	>60	0.24/0.28
Berkshire		> 72	N	>60	0.32
Biddeford	Apparent	+12 to 6	Y	>60	0.32/0.49
Buxton	Perched	18 to 36	N	>60	0.32/0.49
Colton		> 72	N	>60	0.17
Dixmont	Perched	12 to 24	N	>60	0.28
Leicester	Perched	0 to 12	Y	>60	0.32
Lyman		----------	N	10-20	0.32
Madawaska	Apparent	18 to 36	N	>60	0.28/0.17
Melrose		> 72	N	>60	0.32/0.49
Monarda	Perched	0 to 12	Y	>60	0.28
Paxton	Perched	24 to 42	N	>60	0.24/0.32/0.20
Peat and Muck		----------	Y	>60	----------------
Peru	Perched	18 to 30	N	>60	0.24/0.32/0.37
Rifle	Apparent	+12 to 12	Y	>60	----------------
Scantic	Perched	0 to 12	Y	>60	0.32/0.49
Skowhegan	Apparent	12 to 30	N	>60	0.24/0.15
Stetson		> 72	N	>60	0.17/0.10
Suffield	Perched	18 to 36	N	>60	0.32/0.49
Vassalboro	Apparent	+12 to 6	Y	>60	-----------------
Walpole	Apparent	0 to 18	Y	>60	0.24/0.10

* There are no K factors for organic soils. Multiple values of K factor are listed for those soil types that have significantly different values at different depths.(see Erodibility Methodology)
† A + indicates a water level above the soil.

The K-factor layer was superimposed on the slope data layer producing an erodibility map that ivided the land in the watershed into two groups; the two categories were soils that had a high rodibility and those with a low erodibility. Criteria were created to place all soils in one of these two roups. Soils with K-factors less than 0.24 were severely erodible on land with a slope greater than 5%, soils with K-factors of 0.24 to 0.31 had a high erodibility on slopes greater than 8%, and soils ith K-factors greater than 0.32 were severely erodible on all lands except those with a slope of 0% to %.

This soil erodibility map was then used to look at areas of the watershed that were comprised of rested and cleared lands to determine future logging and agricultural limitations. A land use type ap was made using data gathered from ZIDAS (see Land Use Methodology). Wetlands, generating forests, reverting, municipal, cleared, and forested lands were mapped. This data layer s simplified further by dividing the watershed area into forested land and all land not forested to ate a new data layer which was superimposed onto the erodibility map. From this new map, areas with severely erodible forested lands which should not be logged could be examined. When considering forested land, it was assumed this land was mature forest with a closed canopy and suitable for logging. The land use map was also divided into groups of cleared and uncleared land, creating a new data layer. This was also superimposed on the erodibility map to determine which cleared lands should not be tilled for agriculture use. When determining agriculture suitability, it was assumed that cleared land is land where hay is being harvested or cultivated. Although not all cleared land is being harvested or cultivated, a large percentage fits this assumption.

Septic Methodology

Soil groups and slope were used to determine areas suitable for septic systems (see Introduction: Soil Types). A data layer was established for steep slopes (see GIS Methodology: Slope Methodology). A second layer was established for septic limitations.

The soil limitations data layer was created by classifying soils as being slightly, moderately, and severely limited for septic suitability. Slightly limited is best and severe is the worst for building a septic system. These classifications were based on whether or not the soils were perched, apparent, depth in relation to the water table, depth to bedrock, and if it was hydric (USDA no date, USDA 1992; Table 16). The water table is the area in the soil that becomes saturated with water. The depth to the water table is the average distance where this occurs (USDA no date, USDA 1990). It is best for septic systems to have a substantial depth before reaching the water table. A perched soil is one that has an impervious layer which keeps the water table artificially close to the surface during certain times of the year. If a soil is apparent, it has a water table that comes close to the surface during periods of high precipitation. A hydric soil is one that always has a high water table.

Slightly limited soils are ideal for development. An ideal soil for placement of a septic system has a depth greater than 15 inches to bedrock and has a moderate permeability (USDA no date, USDA 1990). It usually is neither apparent, perched, or hydric, and its water table remains low and far from the surface. Slightly limited soils are primarily composed of a sandy loam and its particles are small enough to bind to phosphorus. Slightly limited soils are elevated above the water table and bedrock giving the water sufficient area to drain.

Moderately limited soils are made up of two general types. They can be highly permeable soils composed of sand and gravel or moderately permeability containing more silt and clay than the previous type. The highly permeable soils contain large sized particles that have a high and rapid infiltration of water making it difficult for phosphorus to bind. Therefore, little phosphorus is absorbed and the water reaches the water table without being filtered. The other types of moderately limited soils are less permeable and do not contribute much runoff because they have a low grade. However, these soils are generally saturated due to their low position in the water table.

Severely limited soils are the least suitable for septic systems. These soils have a very low permeability and are composed primarily of silt, clay, and peat. They are often close to the water table and have no depth to bedrock (USDA 1990). Therefore the soil has very little, if any, space for absorption which results in a high amounts of runoff. Runoff is not desirable because the water is more susceptible to pick up additional phosphorus on its way into the lake and tributaries.

Once the slope and soil limitations data layers were completed, they were superimposed to create a map showing septic suitability. Soils with a slope greater than 20% have a greater potential for runoff, therefore making the soil unsuitable for a septic system (USDA 1990). The septic suitability data layer was then overlaid on top of the slope data layer. This was done in such a way that any area with a slope greater than 15% was severely limited for septic systems. A slope of 15% or greater was used because the slope data layer does not contain a group starting at 20%. This created a new data layer with slightly, moderately, and severely suitable areas for septic systems.

GIS RESULTS AND DISCUSSION

Erodibility

Soil erodibility is an important characteristic used to determine the suitability of land for agriculture and logging purposes. Erodibility is the potential rate of erosion that can occur based on K-factors of soil and slope of the area (see GIS Methodology: Erodibility Methodology). Soils that are highly erodible have the potential to erode at a rate much greater than what is considered tolerable soil loss (USDA 1989). The high erosion potential of a severely erodible soil would eventually bring about a significant decline in the long term productivity of that soil type and possibly have negative effects on lake water quality such as increased amounts of sediment and phosphorus in the lake.

Approximately 41.2% of the North Pond watershed area is comprised of soils with high erodibility. Areas of high erodibility are scattered throughout the watershed but the highest concentration is around Mt. Tom and Oak Hill in the northern region of the watershed (Figure 55). Highly erodible soils are also located at the southern part of the Little Pond subwatershed continuing along the west side of Little Pond and further north along the border of this subwatershed reaching to Beacon Road. In the North Pond subwatershed, areas of high erodibility are also found in the northwest corner starting at the border with the Little Pond subwatershed and continuing north past Beech Airport.

The areas of severe erodibility located along the shoreline of North and Little Ponds are highly developed, except along the southern shore of Little Pond (Figure 55). These locations present the biggest problems because of their close proximity to the lake, possibly contributing significant amounts of phosphorus and sediment to the lake. Pine Tree Camp, as well as a considerable number of residences, are located on the most concentrated area of highly erodible soils found along the southern shoreline of North Pond. In Smithfield, there are small pockets of highly erodible lands scattered along the eastern side of North Pond located relatively close to the shoreline. They also occur along a short length of the Serpentine slightly north of Smithfield.

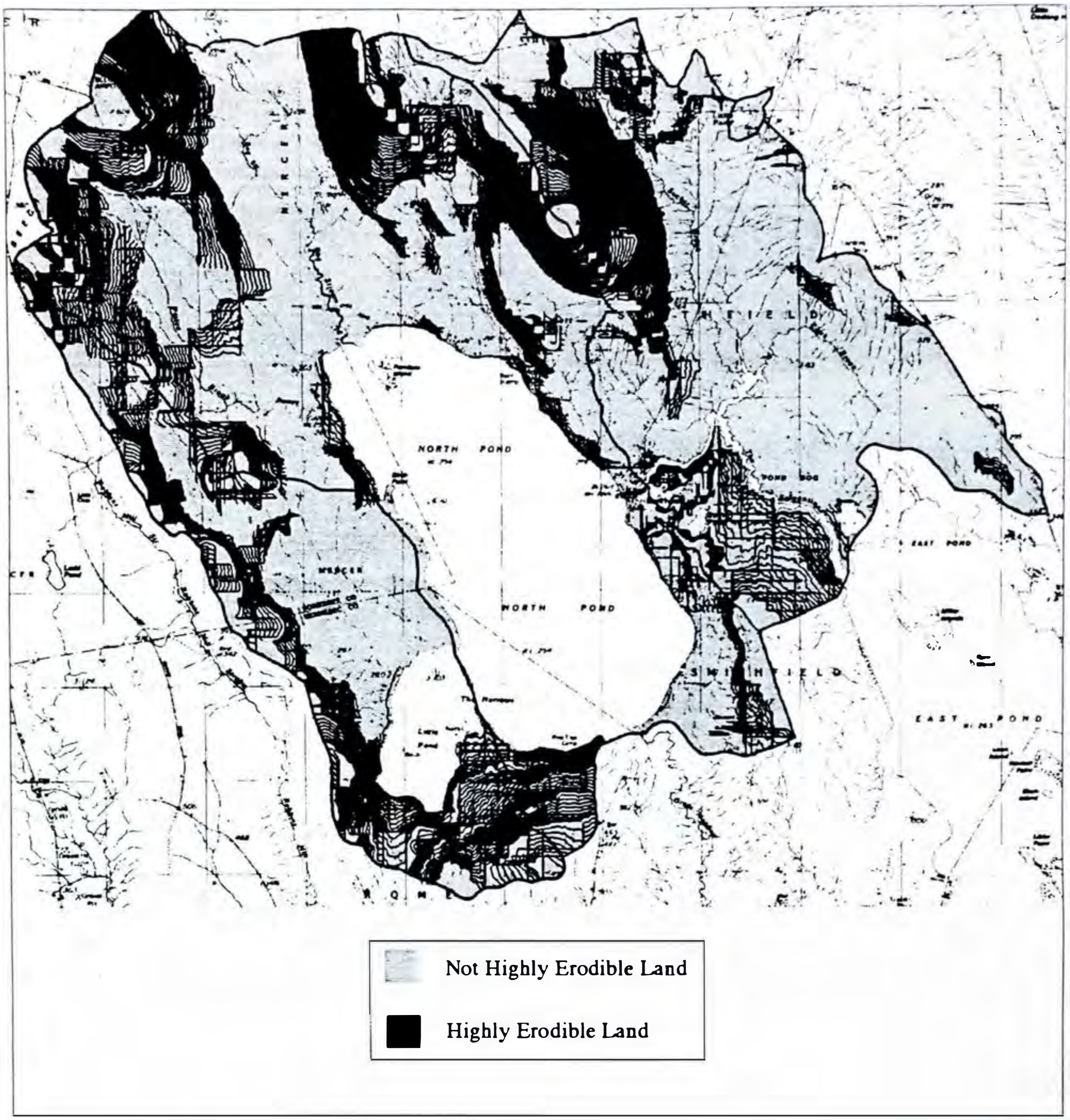

Figure 55. Soil erodibility of land within the North Pond watershed based on K-factors and slope (see Erodibility Methodology). The scale on the map is approximately 0.5 inches equal to 0.55 mi (0.89 km).

Slopes in Watershed

Slope is the vertical rise or fall of the soil surface from a horizontal plane and is expressed as percent gradient (Maine Cooperative Extension Service et al. 1975). It influences the retention and movement of water, potential for accelerated erosion, and engineering uses of the soil (USDA 1990). In general, the steeper the slope the more potential hazards exist. Slope measurements can be used to help determine septic, logging, and agricultural suitability as well as aid in the development of guidelines for future development. Development on slopes greater than 15% requires more fill and grading in addition to more sophisticated sediment and erosion control to minimize erosion and protect water quality (USDA 1990).

Through GIS analysis, the general slope of the North Pond watershed was determined (Figure 56). The majority of the watershed, approximately 55.4%, was of relatively low relief with a slope gradient of 0% to 3%. Areas of high relief were located in the north and northeast corner of the watershed near Oak Hill and Mt. Tom. There were also high relief areas in the southern part along Little Pond and along the western edge of the watershed reaching to Bacon Road, but they were not as steep as in the north. There was a scattering of areas with high relief in Smithfield south of the Serpentine. These high relief areas have slopes that range from 9% to 30% and comprise approximately 18.5% of the watershed. Steeper areas with slopes greater than 31% were comparatively scarce, occupying approximately 3.3% of the watershed. These areas were mostly concentrated in the northern part of the watershed near Oak Hill and Mt. Tom.

Areas Suitable for Development

Agriculture

Limitations on future tilling of cleared lands for agricultural use can be determined by looking at soil erodibility and using land use data (see Land Use Methodology). Activities which take place on a farm that contribute to phosphorus loading include: tree clearing, soil exposure through cultivation of row crops, fertilization of pasture and cropland, erosion from farming operations, and improper storage and use of manure (Fortier et al. 1990). In watershed areas where farming activity is increasing, phosphorus loading into nearby tributaries and lakes will generally increase. Cleared lands that are located on highly erodible soils should not be farmed (Christensen, pers. comm.). The removal or alteration of the natural vegetation cover reduces the amount of rainfall that will infiltrate the soil thereby increasing the rate and volume of surface runoff. This in turn causes an increase in the potential for erosion (Fairchild et al. 1978). Tilling of bare soils would also accelerate the rate of erosion which in turn will result in further phosphorus and sediment runoff.

Approximately 29.8% of the cleared land is severely erodible and therefore should not be farmed. There are several areas of highly erodible cleared lands scattered throughout the watershed, which are primarily located along the western edge of the North Pond watershed near Beech Hill (Figure 57).

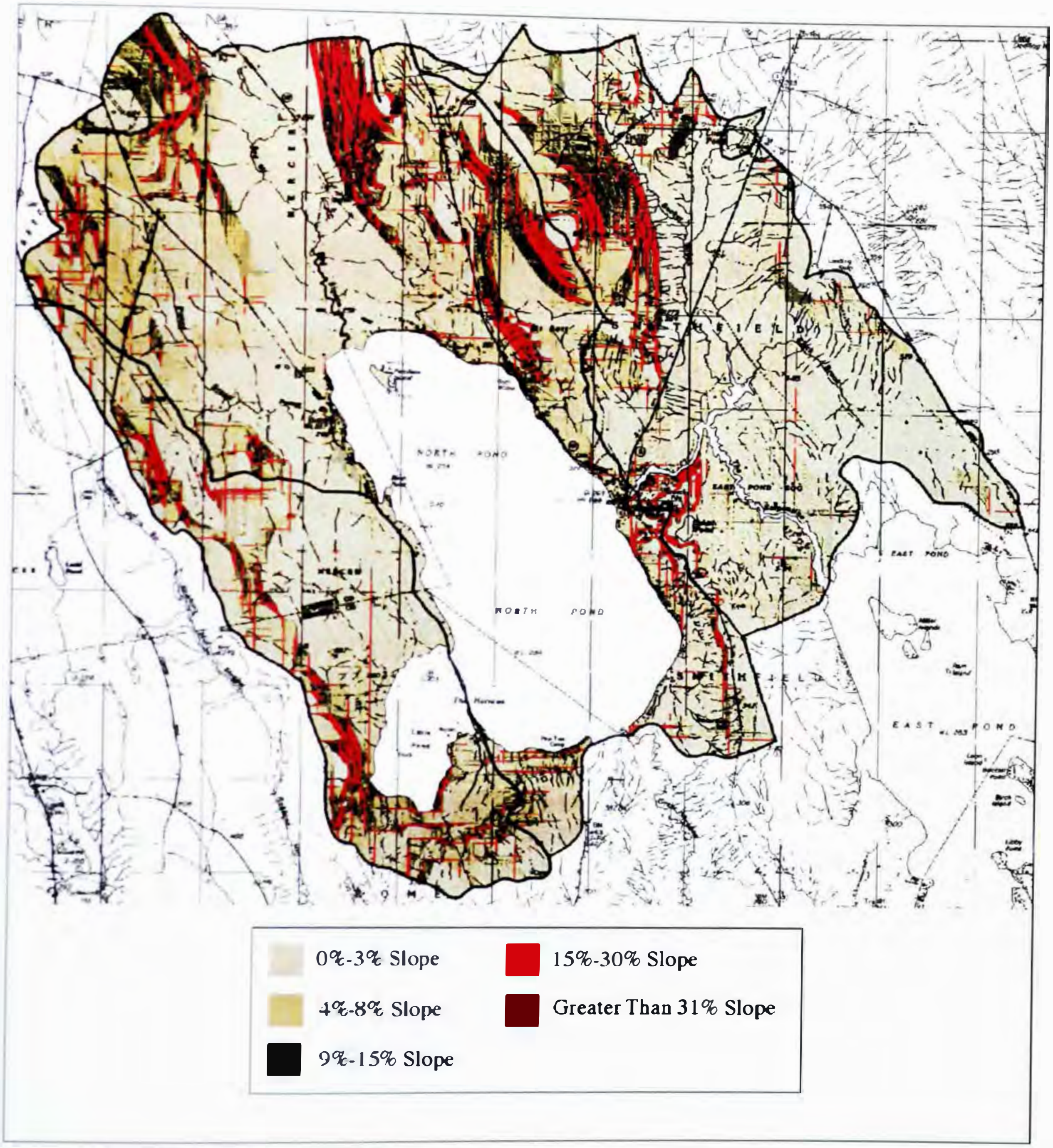

Figure 56. Slope gradients found in the North Pond watershed. The scale on the map is approximately 0.5 inches equal to 0.55 mi (0.89 km).

