1991

An Analysis of East Pond and the Serpentine Watersheds in Relation to Water Quality

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

Colby College

Recommended Citation

Problems in Environmental Science course (Biology 493), Colby College and Colby College, "An Analysis of East Pond and the Serpentine Watersheds in Relation to Water Quality" (1991). *Colby College Watershed Study: East and North Ponds (2011, 1999, 1996, 1991)*. 2.
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AN ANALYSIS OF EAST POND AND THE SERPENTINE WATERSHEDS IN RELATION TO WATER QUALITY

Biology 493
Colby College
Waterville, ME 04901

DATE: May 28, 1991

TO: Report recipients

FROM: Professors David Firmage, Russell Cole and Frank Fekete

RE: Class report on the East Pond and Serpentine Watersheds

This report is the work of students in the Problems in Environmental Science course (Biology 493) taught at Colby College during the fall semester of 1991. The course is taken by seniors who are majoring in Biology with a concentration in Environmental Science. The students are treated 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 outline a workplan and what is necessary to carry the plan out successfully. As part of this learning process the students use methods and tools they have learned about in other courses and are introduced to new methodology as needed. Standard methods of analysis are used as well as up-to-date instrumentation for any of the original analysis done. However, there are time constraints involved in the study as all requirements for the course must be completed within the fall semester. These constraints mean that new data can only be gathered during the months of September through early November and typically that extensive analysis can not be done. 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.

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 each area 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.

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INTRODUCTION

General of

Lake ecosystems are important natural resources because they provide habitats for many floral and faunal species, recharge groundwater aquifers, supply drinking water and provide outdoor recreation sites (Schauffler, 1990). However, human activities may influence lake water quality by accelerating nutrient loading, causing cultural eutrophication (Henderson-Sellers, 1987). Lake *eutrophication* is a natural aging process of a lake in which organic matter accumulates and gradually changes the physical and chemical characteristics of the area. *Cultural eutrophication* occurs when this natural process is accelerated through land use practices such as urban and residential development, road construction, and agriculture within the watershed (Henderson-Sellers, 1987). These activities increase the rates of erosion, sedimentation, and phosphorus and nitrogen loading to the lake. Phosphates and nitrates lead to a rise in organismal production and may result in algal blooms, good indicators of unstable water quality in the lake body. Streams act as vehicles for nutrient transport from the watershed to the lake while wetlands adjacent to streams may play a role as a sink for nutrients flowing toward the lake (Mitsch and Gosselink, 1986). Most of the lakes in Maine are of at least moderate water quality. There are, however, many Maine lakes that are sensitive to degradation (Dominie *et al.*, 1991).

The Belgrade Lakes in central Maine are important local ecological and recreational resources. The Belgrade chain includes the following lakes: East Pond, North Pond, Great Pond, Long Pond, Salmon Lake and Messalonskee Lake. These lakes are all interconnected with the system draining into the Kennebec River through the Messalonskee Stream (Garrity and Putnam, 1971). East Pond is the first lake in the lake chain and plays a pivotal role in influencing subsequent lakes. Therefore, the water quality of this lake is important not only to East Pond residents but to the residents of the entire lakes region.

East Pond is a shallow and typically unstratified body of water. The annual flushing rate is estimated at 0.24 flushes/year which is considered to be slow (DEP, 1990). The Serpentine Stream is the outlet for East Pond which flows into North Pond. The water quality of the lake has been classified as being stable with a moderate nutrient level (DEP, 1990). However, in 1987, an algal bloom occurred in East Pond possibly due to a large increase in phosphorus loading from external sources. One possible explanation was that the Serpentine stream backflushed through the marsh carrying nutrients into East Pond (DEP, 1990). Because of this event and its pivotal role in the lake chain, the Maine Department of Environmental Protection (DEP) and the East Pond Lake Association (EPLA) have become concerned with the water management of the pond.

The focus of our study was to assess the water quality of East Pond and to investigate factors affecting that quality. The study was broken down into three main areas: East Pond, tributaries and wetlands, and East Pond and Serpentine watersheds.

For the East Pond study, the lake itself was sampled and comparisons were made with data from the DEP and Lake Association from previous years to determine any trends or changes in patterns. Comparisons were also made to similar lakes in the state. The Serpentine tributary and wetland investigation focused on the Serpentine, the outlet stream of East Pond, in order to assess its influence on lake water quality. Surrounding wetland was also studied to determine its role in ability to absorb or contribute nutrients to East Pond. Tributaries directly entering East Pond were also examined. The third aspect of our study examined various patterns of land use within the East Pond and Serpentine watersheds in order to assess the extent of human influences and their effects on East Pond water quality.

Through our investigation, we hope to provide information to better understand the dynamics of the East Pond and Serpentine watersheds, and their influence on East Pond. Recommendations, based on evidence gathered during our study, will be proposed to help mitigate potential problems of eutrophication in East Pond.

Lake Characteristics

Definition of a Lake

Lakes, in simplest terms, are holes or depressions in the ground that are filled with water (Wessells, 1988). Most lakes have relatively self-contained ecosystems with obvious natural boundaries. Life in a lake is affected primarily by the unique physical and chemical properties of water, which influence much of what goes on in the lake ecosystem.

Status of Lakes

Lakes are characterized based on their physical, chemical, and biological makeup (Maitland, 1978). Physical traits include environmental, topological, and geological characteristics, all having a large influence on lake water quality. Chemicals dictate to a large degree the relative water quality of a lake. Lake biota often indicate the present condition of a lake. Although lake classification is largely arbitrary, it has proven extremely useful to limnologists through the years.

Among the most commonly used biological classification schemes for lakes was proposed by Thienemann in 1925 (Macan *et al.*, 1968). Three lake types: oligotrophic, eutrophic, and dystrophic are classified based on their trophic (troph=to nourish) state (Table 1). In general, oligotrophic lakes are deep, clear lakes, poor in nutrients and high in oxygen content throughout the water column. Eutrophic lakes are shallower, more turbid bodies, high in nutrients, with a low oxygen content at deeper stratifications.

Table 1. Generalized characters of eutrophic, oligotrophic, and dystrophic lakes (Maitland, 1978).

Character	Eutrophic	Oligotrophic	
Basin shape	Broad and shallow	Narrow and deep	Small and shallow
Lake substrate	Fine organic silt	Stones and inorganic silt	Peaty silt
Lake shoreline	Weedy	Stony	Stony or peaty
Water transparency	Low	High	Low
Water color	Yellow or green	Green or blue	Brown
Dissolved solids	High	Low	Low
Suspended solids	High	Low	Low
Oxygen	High at surface, low under ice or thermocline	High	High
Phytoplankton	Few species, high numbers	Many species, low numbers	Few species, low numbers
Macrophytes	Many species, abundant in shallow water	Few species, rarely abundant but found in deep water	Few species, some abundant in shallow water
Zooplankton	Few species, high numbers	Many species, low numbers	Few species, low numbers
Zoobenthos	Few species, high numbers	Many species, low numbers	Few species, low numbers
Fish	Many species	Few species	Very few species

Dystrophic lakes have variable depths and nutrient levels with a high humus base resulting in brown water which in "extreme examples resembles beer or even stout" (Macan *et al.*, 1968). Because it makes sweeping generalizations, this scheme is far from perfect.

An additional classification system has since been added to Thienemann's scheme: the mesotrophic lake (Maitland, 1978). Mesotrophic lakes are intermediate in character between oligotrophic and eutrophic lakes. For example, a mesotrophic lake may be broad and shallow yet be highly transparent with a stony, inorganic substrate. Many factors must be taken into account to effectively classify a water body.

East Pond is classified by the Lake Body group in our study as a mesotrophic lake. It demonstrates both oligotrophic and mesotrophic properties. It has the relatively shallow and broad basin shape characteristic of eutrophic lakes. However, it is highly transparent with clear water and few suspended or dissolved solids, traits generally seen in oligotrophic lakes. In spite of its physical shape, it has many oligotrophic properties. This balance leads us to classify it as mesotrophic. Again, three factors must be reemphasized: the classification scheme is highly subjective, makes far-reaching assumptions, and must take into account a multiplicity of factors to be useful.

The characteristics of a typical lake vary between seasons. In the summer, a lake is stratified into three levels, the epilimnion, thermocline, and hypolimnion (Figure 1; Brewer, 1988). This stratification is caused by the physical properties of water. Water is most dense at 4° C and as the temperature rises above or below this level, water becomes less dense. As a result of these unique properties, differences in temperature will cause seasonal stratification to occur in lake bodies.

The upper level, or epilimnion, is in direct contact with the atmosphere and therefore is affected most by changes in temperature and also by winds. Beneath the epilimnion is the thermocline which is seldom mixed by winds and shows the greatest variability in temperature, acting as an intermediary between the upper and lower stratification levels. The lowest stratification level is the hypolimnion which is not circulated by winds and receives little sunlight. Much of the nutrients of the lake are restricted to this stratification layer throughout the summer, because the variations in density prevent mixing within the water column. Therefore, when nutrients are used up at the surface, they cannot be replenished until an overturn (a mixing of the water column) takes place. Further, the oxygen level in the hypolimnion gradually decreases over the course of the summer as it is consumed by organisms and is not replenished until overturn occurs.

The three level stratification scheme is disrupted in the early spring as well as the late fall as the whole lake circulates (Figure 1). Overturn occurs when the entire lake body equilibrates

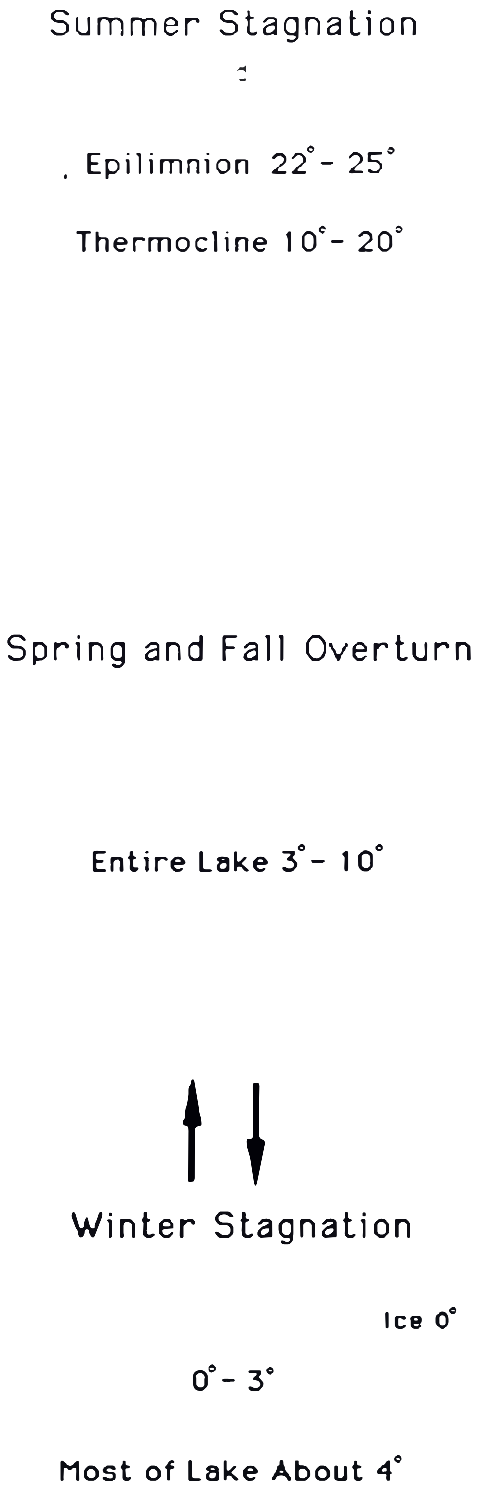


Figure 1: Seasonal cycle of a typical stratified lake.

at about 4° C. At this uniform temperature and density, wind blowing over the surface will mix the water of the lake and combine the previously distinct stratification levels. The important outcome of this mixing are that the hypolimnion becomes reoxygenated and nutrients that were previously trapped in this level due to temperature and density stratification become integrated into the entire water column.

In the fall, overturn occurs as the temperature of the epilimnion and the thermocline drops and the entire lake body equilibrates at a common temperature. Similarly, after the ice melts in the spring, the water on the surface begins to warm up. Once a temperature equilibrium is reached, wind contributes to the overturn of the lake.

When the nutrients are well mixed in the water column as a result of spring turnover, algal blooms can occur. When an algal bloom takes place, algae that live on the surface of the lake eventually die and fall to the bottom. Dead algae provide an increased food supply for microorganisms that are present in lake sediments. With increased nutrients, microorganisms will grow, consuming higher levels of oxygen through anaerobic respiration. The dissolved oxygen levels at the bottom decrease with the increased metabolic activity of the microorganisms and fish may n the extreme case, large scale fish kills may occur as a result of this process.

In the winter, like the summer, the lake is stagnant, with a layer of ice preventing any mixing of nutrients from taking place (Figure 1). The temperature of the water is fairly uniform, with colder, less dense water immediately under the layer of ice. Warmer, more dense water (at 4° C) comprises the remainder of the water column. Oxygen levels tend to decline over the winter months as the oxygen that is used in respiration is greater than oxygen gained in the water column from photosynthesis. This can become a problem when a thick layer of snow covers the ice and sunlight levels are reduced significantly. With decreased light levels, photosynthetic activity is reduced which results in lowered oxygen production.

of East Pond

The buffering capability of East Pond was of interest as we examined issues of water quality. The ability of lake water to neutralize acid and thus resist a change in pH is determined by its buffering capacity; which is a function of the water's pH and alkalinity.

pH is a measure of the free hydrogen ion concentration of water and reflects the level of acidity within a lake. The pH of a lake is important in determining the animal and plant species living there because organisms have different pH tolerance levels (Pearsall, 1971). An increase in acidity (decreased pH level) primarily affects organisms that are in the first developmental stages of life. Acidic environments decrease egg viability and softens the shells of snails and crustaceans. The effects of low pH on some aquatic life are shown in Table 2.

Table 2. Effects of pH levels on aquatic life[1]

	Biotic
6.0	Death of snails and crustaceans
5.5	Death of salmon and whitefish
5.0	Death of perch and pike
4.5	Death of eel and brook trout

[1] Bunce, 1990

In Maine the pH values for lake water typically range from 6.1 to 6.8, as shown in Figure 2. The average pH value for East Pond has been 6.8 over the past 16 years.

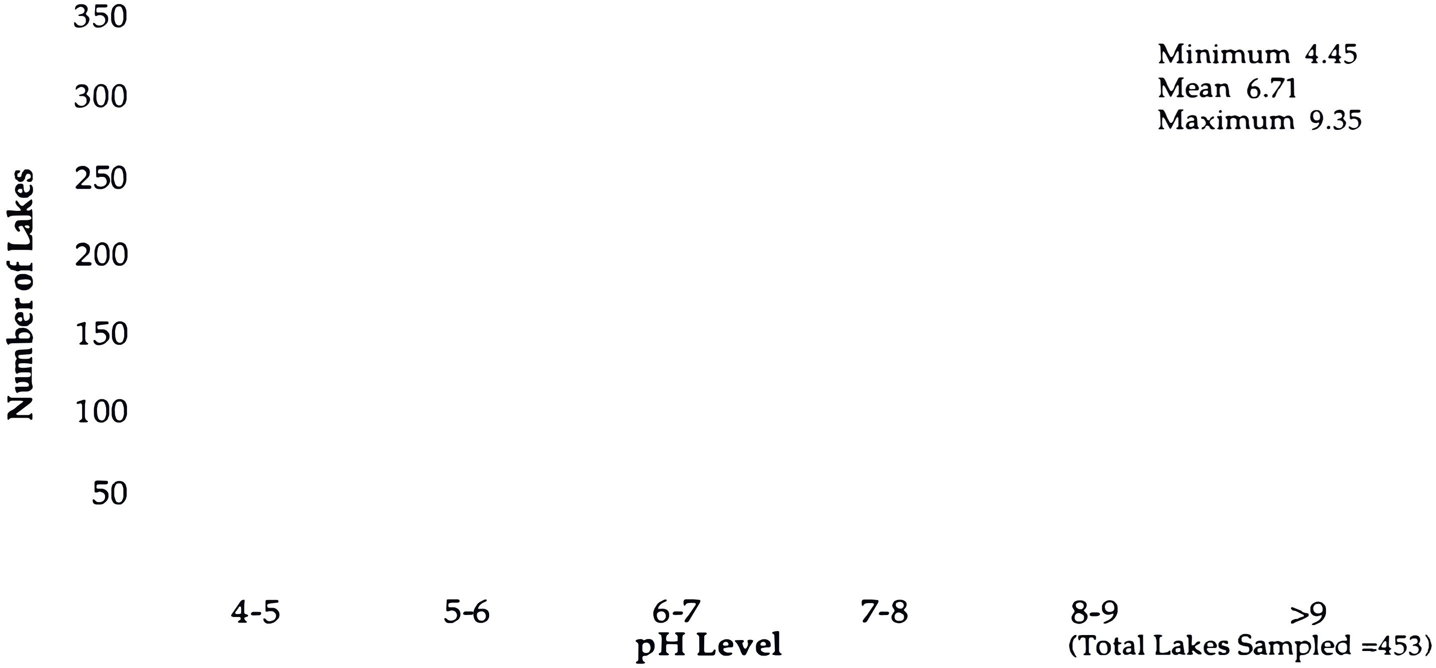


Figure 2. Distribution of pH in Maine Lakes as reported by the DEP.

The alkalinity test reflects the ability of lake water to buffer pH changes, and it is a measure of the calcium carbonate in the water. As a pH buffer and inorganic carbon reservoir, alkalinity also helps in determining the ability of the water to support algal growth and other aquatic life. Alkalinity generally ranges from 4-20 ppm $CaCO_3$ in Maine lakes (Figure 3). A lake with low alkalinity (<4ppm) will be more susceptible to the adverse effects of acid rain than lakes with higher alkalinity (>10ppm) (Pearsall, 1971). The alkalinity levels of the Belgrade chain of lakes are consistent with this high/low range. The alkalinity of East Pond falls in the center of the range with a level of 7.5 ppm $CaCO_3$.

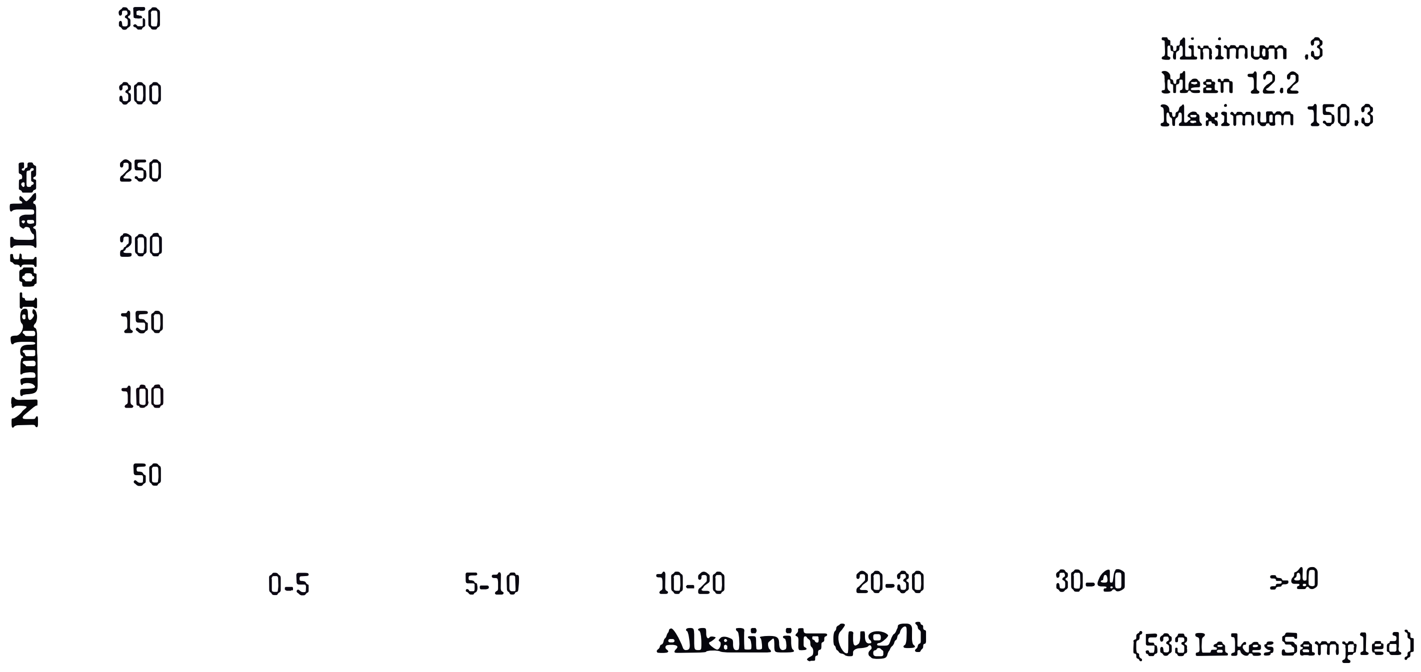


Figure 3. Distribution of Alkalinity in Maine Lakes as reported by the DEP.

A recent study on Maine lakes shows that the overall alkalinities are increasing by +1.6 µeq liter^{-1}/year^{-1} (Stauffer, 1990). The study notes that since the end of World War II, there has been a change in the atmospheric deposition of acidifying anions from SO_4^{3-} to NO_3^-. The switch from coal to oil usage, along with Clean Air legislation, has generated a decrease in SO_4 by -1.7 µeq liter^{-1}/year^{-1}. Sulfates have been a primary contributor to acid rain in Maine. According to Stauffer, the decrease in sulfate levels has resulted in a lower need for buffering in Maine lakes. Because pH and alkalinity levels are complementary, a decrease in the acid level of precipitation allows alkalinity levels to increase.

Two important features that influence pH and alkalinity, and thus the lakes buffering capacity, are geology and hydrology.

Geology: Bedrock chemistry has a great influence on water quality because it is the primary determinant of the pH, alkalinity, and nutrient load capability of a lake's watershed (Davis *et al.*, 1978). Lake acidification is a problem in regions where the bedrock provides a poor buffering capacity. The granite that underlies most of the northeast offers little protection in terms of buffering because granite does not react with the hydrogen ions found in acidic water.

Therefore, neutralization of the acidic rainwater does not take place and the pH level in the lake decreases. Those lakes with bedrock of limestone and chalk have better buffering capabilities because these bedrock types are able to react with the hydrogen ions and neutralize the acidic water (Bunce, 1990). The pH in these lakes is not changed significantly by the addition of acid rainwater. The East Pond watershed has bedrock that is primarily granite. However, the pH level of the rainfall has not been low enough so that the buffering ability of the bedrock was influenced (Pearsall, 1990).

Hydrology: The sources of water inflow and the flushing rate of the lake are also important in determining buffering capability. The groundwater from natural springs supply East Pond with hydrogen ions which may or may not add to the acidity of the surface water. Acid precipitation may especially influence the lake during spring runoff when the acid snow from the winter's accumulation melts into the lake. These influxes of highly acidic water into the lake during the early spring coincides with the time of reproduction for aquatic life (Bunce, 1990). The result may be decreased rates of hatching and viability of offspring; though there is no evidence of such on East Pond. Summer surface water runoff over the land also contributes to the nutrient load which may either change the pH level of the water in the lake or influence buffering activity. The flushing rate of East Pond (0.24 flushes/yr) is important in controlling the residence time of chemicals that pass through the watershed. Typically, a moderate flushing rate will dilute the acid rainwater and decrease the possibility of lowering the pH and acidifying the lake.

Acid precipitation does not appear to be a major problem in Maine. There are at present approximately 100 acidic lakes in Maine (1.7% of the total), with over half of them beingacidic due to naturally occurring organic acids (Pearsall, 1990). No lakes under 2,000 ft in elevation have been found to be acidic entirely due to acid rain, and even the low pH of the most sensitive mountain lakes has only been partially linked to acid precipitation (Pearsall, 1990).

Based on the average ranges for pH and alkalinity in Maine, it was estimated that the buffering capacity of East Pond was moderate. The figures for East Pond's pH and alkalinity are similar to other Belgrade lakes. The values for the Belgrade region were within the median values for the State.

The actual buffering capacity of East Pond, calculated as a function of pH and alkalinity, was determined to be $9.1 \times 10^{-5} \Delta \mathrm{Ca} / \Delta \mathrm{pH}$ (King, 1991). The figure shows the amount of acid needed on the vertical axis to cause a 0.2 change in pH, given variable pH levels on the horizontal axis. Therefore, given a constant alkalinity level of 7.5 ppm $CaCO_3$, lakes with pH levels between 7 and 9 need relatively low amounts of acid to change the pH of the water.

Despite the fact that there are data which indicate acid precipitation is not a great threat in Maine and alkalinity levels may be increasing, there is still a need for concern (Figure 4). Depending on certain conditions, buffering capacities may be quickly exhausted. Monitoring pH and alkalinity levels is important in order to avoid disastrous situations similar to the acid lakes of the Adirondack mountain region.

Eutrophication is the nutrient enrichment of a body of water which leads to excessive

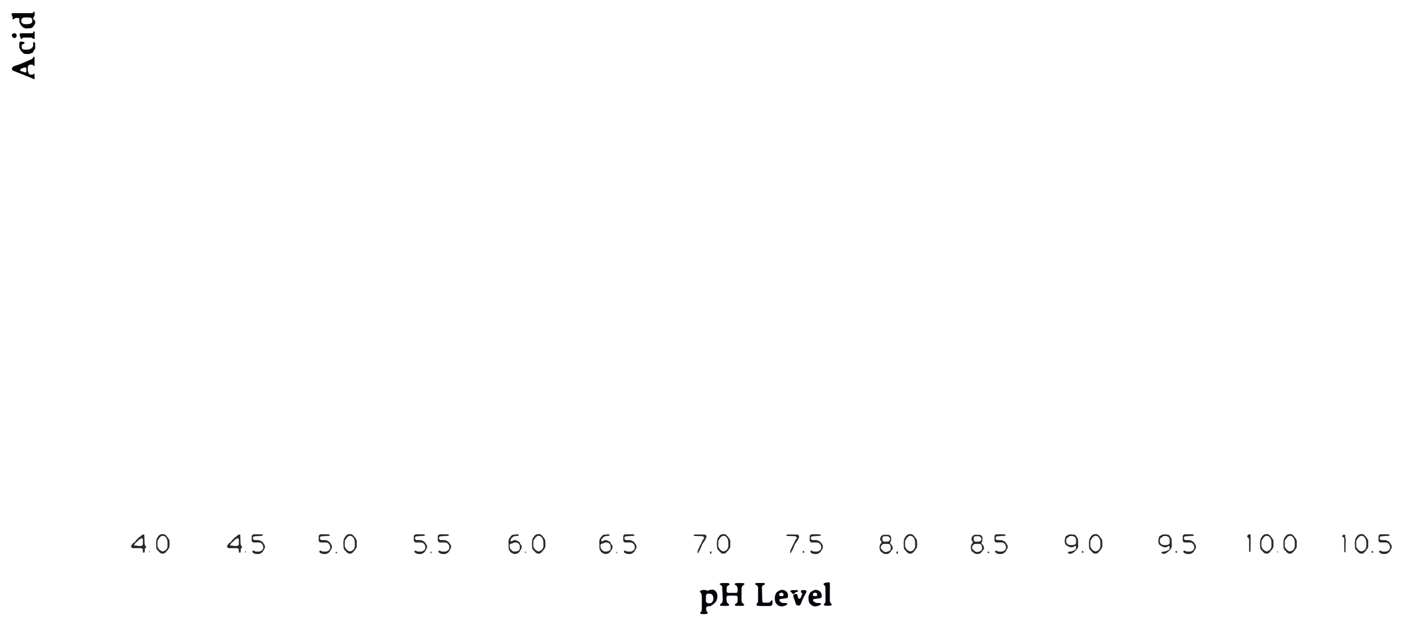


Figure 4. The buffering capacity of East Pond given an alkalinity of 7.5 ppm CaCO3. The line shows the amount of acid needed on the vertical axis to cause a 0.2 change in pH, given variable pH levels on the horizontal axis.

growth of algae. Algal growth results in a depletion of dissolved oxygen as dead algae are decomposed (Nebel, 1990). As a natural aging process, lake eutrophication occurs when the sediment and decaying matter accumulate which eventually fills the lake basin until it becomes dry land. This occurrence not only affects the physical make-up of the lake, but the ecological and biological composition (see lake characterization). Shallow bodies of standing water are especially susceptible to this gradual process of degradation because of the small volume of water and slow flushing rate. This process occurs naturally over thousands of years, however human activities can increase nutrient loading which compromises lake water quality through cultural eutrophication (Tietjen, 1987).

Nitrogen, and phosphorus in particular are the main nutrients limiting primary production. In contrast to phosphorus, nitrogen is usually readily available in a lake ecosystem. Thus, increasing levels of phosphorus lead to greater algal productivity and eventually lake eutrophication (Planning Board of the Town of Smithfield, 1990).

Land use patterns within the watershed of a lake are the main factors determining the entry of nutrients to the lake body. Because nearly 90 percent of the land area in Maine is wooded, the dominant land use in Maine's lake watersheds is forest. Relatively little phosphorus is carried from forested land to a lake because the volume of water run-off is low

(Dennis, 1987) . The leaves of the forested land serve as a canopy to catch precipitation which then evaporates. The irregular forest floor diverts and slows the velocity of run-off. The undisturbed land in a forest then tends to filter, trap, and store phosphorus rather than release it into the lake body. For most lakes in Maine the nonforested land is made up of shoreline cottages, roadside development, and agriculture. The watersheds are usually so sparsely developed that the trophic state of most Maine lake's tends to be quite low when compared to national figures (Dennis, 1986).

Recently, cultural eutrophication of Maine lakes has caused great concern. East pond is a typical Maine lake in that it has a high percentage of forested land within the watershed; but it also has seasonal homes and camps, roadside development, and a small amount of agriculture. All development in the watershed (residential, recreational, and agricultural) contributes to lake degradation through the process of cultural eutrophication. In a residential area much of the ground surface that was once permeable to water becomes impermeable because it is covered with buildings, roads, and driveways. The land is also flattened by sloping lawns and ga dens which accelerates surface run-off entering the lake body. Industrial and domestic effluent (especially treated wastewater and leached agricultural fertilizer) and animal waste represent the most significant nutrient point sources. Agriculture is responsible for increasing levels of both phosphorus and nitrogen. There may be five to ten times as much phosphorus resulting from run-off in developed areas than in natural forested regions (Dennis, 1987).

Phosphorus found in the sediments and water column of a lake interact in a natural cycle which maintains the water quality of a lake ecosystem (Figure 5) . Phosphorus in a lake exists in a biologically unavailable organic form and a transitory, available inorganic form. The sum of the two forms of phosphorus is termed the total phosphorus concentration. Phosphorus is recycled from the sediment back into the water column where it is available for ogranismal metabolism. Phosphorus returns to the sediment when organisms decompose. The cycle is fed by concentrations of phosphorus from precipitation, springs, groundwater seepage, human or industrial impact, and streams. Outlet streams carry phosphorus out of the lake ecosystem.

The sediment of a lake body contains organic phosphorus in decaying plant material, as well as inorganic phosphorus, both of which serve as lake nutrient stores. Organic phosphorus is converted to inorganic phosphorus by the decomposition process of the bacteria in the sediments. Under aerobic conditions, a layer of iron, chemically complexes the phosphorus and their subsequent decomposition as ferric oxyhydroxides in the sediment which inhibits the mobility phosphorus into the water column.

Algal blooms cause the sediment environment to become anaerobic. When dissolved oxygen levels drop below 1 ppm, the iron is reduced from a ferric to a ferrous form which

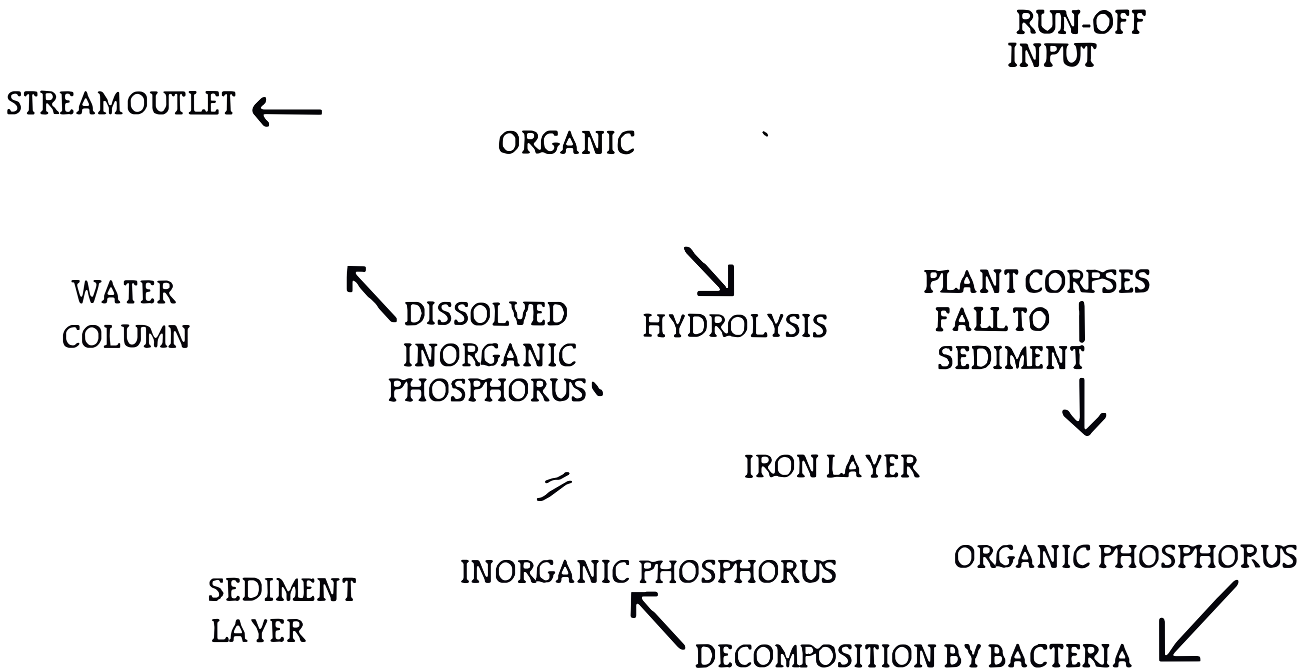


Figure 5. The total phosphorus cycle in a lake ecosystem: phosphorus inputs, internal recycling of phosphorus between the sediments and the water column, and phosphorus outputs.

chemically releases the bound phosphorus; this internal cycling of phosphorus stimulates further algal growth. During aerobic conditions small amounts of phosphorus not bound to the iron are released to maintain the balance in the lake body between phosphorus in the soluble phase and phosphorus in the solid phase.

A lake will store phosphorus naturally in its sediments and balance the phosphorus levels between the sediment and the water column by internal recycling. Phosphorus in the water column exists as dissolved inorganic orthophosphates (DIP) and also as organic particulate phosphates (PP). Orthophosphates are a transitional form and are quickly metabolized by plants. Particulate phosphates must be hydrolyzed or transformed before they become available to plants.

This delicate balance of phosphorus recycling in a lake ecosystem can readily be disrupted. Additional contributions of phosphorus by human activity can overload natural phosphorus cycling in a lake body. This can result in serious algal blooms.

Stream characteristics

Streams are examples of lotic (flowing water) ecosystems and are important links between terrestrial and aquatic environments (Smith, 1990). Water falls throughout the watershed and flows down-slope toward lakes and oceans. As it travels across the surface area of the watershed, organic and inorganic particles become suspended in the water. Topographical irregularities in the terrain concentrate the water flow into stream channels (Purdom and Anderson, 1980). The streams act as transport systems which carry water, organic materials, and nutrients to lakes and oceans.

Streams serve not only as transport systems, but also as processing systems for organic material from adjacent terrestrial ecosystems (Smith, 1990). Since the primary trophic function of the stream is heterotrophic (decomposing), organisms living in the stream ecosystem depend largely upon the external sources of energy and nutrients. Large particulate organic materials (LPOM) such as litterfall and blown litter become incorporated into surface water flow (Figure 6.; Smith, 1990). Organic materials (LPOM) can be reduced in size and ingested by shredders and predators, which transport them (within their biomass or through defecation) to the downstream ecosystem. An alternative includes the leaching of the LPOM into dissolved organic material (DOM). DOM can be ingested by microbes and consuming organisms such as shredders, collectors, and grazers. The DOM may be transported downstream (via organismal biomass or defecation) or it can undergo physical flocculation, a process in which most of the organic material is precipitated out of solution. This coagulates the DOM into fine particulate organic matter (FPOM), which again becomes available to the downstream ecosystem (Smith, 1990). As organic material is ingested by shredders, microbes, grazers, collectors, and predators, energy and nutrients are transferred along major food chains

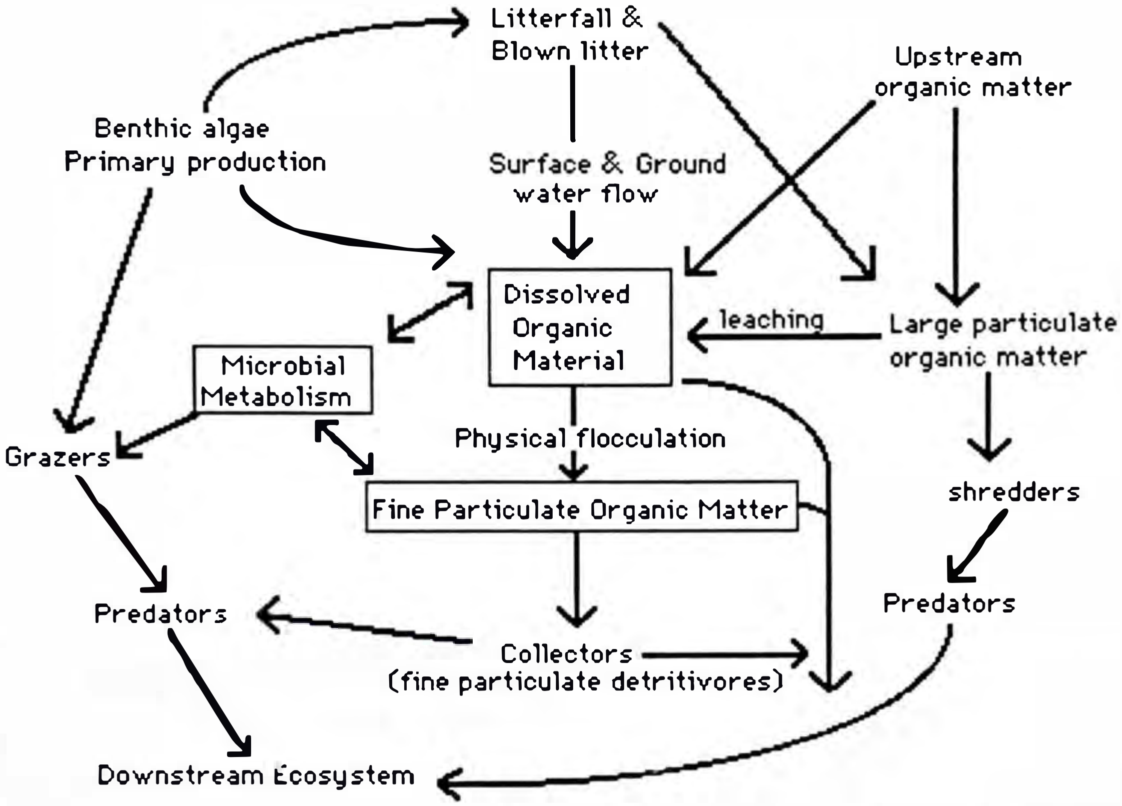


Figure 6. Energy Flow and Nutrient Cycling of a Lotic Ecosystem. Illustrates the relationship between terrestrial and lotic ecosystems, and emphasizes the energy flow and the nutrient cycling throught the heterotropic (decomposing) chain. (Adapted from Smith, 1990).

(grazing and detritus) and between trophic levels (ie. decomposer, herbivore, carnivore), eventually reaching the downstream ecosystems (Smith, 1990).

The character of a stream is determined by a number of variables such as soil type, vegetation, substrate, morphology, and climate, including rainfall and temperature (Moriswa and Vemuri, 1975). The primary factor which influences the stream character, however, is velocity. The velocity of a stream changes from mouth to outlet, forming a gradient of abiotic and biotic factors (Figure 7.; Smith, 1990). Organisms along this ecological continuum face changing environmental conditions (ie. current, oxygen concentration, and temperature) and possess different adaptations which may increase survivorship.

Organisms living in rapidly flowing water have specific adaptations for stabilizing themselves against a swiftly moving current (Smith, 1990). Examples of these adaptations include stream-lined bodies, hooks and suckers for attachment to the substrate, and the ability to walk along the surface of the substrate. Because most primary producers, especially rooted plants, are unable to survive in a swift current, low rates of productivity are typical of rapid water ecosystems.

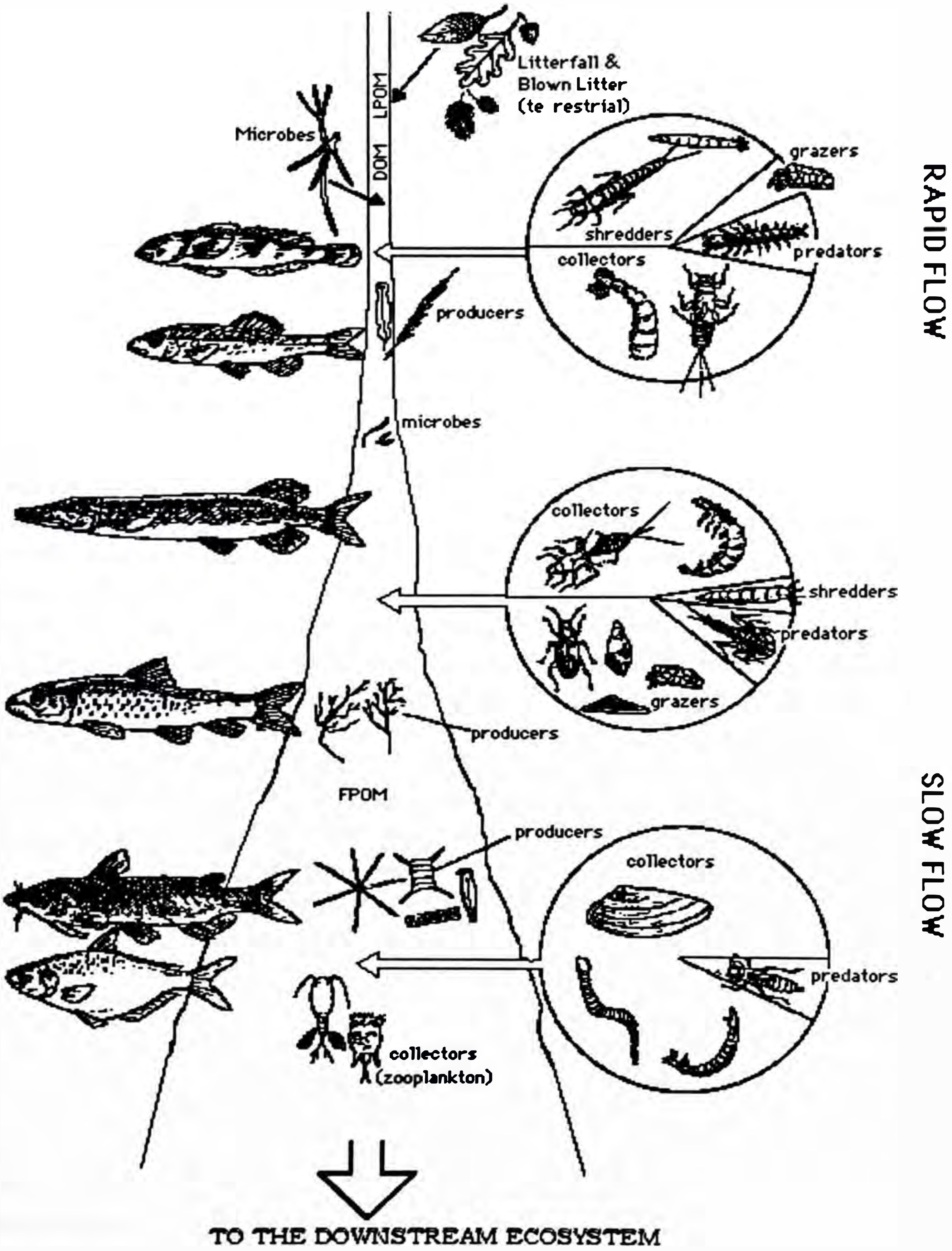


Figure 7. Ecological continuum of a lotic ecosystem. Indicates morphological changes in organisms from an area of rapid flow to an area of slow flow. (Adapted from Smith, 1990.)

Organisms living in slow flowing areas resemble those found in lentic (still water) environments (Smith, 1990). This area is characterized by higher primary productivity. A weaker current, warmer temperature, and sediment and organic material buildup, indirectly diminish the diversity morphological adaptations which help to resist the current. The new environmental limiting factor becomes oxygen, since it is being actively utilized by the detritus food chain. Thus, these organisms will develop adaptations which will allow them to utilize oxygen more efficiently.

A thorough understanding of the stream's heterotrophic (consuming) functions and an accurate conception of the stream's ecological community is crucial to the struggle to understand the human influence on lotic ecosystems and its implications for their protection.

Nutrient Loading as a Function of Streams

Tributaries are an important source of nutrient loading to lakes. The degree to which nutrient loading affects the lake depends on specific land use within the watershed and the proximity of streams to these uses. Disturbed land contributes a greater amount of nutrients because of an increase in runoff and a decrease in infiltration due to such activities as urban and rural development, agriculture and silviculture.

Limiting nutrients such as phosphorus and nitrogen are the biggest threat to lake water quality. Nitrates are usually more readily available within the lake ecosystem than phosphates. Therefore, phosphorus is typically the primary limiting nutrient and increases in phosphorus lead to increases in primary productivity. These nutrients are normally found in soil and in undisturbed land and are taken up by plants for growth. However, in disturbed land, these nutrients are transported attached to eroding soil particles and deposited in lotic ecosystems. Phosphorus, bound to fine soil particles (silt) which are suspended in the sediment load, is transported downstream. Silt may remain suspended for a long period of time in both flowing and still water. Although streams do remove some phosphorus through biological uptake and sediment deposition, most eventually reaches the lake (Shroeder, 1979).

Form and availability of nutrients as they are delivered to the lake is another important consideration. Phosphorus is termed available or nonavailable depending on its form. Available phosphorus includes dissolved organic phosphorus (DIP), also called orthophosphorus, and any other forms that can supply DIP and support plant or algal growth. Total phosphorus includes all forms of phosphorus: dissolved and particulate, available or not. Most phosphorus is transported by the stream in its particulate form, remaining unavailable to the stream ecosystem (Shroeder, 1979).

Erosion and sedimentation are the principle mechanisms for nutrient transport. Erosion occurs when bare ground is exposed to wind or water and soil particles become detached and later may be deposited in a lake or tributary. Disturbed lands with exposed ground and little vegetation are more vulnerable to erosion. The effects of erosion are amplified by a storm.

Storms increase water flow within the watershed and water that is not absorbed by soil infiltration is termed runoff. As runoff progresses through the watershed, it collects sediments and is channeled into streams. Undisturbed lands with forest areas have increased infiltration capacity and permeability of the surface. They decrease both the volume of water entering streams and the amount of phosphorus contained within this flow. A comparison of total phosphorus export from adjacent watersheds in Maine was conducted in 1983 during storm conditions (Figure 8; Dennis, 1986). Total phosphorus and stream discharge were monitored in a residential area as well as a forested area near Augusta, Maine. Runoff, phosphorus concentration, and phosphorus export were reported to be consistently higher in the residential area.

Development along borders of lotic waterways greatly affects the lotic ecosystem. Land use practices along stream watersheds may accelerate erosion and initiate rapid sedimentation, nutrient loading (of phosphorus and nitrogen) and eutrophication in downstream ecosystems (lakes and ponds). Certain land use practices may have a direct result on the downstream ecosystem (Figure 9).

Wetland Characteristics

Wetland types

Freshwater wetlands are transitional areas between terrestrial and aquatic ecosystems. General features include: 1) a water table near, at, or above the level of the land, 2) soil that is periodically or perpetually saturated, 3) non-soil substrates such as peat and 4) hydrophyte vegetation which is adapted for life in saturated and anaerobic soils (Chiras, 1991). Although there are many different wetland types, four main categories of freshwater wetlands are common in Maine.

Bogs are considered to be the most common freshwater wetland in Maine (Zorach, 1979). These wetlands are composed of deep peat deposits with a high water table. Classified as ombotrophic because there is no inflow or outflow of water, bogs receive nutrients, water, and other minerals exclusively by precipitation. Because of this characteristic, they contain nutrient poor water and generally are acidic due to the large amount of organic decomposition. Vegetation is dominated by *Sphagnum* moss, sedges and black spruce, Ericaceous shrubs which are heath loving, and carnivorous plants like the pitcher plant and sundew (Mitsch and Gosselink, 1986).

Fens are peatlands which generally have a high groundwater level. They are minerotrophic because they are open systems and are fed mainly by water which has passed through mineral soil, in addition to precipitation (Sorenson, 1986). These wetlands are nutrient rich and generally have neutral to slightly acidic conditions. Vegetation is dominated by liverwort, Sphagnum moss, sedges, bladderwort and cattail.

Marsh wetlands are characterized by variable water levels and receive drainage

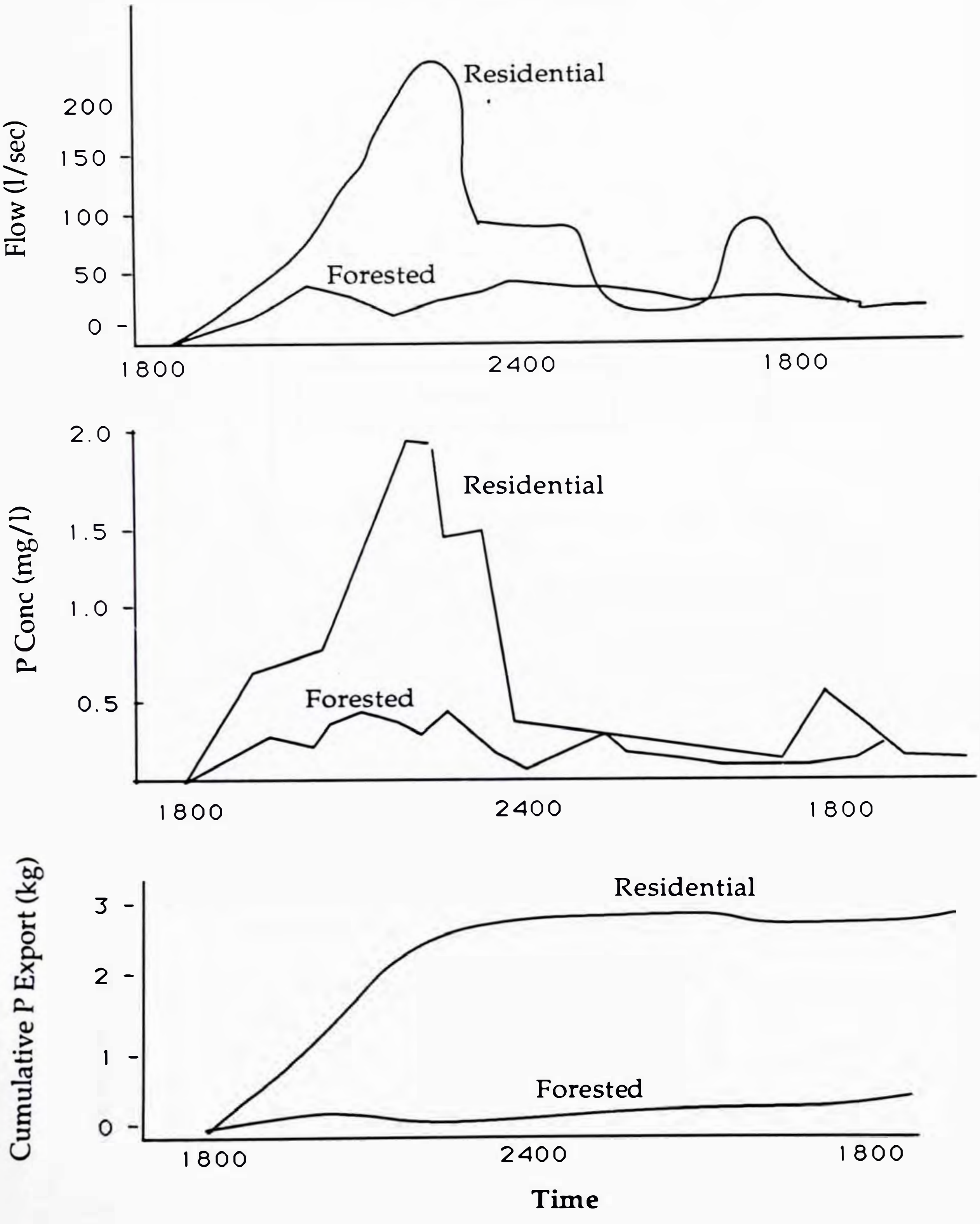


Figure 8. Comparisons of run-off after an April rain storm in two neighboring watersheds near Augusta, Maine. Top: volume of immediate run-off over a 12 hour period; Middle: phosphorus concentration in the run-off; Bottom: total amount of phosphorus exported into local streams and lakes from the storm. (From Dennis, 1986).