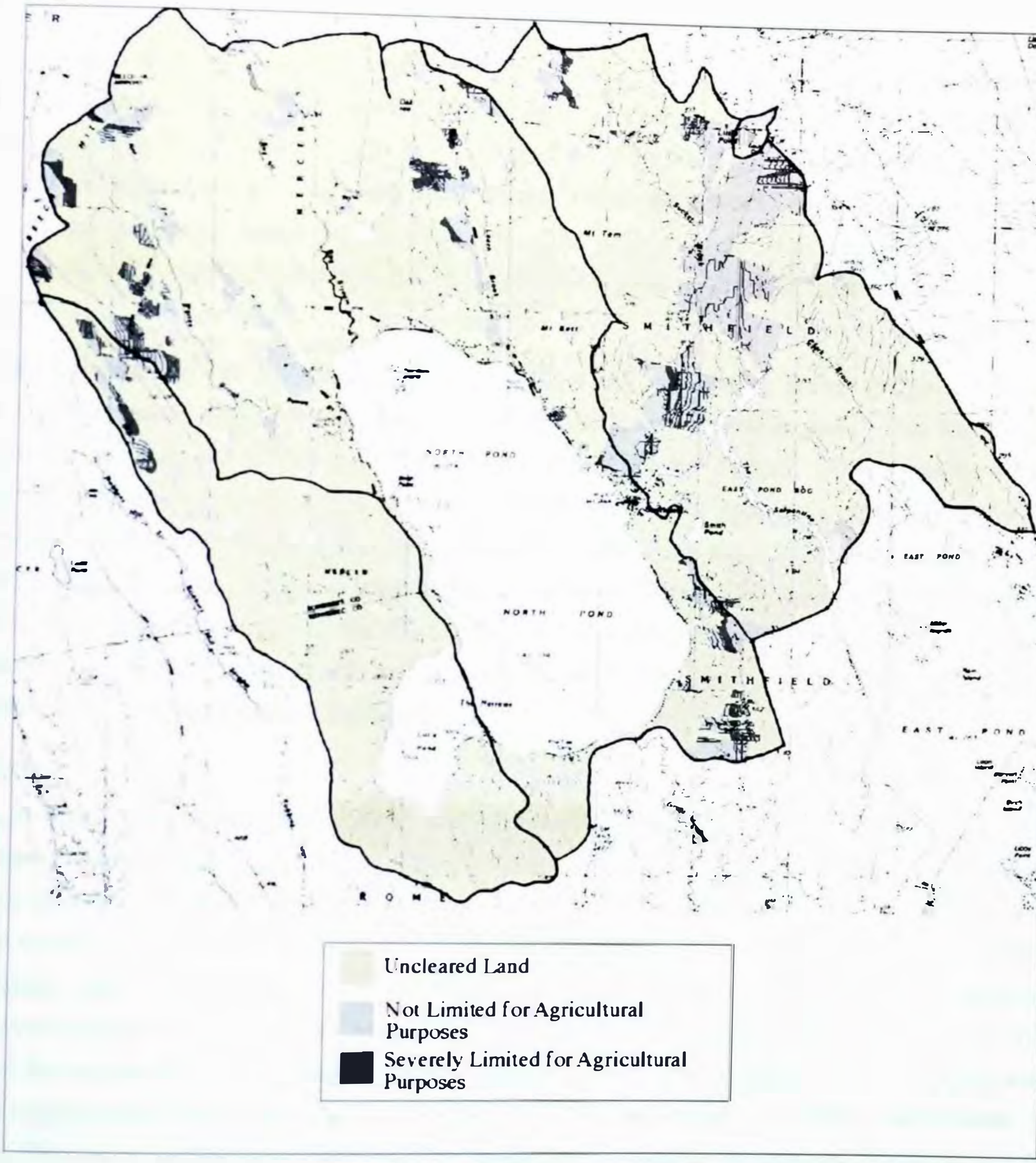

Figure 57. Soil limitations for agricultural purposes in the North Pond watershed based on cleared lands that are located on soils of high and low erodibility (see Erodibility Methodology). The scale on the map is approximately 0.5 inches equal to 0.55 mi (0.89 km).

Septic

Areas with soil types suitable for septic systems are important in determining where development should take place and can be categorized into slightly, moderately and severely limited locations (see GIS Methodology: Soil Methodology). In the North Pond watershed approximately 29% of the area is best suited for septic systems. The soils most suitable for septic systems are scattered throughout the watershed and are rarely found on the shoreline. The soils that are moderately suitable for septic systems occupy 31% of the area while the remaining 40% goes to severely limited suitability. These severely limited areas are primarily found around Bog Stream and the Serpentine (Figure 58).

The shoreline of the lake is important to study when considering septic systems. Since the runoff in these areas is closest to the lake, there is less area to act as a buffer zone. This buffer zone is important for the removal of phosphorus (see Introduction: Buffer Strips). The shoreline of North Pond is primarily composed of soils that are moderately suitable for septic systems (Figure 59). The northern perimeter of North Pond and the perimeter of Little Pond have large areas that are severely limited for septic systems. The only large area of suitable soil for septic systems is located on the west side of North Pond. This suggests that the majority of the watershed should not have septic systems. Fortunately, alternatives to the traditional systems do exist (see Land Use Results and Discussion: Subsurface Waste Water Disposal Systems).

Forestry

Land use data gathered from ZIDAS and soil erodibility information can be used to determine limitations for future logging practices. The two major effects of logging on lake water quality are increases in sediment and phosphorus levels. Of all the possible land use types, forested land is the smallest contributor to phosphorus loading (Fortier et. al. 1990). When the forest canopy is removed by logging, more precipitation is able to reach the forest floor, thereby causing an increase in phosphorus and sediment runoff into nearby tributaries and lakes. Logging practices also increase the potential for erosion by the disturbance of the soil and the loss of root systems which hold the soils in place. Logging should not take place on forested lands that are severely erodible (Christensen, pers. comm.). Erosion would be more likely to occur resulting in a number of negative effects on lake water quality such as an increase in phosphorus loading to the lake (see Introduction: Forestry).

Of the forested land in the North Pond watershed, approximately 43.7% is located on highly erodible soil and should not be logged. The more concentrated area of highly erodible forested lands is in the northern region of the watershed near Oak Hill and Mt. Tom (Figure 60). The largest problem area is along the southern shoreline of North and Little Ponds. This area is severely erodible and located on the shoreline. If cleared, a considerable increase of sediment and phosphorus loading into the lake might occur.

There are current logging operations scattered throughout the North Pond watershed except in the Serpentine subwatershed, but of major concern is the southern part of the watershed previously

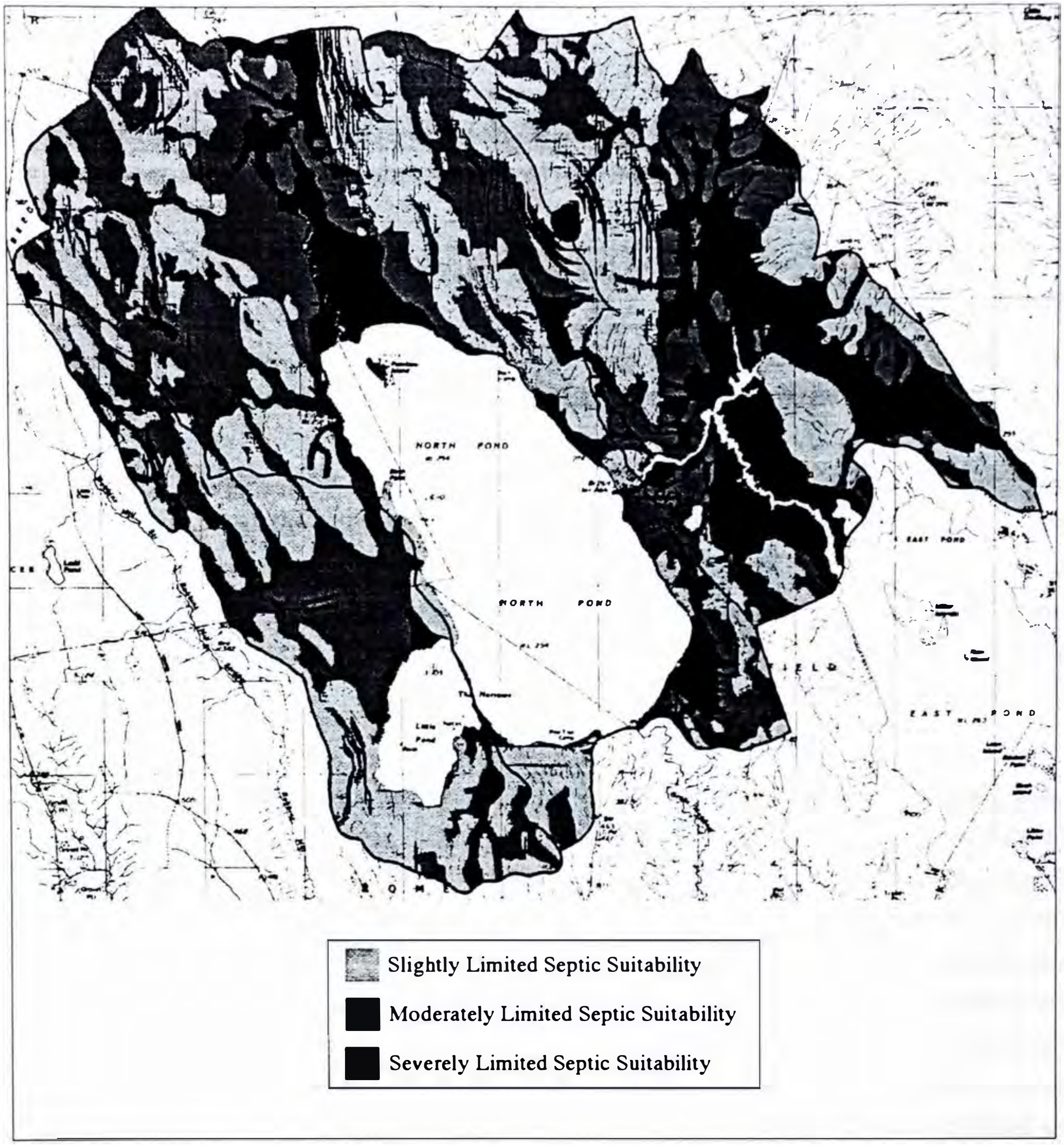

Figure 58. Areas limited for septic systems in the North Pond watershed based on soil limitations and slope (Table 15). The scale on the map is approximately 0.5 inches equal to 0.55 mi (0.89 km).

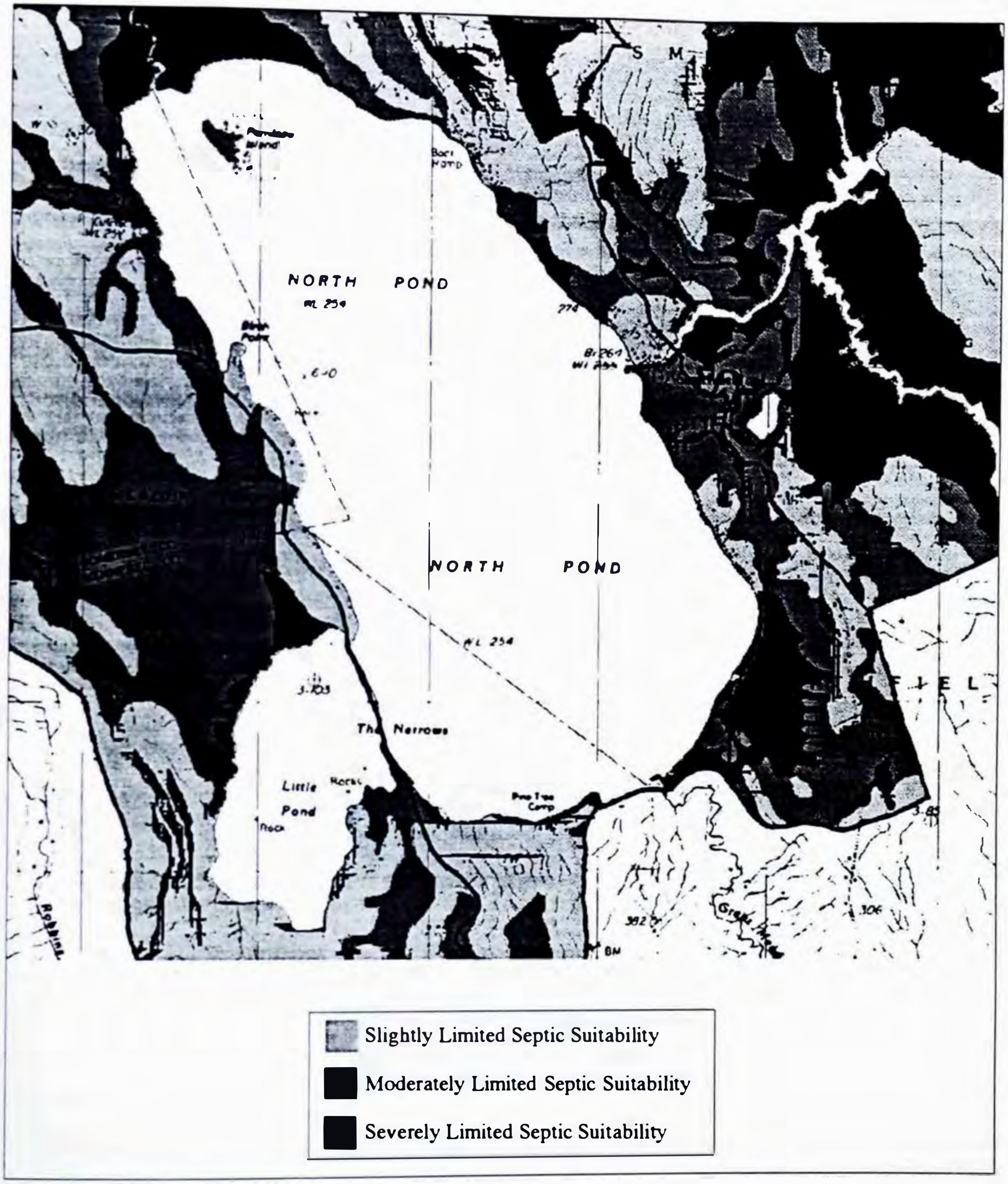

Figure 59. **Areas on the shoreline of North Pond and Little Pond limited for septic systems (Figure 55). The scale on the map is approximately 1.0 inch equal to 0.53 mi (0.85 km).**

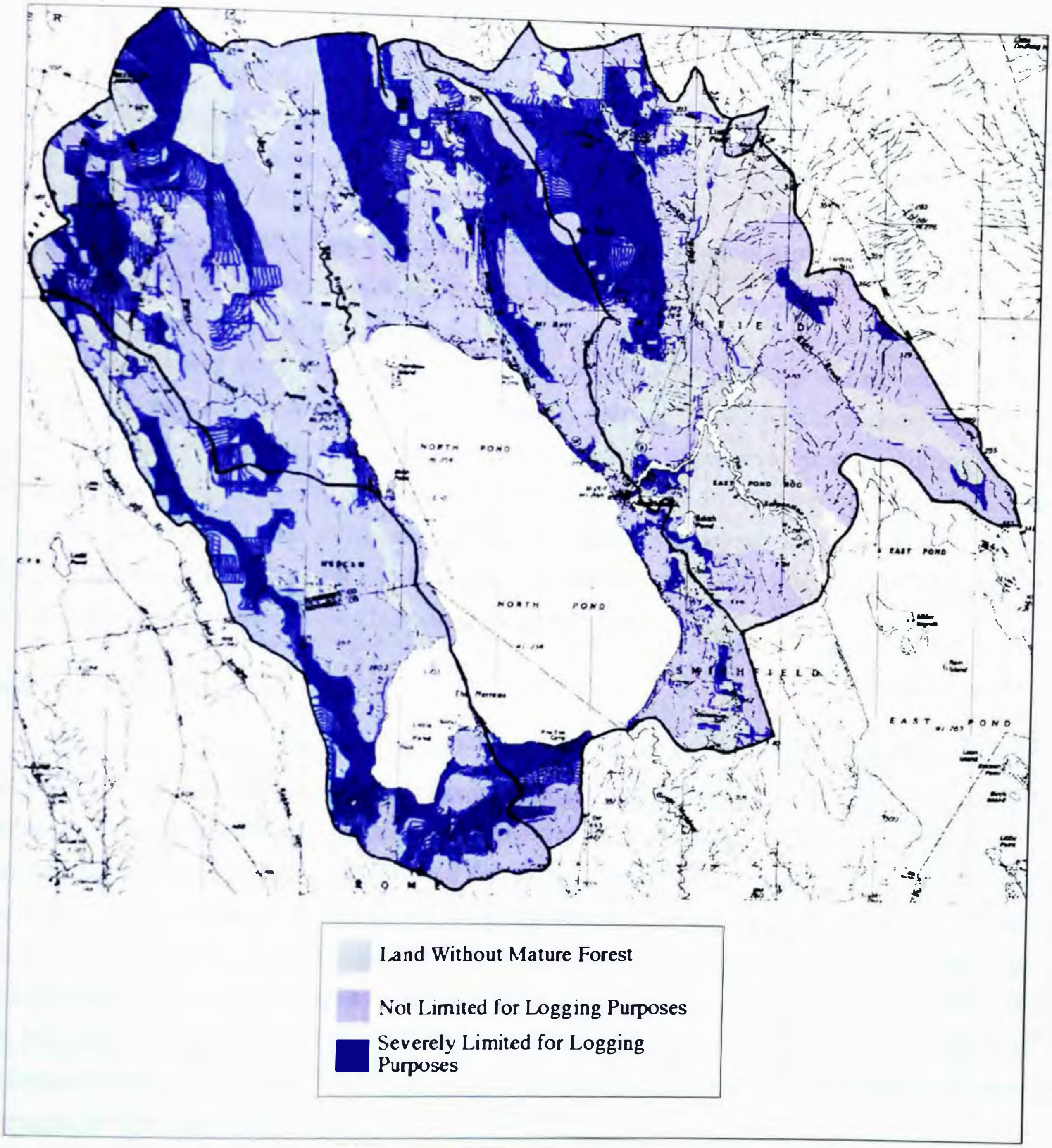

Figure 60. Logging limitations of forested lands within the North Pond watershed based on mature forests located on soils of high and low erodibility (see Erodibility Methodology). The scale on the map is approximately 0.5 inches equal to 0.55 mi (0.89 km).

mentioned. The timber harvesting being conducted by the Rome and Carmel Forestry Corporation along the western shore of Little Pond, which is severely erodible, should be monitored closely. Cutting is not only taking place on severely erodible land, but also along the shoreline thereby exacerbating any negative effects already occurring on the lake. The company started to selectively cut in 1995 and will probably refrain for two or three years before cutting again (Moreau, pers. comm.). If logging occurs it will be detrimental to the future water quality of Little Pond. Currently there is logging taking place on Pine Tree Camp Road, west of Great Meadow Stream, and on Foss Hill Road. In the spring of 1995, there was some cutting on McNulty Road.