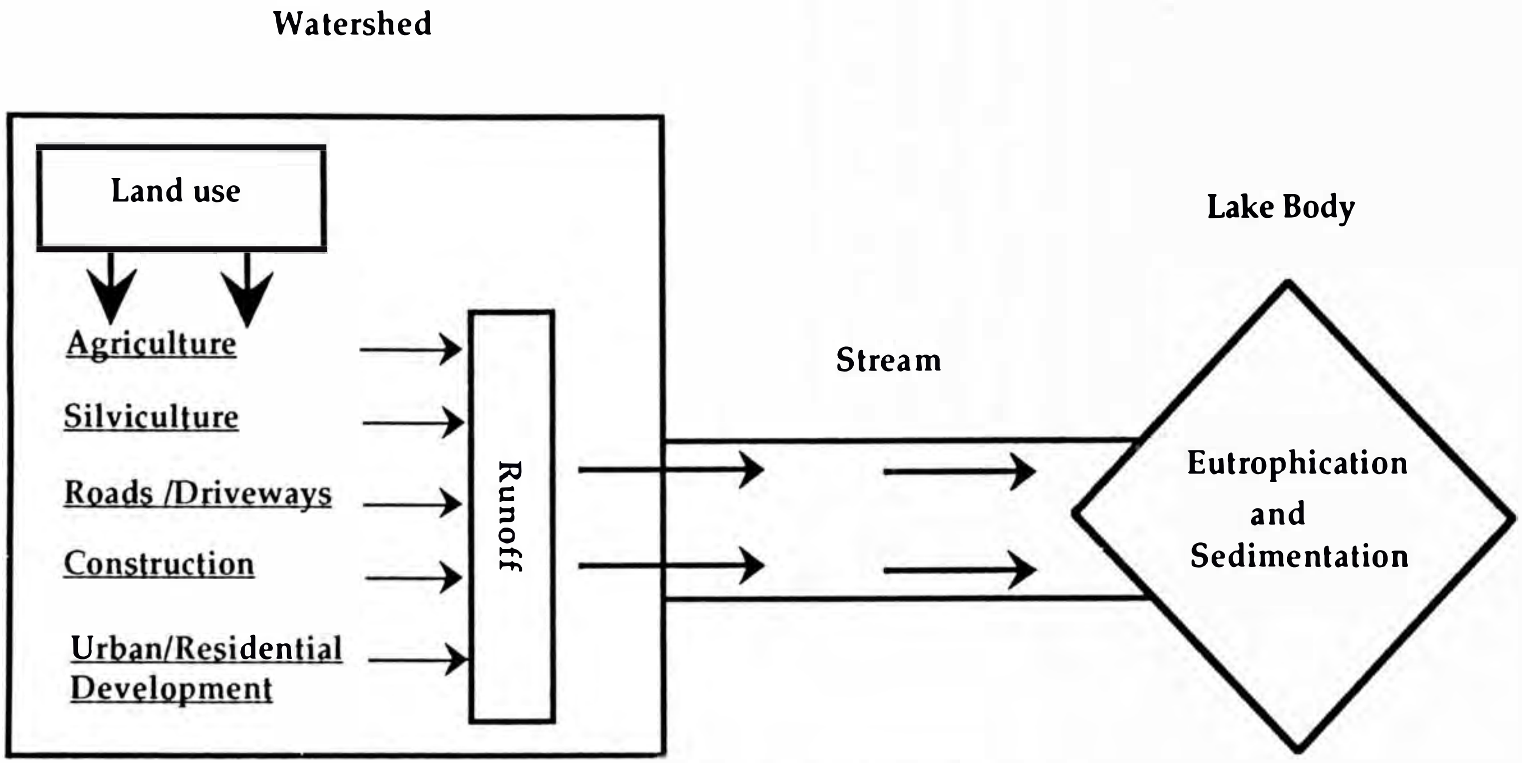


Figure 9. Nutrient and sediment flow model indicating the interrelationships among watershed land use, stream flow, and lake water quality.

primarily from groundwater movement. They are characterized by generally shallow peat deposits and tend to be nutrient rich. Marsh vegetation includes emergent soft-stemmed vegetation such as sedges, pickerel-weed, cattails, arrowheads and buttonbush.

Swamps are a fourth freshwater wetland type in Maine. They are classified as either woody swamps or shrub swamps (Zorach, 1979). Shrub swamps generally have water levels that remain constant over seasons and woody swamps are typified by soil that is waterlogged or seasonally covered with one foot or more of water. There is no abundant peat present in either of these swamp types. Finally, wooded swamps are dominated by such vegetation as hemlock, tamarack, red maple, Eastern white cedar, birch and alders while shrub swamps are dominated by alder, willow, buttonbush and dogwoods.

Nutrient dynamics

Many wetlands influence the nutrient balance of the aquatic ecosystems they border by controlling the concentrations of certain nutrients leaving the wetland and entering a lake system (Mitsch, 1986). A wetland is considered a nutrient sink if the input of nutrients to the system exceeds the output Conversely, if outflow of nutrients exceeds inflow, the wetland is considered a nutrient source (Figure 10).

One wetland may be a sink for a particular nutrient, while another wetland, with different vegetation, might be a source for that nutrient. Willow and birch for example, store more nitrogen and phosphorus (% dry weight) than do sedge and leatherleaf (Mitsch, 1986). Additionally, because vegetation assimilates individual nutrients differently, a wetland may be a sink for one nutrient and a source for another. Sedge, birch, willow and leatherleaf, for instance, all tend to take up more nitrogen than phosphorus. The amounts of various nutrients which are stored or released by vegetation depends on the presence of the nutrient in its usable form. Nitrogen, for example can be utilized by plants when it exists as ammonium and nitrate, but not in the form of diatomic elemental nitrogen (Nebel, 1987).

The main source of nutrients into all wetland types is atmospheric precipitation (Mitsch, 1986). Bogs rely primarily on this precipitation, while other wetland types (marshes, swamps, and fens) receive additional nutrients from surface and ground water inflows, as well as river flooding. Output of nutrients from a wetland is facilitated mainly by surface water runoff, especially in times of flood, and by nutrient accumulation in sediments.

Phosphorus and nitrogen are the main nutrients involved in wetland nutrient cycling. Phosphorus (typically in the form of phosphate, $PO4^{3-}$) is important to consider both because it tends to be a limiting nutrient in aquatic ecosystems and because its behavior is representative of other elements found in wetlands. Much phosphorus enters aquatic ecosystems because of leaf decomposition in the fall and as an agricultural byproduct because of the use of phosphorus based fertilizers. Sediments are the major sink for phosphorus which is removed from the water. In addition, large amounts of phosphorus are flushed out of the wetland by

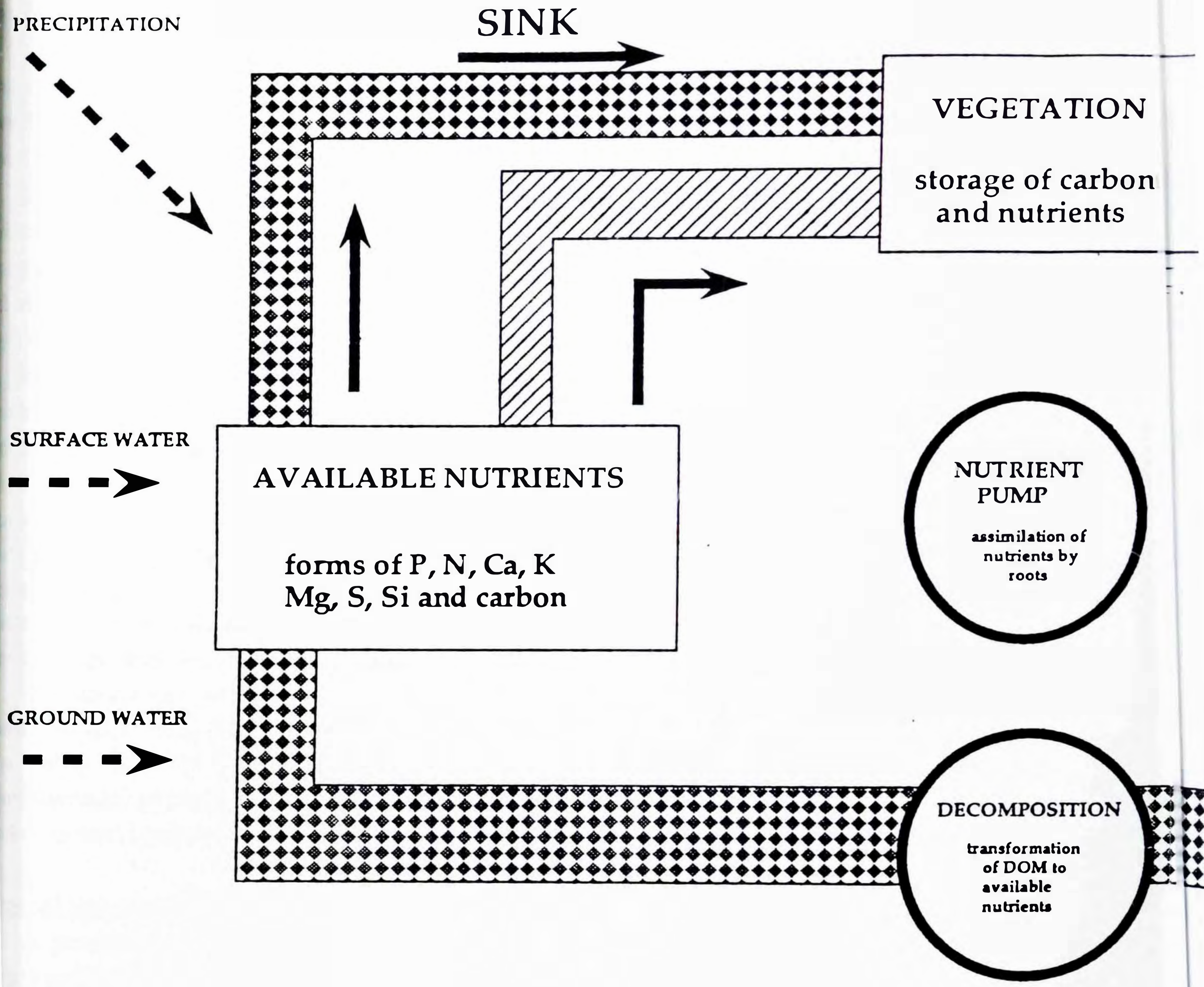
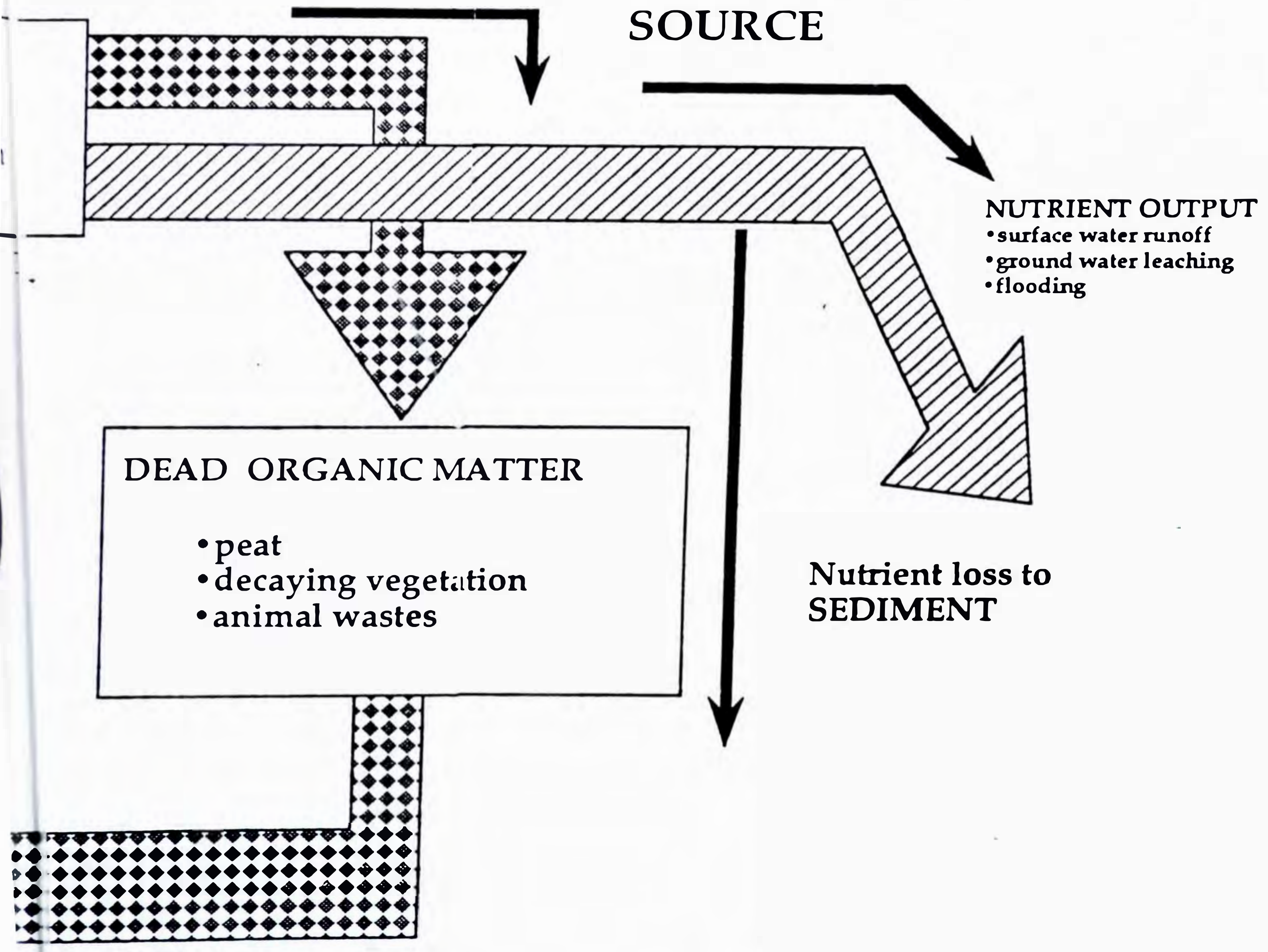


Figure 10. Diagram of the wetland nutrient balanc
view of the source/sink model as well as nutrient inp
wetland ecosystem.



including a schematic
us and outputs from a

significant volumes of spring runoff (Nebel, 1987).

Nitrogen (in the forms of NH_4^+ and NO_3^-) is also a key limiting nutrient with particularly complex cycling patterns. Ammonium ion (NH_4^+) tends to build up in wetland soils because the anaerobic environment favors the reduced ionic form over the nitrate (NO_3^-) form commonly found as a byproduct of agricultural inputs. Nitrate is also removed from the water in wetlands by denitrification processes which result in the formation of nitrogen in its gaseous state (N_2) and subsequent loss from the system (Lee, 1972).

Other significant nutrients found in wetland systems include ionic forms of sodium, calcium, potassium, magnesium which enter the wetland via surface water transport. Also important are sulfur (in the form of sulfate, SO_4^{3-}), concentrations of which are increased by acid rain. Silicon (SiO_2), a byproduct of geologic decomposition, is typically assimilated to a large extent by sediments (Nebel, 1987).

Nutrient balance in wetlands varies seasonally because of fluctuations in hydrologic inputs (Mitsch, 1986). Rainfall patterns, for example, affect the volume of water present in the system, thus changing nutrient concentrations. Rainfall also affects the growth of vegetation which further influences nutrient cycling because of the active role of vegetation in nutrient uptake, utilization and storage. A summertime peak in vegetative growth and nutrient pumping through roots results in increased uptake of nitrogen and phosphorus, therefore decreasing concentrations of these nutrients in both the water and sediments. As previously mentioned, wintertime anoxic conditions in the sediments release inorganic phosphorus and nitrogen, thereby increasing concentrations of these nutrients in the water (Fontaine, 1983).

Wetlands can increase the quality of the open water they border by influencing concentrations of nutrients, as well as filtering BOD, metals, oils, and toxins (Mitsch, 1986). This buffer between terrestrial and aquatic habitats may benefit the flora and fauna of lake ecosystems by providing protection from rapid fluctuations in nutrient levels and acting as a barrier to toxic substances.

Practical use of wetlands

A practical application of wetlands to enhance water quality is their employment to absorb pollutants from various sources, including municipal and industrial wastewater, and stormwater and agricultural runoff. In the treatment of wastewater, wetlands can receive water from either a primary treatment source (physical removal of solids and settling of suspended silt to decrease biological oxygen demand (BOD)) alone, or be complemented by a secondary treatment source (aeration and bacterial decomposition to increase efficiency of BOD removal), depending on the quality of water desired and volume being processed. Storm water and runoff can be directed immediately into the wetland for sediment filtration and nutrient removal. The growing interest in the applications of wetlands for nutrient removal is due to various factors: 1. demand for better cleansing; 2. rising cost of construction and operation of treatment facilities; 3. recognition of the capability of wetlands to act as nutrient sinks (Figure 11); and 4. the ability of wetlands to remove pollutants such as heavy metals and pesticides (Godfrey, 1985).

There are three basic characteristics of wetlands that make them attractive for water treatment: 1. they allow physical entrapment of pollutants through absorption onto surface soils and organic litter; 2. they facilitate nutrient uptake and metabolic utilization by plants; 3. and they increase utilization and transformation of pollutants by microorganisms (Godfrey, 1985).

Since wetlands have been shown to be effective in the absorption of pollutants, the interest in constructing artificial wetlands for water treatment has grown. A constructed wetland, located at the Brookhaven National Laboratory in New York, is a good illustration of the capabilities of a constructed wetland system. The efficiency of nutrient removal by this wetland included: suspended solids, 91.5%; biological oxygen demand, 88-92%; total nitrogen, 79%; total phosphorus, 77%; heavy metals, 23-94% (Godfrey, 1985). These figures clearly show the potential that wetlands have for increasing water quality.

Nutrient dynamics may differ among wetland types due to differences in vegetation composition. In addition, most wetlands are capable of some removal of pollutants. More research is needed to be able to determine the long-term detrimental effects of wastewater on wetlands, as well as their ability to function under different loading regimes.

Watershed Land Use

General Land Use Patterns and Trends

Land Use Types

Poor water quality, as discussed previously, is a function of phosphorus loading which may be increased by certain land use practices. Different land use practices disturb the soil in many ways causing varying degrees of erosion and run-off.

Forests and reverting fields are two land uses which offer potential systems for buffering against nutrient loading. Root systems deter erosion and run-off by holding soil in place and they also absorb nutrients before entering the lake. Forests or reverting fields are especially important in areas of severe slope within the watershed.

Agricultural and pasture land enhance nutrient loading with the mowing of fields and the addition of livestock. Fecal matter can enter East Pond either directly due to manure spreading for fertilizer, or indirectly resulting from run-off. The destruction of natural buffer strips coupled with the addition of fecal matter increases the amounts of nitrates and phosphorus in East Pond.

Residential areas may be characterized by year-round or seasonal homes. Year-round homes have the potential to cause greater damage to East Pond due to increased duration of use. However, some seasonal homes may have antiquated septic systems which treat waste

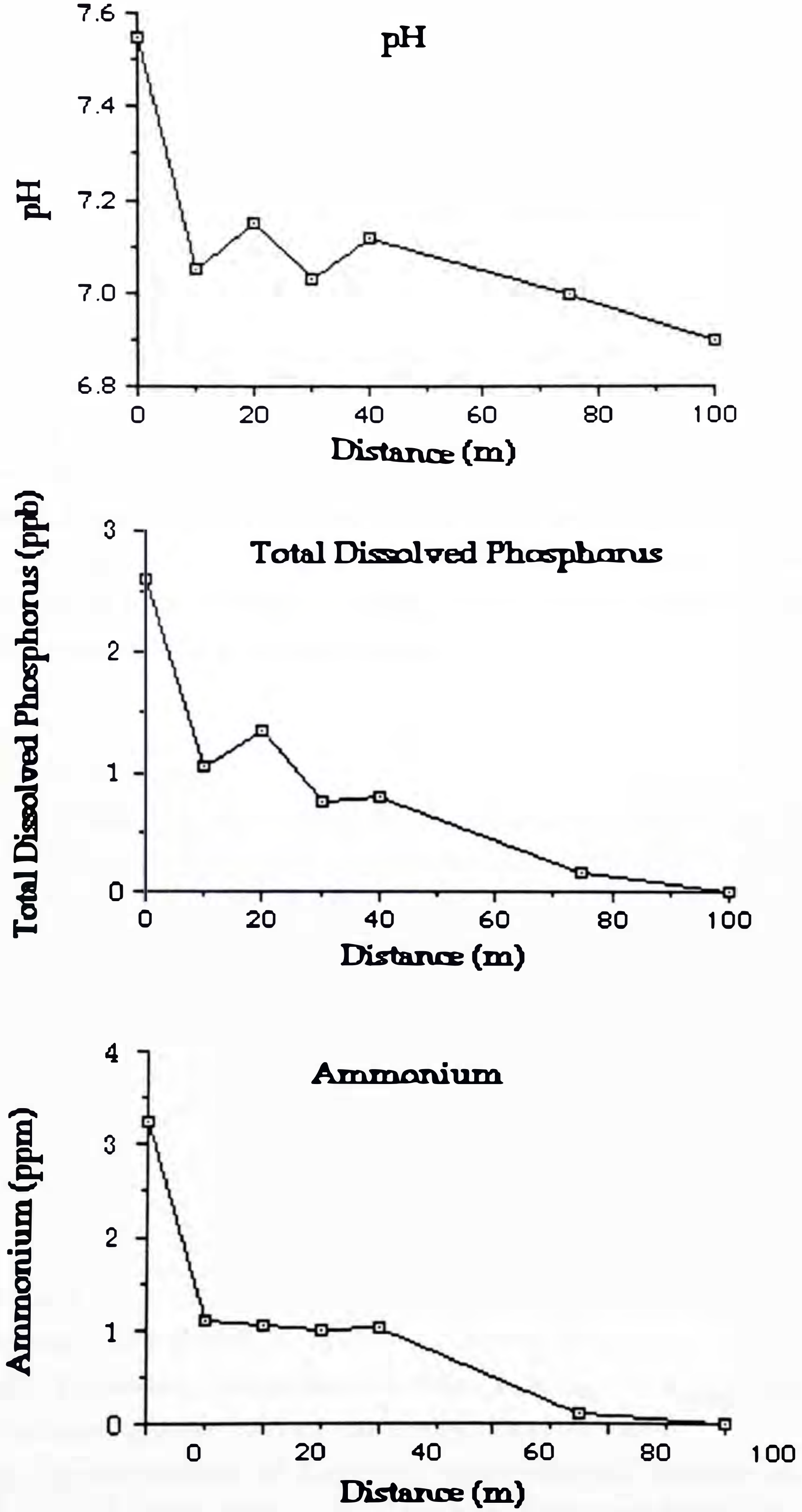


Figure 11. Removal of nutrients and pH buffering in a northern wetland (Mitsch, 1986).

improperly. Residential land uses often include fertilized lawns, sloping to the edge of a lake without any buffer strip. This is a serious problem in watershed preservation.

Commercial land use, such as forestry and gravel mining, propel the addition of nutrients even further with the destruction of natural buffers which increases the potential for nutrient loading.

The four types of roads in the two watersheds: state, municipal, private and fire roads, can potentially contribute to water quality destruction. Improper construction and maintenance techniques increase nutrient input caused by roads.

Recreational land uses are characterized most frequently by summer camps, boat ramps and public beaches. These uses increase human impact on the natural system causing the potential for water quality to deteriorate.

Land use practices, whether forest or reverting fields, agricultural, residential, commercial, roads, or recreational are important factors affecting East Pond water quality. The fragile balance between land use and water quality is dictated by the degree of erosion and run-off. Land use practices must be thoroughly investigated to determine the access of nutrients and to predict the future status of a lake ecosystem.

Nutrient Loading

Pathways of Nutrient Transport

Excess nutrients released by various land use practices entering a lake body have the potential to cause detrimental effects on water quality. Transportation of nutrients from the land, to a water body, occurs by three possible pathways: erosion, run-off, and leaching. Nitrogen and phosphorus, for example, two limiting nutrients for lake vegetation, are transported via these routes.

Erosion is the displacement of soil by activities such as construction practices and forestry. Soil is loosened, and as rain and surface drainage carry soil into a lake body, phosphorus and nitrogen bound to the sediment particles will dissolve into the water column. The resulting increase in nutrients may lead to eutrophication.

Run-off is the transportation of nutrients across the soil surface into a water body. Areas characterized by soils with low permeability, such as clays, do not allow surface waters to be absorbed. Water remains on the surface of the soil, where increased flows, such as heavy rains, transport phosphorus-laden soil into a lake body. The slope of the land directly influences the amount of run-off. Dissolved nutrients and those binding on to soil particles increase the nutrient level of the lake system as they are transported by run-off.

Leaching is the movement of nutrients from the soil surface to ground water or underwater flows. As nutrients contact soils with rapid permeability, they soak through too quickly to bind to sediment particles. As a result, phosphorus and nitrogen enter ground-water and flow into a lake body.

Nitrate Loading

In aquatic ecosystems, nitrates can lead to nutrient overloading and subsequent algal growth, as well as the possibility of disease. Nitrogen, often the most limiting nutrient in flooded soils can be absorbed by plants through root systems, decomposed by anaerobic microorganisms, or taken up by soil particles once the ammonium ion (NH_4^+) is formed (Mitsch, 1986). Nitrates, in the form of the ammonium ion, can then cause biota to flourish and promote the eutrophication process similar to the effects of phosphorus loading.

In drinking water, nitrate ions themselves are not toxic, but, nitrite ions (NO_2^-) are toxic. Once ingested, nitrite ions combine with hemoglobin to deprive the tissues of oxygen. This causes a disease, known as methemoglobinemia which leads to mental retardation, especially in young children.

The presence of nitrates in natural water systems is most commonly a result of agricultural land use (Bunce, 1990). High concentrations of nitrates exist because manure seepage occurs from feedlots, liquid manure holding tanks, and the excessive use of fertilizer on fields. The combination of low crop prices and high land prices encourages farmers to cultivate fields fully to their boundaries, thus promoting increased run-off from fields to waterways (Bunce, 1990). These practices often result in nitrate loading, causing eutrophication and the deterioration of lake water quality.

Total External Phosphorus Loading

Phosphorus loading to lake systems from external, non-point sources can be estimated using loading coefficients when direct measurement is not possible (Bouchard, 1991). The coefficients are based on land uses and patterns found in the watershed. In the East Pond study, these land patterns included wetlands, forests, reverted crop land, pastures, residential land, roads as well as precipitation and dry fallout. Because the phosphorous loading is not measured directly, but extrapolated using coefficients based on phosphorus inputs in other similar lakes, error bounds are established by assigning a range from low to high possibilities. By computing a value of kilograms phosphorus exported per year for each land use, it is possible to assess their relative impact on lake water quality (Dennis, 1989).

Soils Types

Soil type is of critical concern when assessing lake water quality. The degree of nutrient leaching and run-off is due to soil permeability. Soils were characterized by a range of permeabilities, from rapidly permeable to slowly permeable. The most beneficial soil permeability type for nutrient buffering was moderately permeable which prevents leaching and run-off from occurring.

Forestry

Forestry practices in a lake or tributary watershed can have detrimental effects on the water quality of the system. Forestry contributes to phosphorus loading primarily because of increased erosion. Heavy equipment such as skidders are used in harvesting practices to remove cut logs out of an area. Skidders may illegally use stream beds and tributaries as roads which increases erosion and sedimentation. The layout of a skidder or a tractor road can also cause increased erosion if located parallel and close to the shore of a lake or if perpendicular to the water's edge.

Agriculture

Agricultural practices in a surrounding watershed can have detrimental effects on lake water quality by increasing nutrient loading. Animal manure, the most commonly used fertilizer, is the primary contributor of phosphorus loading from agricultural practices. Livestock in a concentrated area increase the sewage effluent greatly. A typical dairy farm may have a nutrient output equal to a whole village of 2,000 people. Each cow excretes the phosphorus equivalent of 16 human beings (Tom Gordon, Cobbossee Water District, pers. comm.). Nutrients from manure used to fertilize fields or left in pastures will eventually reach the lake body via runoff or leaching. A common practice in the winter is to spread excess manure on frozen ground. The manure will have no opportunity to percolate into the soil, and as a result will readily runoff into the lake. Cattle will often use streams and tributaries as their drinking source, walking directly into the water. This may result in defecation in the water or increased erosion and sedimentation due to the movement of the cattle. Manure is not only detrimental for its effect on nutrient loading but also may carry diseases which may contaminate lake and drinking water.

Artificial fertilizers and pesticides can also contribute greatly to phosphorus loading in a lake. Runoff from fields will eventually reach a lake through its tributaries. Erosion due to farm equipment, grazing, rain and improper drainage systems will enhance the transport of phosphorus to the lake as well. Unsound cultivation practices, such as turning fields over often or plowing perpendicular to the edge of a lake, can increase erosion and sedimentation to a lake body. Phosphorus bound to soil particles are carried to the lake and eventually dissolve in the lake body. The use of fragile land near the water's edge eliminate an area of buffering capacity and increase the chances of nutrient input into the system. All of the above sources of nutrients and contaminants from agricultural practices must be considered when evaluating the quality and sustainability of a lake system.

Subsurface Waste Disposal

Subsurface waste disposal is the common method for handling household wastes in areas where municipal waste treatment is not an option. Non-adequate subsurface waste water disposal around a body of water can pose dangers not only to the quality of water, but human health as well. Understanding how subsurface waste water disposal systems function can help to lessen the threat to water quality.

Subsurface waste water disposal systems, as defined by the Department of Human Services, means any system for disposing of wastes or waste waters on or beneath the surface of the earth (Dept. of Human Services, 1988). There are three major types of subsurface wastewater disposal systems used within the East Pond watershed: privies, holding tanks, and septic systems.

A pit privie, also known as an outhouse, is the most primitive form of subsurface waste disposal. A privie is described as a waterless toilet placed over excavation where blackwaste is deposited (Dept. of Human Services, 1988).

A holding tank is defined as a watertight receptacle, with an alarm, which receives and holds wastewater prior to disposal at a location licensed by the Department of Environmental Protection (Dept. of Human Services, 1988). Holding tanks are installed only to replace existing systems or for commercial or industrial structures when no other reasonable disposal alternative is available (Dept. of Human Services, 1988).

Septic systems are more complex than both privies and holding tanks and consist of three critical components: the actual septic or settling tank, porous pipes, and a leaching field (Figure 12). Household waste, including waste water and human wastes, is transported from the home by a sewer line to the settling tank.

In the settling tank, solids settle to the bottom. Anaerobic digestion, the breaking down of materials in the absence of oxygen, takes place, allowing the solids to be slowly broken down by microorganisms. The separated fluid drains from the settling tank by means of the porous pipes (Montgomery, 1986).

The porous pipes extend from the settling tank to the leaching field. The perforated pipes enable the septage effluent to slowly seep into the surrounding soil of the leaching field. Any remaining solids are removed from the liquid by aerobic microbial degradation, the breaking down of materials with oxygen, and through the naturally occurring filtering quality of the soil, providing that the soil is sufficiently permeable. Ideally, the liquid from the septic tank is free from pathogenic organisms as well as other contaminants by the time it reaches the water table or any body of water (Montgomery, 1986).

Three major types of waste components comprise the septic tank and holding tank receiving water: garbage disposal wastes, black water, and grey water (Mitchell, 1974). Each type of waste contributes various amounts of nutrients and microorganisms to the system. Garbage disposal wastes (ground up garbage from a disposal system) are deposited in septic and holding tanks. This type of waste tends to put an unnecessary strain on septic systems (COLA, 1991). A second type of waste is black water which consists of toilet wastes contributing nitrogen, phosphorus, and microorganisms from human excreta. The third major

Figure 12. Diagram of Septic System

type of waste deposited in the septic tank is grey water which includes wastewater that comes from sinks, basins, showers, and household appliances such as washing machines and dishwashers. This wastewater often contributes chemicals and phosphorus from detergents.

There are many factors that influence a properly functioning septic system. Four important things to keep in mind when designing and installing a septic system are the permeability of the soil where the system is to be placed, the distance from a body of water, soil depth above and below the porous pipes in the leach field, and the slope of the land.

The permeability of the soil on which a leach field is located plays an important role in determining the success of the soil to filter out remaining solids in the effluent. If the effluent does not drain through the soil sufficiently, effluent can back up into the septic tank, clogging the entire system. On the other hand, soil should not be so permeable that the effluent is not sufficiently filtered before reaching the water table. Soil should drain water easily, yet slowly enough for the fluid to be filtered adequately.

The septic system should be placed far enough away from bodies of water so that septage fluid does not contaminate the water. If there is not enough distance between the leach field and the body of water, pathogenic organisms as well as other contaminants may remain in the effluent when it reaches the water table or body of water.

Soil depth in the leaching field is important both above and below the porous pipes. Generally, at least 60 cm of soil are needed above the pipes and 150 cm below for the soil to successfully filter septage fluid (Montgomery, 1986).

High slope gradients can cause septage fluid to flow rapidly through the pipes, so that percolation occurs only at the end of the pipes. One solution is to lay the porous pipes out in a zig-zag pattern across the slope, causing the effluent to seep evenly over the leaching field (Dunne, 1978).

Furthermore, maintenance and early problem detection of septic systems are essential in ensuring that systems continue to function properly and that high water quality standards are maintained. Maintenance begins with limiting what goes into a septic system. Avoid or reduce use of garbage disposals. The extra garbage can cause an unnecessary strain and perhaps permanent failure of the system (Save the Bay, 1990). Materials such as cigarette butts, diapers, paper towels, and sanitary napkins are not easily broken down by the microorganisms in the septic tank. Flushing these items down the toilet can cause the system to clog (COLA, 1991). Household chemicals including bleach, paint, and disinfectants actually kill the microorganisms which are responsible for breaking down organic wastes in the septic tank (COLA, 1991). Use only non-phosphate detergents. In addition, decreasing the amount of phosphorous increases the efficiency of septic systems (COLA, 1991). Finally, reducing the amount of water that enters the septic tank can prevent the possibility of overflow.

Even a well maintained septic system needs to be pumped out regularly. Pumping is necessary to prevent the solids that settle on the bottom of the septic tank from flowing into and clogging the leach field and possibly causing a complete system failure (Save the Bay, 1990). In general, a septic system should be pumped out when the tank is half full of solids, usually every three to five years depending on the amount of use.

Should a septic system fail it is important to detect problems early in order to prevent damage to East Pond. If water drains slowly or gurgles as it goes down the drain or it smells like sewage anywhere near the house or yard, the septic system may be clogged or overflowing. This could mean the septic tank needs to be pumped out. If grass should appear lush and green or the ground is soggy over the septic system, the system could be improperly designed or it may be time for servicing. Furthermore, a high coliform count in a well or nearby water source is a good indicator of failing septic systems. Often, delaying repair of what may seem like a minor problem may lead to the failure of the whole system which is very costly. Repairing minor problems will save money in the long run.

Septic systems that do not adequately treat wastes can pose threats to water quality, aquatic life, and human health. Increased Biological Oxygen Demand (BOD), eutrophication, and water contamination are three potential effects that sewage can have on a body of water.

BOD describes the amount of oxygen that is needed to aerobically break down organic matter in a body of water. The higher the BOD, the more organic matter is present. An increase in organic matter can occur as a result of human and animal wastes, due to failing septic systems, for example. If the BOD exceeds the amount of dissolved oxygen, aquatic plants and animals that require oxygen begin to die (Montgomery, 1986). In lakes, where there can be very low rates of flushing, low dissolved oxygen content can become a long term problem.

When eutrophication occurs, as the algae die, they sink to the bottom of the lake, increasing the BOD and the nutrient level again as they break down (Montgomery, 1986)

Coliform Testing

Water contamination can occur when pathogens or chemical pollutants reach the water supply. If septic systems, such as those around East Pond, are not functioning properly, untreated effluent may seep into the water supply. Fecal pollution of water can potentially cause the spread of such diseases as typhoid fever, dysentery or gastroenteritis (Mitchell, 1974). Besides potentially spreading disease, organic pollution will cause the depletion of oxygen, and increase the rate of eutrophication.

A test methodology to evaluate water supplies and the establishment of safe drinking water standards, as well as water standards for other uses of clean drinking water, was deemed necessary to protect public health (Mitchell, 1974). For example, it is a state requirement that drinking water sources meet a specific quality standard, and testing must be performed to adhere to these standards (Wentworth, 1991). Water quality is assessed most effectively and safely through bacteriological analyses, which establishes the fact and degree of fecal contamination. If animal or human waste is present in the lake, indicator organisms such as

E. coli or coliform bacteria can be enumerated and directly correlate with the extent of fecal pollution. Total coliform indicates the presence of bacteria from both enteric and non-enteric sources, while fecal coliform specifically indicates recent fecal waste from warm blooded animals (Mitchell, 1974).

If there is a problem of fecal contamination of water, coliform testing allows for early detection which can eliminate long term damage to lake water quality if proper corrective actions are taken.

Zoning and Development

Zoning laws are very important when it comes to the regulation of development within a lake watershed. If unmonitored, development will quickly spread and will probably have adverse effects on the water quality of a lake. Zoning laws control lot sizes, the proximity of the building or buildings to bodies of water, how the land can be developed, and many other components. State regulations have become more strict over the years as pressures from development have increased (Dominie and Scudder, 1987; Table 3).

The major concern over development is that it contributes to the phosphorus loading of a lake. Many household detergents and soaps contain a large amount of phosphorus. Inadequate draining can cause this excess phosphorus to leak into the water column. Lawns and gardens are another source of phosphorus. The fertilizers and pesticides people use to promote plant growth contribute to phosphorus loading. These phosphorus-containing substances can be washed into a lake during a rainstorm, especially if there is very little buffer zone between the lawn and the shore.

A buffer zone, or filter strip, is an area of natural vegetative growth between a structure on the shore and a body of water. Its width varies, but town zoning ordinances regulate minimum widths. The buffer strip absorbs phosphorus and other nutrients from fertilizers and pesticides which would otherwise be swept into the water. Many house lots have no buffer strips at all so the lawn extends to the water's edge. Buffer strips also aid in the prevention of erosion. Construction sites that have little or no vegetation on them lose massive amounts of soil during rain or wind. Dirt paths also erode very easily. Vegetation captures the runaway soil and prevents the soil from building up in the lake as sediments. This also indirectly lowers phosphorus levels, because phosphorus that is bound to the soil particles is not washed into the lake.

Roads

There are four different types of roads found specifically in the East Pond and Serpentine watersheds: 1) state, 2) municipal, 3) fire, and 4) private. Public roads, or any roads owned, leased or otherwise operated by a governmental body or public entity, incorporate the first three road types. State roads are under the jurisdiction of the state, and are usually the widest

Table 3. Some minimum zoning standards for the State of Maine and two Maine towns, Oakland and Smithfield. [1]

Standard	Maine (effective Mar 1990)	Oakland (Latest revision May 1988 [2])	Smithfield (Latest revision Mar 1988 [2])
Minimum residential lot area for shoreland zone (non-tidal area)	40,000 sq. ft.	30,000 sq. ft.	80,000 sq. ft.
Minimum shore frontage	200 sq. ft.	150 sq. ft.	100 sq. ft.
Minimum building setback from shore	100 ft. great ponds, 75 ft. streams	75 ft.	75 ft.
Area of structures and non - vegetated surfaces	max. 20% of total area	max. 20% of total area	max. 20% of total area
Vegetation clearing	100 ft. from waterline	75 ft. from waterline	75 ft. from waterline

[1] Sources: Shoreland ordinances for the towns of Smithfield and Oakland, and State of Maine Guidelines for Municipal Shoreland Zoning Ordinances, 1990.

[2] The state of Maine's standards have been updated. Towns are required to update to at least state standards by Dec. 31, 1991.

roads since they handle the greatest volume of traffic. Municipal roads are governed by their respective towns, and are either as wide or slightly narrower than state roads. Both state and municipal roads are usually paved. Fire roads are also under town jurisdiction, are quite narrow, and are most frequently dirt in rural Maine towns. Private roads primarily include driveways, but may include some other roads as well. While under town legislation, their construction and maintenance is the responsibility of the private owners. The private roads examined in this study are mostly narrow dirt roads.

Proper drainage of roadways is of critical importance when attempting to control phosphorus loading within a watershed. The materials of which roads are constructed, pavement and other impervious surfaces, increase rates and amounts of runoff (Woodard 1989). Erosion of these materials is inevitable as vehicles and other traffic travel over them constantly, causing wear and surface deterioration. This deterioration is accelerated when any moisture is present on the road surface, allowing sediment and other particulate matter carrying bound phosphorus to travel into a lake. Roads serve as a potentially large source of phosphorus loading to a water body, when poor road construction, maintenance, and/or erosion control practices occur.

Road construction should attempt to achieve the following long-term goals: 1) minimizing surface area covered, 2) minimizing runoff and erosion with proper drainage, and 3) maximizing lifetime and durability.

A well constructed road most efficiently allows surface water to run off the road surface and away from the road. Detaining excessive amounts of phosphorus from entering a water body is the ultimate goal of a well constructed road network, encompassing both proper drainage and channeling of road surface waters. When properly constructed and maintained, a road will last longer and will have a far less impact on nearby water bodies.

The characteristics of a road which should be considered <u>before</u> any road construction begins, include the following: 1) road location, 2) road area, 3) road surface material, 4) road cross section, 5) obstructions to road drainage, 6) ditches, 7) culverts, and 8) road maintenance.

1) Road Location

The location of a road will be determinedmost often by the area requiring accessibility. However, all roads in the State of Maine must be set back at least 100 feet from the shoreline of a lake body for residential use, and 200 feet for commercial, industrial, and other non-residential uses involving one or more buildings (Maine DEP, 1991). Beyond this distance, it has been determined that phosphorus loading rates do not decrease substantially with an increase in setback (Roy Bouchard, DEP, pers. comm.). An erosion site within a particular watershed, no matter how far away from the lake, always has the potential to deteriorate a lake's water quality because eroding sediments and runoff will continue to travel until they reach a water body. In addition, road construction should be avoided on steep slopes (greater than 10%) because the potential of erosion of these surfaces is substantial.

2) Road Area

Increased road surface area leads to an increased potential of erosion and runoff, and therefore, an increased amount of external phosphorus loading. Consequently, it is critical to thoroughly assess a road's function before it is built. Roads should be constructed no longer than absolutely necessary. Developers and private owners, especially, should be encouraged to minimize road length. Road width is often based upon maintenance capabilities of the area (Cashatt, 1984). Low-structural management alternatives to substitute for greater road surface areas are often more effective, less expensive, and are simply more practical ways of developing potential road land (Woodard, 1989).

3) Road Surface Material

Studies show that phosphorus washes from paved surfaces at a higher rate than from more permeable surfaces such as dirt (Lea *et al.*, 1990). However, dirt roads erode more readily. Therefore, pavement is the road surface of choice for roads serving high volumes of traffic, while dirt roads are favored under low traffic volume and/or infrequent (e.g. seasonal) use conditions.

Fine particles should be used in dirt roads as they aid in compaction of the road surface. However, if the amount of fine sediment in the surface layer is too great, during wet periods, the compaction will be lost, and the road will become a muddy mess. Also, stones larger than 2 inches in diameter should not be used in surface material because they are easily kicked out by vehicle tires allowing the formation of potholes in the road surface. Road surfaces should be periodically replaced and graded so as to maintain a stable base and minimally-eroding road surface.

4) Road Cross Section

Proper road drainage is achieved by creating a crowned road cross section. A crown should have a slope 1/8 to 1/4 in per asphalt foot road width and 1/2 to 3/4 in per aggregate foot road width (Maine Department of Transportaion 1986). Constructing such a slope allows surface water to flow down either side of the road. Shoulders should have a slightly steeper cross slope than the road itself, so that drainage over the rougher shoulder surface and into a ditch or buffer zone, may be facilitated. Lack of a sufficient crown on a road will result in potholes and a more rapid deterioration of the road surface.

5) Obstructions to Road Drainage

A smooth shoulder is also necessary for proper road drainage. Obstructions such as a ridge-like build-up of sediment along a shoulder (termed a berm) will not allow complete water drainage and will cause pooling. Depressions, cracks, or potholes in a roadway will also allow pools of water to stand on the road surface. Water which does not drain off asphalt road surfaces will seep into any existing cracks and infiltrate the subsurface soils. This process weakens the underlying structure of a road. On dirt roads, depressions which hold standing water, or an overall insufficiently packed and aggregated surface, allows water to permeate through the sediments to cause increased rates of surface weathering. It is important to seal any cracks and fill any potholes as soon after their appearance as possible, so as to prevent further erosion of the road surface, and to minimize greater future costs of maintenance.

6) Ditches

Ditches are structures necessary along wide and/or steep road stretches. The purpose of ditches is to provide an avenue for the diversion of water flow off the road and away from water bodies. Ideally they should be of a trapezoidal shape with a flat or rounded bottom, a sufficient depth with a slope no greater than 2 : 1 (depth : width), clean and free of excess debris, and covered with abundant vegetation (Kennebec County Soil and Water Conservation District, unpublished document, 1991). Also, ditches need to be constructed of proper soils which will not erode excessively under the predicted velocities of water which will be traveling within them.

Lining ditches with natural vegetation is a highly effective and economical means of erosion control which reduces nutrients and suspended solids in surface water flow (Woodard, 1989). Vegetational filter strips allow increased infiltration, deposition, filtration, and absorption of suspended solids. Allowing adequate time for growth of vegetation in ditches after their construction is necessary to stabilize soils for storm and winter conditions.

7) Culverts

Culverts are hollow pipe channels installed underneath roads to channel water in natural drainage patterns. Most often they run under driveways, to continue ditch channels, or under roads themselves, when carrying stream water. Today, culverts are typically made of corrugated metal or plastic and are 12 or 15 inches in diameter.

The greatest factor to consider when installing a culvert is its size. Correctly sized culverts are necessary for proper drainage because culverts which are too small will be subjected to excessive stress and pose the potential for a blowout. Culverts that are too large are economically impractical, since they waste money and time required to install them. Charts specifying correct culvert sizes are based on stream width and depth which yield a square area of water flow to be accommodated (Kennebec County Soil and Water Conservation District, unpublished document, 1991).

Culverts should be set in the ground at a 30° angle downslope with a pitch of 2 to 4 % (Kennebec County Soil and Water Conservation District, unpublished document, 1991). The ditch on the upper side of the road is the primary one, and should be dug deeper, if necessary, so that water will be able to enter the culvert with relative ease. Also, the bottom edge of the culvert inlet should be slightly below the level of the ditch channel. It is also necessary to keep ditches clean and culvert openings unobstructed so that proper drainage will be facilitated. On the lower side of any culvert, if there is a drop before the water hits the stream channel, rocks should be placed so as to break the force of water and minimize erosion. Also, a culvert should extend past the road edge sufficiently so that adequate drainage may occur without eroding the roadside.

Culverts should be spaced according to the road grade. On gentle slopes (1 - 2 %), they may be spaced 300 feet apart, whereas on moderate slopes (3 - 9 %), they should be spaced 150 feet (or less) apart. For steeper slopes (10 % or greater), culvert frequency should be increased to every 100 feet (Kennebec County Soil and Water Conservation District, unpublished document, 1991).

8) Road Maintenance

Well constructed roads don't necessarily persist after carefully planned and proper construction. Over time, extensive use and wear will erode a road and cause it to deteriorate. If not adequately maintained, a road's rate of deterioration will be substantially increased (Roy Bouchard, DEP, pers. comm.). It is important to spend money annually to maintain roads so that problems do not accumulate and become of greater magnitude and repair expense than would be otherwise necessary. The main components of road maintenance include: a) surface grading, b) ditches, c) culverts, d) erosion control practices, e) when to perform maintenance, and f) inspections.

a) Surface Grading

Regular road maintenance should include road grading at least once yearly. Grading helps to maintain a proper crown (sometimes necessitating an import of sediment for dirt roads which undergo greater erosion), and keeps shoulder surfaces smooth. If grading is carried out improperly, material may be piled up along the road edge, prohibiting water flow off the roads, promoting the development of ruts. Consistent and proper grading greatly increases the life of a road.

b) Ditches

Ditches should be inspected at least once annually to locate any gross problems and to assess areas of potential concern. If left unattended, potentially avoided ditch problems will develop causing greater difficulty and expense to repair in the future. Things to check during ditch inspection include: a good cover of vegetation, proper shape, and erosion of sides.

c) Culverts

Culvert maintenance requires a similar inspection and treatment program. Things to look for include: maintenance of proper size and clogging and erosion of inlets and outlets.

d) Erosion Control Practices

Any road maintenance or construction activity should attempt to stabilize the disturbed soil of an area. The placement of silt fencing, hay bale dike placed below erosion slopes, along with the stabilization of eroding ditch channels with a mat of mulch (3 - 4 in thick) and netting staked into the channel effectively achieves this goal. Staked hay bales or stone checkdams may also be used to slow down water flow in areas of long, steep slopes.

e) Timing Considerations

Proper timing for road maintenance is crucial so as to minimize erosion and runoff. The best time to maintain and work on roads is in late spring and early summer (Kennebec County Soil and Water Conservation District, unpublished document 1991). If all work is completed early enough, a vegetative buffer may be seeded and begin growing by early August. This will allow the soil to be stabilized for the winter. When grading roads, the optimal time is after a heavy spring rain since water helps to loosen sediment, making it easier to reshape.

f) Inspections

Road inspections by road commissioners, or the equivalent, should occur twice a year. The first road check should occur in early spring, when wet weather causes runoff problems to be most evident. Then, a second inspection should take place in late summer/early fall, to check previously identified areas of special concern to insure that they have been properly stabilized for the winter.

The use of these erosion control practices in both the construction and maintenance of roads is crucial to the preservation of lake body's water quality. Guidelines such as the Best Management Practices, aid states and towns in developing regional and local legislation which may be implemented to outline control measures within a watershed. The North Kennebec Regional Planning Commission (NKRPC) has outlined minimum road standard and construction specifications for town acceptance in its handbook, Implementation Strategies for Lake Water Quality Protection: a Handbook of Model Ordinance and Non-Regulatory Techniques for Controlling Phosphorus Impacts from Development (June 1990). Both of these publications are valuable sources in decreasing phosphorus loading to a lake system as caused by road construction and maintenance activities.

Recreation

Recreation on East Pond consists of boating, camping, and other activities. Each of these actions could potentially affect the water quality and aesthetic nature of East Pond through altering the natural habitat of the lake, increasing shoreline erosion, and introducing chemicals foreign to a lake environment. A new public access boat ramp has been installed by the Maine Department of Fisheries and Wildlife on the southeast side of the pond potentially causing an increase in recreational boating and the pollution problems associated with boating.

Biotic Indicators of Lake Quality

Definition of Indicator Species

Lake biota are influenced by various lake conditions. In nutrient enriched bodies, plant, algal, and bacterial populations deplete dissolved oxygen levels by shading the water column, decreasing contact between the atmosphere and the lake, and by consuming oxygen through respiration (Macan *et al.*, 1968). Different species are affected in different ways depending upon conditions such as acidity, temperature, and dissolved oxygen. Many species have narrow tolerance ranges for certain conditions. The presence or absence of these species can indicate different lake and water quality conditions, thus they are called "indicator" species. Three examples of indicator species, the common loon, lake trout, and duckweed are presented here.

Common Loon

The Common Loon can be found in Maine from early spring to late fall, and coastal bays in the winter. Loons are usually found in mating pairs and can be very territorial. Loons are also extremely sensitive to disturbance, particularly around the month of June when they are mating and laying their eggs. Although loons are very adept at swimming, diving, and flying, they lack the ability to walk well on land. Consequently, loons prefer very isolated areas close to the water's edge to nest (Knight, 1908). A loon's diet consists primarily of fish, and an abundant population of fish can occur only if the lake is in a relatively clean state. During our field reconnaissance of East Pond, several families of loons were spotted swimming and feeding throughout various parts of the lake. Their presence alone cannot lead one to make a definitve statement about the health of the pond, but it can with other supportive evidence, aid in the assessment that East Pond is in a relatively healthy state.

Duckweed

Duckweed (Family Lemnaceae), the world's smallest flowering plant, is made up of minute flattened globular bodies, called fronds, which rarely exceed ten millimeters in diameter. The plant thrives in stillwater areas rich in dissolved nutrients such as nitrates and phosphates. Duckweed populations can serve as an indicator of eutrophication (high nutrient levels) in bodies of water (Maitland, 1978). Also, a solid cover of duckweed can reduce dissolved oxygen levels in the water by: shading the water column, preventing photosynthesis by deeper species; reducing contact between the water and the atmosphere; and dying, sinking, and decaying on the bottom, increasing biological oxygen demand.

Lake Trout

The lake trout is an important food and sport fish as well as a very sensitive biological indicator. The fish, native to cold temperate waters of the Northern Hemisphere, spawns and lives in fresh water. Lake trout are highly sensitive to environmental change. They reside in deep waters with a dissolved oxygen level greater than five parts per million, a temperature below 17° C, and a pH between 6 and 8 (Cooper, 1941). Lake trout feed on small fish, although they can eat a wide variety of foods. The presence of lake trout indicates that the lake is in a relatively oligotrophic (low nutrient level) state.

Study Area

Historical Perspective of East Pond

Lake Formation

Types of Lake Formation - Geological Processes

The most common way in which lake basins are formed is by the actions of glaciers, volcanos, and wandering rivers (Colinvaux, 1986). Most lakes are formed as glaciers passing over the land. Shallow lakes formed in these depressions. Lakes also formed when large pieces of ice were left in the soil after a glacier had passed. When the glaciers retreated, the ice melted and lakes developed. A smaller percentage of lakes developed as a result of volcanic activity. Volcanos formed lakes when lava flows dammed valleys and also when a large crater was left after a volcano erupted. Finally, lakes were formed by rivers that meandered across plains. In this situation, channels that were abandoned by the river became lakes.

East Pond Lake Formation - Belgrade Lake Chain Formation

Although there are several different ways in which lakes form, glaciers are responsible for most of the lakes that are found in Maine (Davis, 1978). A majority of these, such as East Pond and the rest of the Belgrade chain, were formed during the most recent glaciation of the Pleistocene period (also known as the Great Ice Age) which ended about 10,000 years ago (Bates, 1987). These glaciers dug relatively shallow depressions into the earth and deposited this soil and rock in what is now the surrounding hills. Water from underground springs and other sources then filled the depressions and lakes developed.

East Pond Characteristics

A characterization of East Pond is described according to location, physical parameters, and phosphorus levels for 1991 (Table 4). East Pond is a moderately sensitive, shallow Maine lake, with minimal annual flushing.

Table 4. East Pond description of location, physical, and chemical parameters.[1]

Overview	
Lake name	East Pond
State	Maine
County	Somerset and Kennebec
Towns on shore	Smithfield, Oakland, Fairfield, Belgrade
Surface Area	4505 hectares
Maximum depth	8 meters
Minimum depth	5 meters
Volume	33.68×10^6 m^3
Drainage Area	17.4 km^2
Flushing Rate	0.24 flushes/year
DEP Classification of water quality	
Water Quality	moderately sensitive
Phosphorus Coefficient	30.8 lbs/year would cause a 1ppb phosphorus increase
Acceptable Phosphorus Increase	1 ppb (would qualify lake body as medium water quality)

[1] DEP East Pond data, 1991.