When suggesting guidelines for future logging operations, careful consideration should be taken of limiting parameters such as soil erodibility, proximity of possible harvesting areas to roads and surface waters, and soil composition. For this study, only soil erodibility was considered. The type of harvesting patterns should also be examined (e.g. clear-cutting and selective cutting). Clear-cut areas are more susceptible to erosion than selectively cut lands and therefore would contribute more to phosphorus loading. Buffer strips should also be considered when determining areas of logging suitability. Forested buffer strips would reduce the amount of phosphorus and sediment entering the lake due to logging operations (see Introduction: Buffer Strips).

Residential Development

The amount of land suitable for development was determined by using macGIS. A data layer containing all of the roads, both dirt and paved, in the North Pond watershed was created. This data layer containing all of the roads was then augmented to show an area including 300 ft on either side of the roads. This is the distance from the road that the local utility is willing to extend residential power lines without any additional charge (Central Maine Power operator, pers. comm.). The assumption used in our study was that this additional cost is enough of a deterrent to discourage significant development from occurring farther than a 300 ft distance from the road in the near future. If people were willing to pay the additional installation costs than the area around the roads that is suitable for development would increase. This would have significant ramifications on the amount of land that is designated for development.

The land for development was divided into two parts: shoreline and nonshoreline regions. Shoreline areas were defined as being within 250 ft of any water bodies in the watershed, while nonshoreline areas extended more than 250 ft from water bodies. The house surveys performed by CEAT were done using 200 ft as the delineation. The reason that this distance was changed for the calculations in this section was to increase the number of houses included in the most potentially detrimental area of the watershed. To determine this distance, another data layer was constructed. This data layer radiated a distance of 250 ft from the main water bodies of North Pond, Little Pond, and the Serpentine. The road and water body radiation layers were then combined, to create a map showing land for development (radiation from the roads) that is in two distinct categories: shoreline and nonshoreline.

The septic suitability of soils within the shoreline and nonshoreline developable areas were determined by overlaying the developable land map with the septic suitability map (see GIS Methodology: General GIS Methodology). A total area of 2016 acres within the watershed were found to be limited for development in respect to the road proximity criteria (Figure 61). Of these 2016 acres, 1792 acres (88%) were located in the nonshoreline portion of the watershed. From this number the amount of previously developed land was subtracted. To do this, the recorded number of houses, 223, was multiplied by the MDEP standard for nonshoreline lot size, which is one acre (Bouchard, pers. comm.). For the nonshoreline areas 513 acres were found in the best category and 740 in the moderate category for a total of 1253 acres in the two soil classes that are suitable for septic installation (see GIS Methodology: Septic Methodology). After the developed land was subtracted from the septic suitable land there were 1030 acres of developable nonshoreline land suitable for septic systems. This means that development in the nonshoreline areas of the watershed has possibilities without any further building of roads and without being forced to use soil types that are inappropriate for septic systems

The shoreline area of the watershed is characterized by a different set of circumstances. There are 224 acres of land within a 250 ft radius of water bodies and within a 300 ft radius of the roads in the North Pond watershed. When the recorded number of houses, 307, was multiplied by the one-half acre MDEP standard for shoreline lot sizes, the acreage of currently developed shoreline property was obtained (Bouchard, pers. comm.). One hundred and fifty-four acres were subtracted as the approximate area of currently developed shoreline property. There are only 137 acres, 50 acres in the highest, and 87 acres in the septic suitability categories. These data imply that there are 17 acres, therefore at least 34 house lots that have been developed in soil with the poorest characteristics for septic suitability. While it is possible that this is true, there also is the possibility that the houses that are on the shoreline have house lots that are smaller than one-half acre. This would allow a greater number of houses to fit on the land most suitable for septic.

When the macGIS map of the development and soil suitability for septic is overlaid with the USGS culture and drainage map (see GIS Methodology: General GIS Methodology) a rough estimate of the number of houses that are in close proximity to North Pond, Little Pond, and the Serpentine water bodies is obtained. The culture and drainage map used was from 1982. There are a number of differences between the data collected from the USGS map and the house count numbers collected by CEAT. The numberss from the USGS map include any structure in the watershed while the CEAT survey only recorded houses. There is also a sizable discrepancy in times that the surveys were done, the USGS map representing a view of the situation in 1982 and the CEAT data reflecting the current situation. The USGS map was probably missing a number of current residences due to its age, but the houses that were in the North Pond watershed in 1982 probably still remain. Nonresidential structures such as garages and barns were shown on the USGS maps and yet go unrecorded in the CEAT field reconnaissance. This explains why the number of structures around water bodies in the watershed, recorded by map, were higher in 1982 then the present day house count. The 1982 USGS map has

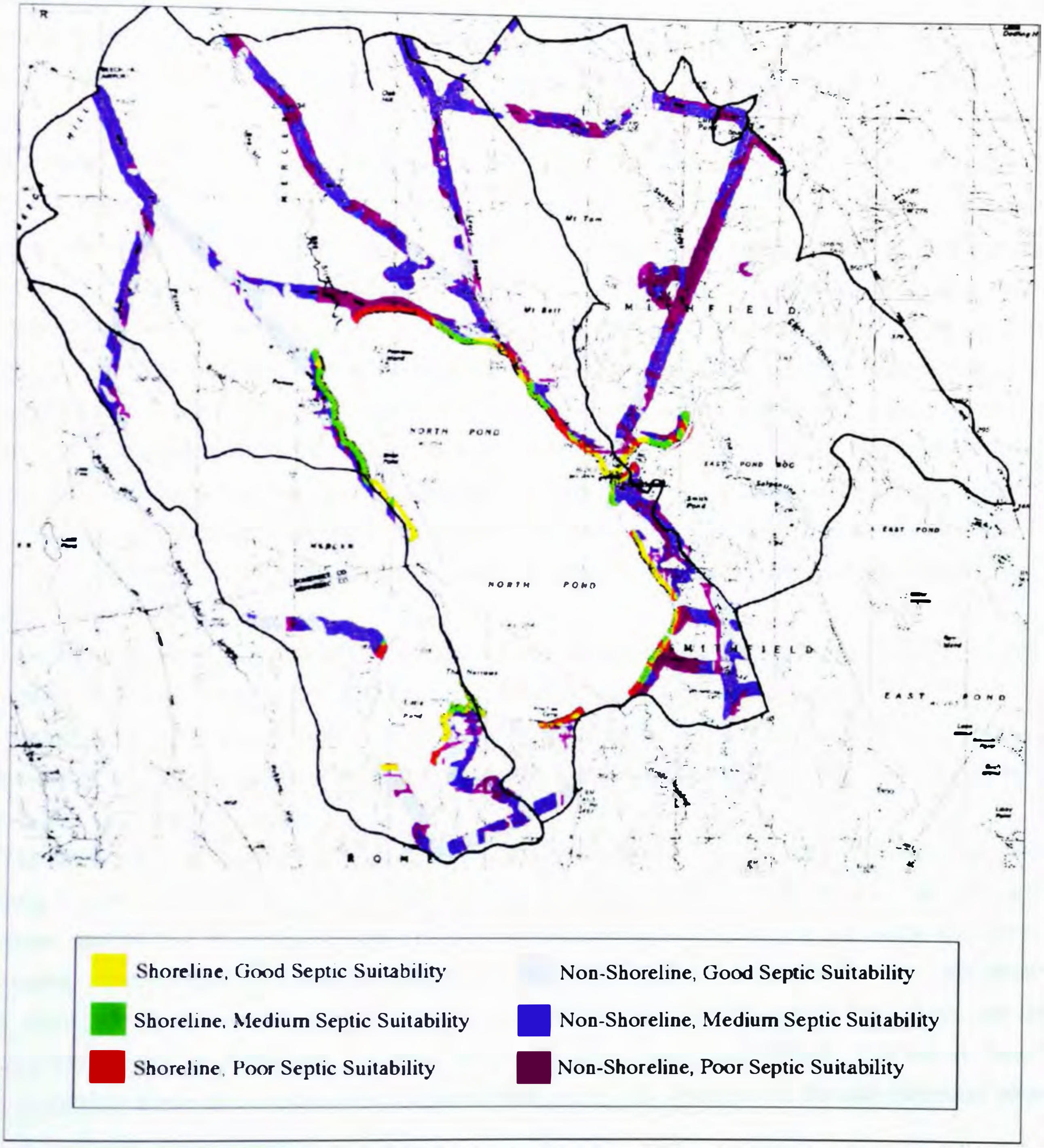

Figure 61. Land limited for development, showing three different levels of septic suitability for both shoreline and non-shorline areas. The scale on the map is approximately 0.5 inches equal to 0.55 mi (0.89 km).

340 structures within 250 ft of water bodies. Currently the number of houses within 250 ft of the shoreline area is 307. This shows the difference in the way that the data was recorded between the two methods. Even with this sizable discrepancy there is valuable information that can be learned by looking at the USGS and macGIS maps.

Based on the total number of structures found in 1982, 86 structures were on the soil best suited for septic systems, 142 structures were moderately suitable, and 112 structures were in the severely limited for septic systems soil category. By conservative estimates it was determined that one quarter of these 112 structures were nonresidential and therefore without septic systems. Thus approximately 84 houses would still be situated in soil that is not suitable for septic systems. A more likely situation is that the proportion of these structures that had septic systems is even higher than three quarters. That would mean that more than 84 houses with septic systems within 250 ft of the lake were situated on poor soil. This is significant because this structure census, taken in 1982, was only eight years after the new septic regulations were formalized. A majority of the houses that were built on the poorest quality soil in respect to septic suitability may have originally had poor septic systems. The combination of these two factors has the potential to cause a substantial amount of phosphorous and nitrogen leaching into the lake.

One significant consideration is that some of the houses that were pre-regulation have upgraded their septic systems. Another possibility is that a residence located in a soil that is poorly suited for septic installation could pump their sewage away from the lake into a more septic suitable soil type, which is often done when a system is upgraded (see Land Use Results and Discussion: Subsurface Waste Water Disposal Systems).

The data compiled in this study suggests that the roads on the lake are already too densely settled according to the availability of soil suitable for septic systems. The highest level of development on the poorest quality soil is on the northern and southernmost ends as well as on the northeast shoreline. The number of residences allowed around the water bodies should be limited. The inhabitants of houses already built in soil unsuitable for septic systems should set their systems back from the lake in more appropriate soil or create new systems that at least meet current guidelines. The use of land with septic unsuitable slope and soil does not seem to be as much of a problem in the nonshoreline areas.

PHOSPHORUS LOADING

A model for total phosphorus loading was adapted from Reckhow and Chapra (1983), as an indicator of total input of atmospheric and land use phosphorus into North Pond. The model is described by the following equation:

$$W = (Ec_a \times As_1)+(Ec_f \times Area_f)+(Ec_{rf} \times Area_{rf})+(Ec_{rl} \times Area_{rl})+(Ec_w \times Area_w)+(Ec_c \times Area_c)+(Ec_m \times Area_m)+(Ec_r \times Area_r)+(Ec_s \times Area_s)+(Ec_n \times Area_n)+(Ec_{cp} \times Area_{cp})+[(Ec_{ss} \times \#\text{ of capita years}_1 \times (1-SR_1))+(Ec_{ns} \times \#\text{ of capita years}_2 \times (1-SR_2))+(Ec_{sc} \times \#\text{ capita years}_3 \times (1-SR_3))]+PSI$$

In this equation, **W** is the total mass of phosphorus in kilograms per year entering North Pond. Ec is the export loading coefficient of each category (a = atmospheric input, f = mature forested land, rf = regenerating forest, rl = reverting land, w = wetlands, c = cleared land, m = municipal land, r = roads, s = shoreline development, n = nonshoreline development, ss = shoreline septic, ns = nonshoreline septic, sc = Pine Tree Camp, As_l = area of lake, PSI = total of all point source inputs). Shoreline septic and nonshoreline septic were multiplied by the number of capita years and multiplied again by one minus the coefficients for soil retention (SR). Soil retention refers to how well different soils in the watershed retain phosphorus and other nutrients (see GIS Methodology: Soil Methodology). The total for point source inputs (PSI) represents the phosphorus concentrations entering North Pond at major points of inflow (see Appendix F). Low and high coefficients were modified from coefficients defined by Reckhow and Chapra (1983), and the following case studies: Higgins Lake (Reckhow and Chapra 1983), East Pond (BI493 1991), Pattee Pond (BI493 1993), Salmon Lake (BI493 1994), Long Pond, North Basin (BI493 1995), and Long Pond, South Basin (BI493 1996). The range between low and high coefficients represents uncertainty in loading estimates. Uncertainty could come from bias (human judgment errors) or variability from natural fluctuations or statistical analysis. Multiplying each coefficient, both low and high, by the area of the corresponding land use produced total low and high projections of phosphorus entering North Pond. The coefficients were adjusted so that the actual phosphorus concentration measured in the pond would fall within the low and high range.

The area of the lake, its watershed, and the various land types were determined using ZIDAS analysis, a topographical map, and aerial photos from 1965/1966 and 1991 (see Land Use Methodology). The area of shoreline houses and nonshoreline houses was adapted from MDEP estimates of lot size (Bouchard, pers. comm.). The lot sizes were then multiplied by the number of developed lots in the watershed.

Using the low and high total phosphorus loading values and the water budget data for North Pond, a low and high range estimate of the phosphorus concentration for North Pond was determined using the following equations from Reckhow and Chapra (1983):

$$\mathbf{L} = W/A_s$$

Where **L** is the annual aerial phosphorus loading (the loading from the watershed area spread over the pond in $kg/m^2/yr$), and is calculated by dividing W (annual mass rate of phosphorus inflow in kg/yr) by A_s (surface area of the pond in m^2).

$$\mathbf{q_s} = Q/As$$

$\mathbf{q_s}$ is the annual aerial water loading (m/yr) and is calculated by dividing Q (volume of water inflow in m^3/yr). The Q for North Pond is the sum of the inputs from East Pond, Little Pond, the Serpentine, and North Pond watershed.

$$P = L/(11.6+1.2q_s)$$

P is the predicted phosphorus concentration for North Pond. See Appendix F for calculations and results.

Results and Discussion

The land in North Pond watershed encompasses a total area of 11,773 acres. Mature forests make up 75.3% of this area in 1991 aerial photographs (Figure 41). Residential areas, municipal land, and roads make up 5.1%. Cleared, reverting, and regenerating land comprise a total of 12.5% while wetlands make up 7.1% of the total watershed area.

Phosphorus loading coefficients were used in the phosphorus loading model to predict a mass rate of inflow in parts per billion (ppb). This was then used to compare results with the data obtained by CEAT. Results of the actual data obtained were closer to the low estimate we calculated in the phosphorus loading model for North Pond. The estimated concentrations of phosphorus ranged from 7.77 to 27.26 ppb. The actual range measured in the Colby Environmental Laboratory ranged from 8.5 to 11.6 ppb. Since the actual range of phosphorus falls within the estimated range, the model is considered to be accurate.

Results of the phosphorus loading model projected a total mass input into North Pond between 1342.42 to 4710.28 kg/yr of phosphorus. The majority of this comes from mature forest which contributes between 39.5% for the low range value and 27.6% for the high range value (Figure 62). The decrease in percentage is due to an increase in relative importance of other coefficients. Since mature forest makes up over three-quarters of the watershed in area, it is not surprising that it contributes such a large amount of phosphorus.

The second largest contributor to phosphorus loading is cleared land, which makes up 10.1% of the watershed. It contributes between 15.3% and 35.7% of the phosphorus entering North Pond. Development, which includes shoreline and nonshoreline residences and their respective septic systems, accounts for 33.9% of phosphorus for the low range value and 19.8% for the high range value. Shoreline development contributes more than nonshoreline development, primarily because of the close proximity to North Pond and the large amount of land it makes up. Again, the decrease in percentage indicates an increase in percentages of other land types.

Pine Tree Camp, the only camp on North Pond, contributes from 4.6% to 1.5% of total phosphorus entering the pond. The camp is a contributor of phosphorus because of its close proximity to the water and lack of a significant buffer strip. The camp is also located on soil with poor retention; yet, to counteract this, the camp has a good septic system.

Atmospheric input contributes between 14.2% and 12.1% of total phosphorus, which is representative of the surface area of North Pond. Roads contribute from 0.9% to 1.2% of phosphorus entering the lake, while both regenerating forests and wetlands contribute the least amount; about 1%.