Serpentine Stream and Wetland Characteristics

Clark and Sucker Brooks

The Serpentine Stream and surrounding watershed lie to the north of East Pond. The Serpentine Stream forms a T, with one section flowing east-west towards North Pond. A longer section, flowing north-south, connects East Pond to the T section of the Serpentine.

The upper northern section of the Serpentine is fed by Clark and Sucker Brooks, two small, slow-flowing streams. Clark Brook runs through agricultural areas including cattle farms and croplands. Sucker Brook passes under Maine State Highway 8, travels through forested areas and in several places is lined by residential areas. Both brooks enter the Serpentine Stream at the northeast corner of the Serpentine watershed. The volume of water flowing into the Serpentine Stream from Clark and Sucker Brooks is highly dependent on rainfall, as noticeably more water enters the stream via these tributaries following heavy rains.

The section of the Serpentine traveling north-south is surrounded by 164 acres of marsh and bog wetland area. This section receives water input primarily from precipitation, surface water runoff, and groundwater sources. Because of the nature of the wetland, no development is possible within the marsh and bog themselves. There is, however, a large gravel pit located to the southwest of the wetland, as well as residential areas to the west of the wetland.

The Serpentine Stream typically flows north out of East pond, reaching the T section as it heads west, finally dumping through a dam into North Pond. The water in the T section goes straight to North Pond, generally without entering the southern Serpentine. Following heavy rainfall, however, water from the T section (especially input from Clark and Sucker Brooks) flows down the southern Serpentine toward East Pond.

Serpentine Stream and Wetland

The Serpentine wetland is 66.4 hectares and is comprised of 3 distinct community types: the bog which comprises the western and eastern sections, the raised bog which is located near the center of the wetland, and the marsh which dominates the northern part of the wetland as well as a few smaller areas spread throughout the Serpentine bog (Figure 13). The northern watershed flows into the Serpentine wetland through Clark and Sucker brook. The Serpentine stream typically drains into East Pond through the wetland while also flowing towards the dam and into North Pond.

Each community type in the Serpentine wetland has unique flora and fauna as well as chemical differences that distinguish it from the others. The bog, comprising about 63 % of the Serpentine wetland, is an ombrotrophic peatland which consists primarily of *Sphagnum* moss with ericaceous shrubs and small trees such as black spruce and tamaracks. The raised bog, which covers approximately 12 % of the wetland, has a much firmer land mass which prevents water from flowing though it. The raised bog in the Serpentine wetland consists primarily of well-developed black spruce and tamaracks. The Serpentine marsh, comprising about 25 % of the wetland, is made up of decomposed peat, cattails, grasses, rushes and submergent and floating vegetation such as arrowheads.

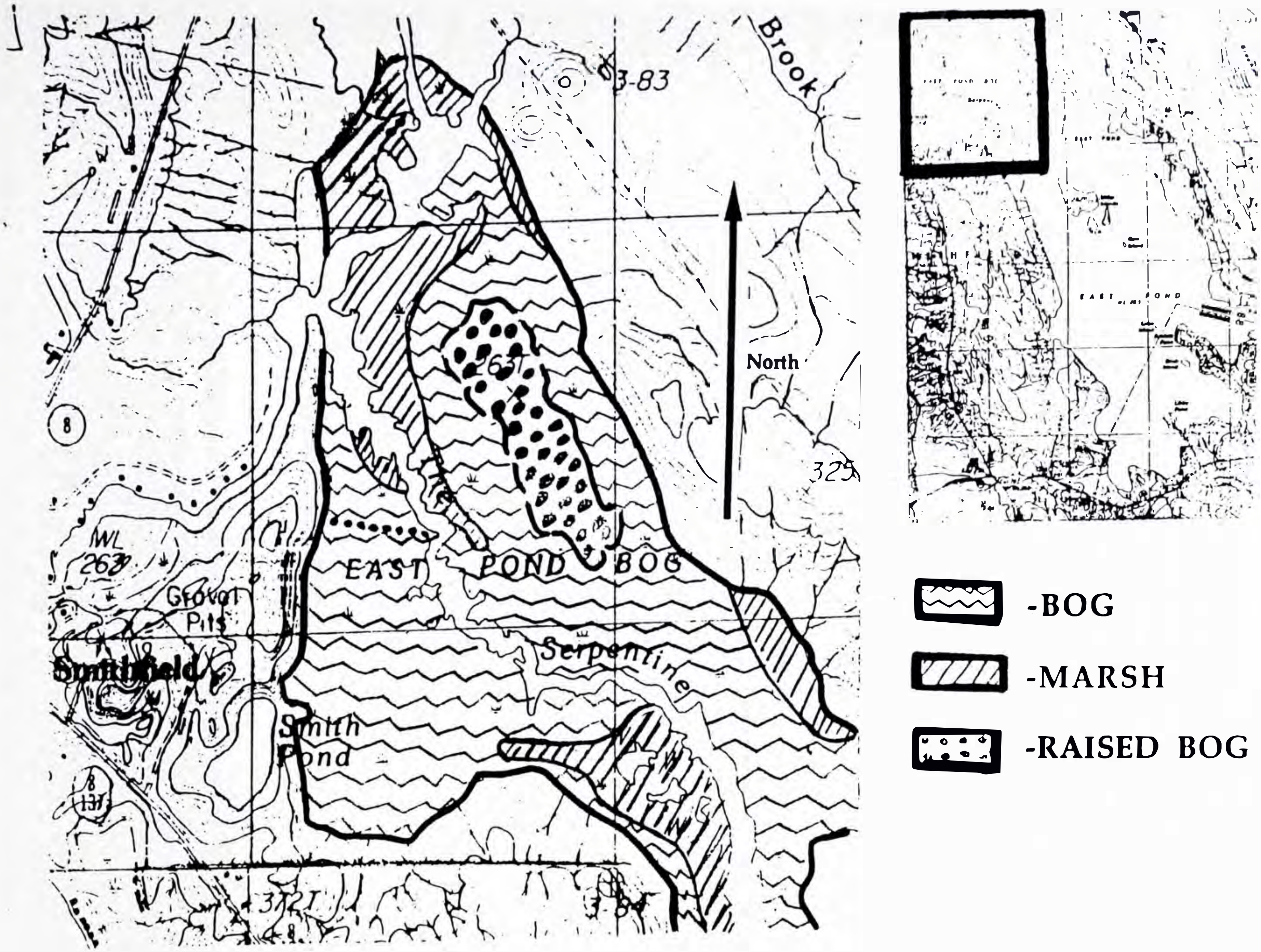


Figure 13. Community types in the Serpentine wetland as indicated by infra-red aerial photography. Transect of temperature, pH and conductivity and the sample points in the Serpentine marsh taken on October 10, 1991 are indicated by black dots. The relationship of the Serpentine wetland to East Pond is indicated on the inset map (right) by a black border.

Development of the East Pond and Serpentine Watersheds

East Pond, located in the towns of Oakland, Belgrade, and Smithfield, is the uppermost lake of the Belgrade Lakes chain. Development along the shores began when the railroad that runs through Oakland transported vacationers to the region from New York and Massachusetts. Now, though the property taxes from seasonal dwellings are revenue for the surrounding towns, development has its drawbacks. The citizens of Maine highly value the state's natural beauty and what it offers for enjoyment. The current development boom will most likely come into conflict with the preferred quality of life in Maine if is it not strictly regulated. Many of Maine's towns are not sufficiently prepared to deal with future development plans (Dominie and Scudder, 1987).

Based on the development trends of the past ten years, there are speculations that we will see 56% of the developable land on East Pond being developed over the next fifty years (Planning Board of the Town of Smithfield, 1990). There will most likely be a decrease in farming acreage, along with an increase in subdivision of the land. Sport and summer camps, as well as cottages may be converted to year round homes or sold for condominium construction. With such changes and developments there will probably be a decline in the quality of the lake and its surroundings.

The Serpentine watershed is a component of the North Pond watershed. It is within the boundaries of Smithfield, and almost all of the land along the Serpentine falls under Smithfield's Resource Protection District. This means new development and changes to existing development are minimal at most. There are many seasonal camps along the Serpentine, especially near the dam connecting the tributary to North Pond. Septic systems and recreational activities from these camps, as well as runoff from farms, may have a large effect on the Serpentine. The tributary is supposed to drain from East Pond into North Pond, but if the tributary backflows into East Pond during storms, it carries with it the nutrients from development it may have acquired, which will decrease East Pond's water quality.

Study Objectives

Lake Body

East Pond is classified by the DEP as a moderate to sensitive lake; it is relatively sensitive to phosphorus loading. The water quality of the lake has been described as "good" or clear of algae, with the exception of the 1987 algal bloom (EPLA, 1991). The goal of our study was to assess the present lake water quality and compare the results with DEP and EPLA data.

The DEP investigated the algal bloom of 1987 and determined the cause to be an external input of phosphorus. It was speculated that the Serpentine Stream, which was normally an outlet for East Pond, may have backed into the lake as a result of high precipitation levels during the April flood of 1987. However, since 1986 phosphorus levels have been above 15 ppb. With these relatively elevated levels as compared with the past, the East Pond study focused attention on current phosphorus levels. Both the bloom and increased phosphorus levels indicate that East Pond is sensitive to increased loading of small amounts of phosphorus. Therefore, the lake may in fact be susceptable to algal blooms and poor water quality.

Between 1979 and 1988 there was a 22% increase in development within the East Pond watershed. The impact of such development on the water quality and the potential for future problems are of concern. We will focus on such issues as part of this report.

The objective of the lake body study was to determine and evaluate the current water chemistry of the lake. In addition, we looked for correlations that might have existed between the water chemistry at a particular site and shoreline development.

Tributaries and Wetlands

The DEP believes that backflushing of the Serpentine caused phosphorus loading of East Pond which then resulted in the algal bloom of 1987. The tributary and wetland study objectives are to determine the role of the Serpentine and wetlands in affecting East Pond water quality.

Specific objectives include examination of the relationships between tributaries and the Serpentine Stream to determine the nutrient inputs into the stream from Clark Brook and Sucker Brook. We will also study the effects which the Serpentine Marsh and Serpentine Bog on the water quality of East Pond. We will also try to determine the extent of infiltration of the Serpentine into the bog. Comparisons will be made between the Serpentine and East Pond to see if a gradient exists along the Serpentine Bog and the Serpentine Marsh. Finally, the tributary and marsh group will study and determine the effects of storm activity on nutrient input and water flow in the watershed.

General Classification and Patterns of Land Use

Land use patterns provide a fairly accurate method of potential nutrient loading to a lake system. This study attempted to discern land use trends in the East Pond and Serpentine watersheds over time and to make recommendations for future use. From land use classifications in 1965 and 1991 the percentages of each land use type in the two watersheds were calculated to enable comparison. According to current land use and soil type patterns, recommendations were made for suitable sites of possible future development.

External Phosphorus Loading

This study attempted to estimate the total external phosphorus loading (kg-P/yr) to East Pond and the Serpentine Stream by determining the amounts of each type of land use, and by using phosphorus coefficients appropriate to the area. It was thus possible to assess the relative impacts of each different land use on the total phosphorus loading level by determining which types of land use were loading the most significant amounts of phosphorus into each system.

Soils

By determining nutrient buffering capabilities of soil in the Serpentine and East Pond watersheds, this study attempted to discern the possible locations of phosphorus loading. Permeability classifications allowed specific locations to be marked as potential threats to lake water quality, and provided recommendations for areas of future development.

Forestry

The goal of the forestry study was to assess the impact on the Serpentine and East Pond systems from timber harvesting practices. With this information, an evaluation of forestry in the Serpentine and East Pond watersheds was conducted, and any suggestions for environmental improvement were made.

Agriculture

The objective of the study of agricultural practices was to determine the extent of water quality degradation occurring in the East Pond and Serpentine watersheds. Based on evaluation of the farms in these watersheds, and reforms available to farmers in the area, suggestions were made to help alleviate any environmental degradation possibly due to the agricultural practices.

Subsurface Waste Disposal

In terms of the East Pond Watershed and subsurface waste disposal, there were three main study objectives. The first was to determine the percentage of each different type of subsurface waste water disposal system. The next objective was to determine where the greatest threat to the East Pond exists by performing coliform tests to detect possible failing systems. Finally, through the information gathered obtaining these objectives, recommendations on how to prevent future problems concerning waste water disposal were made.

Zoning and Development

Development in the East Pond watershed is growing, and is expected to continue doing so (Planning Board of the Town of Smithfield, 1990). Because the East Pond and Serpentine watersheds are shared by three towns, the possible impacts of development on the water quality of the lake are complicated. This study attempted to discern the differences between the three towns' zoning laws and shoreline ordinances, and to determine whether a correlation between zoning laws and phosphorus levels in East Pond existed.

Roads

Roads are a potentially significant source of phosphorus and sediment in most lake watersheds, contributing thousands of tons of sediment to Maine lakes every year (Maine DEP, unpublished document, 1991). This study evaluated the conditions of the roads in the East Pond and Serpentine watersheds to assess their impact on the water quality of East Pond, and identify those roads or road types requiring special attention and/or increased maintenance.

Recreation

The objectives in studying recreation were to assess the impact of recreation on water quality in East Pond, and more specifically to determine the potential influence of the newly installed public-access boat ramp on the lake.

ANALYTICAL PROCEDURES AND FINDINGS

Study Sites

Serpentine Tributaries and Wetlands

Ten sample sites were selected to investigate the water quality of the Serpentine Stream and adjacent wetland. Sites were chosen to enable measurement of the water entering the wetland through Clark and Sucker Brooks. In addition, the Serpentine stream and wetland were divided into two components for analysis. The Serpentine Marsh (the northern component) encompasses wetland from the mouths of Clark and Sucker Brooks on the east to the developed section of the Serpentine stream, adjacent to the dam which leads to North Pond. The Serpentine Bog (the southern component) represents the part of the Serpentine stream that runs from the outlet of East Pond, through the East Pond Bog, and ends at the intersection with the marsh section of the Serpentine.

SITE 1: Situated in the developed area of the Serpentine Marsh, approximately 5 m from the edge of the dam.

SITE 2: Located in the developed area of the Serpentine Marsh about 75 m to the east of the Northern opening of the Serpentine Bog.

SITE 3: Located at the confluence of Clark and Sucker Brooks in the Serpentine Marsh where water from the two streams appeared to mix together.

SITE 4: Located in the Serpentine Marsh next to a dairy farm at the mouth of Clark Brook. Samples were taken from a foot bridge which spans Clark Brook.

SITE 5: Situated at the northern edge of the Serpentine Bog, approximately 17 m south of the intersection with the Serpentine Marsh component of the wetland.

SITE 6: Located in the Serpentine Bog, 600 m south of the intersection with the Serpentine Marsh.

SITE 7: Located in the Serpentine Bog, 1250 m south of the intersection with the Serpentine Marsh.

SITE 8: Located in the Serpentine Marsh, 1900 m south of the intersection with the Serpentine Marsh (approximately 200 m from where the Serpentine stream enters East Pond).


Ross Hill
Brook
Dodling
3-8
505
6-12
OAK
HILL
ROAD
Leech Brook
SAND HILL ROAD
408
Cul 335
WL 328
393
Little Pond
295
8
322
Mt Tom
35
Sucker Brook
700
650
600
550
500
450
Mt Bett
478
Cul 273
WL 264
9
S M I T H F
Landing Strip
359
285
Cul 281
WL 276
In Line

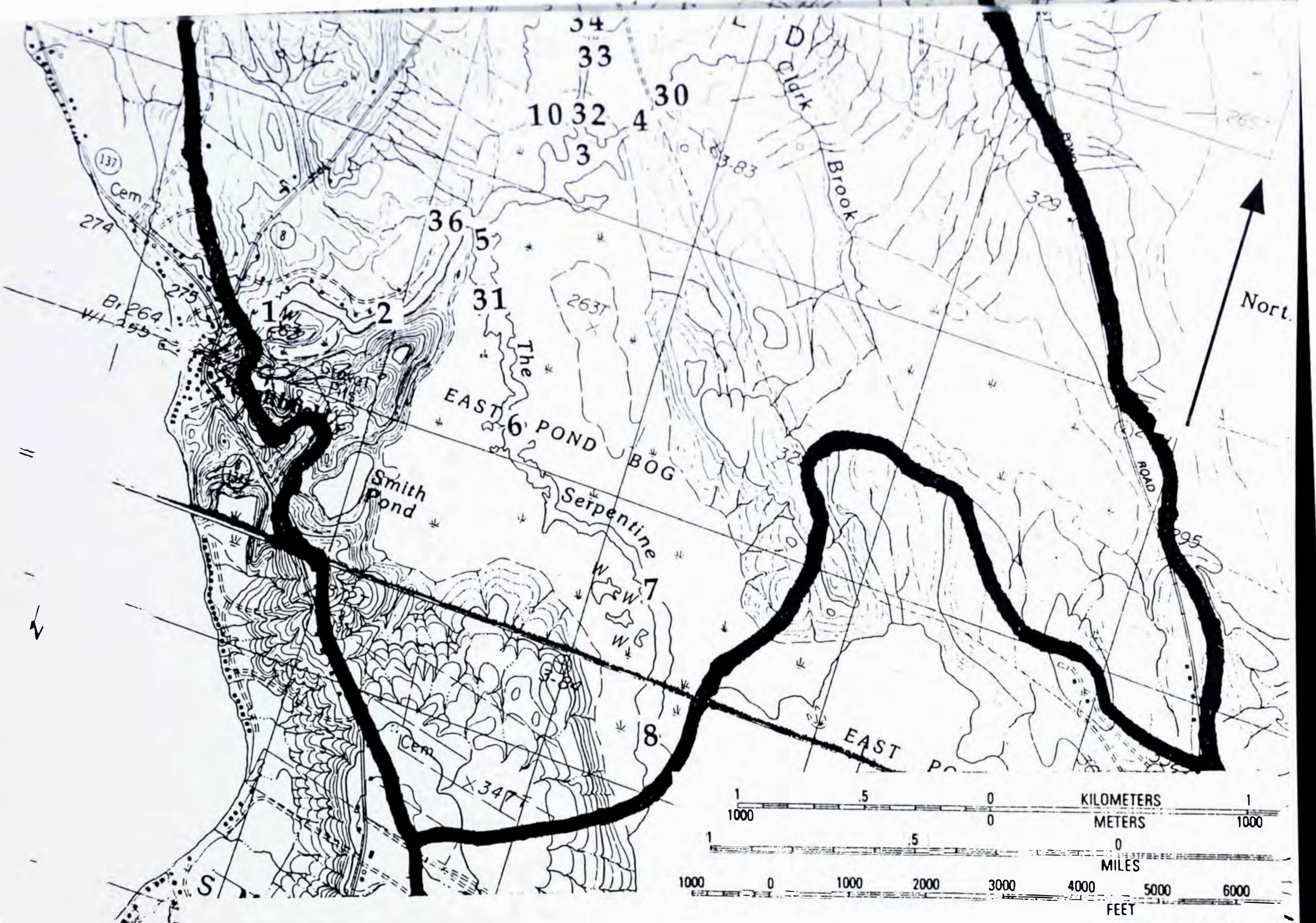


Figure 14a Sampling sites for the Serpentine bog and marsh. 1982 USGS map, scale (1:16,000).

SITE 9: Located in Sucker Brook and accessed from Route 8 in Smithfield. Samples were taken one meter upstream from a culvert which goes under Route 8.

SITE 10: This site was also located in Sucker Brook and was accessed by canoe from the Serpentine Marsh approximately 75 m from the mouth of the brook.

East Pond Tributaries and Marsh Area

SITE 11: Located in a stream about midway down on the west side of East Pond. Because we had access to the stream from Bob Joly's (member of the East Pond Lake Association) property, this tributary is referred to as Joly Stream.

SITE 12: Located next to Route 137 in a marsh in the southwest portion of East Pond.

SITE 13: Located in a stream in the southeast portion of East Pond, approximately 5km (3mi) off of Route 8 on East Pond Road. This tributary is referred to as the Libby Point Stream.

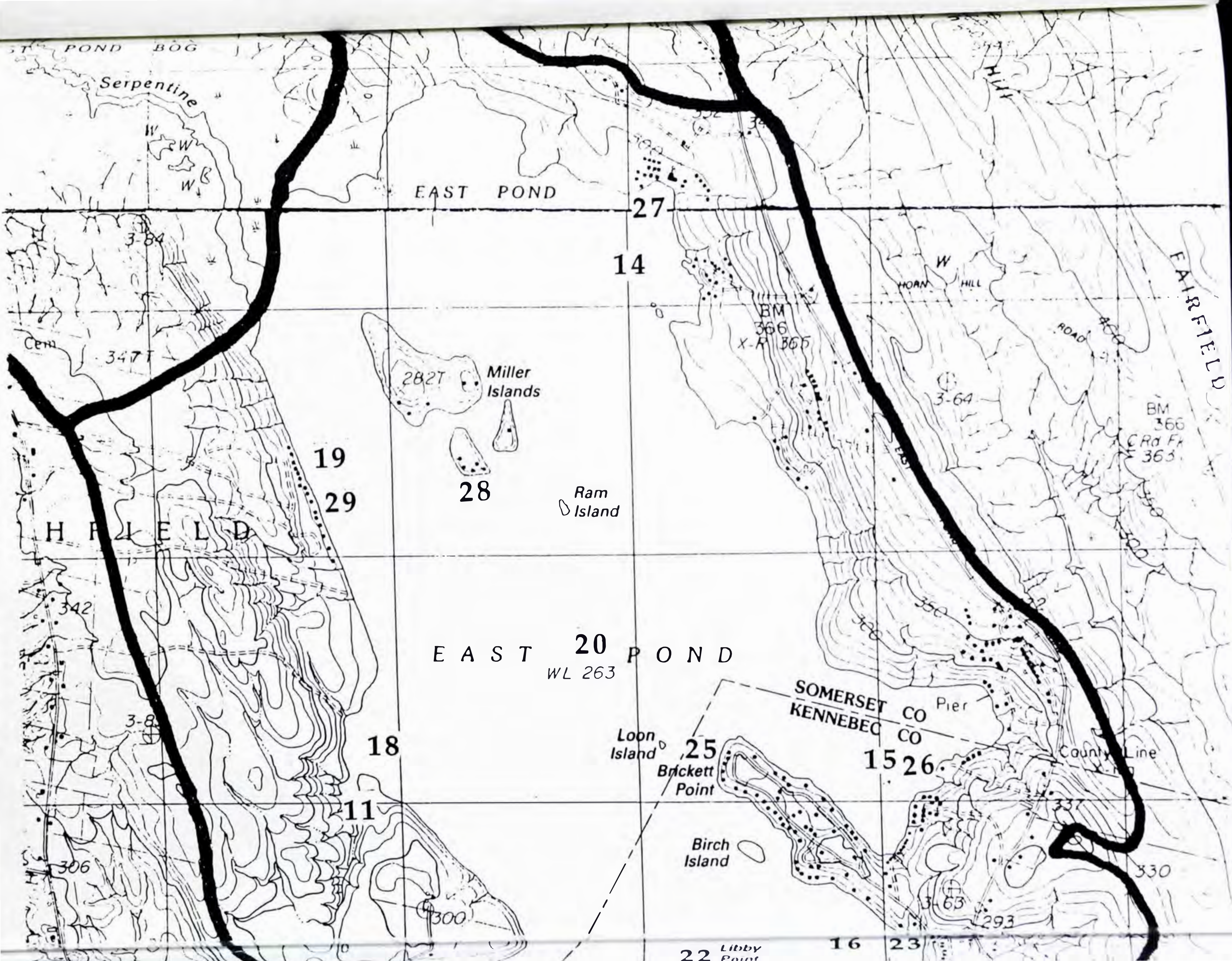
East Pond

Seven sites were selected to investigate factors which might affect the water quality of East Pond (Figure 14b). Six sampling sites, located 50 m from shore, were scattered around the perimeter of the lake. They were chosen to gauge the relative impact of prominent residential, recreational, and marsh areas. One site was located in the center of the lake body, to serve as a control (the least likely to be affected by land use patterns). A geographic description for each site is listed below.

SITE 14: Located in the northeast corner of the lake in a small cove. It was equidistant from two developed residential areas on the northern and southern corners of the cove. It was chosen to measure the impact of a densely developed residential areas.

SITE 15: A developed residential area with the sampling site located in the center of a major cove directly north of Brickett Point on the Somerset/Kennebec County line on the eastern shore of the lake. The sample was taken 50 m from the shoreline. This site was selected to gauge the effects of residential areas, as well as a pier with road access.

SITE 16: Represented the most concentrated residential area of the pond. The sampling location was 50 m from shore, equidistant from Libby Point and Brickett Point shorelines, in the southeast corner of the lake. The cove is lined by many homes close to shore with docks and boats.


POND BOG
Serpentine
W
W
W
EAST POND
27
14
3-84
Cem
347T
282T
Miller Islands
19
29
28
Ram Island
H F I E L D
342
EAST 20 POND
WL 263
3-83
18
11
306
300
Loon Island
25
Brickett Point
Birch Island
SOMERSET CO
KENNEBEC CO
Pier
15
26
County Line
337
330
3-63
293
16
23
22
Libby Point
352
34
400
HILL
HORN HILL ROAD
W
BM 366
X-R 365
3-64
BM 366
C Rd Fk 363
FAIRFIELD
350
360

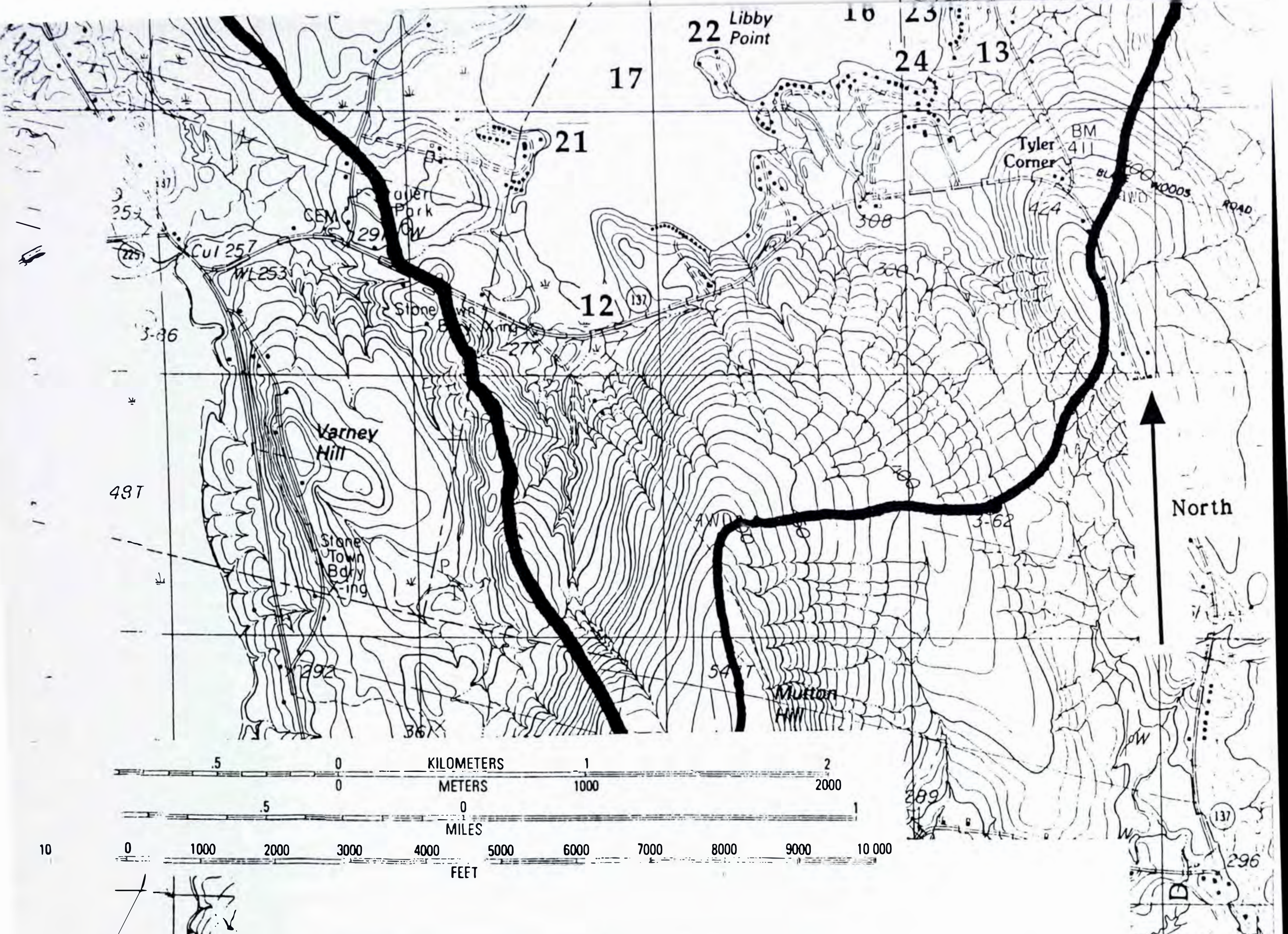


Figure 14b. Sampling sites for East Pond. 1982 USGS map, scale (1:16,000).

SITE 17: Located in the center of a major cove at the southern tip of East Pond, the site was selected to measure the effects of two large recreational compounds. It was 50 meters from shore and centered between the Libby Point shore line to the east and the Somerset/Kennebec County line to the west.

SITE 18: Located in the center of a small cove on the western shore, roughly 50 m from the shore, this site was chosen to contrast the densely populated areas and to detect the influence of an isolated marshy area close to the lake shore and near Joly Stream.

SITE 19: Located along the northwestern shore, south of the Serpentine Stream and southwest of the Miller Islands. The sampling location was in the center of a cove adjacent to a highly concentrated group of homes, many of which are very close to the shore. Sampling was completed approximately 50 m from the shore.

SITE 20: The control site located in the center of the pond and at the deepest point, least affected by the surrounding land. The site was equidistant from the eastern and western shore, and centered North to South between Ram and Loon Islands.

Land Use Study Sites:

Sixteen sites were chosen to study the effects of different land use patterns on the lake and its tributaries (Figures 14a and b).

SITE 21: Located 7 m offshore from the point at Alden Camps.

SITE 22: Located 7 m offshore from the large house with the sculpted lawn on Libby Point.

SITE 23: Located 7 m offshore from the northeast corner of Libby Point Cove.

SITE 24: Located 7 m offshore from the southeast corner of Libby Point Cove.

SITE 25: Located 7 m offshore from the tip of Brickett Point, between Loon Island and Brickett Point.

SITE 26: Located 7 m offshore at the midpoint of the shoreline in Brickett Point Cove.

SITE 27: Located 7 m offshore from the abandoned camp buildings on the northeast end of East Pond.

SITE 28: Located 7 m offshore from the development on the southern end of the southernmost island of the Miller Islands.

SITE 29: Located 7 m offshore from the midpoint of the strip of development on the northwest side of East Pond.

SITE 30: Located 7 m off Clark Brook's shore closest to Route 8 on the eastern side of the snowmobile bridge crossing the brook.

SITE 31: Located on the Serpentine Bog, approximately one fourth of the distance from the confluence of the Serpentine Marsh and the Serpentine Bog to the entrance to East Pond. Sample was taken in the middle of the stream.

SITE 32: Located in the middle of the tributary immediately to the east of Sucker Brook, at the point where Sucker Brook joins this tributary.

SITE 33: Located 1 m from the eastern shore of the tributary immediately to the east of Sucker Brook, at the point where the field directly touched the edge of the water.

SITE 34: Located 1 m from the northern tip of the tributary immediately to the east of Sucker Brook, at the point where the canoe could no longer traverse.

SITE 35: Located on Sucker Brook 2m upstream from Route 8.

SITE 36: Located 2 m offshore from the indentation immediately to the west of the confluence of the Serpentine Marsh and the Serpentine Bog, where the field slopes down to the water's edge.

Water Quality Methodology

Physical Measurements:

Temperature: Temperature influences the amount of dissolved oxygen in the water, consequently affecting the biota of the pond. Cold water has the ability to hold a greater amount of oxygen than warm water. Temperature was recorded with a Beckman pH/ temperature meter.

Secchi Disk: A secchi disk measures the turbidity in the water column. Very turbid waters can indicate low fish populations due to poor reproductive success, and possible nutrient loading which may lead to pond eutrophication. Transparency in Maine lakes usually ranges from 3-7 meters(Pearsall, 1991); any reading below two meters is classified as an algal bloom.

Turbidity: Turbidity is an index of the amount of suspended solids in the water. High turbidity may indicate a high concentration of algal biomass in the water column. Turbidity is measured in the form of Formazin Turbidity Units (FTUs) using the DR/3000 spectrophotometer.

Conductivity: Conductivity measures the amount of solutes in the water and is measured in µmhos/cm2. In Maine, a clean lake will have a conductivity ranging from 20-40 µmhos/cm2(Pearsall, 1991). Conductivity was measured with the YSI Model 33 S-C-T meter which measures dissolved salts and ions.

Chemical Measurements:

pH: The pH is a measure of the concentration of hydrogen ions in the water. Typically, Maine lakes range from 6.1 - 7.4 in pH(Pearsall, 1991). The pH was recorded with a Beckman pH/temperature meter.

Dissolved Oxygen: Dissolved oxygen (DO) is a measure of oxygen content in the water column. A healthy lake should have a high level of DO. A DO level below 5 ppm puts stress on the fish population, and a level below 2 ppm may result in accelerated phosphorus loading from the sediments(Pearsall, 1991). DO levels were determined by using a dissolved oxygen probe with Clark-type polarographic electrodes.

Total Phosphorus: Phosphorus is the primary limiting nutrient in algal growth, which may lead to accelerated pond eutrophication. Any level of total phosphorus over 15 ppb may accelerate eutrophication(Pearsall, 1991). This test was conducted by using the Hach DR/3000 spectrophotometer and the persulfate/UV oxidation method with a range of 0-20 mg/l (Hach, 1985). Values were divided by a factor of 3, in order to express results as total phosphorus.

Orthophosphate: Orthophosphate is the form of phosphorus available to vegetation as a nutrient, and plays a significant role in accelerating pond eutrophication. The Hach DR/3000 spectrophotometer and the molybdovanadate method with a range of 0-20 mg/l was used for analysis of samples (Hach, 1985). The orthophosphate values were divided by 3 to express results as reactive phosphorus.

Nitrate: Nitrate is an important nutrient in algal growth. High levels of nitrates are usually associated with agricultural and fecal pollution in lake water (Pearsall, 1991). The Hach DR/3000 spectrophotometer and the cadmium/reduction method with a range of 0-5 mg/l was used for sample analysis (Hach, 1985).

Ammonia: Ammonia is one of the primary forms of nitrogen in aquatic ecosystems and is a limiting nutrient in plant growth. Ammonia concentration is generally used as an indicator of untreated sewage (R.S. Irving and Associates Inc., 1982). Large amounts of ammonia in an aquatic ecosystem can hasten the eutrophication process. In our study, the Wescan Model 360 Ammonia Analyzer was used for sample analysis.

Tannins and Lignins: Tannic acid is a product of vegetative decomposition. A high level of tannins and lignins turns the water brownish yellow in color and may influence turbidity. Tannins were measured in mg/l with a Hach tannin and lignin test kit and the DR/3000 portable spectrophotometer (Hach, 1985).

Biological Measurements:

Chlorophyll a: Chlorophyll a is an index of the biomass of algae present in the water column. Values for Maine lakes typically range from 2 to 8 ppb(Pearsall, 1991). Values greater than 30 ppb are considered to indicate an algal bloom.

Coliform: *E. coli* or coliform bacteria are indicator organisms of fecal pollution. Total coliform indicates the presence of intestinal bacteria, while fecal coliform specifically indicates recent fecal waste from warm blooded animals. For recreational waters such as East Pond, the maximum permissible fecal coliform count per 100 ml water is 1,000 colonies. Water samples taken from surface grabs 15 m from shore were analyzed using the standard membrane filter technique.

Water Budget

Methods:

The water budgets for both the East Pond watershed and the Serpentine watershed (part of North Pond Watershed) were calculated to compare the two and gauge possible effects each watershed might have on the other. Using the Zeiss Interactive Digital Analysis System (ZIDAS) and a United States Geological Survey (USGS) map of known scale (1:24,000), values were found for both the water and land surface area. With the areas and average annual rainfall data from a weather station at Madison (15 km north of Smithfield) for the years 1982-1990, a water budget for both the Serpentine and East Pond watersheds was calculated (Appendix C).

Water Budget for the East Pond and Serpentine Watersheds

Runoff: 24.5 in/yr (0.62 m/yr) (North Kennebec Regional Planning Commission, pers. comm.)

Precipitation: 40.11 in/yr (1.02 m/yr) (Madison) taken as an average for the years 1982-1990.

Evaporation: 22 in/yr. (0.56 m/yr) (Prescott, 1969) Ground-water favorability areas and surficial geology of the lower Kennebec River Basin, Maine. Hydrologic Investigations Atlas HA-337. U.S. Dept. of Interior, U.S. Geological Survey, Washington, D.C.).

Equation for calculating the water budget:

East Pond:

new input to East Pond per year in m^3 I_{net} =
(runoff x land area) + (precipitation x land area) - (evaporation x lake area)

Therefore the change in the volume of East Pond per year $I_{net} = 9,880,216\ m^3$

There would be 2,608,377,024 gallons (264 gallons in 1 m^3) net increase per year in East Pond.

This increase flows into the Serpentine stream, the major outlet for East Pond.

Serpentine Stream and Wetland:

new input to the Serpentine stream and wetland per year in m^3 I_{net} =
(runoff x land area) + (precipitation x land area) - (evaporation x lake area)

Therefore the change in the volume of the Serpentine stream and wetland per year $I_{net} = 10,061,216\ m^3$

There would be 2,656,161,024 gallons net increase per year in the Serpentine stream and wetland.

This increase normally flows into North Pond, the next link in the Belgrade chain of lakes.

Water Quality Testing

Lake Water Quality Testing Procedures

The water quality of East Pond was tested for physical, chemical, and biological characteristics (Table 5). All water sampling was conducted on October 3 and 10, 1991. The samples were collected from all sites, except for the chlorophyll a test, which was only collected

Table 5. Lake water quality tests of physical, chemical, and biological characteristics. Sample sites and date of sampling and analysis are indicated. Samples were not conducted at all depths for each site. Refer to Appendix D for a complete summary of the data including the depths sampled for each site.

Test	Sampling date	Testing date	Site(s)
Physical factors			
Temperature	10/3/91	10/3/91	14-20
Secchi disk	10/3/91	10/3/91	14-20
Turbidity	10/3/91	10/3/91	14-20
Conductivity	10/10/91	10/10/91	14-20
Chemical factors			
pH	10/10/91	10/10/91	14-20
Dissolved Oxygen	10/3/91	10/3/91	14-20
Orthophosphate	10/10/91	10/11/91	14-20
Total Phosphorus	10/10/91	10/17/91	14-20
Nitrate	10/10/91	10/10/91	14-20
Ammonia	10/10/91	10/17/91	14-20
Biological factor			
Chlorophyll a	10/3/91	10/4/91	20

at the control site (site 20) at the surface. The stratification for sampling was split into surface, mid-depth, and bottom. Nitrate, orthophosphate, and reactive phosphorus were not tested at mid-depth at sites 14, 15, 17, and 20 (Appendix D). Orthophosphate, and therefore reactive phosphorus, was not tested at the bottom at site 14. Total phosphorus was not tested at the bottom at sites 15 and 16, and at site 19 it was not tested at the surface. For mid-depth at sites 16 and 19, the following tests were not conducted: pH, nitrate, ammonia, orthophosphate, reactive phosphorus, and total phosphorus. No testing was conducted at mid-depth at site 18 due to shallow water at this point. Water quality analyses were carried out between October

3 and 17, depending on the test. Sampling and testing were conducted according to procedures described in the quality assurance plan (Appendix B).

Results and Discussion

Physical Measurements

Secchi disk: Secchi disk readings were taken at sites 14-20 on October 3. The secchi disk hit the bottom at every site except site 20. The deepest depth hit (4.3 m) was recorded at site 16. The shallowest depth hit (2.0 m), occurred at site 19. At site 20, the deepest site in our testing series and in the lake, the secchi disk transparency depth was 4.0 m.

Secchi disk transparency is a simple way to measure water quality trends over extended periods. In Maine, secchi disk transparency ranges from 3 to 7 m with an average of 5.6 m (Pearsall, 1991). The average secchi disk readings over a season can be related to aquatic ecosystem productivity, with visibility under 4 m denoting productive water, over 7 m indicating unproductive water, and in between this range are moderately productive waters (Pearsall, 1991).

Our reading of 4 m is consistent with DEP data taken over extended periods (Figure 15). It is slightly lower than DEP averages perhaps due to the overcast conditions on our sampling day as well as expected variation among sample takers.

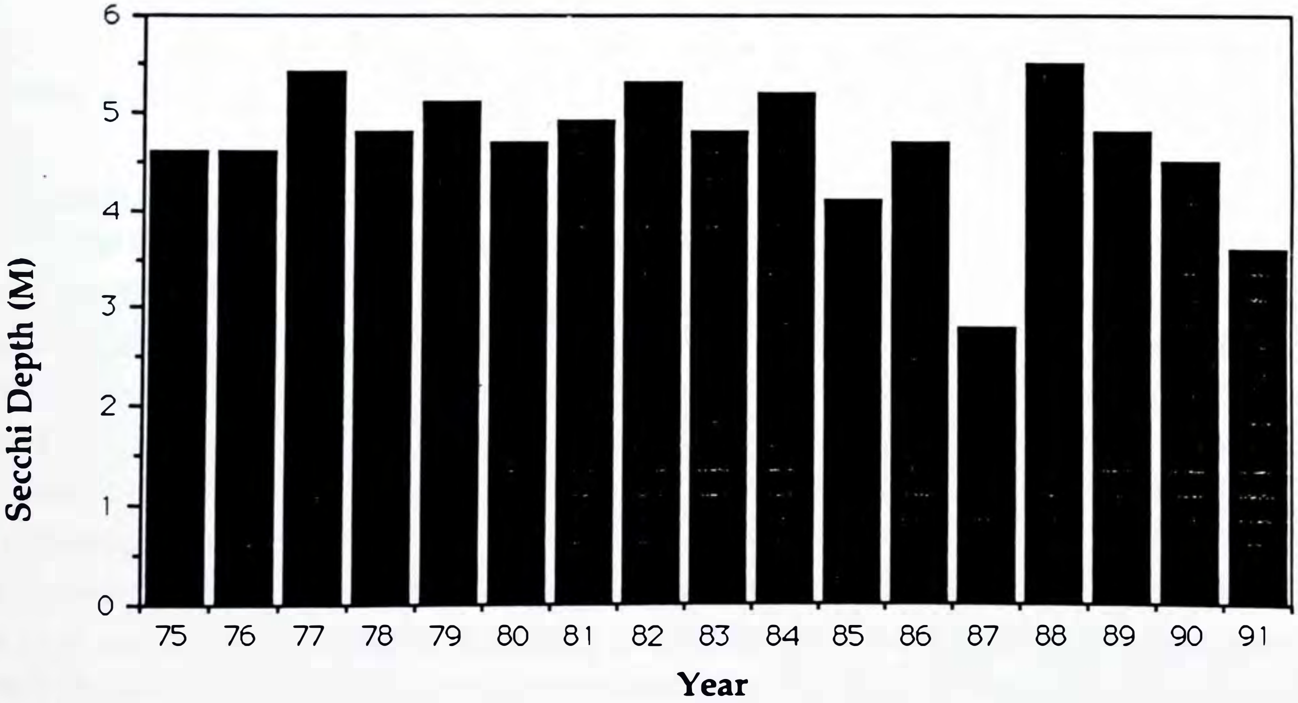


Figure 15. East Pond secchi transparency depths in meters for 1977-1991.

DEP annual secchi transparency averages give an interesting depiction of the last seventeen years in the life of East Pond. These annual averages show a general steady trend before and a declining trend after 1987. In 1987, when an algal bloom occurred, average secchi depth dropped to 2.8 m. This drop indicated a water quality problem in East Pond.

Turbidity: The turbidity data indicates little variation in the clarity of East Pond at the seven sites as well as the stratification levels tested (Table 6). The mean turbidity value for the lake at all sites and stratifications is 4.7 FTUs with a range of 1.8 FTUs. The DEP does not conduct the turbidity test; instead they conduct the secchi disk test which also measures the clarity of the lake body. Due to the lack of DEP or any previous turbidity data recorded for East Pond, our turbidity test simply indicates a relatively uniform clarity throughout East Pond.

Table 6. Turbidity profile at East Pond, October 1991.

Site	Surface	Mid depth	Bottom	Mean
14	4.0	5.0	8.5	5.8
15	4.0	6.0	4.0	4.7
16	5.0	*	4.0	4.5
17	4.0	4.0	5.0	4.3
18	5.0	*	5.0	5.0
19	5.0	*	4.0	4.5
20	3.0	4.0	5.0	4.0
Mean	4.3	4.8	5.1	4.7

*No mid-depth sample taken due to shallowness of site

Chemical measurements

Conductivity

The conductivity measurements taken Oct. 3 at taken at sites 14 thru 20 on East Pond are comparatively low in value and ranged from 25 µmhos/cm^2 to 40 µmhos/cm^2. The overall average conductivity for all of the sites at all levels was 29 µmhos/cm^2 (Appendix D).

In Maine, a clean lake has an average conductivity value in the range from 20 µmhos/cm^2 to 40 µmhos/cm^2. The conductivity measurements for East Pond over time show that this lake is relatively healthy because conductivity values are well within the "clean lake" range. Increasing conductivity values indicate increasing amounts of sediment, nutrients, and algae in the water column. The results for previous years obtained from the DEP show that the mean annual conductivity declined from 1978 to 1980 and remained relatively constant from 1981-1991 (Figure 16). Thus, the conductivity measurements do not indicate any increase in biomass or sediment loading in East Pond. It is important to consider, however, that the measurement for 1991 was only taken at one time of the year where as the other values represent annual

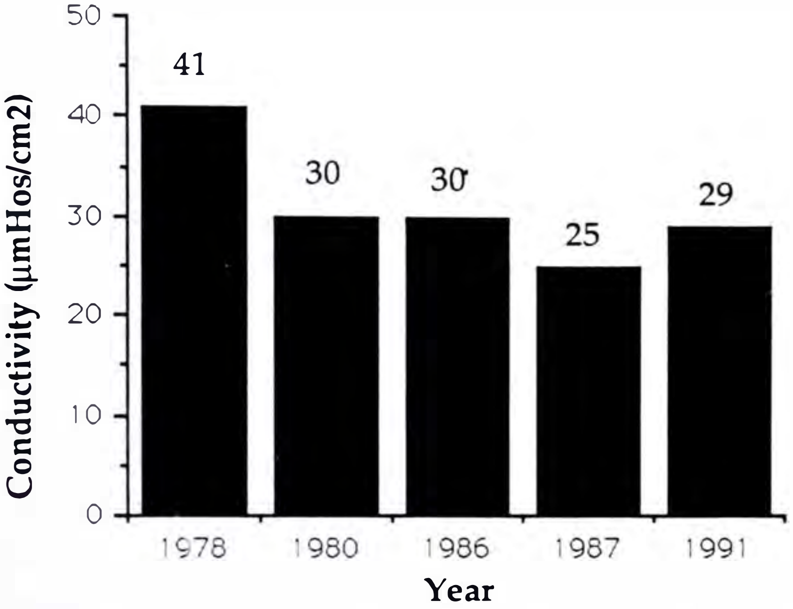


Figure 16. Mean annual conductivity over time collected by DEP. Value from 1991 represents one sample taken in October.

averages. There was also a difference in test sites between 1991 and the other years so these data may not be fully comparable.

pH: On Oct. 3 pH readings were taken at East Pond for every site at varying depths depending on the site (Appendix D). The pH values had a narrow range between 6.9 and 7.2. The overall mean pH for the lake was 7.1, which is essentially neutral.

The pH of a lake is important in determining the plant and animal species present. The typical pH values of lakes in Maine range from 6.1 to 6.8 (Pearsall, 1991). The pH level in East Pond (7.1) is higher than the average pH for most Maine lakes. The DEP took pH readings during previous years at East Pond that also show a higher pH (Table 7). It is important to remember that the data for 1991 were only taken at one time of the year whereas the DEP values represent annual averages.

Table 7. Mean annual pH of East Pond collected by DEP. 1991 value represents one sample taken on October 3.

Year	pH
1983	7.2
1984	7.2
1986	7.2
1987	6.9
1991	7.1

Dissolved Oxygen and Temperature: A relationship exists between water temperature and dissolved oxygen concentrations. As water cools, dissolved oxygen levels increase and as water warms, its ability to hold oxygen decreases. Therefore, when temperature and dissolved oxygen are analyzed over time, their relative values oppose each other.

On Oct. 3, temperature and dissolved oxygen data were collected at seven sites in East Pond. Dissolved oxygen was not collected at mid-depth at site 18.

The EPLA monitored temperature and dissolved oxygen levels in the fall of 1990. These data offer a good comparison to the data that we collected (Figure 17).

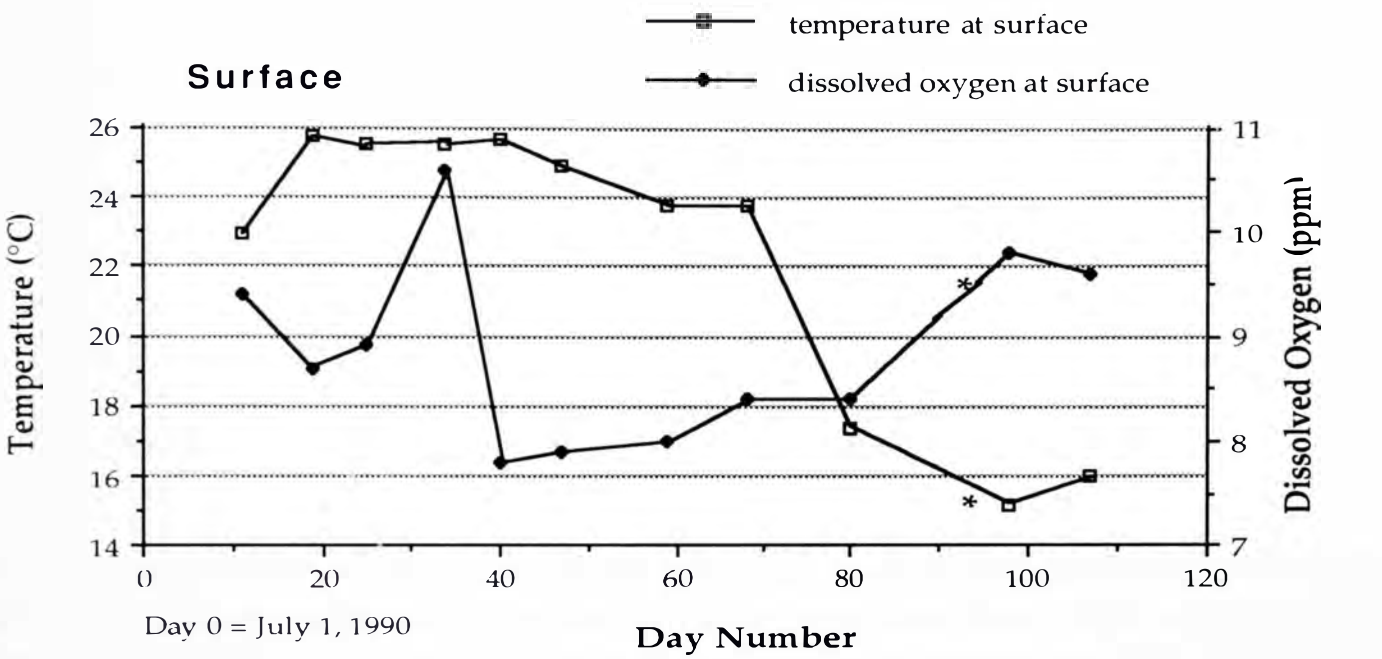
Our findings for temperature and dissolved oxygen on Oct. 3 (indicated by asterisks on the figure), are very close to the findings of the EPLA for the same time period in 1990. Our temperature findings are slightly lower and our dissolved oxygen findings are slightly higher than those found by the EPLA a year earlier.

As expected, the data for temperature and dissolved oxygen levels mirror each other (Figure 17). As the seasons change from summer to fall and the air temperature drops, the water temperature falls and dissolved oxygen levels increase. The figure illustrates the cooling of the lake and the approach of fall overturn. The one exception to this trend is seen in early June (day 35). This may have occurred due to two or three consecutive windy days. As East Pond is relatively shallow, strong winds could disrupt any stratification that may exist and mix the water column. This would increase the dissolved oxygen levels throughout the water column and therefore account for the peak in dissolved oxygen levels at both the surface and six meters.

The DEP has also collected temperature and dissolved oxygen data for East Pond over the past several years. These data, in general, correspond with EPLA data and our data. Temperature and dissolved oxygen levels in East Pond have varied slightly in past years, but not enough data are available for any single past year to make a direct comparison with the EPLA data and therefore long term trends cannot be interpreted.

Total Phosphorus: The mean total phosphorus for October 1991 was 7 ppb, ranging from a minimum of 3 ppb to a maximum of 14 ppb (Appendix D). Means for each site could not be calculated, because stratification levels at certain sites were not tested.

Total phosphorus is present in small amounts in all Maine lakes and does not present a problem to the health of the lake. However, if phosphorus is added in large enough quantities by human activity, excessive plant growth may result in the form of an algal bloom. Values exceeding 15 ppb are cause for concern for the DEP, because this level can support algal blooms and deteriorate the relative health of the pond (Pearsall, 1991). In 1987, an algal bloom was observed on East Pond and a mean annual total phosphorus value of 23 ppb was recorded by the DEP (Table 8). Fortunately, since 1987, the amount of total phosphorus has steadily



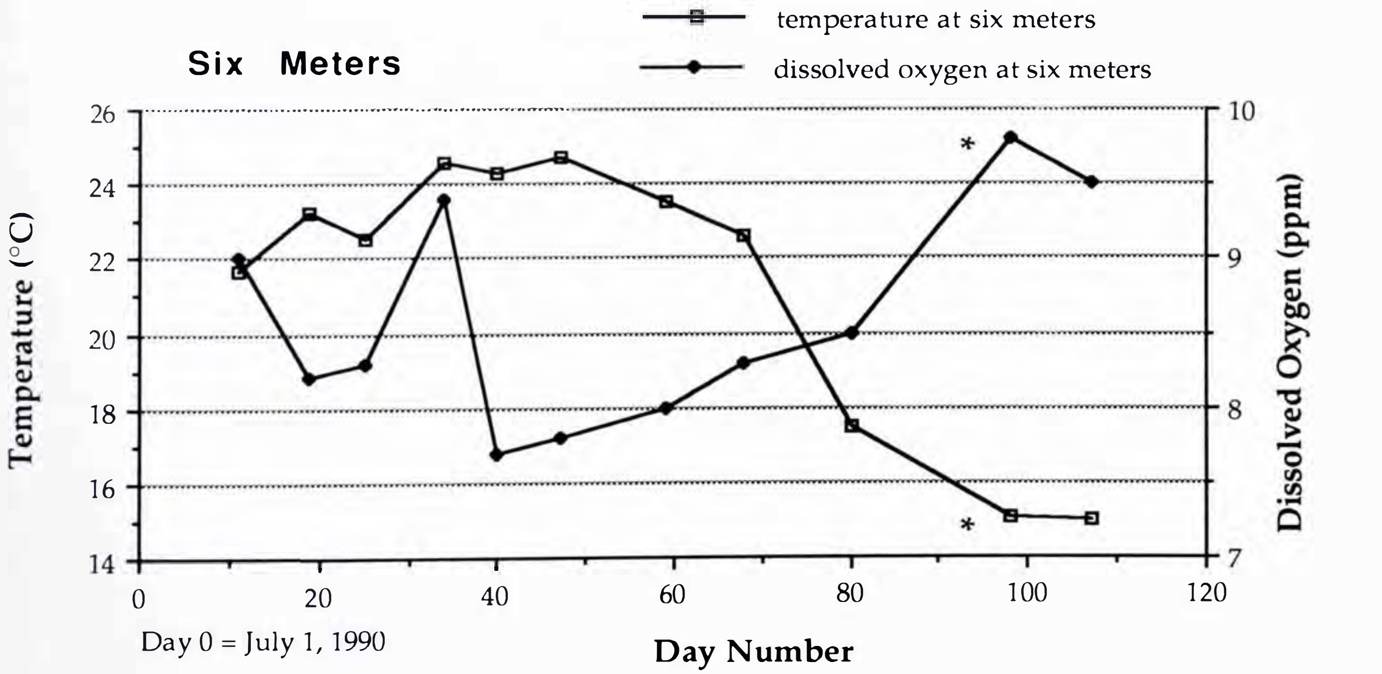


Figure 17. Temperature and dissolved oxygen levels taken in 1990 by the East Pond Lake Association at the surface and at a depth of six m. Data points from the present study, taken Oct. 3, 1991, are indicated by an asterisk.

Table 8. DEP mean annual total phosphorus data for East Pond.

Year	Mean Total Phosphorus (ppb)
1987	23
1988	17
1989	12
1991[1]	7

[1] East Pond data taken October 10, 1991

declined to an acceptable level of 7 ppb for 1991 (Figure 18). If total phosphorus continues to follow the downward trend it has shown in the past, East Pond could reach a level of phosphorus of 6 ppb or lower. Lakes with phosphorus levels this low are characterized by the DEP as unproductive which means that the general quality of the water is high (Pearsall, 1991).

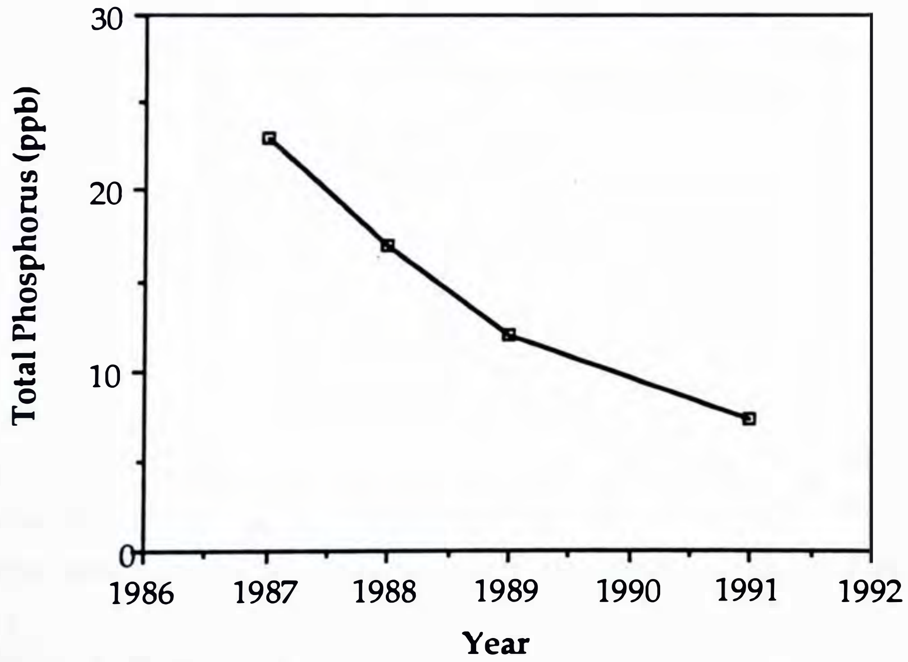


Figure 18. Mean annual total phosphorus in East Pond. 1987-89 data from DEP; 1991 data from the present study.

Orthophosphate: Water was collected on Oct. 10 at sites 14-20 at both the surface and bottom to test orthophosphate levels in East Pond (Table 9). Orthophosphate concentrations ranged from 13 ppb on the bottom at site 18 to 31 ppb at the surface at site 19. The mean orthophosphate concentration of the samples taken was 24 ppb. Orthophosphate values expressed as reactive phosphorus are presented in Appendix D.

Table 9. Orthophosphate levels in East Pond at sites 14-20. Samples taken 0.5 m below the surface and 0.5 m above the bottom on October 10, 1991.

Sites	Surface (ppb)	Bottom (ppb)
14	23	--
15	22	24
16	18	16
17	20	13
18	31	20
19	26	26
20	25	15

Nitrate: The test results for nitrate were inconclusive. Because the DEP does not test for nitrate, there were no data available to make comparisons. The mean nitrate level was .03 ppm, the high was .04 ppm , and the low was .02 ppm. There appears to be no correlation between the level of nitrate and the individual test sites (Figure 19).

Ammonia: Results of 0.0 ppm ammonia were found at all of the sites and stratification levels tested on East Pond (Appendix D). These data are consistent with the location of the testing, since ammonia is not a problem in most Maine lakes (Pearsall, 1991). These data also show that ammonia levels are insufficient to affect the water quality of East Pond.

Biological parameters and observations

Chlorophyll a: The chlorophyll a test was conducted at Northeast Labs in Winslow, Maine. The uncorrected value for chlorophyll was 3.1 ppb for the sample. However, the corrected value, which excludes all chlorophyll pigments except chlorophyll a, yielded a value of 2.6 ppb. This corrected value is a direct indicator of the amount of algal production in the

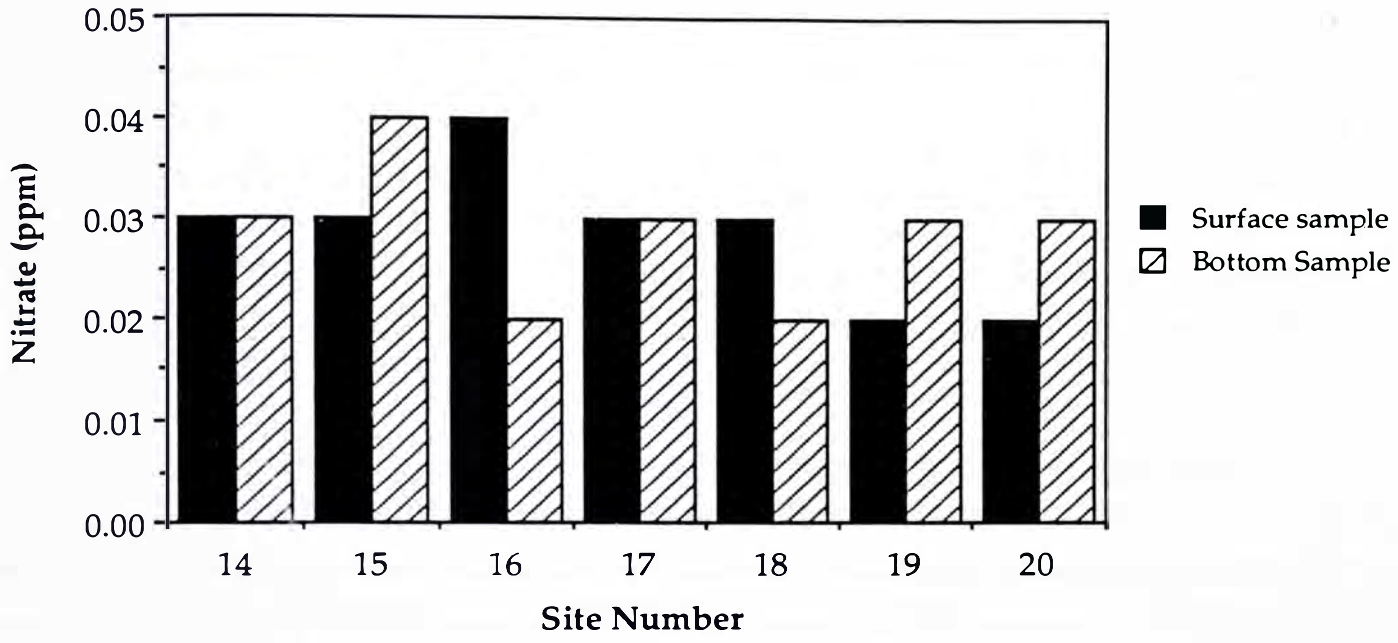


Figure 19. Nitrate levels measured at the surface and near the bottom at seven sample sites in East Pond.

lake body.

According to DEP standards (Table 10) the 1991 East Pond chlorophyll a value of 2.6 ppb classifies East Pond in a safe category at present. It is within the low range of average Maine lakes, significantly below the value of 30 ppb for an algal bloom. East Pond is classified as a moderately productive lake, falling between 2 and 7 ppb. The one sample collected, however, was taken at site 20 which is located in the middle of the lake body (the control site) and represents the area in the lake least affected by activity on the shore.

Table 10. DEP standards for chlorophyll a in Maine lakes.[1]

Classification	ppb
Algal Bloom	≥ 30
Productive Lake Body	≥ 7
Moderately Productive Lake Body	2-7
Unproductive Lake Body	≤ 2
Average range for Maine Lakes	2-8

[1](Pearsall, 1991)

DEP recorded low levels of mean annual chlorophyll a during 1976, 1978, 1980, and 1988, with values of 3.1, 3.1, 3.0, and 2.2 ppb, respectively (Table 11). Only chlorophyll a in 1987 indicates a high level of algal production at 7.2 ppb. The low level of chlorophyll a recorded in 1991 is similar to annual values kept by the DEP for every year except 1987 (Figure 20). The chart represents a trend of low algal biomass from 1976 to 1980, an unusually high value in 1987, and a quick recovery to low levels of biomass in 1988 and 1991. Thus in relation to previous annual data recorded, low levels of chlorophyll a in October of 1991 signify the general health of East Pond and a quick recovery from the highly productive year of 1987.

Table 11. Annual mean chlorophyll a at East Pond during 1976, 1978, 1980, 1987, and 1988 measured by the DEP, and 1991 data from the present study.

Year	Minimum (ppb)	Maximum (ppb)	Mean (ppb)	Range
1976	3	3	3	0
1978	3	3	3	0
1980	3	3	3	0
1987	3	13	7	10
1988	0	4	2	4
1991[1]			3	

[1] Represents one value taken in October, 1991.

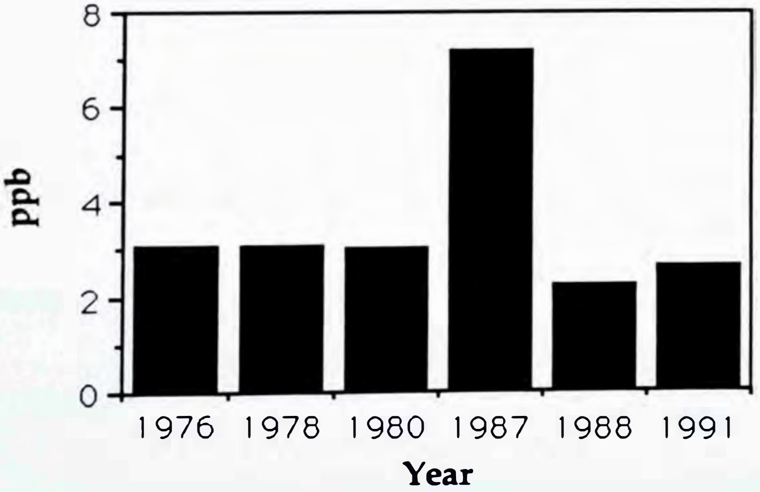


Figure 20. Mean annual Chlorophyll-a collected by DEP. Value from 1991 represents sample taken in October during the present study.

East Pond Tributaries

Description of sampling sites

Tributaries entering East Pond directly were sampled on October 24, 1991, to investigate their effects on nutrient loading and for comparison with findings from Clark and Sucker Brooks entering the Serpentine. Several sites were reviewed for possible sampling. There was evidence of several ephemeral streams flowing only after storms. Two streams were identified as flowing steadily to East Pond during normal conditions. These streams were chosen for sampling. The streams are located adjacent to the home of Bob Joly (Joly Stream; site 11) and at Libby point (Libby Point Stream; site 13) (Figure 14b). Site 11 is located near a summer camp and the sampling was done approximately 75 m from East Pond. Site 13 is near a residential neighborhood and the sampling was done where the East Pond Road crosses the stream, approximately 500 m from East Pond.

Flow rate and pattern

Flow measurements were taken at sites 11 and 13 on October 24, 1991. Flow rates were measured by using a float and recording both the distance traveled and the length of time it took the float to cover this distance. This procedure was repeated three times and an average value was calculated. A meter stick was used to determine width and depth of the stream where the flow was measured. The width of the stream at site 11 was highly variable, ranging from 29 in to 36 in where readings were made. The stream narrowed considerably more as it approached East Pond. Average depth at the sample site was 6 in. Flow rate was calculated to be 1.44 cubic feet per second (Refer to Tributaries and Wetlands: Flow Patterns and Rate for methods description). Site 13 was 43 inches in width at the sampling site and had an average depth of 7.25 in. Flow rate was calculated to be 0.77 cubic feet per second.

Water quality tests

Materials and methods

On October 24, 1991, sites 11 and 13 were tested during normal weather conditions for pH, turbidity, reactive phosphorus, and total phosphorus. Due to the shallow depth of the stream, water samples were collected only from the deepest area of the stream. Care was taken not to stir up bottom sediments during this collection (Refer to Analytical Procedures and Findings:

Water Quality Methodology for a description of tests).

Results and discussion

The pH values at sites 11 and 13 were similar (pH 5.9 and 5.8, respectively). Turbidity at site 11 was slightly higher (7 FTU) than site 13 (4 FTU). Reactive phosphorus was identical at the two sites with values of 5 ppb (Figure 21). Total phosphorus at site 11 (25 ppb) was more than double total phosphorus at site 13 (11 ppb). Total and reactive phosphorus values from sites 11 and 13 were then compared to total and reactive phosphorus values at sites 4 and 10 (Clark Brook and Sucker Brook) in order to determine relative contributions between tributaries entering the Serpentine (sites 4 and 10) and tributaries entering East Pond directly (sites 11 and 13). Site 10 had the highest values for both types of phosphorus with total phosphorus 63 ppb and reactive phosphorus 17 ppb. Site 4 also had a high value for total phosphorus at 41 ppb. Reactive phosphorus was much lower at site 4 at 7 ppb (Figure 21).

From comparisons made between the tributaries entering East Pond directly and tributaries entering the Serpentine, we believe that tributaries entering the Serpentine wetland may be more important sources of nutrient loading to East Pond. Total phosphorus during our sampling was more than double at site 10, Sucker Brook, than values found at site 11 and more than five times greater at site 10 than site 13. Clark Brook (site 4) is also showed higher total

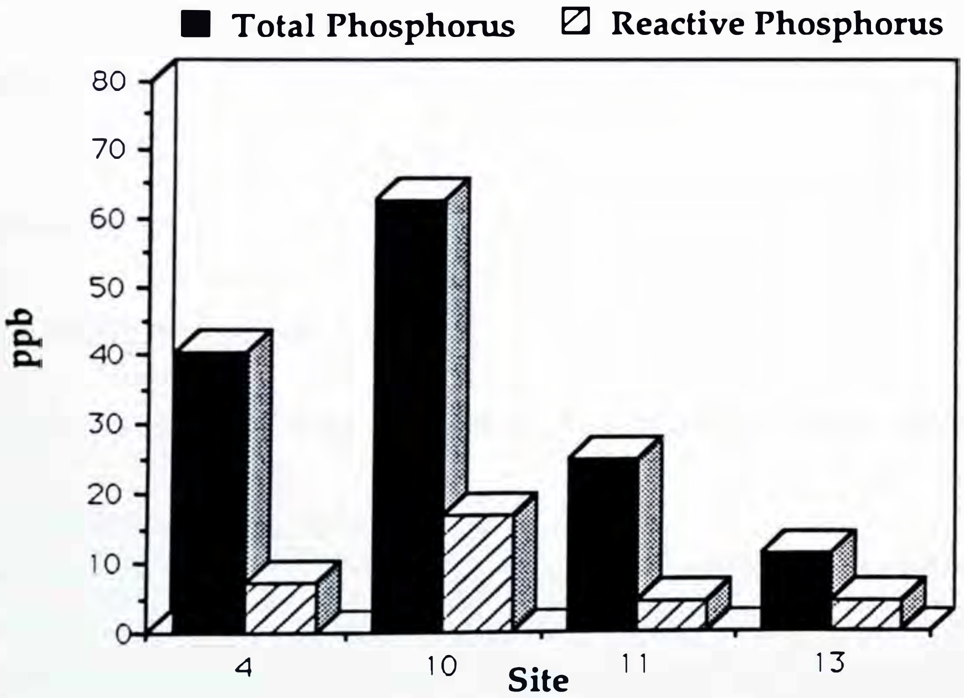


Figure 21. Total and reactive phosphorus data comparing East Pond (sites 11 and 13) and Serpentine marsh tributaries (sites 4 and 10). Samples taken on October 24, 1991 at East Pond tributaries and on October 10, 1991 at Serpentine marsh tributaries.

phosphorus values than both sites 11 and 13. This indicates both Sucker and Clark Brook may be transporting a greater sediment load than tributaries located at Libby Point and adjacent to Bob Joly's property. The tributaries entering the Serpentine run through agricultural lands with increased erosion, while the East Pond tributaries travel primarily through forest land. However, it is important to note that site 11 is located near a summer camp which may cause increased nutrient loading during summer months. In particular, nitrate values may significantly increase when camps are in use due to an increase in nitrogenous waste production and septic system use. We did not analyze for nitrate at this time because the camps had not been in use for two months.

Conclusion

Tributaries at sites 11 and 13 enter East Pond directly and therefore may be sources of nutrient loading to East Pond. Our analyses indicate they may not be important sources of nutrient loading, however increases in nitrate during summer months should be considered when assessing the significance of these tributaries. It was not possible to test the impact of ephemeral streams on East Pond during our study period, however these streams should be considered if future development is to be located near them. Potential nutrient loading from the Serpentine watershed appears to be more important to consider when investigating the water quality of East Pond.

Tributaries and Wetlands

Description of sampling sites

Serpentine Stream and wetland study sites:

Ten sites were chosen for analysis of the Serpentine stream and wetland (Figure 14a).

Serpentine Tributaries:

Three sampling sites were located in the tributaries in the northeastern section of the Serpentine wetland. Site 4, located at the mouth of Clark Brook, was chosen because of the dairy farm next to the stream which could have an impact on the water quality. Site 9 is located near the mouth of Sucker Brook. Both sites were chosen to measure physical and chemical parameters as the water enters the wetland. Site 10 was also located on Sucker Brook but to the north of site 9 and situated next to Route 8. This site was selected to see if differences in physical and chemical parameters occurred between site 10 and site 9, as water passes under Route 8 (site 10) and then through the wetland to site 9.

Serpentine Marsh:

The Serpentine Marsh is comprised of the northern marsh drainage and the developed area of the Serpentine which extends to the dam in Smithfield. Site 4 was located at the mouth of Clark Brook in order to determine the amount of nutrients entering the marsh from Clark Brook. Site 3 was located in the Serpentine Marsh at the confluence of Clark and Sucker Brooks to determine total contribution of these tributaries to marsh water quality. Sites 2 and 1 were located in the developed area of the Serpentine stream. Site 2 was located near site 5 and was chosen to measure water quality after the Serpentine Bog flow had joined water flowing from the marsh drainage. Next to the dam, site 1 was selected in order to record physical and chemical parameters as the water leaves the Serpentine watershed.

Serpentine Bog:

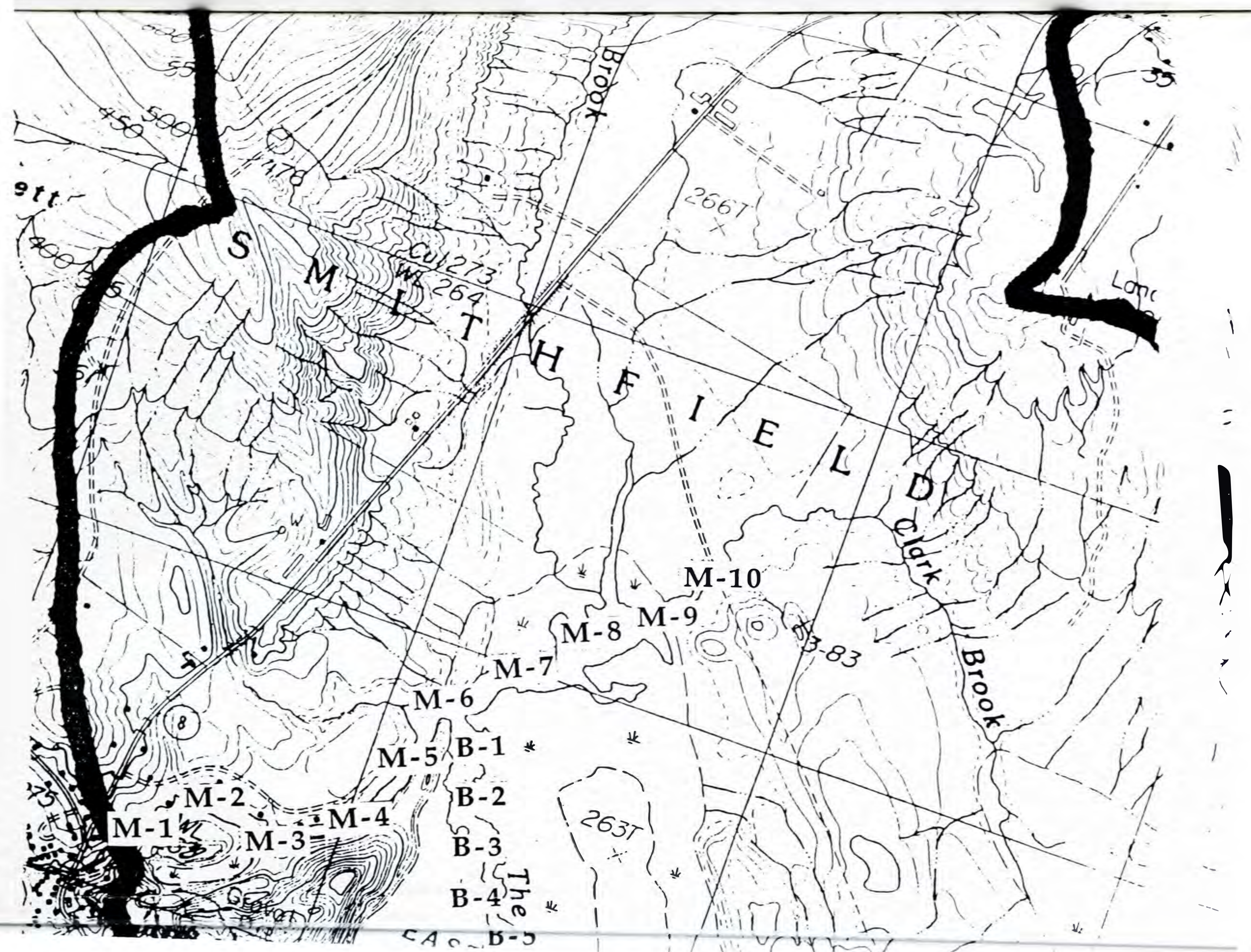
The Serpentine Bog is comprised of the waters adjacent to East Pond bog, and extends from its conjunction with the Serpentine Marsh in the north to the mouth of the Serpentine stream, located at the opening of East Pond in the south. Four sampling sites separated by approximately equal spacing (sites 5-8) were located in the Serpentine Bog region. The reason for choosing these sites was to note differences in both physical and chemical parameters that may exist under normal and back flush flow conditions along this portion of the Serpentine. Specifically, when water is flowing into the Serpentine from East Pond, and during a backflushing event when flow is from the Serpentine wetland into East Pond.

Serpentine Marsh transect:

Due to patches of turbidity observed on Sept. 26 at the area where the Serpentine Marsh meets the Serpentine Bog and at the confluence of Sucker and Clark Brooks, a transect extending the length of the Serpentine Marsh was established. The transect had ten sites (M-1 through M-10) spread at approximately equal intervals from the dam site to Clark Brook (Figure 22). Testing along the transect was conducted on Oct. 3 and Oct. 10 with turbidity, secchi disk, conductivity, and pH being measured.

Serpentine Bog transect:

The Serpentine Bog transect followed the flow of water along the Serpentine stream from the outlet of East Pond to its conjunction with the waters of the Serpentine Marsh (Figure 22). The Serpentine Bog sampling sites were comprised of fourteen equidistant points, sites B-1



SMITHFIELD
Brook
Clark Brook
2667
Cul 273
Wt 264
500
450
400
476
263T
3-83
The
M-1
M-2
M-3
M-4
M-5
M-6
M-7
M-8
M-9
M-10
B-1
B-2
B-3
B-4
B-5

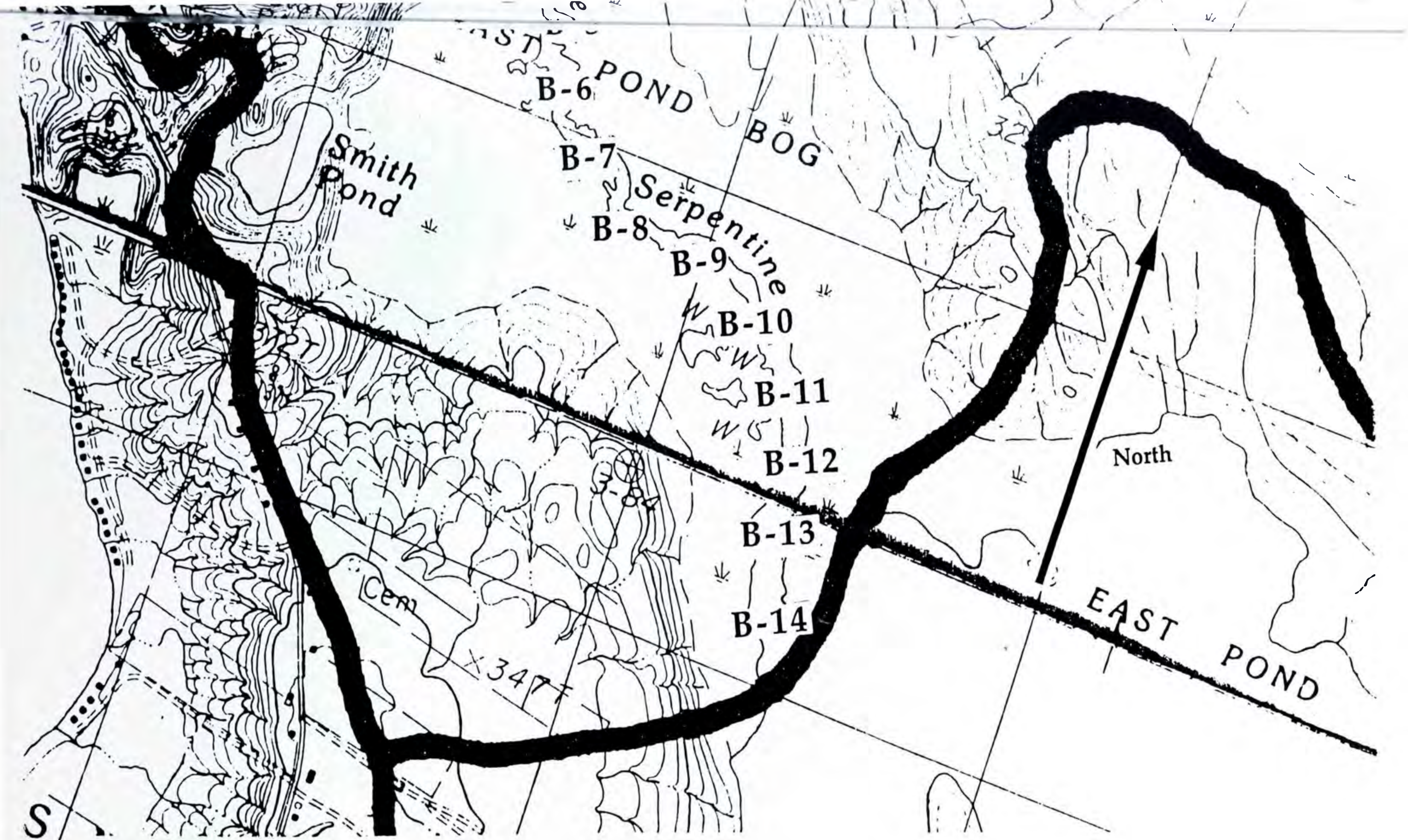


Figure 22 Sites for the Serpentine marsh and bog gradients. M-1 to M-10: marsh gradient; B-1 to B-14: bog gradient. 1982 USGS map, scale (1:12600).

through B-14, which were chosen along the transect. Water sampling and monitoring occurred on Sept. 26, Oct. 3, and Oct. 10 and included the following parameters: turbidity, pH, conductivity, and secchi disk.

Wetland Study Sites:

Serpentine Marsh study sites:

Two mat sites were sampled in the Serpentine Marsh near the confluence of Clark and Sucker Brooks. Temperature (°C), conductivity (μmhos/cm^2), and pH were measured at both surface and at depth. Surface measurements were taken by using standing water or depressing the mat and allowing water to collect. Depth measurements were taken using a piezometer to collect water underneath the mat in a range of 0.5-1.0 m. The two sites were selected in order to compare and contrast readings with those obtained for the Serpentine Bog. Site 1 was 6 m from the water's edge in an area with cattails, small-leaf cranberry, buttonbush, and a small amount of *Sphagnum* moss. Site 2 was 10 m from site 1 in a clump of sweet gale.

Serpentine Bog study sites:

A transect consisting of 8 study sites and running perpendicular to the Serpentine stream was established in the Serpentine Bog on October 24, 1991. The compass reading for the transect was 312°. Temperature (°C), conductivity (μmhos/cm^2), and pH were tested at each site at both surface and at depth. Surface measurements were taken by using standing water or depressing the mat and allowing water to collect. Depth measurements were taken by using a piezometer to collect water underneath the mat in a range of 0.5 to 1.0 m.

Flow patterns and rate

Material and Methods

Flow measurements were taken at five separate sites; the outlets of Clark and Sucker Brooks, at the northern end of the Serpentine stream, at the southern end of the Serpentine stream, and below the dam which separates East Pond and North Pond (Figure 23). Clark Brook (site E) originates from the east and Sucker Brook (site D) originates from the north of the Serpentine watershed. Flow measurements were taken approximately 20 m into each stream from the marsh area and each flow was determined separately. Sites D and E were chosen to determine the flow contributed by the Serpentine tributaries. Flow rate was also measured at the southern end of the Serpentine stream (site F) approximately 75 m into the stream. This site was chosen to determine the volume of flow leaving East Pond. The final flow rate site was at the dam which separates East Pond from North Pond (site G). Site G was chosen to determine the total flow which leaves the Serpentine and East Pond watersheds. If backflushing of the Serpentine stream were to occur, then water flow from Clark and Sucker Brooks may contribute to the flow of water into East Pond. By determining the volume of water flowing out and perhaps into East Pond, the relative nutrient loading rates may become clearer.

When the current was strong, a flow meter (Swoffer Instruments 2100L) was used to measure stream velocity. The flow meter was set at the minimum scale velocity setting for ft/sec. A tape measure was then stretched across the stream channel and flow measurements were taken along the transect at approximately 2 ft. intervals at a 3 in depth, each time recording the depth of the channel, transect distance, and velocity. The flow meter was used for all three testing days at the dam site, at Clark Brook on Sept. 26 and at Sucker Brook on Oct. 3. Between Oct. 3 and Oct. 10 dam boards were removed and the flow was greater at the original dam site on Oct. 10 making measurement impossible. A new dam site was located above the bridge over Route 8 and readings were taken by lowering an extended flow meter into the water on the East Pond side of the bridge.

When stream flow could not be detected by flow meter, flow was determined using a water soluble dye marker or a float bottle partially submerged to reduce the influence of wind. On Sept. 26 and Oct. 3, floats were used to measure the velocity at the northern end of the Serpentine stream. Polypropylene bottles filled with water and marked with red tape were used as floats. A travel distance was marked and measured, and the time the bottle travelled between the points was recorded. On Oct. 10 at Clark Brook, Sucker Brook, and the northern Serpentine stream a dye flow test was used to calculate stream velocity. The dye was released from a polypropylene bottle by opening the bottle approximately 3 in. under the surface of the water from the downstream side of a canoe. The dye was allowed to travel a measured distance downstream. When the center of the dye spot covered the measured distance, the time elapsed was recorded. It should be noted that Oct. 10 was an extremely windy day and the water was agitated. These conditions may have influenced the movement of dye.

The following calculation was used to calculate flow rate expressed in cubic feet per second:

Stream flow per cell (cfs) = (Length of cell (ft)) x (Average depth of cell (ft)) x (Average cell velocity (ft/s))

Length of the cell equals the distance measured from the first transect point (a) to the next transect point (b). Velocity measurements were normally recorded at 2 ft intervals so the length of the cell for each measurement would be 2 ft.

Average depth of cell equals depth measured at (a) plus depth measured at (b) divided by 2.

Average cell velocity equals the velocity measured at (a) plus the velocity measured at

(b) divided by 2.

Therefore, the sum of the flow for each cell is the flow (cfs) of the stream at that point.

For the data obtained from the dye and flow bottle tests the following equation was used:

Stream flow (cfs) = (Average depth of stream(ft)) x (Stream velocity (ft/s)) x (Stream width (ft))

Average depth of stream equals the sum of the stream depth measurements divided by the total number of measurements.

Stream velocity equals the distance bottle or dye travelled during the elapsed time.

Stream width equals total width of stream at the site.

Stream profiles were recorded at Clark and Sucker Brooks at the same sites where flow rates were recorded. Also, profiles were determined for the confluence of the Serpentine stream and marsh flow (Figure 23) to aid in interpreting the flow direction. A tape measure was stretched across the stream channel between sites A-B, A-C, and B-C; the depth along these transects was recorded at approximately 2ft. intervals by lowering a weight to the bottom of the stream bed at each interval.

Precipitation data was obtained from the National Oceanic and Atmospheric Administration (National Climatic Center, 1987-1991). The data was recorded in Madison approximately 15 km from East Pond. Precipitation data for July - October 1991 was recorded at the Waterville pump station, approximately 15 km from East Pond.

Results

September 26 testing followed a large storm. A total of 2.6 in of precipitation fell on Sept. 25 and 26. Flow measurements were taken on Sept. 26 just as the storm ended and after most of the precipitation had accumulated. A total of 1.27 in of precipitation fell during the month prior to this storm. On Oct. 7 and Oct. 8 a total of 1.81 in of rain fell (total of 2.03 in for Oct. 1-8) prior to the Oct. 10 flow measurement. The mean monthly precipitation from 1987-1991 indicates that most precipitation occurs during late spring and late fall (Figure 24). The greatest number of storms generating more than 2.5 in. of precipitation occurred in August through November, with a total of 10 storms for these four months during 1987 to 1991.

The rate of water inflow into the wetland from Clark Brook was ten times higher on Sept. 26 than on Oct. 10 (Table 12). The inflow from Sucker Brook, not measured on Sept. 26, was two times greater on Oct. 10 than Oct. 3. Flow at both sites was minimal on Oct. 3. Approximately ten times more flow was received from Sucker Brook than Clark Brook on Oct.

Table 12. Flow direction and rates (cfs) of Serpentine Stream and tributaries. All flows were measured with a flow meter unless indicated by [1](dye test) or [2](float). Water flow from Clark and Sucker Brooks and East Pond normally flows into the Serpentine Stream. The water then flows toward the dam and into North Pond. However, on Sept. 26 the direction of flow was from the Serpentine into East Pond. It should be noted that dam boards were removed before the Oct. 10 testing and dam testing site had to be relocated.

Site	Sample Dates		
	Sept. 26	Oct. 3	Oct. 10
Serpentine Inflow			
Clark Brook	2.9	NDF*	0.2[1]
Sucker Brook	___	0.9	1.9[1]
East Pond Outflow/Inflow			
Mouth of Serpentine	49.2[2]	11.4[2]	55.2[1]**
Serpentine Outflow			
Dam	8.6	10.0	103.8

* No Detectable Flow.

** Measured at the northern end of the Serpentine

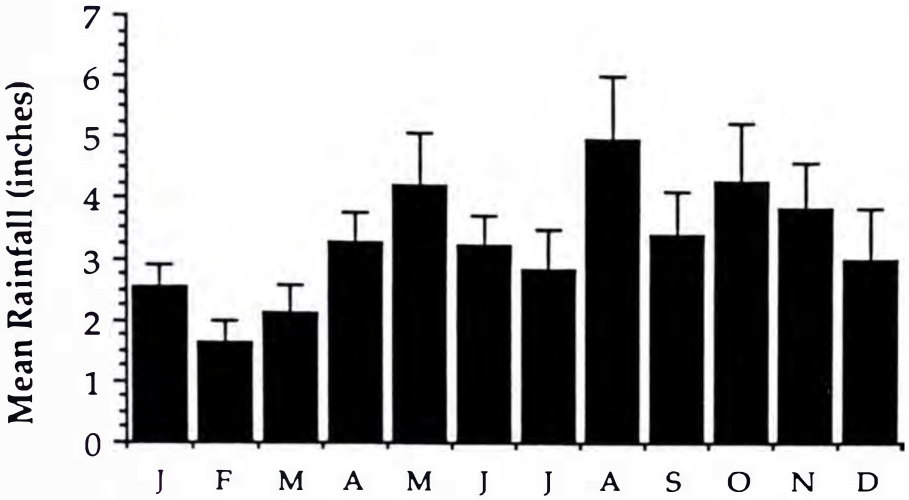


Figure 24. Mean monthly precipitation for 1987-1991 collected at the Madison station.

10 (the only date when flow was measured at both sites). Although Oct. 10 was a windy day, the measurements from these tributaries, and sites on the Serpentine were taken after the wind had died down in the late afternoon. The Oct.10 outflow from East Pond was 5 times more than that recorded on Oct. 3 (11.4 vs. 55.2 cfs). The rate of outflow from the East Pond and Serpentine watersheds, as measured at the dam, was similar on Sept. 26 (backflush flow) and Oct. 3 (normal flow) despite the heavy rainfall on Sept. 25-26. Outflow was ten times higher on Oct. 10 than Oct. 3 because of the recent rainfall and the fact that the dam boards were removed before the Oct. 10 testing. On Sept. 26 the flow of the Serpentine was into East Pond (backflush) at 49.2 cfs. This flow into East Pond was similar in rate to the outflow recorded on Oct. 10.

Normally water flows into the wetland from Clark and Sucker Brooks. The confluence of these flows is located in the marsh area at Site 3 (Figure 14a). Flow continues through the marsh where it meets the northern end of the Serpentine Stream. Typically water flows from East Pond north into the Serpentine stream which passes through the East Pond Bog. As the Serpentine stream flow meets the flow from Clark and Sucker Brooks coming out of the marsh, the stream makes a wide turn to the west and continues towards the dam. After a large storm (Sept. 26 - 2.6 in) direction of the Serpentine flow reversed, transporting water into East Pond. Since the flow at the dam site was similar on Sept. 26 and Oct. 3, it appears that most of the storm flow coming into the wetland was diverted down the Serpentine and into East Pond. On other measurement days the flow was out of East Pond, slowly on Oct. 3 and more rapidly on Oct. 10.

The data obtained from the stream soundings were used to graph the stream channels (Figure 25 and 26). The stream profiles of both Clark and Sucker Brooks are relatively symmetrical with a V-shaped channel (Figure 25). A profile of the confluence of the northern end of the Serpentine stream and marsh drainage was also constructed (Figure 26). The channel of the Serpentine closest to the dam (A) was steeper on the western bank and had a

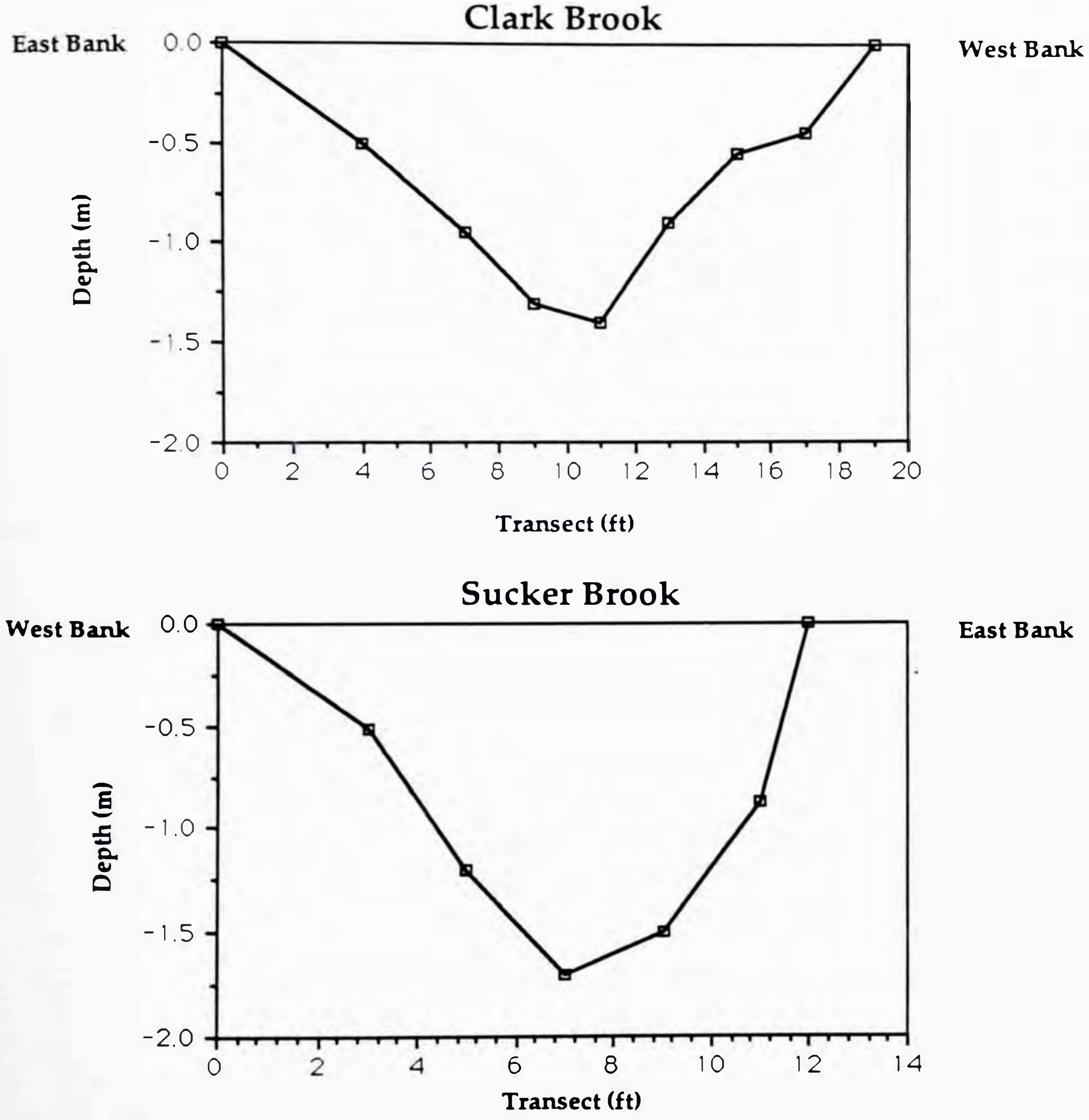


Figure 25. Stream morphology for Clark and Sucker Brooks.

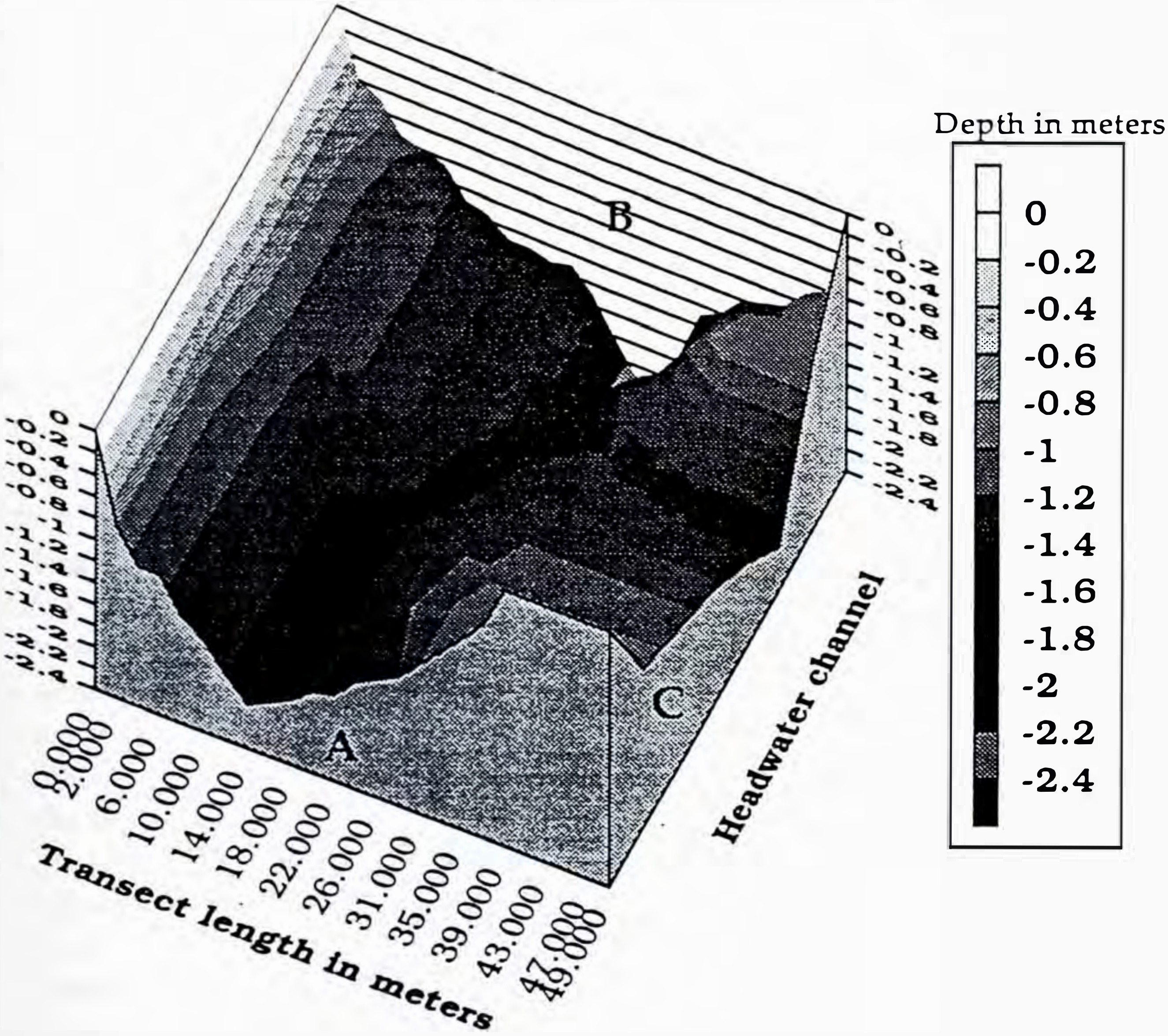


Figure 26. Stream channel morphology of the confluence of the Serpentine Stream and flow from Clark and Sucker Brooks. Channel A indicates the channel where water flows from Clark and Sucker Brooks and East Pond towards the dam. Channel C indicates the water flow from the Serpentine Stream.

gradual slope on the eastern bank. The channel originating from the marsh drainage (B) followed the same pattern as channel A. The channel for the northern end of the Serpentine stream (C) had a gradual slope on the western bank while the eastern one was steeper. Channel A to B of Figure 26 was created by extrapolating from depth measurements taken along two transects running diagonally across the channel.

Discussion

Flow rate indicated the volume of water which flows past a particular point in the stream channel. Flow is determined by the physical characteristics of the width and depth of stream channel, the amount of runoff flowing into the stream from the watershed, and the precipitation falling directly into the stream. Storms increase the runoff from a watershed into a stream. Increased runoff rate may cause increased nutrient loading into a stream. The discharge will then be carried in the stream flow to the receiving water body.

A storm with precipitation greater than 2.6 inches will probably cause backflushing of the Serpentine into East Pond, as indicated by the flow into East Pond observed on Sept. 26. Precipitation for September, including the storm on the 26th, suggests that the ground may have been saturated prior to Sept. 26 testing. This would decrease the opportunity for ground infiltration, contribute to a greater amount of runoff from the watershed, and create a greater potential for nutrient loading. The Oct. 7-8 storm generated about 1/3 less precipitation (1.81 in) than the Sept. 26th storm. It might be expected that under these conditions the Serpentine stream would backflush into East Pond. However, prior to Oct. 10 there were two days for the water table to go down. Also flow (out of East Pond) was greater because the dam boards had been removed.

Rainfall is more concentrated in the late spring and late fall, indicating that these may be the most likely times for backflushing of the Serpentine into East Pond (Figure 24). Storms greater than 2.5 in have occurred in the past in the months of April-November and are most likely to occur in August and October. Also, during the spring melting the ground is frozen which decreases water infiltration and increases the amount of flow into East Pond from the Serpentine and East Pond watersheds. Figure 24 does not reflect snow melt, therefore the amount of runoff from the watershed may be greater than indicated by the precipitation alone, especially during the late winter and early spring. For example, the combination of heavy rain and rapid snow melt is thought to have caused the backflushing of the Serpentine stream into East Pond in 1987 (Jeff Dennis, DEP, pers. comm.).

Backflushing of the Serpentine into East Pond can occur after storms greater than 2.5 in. This figure is based on observations after the Sept. 26 storm and is probably conservative. Backflushing may also occur after less rainfall. The effects of backflushing may increase nutrient loading into East Pond from the Serpentine wetland. Removal of dam boards at the outlet of the Serpentine may decrease the effects of large storms and reduce the amount of backflushing which may occur into East Pond. However, the desired water level for East Pond as well as the increased nutrient loading of North Pond should be considered.

Water Quality Testing

Serpentine Stream and Wetland Water Quality Testing Procedures

The water quality of the Serpentine stream and wetlands was tested for physical and chemical characteristics (Table 13). Water sampling was conducted on September 26 (backflush flow) and October 10 (normal flow). In addition, samples were taken along transects located in the Serpentine Marsh section and Bog section of the wetland. Physical factors were measured at these sites on Oct. 3 and 10. Water quality analysis was conducted according to guidelines of the Water Quality Assurance Plan (Appendix B).

Results and Discussion

Physical Measurements

Data for sample sites 1-8 show a general consistency for turbidity, nitrate, and tannin and lignin, in that site 8 has lower results than points further up the Serpentine for both Sept. 26 and Oct. 10 (Table 14). The pH on Oct. 10 was highest at sites 7 and 8, with lower pH readings in the northern parts of the Serpentine stream. For Sept. 26, pH readings were similar among sites (range 5.8 to 6.1).

For Serpentine Marsh sites, turbidity values on Sept. 26 ranged from 13.8 FTU (site 1) to 21.0 FTU (site 4) (Figure 14). The highest value occurred at site 4, the site located at the entrance of Clark Brook to the Serpentine Marsh. The value at the confluence of Sucker and Clark Brooks was similar. On Oct. 10, values showed a similar pattern. For sites 5 - 8, the turbidity on Sept. 26 ranged from 20.0 to 12.0 FTU with values decreasing towards East Pond. On Oct. 10 the pattern was similar but the magnitude of the values was smaller, 7.0 FTU (site 5) and 3.0 FTU (site 8). For sites 9 (Sucker Brook by canoe) and 10 (Sucker Brook by road), the levels on Sept. 26 were 20.5 and 17.0 FTU respectively. On Oct. 10 the level for site 9 was 13.5 FTU.

Overall turbidity levels for sites 1-8 were higher on Sept. 26 than on Oct. 10. The heavy rains ending on Sept. 26 most likely increased volumes of surface water runoff, resulting in the input of much sediment from erosion. It is also likely that sediments within the wetland were stirred and suspended in the water column. Sites 5-8 were especially affected by the rain as the turbidity levels here were approximately 3 times higher on Sept. 26 than Oct. 10. Turbidity results for site 9 also show the influence of the rain, as the Sept. 26 value was higher than that of Oct. 10. Runoff from the road and the roadside into Sucker Brook at this site likely contains a large amount of sediments and dissolved salts. Site 10, further south along Sucker Brook, had

Table 13. Serpentine Stream and wetland water quality tests of physical and chemical characteristics. Sample sites and dates of sampling and analysis are indicated.

Test	Sampling Date	Testing Date	Site(s)
Physical Factors			
Temperature	10/10	10/10	
Secchi Disk	10/3, 10/10	10/3, 10/10	
Turbidity	9/26, 10/3, 10/10	9/26, 10/3, 10/10	1-10
Conductivity	10/10	10/10	
Flow Rate	9/26, 10/3, 10/10	9/26, 10/3, 10/10	1,4,8
Chemical Factors			
pH	9/26, 10/10	9/26, 10/10	1-8
Reactive Phosphorus	9/26, 10/10	9/26-27, 10/10-11	1-10
Total Phosphorus	9/26, 10/10	9/26-27, 10/10-11, 10/24	1-10
Nitrate	10/10	10/10	1-8
Ammonia	10/10	10/10	1-8
Tannin and lignin	9/26, 10/10	9/26, 10/10	1-9

Table 14. Post storm and normal results for sample sites 1-8 on the Serpentine (Tan-tannin and lignin, Turb-turbidity, Nit-nitrate, Am - ammonia). Turbidity is measured in formazin turbidity units.