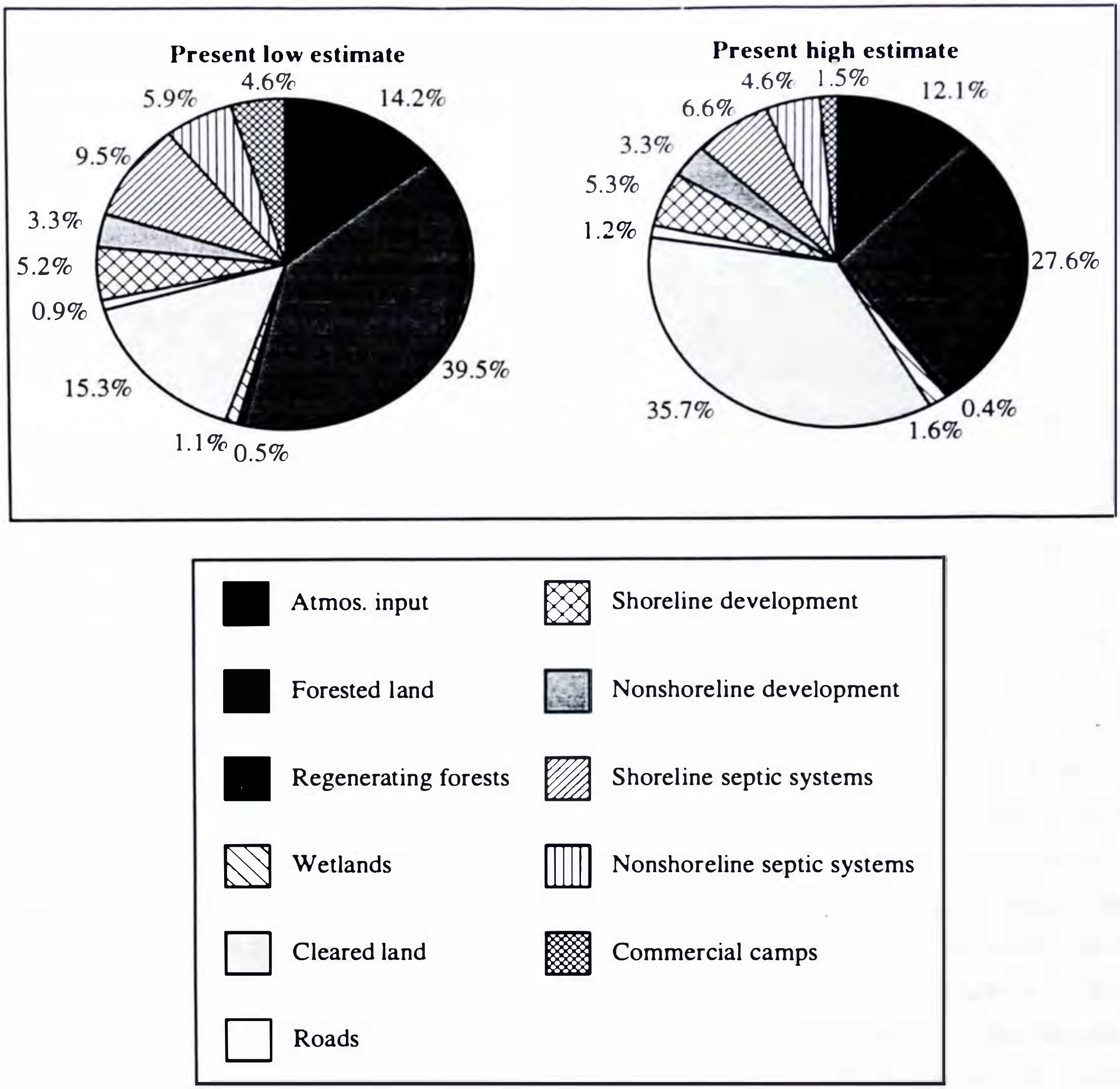

Figure 62. Low and high present estimates of total phosphorus export loading from each land use within the North Pond watershed.

The phosphorus loading model is important in establishing present phosphorus levels and identifying land use types that contribute significant amounts of phosphorus to a lake. This is helpful in monitoring and assessing present sources of concern as well as examining future trends. Changes that occur in a watershed can be manipulated in the model to control future phosphorus loading (see Future Projections: Ramifications of Phosphorus Loading).

Future Projections

Population Trends

PAST POPULATIONS

To predict the future population of the North Pond watershed, it was necessary to examine the current and past populations. Information on past populations in the four towns that share the watershed came from two different sources. Government records provided population data and residential development information. In addition, local residents estimated past populations and population trends.

The United States Census provided information on the populations of Smithfield, Mercer, Rome, and Norridgewock in 1970, 1980, and 1990 (Maine Register 1996). Town population estimates for 1996 were provided by the Maine Municipal Association (1996). The populations of the four towns that share the watershed all grew greatly over the period 1970 to 1996 (Table 17). From 1970 to 1996 the populations of Smithfield, Mercer, Rome, and Norridgewock increased 75.1%, 97.4%, 122.0%, and 67.7% respectively. However, from 1990 to 1996, the annual population growth rates in these four towns was quite low (KVCOG 1996). Rome had the highest growth rate at 3.2%. The other three towns in the North Pond watershed experienced population increases of under 1.0%: Smithfield, 0.9%; Mercer, 0.6%; and Norridgewock, 0.2%. However, these increases in the town populations do not necessarily mean that the population of the North Pond watershed has been increasing. The new residents may not all have been settling in the watershed.

Table 17. The past, present, and projected future populations of the four towns that share the North Pond watershed.

Town	1970*	1980*	1990*	1996†	2000‡	2010‡
Smithfield	527	748	865	923	952	1080
Mercer	313	448	593	618	635	776
Rome	362	627	758	802	1038	1315
Norridgewock	1964	2552	3105	3294	3187	3638

* Maine Register 1996
† Maine Municipal Association 1996
‡ KVCOG 1996

CURRENT POPULATION

Town Populations

In 1996, there were 923 residents in Smithfield, 618 residents in Mercer, 802 residents in Rome, and 3294 residents in Norridgewock (Maine Municipal Association 1996). The total population in the four towns was 5637. The population density of Smithfield can be determined from a map found at the Smithfield Town Office (Doan 1996). On this map, the land in Smithfield is divided into areas with a population of 150. The area with the highest density was in the town center of Smithfield and along the shoreline of North Pond.

Summer residents in the four towns were probably not included in the data already presented, therefore the number of seasonal residents must be estimated. The population change of the four towns in the summer is not evenly distributed. As a result, a majority of the population change will likely occur in the watershed, where most of the seasonal residences are located. In Smithfield, the population at least doubles in the summer (Turner, pers. comm.). Another estimate was that about 2000 additional people move to Smithfield during the summer (Zarcone, pers. comm.). Smithfield has approximately 800 residences and approximately 800 year-round residents. Not everyone lives alone and so a large number of people probably use seasonal residences. In addition, in Mercer during the summer, trailers are often set up on undeveloped shoreline lots during the summer (Springer, pers. comm.). In Rome there were 17 residences on Little and North Ponds (Moreau, pers. comm.). The population of Rome in the North Pond watershed only increases seasonally by about 34 people, the number of people who use these residences. Considering that many shoreline residences are for seasonal use only and most of the nonshoreline residences are used year-round, the majority of the summer visitors probably use residences on the shoreline. The shoreline residences may or may not be in the North Pond watershed.

Watershed and Subwatershed Populations

The data previously discussed represent the total population of the towns. However, the number of residents of the North Pond watershed is more important for this study. The house count and a mean number of people per residence can be used to estimate populations. House surveys performed by CEAT gathered information on the location and use of residences in the watershed. This information can be used to determine how many people live in each town's section of the subwatersheds. In addition, the house surveys can be used to judge the number of people who live in shoreline and nonshoreline residences. The house surveys can also be used to estimate the seasonal and year-round populations of each town's portion of the watershed. Many of the houses that were only accessible by water were not counted so the estimates of summer populations based on seasonal residences are rough.

A mean number of residents per residence had to be determined in order to calculate the approximate number of people in various sections of the watershed. The total population of an area was divided by the total number of residents. It is unknown whether the population data describes year-round or seasonal populations. If only year-round populations are included, then the average number of residents per residence will be higher in the summer. The mean number of people per residence in the state of Maine and Kennebec and Somerset counties is two (Bureau of the Census 1993). Dividing the number of new residents in Smithfield, Mercer, and Norridgewock from 1990 to 1996 by the number of new residences built during the same period provided a mean of two people per residence as well (KVCOG 1996). Therefore, the mean number of people per residence in the North Pond watershed is estimated to be two.

In the North Pond watershed the majority of the population, 896 people, lives in the North Pond subwatershed (Figure 63). This population is distributed among the towns of Smithfield, Mercer, and Rome. Smithfield has the highest number of people living in the North Pond subwatershed: 562. The Serpentine subwatershed has the second highest population with 120 residents. This subwatershed's population is composed of portions of the populations of Smithfield and Norridgewock. However, Norridgewock contributes only about four people. The subwatershed with the fewest residents, 44 people, is the Little Pond subwatershed. Portions of the populations of Mercer and Rome constitute this subwatershed's population. Overall, Smithfield has the most residents in the North Pond watershed.

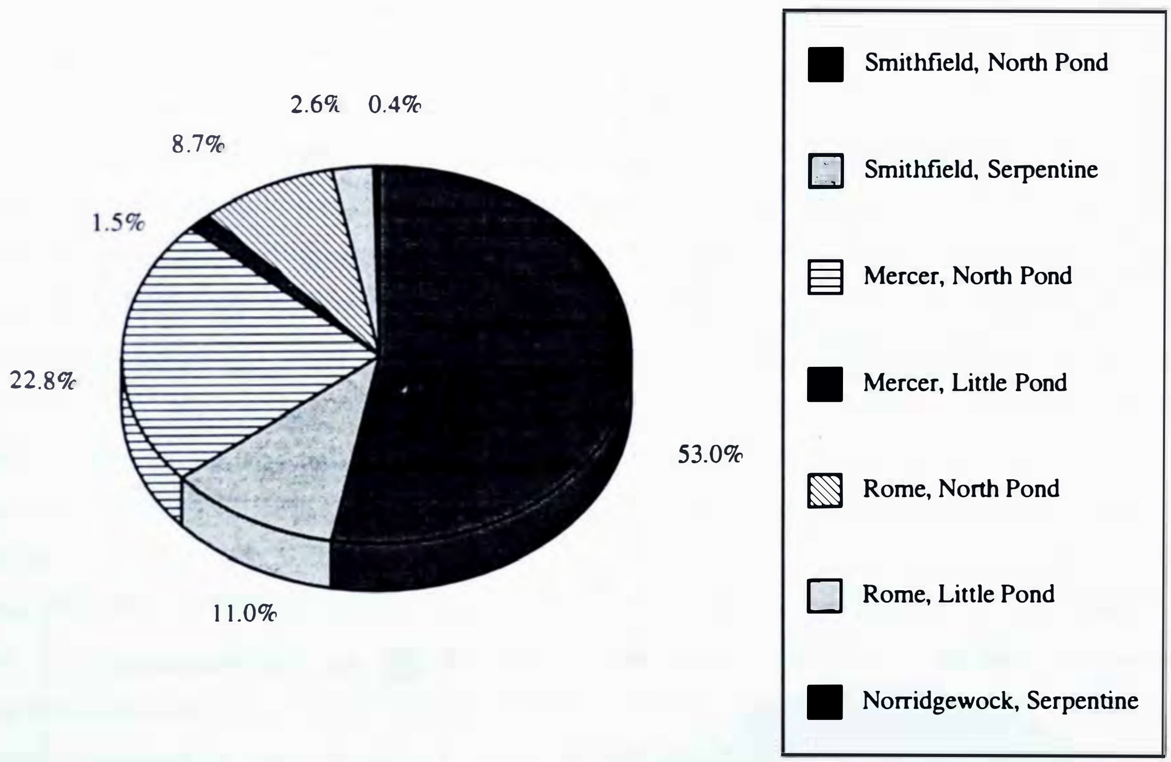

Figure 63. Percentages of the populations of the four towns that share the North Pond watershed.

About half of Smithfield's residents within the watershed, 326 people, live in shoreline residences during the summer, and 40.6% of the population, 268 people, live in nonshoreline residences all year (Figure 64). Therefore, the population of Smithfield in the watershed likely doubles in the summer and these summer residents live on the shoreline. Mercer has the second highest population within the watershed with 276 people (Figure 63). About half of these residents, 132 people, live in shoreline residences during the summer. About one-third of the population, 100 people, live in nonshoreline residences all year. As in Smithfield, the population of Mercer within the watershed probably doubles in the summer with most of the residents living on the shoreline. In Rome, there are 120 residents living in the North Pond watershed. Eighty-four of the residents (70.0%) use shoreline residences during the summer. The remaining 36 (30.0%) residents use nonshoreline residences all year. There are many more seasonal residents of Rome living on the shoreline of North Pond during the summer than nonshoreline residents living in the rest of the watershed all year. The four residents of Norridgewock that live in the watershed live in nonshoreline residences all year.

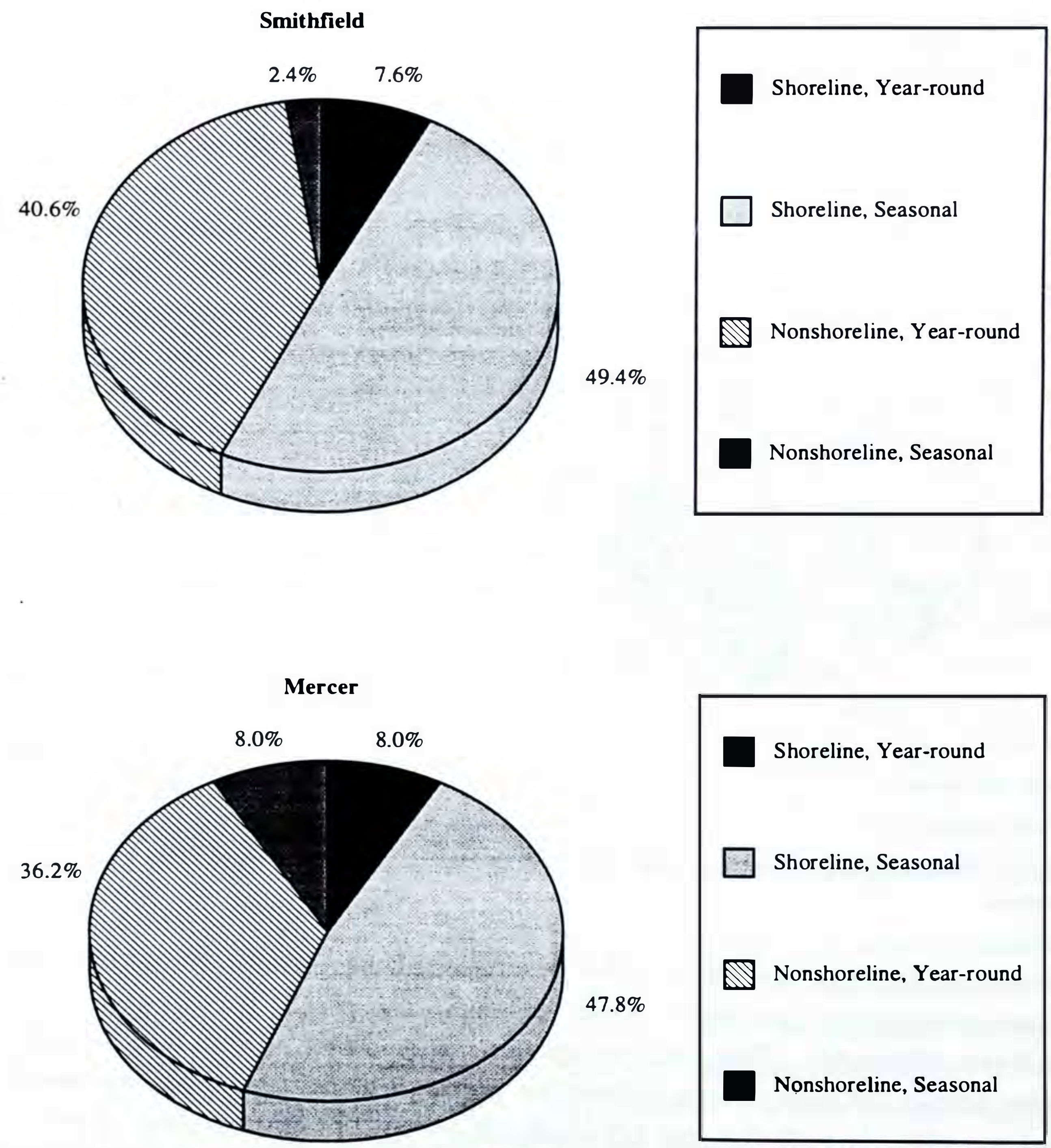

Figure 64. Percentages of residents of the North Pond watershed living on shoreline and nonshoreline, in seasonal and year-round residences.

POPULATION PROJECTIONS

The future population of the North Pond watershed is important because human activity impacts water quality. An increase in population usually means an increase in residential development, production of waste water, recreational use of the water bodies, road use, and possibly the number of roads. Also, the proximity of the population to the lakes has various effects on the lakes. The closer that people live to North and Little Ponds, the greater the impact on the water quality. The effect of current populations can be determined by looking at the current water quality of the lakes. The influence of past populations can also be estimated. However, the goal of this study is not only to report on the current condition of North Pond but also to make predictions on the future condition. Recommendations can be made based on this information. Population projections are very important in predicting the future condition of the watershed.

Predictions of the future population in the watershed are based on past and present population records. Local residents also used their knowledge to predict population growth and future populations. As can be expected, based on the annual growth rates from 1990 to 1996, the populations of all four towns in the watershed will probably grow in the next fifteen years (KVCOG 1996; Table 17). Rome and Norridgewock are predicted to add the greatest number of people. The populations of Smithfield and Mercer will both increase by about 150 people. The populations in these towns have been increasing and so they will likely increase in the future. Additionally, in the North Pond area there is an overall trend of seasonal residences being converted into year-round residences (Joly, pers. comm.). Residences that were previously only occupied during the summer are now used year-round thereby increasing the human activity near the lakes. However, the new residents of the towns may not move into the North Pond watershed area. Therefore, it is necessary to estimate where the future population growth will be found.

Local residents provided useful estimates of future population trends in the North Pond watershed. Lisa Turner (pers. comm.) and Bob Moreau (pers. comm.) agreed that the population increase in Smithfield is due to the developments near East Pond. The population near North Pond is probably not increasing because the area is already developed. Mike Zarcone (pers. comm.), who has lived in Smithfield for 22 years, believes the current population is fairly stable and the potential for future residential development is low. One reason is that industrial and commercial development will not happen as long as Route 137 and 8 are posted. These posted roads do not allow heavy trucking from March to May because of potential for road damage. Also, much of the eastern shoreline is already developed so the population may not have the potential to increase in that area. Mercer is growing at a slow and steady rate but there is no indication which area of Mercer is experiencing the biggest population growth. As for Rome, Bob Moreau stated that new houses are not being built near Little Pond or North Pond. He feels that the undeveloped areas near Little and North Ponds probably will not be developed in the near future. Although the population of the North Pond watershed may grow only slightly in the next few years, as the more desirable land in nearby areas is developed, people may choose to develop areas that are less ideal such as certain areas in the North Pond watershed (see Analytical Procedures and Findings: Zoning and Development Patterns).

Based on all this information, the year-round population of the North Pond watershed may reach approximately 1130 by the year 2010. Some of this population increase may be on the shoreline where seasonal residences are being converted into year-round residences. However, zoning laws and other restrictions may limit new residential development, either seasonal or year-round, near the shoreline. The number of seasonal residents will probably not increase for these same reasons. There are fewer restrictions to development in nonshoreline areas; this is likely where the population increase will occur.

These projections are logical considering the general situation in the area where the watershed is located. The towns of Smithfield, Mercer, Rome and Norridgewock are considered attractive places to live. These towns still have the atmosphere of rural Maine while providing the necessities for comfort such as grocery stores, restaurants, and gas stations. Large population centers such as Skowhegan, Waterville and Augusta are nearby enabling people to live in the North Pond watershed and commute to larger towns for work and recreation. Similarly, people whose year-round residences are not near North Pond can visit the area for recreation. This activity accounts for the large number of seasonal residences on the shoreline. However, once the population reaches a point where the balance of the rural and suburban is upset, the population increase will probably slow. People will no longer be able to find the small-town atmosphere in the region. The prediction is that this level will not be reached for many years.

Although the population of the North Pond watershed has not yet reached a critical number, population growth should be monitored. Careful attention must be paid to the many seasonal residences in the watershed, especially because several of these residences per year are being converted for year-round use. The impact of population on the lake water quality should be minimized as much as possible. Minimization could include further restriction of the areas open to development. Nonetheless, even a gradual but steady increase in nonshoreline population will have an effect on the lake water quality. The runoff from any area within the watershed will enter North and Little Ponds so a population increase anywhere in the watershed will affect the lakes. Without a plan for protecting water quality, a population increase in the watershed will mean an increase in the phosphorus loading of the lakes and result in a decrease in water quality. Although restricting population growth may be beneficial to lake water quality and the quality of the environment, the practice may not be beneficial to the towns in other ways. Therefore, in order to minimize the effect of additional residents, the best methods to employ may be found in the other recommendations that were made.

Development Trends and Potential

The future residential development of the North Pond watershed is directly related to the future population increase (see Population Trends: Population Projections). It is estimated that 70 people will move to the North Pond watershed area before the year 2010. Assuming that the new year-round residents will be moving in to new residences, there will be about 35 new residences built in the area. However, some seasonal residences are currently being converted into year-round residences so there may be fewer than 35 new residences added.

The location where the new residences will probably be built depends on the availability of developable land. The majority of the shoreline of North and Little Ponds is categorized as appropriate for limited development under zoning laws (see Analytical Procedures and Findings: Roads and Residential Areas, Tax Map/ Property Card/ House Count Methods). However, only about two-thirds of shoreline land is developed. Nonshoreline lots are mostly undeveloped. Much of the land in the watershed is undeveloped; however, the development of this land depends on zoning regulations and cost. In order to build a residence, it is necessary to cover such costs as building an acceptable subsurface waste water disposal system, connecting to utilities, and accessing roads. Due to zoning laws and restrictive costs, there may not be much development of shoreline lots in the near future. Overall, the majority of the new year-round residences will probably be built on nonshoreline lots. Therefore, an additional 35 acres of the North Pond watershed may be developed in 2010 (see Analytical Procedures and Findings: Land Use Methodology). In the distant future, when the best local land has been developed, development may increase in the watershed, both on shoreline and nonshoreline lots.

New residential development will affect the water quality of North Pond and Little Pond. First, the building process leaves soil open to erosion and susceptible to transportation into the lakes by runoff (see Analytical Procedures and Findings: Zoning and Development Patterns). Second, residences often contribute excess nutrients to a water body through lawn maintenance. If runoff is not controlled by adequate buffer strips, which are often not present in shoreline lots, the sediment will run directly into the lakes (see Analytical Procedures and Findings: Roads and Residential Areas, Tax Map/ Property Card/ House Count Methods). Third, new residential development will probably also require new driveways and roads which easily carry runoff quickly into bodies of water. Four, new residences will need some form of waste water management so that excess phosphorus will not enter the lakes through seepage. All new residences must dispose of waste water according to the Maine Subsurface Waste Water Disposal Rules (see Analytical Procedures and Findings: Subsurface Waste Water Disposal Systems). Also, the location and use of the new residences will influence their impact on water quality. Although shoreline residences often have the greatest impact on water quality, shoreline residences are usually seasonal, and will have the greatest effect on the lakes during the summer.

Ramifications of Phosphorus Loading

This study compared land use practices in the North Pond watershed over the past twenty-five years. By assuming population increases, as well as taking into account that logging currently exists in the area, we used the phosphorus loading model to predict a phosphorus concentration for twenty-five years in the future.

A 35% increase in population translates into a 30% increase in both area and number of lots of nonshoreline residences as well as a 5% increase in shoreline residences. This caused the low range of North Pond concentration to increase from 7.77 ppb to 7.95 ppb. It also caused the high range to increase from 27.26 ppb to 27.93 ppb. This increase is small, which reflects the conservative projection of population increase. Over the past twenty-five years, the four towns in the watershed have increased about 50%. Yet these numbers represent the entire town, not just the areas inside the watershed. Therefore, the 35% was chosen as a probable population increase over the next twenty-five years.

In addition, a 20% decrease in mature forest was assumed, due to increased logging practices in the future. This translates to a 20% increase in cleared land which results in an increase of the high range of phosphorus concentration from 27.26 ppb to 30.34 ppb. The low range did not change since the coefficients were the same. Again, this estimate is extremely conservative, largely due to the fact that logged land will erode much faster than cleared land (Cole, pers. comm.).

Both these projections combined results in an increase in the low range phosphorus concentration to 7.95 ppb and an increase in the high range concentration to 31.01 ppb. Figure 65 shows the land use contributions to the increase in phosphorus. The percent of phosphorus from cleared land increased significantly from the present estimates, jumping from 15.3% to 22.5% in the low range and 35.7% to 46.7% in the high range.

North Pond is susceptible to future increases in both development and logging. Logging practices on steep slopes and development on soil with poor retention present dangers to future phosphorus loading into the lake. Yet if management practices are monitored and land use practices are done on suitable land, the future of North Pond could be saved from high levels phosphorus loading.

SUMMARY

Land Use

RESIDENTIAL DEVELOPMENT

Residential development in the North Pond watershed exists around the entire lake but is concentrated on the east side of the lake in Smithfield. There are 222 shoreline lots in Smithfield and 83.7% of these lots are developed (See Analytical Procedures and Findings: Roads and Residential Areas, Tax Map/Property Card/ House Count Methods). Residences surrounding North Pond consist of a combination of seasonal year-round homes. On the shoreline in Smithfield 87.0% of the houses are seasonal. It is estimated that the population in Smithfield doubles during the summer months (Turner, pers. comm.). This increase in population occurs mostly on the shoreline and could have a substantial impact on the lake through increased use of septic systems and runoff carrying lawn fertilizers. This area also contains moderately to severely limited soils (See Analytical Procedures and

Findings: Soil Methodology). The high density of developed lots in an area where the soils have low permeability could result in a significant impact on the lake water quality due to large amounts of phosphorous runoff from septic systems, driveways, and lawns.

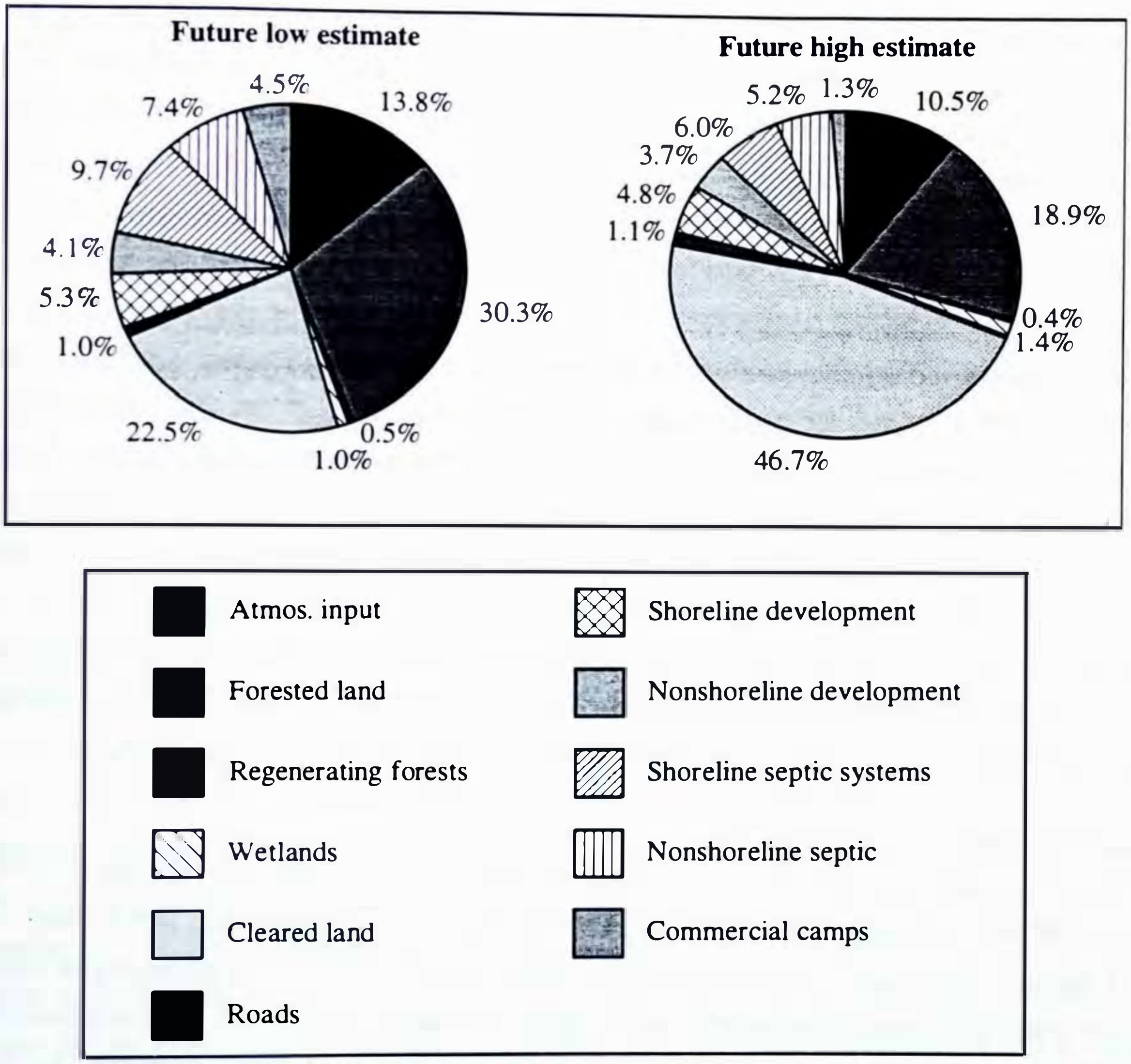

Figure 65. Low and high future estimates of total phosphorus export loading from each land use within the North Pond watershed

The status of waste water disposal systems on North Pond is improving each year as the number of replacement increases. Most systems on North Pond are septic systems containing a septic tank and some form of a leach field to facilitate dispersal and absorption of waste water. Many of these systems have been recently replaced and follow the state of Maine regulations for waste water disposal systems (MDHS 1996). However, there is a high percentage of old systems that have been grandfathered and do not follow the state rules but are considered by plumbing inspectors to be functioning systems. Though these systems do not show obvious signs of malfunction, such as odors or seepage, they still may present problems. If an old system was built too close to the shoreline or installed in inadequate soils, it may appear to the resident to function properly while in fact it is leaching waste water directly into the lake. The only way to ensure minimal impact of waste water disposal systems on the lake water quality is to bring all systems up to date and in accordance with the current Maine Subsurface Waste Water Disposal Rules. Under these rules, site evaluators, soil scientists and plumbing inspectors work together to design a system that works efficiently for a particular property.

In conclusion, residential development in the North Pond watershed contributes to the deterioration of water quality. Shoreline residences built in congested areas and on inadequate soils promote phosphorus runoff to the lake. Also inefficient waste water disposal systems may leach sewage directly into lake water.

NON-RESIDENTIAL

Managed Land (Cleared Land)

Despite the general trend away from agricultural practices, it was found in our study that the amount of cleared land did not decrease profoundly from 1965/66. In the North Pond watershed, cleared agricultural land decreased by 18.6% of which a portion was found to be reverting. Row crops appeared less in 1991 than in 1965/66, but pastures, potentially with grazing livestock, remained prevalent in 1991. In 1996, members of CEAT observed signs that livestock had access to the Serpentine resulting in erosion and pollution.

Municipal/industrial land increased 137.5 acres between 1965/66 to 1991. The gravel pit in downtown Smithfield is of most concern in the North Pond watershed. Members of CEAT noticed that expansion in it's area includes land on the east side of Rte. 8, between the road and the lake.

Natural Land (Forests and Wetlands)

In 1991, forested area composed 75.3% of the North Pond watershed, representing a 2.5% decrease from 1965/66. Increases were observed in the amount of regenerating forest only in Smithfield and Mercer. The only areas of logging that were detected on the aerial photographs from 1965/66 and 1991 were the areas of regenerated land (logged land left to grow back). The regenerated land implied that logging occurred in those areas of the watershed on dates previous to the photographs. However, in 1996, CEAT detected several areas of logging in Rome surrounding Little Pond. As there are large amounts of mature forest in the North Pond watershed that could potentially be logged, the present logging in Rome implies that additional logging may be occurring today and may be likely to continue in the future. Logged land is potentially detrimental for water quality due to increased runoff and erosion of the cleared areas.

The amount of wetland acreage in the North Pond watershed did not change from 1965/66 to 1991. There were also no signs of development within the areas classified as wetlands. One exception was the gravel pit in downtown Smithfield which expanded it's 1965/66 size and appeared, in 1991, to cover land much closer to the East Pond Bog. Further studies need to be conducted specifically on the wetlands in order to determine their exact contribution to water quality within the watershed.

RECOMMENDATIONS

Community Involvement

EDUCATION

The community of the North Pond watershed area is affected by the water quality of the lakes. Therefore, local residents should be actively involved in promoting environmental awareness. One way people can do this is by becoming members of the North Pond Lake Association. In addition, residents can learn about the lakes themselves and also educate other members of the community. Information should be provided to the population at large regarding proper land use management so that low-impact practices can be put into use. For example, shoreline property owners should be educated about the purpose and necessity of buffer strips near their camp roads.

There are a number of ways to provide the local community with the necessary information. One possibility is having a core group in each township that will take on the responsibility of educating the community. State and local pamphlets and zoning ordinances are already available for the education of area residents. The core group could also provide further information about factors which directly affect the water quality of North and Little Ponds. When changes are planned for the area, core groups could inform the local community and ask for the public's opinion. In that way, local residents would have more control over the condition of the watershed. In addition, the formation of core groups would heighten awareness of watershed management.

The local community can be made more aware of environmental issues directly affecting them by implementing two additional suggestions. One possibility would be to hold an event, possibly in conjunction with an existing annual town gathering or function. This meeting would provide a good opportunity for the core group to introduce visual aides and disperse informative literature. Another way for information to be dispersed is by incorporating a Lake Appreciation Day into the science curriculum of local schools. High school students could do complex analytical study while lower school students simply learn about the factors that affect lakes. Information for these classes could be provided by the towns. The students would be encouraged to bring materials home to share with their family and friends.

Over a period of time these types of practices would be very beneficial to the local community. Not only would there be a general increase in environmental awareness, but local residents would be more informed about their impact on the later quality of the lakes. A secondary benefit would be that townships could justify imposing stiffer penalties when the rules that dictate proper land use are violated because the regulations would be common knowledge within the community. When everyone in the watershed knows what should be done they could take pride in doing their individual part to help maintain the water quality of North Pond.

MONITORING

Various factors affecting the condition of the North Pond watershed should be continually and systematically monitored. In this way, the community can be informed about the current conditions in the watershed and can predict future changes. Essentially, an organization such as the North Pond Lake Association or a core group should monitor the effects of phosphorus loading on water quality. Also, the local water bodies need to be checked often for the presence of other polluting substances. In particular, transparency levels should be monitored every summer as an indication of the likelihood of algal blooms. A study should be performed on water bodies with low acidity, such as Clark Brook. Additionally, monitoring of population growth is necessary to determine human impact on water quality, with special attention paid to shoreline seasonal residences. Roads should also be monitored regularly for damage, especially after the winter season when frost heaves may have occurred.

Development

ROADS

Roads which are well-designed and do not contribute a large amount of runoff to the lakes must be maintained in good condition. Roads which are not well-designed need to be improved. Many existing roads which lead to the water require buffer strips as well as drainage mechanisms such as culverts, ditches, and water diversions. Roads leading to industrial areas such as gravel pits should be able to effectively drain runoff away from the lakes. New camp roads should not be installed where they lead directly to the water's edge. All dirt and paved roads should be crowned consistently to avoid cracking, gullying and allow for proper drainage.

Certain roads in the North Pond watershed are in poor condition and need immediate improvement. In Smithfield, W-5 and W-7 require significant road surface, ditching, and diversion maintenance. Also, S-1, S-7, W-6, W-9 and Sunset Camp Road A require ditching work. Sandhill Road, Wilder Hill Road, Ross Hill Road, and Park Farm Road need cracking, gullying, ditching, and crowning maintenance. In Mercer, Fire Lanes 1, 2, 3, and 4 need road surface work, as well as ditch and culvert installations.

The boat launch ramps off of North Shore Drive next to Bog Stream and Rte. 8/137 near Leech Brook are areas where runoff from roads takes an unobstructed path directly into the lake. The pavement on these ramps is in bad condition, with many cracks and gullies, some of which have vegetation growing in them. These ramps need surface work as well as installation of diversions such as water bars so that runoff can be channeled to an adjacent buffered area where it will infiltrate the soil instead of emptying into the water body.