	Post Storm			Normal				
Sites	Tan ppm	pH	Turb	Tan ppm	pH	Turb	Nit ppm	Am ppm
Marsh								
1	2.0	6.1	13.8	6.2	5.2	12.5	0.05	.00
2	---	---	---	3.9	4.4	9.0	0,05	.00
3	2.6	---	19.7	8.5	5.6	22.0	0.06	.00
4	3.8	---	21.0	6.1	4.2	26.0	0.06	.00
Bog								
5	2.7	5.9	19.0	4.6	5.8	7.0	0.03	.00
6	2.7	5.8	20.0	1.9	5.9	6.0	0.04	.00
7	2.6	5.9	15.0	1.3	6.0	4.0	0.03	.00
8	2.4	5.9	12.0	1.7	6.0	3.0	0.03	.00

a slightly lower level of turbidity than site 9 suggesting that as the water travelled towards the Serpentine Marsh, some settling of sediments occurred. Site 4 had the highest level of turbidity on both sampling dates. This site is adjacent to agricultural land and subject to surface water runoff containing soil and animal wastes. Site 3, the confluence of Clark and Sucker Brooks, also exhibited high turbidity. This is most likely due to the mixing of the two tributaries which both had relatively high turbidity levels.

Trends in turbidity may also be attributed to the flow patterns of the Serpentine. On a typical day, water flows out of East Pond, north through the Serpentine Bog and Marsh and finally leaves the watershed by flowing into North Pond. As the water travels through the Serpentine wetland it is likely that some sediment settles out of the water column and that some nutrients are released and enter the water. Because of the backflushing caused by heavy rains, the water flowing into East Pond from the north on Sept. 26 probably carried sediments and other materials, thereby increasing turbidity of the entire system. Normally water would have left the system via the Serpentine Marsh and directly entered North Pond.

A third possible explanation for the observed trends was the removal of a dam board controlling outflow of the Serpentine stream into North Pond. This greatly increased the flow volume into North Pond, effectively flushing particulate matter out of the Serpentine area. The water of the Serpentine stream was clear to the bottom on Oct. 24 which suggests that this flushing is an effective means of reducing particulate matter suspended in the water column.

Chemical Measurements

For sites 1-4, the nitrate levels tested on Oct. 10 ranged from .05 mg/l - .06 mg/l (Table 14). The highest levels occurred closest to Clark Brook (site 4), while the lowest level occurred near the head of the Serpentine (site 2). For sites 5-8 the nitrate range was narrower, from .03 mg/l - .04 mg/l, with the highest value recorded at site 6. Sample site 9, where Sucker Brook meets the road, had a value of .02 mg/l.

High levels of nitrate typically corresponds with the presence of agricultural or fecal pollution. Nitrate levels were highest at sites 3 and 4 which are adjacent to agricultural lands, and are subject to runoff from fields with animal waste. Cows also graze on land directly adjacent to Clark Brook. Sites 5-8 collectively had a lower concentration of nitrate than did sites 1-4. It is likely that the close proximity of agricultural land to the Serpentine Marsh influences these levels. It is also probable that the lush vegetation of the lower Serpentine Bog area quickly assimilates nitrate. Site 9, although in close proximity to State Highway 8, appears not to be affected by cattle farms and the nitrate levels here are lower than those of the Serpentine Marsh (site 4). The maximum allowable concentration of nitrate in public drinking water is 45 mg/l. The values recorded in our study were below this maximum by a factor of one thousand.

For sites 1-4 the tannin and lignin concentrations ranged from 2.0 to 3.8 mg/l on Sept. 26, with the highest levels at site 4 (Table 14). For Oct. 10, the levels ranged from 3.9 to 8.5 mg/l. High levels occurred at sites 1, 3, and 4, with 3 being the highest. For sites 5-8, the range on Sept. 26 was 2.4- 2.7 mg/l, with levels increasing going up the Serpentine Bog from East Pond. On Oct. 10, a similar trend was found, with the range going from 1.7 to 4.6 mg/l. Sites 9 and 10 on Sept. 26 had values of 2.0 and 2.2 mg/l respectively. On Oct. 10, site 9 had a value of 6.0 mg/l. Turbidity and tannins/lignins were positively correlated on Sept. 26 (r= .65) as well as on Oct. 10 (r= .85). For Sept. 26 and Oct. 10 together, there was a positive correlation between tannins and turbidity (r= .57). A simple regression comparing pH to tannins/lignins on Sept. 26 resulted in significance (r= .94, R^2= .87, p= .02). For Oct. 10, turbidity was compared to tannins/lignins (r= .85, R^2= .72, p= .008) and to nitrate (r= .90, R^2= .82, p= .002).

Tannins and lignins are complex hydrocarbons which include major structural constituents of most plants (Afghan, 1989). Measurement of tannin/lignin concentrations allows a quantitative measurement of plant degradation. There was an increase in tannin/lignin concentrations as the Serpentine stream moves through the bog, away from East Pond. This was especially noticeable on Oct. 10. Surface water or rainfall entering the Serpentine Bog must first travel through the dense vegetation of the bog and is likely to build up concentrations of tannic acid due to high rates of vegetative decomposition. Lower tannin/lignin levels and a less obvious gradient from one end of the Serpentine to the other on Sept. 26 might be explained by the larger volume of water in the Serpentine due to storm runoff. This increased water might serve to dilute the tannic acid in the water. As well, reversed flow of the Serpentine stream may have some affect on tannin/lignin concentrations. Statistical analysis resulted in a positive correlation between tannins and turbidity. Presence of tannic acid in water results in a brownish-yellow tint. Therefore, the higher the concentration of tannin/lignin, the darker the tint, explaining the higher turbidity levels as tannin/lignin levels increase.

The pH for sites 1-4 on Sept. 26 was incomplete with only one value of 6.1 at site 1. On Oct. 10 the pH ranged from 4.2 - 5.6 (Site 3) with no obvious trends. For sites 5-8, the range on Sept. 26 was from 5.8 - 5.9, showing very little variation. On Oct. 10 the values ranged from 5.8 - 6.0, with the values decreasing going up the Serpentine stream from East Pond.

Lower pH values at the north end of the Serpentine stream on Oct. 10 were expected because tannic acid concentrations increase in the water as it flows through the Serpentine Bog and Marsh area. There was a statistically significant negative correlation between pH and tannins (r= -.55). Because the tannin/lignin test measures concentrations of tannic acid in the water, it makes sense that as tannin concentrations increase, pH levels decrease.

Total phosphorus samples collected at the Serpentine Marsh sites on Sept. 26, ranged from 51 ppb (site 1), to 124 ppb (site 4) (Table 15 and Figure 27). With the exception of site 2 (probably due to sampling error), total phosphorus decreased as the water flowed from the Serpentine Marsh towards the dam. Reactive phosphorus samples collected on Sept. 26, ranged from 10 ppb (site 1) to 98 ppb (site 3 - confluence of Clark and Sucker Brooks) during backflushing conditions. In the Serpentine Bog section, total phosphorus observations for Sept. 26 were highest at site 5 (at the northern end). Values ranged from a high of 247 ppb at site 5, to a low of 46 ppb at site 7. No total phosphorus sample was taken at site 6 (Table 15 and Figure 28). Reactive phosphorus levels on Sept. 26 showed a high of 117 at site 5 and a low of 14 at site 7. Total phosphorus values during normal flow conditions (Oct. 10) were similar for the Serpentine Marsh and the Serpentine Bog sites (Table 15 and Figures 27 and 28). Levels of total phosphorus were considerably higher than reactive phosphorus for all sites along the Serpentine Marsh and Bog. Reactive phosphorus values were higher in the marsh section of the wetland than in the bog section. The range of reactive phosphorus values was narrow in both sections (3 to 5 ppb in the marsh and 14 to 29 ppb in the bog). Total phosphorus at sites 9 and 10 (Sucker Brook) ranged from 43 to 62 ppb while reactive phosphorus values ranged from 11 to 17 ppb.

The mean value for reactive phosphorus during backflush conditions was 46± 14 ppb and 10 ± 3 ppb during normal flow conditions. This difference for reactive phosphorus between the two sampling dates was statistically significant (t-test, p= .02). In addition, for Oct. 10 there was a positive correlation between turbidity and reactive phosphorus (r= .60).

Results from the Serpentine Marsh sites during backflush conditions (Sept. 26) suggest that total phosphorus was flowing into the wetland from Clark and Sucker Brooks and running into the Serpentine Bog rather than flowing toward the dam. Noticeably high levels of total phosphorus at Clark Brook may be due to runoff from the watershed following the heavy rains which preceded the sampling date. Much of the phosphorus detected may have been bound to the sediment flowing in through Clark Brook rather than in the form of orthophosphate.

During normal conditions (Oct. 10), similar levels of total phosphorus were recorded for the bog and marsh sections of the Serpentine wetland. This pattern might be expected because

Table 15. Total and reactive phosphorus values for the Serpentine stream and wetland. Samples taken during post storm conditions (Sept. 26) and normal conditions (Oct. 10).

Site	Backflush Flow		Normal Flow	
	Total Phosphorus (ppb)	Reactive Phosphorus (ppb)	Total Phosphorus (ppb)	Reactive Phosphorus (ppb)
Marsh Section				
1	51	10	56	14
2	6*	21	48	11
3	82	98	69	29
4	124	29	40	7
Bog Section				
5	247	117	48	5
6	-	47	67	6
7	46	14	50	3
8	72	36	56	5

*This value may be due to sample or analysis error.

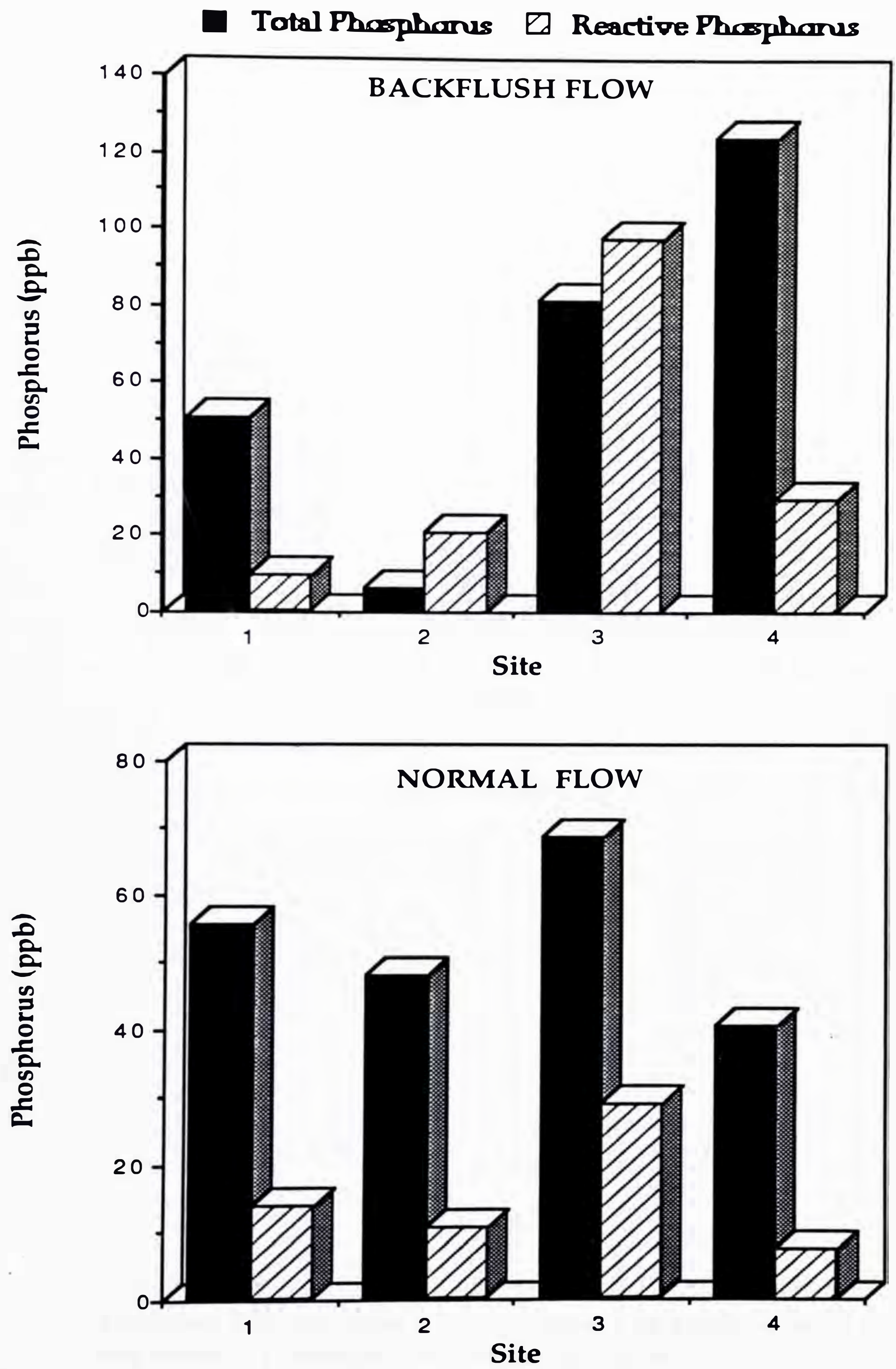


Figure 27. Backflush flow (Sept. 26) and normal flow (Oct. 10) sampling of the Serpentine Marsh study sites. Data expressed as total or reactive phosphorus.

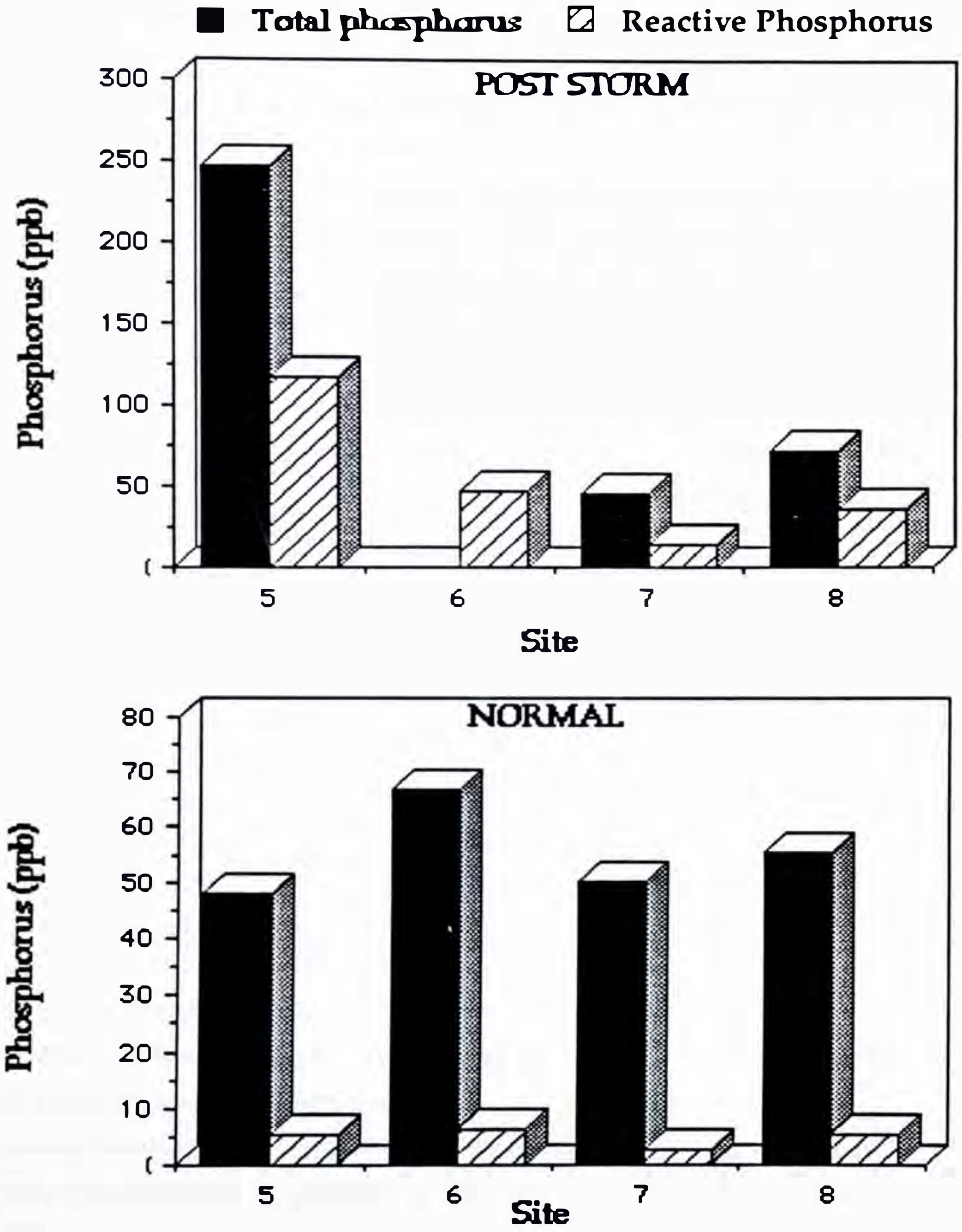


Figure 28. Post storm (September 26) and normal (October 10) sampling of Serpentine bog study sites. Data expressed as total or reactive phosphorus.

of the increased water flow leaving the watershed due to the removal of the dam boards.

The positive correlation between turbidity and reactive phosphorus on the backflush flow sampling date might be explained by the biomass present in the water. Increasing levels of reactive phosphorus implies that more nutrients become available to the organisms (especially algae and cyanobacteria) in the water. With greater amounts of nutrients available, organisms will multiply and their biomass in the water column will increase. This will then raise the turbidity levels in the water.

The significant difference in reactive phosphorus between the two sample dates suggests that storm activity not only increases runoff, but also the amount of reactive phosphorus available. Runoff may be the major source of reactive phosphorus which is why the post storm conditions show high levels of reactive phosphorus. A comparison of results suggests that heavy rains may release reactive phosphorus from the surrounding watershed. This does not happen as rapidly during normal conditions. Instead, reactive phosphorus levels remain low, probably because runoff is less and uptake by plants is rapid.

Results from total and reactive phosphorus testing at sites 5-8 along the Serpentine stream indicate a clear distinction between backflush and normal flow conditions. High total and reactive phosphorus values during backflush sampling at site 5, the area where marsh drainage enters the Serpentine stream, may be caused by increased turbidity due to flow of the Serpentine stream into East Pond. Under these conditions, water flow from sites 3 and 4 (inflow from Clark and Sucker Brooks) enters the Serpentine stream and flows back to East Pond, contributing to high values of phosphorus at site 5. Reactive phosphorus was lower at site 6 than site 5, which suggests sediments may be settling as water flows south towards East Pond. Stream width may also influence total and reactive phosphorus values by increasing or decreasing flow rate and affecting sediment settling rates. This may account for the higher values of total and reactive phosphorus at site 7 than site 8 (Figure 14a).

During normal conditions, total and reactive phosphorus levels were very consistent between sites 5 to 8 with a small range of values. Reactive phosphorus ranged from 48 to 67 ppb and total phosphorus ranged from 3 ppb to 6 ppb along the Serpentine Bog. Total phosphorus was nine to nineteen times higher than reactive phosphorus at all sites. This shows much more particulate phosphorus is present in the water than dissolved phosphorus during normal conditions.

Comparisons between data from backflush flow sampling on Sept. 26 and normal flow sampling on Oct. 10 clearly indicate an increase in phosphorus loading to the Serpentine stream and East Pond during a storm. Nutrient loading by Clark and Sucker Brooks and increases in turbidity within the wetland appear to be the primary sources for increased phosphorus levels.

Conclusion

Storm activity plays an important role in the nutrient input and water flow of the East Pond watershed. During normal conditions (when flow direction is out of East Pond into the Serpentine stream), no significant nutrient loading into East Pond can be detected. However, periods of heavy rain cause the Serpentine stream to reverse directions and travel southward, into East Pond. This flow includes the water from Clark and Sucker Brooks, which normally flows directly into North Pond, bypassing the lower Serpentine Bog area altogether. Clark and Sucker Brooks flow through agricultural areas where runoff contains high concentrations of nutrients, most importantly phosphorus. Consequently, the change of flow patterns due to heavy rainfall may create significant changes in nutrient inputs into East Pond. Because phosphorus is a limiting nutrient for vegetation growth in aquatic ecosystems, large increases in its concentration may create algal blooms leading to eutrophication.

Serpentine Marsh transect

The tests utilized for the Serpentine Marsh gradient were turbidity, secchi disk, conductivity, and pH. Patches of turbidity were apparent at the point where the Serpentine Bog section meets the marsh section, and at the confluence of Clark and Sucker Brooks. These patches led to the quantitative investigation of the marsh gradient. The turbidity on Oct. 3 ranged from 14.0 - 26.5 FTU (Figure 29). The highest level, 26.5 FTU, occurred at site M-10 where Clark Brook enters the marsh. The mean turbidity on Oct. 3 was 18.4 FTU. On Oct. 10

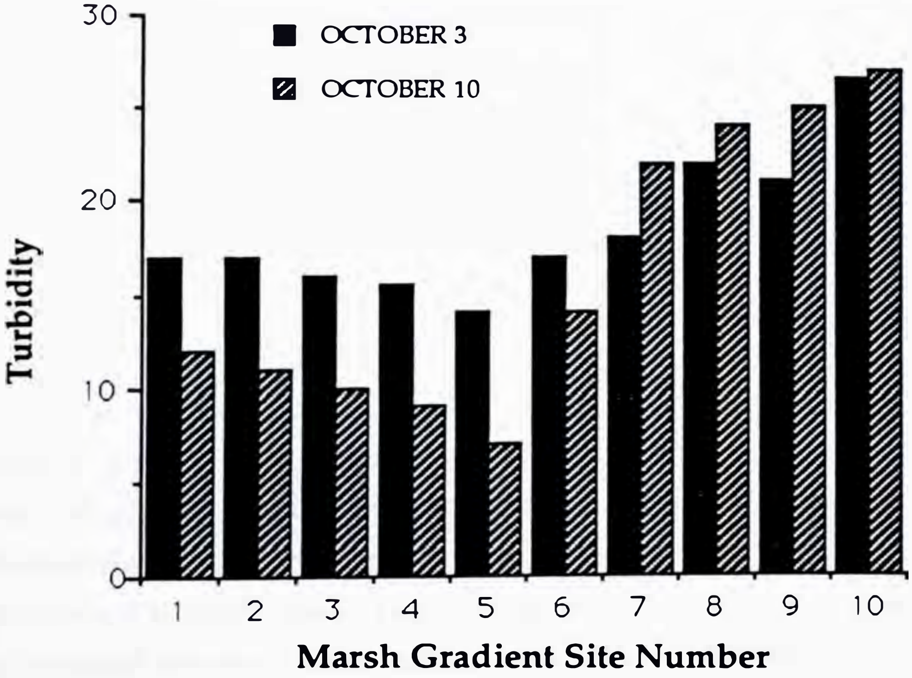


Figure 29. Turbidity of the Serpentine Marsh gradient. Turbidity is expressed as Formazin Turbidity Units.

the turbidity ranged from 7.0 - 27.0 FTU with the high level occurring in the same place as on Oct. 3 (Site M-10). The mean turbidity for Oct. 10 was 16.1 FTU. An interesting trend was seen on both Oct. 3 and Oct. 10; between sites M-1 through M-5, the turbidity levels were decreasing, while from M-6 to M-10, the levels were increasing.

The turbidity on the marsh gradient was highest at the entrance of Clark Brook to the marsh. This was most likely due to runoff from the surrounding fields into Clark Brook. There is an obvious dichotomy seen in the gradient for turbidity in that sites M-1 to M-5 show a separate trend than sites M-6 to M-10. This trend in the turbidity data on both days could be attributed to the possibility that the runoff entering the marsh from Clark and Sucker Brook settles out between marsh sites M-10 down to M-6, thus causing the decrease from M-10 through M-6. The increase between sites M-5 and M-1 could be a result of the water coming in from East Pond meeting the water from Clark and Sucker Brooks, thus causing an increase in turbidity as the water flows toward the dam. The higher mean turbidity on Oct. 3 is most likely due to the build-up of tannic acids and algal biomass resulting from the reduced flow of water through the Serpentine system. On Oct. 10 the flow of water had been increased by the removal of the boards from the dam between the Serpentine and North Pond. However, the values on Oct. 10 are higher for sites M-7 through M-10. This is probably a result of the windy conditions in the open area of the marsh stirring up the water. The data for turbidity on the Serpentine Marsh gradient indicates a possible influx of phosphorus into the Serpentine Marsh from Sucker and Clark Brooks.

The secchi disk readings for Oct. 3 ranged from 1.1 - 1.6 m, with a mean of 1.3 m. The data for Oct. 10 is incomplete due to high winds, however spot readings showed a range from 1.0 - 1.8 m , with a mean of 1.5 m. No trends were seen.

Although it is incomplete, the secchi disk data seem to indicate that the water was slightly clearer on Oct. 10 than on Oct. 3. This observation is probably due to the same reason as turbidity. The reduced clarity of the water on Oct. 3 is probably due to lack of flow in the Serpentine system, whereas the higher clarity on Oct. 10 is probably due to the increased flow resulting from the removal of the dam boards.

The pH of the marsh gradient was only taken on Oct. 10. The values ranged between 4.4 and 5.4, with a mean value of 5.1. The pH was rather uniform and no trends were seen. This uniformity is probably a result of the increased flow as well.

Conductivity was sampled only on Oct. 10. The conductivity was taken two feet below the surface of the water and two feet above the bottom sediment (Figure 30). The data for two feet below the surface showed a range from 25-90 μmhos/cm^2. The data for two feet above the sediment ranged between 25-80 μmhos/cm^2. Values for sites M-9 and M-10 were eliminated due to the presence of canoes stirring up the bottom sediments and preventing accurate measurements. The conductivity therefore showed relatively uniform results.

The uniformity of the conductivity data can most likely be attributed to the higher flow

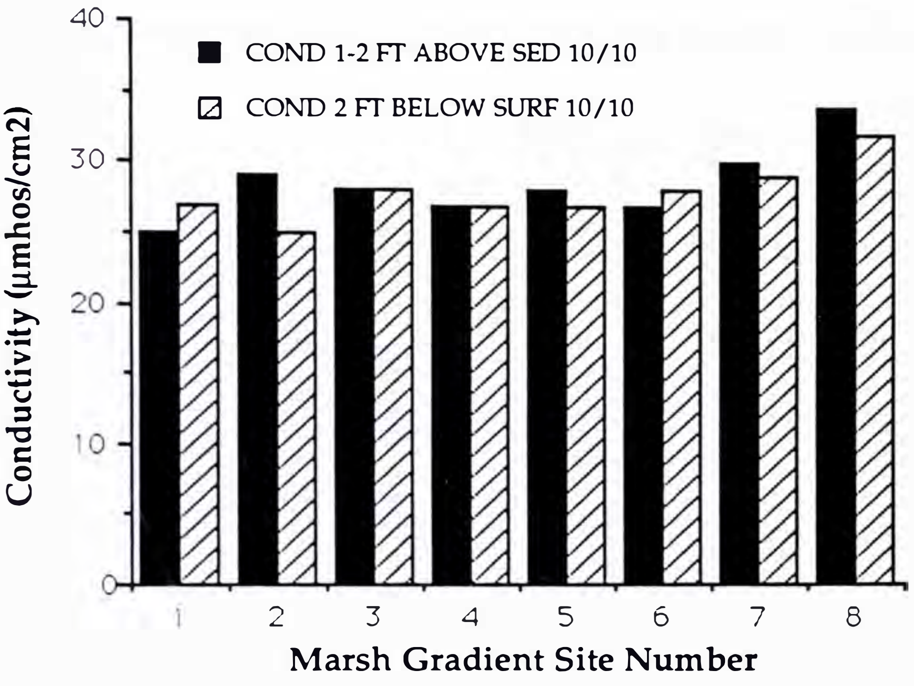


Figure 30. Conductivity of the Serpentine Marsh gradient.

rate of the water in the Serpentine system.

The high, positive correlation between turbidity on Oct. 3 and turbidity on Oct. 10 (r= .89) is probably due to the almost identical pattern on the two days (Figure 29). The reason for the low correlation between turbidity and secchi disk (r= .33) is most likely due to the incomplete secchi disk data, as well as general difficulty in obtaining accurate secchi disk data due to windy conditions. The correlations between turbidity and surface conductivity (r= .74) and turbidity and bottom conductivity (r= .81) are probably a result of the contribution of salts in the water to the turbidity. As more salts are present in the water, the percent absorption of the water increases. The comparison of the conductivity two feet below the surface with two feet above the sediment shows a high correlation (r= .72) because of the relative lack of variance between the two levels of testing. Windy conditions and the shallow channel helped mix the water column, reducing stratification.

The data for the Serpentine Marsh gradient shows a clear pattern of turbidity entering into the marsh from Sucker and Clark brooks. This is a probable source for phosphorus loading into the Serpentine system.

Serpentine Bog Transect

The secchi disk data from Oct. 3 showed a lower level of clarity toward the Serpentine Marsh (site B-1), and a higher level of clarity toward the mouth of the Serpentine (site B-14) (Figures 22 and 31). The lower level of clarity for sites B-1 through B-6 averaged at 1.80 ± 0.04

m (x ± SE) while the higher level of clarity for sites B-7 through B-14 averaged at 2.17 ± 0.07 m (Figure 22).

Turbidity was measured along the Serpentine Bog on Oct. 3 and 10. On Oct. 3, the flow was at its slowest rate, and was flowing out of East Pond. On this date, the turbidity increased from the mouth of the Serpentine at site B-14 toward the SerpentineMarsh at site B-1 (Figure 32). The mean turbidity at sites B-14 through B-8, toward the mouth of the Serpentine, was 5.2 ± 0.2 FTU. The mean turbidity at sites B-7 through B-1, toward the Serpentine Marsh, was 10.9 ± 0.7 FTU. Thus, the mean turbidity was higher toward the Serpentine Marsh than it was toward the mouth of the Serpentine.

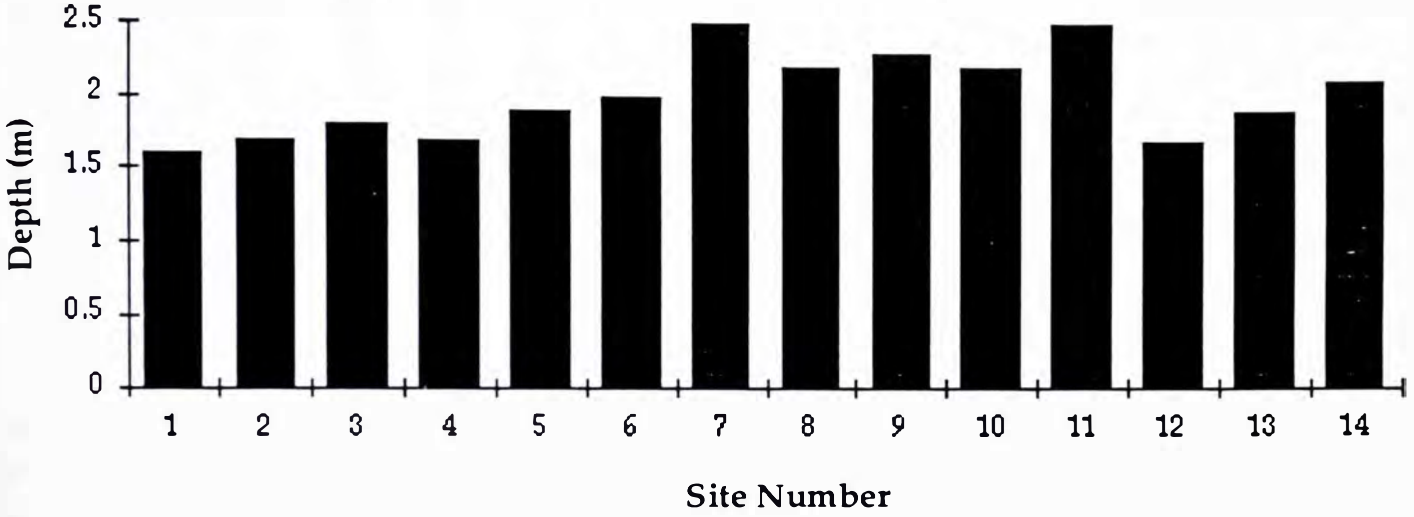


Figure 31. Secchi Disk Readings on Serpentine Bog transect. This shows depths of clarity of the water at the Serpentine Bog transect at sites B-1 through B-14 on October 3, 1991. Site B-1 islocated toward the Serpentine Marsh, and site B-14 is located at the mouth of the Serpentine.

On Oct. 10, there was a faster flow of water, since the boards of the dam at the outlet of the Serpentine had been removed. Turbidity levels were significantly lower and more uniform on Oct. 10 (Figure 32). The mean turbidity at sites 14 through 8, toward the mouth of the Serpentine, was 3.4 ± 0.1 FTU. The mean turbidity at sites B-7 through B-1, toward the Serpentine marsh, was 4.7 ± 0.2 FTU. The mean turbidity increased from the mouth of the Serpentine to the Serpentine Marsh, however, the increase was not as obvious as it was on Oct. 3.

A significant correlation exists between the turbidity and secchi disk data (r= -.59). The clarity of the water (Oct. 3) increased toward the mouth of the Serpentine (site B-14) as the turbidity (Oct. 3) decreased. Toward the Serpentine Marsh, however, the turbidity was higher and the clarity was lower. This parallels the trend found in tannin levels. The tannin levels within the Serpentine Bog were lower near East Pond and higher near the Serpentine Marsh. These trends may be explained by the fact that the marsh vegetation near the Serpentine

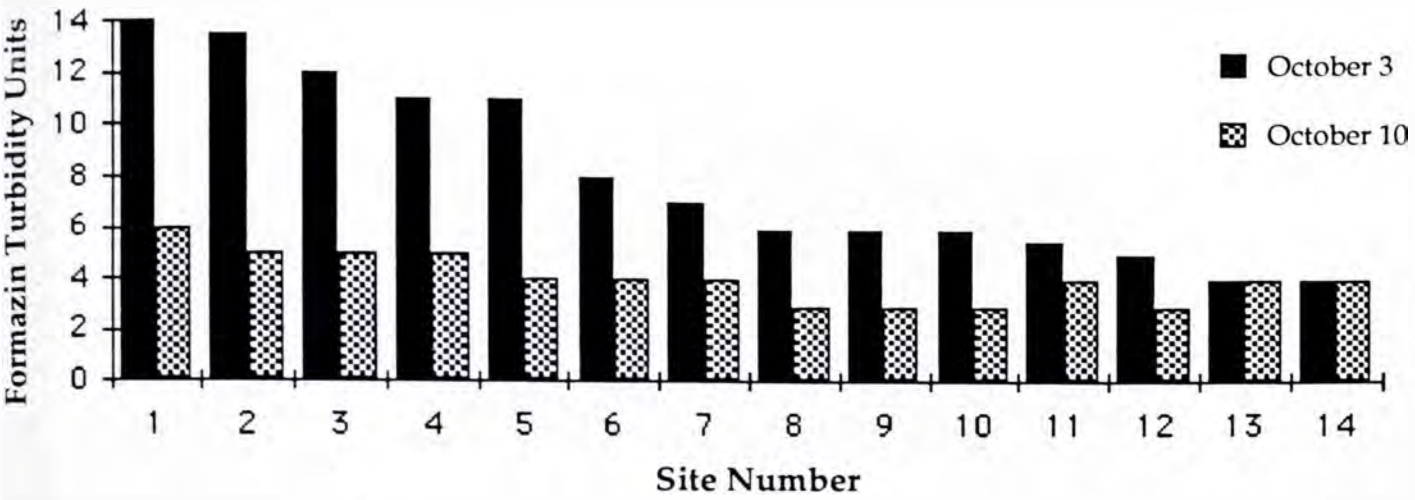


Figure 32. Turbidity of the Serpentine Bog transect. This shows the turbidity of the Serpentine Bog transect at sites B-1 through B-14 on October 3 and October 10, 1991. Site B-1 is located at the Serpentine Marsh intersection, and site B-14 is located near the mouth of the Serpentine.

contributes to the amount of suspended materials (vegetation, tannic acid) in the water column.

Correlations between surface conductivity and depth conductivity were performed for each sampling date. The correlation for surface and depth conductivity for Sept. 26, when the flow was fastest into East pond, was highly significant (r = .90). This suggests that there was no stratification within the water column. This could be attributed to a high amount of mixing, which could have resulted from the storm event which preceded the sampling day. The correlation for surface and depth conductivity for Oct. 3, when the flow was slowest out of East Pond, had lower significance (r = .64). This suggests that some stratification and less mixing occurred. The correlation for surface and depth conductivity for Oct. 10, after the dam boards were removed, was also significant (r = .74). This suggests less mixing than that which occurred on Sept. 26, but more mixing than that which occurred on Oct. 3. The increased mixing may have been caused by the increase in flow (out of East Pond) after the boards of the dam were removed. Since the conductivity readings at both surface and depth measurements (on each sampling date) significantly correlated with each other, they were averaged.

The trend in conductivity on Sept. 26 showed gradually increasing conductivity from the mouth of the Serpentine at site B-14, toward the Serpentine Marsh, until the highest conductivity level at site B-5 (Figure 33). At site B-4 there was a drop in conductivity. Sites B-3 through B-1 (near the Serpentine Marsh) showed very little difference in conductivity relative to each other and to the lower conductivity level at site B-4.

The conductivity pattern on Oct. 3 varies from that of Sept. 26. No conductivity reading was taken at the mouth of the Serpentine at site B-14. Site B-13, toward the mouth of the

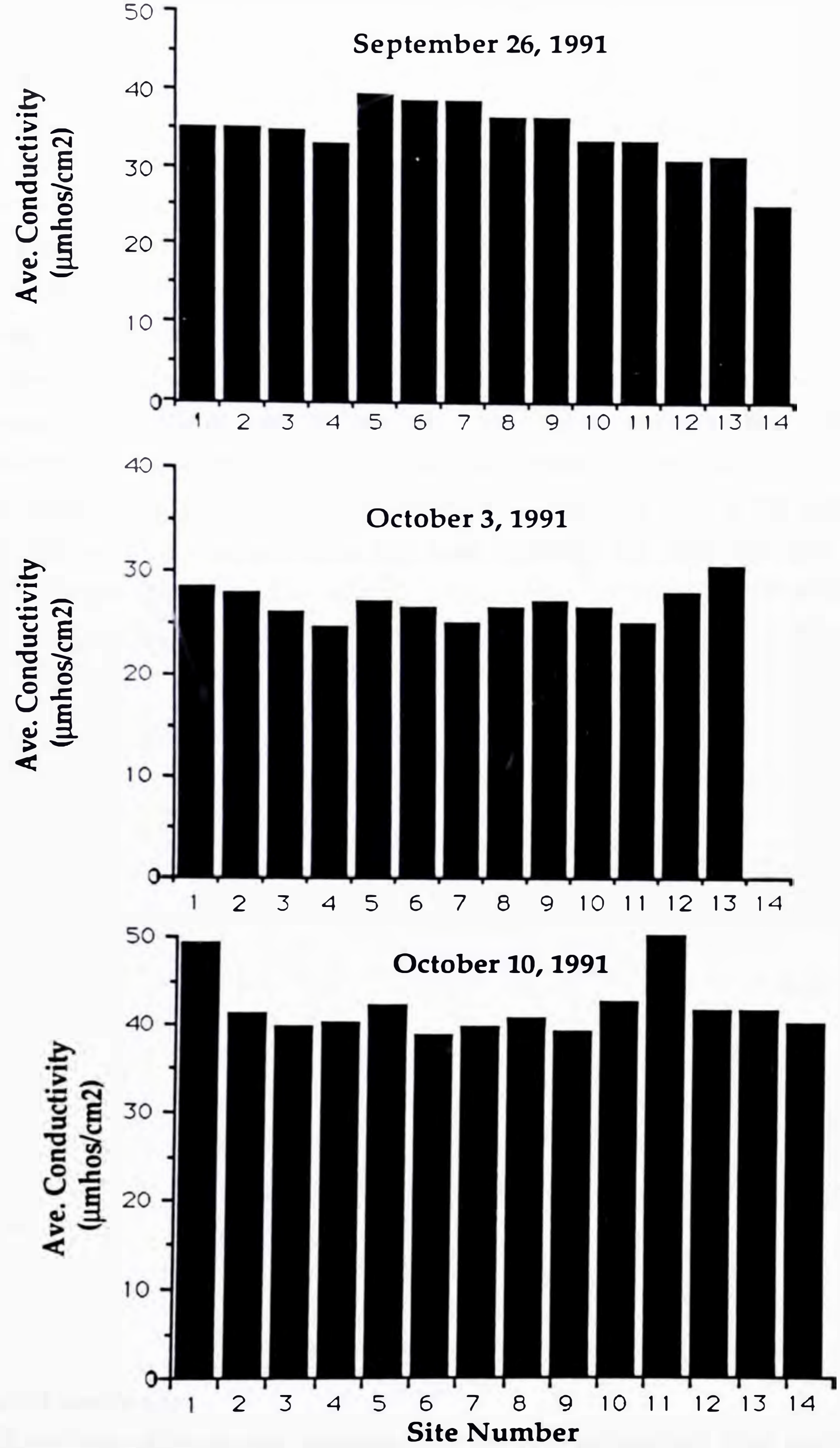


Figure 33. Conductivity of the Serpentine Bog transect on Sept. 26, Oct. 3, and Oct. 10, 1991. The Sept. 26 graph represents average conductivity of the water flowing into East Pond at sites B-1 (marsh) through B-14 (mouth of the Sepentine), and the Oct. 3 and Oct. 10 graphs represent the average conductivity (of the surface & sediment readings) of the water flowing into and out of East Pond. No samples were taken from site B-14 on Oct. 3, 1991.

Serpentine, had the highest level of conductivity, while site B-1, toward the Serpentine Marsh, had the second highest level of conductivity (Figure 33). Between those two points, conductivity varied, and no significant trends were apparent. Among sites B-12 through B-2, sites B-12, B-9, B-5, and B-2 had the higher conductivity levels.

The conductivity readings from Oct. 10 showed the highest level of conductivity at site B-11, toward the mouth of the Serpentine, and the second highest level of conductivity at site B-1 (Figure 33). Other than those higher conductivity levels, there was no obvious trend in conductivity along the Serpentine Bog.

The lowest mean total conductivity was 26.8 µmhos/cm^2 and occurred on Oct. 3. The medium mean total conductivity was 35.4 µmhos/cm^2 and occurred on Sept. 26. The highest mean total conductivity was 41.8 µmhos/cm^2 and occurred on Oct. 10, 1991.

The highest mean conductivity at the Serpentine Bog was 41.8 ± 0.9 µmhos/cm^2 and occurred on Oct. 10, after the removal of the dam boards. On this day, the movement of dissolved salts and ions would be at its greatest due to the increased flow out of East Pond. The medium level of conductivity was 34.4 ± 1.0 µmhos/cm^2 and occurred on Sept. 26 after the storm, but before the removal of the dam boards. During this time period, increased flow from the storm would cause more movement of dissolved salts and ions within the water column. The lowest conductivity readings was 26.8 ± 2.0 µmhos/cm^2 and occurred on Oct. 3, before the removal of the boards occurred. The relative movement of dissolved salts and ions would be at a minimum on this day since there was no increase of flow from a storm or removal of boards.

The waters of the Serpentine gradient were tested for pH on Oct. 10. The Serpentine Bog was slightly more acidic at the Serpentine Marsh than at the mouth of the Serpentine at site B-14 (Figure 34). The decreasing trend in pH was obvious, but was not continuous between each site. The highest pH occurred at site B-14 and approached 7 (neutral). In general, the pH decreased from site B-14 to site B-3. At site B-3 the pH was at its lowest value approaching 6 (slightly acidic). This trend of a lower pH in the area of the marsh correlates with the fact that vegetation, such as *Sphagnum* moss, releases hydrogen ions and simultaneously lowers the pH of the water encompassed by the bog. The average mean of the pH of East Pond was 7.1, similar to the pH at the mouth of the Serpentine.

Conclusion

Characterization of wetlands

In our study of the Serpentine wetland, both the Serpentine Bog and Marsh were analyzed. Vegetation types were qualitatively measured and a transect was established in the Serpentine Bog in order to investigate the possible influence of the bog on the Serpentine stream.

The Serpentine Bog comprises about 63% of the Serpentine wetland (Figure 13).

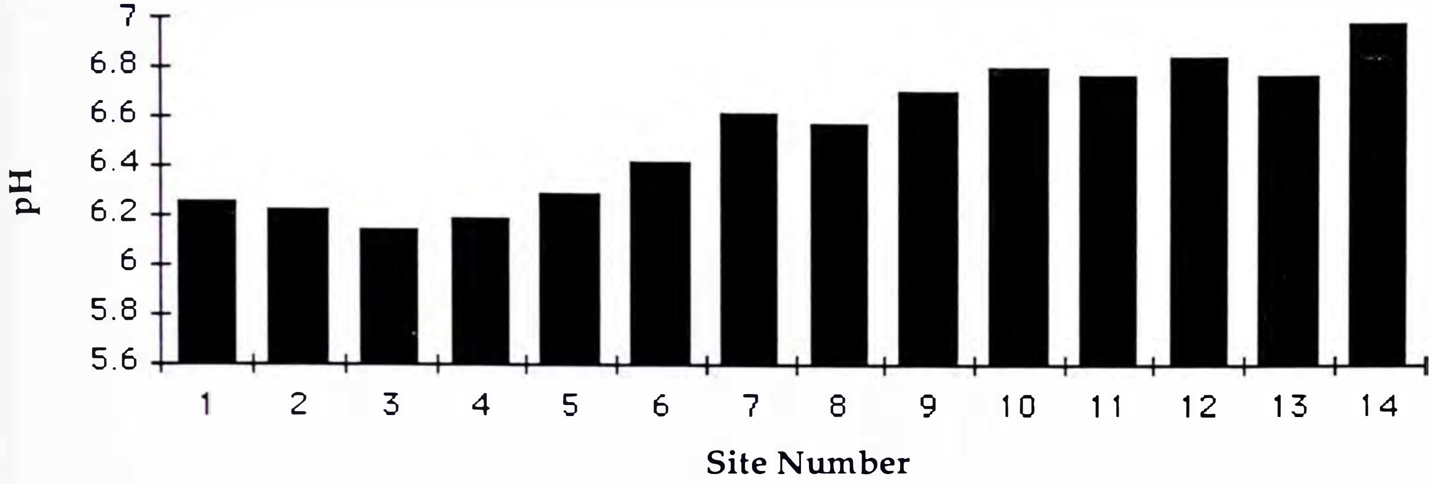


Figure 34. The pH of the Serpentine Bog transect. This shows the pH approximately one foot below the surface at sites B-1 through B-14 on the Serpentine Bog transect on October 10, 1991. Site B-1 is located at the Serpentine Marsh intersection, and Site B-14 is located near the mouth of the Serpentine.

General characteristics include a deep peat deposit, slightly acidic conditions and a water table at or near the surface. Vegetation close to the Serpentine was primarily *Sphagnum* moss, small leaf cranberry and pitcher plants while cotton grass, sheep laurel, bog laurel, sedges, small tamaracks and black spruce were more abundant further away from the Serpentine (Refer to Description of Sampling Sites).

The Serpentine Marsh covers about 25% of the Serpentine wetland (Figure 13). It has a shallow peat deposit and is periodically flooded with slow-moving, nutrient-rich water from the Serpentine, Clark and/or Sucker Brook. The primary vegetation at our study sites were cattails, emergent sedges, grasses, sweet gale and arrowhead.

As water flows from East Pond into the Serpentine, some water may flow under the overhanging bog mat, infiltrating into the bog mat. This flow of water could be flushing out nutrients from the bog into the Serpentine stream. The influence of the flowing water on the bog can be investigated by looking at changes in temperature, pH and conductivity. These three parameters were measured along a transect established in the Serpentine Bog on October 24, 1991 between 1300-1600 h (Figure 35).

From the first to the fifth site along the transect, temperature taken at depth gradually decreased and then leveled out in the last three sites (Figure 35). Warmer water flowing up the Serpentine and under the over-hanging mat may account for depth temperatures being the highest at the first few sites until the overhanging mat ended. A depth temperature reading of 14 °C was recorded for site 1 while a reading of 11 °C was recorded at site 8, thus showing the decrease in temperature as the sample site was moved further from the Serpentine. Sites 1 - 4 had an average depth temperature of 12.4 °C which was higher than then average

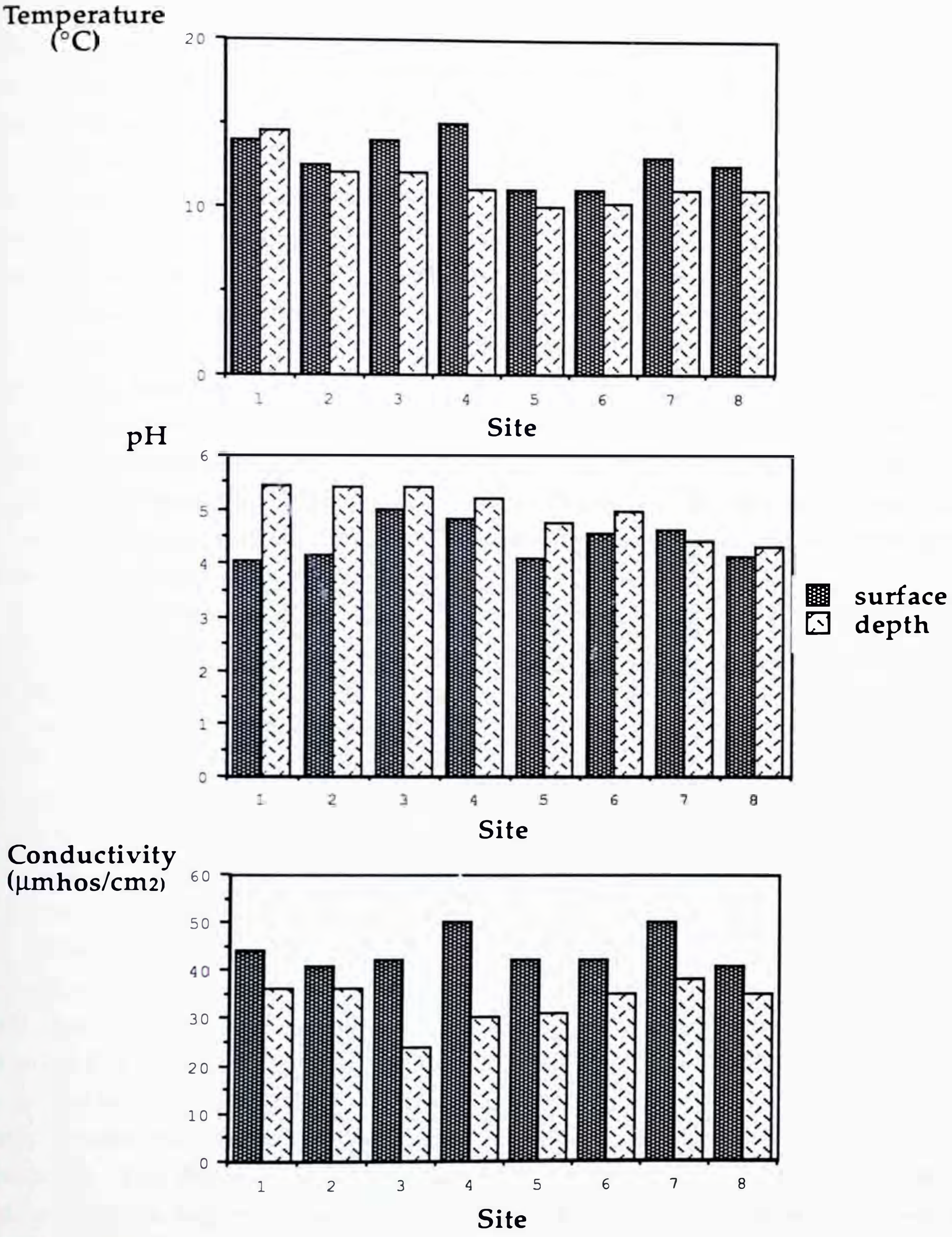


Figure 35. Temperature, pH, and conductivity results for the Serpentine bog taken on October 24, 1991 with a transect perpendicular to Serpentine and beginning 3 meters from the water's edge. Water samples were taken 0.5-1 meter below the mat surface.

temperature of the last four sites which was 10.6 °C. This pattern was most likely due to the infiltration of the Serpentine. Surface temperature was variable. The surface temperature for the first four sites, with an average of 13.9 °C, was higher than that of sites 5-8 which had an average reading of 11.9 °C.

The pH at depth also declined as we moved away from the Serpentine with site 1 having the highest depth pH of 5.43 and site 8 having the lowest depth pH of 4.3 (Figure 35). The first four sites had an average pH of 5.4 while the last four sites had a lower average pH reading at depth of 4.6. The increased pH at the first four sites is possibly caused by a continuous flow of water under the overhanging mat which helps to remove the by-products of decomposition (e.g. tannic acid) that can build up over time and increase the acidity of the wetland (Johnson, 1985). East Pond has a neutral pH (6.7 - 7.0 pH) and thus, may affect the pH of sites near the water by increasing their pH. Surface pH was slightly lower than depth pH but variable. Surface pH fluctuated from 4.1 to 5.0, with site 1 having the lowest pH and site 3 having the highest pH (Figure 35). One possible reason why the surface pH was lowest at site 1 was because of the presence of *Sphagnum* moss which releases hydrogen ions into the water as it takes up nutrients such as Ca, Mg and K.

Conductivity taken at depth was highest at sites 1 and 2 with a reading of 36 μmhos/cm^2 (Figure 35). Depth conductivity declined and then gradually increased as we moved further along the transect with the last site having a reading of 35 μmhos/cm^2. The flow of the Serpentine stream under the mat is once again a possible explanation as to why the depth conductivity readings for the first 2 sites was higher. Due to the possibility of increased water flow in these areas, there is tendency for the Serpentine's current to stir up the dissolved solids in the water. Surface conductivity was variable but higher than depth conductivity at all sites along the transect. Site 1 had a reading of 44 μmhos/cm^2 , site 8 had a reading of 41 μmhos/cm^2, and site 4 had the highest reading of 50 μmhos/cm^2.