NONRESIDENTIAL

Logging and Agriculture

The steep area to the west of Little Pond has been divided into approximately 530 lots of about one-half an acre in size. These lots were part of a real estate project that took place in the 1970s and were sold to individuals across the country. Many of these lots have been repossessed by the town of Rome or bought by the Rome and Carmel logging company (Bouchard, pers. comm.). However, many of these lots still remain under the ownership of individuals from other states. It is not likely that any of these lots will be developed by their individual owners because they are remote and inaccessible. Were individual development of these lots to take place, it would be likely that they would have a very detrimental effect on the water quality of the lakes, particularly due to the steep slope on which they are located.

Currently these lots are being consolidated by the Rome and Carmel logging company to be used for selective cutting (Bouchard, pers. comm.). Insuring that these lots are consolidated and protected in the future is a good precaution against phosphorus loading of the lakes.

Development concerning future logging and agriculture operations should take careful consideration of limiting factors such as soil type, slope, and soil erodibility. A close eye should be kept on the mature forest surrounding Little Pond in Rome.

Livestock Practices

Pastures adjacent to the Serpentine should be fenced-in to prevent cattle from defecating directly into the bog. Fecal loading not only contributes to nutrient loading into a lake, but it also causes a public health risk by delivering disease-causing organisms into the water column. The CEAT in past and present years has observed cattle in or near the waters edge just north of the Sucker and Clark Brook confluence.

Municipal/Industrial Land Uses

Municipal/Industrial areas should be limited to land that will not promote erosion and runoff into water bodies. For example, the gravel pit in downtown Smithfield is bordering the East Pond Bog and recently expanded close to North Pond. Further expansion in these directions should be stopped as it is a potential source of serious erosion and consequent phosphorus loading.

RESIDENTIAL

Houses

The impact of increased population in the North Pond watershed on water quality should be minimized as much as possible. Minimization could include using zoning laws to further restrict residential development. If restricting population growth is not practical or beneficial for the towns, the other recommendations suggested in this study could be implemented.

Septic Systems

There are many ways the towns in the watershed can improve the quality of septic systems. First, a random survey of old septic systems should be conducted by the plumbing inspectors to determine if the old systems are polluting the lakes. Currently, inspectors do not inspect old septic systems unless there is a complaint of a nonfunctioning system. As many as possible of the old systems should be changed to new, efficient systems using stone beds or chambers. At the moment there is no incentive for residents to change their system from a pit privy to a septic system because this will result in an increase in taxes. Therefore, state or town governments should support tax incentives for residents who decide to upgrade their system.

Towns can also improve septic system efficiently by regulating development. Development should not occur in areas where soil is unsuitable for septic systems such as the northern edge of North Pond. The best area for development to occur, in terms of soil suitability for septic systems, is the area in Mercer on the west side of North Pond. Development in crowded areas such as the part of Smithfield near the Serpentine should not increase because of the stress placed on the land. The soils in highly developed areas may become saturated with waste water and may not be able to support additional septic systems.

Apart from complying with plans developed by the towns, local residents can individually contribute to the improvement of lake water quality. Residents should be careful that they do not flush solid objects into their septic systems which may cause septic tanks and leach fields to malfunction. Also, chemicals such as bleach should not enter subsurface waste water disposal systems because these chemicals kill the bacteria that are necessary for the breakdown of wastes (MDEP 1974). Residents are encouraged to use phosphorus-free laundry detergents in order to lower the amount of phosphorus entering the lakes.

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APPENDICES

APPENDIX A. ON-SITE AND LABORATORY WATER QUALITY TESTS

Table 1. Field measurements and laboratory tests performed in the North Pond watershed. See Figure 12 for site locations.

Test or Measurement	Sampling Date	Analysis Date	Sites
Physical Factors			
Conductivity†	23-SEP-96	24-SEP-96	9, 10, 11, 12, 13, 14, 15, 16, 17, 18
	30-SEP-96	01-OCT-96	1, 2, 5, 6, 7, 8, 10
Depth*	23-SEP-96	23-SEP-96	9, 12, 13, 15, 16, 17, 18
	30-SEP-96	30-SEP-96	1, 2, 3, 5, 6, 7, 8, 10, 11, 14
DO/Temperature*	10-JUL-96	10-JUL-96	1
	16-SEP-96	16-SEP-96	2
	30-SEP-96	30-SEP-96	1, 3, 5, 6, 7, 8, 18
Flow Rate*	23-SEP-96	23-SEP-96	10, 18
	30-SEP-96	30-SEP-96	9, 12, 13, 14, 17
	20-OCT-96	20-OCT-96	9, 11, 12, 17
Transparency*	10-JUL-96	10-JUL-96	1
	16-SEP-96	16-SEP-96	1
	23-SEP-96	23-SEP-96	15, 16
	30-SEP-96	30-SEP-96	3, 5, 7, 10
Turbidity†	23-SEP-96	23-SEP-96	9, 10, 11, 12, 13, 14, 15, 16, 17, 18
	30-SEP-96	30-SEP-96	1, 2, 5, 6, 7, 8, 10
	20-OCT-96	22-OCT-96	9, 11, 12, 17
Chemical Factors			
Alkalinity†	23-SEP-96	29-SEP-96	1, 5, 15, 18
	30-SEP-96	06-OCT-96	1, 3, 5, 7
Color†	23-SEP-96	23-SEP-96	9, 10, 11, 12, 13, 14, 15, 16, 17, 18
	30-SEP-96	30-SEP-96	1, 2, 5, 6, 7, 8, 10
Hardness†	30-SEP-96	20-OCT-96	1, 3, 5, 7
Nitrate†	23-SEP-96	25-SEP-96	9, 10, 11, 12, 13, 14, 15, 16, 17, 18
	07-OCT-96	09-OCT-96	1, 2, 3, 5, 6, 7, 8, 10, 11
pH*	23-SEP-96	23-SEP-96	9, 11, 12, 13, 14, 15, 16, 17
	30-SEP-96	30-SEP-96	1, 3, 5, 7, 10, 18
Total Nitrogen†	30-SEP-96	20-OCT-96	3, 5, 7, 15
Total Phosphorus†	10-JUL-96	14-OCT-96	1
	26-JUL-96	14-OCT-96	1
	16-SEP-96	27-SEP-96	1, 2, 11
	23-SEP-96	27-SEP-96	4, 9, 10, 12, 13, 14, 15, 16, 17, 18
	30-SEP-96	06-OCT-96	1, 2, 3, 5, 6, 7, 8, 10
	20-OCT-96	24-OCT-96	9, 11, 12, 17
Biotic Factors			
Coliform‡	23-SEP-96	23-SEP-96	15

*Measurements were made on site
†Analyzed at Colby Environmental Laboratory, Waterville, ME
‡Analyzed at Northeast Laboratories, Winslow, ME

APPENDIX B. QUALITY ASSURANCE GUIDELINES

The North Pond study followed a quality assurance plan based on previous studies conducted by CEAT (BI493 1995, 1996). Field techniques follow the MEPA standards set by Potvin and Bacon (1993), while laboratory techniques follow guidelines described in the Hach test kit manuals (Hach 1991, 1992).

Approaching Site and Sampling

1. When approaching the test site, speed up first, then shut off the boat engine and coast to the sampling site.
2. Sample from the bow of the boat into the wind.
3. When surface sampling, hold the bottle upside down, draw water into the bottle by pushing horizontally away from the boat to 0.5 meters down. Then lift the bottle out of the water and cap.
4. Hands should never touch sampled water. Use gloves.
5. Bottle lids should not touch the bottom of the boat. Rinse the lids with distilled water if they are dropped.

Sample Handling

1. Samples are immediately stored in ice in the field after sampling.
2. Samples were then stored in laboratory refrigerator upon return from the field.

Quality Control Sampling

1. Duplicate samples every tenth sample in field to test sampling procedure.
2. Samples are split every tenth sample in laboratory to test lab precision.
3. Field spikes are made every tenth sample to determine percent recovery.
5. Spikes into distilled water are made on every run to test lab precision.
6. Reagent blanks are used to make a standard curve to determine the concentration of phosphorus studied. The standard curve should have a minimum of six points.

Depth

1. A Humminbird depth finder is used to determine depth.
2. A second method is to drop a depth line into the water until you feel slack, then gently pull the slack out of the line bringing it through the muck being careful not to lift the sinker off the bottom. Record this depth.
2. Repeat this process again.

Dissolved Oxygen and Temperature

1. On the tenth profile three duplicate readings should be made randomly.
2. Duplicate readings should not vary more than ± 0.2 ppm.
3. If readings vary more than 0.5 ppm, repair of the membrane or meter is advised.
4. The electrode must be in a flow of water.
5. Record a DO measure immediately. If the reading is decreasing, keep the electrode moving in the water.

Secchi Disk

1. Duplicate reading on every tenth sample.
2. Use Aqua-scope to view disk.
3. Lower disk until the disk is out of site, then record the depth.
4. Lower the disk an extra meter. Bring it back into sight and record the depth.
5. Repeat the process two more times.

Core Sampling

1. Determine the depth where the core samples will be taken.
2. Rinse the mixing jug and cover three times with surface water. Be sure that all interior surfaces have been in contact with surface water.
3. Rinse the container in which the core and jug are stored to avoid contamination.
4. Rinse the core tube three times by lowering the core into the water at least 1 m greater than the core will be taken. Core should be taken no lower than 0.5 m from the bottom. Drain all the water into the lake.
5. To obtain core samples, lower the core slowly to the appropriate depth. The water outside the core should be about the same level inside the core during the lowering procedure otherwise the water sample will be weighted with a disproportionate amount of water from lower levels.
6. Pinch the core tightly at the water surface to ensure that sample stays within the core. If any of the sample is lost, sample again.
7. Only the weighted portion of the core should enter the boat.
8. Hold the weighted end over opening of mixing jug. Release the pinched end of tube and thoroughly drain water into mixing jug. Avoid contamination with hands.
9. For adequate sample volume, repeat core sample twice more.

Flow Measurements

1. Divide the stream into sections determined by the topography of the stream bed. If the topography is uniform along the bottom, divide the stream into two equal sections and measure flow in the center of each. However, if the topography varies, then divide the stream into representative segments (ideally three or more sections).
2. At the center of each section, measure flow at 60%.
3. Make sure the sensor bulb is facing upstream.
4. If the stream is too deep or otherwise inaccessible for wading with the flow meter, measure flow at the culvert by timing how long it takes to fill up a 1000 ml bottle or a bucket depending on the volume of water flowing out. Record the time and specify volume of bucket or bottle on the data sheet so flow can be calculated in the laboratory.

Rain Measurements

1. Rain gauge should be stuck into the ground for the duration of the storm and should be in a location where rainfall is unobstructed.
2. To measure change in stream water level, anchor a meter stick in stream channel with rocks for duration of storm and record water level each half hour.

Acidification of Hardness

1. To prepare the water samples for the analysis of hardness, nitric acid is titrated drop by drop.
2. Rinse bottle lids with distilled water, then add a small amount of sample to the lid.
3. Test the pH of the water in the lid. If it is lower than two, discard, rinse the lid, and cap the bottle. If the pH is greater than two, keep adding acid drop by drop until pH reaches a value of two.
4. The same amount of acid should be added to all bottles of the same volume for all tests of hardness.

Acidification of Total Nitrogen

1. To prepare the water samples for the analysis of total nitrogen, sulfuric acid is titrated drop by drop.
2. Rinse bottle lids with distilled water, then add a small amount of sample to the lid.
3. Test the pH of the water in the lid. If it is lower than two, discard, rinse the lid, and cap the bottle. If the pH is greater than two, keep adding acid drop by drop until pH reaches a value of two.

4. The same amount of acid should be added to all bottles of the same volume for all tests of total nitrogen.

pH

1. Before any testing is done, the pH meter must be calibrated using a three point calibration method at pH values of 4, 7, and 10. This must be done once during the testing day only as long as the meter's calibration is not accidentally deleted.
2. Check that probe is working properly by measuring aerated de-ionized water. The meter should return to a value of 5.65.
3. Take care to rinse probe with distilled water prior to and following each measurement.

APPENDIX C. RESULTS OF NORTH POND AND TRIBUTARIES WATER QUALITY TESTS

Table 1. Chemical measurements conducted on surface samples taken from North Pond, Little Pond, and tributaries on 07-OCT-96, 23-SEP-96, and 30-SEP-96. See Figure 12 for site location.

Site	Color (SPU)	Hardness (ppm)	Alkalinity (ppm $CaCO_3$)	pH	Phosphorus (ppb)	Nitrate (ppm)	Total Nitrogen (ppm)
1	10*	11.0	12.8*	6.99	8.9	0.040	--
2	15	--	--	--	7.3	0.030	--
3	--	10.5*	--	7.05	10.6	0.050	0.50
4	--	--	--	--	5.5	--	--
5	14	10.0*	12.0*	7.17	11.0*	0.040*	1.25*
6	15	--	--	--	9.2	0.060	--
7	22	9.0	12.3	6.73	9.7	0.065*	0.25
8	24	--	--	--	9.7	0.030	--
9	102	--	--	7.10	24.2	0.030	--
10	162	--	--	6.53	20.4	0.090	--
11	221*	--	--	5.90	--	0.110	--
12	18	--	--	7.30	3.2	0.050	--
13	73	--	--	6.79	28.1	0.050	--
14	310	--	--	4.82	18.8	0.050	--
15	203	--	--	5.34	24.2	0.070	0.75*
16	155*	--	--	5.89	--	0.047*	--
17	105	--	--	6.44	28.2	0.030	--
18	19	--	--	6.80	7.5	0.055*	--

* indicates duplicate and/or split samples taken, with the average reported

Table 2. Physical measurements conducted on surface samples taken from North Pond, Little Pond, and tributaries on 23-SEP-96 and 30-SEP-96, unless otherwise indicated. See Figure 12 for site location.

Site	Depth (m)	Temp (°C)	Dissolved Oxygen (ppm)	Transparency (m)	Turbidity (FTU)	Conductivity (µmhos/cm)
1	5.25	15.5	9.7	4.00† 5.10‡	2	30.0
2	2.40	--	--	--	3	30.0
3	3.70	15.8	9.4	3.20	--	--
4	--	--	--	--	--	--
5	4.41	15.5	7.1	3.38	3*	31.0*
6	1.62	16.1	10.8	--	2	30.0
7	4.70	15.7	9.1	3.45	3	22.0
8	1.30	16.5	9.5	--	3	21.0
9	0.49	--	--	--	11	29.0
10	1.34	--	--	0.85	11	30.0
11	1.21	--	--	--	2	29.5
12	0.11	--	--	--	6	64.0
13	2.10	--	--	--	7	38.0
14	2.00	--	--	--	19	25.0
15	2.20	--	--	1.25	12	23.0
16	1.75	--	--	1.25	9*	24.0*
17	2.70	--	--	--	9	28.0
18	0.53	16.6	10.9	--	3	22.0

* indicates duplicate and/or split samples taken, with the average reported
† indicates sample taken 16-SEP-96
‡ indicates sample taken 10-JUL-96

Table 3. Water quality tests taken at Bog Stream during the storm event on 20-OCT-96 and 21-OCT-96.

Time (hours)	Turbidity (FTU)	Total Phosphorus (ppb)	Rainfall Accumulation (cm)	Flow Value at 60% of Depth*		Water Level (cm)
7:00 PM	--	--	0.00	--	--	32.4
7:40	--	--	0.00	0.05	0.07	32.4
8:30	2	34.7	0.00	0.22	0.19	32.5
9:05	2	26.8	0.00	0.04	0.06	32.8
9:40	2	22.6	0.23	0.15	0.12	32.4
10:15	3	37.4	0.23	0.15	0.12	32.4
10:45	1	30.6	0.43	0.10	0.01	32.9
11:30	2	29.8	0.50	0.07	0.02	33.4
12:00 AM	2	32.7	0.50	0.09	0.12	33.4
12:30	3	26.3	0.50	0.07	0.13	33.4
1:00	6	33.7	0.80	0.01	0.08	33.4
1:30	5	23.8	1.00	0.05	0.04	33.8
2:15	3	88.5	1.60	0.17	0.17	34.5
2:45	3	49.4	2.00	0.24	0.19	35.0
3:10	3	22.1	2.45	0.25	0.20	35.8

* Measurements in the first column taken at a width of 9.00 ft and a depth of 2.51 ft. Measurements in the second column taken at a width of 12.00 ft and a depth of 2.03 ft.

Table 4. Water quality tests at Leech Brook taken during the storm event on 20-OCT-96 and 21-OCT-96.

Time (hr)	Turbidity (FTU)	Total Phosphorus (ppb)	Rainfall Accumulation (cm)	Flow Value at 60% of Depth*		Water Level (cm)
7:40 PM	6	16.1	0.0	0.08	0.23	20.0
8:20	6	17.5	0.0	0.08	0.23	20.0
9:20	7	26.6	0.0	0.16	0.06	20.5
10:10	7	19.9	0.2	0.24	0.04	20.5
10:40	5	22.0	0.3	0.11	0.10	21.0
11:30	7	23.2	0.3	0.12	0.10	21.0
12:30 AM	7	15.1	0.5	0.25	0.18	22.0
1:30	8	15.3	1.0	0.11	0.21	22.5
2:30	8	11.3	1.8	0.25	0.31	27.0

*Measurements in column one were taken at a width of 6.4 ft and a depth of 1.215 ft. Measurements in column two taken at a width of 10.15 ft and a depth of 1.05 ft.

Table 5. Water quality tests taken at Pattee Brook during the storm event on 20-OCT-96 and 21-OCT-96.

Time (hours)	Turbidity (FTU)	Total Phosphorus (ppb)	Rainfall Accumulation (cm)	Flow Value at 60% of Depth*			Water Level (cm)
7:20 PM	--	--	0.00	--	--	--	35.3
8:10	11	10.5	0.00	0.03	0.03	0.27	35.8
8:45	11	11.6	0.00	0.04	0.06	0.21	36.4
9:25	11	19.0	0.20	0.04	0.06	0.21	37.2
10:00	11	12.4	0.20	0.04	0.06	0.24	37.9
10:30	11	16.5	0.25	0.05	0.10	0.29	36.8
11:10	11	17.4	0.40	0.04	0.06	0.22	36.2
11:45	12	24.7	0.40	0.04	0.06	0.13	36.4
12:15 AM	12	15.3	0.45	0.04	0.09	0.30	36.5
12:45	12	11.7	0.48	0.04	0.10	0.30	37.0
1:15	12	30.7	0.90	0.04	0.10	0.20	37.2
1:45	11	17.5	1.20	0.04	0.08	0.10	38.0
2:30	13	14.6	1.95	0.03	0.11	0.30	39.0
3:00	13	24.7	2.60	0.06	0.10	0.20	41.0

* Measurements in column one were taken at a width of 3.1 ft and a depth of 0.53 ft.
Measurements in column two were taken at a width of 5.0 ft and a depth of 0.59 ft.
Measurements in column three were taken at a width of 8.6 ft and a depth of 0.2 ft.

Table 6. Water quality tests taken at the Serpentine during the storm event on 20-OCT-96 and 21-OCT-96.

Time (hours)	Turbidity (FTU)	Total Phosphoru s (ppb)	Rainfall Accumulation (cm)	Flow Value at 60% of Depth*			Water Level (cm)
7:00 PM	9	19.1	0.00	0.75	0.60	0.10	37.0
8:00	8	17.7	0.00	0.50	0.60	0.60	37.0
9:00	7	18.3	0.00	0.50	0.70	0.54	37.2
9:50	7	13.6	0.10	0.42	0.60	0.42	37.4
10:30	7	9.9	0.20	0.54	0.72	0.50	37.5
11:00	7	10.4	0.20	0.48	0.58	0.51	37.5
12:00 AM	8	10.8	0.20	0.43	0.65	0.44	37.5
1:00	8	12.0	0.25	0.60	0.67	0.35	38.0
3:00	8	11.5	1.80	0.62	0.50	0.54	40.5

* Measurements in column one were taken at a width of 5.5 ft and a depth of 1.12 ft.
Measurements in column two were taken at a width of 9.6 ft and a depth of 1.31 ft.
Measurements in column three were taken at a width of 12.9 ft and a depth of 1.12 ft.

Table 7. Water quality tests done at the characterization sites on 23-SEP-96 and 30-SEP-96. See Figure 12 for site locations.

Site	Depth	Total Phosphorus (ppb)	Nitrate (mg/l)	Hardness (mg/l)	Color (SPU)	Conductivity (μmhos/cm^2)
1	Core	--	--	--	--	--
1	Surface	8.9	0.04	11	11† 9†	0.30
1	Mid	9.2	--	10	8	0.35
1	Deep	--	0.05	11	9	0.35
5	Core	8.5	--	--	--	--
5	Surface	11.6	0.04 0.04*	10 10*	14	0.31 0.31*
5	Mid	9.9	--	--	8	0.40
5	Deep	11.4	--	--	15	0.30
7	Core	31.8	--	--	--	--
7	Surface	9.7	0.07† 0.06†	9	22	--
7	Mid	9.5	--	--	26† 23†	--
7	Deep	9.1 19.1‡	--	11	24	--

* indicates duplicate sample
† indicates split sample
‡ indicates a 10 ppb spiked sample

Table 8. Dissolved oxygen (ppm) and temperature (°C) readings taken at various depths (m) from characterization sites in North and Little Ponds. Site 1 was sampled on 16-SEP-96 (*) and 30-SEP-96 (†). Sites 5 and 7 were sampled on 30-SEP-96. See Figure 12 for site locations.

	Site 1 *		Site 1 †		Site 5		Site 7	
Depth	Temp	DO	Temp	DO	Temp	DO	Temp	DO
0	18.1	8.6	15.5	9.7	15.5	7.1	15.7	9.1
1	18.1	8.5	15.5	9.7	15.5	7.1	15.7	8.6
2	18.1	8.3	15.5	9.6	15.5	7.1	15.7	8.9
3	18.0	8.4	15.5	9.8	15.5	7.0	15.7	8.9
4	17.8	8.3	15.5	9.8	15.5	6.6	15.4	9.1
5	17.8	8.1	15.5	9.8	15.5	6.4	–	–

APPENDIX D. WATER BUDGET AND FLUSHING RATE CALCULATIONS FOR NORTH POND

Table 1. Water budget calculation for North Pond watershed (see Analytical Procedures and Findings: Water Budget for explanation).

Parameters	Units	Value
Runoff	meters/yr	0.622
Precipitation[a]	meters/yr	1.01
Evaporation	meters/yr	0.56
Land Area	square meters	30,920,000
Lake Surface Area	square meters	9,123,000
Average Depth[b]	meters	4.07
I_{net} North Pond (NP)[c]	cubic meters/yr	23,296,582
Q (North Pond)	cubic meters/yr	28,405,462
Q (Total)	cubic meters/yr	55,807,085
I_{net} East Pond (EP)[d]	cubic meters/yr	9,782,000
I_{net} Little Pond (LP)[e]	cubic meters/yr	6,798,000
I_{net} Serpentine (S)[e]	cubic meters/yr	10,820,000
Flushing Rate[f]	flushes/yr	1.36

a. Ten year average of precipitation data from Waterville and Augusta NOAA Weather Stations.
b. Average depth obtained from unpublished MDEP Bathymetric data.
c. I_{net} = (Runoff x Land Area) + (Precipitation x Lake Area) - (Evaporation x Lake Area)
d. Obtained using the East Pond land and lake areas as reported in the BI493 study (1991). The current ten year average for precipitation was used. Runoff and evaporation constants listed above.
e. Land and lake values obtained using ZIDAS methods (see Land Use Methodology). I_{net} LP and I_{net} S calculated using precipitation data, runoff, and evaporation constants listed above.
f. **Flushing Rate** = Q_{NP} + I_{net} EP + I_{net} LP + I_{net} S / (Lake Area x Average Depth)

APPENDIX E. PHOSPHORUS EQUATION

$W = (Ec_a \times As_1) + (Ec_f \times Area_f) + (Ec_{rf} \times Area_{rf}) + (Ec_w \times Area_w) + (Ec_c \times Area_c) + (Ec_r \times Area_r) + (Ec_s \times Area_s) + (Ec_n \times Area_n) + [(Ec_{ss} \times \#\text{ capita years}_1 \times (1-SR_1)) + (Ec_{ns} \times \#\text{ capita years}_2 \times (1-SR_2)) + (Ec_{sc} \times \#\text{ capita years}_{sc} \times (1-SR_3))] + PSI$

Ec_a = export coefficient for atmospheric input [kg/ha-yr]

Estimate Range (ER) = 0.15 - 0.55

The export coefficient range for atmospheric input reported in Reckhow and Chapra (1983) was 0.15 - 0.60. An additional study on Higgins Lake had a range of 0.15 - 0.50. The North Pond watershed was similar to the Higgins Lake watershed in that there was not a lot of agricultural land. The proximity of the gravel pit to North Pond and the Serpentine, as well as new logging operations on the west side of Little Pond, probably increases the amount of airborne phosphorus. As a result, the low and high coefficient estimates for North Pond atmospheric phosphorus input are higher than recent lake studies in the Belgrade chain have reported (BI493 1995, BI493 1996).

Ec_f = export coefficient for mature forested land [kg/ha-yr]

ER = 0.10 - 0.30

The mature forest coefficient range reported by Reckhow and Chapra (1983) for Higgins Lake was 0.10 - 0.30. The forests in the Higgins Lake watershed were mostly conifers and comprised a majority of the watershed. North Pond watershed is similar to the Higgins Lake watershed in mature forest composition, so the same export coefficient range was used in the phosphorus equation.

Ec_{rf} = export coefficient for regenerating forested land [kg/ha-yr]

ER = 0.20 - 0.70

Long Pond, North Basin reported a range of 0.10 - 0.70 for young cut over forests (BI493 1995). Long Pond, South Basin reported a range of 0.30 - 1.0 (BI493, 1996). The values for both of those studies were based on considerable openings in the canopy and visible skidder trails on steep slopes near the lakes. The ranges fell between the high value coefficients for mature forest and cleared land. The coefficient range assigned for regenerating land in this study falls between the high values of cleared and mature forest. The low coefficient is somewhat higher than Long Pond, North Basin due to substantially large openings in the canopy. The high coefficient is lower than Long Pond, South Basin as there were no visible skidder trails and most areas of regenerating land were on mild slopes.

Ec_w = export coefficient for wetlands [kg/ha-yr]

ER = 0.03 - 0.20

This coefficient range was taken from Long Pond, South Basin (BI493 1996), Long Pond, North Basin (BI493 1995), Pattee Pond (BI493 1992), and East Pond studies (BI493 1991). The wetland areas in North Pond watershed are similar to the wetland areas in the other studies cited above.

Ec_c = export coefficient for cleared land [kg/ha-yr]

ER = 0.10 - 1.0

Pattee Pond (BI493 1992) and Long Pond, North Basin (BI493 1995) had cleared land coefficient ranges from 0.10 - 1.0. These watersheds had few farms and would therefore contribute less phosphorus. A watershed that had more farms would contribute more phosphorus, such as Long Pond, South Basin (BI493 1996). The North Pond watershed does not have many farms, so the same range as Pattee Pond and Long Pond, North Basin was used.

Ec_r = export coefficient for roads [kg/ha-yr]

ER = 0.30 - 1.60

Salmon Lake had a road coefficient range of 0.3 - 1.50 (BI493, 1994). The roads in the North Pond watershed were found to be slightly worse than the roads in the Salmon Lake watershed, so the high value coefficient was raised.

Ec_s = export coefficient for shoreline development [kg/ha-yr]

ER = 0.80 - 3.50

Reckhow and Chapra assign a range of 0.50 - 5.0 to urban areas (1983). Higgins Lake was assigned a range of 0.35 - 2.70 as it is mostly a residential and recreational area. Salmon Lake (BI493 1994) and Long Pond, North Basin (BI493 1995) were given ranges of 0.8 - 3.2 and 0.8 - 3.0 respectively due to the large number of residences close to the shoreline. North Pond has many residences that are very close to the shoreline, many of them without adequate buffer zones. Some residences have lawns that extend to the water's edge. The export coefficient range assigned for shoreline development for this study is, therefore slightly higher than Salmon Lake and Long Pond, North Basin.

Ec_n = export coefficient for nonshoreline development [kg/ha-yr]

ER = 0.35 - 1.50

Nonshoreline development has a lesser impact on phosphorus loading as they are further back in the watershed; there is more land acting as a buffer in between the residences and the lake. Long Pond, North Basin (BI493 1995) and Salmon Lake (BI493 1994) assigned the same range due to the distance of nonshoreline residences from the lake. The range is much lower than the shoreline range because of the lessened impact on the lake.

Ec_{ss} = export coefficient for shoreline septic tank systems [kg/ha-yr]

ER = 0.6 - 1.50

Salmon Lake used a shoreline septic tank coefficient of 0.40 - 1.00 (BI493 1994). They had a high percentage of grandfathered systems and moderate soil. The Pattee Pond shoreline septic tank coefficient was 0.60 - 1.80 (BI493 1993a). Pattee Pond also had a high percentage of grandfathered systems, but it also had very unsuitable soil for septic systems. North Pond watershed has moderate to poor shoreline soil for septic suitability and approximately the same percentage of grandfathered systems. The coefficient assigned for this study was between the coefficients for Pattee Pond and Salmon Lake.

capita $years_l$ = number of persons contributing to shoreline septic tank systems: (# persons x days/yr) x # shoreline living units

The Higgins Lake study used an estimate of 3.5 persons per living unit (Reckhow and Chapra 1983). Year round days per year is estimated to be 355. Seasonal days per year is estimated to be 70, slightly higher than Salmon Lake (BI493 1994) and lower than Long Pond, South Basin (BI493 1995). The reason for lengthening the number of days is that there were people occupying their residences during the first week or two of the lake survey. The number of shoreline residences was determined from property cards obtained from town offices and road surveys conducted by CEAT. There were 271 seasonal shoreline residences and 36 year round shoreline residences. It was not assumed that seasonal residences would be found only along the shoreline.

SR_l = soil retention coefficient for shoreline development

ER = 0.70 - 0.50

Soil retention is an estimate of how well different soil types are able to retain phosphorus on a scale from 0 to 1, with 0 representing no phosphorus retention and 1 being full phosphorus retention. The higher the value, the more phosphorus is held in the soil and the less is washed into the lake. The soil around the shore of North Pond and Little Pond is a mix three different septic suitability types based on soil permeability and slope (see Analytical Procedures and Findings: Soil Methodology). There is a majority of soil that is either too wet and cannot hold much phosphorus or too permeable and cannot retain a lot of phosphorus. In light of this, the soil retention coefficient range is lower than in previous reports, representing less phosphorus held by the soil.

Ec_{ns} = export coefficient for nonshoreline septic tank systems [kg/ha-yr]

ER = 0.40 - 0.90

Pattee Pond reported a range of 0.40 - 1.80 for nonshoreline septic systems (BI493 1993a). The range for Salmon Lake was slightly lower, 0.40 - 0.90, due to larger areas of soil suitable for septic system construction (BI493 1994). North Pond watershed is similar to Salmon Lake in that there is more septically suitable land, so the same coefficient was used.

capita $years_2$ = number of persons contributing to nonshoreline septic tank systems:
(# persons x days/yr) x # nonshoreline living units
The same estimate of number of persons per residence was used, 3.5. The year round days per year was estimated to be 355. Seasonal days per year was estimated to be 70. The number of nonshoreline residences was determined from property cards obtained from town offices and road surveys conducted by CEAT. There were 19 seasonal nonshoreline residences and 204 year round nonshoreline residences.

SR_2 = soil retention coefficient for nonshoreline development

ER = 0.80 - 0.70

Phosphorus from nonshoreline residences has more of a chance to be absorbed than shoreline residences as the nonshoreline residences are further from the lake shore. There is more land area that can absorb the phosphorus from nonshoreline sources. A higher soil retention coefficient is therefore used in this model.

Ec_{cs} = combined export coefficient and number of capita years for Pine Tree Camp
The design manual written by the U.S. Environmental Protection Agency lists pollutant concentrations of major residential wastewater fractions (23 mg/l) and wastewater flow from institutional sources (52.8 - 106 gal-day/unit) (1980). Pine Tree Camp is a seasonal camp, but it is open longer than the typical seasonal residence; the number of days per year was estimated to be 90 days, versus 70 for a seasonal residence. Pine Tree Camp has approximately between 180 and 190 children. The low combined export coefficient and

number of capita years was calculated to be 74.36 kg/ha-yr. The high combined coefficient was calculated to be 157.59 kg/ha-yr.

SR_3 = soil retention coefficient for Pine Tree Camp

ER = 0.60 - 0.40

Pine Tree Camp is situated on soil unsuitable for septic systems. The septic system is relatively new and in good condition. So a medium soil retention coefficient was used.

PSI = point source input [kg/ha-yr]

ER = 380.00 - 580.00

Point source inputs are calculated by multiplying the individual I_{net} for each major inflow into the lake by the amount of phosphorus found in those inflows. The resulting product is then converted to kg/yr. The point sources for North Pond are Little Pond, the Serpentine and East Pond. The I_{net} for the Serpentine and Little Pond inputs were multiplied by the mass of phosphorus determined by water quality tests conducted by CEAT (see Appendix D; Analytical Procedures: Lake and Tributary Water Quality, Phosphorus; Tributary Storm Event, Phosphorus). The I_{net} for East Pond was multiplied by the phosphorus concentration at the mouth of the Serpentine (BI493 1991). The values were converted to kg/yr. High and low values were determined by subtracting and adding 100.00 kg/yr.

Areas for land use components and number of capita years

As_l = area of North Pond = 912.3 ha

$Area_f$ = area of mature forested land = 3798.8 ha

$Area_{rf}$ = area of regenerating forest = 26.35 ha

$Area_w$ = area of wetlands = 340.0 ha

$Area_c$ = area of cleared land = 1473.2 ha

$Area_r$ = area of roads = 30.3 ha

$Area_s$ = area shoreline development = 62.1 ha

$Area_n$ = area nonshoreline development = 90.2 ha

capita $years_1$ = 304.5

capita $years_2$ = 707.2

APPENDIX F. PREDICTIONS FOR ANNUAL MASS RATE OF PHOSPHORUS INFLOW

Equations

For the phosphorus loading model, annual phosphorus input must be expressed as a loading per unit lake surface area. This is done by dividing annual mass rate of phosphorus inflow, W, by the lake surface area, A_s (Reckhow and Chapra 1983):

$$\mathbf{L = W/A_s}$$

where, L = areal phosphorus loading ($kg/m^2/yr$)
W = annual mass rate of phosphorus inflow (kg/yr)
As = surface area of the lake (m^2)

Aerial water loading is calculated by dividing inflow water volume by the surface area of the lake, A_s (Reckhow and Chapra 1983):

$$\mathbf{q_s = Q/A_s}$$

where, qs = aerial water loading (m/yr)
Q = inflow water volume (m^3/yr)

The lake phosphorus concentration can now be calculated, for both low and high values, by substituting in values of q_s and L (low and high) (Reckhow and Chapra 1983):

$$\mathbf{P = L/(11.6+1.2q_s)^*}$$

where, P = lake phosphorus concentration (kg/m^3)

Predictions were made from both the low and high values of annual mass rate of P inflow.

Constants for both low and high predictions for North Pond:

$A_s = 9123000.00\ m^2$
$Q = 55807085.09\ m^3/yr$
$q_s = 6.12\ m/yr$

Low Prediction

W (low) = 1342.42 kg/yr
L (low) = $1.14 \times 10^{-3}\ kg/m^2/yr$
P (low) = **7.77 ppb**

High Prediction

W (high) = 4710.28 kg/yr
L (high) = $5.16 \times 10^{-3}\ kg/m^2/yr$
P (high) = **27.26 ppb**

* equations obtained from Reckhow and Chapra (1983)

APPENDIX G. ROAD SURVEY FORMS

Paved/Dirt Road Survey

DATE: SURVEY:

ROAD NAME/NUMBER:

General Description

Road Dimensions: Length (Miles) Average Width (feet) Average Slope (%)

-

Description Of Road Surface

General Rating: 1, 0.5, or 0 These scores are based on info obtained by driving road and by closely examining three separate sections.