Two sites were sampled in the Serpentine Marsh on October 24 between 1500-1700 h in order to compare the results with those of the bog transect. Both sites had similar temperature and conductivity readings at both surface and depth. Conductivity readings for the marsh (around 20 μmhos/cm^2), were much lower at both surface and depth than those taken at the bog. The slow moving water is a possible reason why the marsh values are much lower. The temperatures for both surface and depth at the marsh (between 9-11 °C) were also lower than the bog's. The decrease in water temperature at the marsh could possible be due to the influence of the Serpentine which was flowing up into the marsh as well as down to the dam after the dam boards were removed for the winter. Another possibility could be that air temperature affects shallow water quicker than it does deeper waters such as East Pond and the Serpentine. One interesting thing to point out is the difference between the marsh's pH readings and those of the bogs. The surface pH for both sites at the marsh were 5.1 and depth pH was between 5.2 and 5.4. The lack of *Sphagnum* moss is the most likely reason why the pH

5.2 and 5.4. The lack of *Sphagnum* moss is the most likely reason why the pH is higher in the marsh than in the bog.

Over all, evidence suggests that nutrient exchange between the Serpentine Stream and the adjacent bog may take place.

LAND USE - General Patterns and Trends

Materials and Methods

In order to determine the land use practices in the Serpentine and East Pond watersheds, 1965 (60 cm X 60 cm) aerial photographs were obtained from the United States Department of Agriculture (USDA) and 1991 (22.5 cm X 22.5 cm) aerial photographs were taken by a private flight firm in Norridgewock. The land use practices were divided into six categories according to patterns of vegetation and development. The six types of land use were: forest, wetlands, agriculture (pasture/grazing or plowed field), reverting agricultural land (fields released from agriculture practices experiencing natural succession), residential and roads (SCOALE, 1989). These land use types were confirmed with stereomicroscopes when resolution was unclear.

The scale of the 1965 and 1991 aerial photographs was determined by measuring the distance of a straight stretch of road and comparing it to a 1982 United States Geological Survey (USGS) map of known scale (1:24,000). The 1965 aerial photograph sequence had a scale of 1:7,902 and the 1991 aerial photograph a scale of 1:11,077.

Areas of forest, wetland, agriculture, and reverting land were measured using a Zeiss Interactive Digital Analysis System (ZIDAS). By tracing patterns on the ZIDAS digitizing tablet, diverse calculations and measurements were obtained. 1965 and 1991 aerial photographs were assembled to display the watersheds and allow comparisons to be made. Each of the four sequences (1965 Serpentine and East Pond watersheds, and 1991 Serpentine and East Pond watersheds) was covered in mylar enabling the exact watershed boundary to be placed on the aerial photographs for the determination of land use percentage. A square millimeter measurement scale for forest, wetland, agriculture, and reverting land was obtained for determination of percentage.

Area of residential land in the watershed was calculated by multiplying 0.5 hectares by each residence counted on the aerial photographs. The number of hectares was transformed to square millimeters for comparison with forest, wetlands, agriculture and reverting land collected from ZIDAS analysis.

Area of roads was determined by measuring road length on 1965 and 1991 aerial photographs. Two width categories were used: 20 feet and 40 feet. The linear distance (in square feet) was corrected for the map scale and calculated to gain square millimeters for comparison with forest, wetland, agriculture, reverting crop land, and residential land uses.

Results and Discussion

The land use patterns for the East Pond and Serpentine watersheds in 1965 and 1991 enable comparison between years and watersheds. The area of the East Pond watershed (1,087.8 ha) is smaller than the Serpentine watershed (1,596.1 ha). The percent of wetlands remained stable over time in both watersheds (Figure 36). Residential land use increased over time, from 10% to 14% in East Pond, and 1% to 3% in the Serpentine watershed. A larger percentage of the land was used for agriculture in the Serpentine watershed than in the East Pond watershed. Agricultural land actually decreased however, from 1965 to 1991 in both watersheds. Reverting land and forest increased over time in the Serpentine watershed, while they both decreased slightly with time in the East Pond watershed. Roads remained generally unchanged with time in both watersheds.

Each of the six land use categories affect the water quality of East Pond to a varying degree (Figure 36). Wetlands provide a sink for nutrients which, if flooded may release nutrients into East Pond. It is crucial to understand this phenomenon because 14% of the Serpentine watershed consists of wetlands whereas only 3% of East Pond watershed is wetlands. During heavy rains on Sept. 25-26, as discussed previously, flow in the Serpentine Bog reversed causing the Serpentine to possibly feed East Pond with nutrients stored in the wetlands. The area of wetlands did not change significantly in either watershed from 1965 to 1991.

The increase in residential land use over time may contribute to phosphorus loading in both watersheds. In the East Pond watershed residential development increased dramatically as individuals built seasonal and year-round homes on the lake shore. This increased development caused more septic systems to be built, increased recreation, and an overall higher potential for nutrients and chemical toxins to enter East Pond. East Pond watershed is probably characterized by higher residential land area than the Serpentine watershed due to recreational opportunities and the aesthetic quality of the lake.

Agricultural land may have decreased with time in both watersheds because of the depressed situation of farming in today's economy. In the Serpentine, the effect was manifested by an increase in reverting land from 1965 to 1991. A slight decrease in reverting land was observed in the East Pond watershed probably due to increased residential rather than agricultural uses. A more important finding however, was the substantially higher percentage of agricultural land in the Serpentine watershed. Agriculture, one of the primary contributors of phosphorus, possibly causes the Serpentine Marsh and Bog to be loaded with nutrients thus causing eutrophication when a reverse flow does occur.

Forested land was higher in the East Pond watershed than in the Serpentine watershed. Natural wetlands are important in preventing erosion and run-off around the shores of the lake. The most plausible explanation is that the lower percentage of forest in the Serpentine watershed was attributed to the increased agricultural land use from 1965 to 1991. Forest land use should be encouraged and maintained, primarily around the shores of East Pond.

The percentage of land use attributed to roads was minimal, however, a one percent increase in the East Pond watershed was found. As residential land increased, access roads most likely increased as well around East Pond.

Conclusions

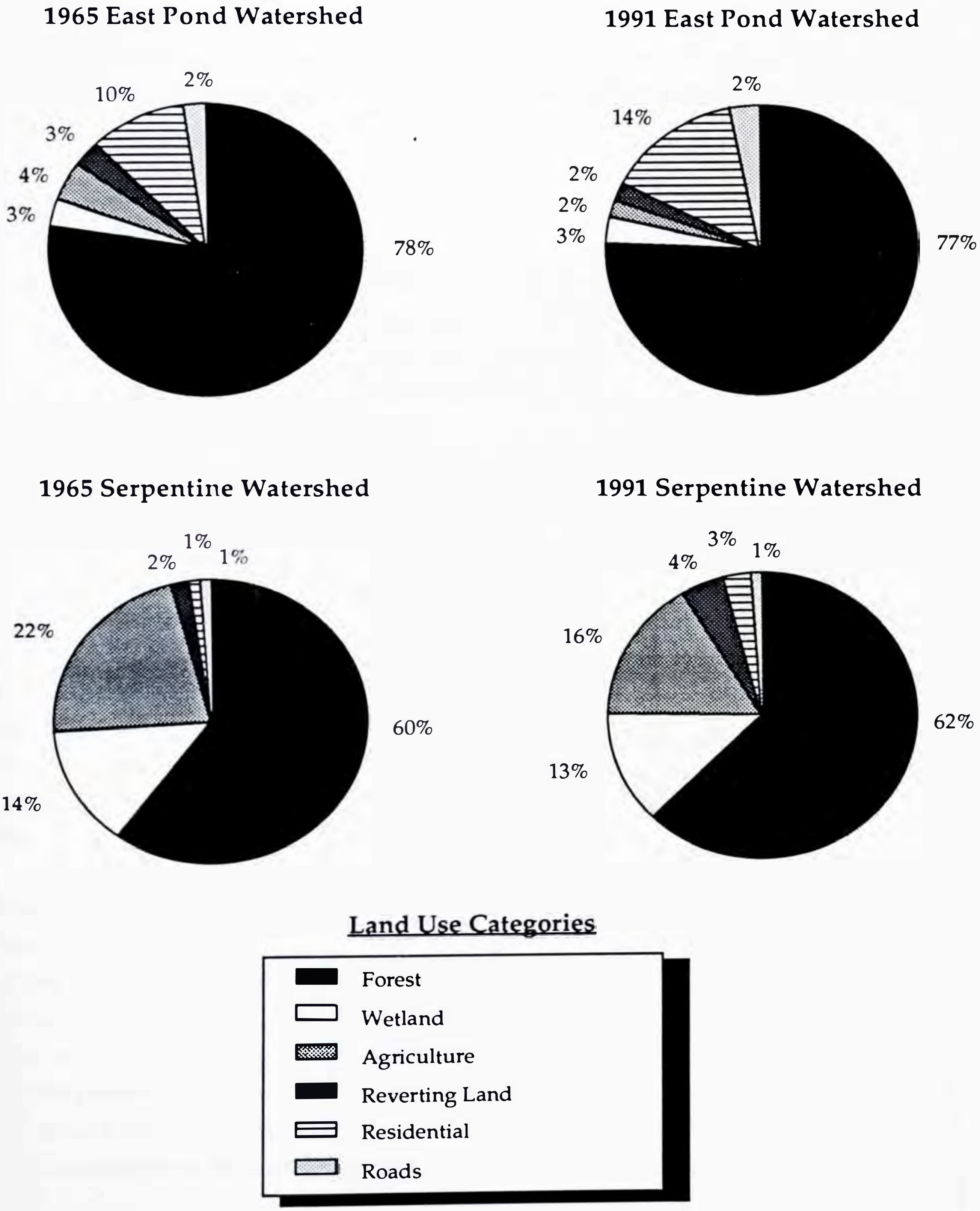


Figure 36. Comparison of general land use patterns for both East Pond and Serpentine Watersheds between 1965 and 1991.

Generally, any sloping lawn in the East Pond watershed which comes down to the water's edge is a highly probable conduit for phosphorus loading. It is necessary to plant buffer strips which absorb nutrients from the soil surface and prevent run-off. Land use trends should be monitored for high concentrations of residential use, agricultural use, roads or commercial land uses.

Critical Areas

Three areas in the East Pond watershed need special attention because the present land uses cause potential point-sources of phosphorus loading. The first, Brickett Point, is a heavily populated residential area, with a high concentration of septic systems, roads, and recreational activities. Future development should be discouraged and those existing homes should incorporate buffer strips along the lake shore.

Secondly, the wetlands at the southern tip of East Pond are bordered closely by Route 137. Run-off and erosion are highly possible; proper road maintenance is encouraged to prevent further nutrient loading of this fragile ecosystem.

The third area of residential and recreational (summer camp) land use in the southwestern corner exists and is lacking proper forest buffers. With the high degree of septic use in summer months, fertilizer on the fields, and direct run-off, it appears necessary to construct a buffer strip in order to decrease run-off and the resultant detriments of nutrient loading.

Critical areas in the Serpentine watershed are characterized by agricultural land uses. There are three farms in the center of the Serpentine watershed which have streams flowing directly through them. These farms will be discussed more thoroughly in the agriculture section regarding their potential for nutrient loading.

Future Development

Future development would be the least detrimental if it were restricted to the northeast corner of the East Pond watershed. New construction must have large buffers and other suitable erosion and run-off controls as discussed in the zoning laws, and be accessed by proper roads. This is a suitable area because of forested land use and a relatively flat grade.

In the Serpentine watershed, future development is possible in the northern third of the watershed, where impacts on the Serpentine are limited. Less pressure from agricultural land use enables these regions to be developed.

External Phosphorous Loading

Materials and Methods

Calculation of Phosphorus Coefficients

In the East Pond study, loading coefficients were based on previous work done by

Reckow *et al.* (1980), Dennis *et al.* (1989), and Bouchard *et al.* (1991). Ultimately, in a long term and properly funded study of a lake system, phosphorus coefficients would be carefully worked out to take into consideration many factors affecting them. For example, in order to compute the coefficient for forested land, one would take into account the dominant tree species type, the soil type, the vegetation age, the climate, the amount of logging, and any forest fires, all of which would affect phosphorus loading into the lake system (Reckow 1980). Reckow (1980) points out that the most important task that the analyst performs in applying the methodology is in selecting the phosphorus export coefficients. Problems arise when there is hidden uncertainty over choice of high or low coefficients which leads to bias in prediction and risk in planning (Reckow, 1980).

A range of low to high values was applied to each land pattern, with the actual phosphorus loading assumed to be somewhere in between these two values. This was done in order to overcome the possible errors due to not measuring directly the phosphorus loading, and not being able to compute exact coefficients for East Pond and the Serpentine Stream. East Pond and Serpentine Stream were assigned the same coefficients, so that a comparison of phosphorous loading between the watersheds would be possible. The phosphorus coefficients were based on the work of Dennis (1989) in the China Lake Restoration Project and Bouchard (1991) in a study of Cross Lake. Both of these previous studies were on Maine lake systems, making the phosphorus coefficients fairly applicable to East Pond.

The precipitation and dry fallout coefficients were set at 0.10 and 0.30. The coefficient for forested land was set at 0.03 and 0.20 because undisturbed forest land would contribute less phosphorus per hectare to East Pond and the Serpentine Stream than other land uses. Wetlands, such as the East Pond Bog, were assigned coefficients of 0.03 and 0.20 based on Bouchard (1991). Reverted crop land, defined and measured as agricultural land that was no longer being farmed and reverting to grassland, was assigned coefficients of 0.10 and 0.20 because it represents a relatively stable soil cover.

Pasture land was assigned coefficients of 0.30 and 1.00 as opposed to a higher value, because it was moderately grazed by animals, had a slight to moderate slope, and moderate soils which would filter phosphorus. There was no other agricultural use of the land in the watersheds other than pasture land. Roads were assigned coefficients of 0.75 and 4.00 which reflects the large number of non-maintained and eroding private roads in the watersheds.

The coefficients for residential land were broken down into shoreline house lots (250 ft. from the shore), non-shoreline house lots (outside 250 ft.), and septic system leach fields, because each of these would export a different amount of phosphorus. The housing coefficients were impacted by the fact that 80% of the houses around East Pond are seasonal and 20% are year-round residences (EPLA, 1989). Shoreline house lots were assigned coefficients of 0.20 and 0.30, and non-shoreline house lots were assigned slightly smaller coefficients of 0.15 and 0.20 because they would have less effect on the lake water quality than houses directly on the water. Septic system leach fields were given coefficients of 0.40 and 0.90 which reflects the number of grandfathered septic systems of questionable condition, and the fact that only 46% of the septic systems have been pumped in the last five years (EPLA, 1989).

Method of Computation of Total Phosphorus Loading

The kilograms phosphorus per year (kg-P/yr) export value was computed by multiplying phosphorous coefficients by the area (ha) of each land use type in both watersheds. In each case, there is a low and high projection of phosphorus loading per year because the areas were multiplied by low and high coefficients. Hectares of forest, wetlands, reverted crop land, and pasture land in the Serpentine and East Pond watersheds were obtained from using the ZIDAS on 1991 aerial photographs (22.5 cm X 22.5 cm), and the hectares of roads were measured and converted from the 1991 aerial photographs. The kg-P/yr for precipitation and dry fallout was computed by multiplying the coefficient by the open water (ha) of East Pond and the Serpentine Stream. The kg-P/yr exported from shoreline house lots, non-shoreline house lots, and septic leach fields were based on counts of each from the 1991 aerial photographs and multiplied by the phosphorus coefficients. The total residential figure is a summation of these three values.

The percent total figures were computed by dividing the kg-P/yr value by the total kg-P/yr value in each category. This was done in order to obtain the relative importance of each land pattern in comparison with the total phosphorus exported.

Results and Discussion

The total external phosphorus loading budgets of East Pond and the Serpentine stream are useful because they show the amount of phosphorus loading from each land use in relation to other land uses (Tables 16 and 17). For instance, residential land may have a high loading coefficient, but if there is minimal residential land in the watershed, then the impact will be less than forested land. The total external phosphorus loading to East Pond in the low scenario was 252 kg-P/yr, and using the highest coefficients, the amount was 760 kg-P/yr (Table 16). The total phosphorus loading in the Serpentine Stream was 183 kg-P/yr in a low scenario and 683 kg-P/yr in a high scenario (Table 17).

From the data of the phosphorus budgets, figures were made which relate the percent area of each land with its effect on phosphorus loading (Figures 37 and 38). Around East Pond, the greatest amount of phosphorus was coming from residential land. The second greatest amount of phosphorus was from precipitation and dry fallout, followed by forested land. In the Serpentine stream watershed, the major input of phosphorus came from pasture land, with the next highest contributions from forested land and residential land.

Conclusions

Table 16. Total external phosphorus loading to East Pond based on land uses, patterns, and precipitation and dry fallout. Asterisks indicate counts rather than hectares.

Land Use	Area (ha)	P Coefficient[1]		kg-P/yr		% Total	
		Low	High	Low	High	Low	High
Precipitation & Dry Fallout	690.0	0.1	0.3	69.0	207.0	27.4	27.3
Forest	837.6	0.0	0.2	25.1	167.5	10.0	22.1
Wetlands	32.4	0.0	0.2	1.0	6.5	0.4	0.9
Reverted Crop Land	21.9	0.1	0.2	2.2	4.4	0.9	0.6
Pasture	17.5	0.3	1.0	5.3	17.5	2.1	2.3
Roads	22.9	0.8	4.0	17.1	91.4	6.8	12.0
Residential							
# Shoreline House Lots	144.0 *	0.2	0.3	28.8	43.2	11.4	5.7
# Non-Shoreline	84.0 *	0.2	0.2	12.6	16.8	5.0	2.2
# Septic Leach Fields	228.0 *	0.4	0.9	91.2	205.2	36.2	27.0
Total Residential	155.5			132.6	265.2	52.6	34.9
Totals	1087.8			252.3	759.5	100.0	100.0

[1] Coefficients based on Reckhow (1980), Dennis (1989), and Bouchard (1991).

x total load
generated by household

Joan Brooks
Wat. @ UMO
Dept. Civil Eng. water
Chet Rock
581-2170

EPA grams P/cap/day

USEPA 625/180012
Design manual: Onsite Wastewater Treatment & Disposal Systems

Table 17. Total external phosphorus loading to the Serpentine Stream based on land uses, patterns, and precipitation and dry fallout. Asterisks indicate counts rather than hectares.

Land Use	Area (ha)	P Coefficient[1]		kg-P/yr		% Total	
		Low	High	Low	High	Low	High
Precipitation & Dry Fallout	29.0	0.10	0.30	2.9	8.7	1.6	1.3
Forest	986.7	0.03	0.20	29.6	197.3	16.2	28.9
Wetlands	205.0	0.03	0.20	6.2	41.0	3.4	6.0
Reverted Crop Land	71.5	0.10	0.20	7.2	14.3	3.9	2.1
Pasture	261.9	0.30	1.00	78.6	261.9	42.9	38.8
Roads	17.2	0.75	4.00	12.9	68.6	7.0	10.0
Residential							
# Shoreline House Lots	14 *	0.20	0.30	2.8	4.2	1.5	0.6
# Non-Shoreline	68 *	0.15	0.20	10.2	13.6	5.6	2.0
# Septic Leach Fields	82 *	0.40	0.90	32.8	73.8	17.9	10.8
Total Residential	53.8			45.8	91.6	25.0	13.4
Totals	1596.1			183.0	683.4	100.0	100.0

[1] Coefficients based on Reckhow (1980), Dennis (1989), and Bouchard (1991).

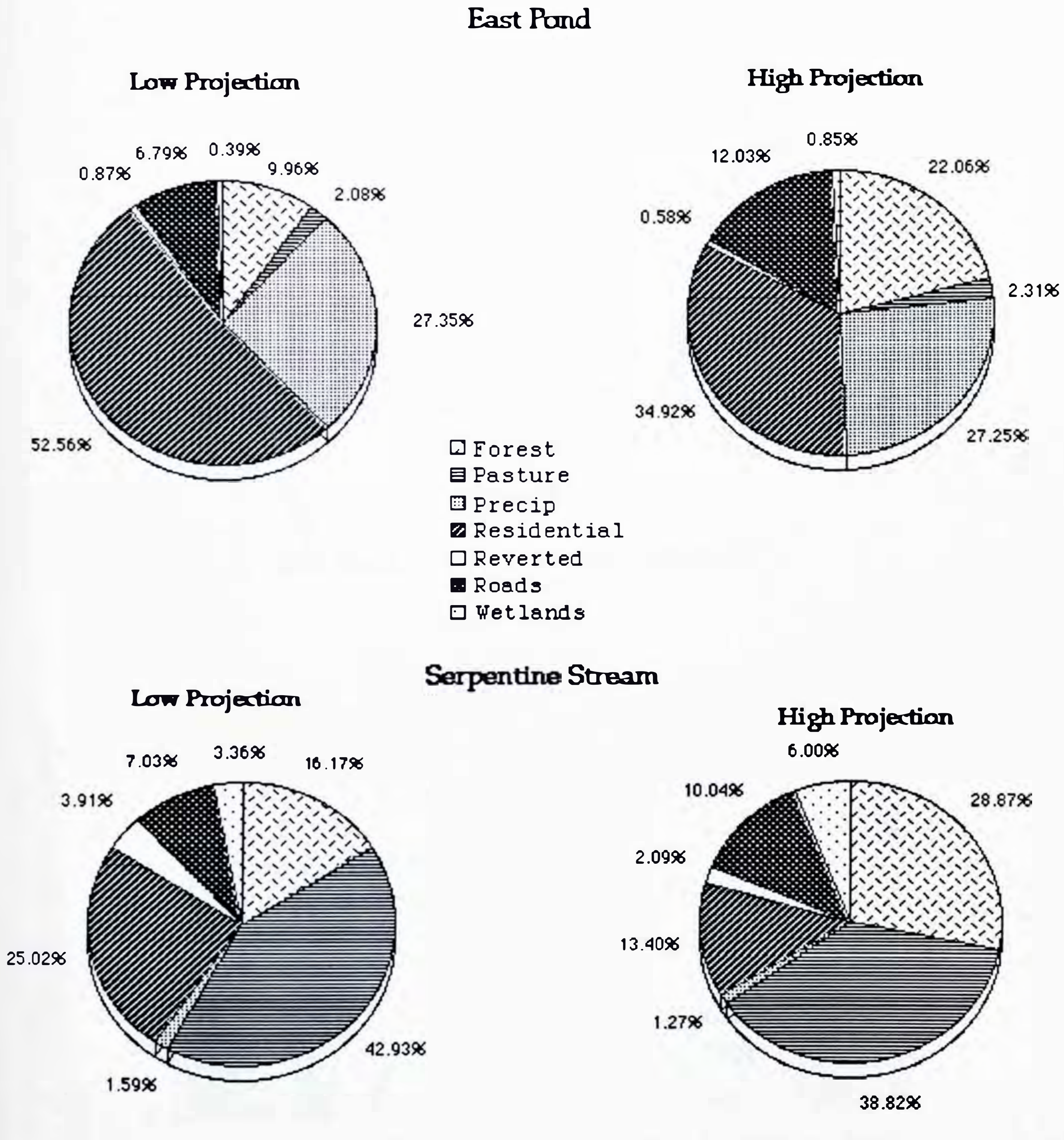


Figure 37. Comparison of percentages of total phosphorus loading based on patterns of land uses within the East Pond and Serpentine Stream watersheds. The low and high projections are based on the range of phosphorus coefficients assigned to each land use in order to compute the kg phosphorus loading per year.

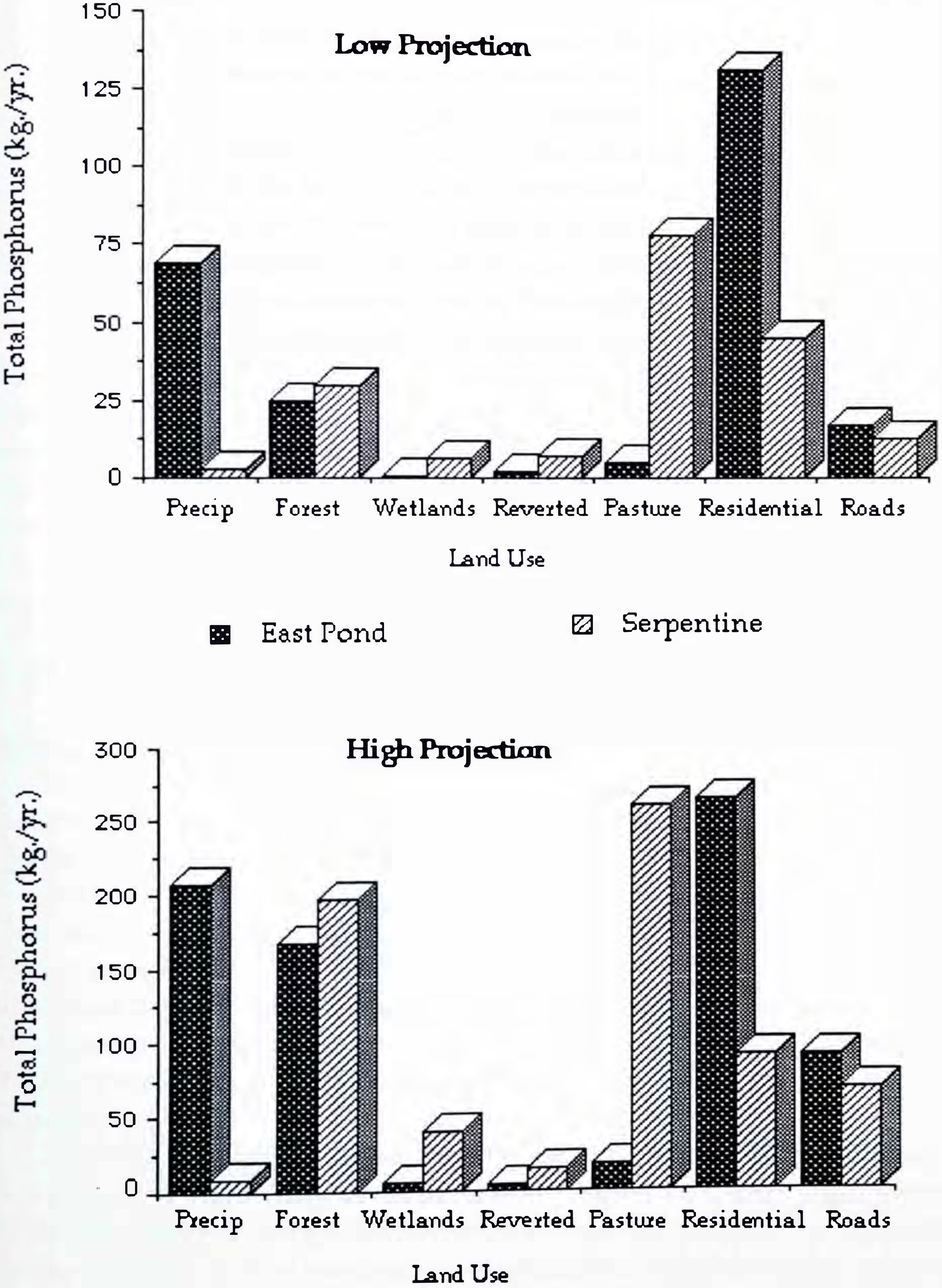


Figure 38. Comparison of low and high projections of total phosphorus loading (kg/yr) between the East Pond and Serpentine stream watersheds.

The highest contributions of phosphorus around East Pond pose somewhat of a problem, for while mitigative measures can be taken to decrease phosphorus loading from residential lands, nothing can be done to stop the inputs from precipitation and dry fallout. It should be recognized that because residential inputs are the highest around East Pond, any increase in development around the lake will have a detrimental effect on lake water quality. It is important to note that development not directly on the shoreline, but within the watershed, will have just as great an impact on annual phosphorus loading. An increase in residential land would also increase the phosphorus loading from roads.

The great amount of phosphorus coming from agricultural lands is probably due to the fact that agricultural land with grazing animals is more easily eroded than soil covered with vegetation. Care must be taken in the future to ensure that the phosphorus loading from agricultural land does not increase, and there are positive steps that could be taken to reduce this value (see section on agricultural land use). Forested land and wetlands, both of which have relatively small coefficients, currently comprise a large portion of the phosphorus budget. Any future residential or road development could adversely affect these natural areas, and would in turn increase the total amount of phosphorus exported per year.

Soil Types

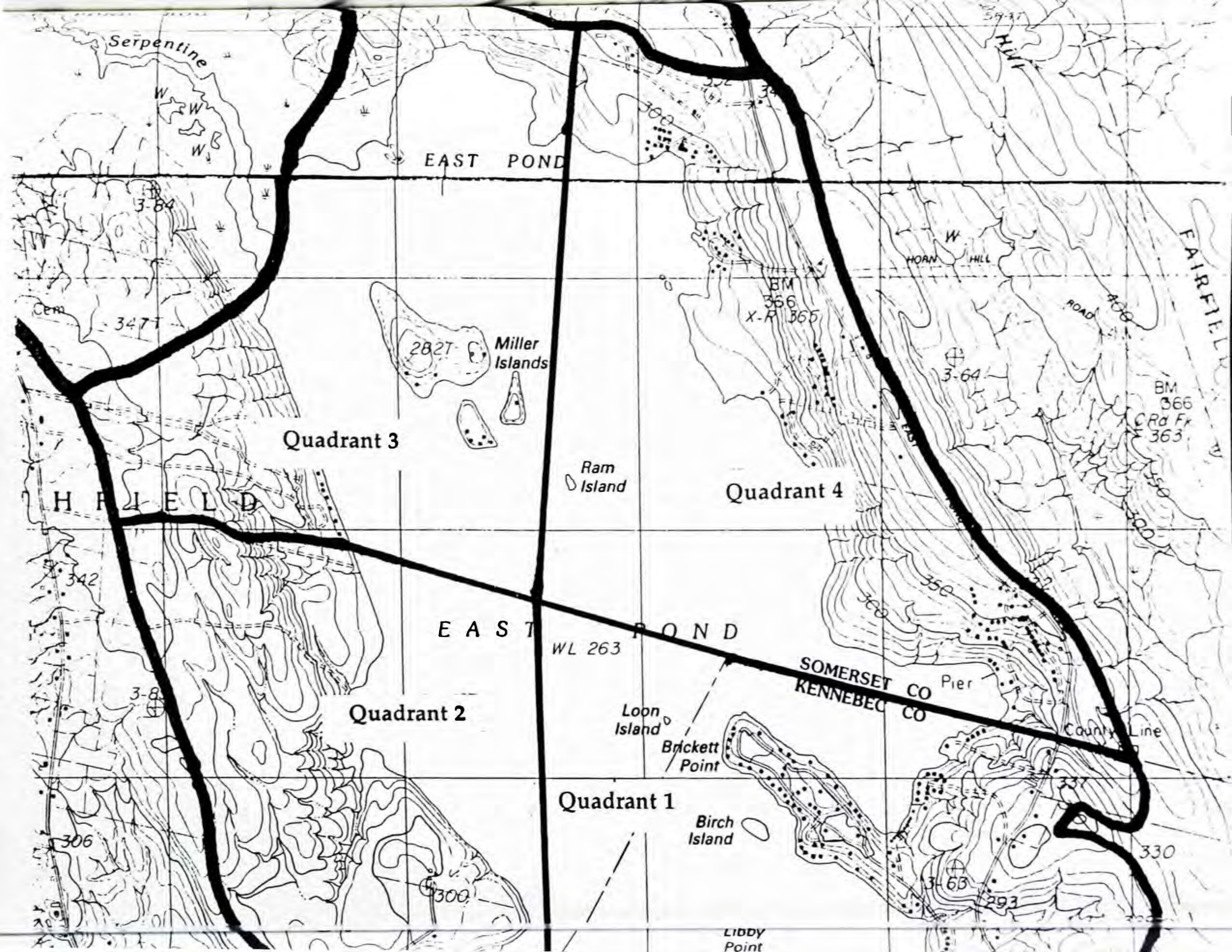
Materials and Methods

Both East Pond and Serpentine watersheds were divided into four quadrants to make the characterization of soils more simple (Figures 39 and 40). The breakdown was fairly random although political and natural (stream) boundaries were followed whenever possible.

Soil types were determined for the Serpentine and the East Pond watersheds from Soil Conservation Service (SCS) soil maps (Arno, 1972; Faust, 1978). Soil types were distinguished through grouping soils by name and by disregarding slope. Each soil type present was rated for permeability and typical use to determine their role in phosphorus loading (Table 18). SCS soil maps were then covered with mylar, enabling the exact boundary of the Serpentine and East Pond watershed to be drawn on the maps. Using ZIDAS the area of each soil type was measured.

In order to determine the effects of soil type on nutrient loading to the lake body, soil types were grouped into five categories of permeability: rapid, moderately rapid, moderate, moderately slow and slow. The permeability of the soil was directly related to runoff potential and leaching potential, both of which may cause phosphorus loading and the resultant threat of eutrophication. A brief description of each classification is needed to understand the potential effects on lake water quality.

Rapidly permeable soils, such as sand, provide less than adequate buffering due to effects on ground water. Nutrients and chemical toxins pass quickly through the soil column unable


Serpentine
W
W
W
EAST POND
3-84
Cem
347T
282T
Miller Islands
Quadrant 3
Ram Island
Quadrant 4
HILL
300
BM 366
X-R 365
HORN HILL ROAD
400
3-64
BM 366
CRd Fk 363
FAIRFIELD
350
300
HFIELD
342
EAST POND
WL 263
360
350
SOMERSET CO
KENNEBEC CO
Pier
County Line
Quadrant 2
Loon Island
Brickett Point
Quadrant 1
Birch Island
337
330
306
300
3-63
293
Libby Point

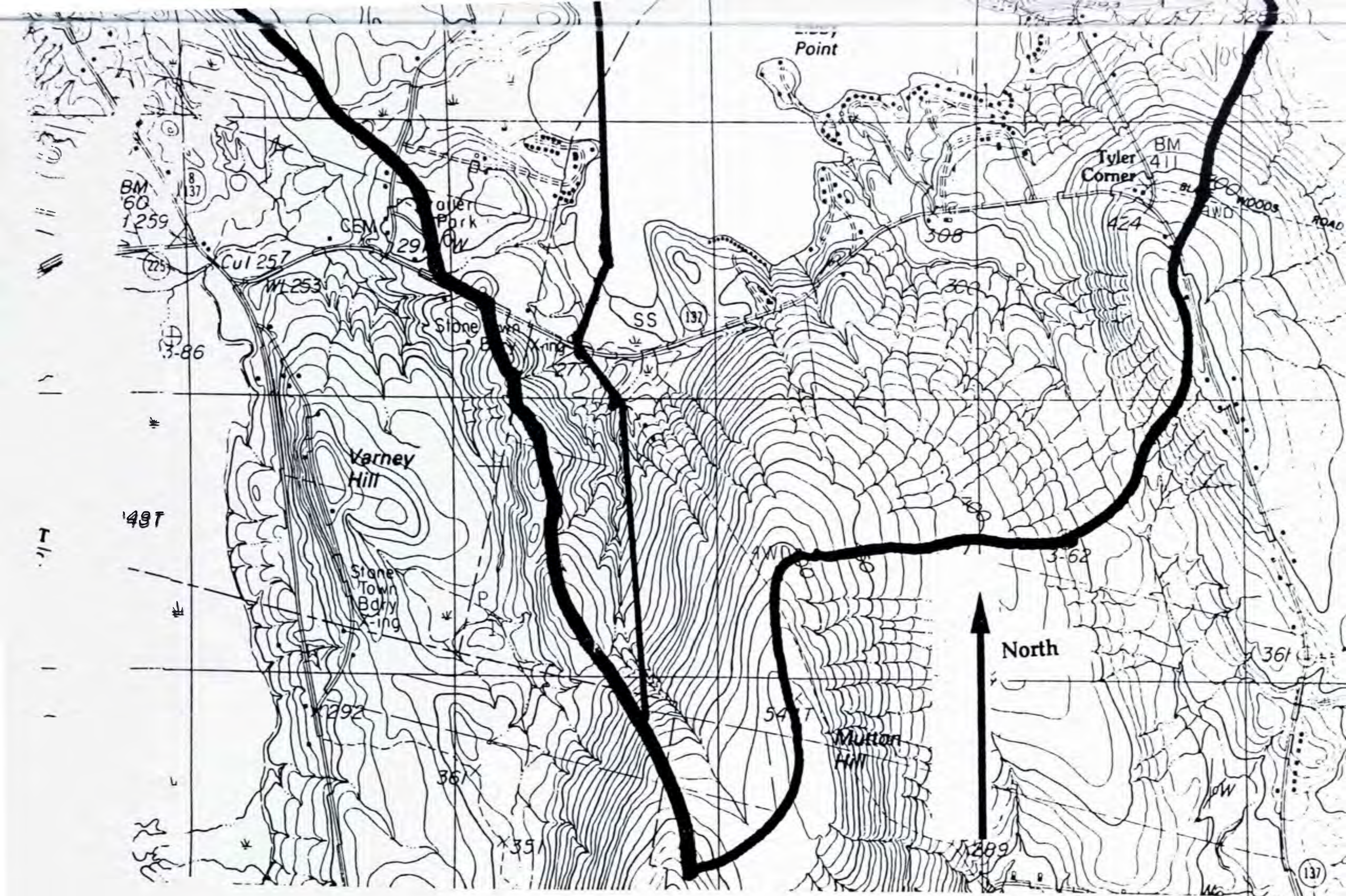
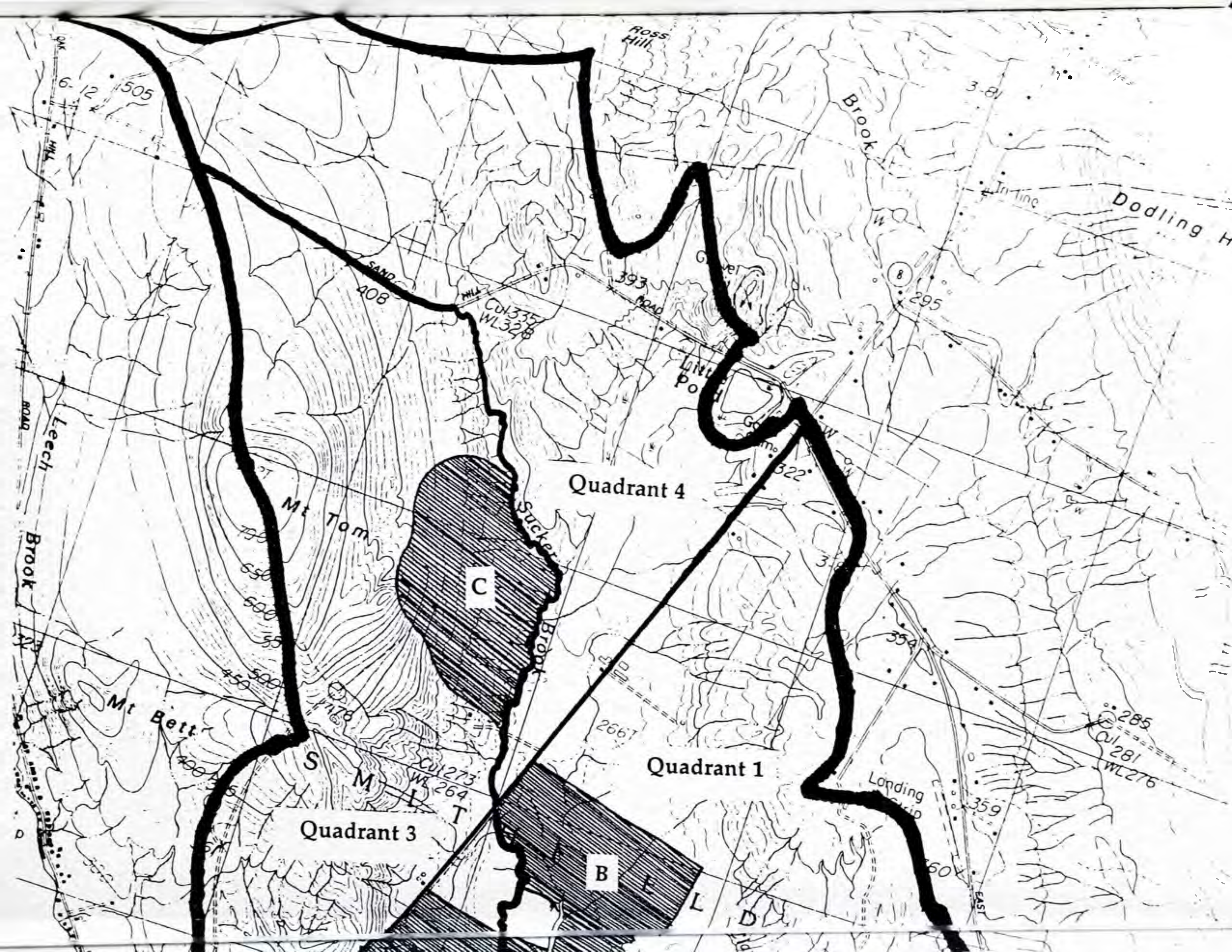


Figure 39. East Pond soil quadrant map. East Pond watershed outlined with the dissection of the four quadrants. 1982 USGS map, scale (1:16,000).


Ross Hill
505
6-12
3-81
Brook
In line
Dodling H
Leech Brook
SAND HILL ROAD
408
393
Cul 335
WL 328
Gravel
Pond
295
8
322
Quadrant 4
Mt Tom
700
650
600
550
500
450
Sucker Brook
C
3-8
354
Mt Bett
478
S
M
L
T
Cul 273
WL 264
Quadrant 3
266
Quadrant 1
285
Cul 281
WL 276
Landing Strip
359
B
E
L
D
360
EAST

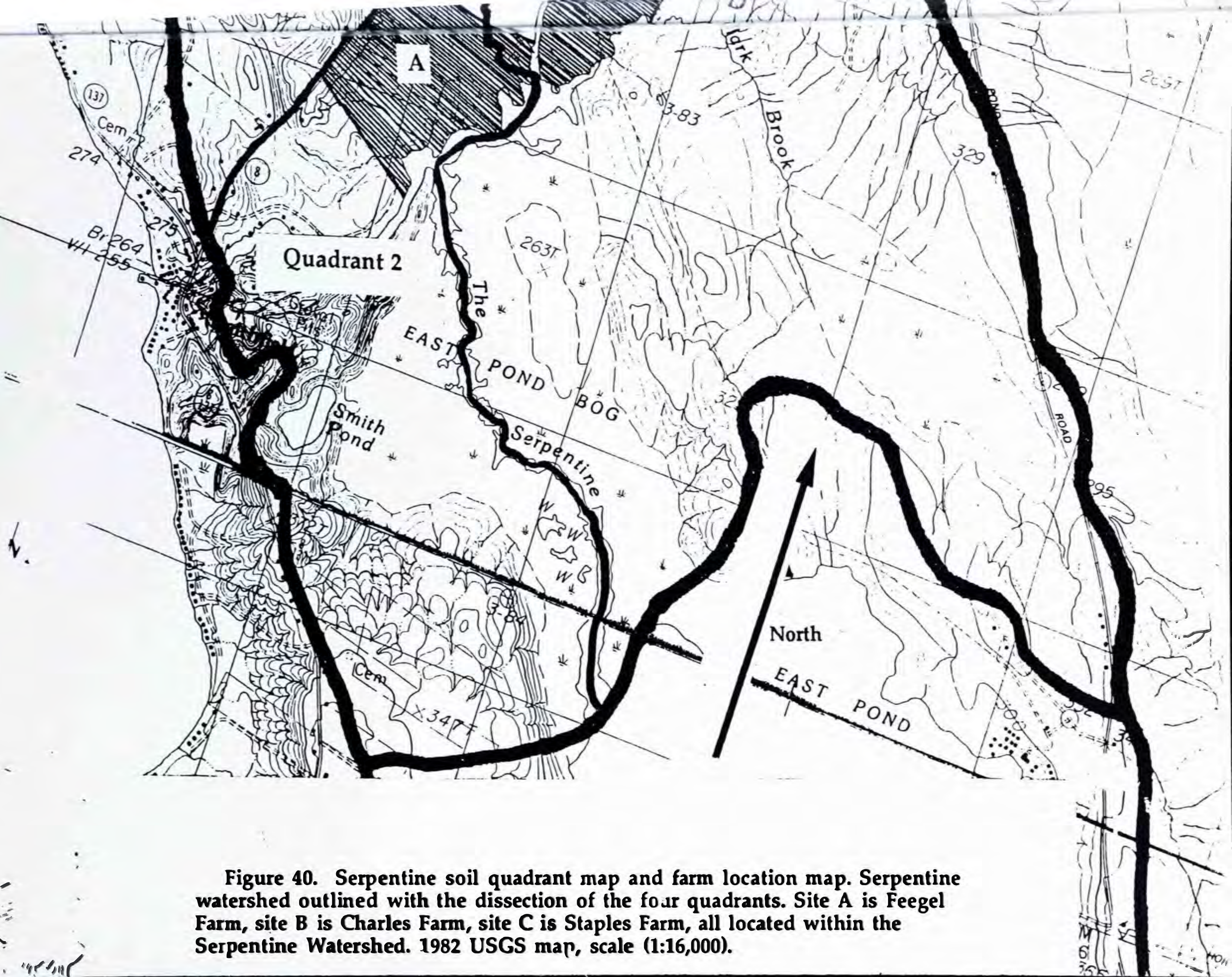


Figure 40. Serpentine soil quadrant map and farm location map. Serpentine watershed outlined with the dissection of the four quadrants. Site A is Feegel Farm, site B is Charles Farm, site C is Staples Farm, all located within the Serpentine Watershed. 1982 USGS map, scale (1:16,000).

Table 18. Soil permeability classifications, names and common uses. Soil permeability divided into five categories which directly affect nutrient loading. Information obtained from the soil surveys for Kennebec and Somerset Counties (Arno *et al.*, 1972; Faust *et al.*, 1978).

Permeability	Soil Name	Uses
rapid	Adams loamy sand	woodland, cropped
rapid	Colton gravely sand loams	woodland, hay, pasture
rapid	Melrose fine sandy loam	cropped, hay, pasture
rapid	Skowhegan loamy fine sand	hay, pasture, woodland
rapid	Stetson fine sandy loam	cropped, hay, pasture
moderately rapid	Berkshire very stony loam	woodland
moderately rapid	Leicester very stony loam	woodland
moderately rapid	Lyman loam	hay, pastuere, wood
moderately rapid	Monardo very stony silt loam	woodland
moderately rapid	Peru fine sandy loam	woodland, pasture
moderately rapid	Walpole fine sandy loam	woodland, pasture, hay
moderate	Bangor silt loam	cropped
moderate	Buxton silt loam	hay, pasture
moderate	Bangor very stony silt loam	woodland
moderate	Berkshire fine sandy loam	hay, pasture
moderate	Dixmont silt loam	crooped, hay, pasture
moderate	Peru very stony loam	woodland
moderately slow	Dixmont very stony silt loam	woodland, pasture
moderately slow	Peru very stony loam	pasture, woodland
moderately slow	Ridgebury very stony fine sandy loam	woodland
moderately slow	Suffield silt loam	cropped, hay, pasture
slow	Biddeford	pasture
slow	Peat and muck	wildlife habitat
slow	Peru loam	cropped, hay, pasture
slow	Rifle mucky peat	wildlife habitat, woodland
slow	Scantic silt loam	hay, pasture

to bind with the large particles and become located in the ground water. Spring fed lakes result in either increased nutrients or increased chemical concentrations, or possibly both in an extreme situation.

Moderately permeable soils provide the best buffering capabilities. Nutrients are saturated into the soil rather than sitting on the surface, however, they do not merely pass through to reach the ground water as with rapidly permeable soils (Roy Bouchard, DEP, pers. comm.). Nutrients locked up in the soil column can be broken down and utilized biologically rather than leading to lake deterioration.

Slowly permeable soils, such as clay, provide poor nutrient buffering abilities because nutrients remain on the soil surface. Surface flow, especially in areas of high slope, transports these nutrients directly to the lake body.

It appeared that not all soils could be grouped into three large categories, rapid, moderate and slow. The moderately rapid and moderately slow classifications describe soils which lay between the moderate classification and either rapid or slow classifications. Although these soils fall in the middle of the spectrum, and provide less threat than rapidly or slowly permeable soils, moderately permeable soils were considered the optimum soil type.

Results and Discussion

Permeability classifications were plotted as a percent of each quadrant (Figure 41). In the East Pond watershed, moderately permeable soils were more abundant in Quadrants 1 and 4 than on the west side of the lake. Conversely, quadrants 2 and 3 contained the largest amount of slowly and rapidly permeable soils totalling 24% and 22%, respectively The Serpentine watershed displayed a high abundance of moderately rapid soils with 71% in quadrant 3 and 65% in quadrant 4. Quadrant 2 was characterized by 42% rapidly permeable soils and 22% slowly permeable soils. In general, a higher degree of slowly permeable soils existed in the Serpentine watershed than the East Pond watershed.

Soil type is an important measure of runoff and leaching into a lake body. The East Pond watershed was characterized by relatively sound soils for development. The eastern shore of the lake (quadrants 1 and 4), was most beneficial for development due to moderately permeable soils (Figure 39). Run-off and leaching along the eastern side of the watershed was minimal and thus land use effects on water quality may be minimal in this region.

The western side of the watershed (quadrants 2 and 3), was characterized by a higher degree of rapidly and slowly permeable soils thus allowing nutrients to enter the lake by runoff and leaching. The western shore was characterized by a steep slope (3%-8%) further contributing to the possibility of runoff.

The Serpentine watershed had more soil type variation than the East Pond watershed. This diverse soil distribution enables natural buffering as well as severe point-source locations. Quadrants 3 and 4 were dominated by moderately rapid permeable soils enabling runoff to be

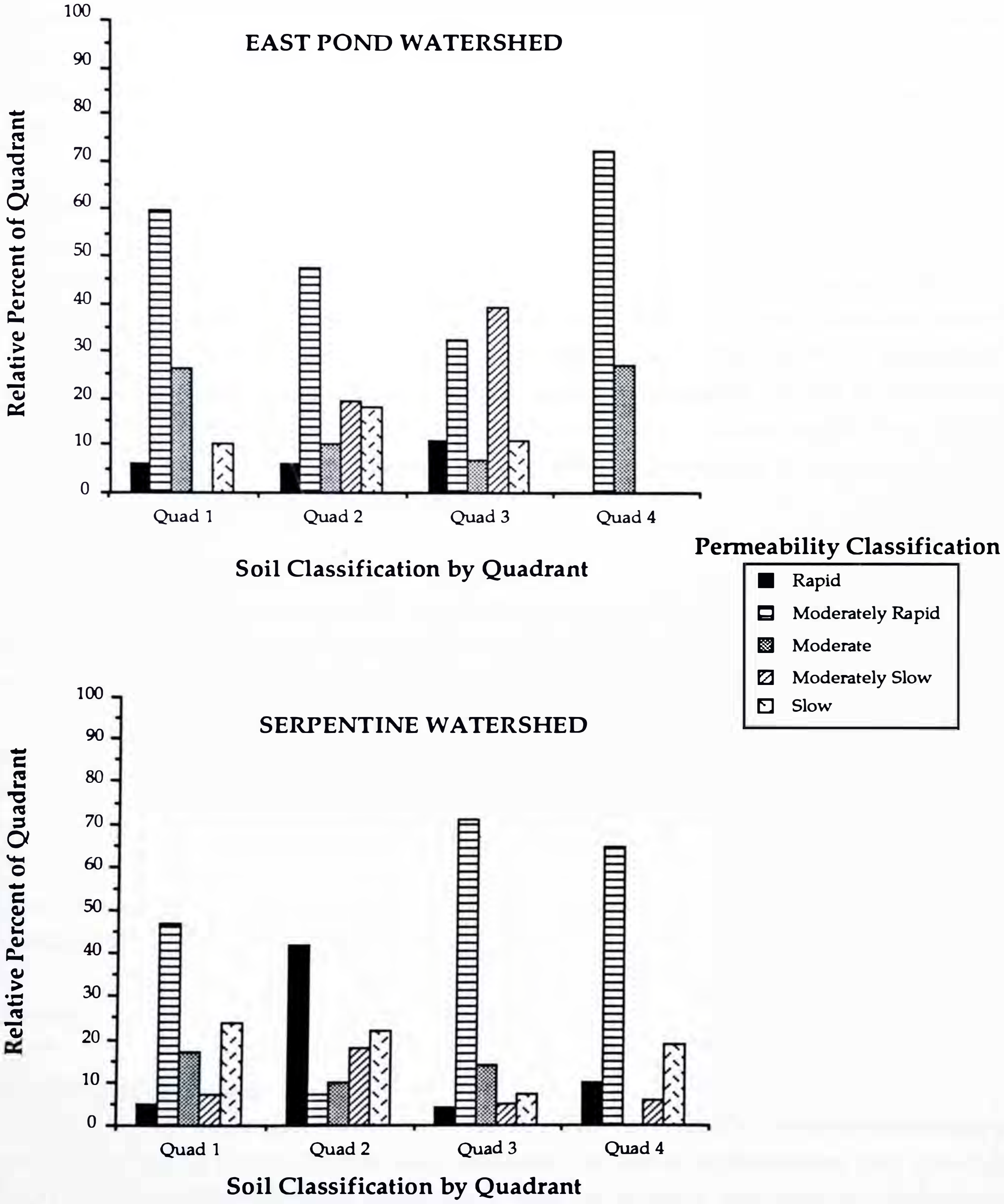


Figure 41. Permeability classification of soils in four quadrants of East Pond and Serpentine Watersheds.

less of a factor than leaching in phosphorus loading (Figure 40).

Quadrant 2 displayed a high percentage of rapidly permeable soils most likely due to the amount of wetlands present in the Serpentine. Quadrant 1, where Clark and Sucker Brooks were located, contained slowly permeable soils possibly leading to run-off. Although this area was flat, there was a pasture adjacent to both brooks which may lead to increases in nutrient flow.

Conclusions

Critical Areas

In the East Pond watershed, development should be limited on the western shore of the lake due to the poor buffering capabilities of the soils and the steep slope. Increased runoff will likely result from future development in quadrants 2 and 3 of the East Pond watershed.

In the Serpentine watershed, runoff prevention techniques should be introduced in quadrant 2 to ensure that phosphorus loading does not occur in this fragile area. The use of forest buffers, proper road techniques, and secure septic systems is necessary to prevent nutrient loading into the Serpentine Stream.

Future Development

In the East Pond watershed, due to sound soils, the most appropriate region for development is the fourth quadrant. Slowly permeable and rapidly permeable soils do not exist in this region. Possibilities of runoff and leaching are thus very minimal.

In the Serpentine watershed, the most beneficial area for increased development lies in quadrants 3 and 4 for two reasons. First, this region contains moderately rapid permeable soils which enable nutrients to be absorbed by the soil rather than causing runoff to occur. Second, this region is farther from Clark and Sucker Brooks which feed directly into the Serpentine and are major sources of run-off. Increased run-off will most likely result if development expands close to these brooks. Subsequently, quadrants 3 and 4 are the most suitable regions for future development.

Forestry

Materials and Methods

Past and present trends in forestry within the East Pond and Serpentine watersheds were examined. Maine Forest Service was contacted for forest regeneration and clearcutting standards, as well as personal notification files for forestry practices for Kennebec and Somerset counties. A field reconnaissance of woodcutting practices occurring in the watersheds was not possible due to the difficulty in identifying and contacting the individual harvesters. Recommendations based on current harvesting techniques and standards were then made to prevent further damage to the lake system.

Results and Discussion

In the East Pond watershed in 1965, 78% of the land was in forest. Today, in 1991, that figure has decreased to 76%. In the Serpentine watershed the reverse trend is occurring. In 1965, 60% of the watershed was in forested land and in 1991 the figure has gone up to about 62%.

Foresters in the East Pond area reported that there has been a general trend towards stripping the land and subdividing it for development (Long, SCS, pers. comm.). In addition, due to the depressed economy, individual landowners have turned to logging to augment their income (Daren Turner, SCS, pers. comm.). In 1989 the Maine state legislature passed the Forest Practices Act which increased the amount of technical assistance provided to forest landowners and which supported forest management activity. It also requires a file of notification for any forestry practice that may occur. The laws of this act are very strict and the penalties are severe (Bessey, pers. comm.) As a result, the logging community is careful for fear of being forced out of business, and trends have been to increase proper logging techniques and practices. The Shoreline Zoning Act prevents forestry from occurring on a large scale around East Pond. According to the act, selective cutting of no more than forty percent of the total volume of trees is permitted. In addition, timber harvesting equipment may not use stream channels as travel routes except when surface waters are frozen and the activity will not result in any ground disturbances (DEP, 1990). The Natural Resource Protection Act also serves to protect streams and rivers from poorly managed logging practices (Jack Dirkman, Maine State Forest Service, pers. comm.).

Local forestry companies in the area, such as Bessey and Sons, and organizations such as the Soil Conservation Service and the Maine State Forest Service report that forestry is not a big problem in the Serpentine and East Pond watersheds because there is not a lot of harvesting activity. In addition, those operations that are ongoing for the most part follow the new resource protection act. Most timber operation are trying to avoid sediment loading of brooks, tributaries and streams (Daren Turner, SCS, pers. comm.). There have been 14 notification files in Oakland and 20 in Smithfield since the Forest Practices Act was passed. Of the Smithfield files, only one forester is planning to convert the land into three different house lots after harvesting, and this site is not located in the watershed.

Impact on the water quality of the Serpentine and East Pond from forestry practices does not appear to be significant. Looking towards the future, there appears to be little potential for harm, because the market for the development of forestry practices does not exist. Any large forestry practices that may occur would be for the development of new camps on the lake (Jack Dirkman, Maine State Forest Service, pers. comm.).

Conclusions

Forestry does not appear to be a huge problem in the East Pond and Serpentine watersheds. There is little known effect on the water quality of the Serpentine and East Pond system from forestry, and practices appear to be following set guidelines and rules.

Coliform Testing

Materials and Methods

Test Dates and Sites

After a field reconnaissance on Sept. 12 and by studying topographic maps of East Pond, initial sites were chosen around the lake for testing on Sept. 26 (Figure 14b). Site 8 at the interface of the Serpentine stream and East Pond was chosen to determine if there was fecal pollution from East Pond entering the Serpentine stream. Site 20 in the middle of East Pond was chosen as a control. Sites 21 - 23, and 25 - 29 were chosen as areas of high residential concentration. Sampling on Sept. 26 followed immediately after a storm event. During testing on this day, it became apparent that fecal pollution from agricultural lands in the Serpentine stream was a potential problem, and water samples were collected for coliform analysis at sites 3 and 4 (Figure 14a). Site 3 was at the confluence of Sucker and Clark Brooks, and Site 4 was at the down-stream side of the snow-mobile bridge on Clark Brook. This site was chosen because cows were observed grazing at the waters edge.

Several more test sites were chosen for sampling on Oct. 3, an overcast day. Water samples were collected from sites 23 and 24 in Libby Point Cove on East Pond because of the high coliform count results of testing on Sept. 26th. Site 23 was near the dense camps close to the waters edge in Libby Point cove, and site 24 was by the house with the large lawn, off the dock with the mermaid figure. In the Serpentine stream, site 2 at the base of the slope leading from the building on the gravel pit property and site 32 at the mouth of Sucker Brook were chosen because they were areas of high turbidity observed on Sept. 26. Sites 3 and 4 were repeated on Oct. 3 to compare post-storm and fair weather coliform data. Sites 7 and 31 along the Serpentine stream in the bog area were chosen to determine if a gradient of coliform bacteria existed between East Pond and the Serpentine stream. Sampling at Site 9 was performed on Sucker Brook to the left of Route 8 in order to determine if agricultural practices along Sucker Brook resulted in high coliform counts. Site 35 was taken farther upstream on Sucker Brook for the same reasons. Site 30 was taken on the upstream side of the snow-mobile bridge crossing Clark Brook in order to compare with coliform counts at site 4. Sampling at sites 33 and 34 at the head of the tributary to the east of Sucker Brook was done because a field in that area sloped directly down to the waters' edge. Site 36 at the inlet immediately to the west of the confluence of the Serpentine Bog and the Serpentine Marsh was taken for the same topographic reasons.

Water Testing Methodology

Water Samples were taken by surface grabs, 7 m. from the shore, and were collected in 500 ml. sterile bottles. The samples were transported to the Biology Laboratories at Colby College, and total and fecal coliform tests were performed following the standard membrane filter technique (Clesceri *et al.*, 1989).

Results and Discussion

Fecal coliform standards exist for U.S. waters and vary for different water uses, with the most stringent standards imposed on drinking water sources, and the least stringent for recreational waters such as East Pond (Mitchell, 1974). Therefore, it is possible to compare the coliform counts from the East Pond study with United States standards (Table 19).

Table 19. United States Water Standards for Fecal Coliform Contamination. [1]

Water Use	Maximum Permissible Fecal Coliform Count per 100 ml
Municipal Drinking Water	1
Water Used for Shellfishing	70
Recreational Waters	1,000

1 Mitchell (1974).

Testing done on Sept. 26 after a storm event revealed significant fecal coliform counts at sites 3 and 4 in the Serpentine stream. Site 3 had a fecal coliform count of 2,640 per 100 ml, much higher than the 1,000 per 100 ml standard for recreational waters (Table 20). Site 4 had a fecal coliform count of 704 per 100 ml. The high coliform counts at these sites are believed to have been caused mainly by the erosion of agricultural lands and the runoff of effluent from grazing animals. In East Pond itself, the only relatively high coliform count was 39 colonies per 100 ml. at site 24. This count may have been elevated from the saturation of septic system leach fields due to the recent storm. Additional coliform testing was performed on October 3, 1991. There were no areas of significantly high coliform counted in East Pond or in the Serpentine stream during fair weather.

There were no comparable coliform data for East Pond from the Maine D.E.P. or other agencies because coliform testing is only performed for municipal drinking water sources or

Table 20. Fecal coliform counts for East Pond and the Serpentine Stream in fall 1991. Sites not sampled on a particular date are indicated by a dash.

September 26				October 3			
Site	Count [1]	Site	Count	Site	Count	Site	Count
2	--	26	7	2	16	26	--
3	2640	27	3	3	12	27	--
4	704	28	1	4	12	28	--
7	--	29	1	7	2	29	--
8	15	30	--	8	--	30	12
9	--	31	--	9	14	31	0
20	0	32	--	20	--	32	8
21	1	33	--	21	--	33	40
22	1	34	--	22	--	34	44
23	--	35	--	23	0	35	22
24	39	36	--	24	0	36	4
25	3			25	--		

[1] Samples were taken by surface grabs, approximately 7 m from the shoreline, and collected in 500 ml sterile bottles. The samples were tested using the membrane filter technique in the Biology Laboratory, Colby College. Fecal coliform counts were expressed per 100 ml water sample.

at the request of landowners. Coliform tests were performed by the Dept. of Health and Human Services at Alden Camps on the south end of East Pond. However, these coliform tests were performed on chlorinated potable water sources, and hence not representative of East Pond lake water (Wentworth, 1991).

Conclusions

At the time of this study, agricultural areas were contributing the greatest amount of fecal contamination due to effluent of grazing animals, while septic systems were found not to be a source of pollution. However, it is important to note that these tests were performed during the off-season on East Pond, and 80% of the homes around the lake are seasonal residences. It is very possible that fecal contamination occurs during the summer months when most human activity is taking place, but further testing would be necessary to test this hypothesis. It is possible that fecal contamination due to severe runoff during storm events could become a significant source of pollution to East Pond and the Serpentine stream.

Agriculture

Materials and Methods

Three farms were examined for their proximity to the Serpentine and East Pond, influence of cattle on nearby water sources, sloping fields, lack of buffer zones, and general farming practices. Owners of the farms were contacted and personal interviews were conducted to obtain specific information for each farm. History of the particular farm, number of cattle, size of farm, acres devoted to pasture, and sources of drinking water for the cattle were a few of the issues discussed. One farm slightly north of the watershed which has implemented successful reforms was also examined for comparison. Water tests for coliform, phosphorus, and nitrogen were also conducted near farms in the Serpentine watershed to determine water quality near these areas.

Organizations such as the Soil Conservation Service (SCS), the Agricultural Stabilization Conservation Service (ASCS) and the Department of Agriculture were contacted to obtain information about reforms available to farmers. Individuals like Sally Butler (Somerset district conservationist), Don Mairs (Department of Agriculture), and Roy Bouchard (DEP) were also contacted to obtain further information. Availability and cost of the reforms were discussed, as was methods of communication between the organizations and the individual farmers. Individuals in the East Pond Lake Association were also contacted to assess their perceptions of the impact of agriculture on the Serpentine and East Pond water quality.

Results and Discussion

Land devoted to agriculture in Somerset County has fallen dramatically in the past 15 years. The Soil Conservation Service (SCS) reports that in 1978 there were 510 farms in all of Somerset County and 125,000 acres devoted to agriculture. In 1987 there were only 462 farms and the acreage was down to 112,000 (U.S. Department of Commerce, 1982 and 1987), and these numbers have been falling since (Sally Butler, SCS, pers. comm.). In the Serpentine watershed, 22 % of land was devoted to agriculture in 1965 (See General Patterns and Trends). In 1991 that figure has changed to 16 %. In the East Pond watershed, the percentage of land devoted to agriculture in 1965 was 4 % and in 1991 is 2 %. Agriculture is no longer as profitable as it has been in the past (Sally Butler, SCS, pers. comm.). The market value for livestock, poultry, and their products was $26,892,000 in 1978, and in 1987 was only $18,254,000 (Census of agriculture report, 1982 and 1978). Due to this drop in value, agricultural land has been abandoned and sold to developers (Sally Butler, SCS, pers. comm.). There are a few small scale farms remaining in the watershed, but the amount of land devoted to development has increased greatly (Don Mairs, DEP, pers. comm.).

The few farms that do exist near East Pond are located in the Serpentine watershed. All three are located on Rte. 8, within three miles of the town of Smithfield (Figure 40).

Roger Staples has been in the Serpentine watershed since 1975 and has a 141.65 ha farm, 40.47 ha in pasture and 101.18 ha in woodland. Before 1981, the farm was a large poultry operation with 90,000 burrows. In 1981, however, the poultry business became dominated by farms in the southern part of Maine, and Roger Staples cut back on poultry. He does, however, lease one of his barns to a local poultry breeder (Avian Farms). The guano from the chicken farm is picked up and used by a local farmer, located outside of the watershed, for fertilizer.

Staples also has 100 head of cattle which are raised as dairy heifer replacements and beef cattle. There are two plots of pasture (one 16.19 ha and one 24.28 ha) where the cattle graze. The manure from the cattle is left in the pastures. Staples uses an automatic watering system, where the water level in a trough is detected by a styrofoam float. It was recently installed at the cost of approximately $100.

Ferrington Charles owns a 40.47 ha farm which was once part of a larger operation. There are 30 head of beef cattle which graze adjacent to Sucker and Clark Brook. The slope of the land near Clark Brook and Sucker Brook is relatively gradual, and the cattle walk directly into the water. Manure from the cattle is left in the pasture. The brook is the water source for the cattle and even in the winter months the ice is broken so the cattle can have access to the water. Charles also has 56 sheep and lambs which use a constructed pond for a water source. There are also two chicken houses containing seventy chickens. The manure from the chicken coups is cleaned out four times a year and taken to a nearby farm outside of the watershed for fertilizer use.

Theodore Feegel owns a 46.14 ha farm, 20.24 ha of which are leased pasture and 25.9 ha of which are forested. The lessee of the pasture brings in 35 heifers to the pasture every summer. The cattle graze adjacent to the Serpentine and drink from a natural spring located in the pasture. The slope of the land near the Serpentine is relatively gradual. The manure is left in the pasture where the cattle graze.

Elroy Chartrand owns a farm which is located out of the watershed on Rte. 8, approximately one mile north. It is 113.32 ha, 12.14 ha of which are pasture, 50.59 ha of which are cropland (corn and hay), and 50.59 ha of which are woodland. Chartrand has 130 head of dairy cattle and sells their milk in its raw form. The cattle are not put out to pasture very often. This farm has a manure storage facility that was built three years ago. It cost $40,000 to make it, but ASCS paid for $17,000 of the total price. SCS also contributed by analyzing the situation and designing the storage facility. Chartrand has also constructed a stone lined ditch to help prevent erosion.

Low and high calculations for total external phosphorus loading to the Serpentine from pasture land are 78.6 and 261.9 kg-P/year, respectively (Figure 17). Phosphorus input from pasture land accounts for about 43 % of all loading with a low coefficient and about 39 % with a high coefficient. Results of the phosphorus testing from sites 3 and 4 , located at the junction of Sucker and Clark Brook and the top of Clark Brook respectively, reveal slightly higher levels than other test sites, especially in post-storm conditions. The total phosphorus reading for site 3 after the storm was 82 ppb and at site 4 was 124 ppb. Fecal coliform tests at sites 3 and 4 had high counts of 2,640 and 704 per 100 ml, respectively.

Agriculture in the Serpentine watershed does not appear to be a significant problem, in most part due to the decrease in agricultural land over the past few decades. The farms existing in the watershed are relatively small and of low intensity. However, this is not to say they have no impact. The total external phosphorus loading calculations for pasture land reveal that pasture contributes more phosphorus on an annual basis to the Serpentine than any other land use. One of the biggest problems with the farms is the location of the cattle and their water sources. All of the farms in the watershed have cattle grazing near the Serpentine or its tributaries, and the cattle from the Charles farm drink directly from Sucker Brook. The nutrients from the manure can therefore more readily reach the tributaries through runoff or leaching. The cattle from these farms are also kept at pasture during the winter months, increasing the possibility of runoff over the frozen surface.

The relatively high values in the total phosphorus test results suggest that runoff from the cattle pasture near these tributaries could be an important factor to consider. A level of 15 ppb, considerably lower than the values obtained in the Serpentine near the farms, can cause an algal bloom. The results from the coliform testing suggest similar conclusions. Both the high phosphorus levels and the high coliform counts in these areas suggest that the effluent from the grazing animals is reaching the water system through runoff and leaching.

Farmers can receive reform assistance from SCS and ASCS. The system is a voluntary one where farmers approach the organizations if they feel they need help. Technical assistance is available and provided by SCS. ASCS will provide funds to implement reforms, with aid up to 75% of the cost of the reform. The SCS service reports that by taking advantage of these reforms, farmers benefit themselves and the public (Sally Butler, SCS, pers. comm.).

The most expensive reform available to the farmers is the manure storage facility. The storage facility allows farmers to store their manure, which is especially beneficial in the winter months. A computer program may be used which takes into account the slope of the land, the soil type and other variables in locating the appropriate site for the facility. The cost of the facility depends on the type of manure. If the manure is of a fluid consistency a concrete facility is necessary which will increase the cost. Prices range from $5,000 to $70,000 (Tom Gordon, Cobbossee Water District; and Sally Butler, SCS, pers. comm.). The advantages of a storage facility are many. The farmer is saved long hours of labor for they no longer need to continually spread the manure on the ground, especially important in the winter because of the frozen soil. In addition, they are transforming a waste product into a useful resource and getting maximum use of an on-farm by-product. They can use the manure in the facility to fertilize their crops or pasture at the appropriate time of the year when it will be most available to crops and at the appropriate rate needed. The manure becomes part of a sustainable agricultural system (Don Mairs, DEP, pers. comm.).

Another simple, yet effective, reform available is fencing. Fences may keep cattle out of a water source which can help prevent water pollution. Another reform designed to keep cattle out of the water, which may be their drinking source, is a pasture pump. There are three major types of pasture pumps which all deliver water conveniently, economically and without damaging the environment: pasture pump, hydro ram and solar pump. Pumps run about $350 (Soil Conservation Service, 1991). Other opportunities available to farmers include water quality workshops, including management of manure and nutrients. A computer program exists that will calculate the load of manure per field the farmer can use, based upon the nutrient content of the manure. Manure tests run about $15 and the soil tests are about $7. Results of such tests may help to prevent an excess of nutrients onto a field or pasture, which may eventually reach and contaminate a water body.

The farmers in the Serpentine watershed are not working with organizations like the Agricultural Stabilization Conservation Service and the Soil Conservation Service at this time. Most of them are indeed aware of the organizations and the help they offer, but do not feel that their farms are problematic. One solution to this problem would be for these organizations to approach the farmers, discuss water quality problems, and propose certain reforms such as a fence or a hydro-pump.

The Charles farm could build a fence to keep its cattle out of Clark Brook at a relatively low cost. This would prevent defecation directly into the brook or near its edge. A water pump should also be installed to provide a drinking source for the cattle. The establishment of a buffer zone of vegetation may also help to reduce the phosphorus loading to the water body, as the vegetation absorbs excess phosphorus. The cattle located on the land that Theodore Feegel leases could also be kept away from the Serpentine with fencing, and nutrient loading could be reduced with a natural buffer zone. Roger Staple's farm, located up Sucker Brook, could also benefit from fencing and a buffer zone. These reforms could be implemented relatively cheaply, especially with technical and monetary assistance from SCS and ASCS. Roger Staple may also consider a manure storage facility due to the number of cattle. This however, is relatively expensive and may not be economically beneficial. Elroy Chartrand's farm, however, is an excellent example of where such reform can be successful, taking a waste product and turning it into a resource.

With monetary aid from ASCS, these reforms could be made more available to the farmers. In the interest of the Serpentine and East Pond, it may also prove beneficial for the Lake Association to appropriate some of their funds for this purpose. Although these farms are relatively small, the location of the farms is a critical factor. Due to the close proximity of the farms to the Serpentine and its tributaries, reforms could prove to substantially limit their effect on the water quality of the Serpentine stream and East Pond.

Conclusions

Agricultural use of land in the Serpentine watershed accounts for a large amount of the nutrient loading occurring on a yearly basis. Combined with phosphorus input from development, roads and other sources, its contribution becomes increasingly important, both now and in the future. There are many sources of phosphorus loading in the Serpentine and East Pond watershed, and the elimination of one will not solve the problem. Therefore, steps should be taken to start controlling not only agricultural sources of nutrient input into the Serpentine and East Pond, but other sources as well.

Subsurface Waste Disposal

Materials and Methods

An initial field reconnaissance made the large number of homes with grandfathered waste disposal systems obvious because of their close proximity to East Pond. Furthermore, the lack of buffer zones along with a number of non-conforming lots made it clear that subsurface waste disposal has the potential of being a problem in the East Pond watershed.

Specific information concerning the East Pond watershed was gathered from contacts who were very kind to share their knowledge. Bob Joly, a member of the East Pond Association, was especially helpful by providing the results of the East Pond Resource Inventory, a survey taken by East Pond residents concerning land use, especially subsurface waste water disposal. Rick Smith of the Department of Human Health, and Roy Bouchard of the Department of Environmental Protection, also provided valuable insight. In addition, Mike Zarcone and Paul Lussier, the plumbing inspectors in Smithfield and Oakland respectively, were contacted.

Laws and regulations concerning subsurface waste water disposal were obtained from the State of Maine Subsurface Wastewater Rules. Local laws concerning shoreline zoning and location of septic systems were found in the Oakland and the Smithfield Shoreline Zoning Ordinances.

The limitation of soil types for septic systems was obtained from soil maps including the East Pond watershed along with the U.S. Department of Agriculture's Soil Surveys of Somerset and Kennebec Counties. The types of soils found within the East Pond watershed were determined by soil maps. The actual limitations to the use of soil for disposal of sewage effluent from septic tanks were found for each type of soil in the Soil Surveys.

Results and Discussion

Both local and state laws regulate subsurface waste water disposal systems. State laws deal with permits, certification, criteria, placement, and construction of subsurface waste water disposal systems and can be found in the State of Maine Subsurface Wastewater Disposal Rules. All local laws must be at least as strict as the state requirements. Local laws in the towns of Smithfield and Oakland concerning subsurface waste water disposal systems are found in the Shoreline Zoning Ordinances of each town. A comparison of Oakland, Smithfield, and the state of Maine's zoning laws that influence the success of subsurface waste disposal can be seen in Table 3. Both Oakland and Smithfield have stricter requirements than the state for minimum lot size. The size of a lot is important for subsurface waste disposal so that systems are not placed too close together causing saturation of the soil. In general, the bigger the lot size, the safer the water quality of East Pond. The minimum distance that a system can be placed from a body of water is called the setback. Setback standards are made to provide waste water with adequate time and distance to be filtered efficiently by the soil before reaching a body of water. Finally, minimum water frontage is important in protecting East Pond from subsurface waste water disposal systems that are too close together. Once again, both Oakland and Smithfield have stricter requirements than the state for minimum water frontage, providing additional protection to East Pond.

In the summer of 1988, the East Pond Lake Association did a survey called the "East Pond Resource Inventory". The response was outstanding with 131 East Pond property owners out of 178 responding. The survey was done door to door. The major results of the survey are as follows:

- 80% of residential use is seasonal, 20% is year round
- 90% of the residences have septic tanks, 5% holding tanks, and 5% outhouses
- Slope of land: 46% is slight, 18% is moderate, and 18% is steep
- 46% of respondents have had septics pumped in last five years
- 75% of owners use water from the lake
- 38% of structures are closer than 50 feet from the lake and 51 % are further than 50 feet from the lake (EPLA, 1989)

If local laws concerning subsurface waste water disposal are followed and systems are properly cared for, systems should not be a threat to water quality. However, survey results indicate that only 50 % of subsurface waste water disposal structures are further than 50 ft. from the lake. Current setback standards are 100 ft. Furthermore, the plumbing inspector of Smithfield estimated that the overwhelming majority of septic systems located around East Pond were non-conforming structures according to current setback standards (Zarcone, Smithfield Plumbing Inspector, pers. comm.). Therefore many systems are not in compliance with state and local laws because they were constructed prior to current regulations resulting in a large number of non-conforming or grandfathered systems.

If septic systems are installed properly and regulations are followed, they should function successfully in the treatment and removal of household wastes. However, certain precautions should be taken in order to ensure that systems continue to function successfully so that in the future East Pond maintains high water quality standards. Maintenance, early problem detection, and voluntarily upgrading systems are all actions that individuals can take to do their part in maintaining the water quality of East Pond.

As development occurs and population density increases, the number of septic systems will also increase, causing an undue strain on the surrounding soil. Although current laws and regulations were enforced to maintain water quality, many subsurface waste disposal systems were built prior to current shoreline zoning regulations making them a potential non-point pollution source to the lake system. Therefore, the voluntary upgrading of systems to meet current regulations is one of the most important actions that can be taken to protect lake water quality.

Another important finding of the survey is the number of homes that use water from East Pond. Because East Pond is rated as a Recreational Water, it has the lowest fecal coliform standards (Table 19). The fact that 75% of the East Pond residents use water from the lake makes protecting water quality even more important because of the danger of water contamination that leads to human health problems.

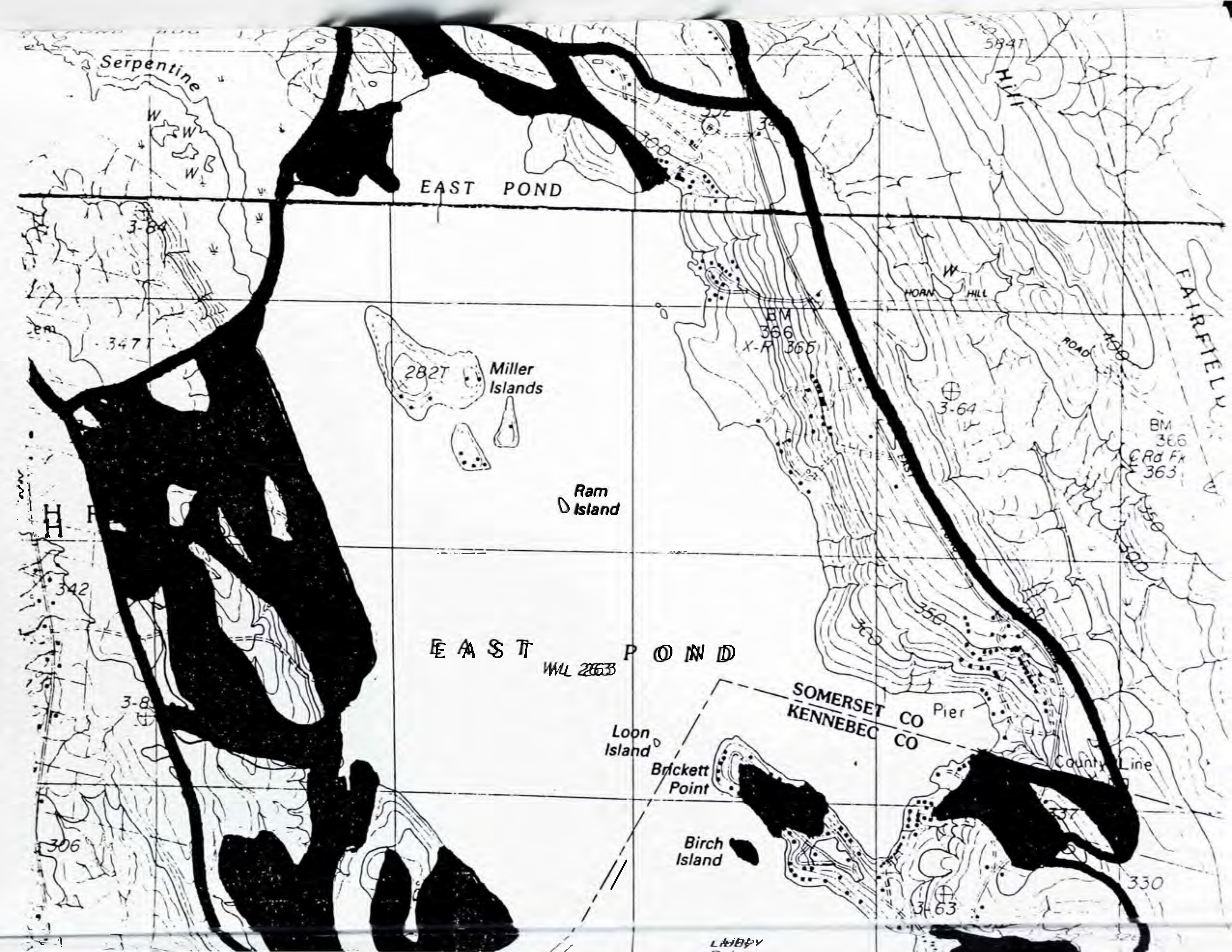
Holding tanks, which make up 5% of the existing subsurface waste water disposal systems, are by definition water tight receptacles (Dept of Human Services, 1988). Therefore, if this requirement is met, holding tanks pose no threat to the East Pond Watershed. The number of privies found within the East Pond watershed was also 5% according to the East Pond Lake Association survey. Septic systems and privies follow the same general principle of treating subsurface waste water by depending on the soil to filter out contaminants. Yet the modern comforts that a septic system provides, such as the use of flush toilets located inside the dwelling, makes septic systems a more desirable form of subsurface waste disposal. Therefore it is more likely that future development will include the addition of many more septic systems as opposed to privies. Already septic systems make up the overwhelming majority of subsurface waste water disposal systems in the East Pond watershed.

The use of septic systems is often limited by the type of soil on which a system is to be installed. The U.S. Department of Agriculture rates soil types according to permeability, slope, depth to water table or bedrock, and susceptibility of flooding and describes the limitations of soils for sewage effluent (1978). Table 21 lists the different types of soil found in the East Pond Watershed. Each soil type is rated as having slight, moderate, or severe limitations for the disposal of sewage effluent from septic tanks. These soil limitations apply also to privies (Rick Smith, pers. comm.). Many areas located within the East Pond and Serpentine watersheds have soils with severe limitations to septic systems (Figures 42 and 43). According to the U.S. Department of Agriculture, septic systems are not permitted on soils rated as severe. However, Maine plumbing rules provide for exceptions. Using an evaluation system called "Soil, site and engineering factors used in assessing potential for a new system variance for land that

Table 21. Limitations of the use of soil for disposal of sewage effluent from septic tanks in the East Pond watershed.

Soil Type	Characteristics
Adams:	
AaB	moderate: rapid permeability; contamination of ground water
Aac	moderate: slope
Bangor:	
BaB	moderate: moderate permeability in subsoil and substratum; silty
BaC2	moderate: moderate permeability in subsoil and substratum; silty; slope
BgB	moderate: moderate permeability in subsoil and substratum; silty
BgC	moderate: moderate permeability in subsoil and substratum; silty; slope
BgD	severe: slope
Berkshire:	
BhB	slight
BhC	moderate: slope
BkB	slight
BkC	moderate: slope; stones
BkE	severe: stones: slope
Biddeford:	
Bo	severe: slow to very slow permeability in subsoil
Buxton:	
BuB	severe: slow to very slow permeability in subsoil
BuC2	severe: slow to very slow permeability in subsoil
Colton:	
CnC	moderate: slope; contamination of ground water
CnD	severe: slope; contamination of ground water
CnE	severe: slope; contamination of ground water
Dixmont:	
DxB	severe: moderately slow permeability in substratum; seasonal high water table; stones
DyB	severe: moderately slow permeability in substratum; seasonal high watertable; stones
Leicester:	
Lc	severe: high water table; seasonal excess water
Melrose:	
MeB	severe: slow permeability in substratum
Monarda:	
Mo	severe: slow permeability in subsoil
Mr	severe: slow permeability in subsoil
Peat and Muck:	
Pa	severe: very high water table

Peru:		
	PcB	severe: seasonal high water table; moderately slow permeability
	PdB	severe: seasonal high water table; moderately slow permeability; stones
	PfB	severe: seasonal high water table; moderately slow to slow permeability
	PkB	severe: seasonal high water table; moderately slow to slow permeability
	PkC	severe: seasonal high water table; moderately slow to slow permeability
Ridgebury:		
	RdA	severe: seasonal high water table; moderately slow to slow permeability
Rock Land:		
	RtC	severe: shallow to bedrock; rock outcrops
Scantic:		
	ScA	severe: slow to very slow permeability
Skowhegan:		
	SkC2	severe: seasonal high water table; moderately slow permeability
Stetson:		
	StB	moderate: rapid to very rapid permeability in substratum;possible contamination of ground water
Suffield:		
	SuC2	severe: slow to very slow permeability in subsoil; slope
	SuD2	severe: slow to very slow permeability in subsoil; slope
Walpole:		
	Wa	severe: high water table


Serpentine
EAST POND
584T
Hill
352
300
3-84
HORN HILL ROAD
BM 366
X-R 365
347T
282T
Miller Islands
3-64
FAIRFIELD
BM 366
C Rd Fk 363
400
Ram Island
350
300
342
EAST POND
WL 263
3-85
SOMERSET CO
KENNEBEC CO
Pier
Loon Island
Brickett Point
County Line
337
Birch Island
306
330
3-63
LIBBY

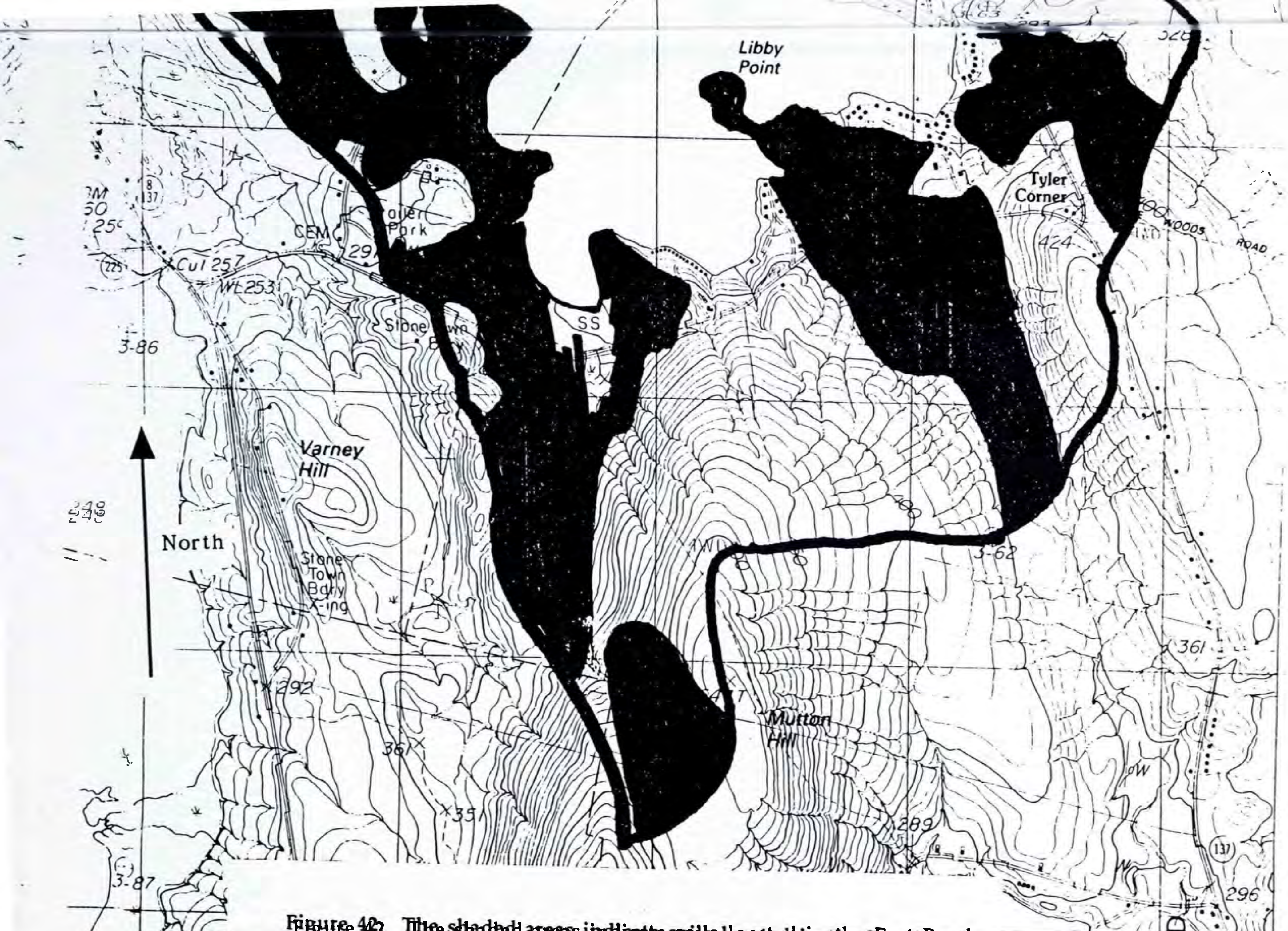


Figure 42. The shaded areas indicate soils located in the East Pond watershed with severe limitations to sewage effluent. 1982 USGS map, scale (1:16,000).


Ross Hill
OAK HILL
6-12
505
Brook
3-81
In line
Dodling H
393
ROAD
Gravel
8
295
Leech Brook
ROAD
650
650
550
500
Mt Bett
476
354
285
281
WL276
Landing Strip
359
360x

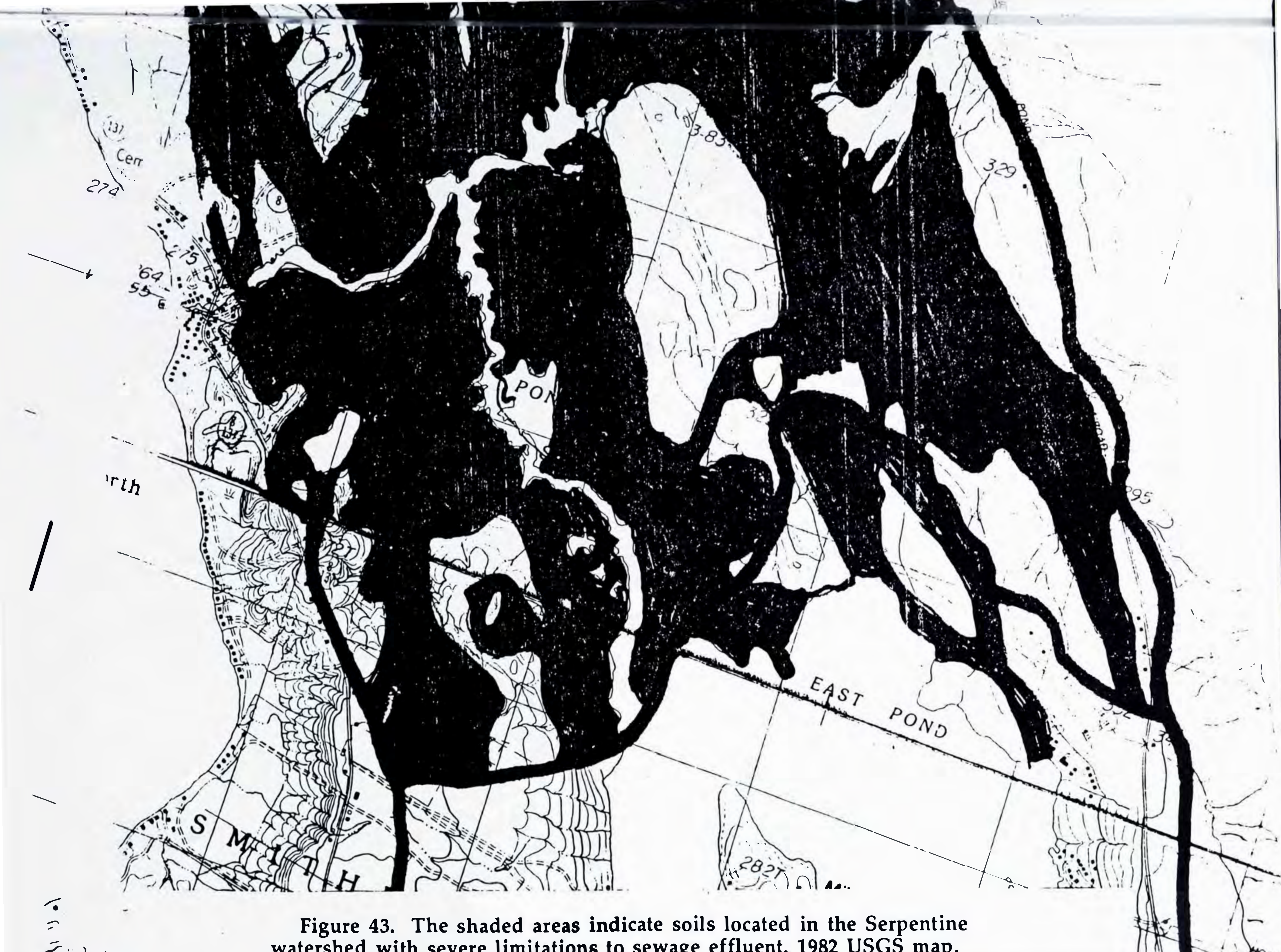


Figure 43. The shaded areas indicate soils located in the Serpentine watershed with severe limitations to sewage effluent. 1982 USGS map, scale (1:16,000).

does not comply with the minimum soil condition criteria," points are given according to soils, drainage, property size, terrain, water body setback, water supply zoning, type of development, design flow, separation distance, and additional treatment. A site within a Shoreline Zoning area must accumulate a minimum value of 65 points to be considered acceptable (Dept. of Human Services, 1988). Systems for these lots are likely to have limitations and be more expensive due to precautions that must be incorporated into the design of the system. Therefore, in terms of subsurface waste disposal it is more economically and environmentally sound to develop land that has suitable soil.

Conclusions

Education should play an important role in decreasing the threat of subsurface waste water disposal to water quality in East Pond. Education for residents should include how to properly care and maintain their septic systems and the importance of detecting problems early. Early problem detection can not only preserve the water quality of East Pond, but can also save individuals money. In addition to this, planning board members should become familiar with state and local laws concerning subsurface waste water disposal and factors that influence the success of a properly functioning septic system, such as soil type, distance from water, and the slope of the land.

Enforcement of subsurface waste water disposal rules is necessary to maintain good water quality. It simply does not suffice to have laws and regulations, they must be followed. Plumbing inspectors are required by law to inspect plumbing as it is being constructed, to certify that it is in compliance with all state and local regulations, and to investigate any complaints of systems which may be in violation of state and local regulations (Dept. of Human Services, 1988). However, enforcement is mandatory to ensure that systems are functioning properly.

Currently subsurface waste water disposal does not appear to threaten water quality. Yet, as population density increases within the East Pond watershed and summer residences are converted to year round dwellings, the likelihood of a decrease in water quality due to subsurface waste water disposal will increase.

Zoning and development

Materials and Methods

The property maps which contain the East Pond and Serpentine watershed land parcels for the town of Smithfield were obtained from Sackett and Brake, Surveyors, Skowhegan, Maine. The Belgrade and Oakland property maps were obtained from Rowe and Wendell, Land Surveyors and Engineers, Waterville, Maine. The town offices in each town were visited and the parcel information (owners' names, acreage if available, and tax status of the land - tree growth management or residential) was recorded onto the property maps.

A comprehensive land use plan is a guideline to be used when new ordinances are necessary to restrict certain activities that are, or will, affect the quality of life of the citizens of a town (Planning Board for the Town of Smithfield, 1987). It is a guide for managing change and it acts as a local legal base for land use regulations. These plans are used by towns to establish what the future appearance and atmosphere of the town should be. Smithfield and Belgrade have both established comprehensive plans, adopted in 1987. Oakland is in the process of approving an updated comprehensive plan.

Each town is required to have a set of land use and shoreline ordinances. Shoreline ordinances exist to maintain the appearance and recreational value of a lake and to protect wildlife habitats as well as the water quality. Land use ordinances are to ensure development meets minimum safe standards set by the state. Towns must attain at least the state's standards, but they can set stricter policies in accordance with the goals of the area if they so desire.

Results and Discussion

Within the East Pond and Serpentine watersheds, Belgrade has eight lots total. None of them are set aside for tree growth. Oakland has 174 lots within the watershed and only one of these is in tree growth. Smithfield has 22 lots in tree growth out of 288 total lots. Also, only Smithfield has any Resource Protection areas designated within the East Pond and Serpentine watersheds. Over the last 20 years Maine has been growing at an increasingly rapid rate, particularly in the lake regions. Statistics from the DEP show that there has been a 22% increase in development along the shoreline of East Pond.

Although the largest portion of the East Pond and Serpentine watersheds is in the town of Smithfield, most development exists in the Oakland portion of the East Pond watershed with many small lots right on the shore. New development continues to take place. In Oakland there is the "Lake's Edge project" which, if it becomes effective, will use 22% of Oakland's allotted remaining amount of phosphorus loading (Chaisson, 1987). Belgrade does not contain any of the shore of East Pond and within the small percentage of the watershed in Belgrade there is only a handful of landowners. Poor development practices in Smithfield and Oakland will have a greater range of effects on East Pond, such as lowering the visual attractiveness of the lake, increasing lake sedimentation, and raising the amount of nutrients entering the water.

Oakland is presently drafting a comprehensive plan and several drafts have already been voted on in town meetings. We attended several Oakland town meetings when the proposed plan and updated shoreline ordinances were discussed. At this point in time everything about the plan is in accordance with state regulations, and many points are stricter. The meetings were for clarification of word choices in the ordinances and comprehensive plan. Smithfield's Planning Board is reviewing its shoreline ordinances and updating its Resource Protection

District standards.

Oakland's proposed comprehensive plan has the same general goals as Smithfield's and Belgrade's plans. Each town is concerned with the growth it has undergone and wants to control it effectively. Most of the growth has been residential. The populations of each town have been continually rising (Figure 44). Smithfield's plan states the reason for this as being the proximity of the town to several larger business areas. Residents can commute to work and live in a small, quiet town. The solitude, beauty, and safety of a small town attract many people who wish to build, and this quality of life is what keeps the residents in their towns. The towns all want to continue growing but in ways that do not reduce this quality of life. Each plan gives an analysis of possible problems and concerns the town might face in the future, and gives recommendations on how to solve these problems. The recommendations are mainly for possible ordinances, but it is stressed that they are suggestions only. In order for ratification to occur the towns must vote on new ordinances or amendments to old ones.

As long as a town has sufficient land use ordinances and efficiently enforces them it should not experience significantly deteriorated water quality due to new development. State mandates require all town shoreline ordinances to be updated by December 31, 1991. The ordinances for Oakland and Smithfield are quite similar. The ordinances cover a variety of areas, such as minimum lot sizes for both shoreline and other zones, subdivision development rules, and regulations for commercial-industrial sites. This works well for new development. However, "grandfathered" plots pose a potential hazard.

Most of the ordinances of the Towns of Smithfield, Belgrade and Oakland contain "non-conformity uses" sections or clauses. The use of this land can continue as is or be improved to meet the requirements of the new ordinance, but it may not be expanded or changed into another non-conforming use. If the land is unused for 12 months the non-conforming use of it cannot be renewed, but instead must be improved to follow the ordinances in effect at the time the re-use begins. Also, if the land is sold to a new owner it must be improved to meet regulations (Planning Board of the Town of Smithfield, 1987).

Because the grandfathered parcels of land do not need to be updated, the possibility that they contribute hazardous levels of nutrient or soil runoff is significant. In addition to being potential sources of East Pond water quality deterioration, they can be unsightly (which decreases the scenic value of the lake) or they may endanger wildlife habitats. However, as long as the use of the land was law-abiding before the updated law was passed, the grandfather clause frees the owner from the responsibility of meeting the new regulations. Incentives are needed to convince "grandfathered" land owners to follow the new standards, as this would promote the use of the lots under laws that more strictly govern the effects on East Pond.

Town land use ordinances designate what types of land within the towns fall under Resource Protection, Limited Residential-Recreational, or General Development Districts. Resource Protection includes areas in which development could severely change the water

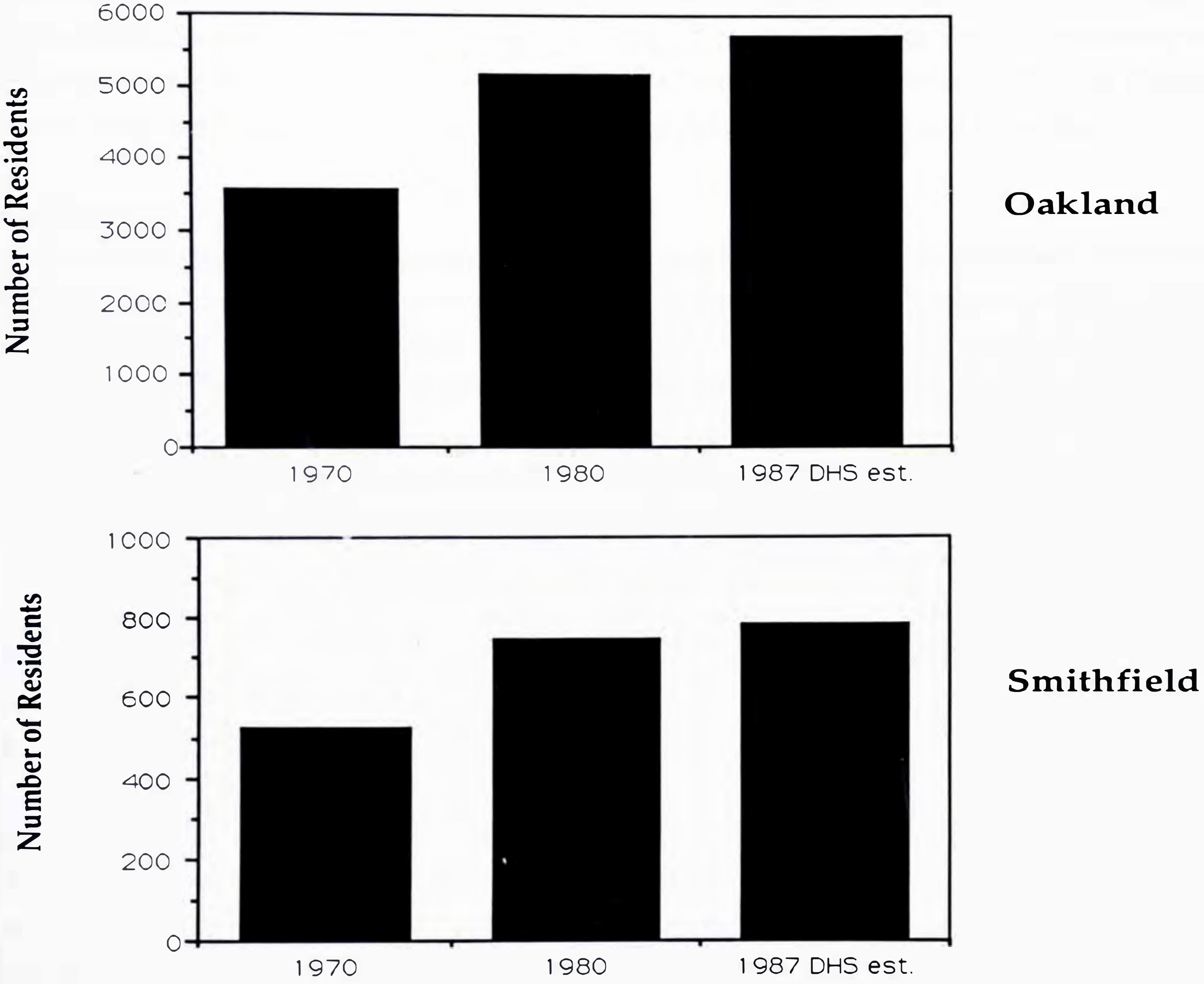


Figure 44. Population growth in the towns of Oakland and Smithfield from 1970-1987; DHS = Dept. of Human Services. (Data from Final Report Oakland Comprehensive Plan, 1990)

quality, habitats, or scenic values (Town of Oakland, 1975). Wetlands, flood plains, and highly sloped areas are all included in this district. Limited Residential-Recreational Districts include areas that are not designated General Development or Resource Protection. General Development areas are usually located next to urban sections of the town characterized by a mixture of residential, commercial, or industrial land uses (Town of Oakland, 1975). Depending how the land owner desires to use her or his land, the town Code Enforcement Officer or Planning Board may need to be contacted and a permit for the activity may need to be filed.

Conclusions

A town needs a strong set of ordinances and an up-to-date comprehensive plan to keep development under control. However, even with special districts designated and regulations set up, a grandfathered parcel of land is still exempt. To counteract the probable inputs from the non-conforming property, parcels that must comply with the updated ordinances should be carefully monitored. Code Enforcement Officers need to be strict and consistent in inspecting sites, and the state regulators also need to keep aware. If new development is kept under a watchful eye, nutrient loading from development will be minimal. This should counteract the effects from older, grandfathered property.

Erosion

Materials and Methods

The study of erosion on East Pond began during the initial reconnaissance on October 12, 1991. Based on that reconnaissance, areas such as the gravel pit and construction sites that required in depth study were identified (Appendix F). To study the gravel pit, personal observations outside the initial reconnaissance were used and were obtained after requesting permission from the office of Donald Gurney to enter their property.

In order to examine construction sites on East Pond, permission to cross the bounds of private property was required. Lists of building permits that had been approved within the past year were obtained from the town offices in Smithfield, Belgrade, and Oakland. The people on those lists were called by phone to ask about viewing the construction sites on their properties. With the help of Tom Gordon of the Cobbossee Water District and Ray Bouchard of the Maine DEP, a rating system for those construction sites was established (Appendix G). Due to time constraints and the difficulty of transferring watershed boundaries from the topographical maps to the parcel maps, the study was limited to the East Pond Watershed, and excluded construction occurring within the Serpentine Watershed and all other tributaries leading to East Pond.

Results and Discussion

During the reconnaissance, new houses were observed to be under construction at two sites. Hay bales had been staked to prevent sediment from moving down the slope and into the water. However, at one site, a path had been cleared in between two of the bales providing a perfect conduit for sediments to enter the lake. In another area, soil had been eroded away from underneath one of the hay bales, leaving a hole which obviously did not provide proper obstruction to sediments. Furthermore, in at least two areas, erosion was seen on private roadways or paths leading directly down to the water's edge.

In several areas, positive methods of erosional control were exhibited. For example, in October, when the boat ramp on the southeast side of East Pond was in its initial construction phase, black plastic silt fences had been installed at the water's edge to obstruct the flow of sediment into the lake. Moreover, in most areas where construction was occurring, mulch in the form of hay or wood chips had been laid down on the newly disturbed soils.

Upon examining the newly installed boat ramp and parking area on November 14, we found a dirt road leading down to a dirt parking lot with no vegetative buffer zone between it and the pond. To the right of the ramp, a small area of road had eroded away and the water marks showed that the sediment had directly entered the lake.