Crowning ______

Culverts ______

Ditches ______

Diversions ______

Cracking/Gullying ______

TOTAL SCORE ______

Widths ______ ______ ______ Average Width_____
Slopes ______ ______ ______ Average Slope _____

Record of Any Problem Areas In The Road and Their Locations:

CAMP ROAD SURVEY FORMS

DATE:______________ SURVEYOR'S NAME(S):______________________________

ROAD NAME/NUMBER:____

GENERAL DESCRIPTION

ROAD DIMENSIONS: Length (miles)_____ Average Width (feet)_____ OVERALL SLOPE (%):_____

TOTAL NO. OF WATER DIVERSIONS:_______ NO. OF MISSING WATER DIVERSIONS:_______

NUMBER OF MISSING CULVERTS NEEDED:________ SIZE OF CULVERTS NEEDED:_________

DESCRIPTION OF ROAD SURFACE

Score each 0.1 mile section of road with checkmark [√] in appropriate column of each row. For roads with uniform surface conditions, simply divide road into one to three equal sections depending upon length of road. When survey is complete, compute average score for each characteristic using values shown in parentheses.

	Good	Acceptable	Fair	Poor	Big Problem		Average Score
Crown	_____(1) 6 in.	_____(2) 4 in.	_____(4) 2 in.	_____(6) 0 in./potholes	_____(8) 0 in./ruts		_____
Surface (dry)	_____(1) hard w/o dust	ØØØØØØ ØØØØØØ	_____(3) hard w/ dust	_____(4) loose	_____(5) dusty & loose		_____
OR Surface (wet)	_____(1) hard	_____(2) hard & slick	_____(3) slick & loose	ØØØØØØ ØØØØØØ	_____(5) mud		_____
Edge	_____(0) no berm/ridge	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	_____(5) berm/ridge prevents surface runoff		_____
Road Material	_____(1) gravel	_____(2) gravel/sand	_____(3) dirt	_____(4) sand/clay	_____(5) clay		_____
					SURFACE TOTAL	[a]	_____
USAGE	_____(1) seasonal	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	ØØØØØØ ØØØØØØ	_____(5) year round	[b]	_____
SUMMARY OF SURFACE CONDITION	_____(1) 100%good	_____(2) 75%good	_____(3) 50%good	_____(4) 25%good	_____(5) 0%good	[c]	_____

_________ X _________ X _________ = _________

SURFACE [a] X **USAGE [b]** X **CONDITION [c]** = **SURFACE TOTAL[d]**

DATE:______________ SURVEYOR'S NAME(S):______________________________

ROAD NAME/NUMBER:____

DESCRIPTION OF WATER DIVERSIONS

Score the quality of water diversions for the entire road with checkmark [√] in appropriate column of summary evaluation. Use the descriptions provided to determine the overall water diversion condition.

Need	Good ample/none needed	Acceptable ØØØØØØ	Fair ØØØØØØ	Poor ØØØØØØ	Big Problem badly needed		
Where does diverted water go?	woods	field or lawn	gully in woods	stream	lake		
OVERALL WATER DIVERSION CONDITION	_____(2) 100%good, or none needed	_____(3) 75%good	_____(4) 50%good	_____(5) 25%good	_____(15) 0%good, no diversions present but needed	[l]	_____

______________ = ______________________________

CONDITION [l] **WATER DIVERSIONS TOTAL** **[m]**

FINAL EVALUATION OF THE ROAD

________ + ________ + ________ + ____________ = ________

[d] SURFACE + [g] DITCHES + [j] CULVERTS + [m] WATER DIVERSIONS = ROAD TOTAL

The lower the total, the better the score for an individual road. Having a low or acceptable score does not mean that road maintenance is unnecessary, but a high score indicates the need for work, and can be used as a guide for making decisions about where and what type of work is needed. As a rule, if any item checked was worth more than two points, it should be given priority when developing a road maintenance plan.

ROAD SEGMENT TOTAL = ____________________ (LESS THAN 25 IS MOST DESIRABLE)

ROAD SEGMENT AVERAGE = ________________________

DATE:______________ SURVEYOR'S NAME(S):______________________________

ROAD NAME/NUMBER:____

DESCRIPTION OF ROAD DITCHING

Score each 0.1 mile section of road with checkmark [√] in appropriate column of each row. When survey is complete compute average score for each characteristic using values shown in parentheses.

	Good	Acceptable	Fair	Poor	Big Problem		Average Score
Need	_____(1) ample/none needed	ØØØØØØ ØØØØØØ	_____(5) some needed	ØØØØØØ ØØØØØØ	_____(15) badly needed		_____
Depth	_____(1) 2 ft. (or road slopes into adjacent land)	_____(2) 3 ft.	_____(3) 4 ft.	_____(4) 1 ft.	_____(5) no ditch present but needed		_____
Width	_____(1) 8 ft. (or road slopes into adjacent land)	_____(2) 6 ft.	_____(3) 4 ft.	_____(4) 2 ft.	_____(5) no ditch present but needed		_____
Vegetation	_____(1) turf, wooded, or rip rap	ØØØØØØ ØØØØØØ	_____(3) weeds	ØØØØØØ ØØØØØØ	_____(5) bare soil		_____
Sediments	_____(1) none	ØØØØØØ ØØØØØØ	_____(3) 2 inches deep	ØØØØØØ ØØØØØØ	_____(5) >4 inches deep		_____
Shape	_____(1) parabolic 	_____(2) trapezoid 	_____(3) round 	_____(4) v-shaped 	_____(5) square or none 		_____
					TOTAL	[e]	_____
SUMMARY OF DITCH CONDITION	_____(1) 100%good, or none needed	_____(2) 75%good	_____(3) 50%good	_____(4) 25%good	_____(5) 0%good, or no ditch present but needed	[f]	_____

_____ **DITCHES [e]** X _____ **CONDITION [f]** = _____ **DITCH TOTAL [g]**

DATE:______________ SURVEYOR'S NAME(S):______________________________

ROAD NAME/NUMBER:____

ROAD SEGMENTS

A road segment is defined as a particular length of road which has a relatively continuous angle of incline (% grade). Start and end segments so that their lengths fall into one of the column headings indicated. For each segment recorded in the segment % grade analysis in the upper table, place a check [√] in the appropriate box of the lower table. The upper table is used to identify particularly troublesome road segments, while the lower table is used to characterize the soil erosion potential (phosphorus loading potential) of the road in general [shaded boxes represent high erosion potential].

Segment							Score = Segment Len. X % Grade
A	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
B	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
C	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
D	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
E	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
F	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
G	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
H	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
I	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
J	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
K	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
L	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
M	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
N	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
O	Length	50	100	200	500	1000	
	% Grade	( )	( )	( )	( )	( )	________
					ROAD SEGMENT TOTAL		________

% Grade	Segment Length (feet)				
	50	100	200	500	1000
0-5% Total	____(4)	____(5)	____(8)	____(12)	____(17)
6-10% Total	____(10)	____(14)	____(19)	____(31)	____(43)
11-15% Total	____(16)	____(23)	____(33)	____(51)	____(73)
16-20% Total	____(29)	____(41)	____(58)	____(91)	____(129)

After surveying road, multiply the number of checks in each box by the erosion potential coefficient for that box to obtain a box total. To obtain the Road Segment Average, add all of the box totals and divide by the total number of checks.

ROAD SEGMENT AVERAGE ______ = TOTAL OF ALL BOXES ______ ÷ TOTAL # OF CHECKS ______

DATE:______________ SURVEYOR'S NAME(S):______________________________

ROAD NAME/NUMBER:____

DESCRIPTION OF CULVERTS

Score the quality of culverts for the entire road with checkmark [√] in appropriate column of summary evaluation. Use the descriptions provided to determine the overall culvert condition.

Criteria	Good	Acceptable	Fair	Poor	Big Problem		
Need	ample/none needed	ØØØØØØ ØØØØØØ	some not working	ØØØØØØ ØØØØØØ	badly needed		
Wear	new	aging (some rust)	old (rust holes)	bottom gone	ØØØØØØ ØØØØØØ		
Size	2 ft. diam.	1-1/2 ft. diam	1 ft. diam.	<1 ft. diam.	ØØØØØØ ØØØØØØ		
Insides	clean	some rocks and/or water	≤2 in. silt	>2 in. silt	ØØØØØØ ØØØØØØ		
Covering Material	at least 1 ft. thick or half diameter of large culverts	ØØØØØØ ØØØØØØ	less than 1 ft. thick	covering inadequate to prevent bent culvert	top of culvert showing through road surface		
OVERALL CULVERT CONDITION	_____(5) 100%good, or none needed	_____(8) 75%good	_____(17) 50%good	_____(21) 25%good	_____(27) 0%good, no culvert present but needed	[i]	_____

__________ = __________

CONDITION [i] **CULVERT TOTAL[j]**

APPENDIX H. PERSONAL COMMUNICATIONS

Name	Affiliation
Warren and Helen Balgooyen	Local Residents
Roy Bouchard	Bureau of Land and Water Quality Control, MDEP
Sally Butler	Soil Conservation Service
Dale Buzzell	Rome Plumbing Inspector
Central Maine Power	
Tim Christensen	Department of Biology, Colby College
Dr. Russell Cole	Department of Biology, Colby College
Linda Cunningham	President of the Belgrade Lake Association
Dr. Paul Doss	Department of Geology, Colby College
Eugene Dumont	State Wildlife Biologist
David Firmage	Department of Biology, Colby College
Bill Grove	Executive Member of the North Pond Lake Association
Bob Joly	MDEP Volunteer
Tom Kirkendall	Local Resident
Frank Landford	Mercer Code Enforcement Officer
Bob Martin	Belgrade Plumbing Inspector
Bob Moreau	First Selectman of Rome
Web Pearsall	MDEP
Ethel Springer	Town Clerk of Mercer
Lisa Turner	Town Clerk of Smithfield
Sally and Arthur Wilder	Local Residents
Mike Zarcone	Smithfield and Norridgewock Plumbing Inspector, Smithfield Code Enforcement Officer
Randolph Zimmer	Mercer Plumbing Inspector

APPENDIX I. LEGAL PERSPECTIVES

Shoreland zoning ordinances establish guidelines for development. Ideally, zoning ordinances are used as basic regulations, intended to be further refined in comprehensive plans, specific for each municipality. Smithfield, Mercer, and Norridgewock have all amended the minimum shoreland ordinances designed by MDEP to create their own ordinances. The ordinances were created using the following acts as a basic framework (COLA 1991).

Act to Greater Enhance and Protect Maine's Great Ponds - This act requires towns, within their subdivision ordinances, to ensure that the water quality will be protected from long-term and cumulative increases in phosphorus from development in great pond watersheds.

Title 38 - Water Classification Program - This title classifies lakes as Great Pond Area (GPA) when natural land is greater than 10 acres, or man-made and greater than 30 acres. The title states that no change in land use by itself or in conjunction with other activities can cause water quality degradation in GPA waters which would impair the characteristics and designated uses of downstream lake waters or cause an increase in trophic state of those GPA waters.

Natural Resources Protection Act (NRPA) - An act administered by MDEP. The Act protects great ponds, wetlands, rivers, streams, sand dunes, fragile mountain areas, and significant wildlife habitat. A permit is required from DEP for activities that could alter natural areas.

Shoreland Zoning Law - This law requires all municipalities to establish land use controls for all land areas within 250 ft of ponds and freshwater wetlands that are 10 acres or larger, rivers with watersheds of at least 16,000 acres, coastal wetlands and tidal waters, as well as all land areas within 75 ft of certain streams. The law also requires a minimum buffer strip of 100 ft along lake shores and river banks and at least 25 ft along road ditches and intermittent streams.

Maine Site Location of Development Act - This act, administered by the MDEP, generally regulates land parcels of 20 acres or more, which are divided into five or more lots for sale or lease within a 5-year period.

Local Subdivision Ordinances - These ordinances usually regulate any division of a tract of land into three or more lots within any 5-year period. The ordinances are administered by municipalities within which a subdivision occurs.

APPENDIX J. HOUSE SURVEY FORMS

GENERAL DESCRIPTION (House survey)

Road Name: ______________________________

Road Location: ______________________________

NUMBER OF DWELLINGS:______ NUMBER OF YEAR ROUND HOMES?______

ROAD DIMENSIONS: Length (miles)________ Average Width (feet)__________

For houses within 200 feet of the shoreline

	Seasonal		Year Round	
	Pre 1970	Post 1970	Pre 1970	Post 1970

For houses greater than 200 feet from the shoreline

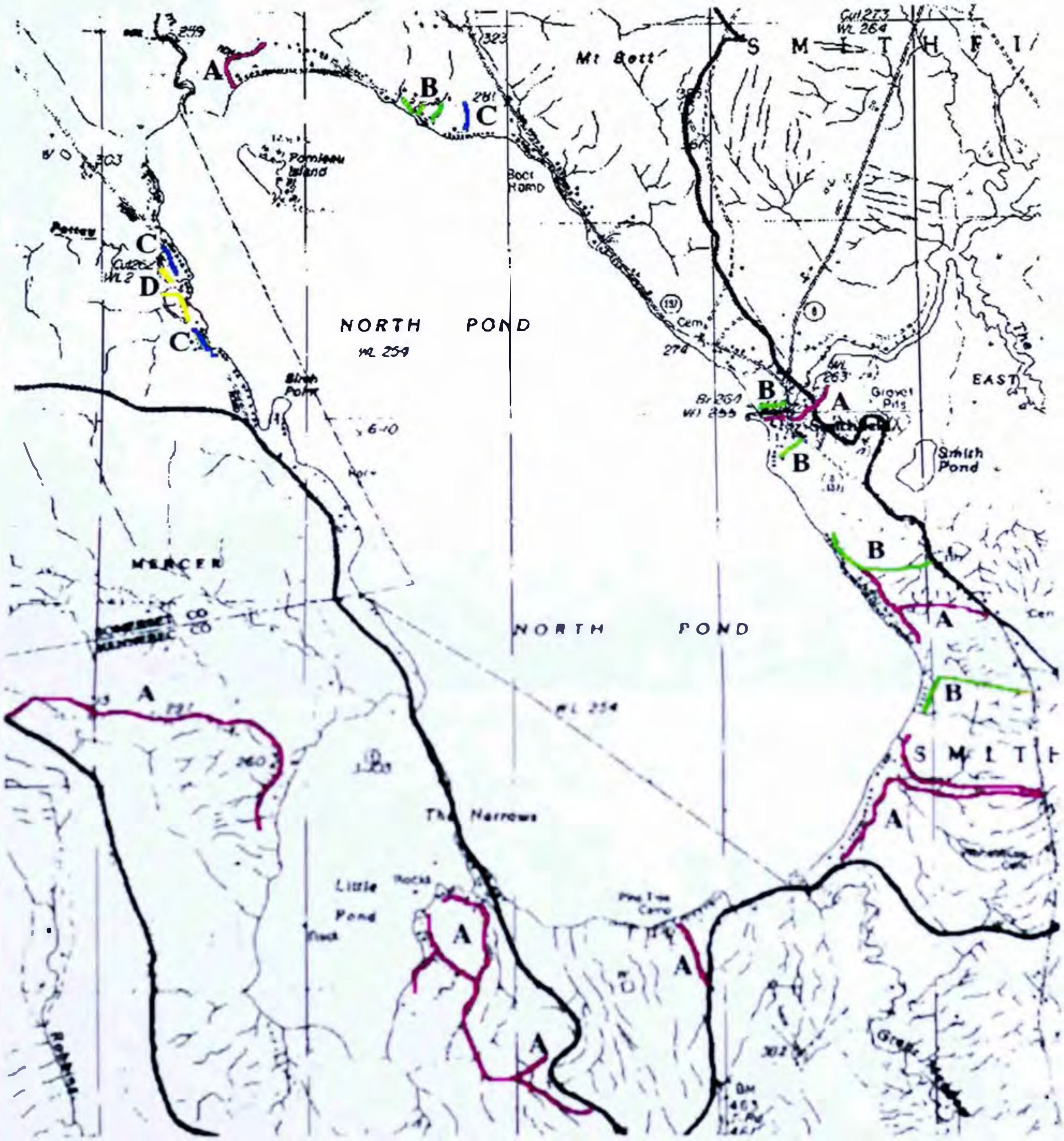
	Seasonal		Year Round	
	Pre 1970	Post 1970	Pre 1970	Post 1970

APPENDIX K. CLASSES OF ROAD TOTAL INDEX VALUES

Table 1. Classes of camp roads in the North Pond watershed based on Road Total Index values.. Class 1 indicates the best quality camp roads.

Class 1	Class 2	Class 3	Class 4
RVFD 225-1A1A	RVFD 225-1A1C	S-1	W-5
RVFD 225-1A1D	S-3	S-7	Fire Ln. 1
S-11	S-5	S-12	Fire Ln. 2
Sunset Camp Rd. B	N-3	W-7	Fire Ln. 3
Pine Tree Camp Rd.	W-6	W9	Fire Ln. 4
	W-12	McNulty Rd.	
	Sunset Camp Rd. A		

Appendix L. Total Road Value Map



Appendix L. Total Road Values for all camp roads in the North Pond watershed. Roads designated A have a Total Road Value of 0 to 2000, B have a value of 2000 to 4000, C have a value of 4000 to 6000, and D have a value of 6000 to 8000. Roads with higher values are greater contributors to phosphorus loading.

APPENDIX M. AREAS OF ROADS

Table 1. Area of paved, dirt, and camp roads organized by municipality and subwatershed.

Municipality	Area of Paved and Dirt Roads	Area of Camp Roads
Mercer	821,002	26,227
Norridgewock	75,369	0
Rome	182,680	112,777
Smithfield	1,807,570	236,008
Total	**2,886,622**	**375,013**

Subwatershed	Area of Paved and Dirt Roads	Area of Camp Roads
Little Pond	210,983	107,677
North Pond	1,891,809	226,449
Serpentine	783,830	40,887
Total	**2,886,622**	**375,013**