On Sunday, Nov. 3, and Thursday, Nov. 8, the gravel pit was visited and examined for sites of erosion. According to the owner, Mr. Donald J. Gurney, the pit has been in operation since 1956 and covers 45 acres. Sand and gravel are extracted year-round but on a slightly reduced basis during the spring when the roads in the area are more vulnerable to damage from heavy trucks. Once extracted, the sand and gravel are sorted at the site, sold to various contractors, and utilized in road construction, fill, and other processes (Gurney, pers. comm., 1991).

Erosion did not seem to be a major concern in the gravel pit. Most of the areas of actual extraction were located well away from the edge of the Serpentine. However, a possible problem existed in the lower road which twisted around near the western edge of the bog surrounding the Serpentine and terminated at the building visible from the Serpentine Marsh. The lower road was a well-packed dirt road of varying width (10-15 ft.) which in most areas was located no more than 10 ft away from the beginning of the bog. Furthermore, to the left of the road (the side away from the bog), a very steep slope existed which exhibited erosion at the bottom, to the extent that the roots of many trees and bushes were exposed to the air. However, actual evidence of sediment entering the bog was found at only one point on the road.

Since the gravel pit on East Pond has been in continuous operation since 1956, no permit was required for its operation. Only operations established after 1984 and those which were established prior to 1984 (but have expanded more than five acres since 1970), have been required to file a permit with the DEP (Hoey, Site Division of the Land Bureau of Maine DEP, pers. comm., 1991).

On Tuesday, Oct. 29, those whose names appeared on the lists of building permits from Smithfield, Oakland, and Belgrade and for whom phone listings were found were contacted (Appendix F). The majority of the owners confirmed that they had altered their property in some form. However, upon asking permission to visit and rate the site, most property owners stated that construction had been completed and that the grass had regrown on the site. At least one owner reported that the expected construction had been cancelled. Thus, this method of study was abandoned. Results were confined to the initial reconnaissance findings and to the examination of the new boat landing under construction by the Maine Department of Fisheries and Wildlife.

Areas of erosion due to poor construction practices were sighted on the initial reconnaissance. Thus, construction could be a source of external phosphorus for East Pond. Perhaps the only way to ensure that construction sites are properly maintained is to ask the code enforcement officers or other state and local official to visit sites on a regular basis, perhaps even during storm events to see if sediment is entering the water system. Another alternative is to provide the homeowners with tax incentives to maintain construction sites properly. Perhaps landowners should be encouraged to complete construction quickly and replant the site, thereby reducing the amount of time soil surfaces remain disturbed and destabilized. Since local code enforcers are already quite busy, the latter suggestion provides a better way of preventing erosion.

Mineral extraction areas such as the gravel pit located at East Pond must follow regulations as established by the State of Maine Land Use Commission as well as the local shoreland zoning ordinances. Buffer strips are necessary to prevent any sediment from leaving the disturbed area and entering the body of water. At the gravel pit on the northwest side of East Pond, the buffer strips around all of the extraction areas appeared adequate; however, the buffer strip between the Serpentine Bog and the lower road was no wider than ten feet in some areas. This could easily be a source of external nutrient loading for the Serpentine.

Furthermore, on the day of storm sampling, Sept. 26, an area of high turbidity was observed on the Serpentine Marsh, downslope from the house-like structure built on the property of the gravel pit. Although this turbidity could not be attributed directly to runoff from the gravel pit, it is a possible source. Further examination from the gravel pit property at the water's edge during a storm event is required to test this hypothesis.

Finally, to ensure that the gravel pit is not affecting the water quality of East Pond or the Serpentine stream, perhaps the Department of Environmental Protection should complete a comprehensive study on the pit's environmental impact.

Conclusions

Many factors contribute to erosion on East Pond, specifically construction sites and possibly the gravel pit. In order to prevent erosion's deleterious effects on water quality, these areas should be closely monitored in the future.

Roads

Materials and Methods

Road Reconnaissance: Initially, all accessible roads in the East Pond and Serpentine watersheds were traveled by auto during September - October, 1991. The roads were examined in order to obtain a general overview of their condition and to identify areas of special concern. Features noted included: proximity of road to lake, surrounding topography, surface conditions, crowns, areas of excessive erosion, vegetative buffer zones, overall road drainage (ditches and culverts), and overall road maintenance.

Road Evaluation: A road rating system was developed with the aid of Roy Bouchard of the Maine DEP to compare and evaluate a selection of each road type (state, municipal, fire, and private) within each watershed. The road features examined in the rating system included: road width, surface material and condition, crown condition, ditch conditions, culvert conditions, surrounding topography (slope), occurrence of erosion, and occurrence of flow obstruction. The roads were compared to ideal standards of a well-constructed road and evaluated with lettered and numbered codes (Appendix E). When possible, a condition was rated on a scale of 1 to 5 with 1 being characteristic of a well-constructed feature and 5 being characteristic of a poorly-constructed feature. All accessible roads were travelled, and at least one, 100 or 200 foot section was evaluated for each road rated. Each section was chosen as a representative sample of each road. While a random sampling method of rating was not used, this road study served to make general evaluations on the overall conditions of each of the four road types, so as to identify those roads requiring attention and maintenance.

Phosphorus Budget Analysis: Total road lengths for state, municipal, and fire roads in the East Pond and Serpentine watersheds were calculated using 1982 topography maps and a map wheel. Road surface areas were then calculated by multiplying these road lengths by averaged road and ditch widths obtained from the above evaluation. Percentages of each road type were computed from the total road lengths of each watershed. The amount of external phosphorus loading from each road type in each watershed was calculated to estimate the amount of phosphorus roads might contribute annually to East Pond (Dennis, *et al.*, 1989).

Results and Discussion

Road Reconnaissance: In the initial auto surveys, it was evident that the roads of concern were the fire and private ones located in the East Pond watershed. These were narrow (one-lane), year-round, dirt roads, which wound along the lakeshore, often very close to the water's edge. The majority of these roads contained eroding surface material, many potholes and ruts, and sunken crowns. The private roads often travelled directly down to the lake's edge, were perpendicular to the lake, and exhibited eroding and gullying on their surfaces. State and municipal roads were in fairly good condition. Route 137 had recently been properly graded and a 1/4 mile stretch of East Pond Road had been recently re-paved. However, sufficient crowns were not present.

Road Evaluation: The rating system depicted a general trend of the overall road conditions. Fire and private roads received the lowest average scores for both crown (4.44 and 5.00, respectively) and surface ratings (3.89 and 5.00, respectively), and had the greatest amount of qualities indicative of poor roads (Table 22). It did not appear that the roads had been graded anytime in the recent past, so the surface often contained material which was too coarse (greater than 2 in in diameter) and/or was not sufficiently compacted (and therefore, was muddy). Also, there was a lack of any or sufficient ditching where it was needed (eg. on slopes), and an overall lack of sufficient vegetative buffer zones, especially where the roads were closest to the East Pond shoreline. The one state road evaluated, Route 137, was in fair and semi-maintained condition with crown and surface ratings of 3.25 and 3.00, respectively. The one municipal road evaluated, East Pond Road, was in between the two above categories with crown and surface ratings of 4.25 and 3.75, respectively. The surfaces needed repair, however, as cracks, some potholes, and eroding edges were frequently present.

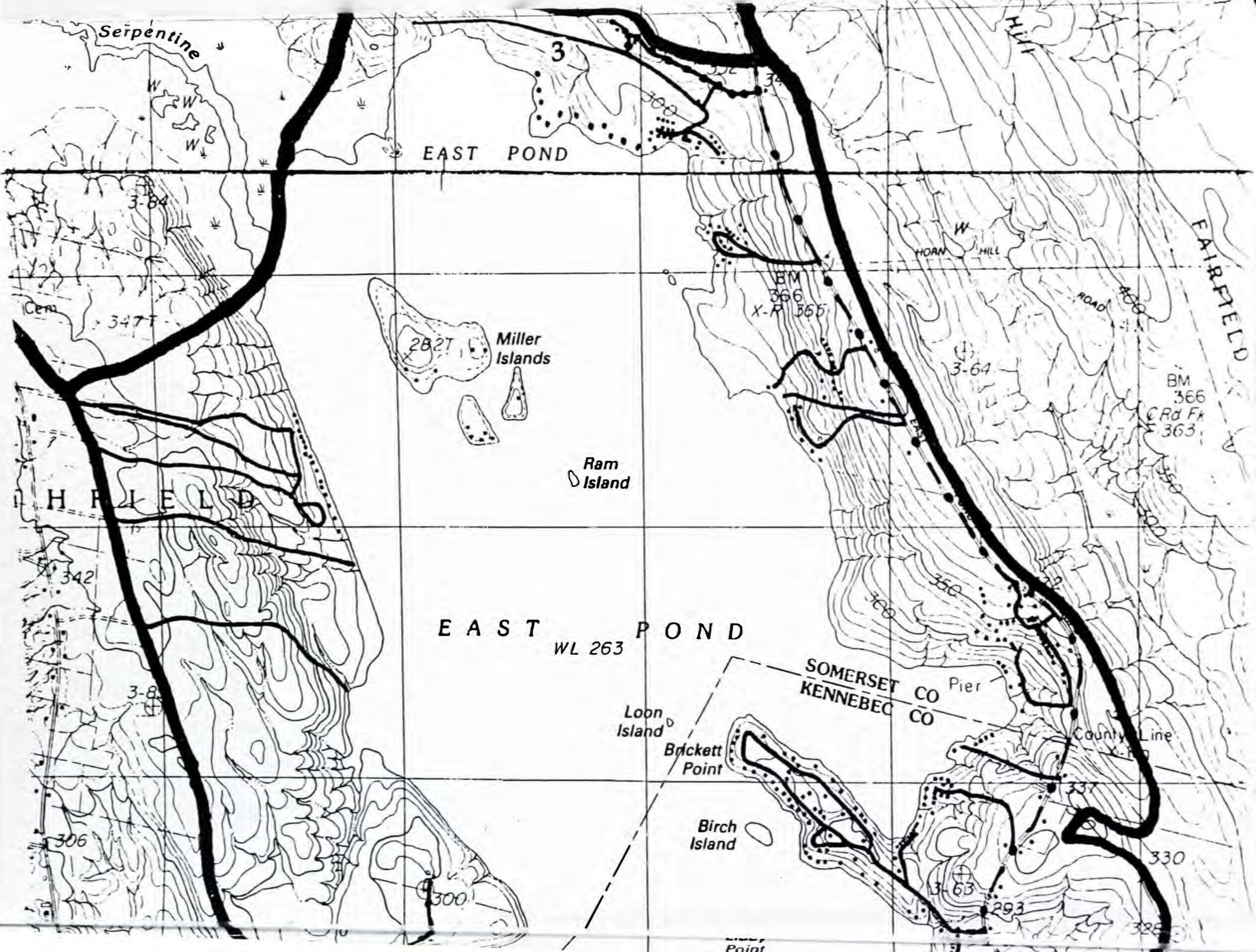
In general, the culverts on all road types were in fairly good condition. The most frequent problems encountered were erosion and/or the rusting of culverts. On East Pond Road, some of the culverts appeared too small for the present waterflow and probably require replacement.

Areas of special concern found in the East Pond watershed included: 1) road leading to the boat ramp, 2) private road in the gravel pit, 3) Horn Road (Smithfield Fire Road E-4) in the Eastwood Development area, and 4) roads crossing over tributaries (Figures 45 and 46).

1) The boat ramp road was constructed in the fall of 1991 and exhibited gullying due to the new sediment which was not completely compacted at the time of inspection (see erosion;

Table 22. Road results from selective rating of 100-200 ft road sections in the combined East Pond and Serpentine watersheds. The values given in parentheses after the total length rated indicate the number of roads rated in each category. Ratings based on a scale of 1 - 5 (see Appendix E).

Road Type	Total Length Rated (ft)	Mean Widest Width (ft)	Mean Crown Rating	Mean Surface Rating
State	300 (1)	23	3.25	3.00
Municipal	1250 (1)	21	4.25	3.75
Fire	1400 (7)	15	4.44	3.89
Private	300 (2)	14	5.00	5.00


Serpentine
3
EAST POND
3-84
Cem
347T
H F I E L D
342
3-8
306
300
282T
Miller Islands
Ram Island
EAST POND
WL 263
Loon Island
Brackett Point
Birch Island
SOMERSET CO
KENNEBEC CO
Pier
County Line
337
3-63
293
330
328
360
350
BM
366
X-R 365
EAST
3-64
HOAN HILL ROAD
400
450
BM
366
C Rd Fk
363
FAIRFIELD
HILL

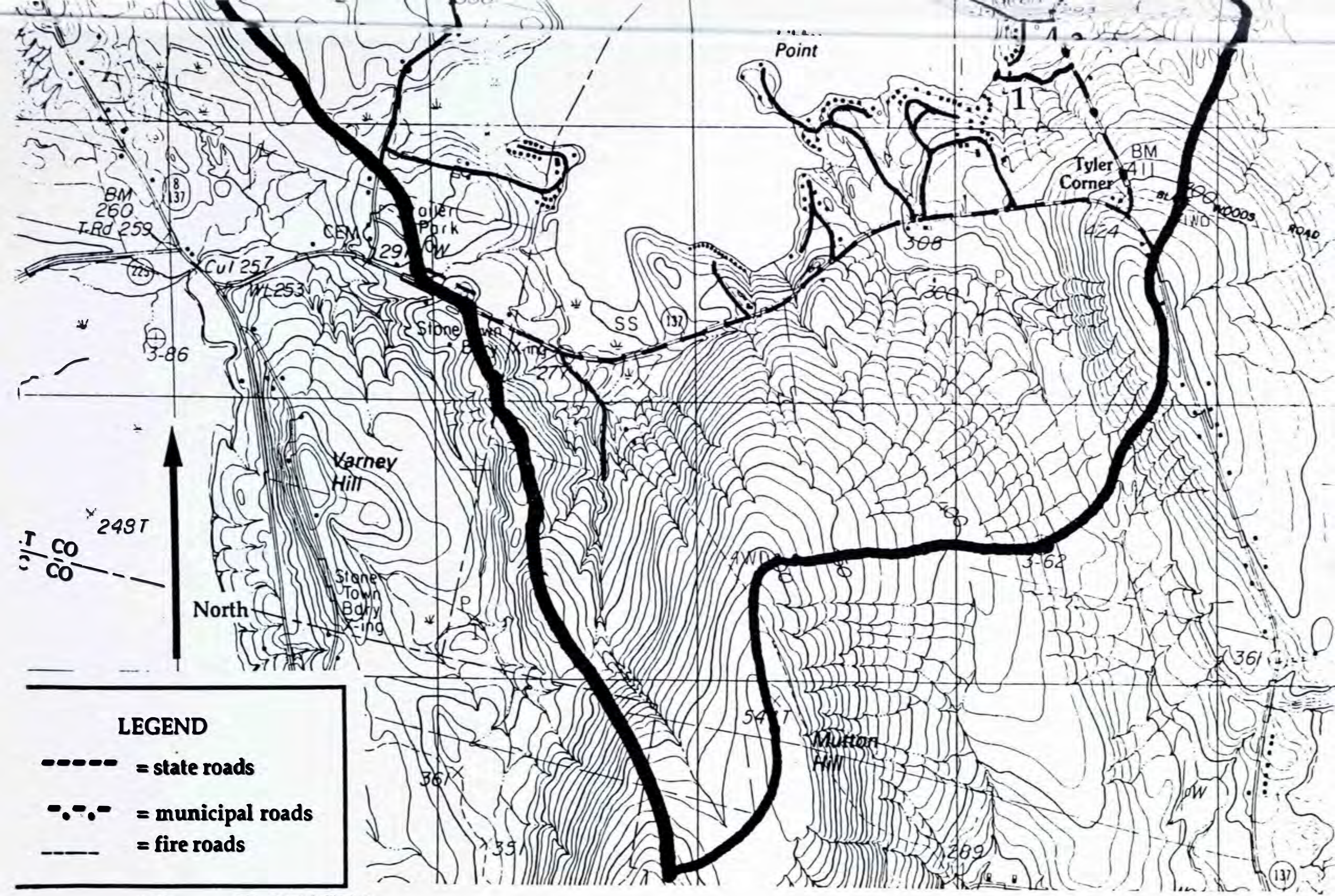
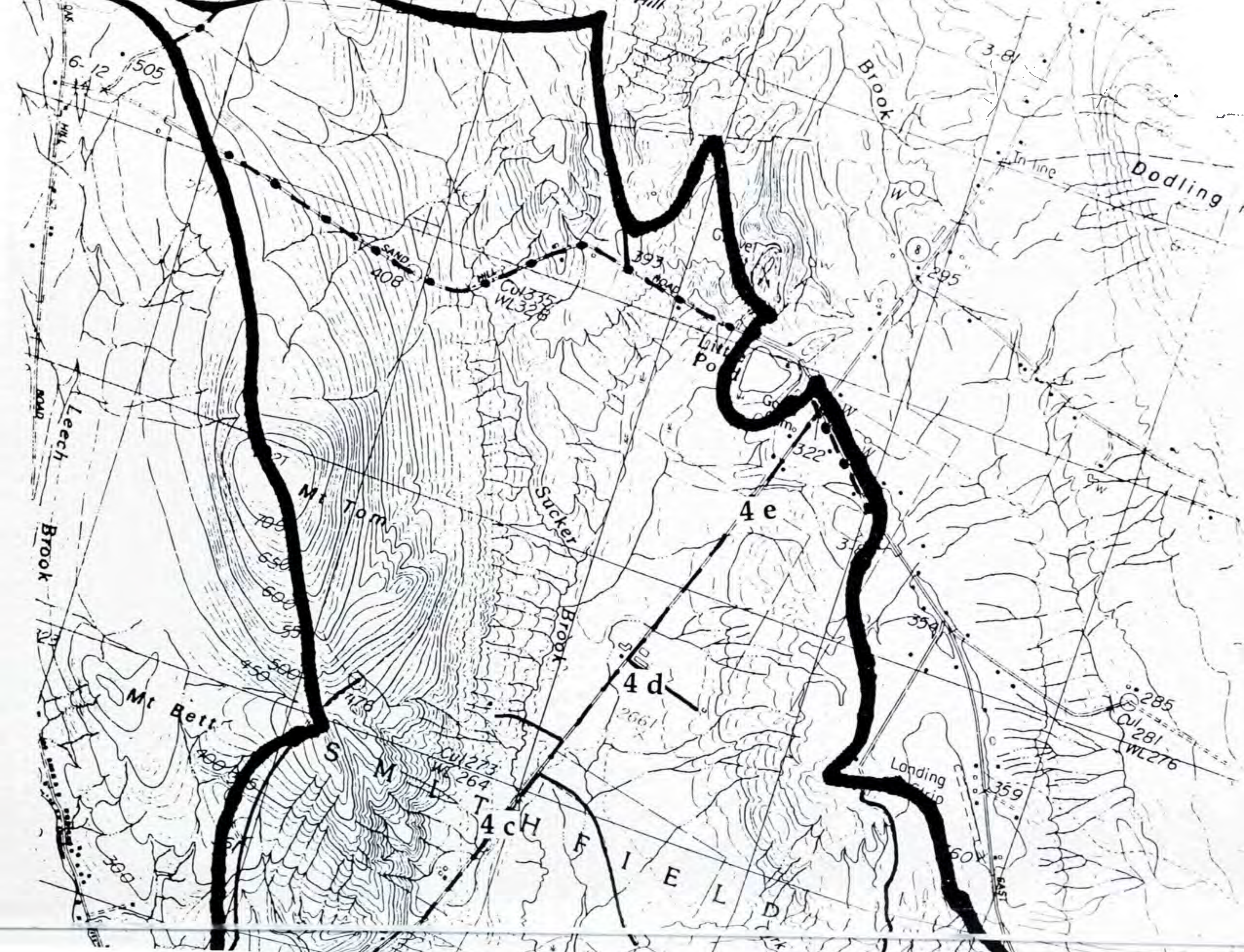


Figure 45. Map of the roads in East Pond watershed. A complete sample of private and fire roads is not shown. The numbers represent areas of special concern discussed in the text. 1982 USGS map, scale (1: 16,000).


OAK HILL
6-12
505
14
3-81
Brook
In line
Dodling
W
8
295
Gravel
SAND
408
HILL
Cul335
WL328
393
ROAD
Little Pond
322
4 e
ROAD
Leech Brook
Sucker Brook
Mt Tom
709
650
600
550
500
450
Mt Bett
1176
4 d
2661
Cul 273
WL 264
400
300
S M I T H F I E L D
4 c
354
285
Cul 281
WL 276
Landing Strip
359
360
EAST

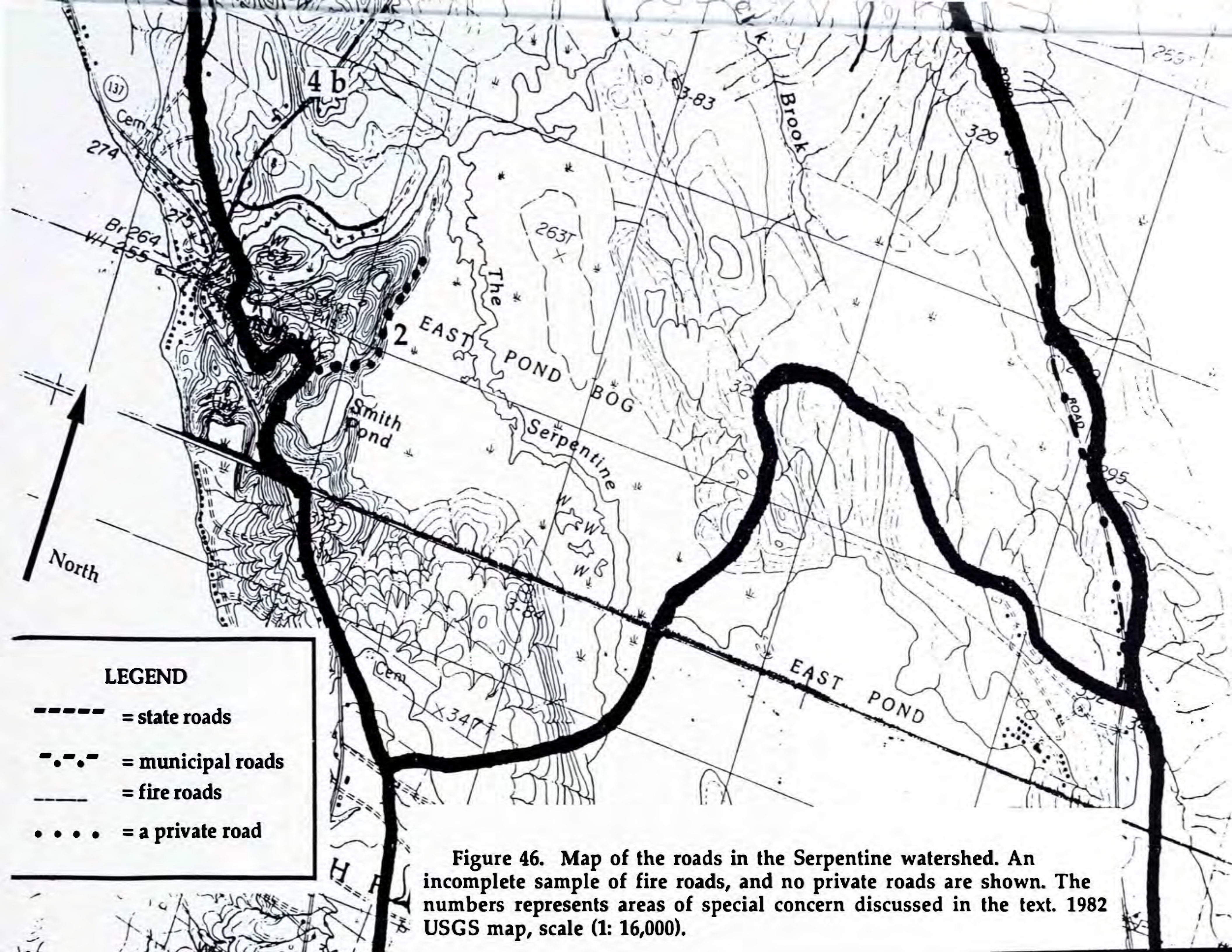


Figure 46. Map of the roads in the Serpentine watershed. An incomplete sample of fire roads, and no private roads are shown. The numbers represents areas of special concern discussed in the text. 1982 USGS map, scale (1: 16,000).

results and discussion). In addition, new culverts were installed under this road as a tributary entered East Pond at this site. Possible sedimentation of this tributary may have occurred because although erosion control measures were employed there was inadequate time for the area to be completely stabilized before winter. However, due to the season, not much traffic would have taken place on this road to exacerbate this problem.

2) The private road in the gravel pit was an example of a private road exhibiting erosion and requiring attention and maintenance.

3) The Eastwood Development is located along the northeastern shore of the lake. This area was an abandoned children's' recreational camp which was approved by the Town of Smithfield for subdivision into 12 lakeshore plots on February 2, 1986. The existing road (Horn Road or Fire Road E-4) connecting these plots was 11 ft wide for 1/4 mi near its end and was to be left this way according to the original development plans. However, this did not happen, and a 1/4 mi stretch of this road was widened to 19 ft possibly to make it more attractive for selling purposes. The developers were sued for this action which violated their original plans (Betsy Tipper, East Pond resident, pers. comm.), and the Maine DEP ruled that they must reduce the road to the 11 ft stipulated in the original development plans.

In the fall of 1991 the developers undertook construction practices to narrow this road section as required by transporting truckloads of gravel and regrading the surface. However, according to site visits and communication with a year-round resident of the area, it appeared that the potential environmental impact from this project was overlooked. The new shoulders were fairly steep (~3 %), and since the work took place in late fall, adequate seeding of a natural vegetative buffer did not occur. Some mulching was done, but probably is not sufficient to stabilize the area through the winter. In addition, a Serpentine tributary, Clark Brook, passes under this section of the road that was narrowed. It is a possibility that excess sediment loading into this tributary and East Pond could have occurred during construction phases.

4) Roads crossing over tributaries leading into the East Pond and Serpentine watersheds were areas of particular concern. If erosion of the road surfaces occurred and/or adequate vegetative buffer zones were absent, runoff into the tributary could be greatly facilitated. Several such areas existed along Route 8, as well as some other areas within the watersheds. While these areas were not individually evaluated, they still deserve attention.

Phosphorus Budget Analysis: Out of the total length of roads in the East Pond watershed, state roads comprised 20%, municipal, 24%, and fire, 56% of the watershed by length. In the Serpentine watershed, total road length was comprised of 27% state roads, 45% municipal roads, and 28% fire roads. While the roads of the Serpentine watershed were shorter in length than the roads in the East Pond watershed, they actually had a larger surface area due to the greater lengths of state and municipal roads which were wider than fire roads.

The amount of phosphorus contributed from roads in both watersheds was found to be on the high end of the range calculated in the overall phosphorus budget for the watersheds (see External Phosphorus Loading; results and discussion). According to the analysis, state and municipal roads in the East Pond watershed were found to contribute 19 and 23 kg-P/yr respectively, while fire roads contributed 52 kg-P/yr. These values were estimates which should only be considered as revealing general phosphorus loading trends. They were based upon the exclusion of private roads, underestimated road lengths, and averaged road and ditch widths obtained from a selective sampling of measurements. They most likely represent underestimated values.

State and municipal roads in the Serpentine watershed contributed 23 and 31 kg-P/yr respectively, while fire roads contributed 10 kg-P/yr.

Conclusions

The roads in the East Pond and Serpentine watersheds are not rated as a significant source of phosphorus loading to the lake. While these phosphorus loading values were high within their calculated ranges, the overall impact of roads on water quality in East Pond was not significant in comparison to other land use activities. However, increased maintenance incorporating greater erosion control practices would improve existing road quality, thereby limiting further phosphorus loading of East Pond. In addition, with increasing pressure from development of the East Pond watershed, the necessity for any increase in road surface area should be carefully evaluated.

Recreation

Materials and Methods

The primary recreational uses on East Pond were investigated to illustrate generally how they could affect the water quality of the lake. Furthermore, the newly-installed boat ramp was evaluated in an effort to determine its influence on the lake.

Results and Discussion

Evidence of recreational use was abundant in the form of numerous docks, both permanent and temporary, numerous boats, motorized and not, several camps, and several snowmobile signs.

The new Maine Department of Fisheries and Wildlife boat ramp consisted of a dirt road, a concrete ramp leading into the water, and three parking lots. Erosion was exhibited in at least one area (see Analytical Procedures and Findings: Erosional Findings on East Pond). The area surrounding the road had been mulched using hay, but had not been secured for the winter. Grass was seen growing underneath the mulch. Furthermore, several large culverts ran underneath the road, diverting runoff into a wetland area connected to East Pond.

This study was not conducted at a peak time of recreational use on East Pond. Therefore, assessing the impact of recreation upon East Pond's water quality presents a difficult task. Methods of quantitative analysis were not feasible, therefore we concentrated on general observations to show the potential effects that recreation may have on a lake system.

Non-natural beach areas are harmful to lake water quality because they provide an extra source of phosphorus loading and may destroy the natural shoreline habitat by suffocating freshwater clams and mussels and eliminating fish breeding areas. Furthermore, a natural shoreline area helps prevent erosion by breaking waves (Congress of Lake Associations, 1991).

Boating is a major concern when considering lake water quality. Exhaust from motors cannot be avoided, but if one uses the smallest motor necessary for the task and keeps that motor serviced, pollution is minimized. Furthermore, one should always be concerned with oil or gas leaks. In a shallow lake such as East Pond, motors have the potential to stir up the lake-bottom sediments, thereby possibly releasing phosphorus into the water column and destroying valuable bottom habitat. At high speeds of operation, the potential for shoreline erosion exists. To prevent these potential problems, one should travel at low speeds and watch the depth of one's motor when travelling close to shore. Washing one's boat on or near the lake with phosphate detergents presents yet another source of external phosphorus loading. Finally, with boating comes the potential for littering.

The Congress of Lake Associations recommends that temporary docks be used as an alternative to permanent docks. Permanent structures alter the bottom habitat and wave patterns of the lake and cause new sites of erosion. Cedar, a durable wood, is the recommended dock material, rather than CCA pressure-treated and creosoted wood which may leach harmful chemicals into the water (Congress of Lake Associations, 1991). Furthermore, the State of Maine Department of Environmental Protection provides guidelines regarding proper installation of docks (State of Maine Guidelines for Municipal Shoreland Zoning Ordinances, 1990).

The commercial camps on East Pond may threaten water quality through faulty septic systems, incorrect boating practices, concentrated shoreline activity and erosion, and poor maintenance of camp roads. Furthermore, if camps are eventually subdivided, that would increase the land use pressures for smaller areas.

Miscellaneous recreational uses around the lake such as horseback riding, mountain/dirt bike riding, and snowmobiling may cause erosion on the edges of the lake.

The primary factor which would be affecting the amount of recreational use on East Pond is the newly-installed public-access boat ramp. Although the magnitude of its effect cannot yet be determined, it has already influenced negatively the water quality of East Pond through erosion. Even though it is beneficial to concentrate access to the lake in a specific area, public access may increase congestion, noise pollution, wildlife harassment, and compromise safety.

Conclusions

Our study was not appropriate for quantitatively analyzing recreation on East Pond. By observation it seems as though recreation does not produce considerable deleterious effects on the water quality of the lake. However, from the information provided, recreation can potentially harm lakes; thus, recreation on East Pond should be monitored carefully in the future, especially with the newly-built boat ramp, to ensure that the lake is not jeopardized.

Sensitive Areas in the East Pond and Serpentine Watersheds

Based upon the findings of this East Pond land use study, certain areas of the East Pond and Serpentine watersheds were considered more ecologically sensitive than others (Figures 47 and 48). These areas were classified as sensitive according to either the current impact of development or the potential impact of future development. This classification is based on the type of soil, vegetation, and current land use patterns. It is recommended that proposed development in these areas be examined closely before receiving approval from town officials.

East Pond Watershed

Site 1

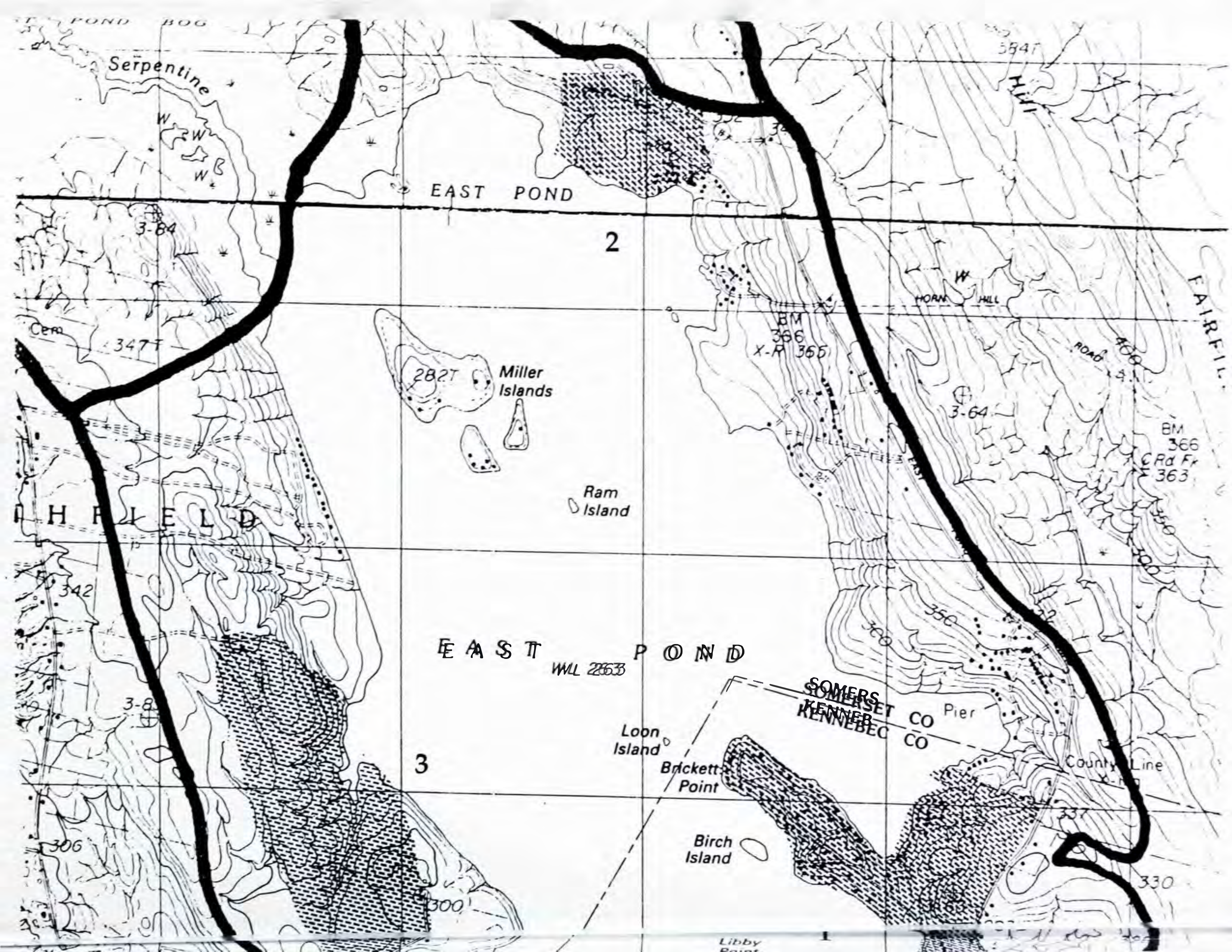
- Dense development and the construction of a new state boat ramp in this Libby Point Cove area require that this area be closely monitored in the future.
- Many grandfathered lots have subsurface waste disposal systems which do not follow current regulations. Upgrading of these systems is recommended.

Site 2

- This area is adjacent to a bog which is under resource protection and is therefore a particularly fragile ecosystem.
- Clark Brook, a major tributary of East Pond, runs under a road which has undergone unsound construction practices, causing this area to have a potentially significant impact on East Pond. To avoid this type of situation in the future, proper erosion control practices should be more clearly stated and implemented.

Site 3

- Steep slopes and poor soils in this area increase the potential for erosion and prevent adequate phosphorus buffering capabilities. Impact from future development needs to be assessed before any future construction begins.


POND BOG
Serpentine
W
W
W
EAST POND
3-84
2
Cem
347T
282T
Miller Islands
BM 366
X-R 365
HORN HILL
HILL
ROAD
400
3-64
FAIRFIL
BM 366
C Rd Fr 363
Ram Island
H F I E L D
342
350
300
EAST POND
WL 2863
350
360
SOMERSET CO
KENNEBEC CO
Pier
Loon Island
Brickett Point
3
County Line
337
3-8
306
Birch Island
330
300
Libby Point
1

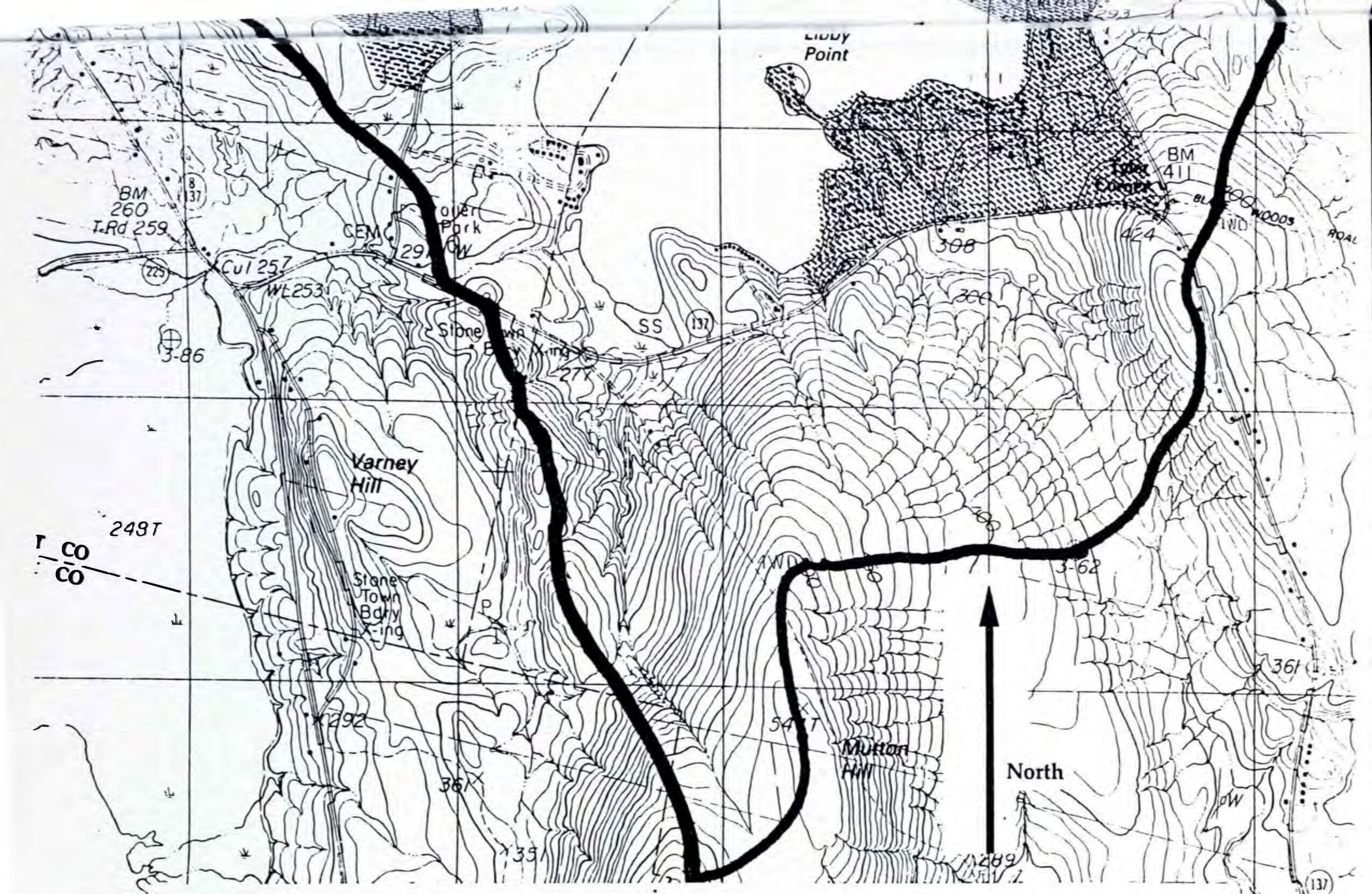


Figure 47. Sensitive areas in the East Pond watershed. Site 1 is a highly developed area that contains many grandfathered lots. Site 2 is adjacent to a particularly fragile bog ecosystem. Site 3 is typified by steep slope and poor soils which might promote the possibility of erosion. 1982 USGS map, scale


505
6-12
MILL
Brook
3-81
Dodling
Tn line
622
580
8
295
SAND
408
Cul 335
WL 328
393
ROAD
Gravel
Little
Pond
322
Mt Tom
705
650
600
550
500
450
Leech
Brook
ROAD
Mt Bett
400
470
2
354
285
Cul 281
WL 276
266
Landing
Strip
359
360
EAST
S M I T H F I E L D

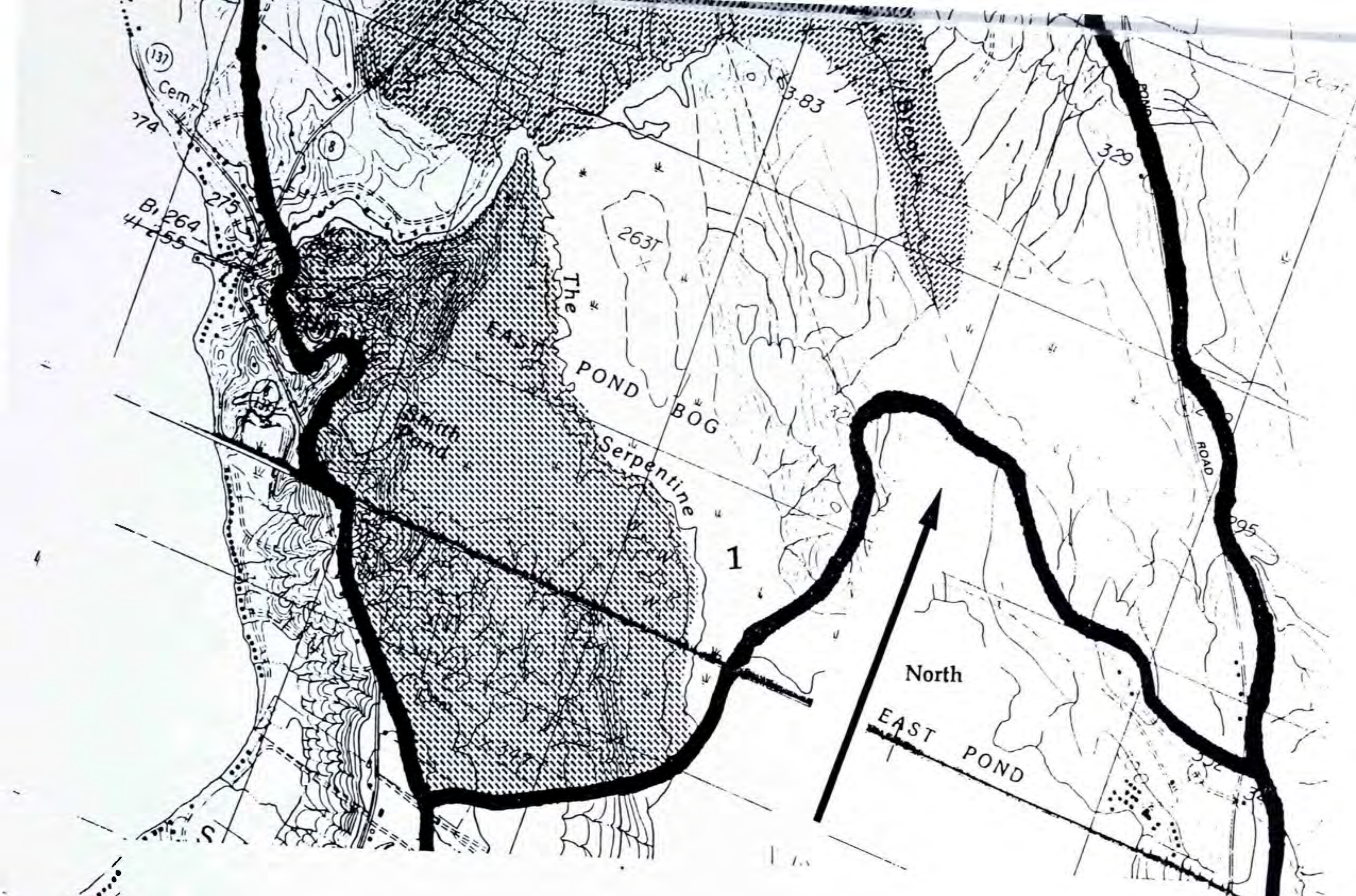


Figure 48. Sensitive areas in the Serpentine watershed. Site 1 is near the East Pond Bog and contains a gravel pit. Site 2 contains three farms and several tributaries which are crossed by roads. Nutrient loading is high in this area. 1982 USGS map, scale (1:16,000).

Serpentine Watershed

Site 1

- The presence of the East Pond Bog limits future development and requires careful monitoring. Any nutrient increases may be harmful to the bog ecosystem.
- The gravel pit in this area may increase erosion and nutrient loading into the bog and lake systems.

Site 2

- There are three farms in this area, all located on major tributaries of the Serpentine. Nutrient loading and erosion from these farms should be examined and monitored in the future.
- Serpentine tributaries are crossed by roads such as Route 8. Proper erosion control and buffering zones should be established to prevent further degradation of lake quality.

III. SUMMARY

East Pond

- The following tests suggest that the overall quality of East Pond is improving:
    - Conductivity values (measuring dissolved solids) have decreased since 1987 with a slight increase occurring in 1991.
    - Chlorophyll a levels have remained low in the past decade with the exception of 1987. This shows that algal growth is not on the increase.
    - According to Secchi disk measurements, water clarity has improved gradually over time with the exception of 1987, when the lake faced the danger of advanced eutrophication. In part, this suggests that the amount of biomass in the water column has fallen over time.
    - Total phosphorus levels have declined steadily since 1987. This is of particular importance because phosphorus is the main limiting nutrient in lake ecosystems and has a direct effect on the rate of lake eutrophication.
    - Dissolved Oxygen measurements are high providing an abundance of available oxygen for the fauna.
- Since 1987, these variables taken together indicate that biomass and algal production levels have decreased in East Pond while visibility has improved.
- Today, East Pond is in a healthy state. Data over time suggest that the health of the lake will continue into the future and that eutrophication will not be accelerated as long as human and industrial impacts are carefully monitored.

Tributary

- To achieve total understanding of East Pond and its surrounding watershed, it is important to consider the influence of the Serpentine stream watershed.
- Significant rainfall (greater than 2.5 inches/storm) causes the Serpentine stream to reverse direction of flow and flow southward into East Pond. Rainfall of lesser amounts may also cause this reversal if several storms occur in a short period of time.

- Turbidity, nitrate concentrations, tannin concentrations, orthophosphate and total phosphate concentrations are all affected by significant rainfall.

- Clark and Sucker Brooks are probable sources of phosphorus input into the Serpentine stream because of the influence of agricultural runoff.

- The Serpentine Marsh area is directly affected by the input of water from Clark and Sucker Brooks. This input contains increased nutrients and particulate matter directly following heavy rains.

- Water quality parameters of the Serpentine wetland (marsh and bog) appear to be affected by factors such as vegetation types, water depth and general land formations such as the over-hanging mat in the bog.

- It is likely that more nutrients enter East Pond via Clark and Sucker Brooks through the Serpentine following heavy rains than via the small perennial tributaries which enter East Pond directly.

- There is an obvious gradient of increasing turbidity, decreasing clarity, and decreasing pH as the Serpentine stream progressed away from East Pond. The effects of the bog and the marsh on these variables are observable.

Land Use

- Certain areas of the East Pond and Serpentine watersheds were identified as ecologically sensitive. These areas were categorized as sensitive due to either the current impact of development or the potential impact of future development. This classification is based on the type of soil, vegetation, and current land use patterns.

- It is recommended that proposed development in sensitive areas be examined closely before receiving approval from town officials. Future development in these sensitive regions, may increase nutrient loading, therefore accelerating the rate of eutrophication. To sustain East Pond's water quality, future development should be thoroughly examined to prevent excessive phosphorus loading.

I V. RECOMMENDATIONS

East Pond

Reduce biotic disturbance by regulating:

a) recreational use of motorized crafts
b) shoreline development
c) overfishing
d) noise pollution
e) septic pollution

Reduce phosphorus loading by:

a) promoting education
b) using phosphorus-free detergents
c) upgrading and maintaining ecologically acceptable septic systems
d) encouraging, enhancing, and maintaining use of effective buffer strips
e) controling agricultural nutrient loading
f) insuring that new development not only alleviates problems it may cause but creates a positive benefit for the lake ecosystem (e.g. creating a buffer strip which reduces phosphorus load to levels below those previous to development).

Serpentine Tributaries and Wetlands

a) The policy employed by the Lake Association of lowering the lake water level to flush nutrients and sediments in the fall appears to be sound and should continue.

b) Future proposals for additional land use development along the Serpentine Stream must be carefully reviewed before any construction can take place.

c) More knowledge is needed about ephemeral streams. Land development along these areas need to be carefully reviewed.

Land use in the East Pond and Serpentine watersheds

Land Use and Soil Type

a) When considering sites within the watersheds for future development, it is necessary to determine the soil type. Varying soil permeabilities can increase runoff and leaching potential in a region.

b) When considering future development in a region it is important to examine surrounding land use practices in order to avoid excessive nutrient loading.

Locations of Extreme Concern

a) Areas which are characterized by the compounding effects of poor soil type, steep slopes, and lack of forest buffers provide express avenues for runoff and erosion, and thus should be protected by more effective buffering zones.

b) Areas which have either rapidly permeable soils or slowly permeable soils should be monitored and closely protected because of their potential impact on water quality due to leaching and runoff.

c) It is imperative to ensure that proper runoff and erosion control measures are implemented to prevent siltation and nutrient loading to sensitive or fragile areas that are crossed by roads.

Locations of Future Development

a) In the northeast corner of the East Pond watershed, moderately permeable and moderately rapid permeable soils provide sound drainage for the construction of septic systems. This currently well-forested region, if maintained with buffer strips along the lake shore, will prevent erosion and absorb nutrient-laden runoff. This area is thus the best location for future development in the East Pond watershed.

b) The region north of Route 8 (quadrants 3 and 4) in the Serpentine watershed contains soils able to buffer against runoff, and is not located directly adjacent to the Serpentine stream or East Pond. Therefore, future development within this area would have less of a detrimental effect than development elsewhere.

Total Phosphorus Loading

When considering future development within the East Pond and Serpentine watersheds, the impact on total phosphorus loading must be considered. Specifically, conversion of undeveloped land such as forests and wetlands to residential use and road construction will increase the kg per year phosphorus loading.

Forestry

Enforce the Forest Practices Act in the Serpentine and East Pond watersheds to ensure minimum impact on water quality from harvesting practices.

Coliform Testing

Perform coliform tests during the summer months when summer cottages are occupied and when the most activity around the lake is taking place, thus being more apt to harm the water quality. Areas of special concern are densely developed land around East Pond and agricultural areas in the Serpentine stream.

Agriculture

a) Encourage communication and cooperation among organizations like the Agricultural Stabilization Conservation Service and the Soil Conservation Service with farmers in the Serpentine watershed.

b) Encourage the East Pond Lake Association to investigate the present situation of agriculture in the Serpentine and East Pond watersheds and consider giving monetary aid to the farmers for appropriate reforms.

Subsurface Waste Disposal

a) Educate residents on how to care for and maintain their septic systems by emphasizing the importance of early problem detection.

b) Familiarize planning board members with state and local laws concerning subsurface waste water disposal, as well as with the factors which influence whether or not a septic system is functioning properly.

c) Encourage individuals to voluntarily upgrade their systems to meet current standards.

Zoning Practices

a) Give town residents more incentive to keep the lake clean. Most of the seasonal residents are from out of state. They don't have to live with the effects of their land use on a year-round basis while town residents do. Informing locals of what may happen will provide incentive to get involved in water quality control.

b) State financial assistance for towns could help raise enforcement levels. Having enough assistants would help the Code Enforcement Officers immensely. Also, state-subsidized improvement projects for grandfathered parcels would provide more incentives for owners to make improvements that are environmentally sound.

c) Establish a state-organized system for Code Enforcement Officers which would give the officers more prominence in the community and also unify their duties. At present CEOs have little incentive to follow up their site inspections, due to lack of organization and public apathy.

Roads

a) Establish increased legislation in the following areas:
    1) the responsibilities of private individuals for the maintenance of their private roads which directly impact lake water quality.
    2) the regulations for road construction in areas of new development. Cluster development should be encouraged and mandated whenever possible so as to minimize the addition of new road surface area in the East Pond and Serpentine watersheds.
    3) Best Management Practices for roads should be reviewed and updated to ensure that they clearly outline the highest possible level of erosion and runoff control during road construction and maintenance activities.

b) Increase awareness of proper road erosion control of town officials, residents, and construction workers. Educational activities such as workshops and/or demonstrations on proper road maintenance and erosion control are excellent ways to give individuals specific ways to limit road phosphorus loading.

c) Implementation of increased inspection and enforcement practices to ensure that the above regulations are carried out. Developing a consistent and thorough road inspection process would also serve to locate and treat existing road problems as they occur.

Recreation

a) The State of Maine should charge fees for access to the boat ramp, thus providing a monetary base from which to maintain the site in an environmentally sound manner.

b) The EPLA should consider developing guidelines for outboard motor size and use on East Pond.

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Appendix A: Field Reconnaissance Report

The field reconnaissance took place at East Pond on Sept. 12. Five motor boats travelled along sections of the East Pond shoreline, while two canoes travelled through the Serpentine marsh. Each group of students noted specific problems or areas of concern within the lake and Serpentine watershed. The boats and canoes, their sections observed, and the observers were as follows:

Boat 1—Southeast Shoreline; center of Libby Point to pier in Brickett Point Cove; Stephanie Clement, Mary Beth Heiskell, Allison Morrill; video camera

Boat 2—Southwest Shoreline; center of Libby Point to 39° longitude; Laura Armstrong, Kim Kennedy

Boat 3—Northeast Shoreline; eastern side of Serpentine mouth to beginning of Horn Hill development; Lisa Cavallero, Jay Hermsen

Boat 4—Northwest Shoreline; 39° longitude line to eastern side of Serpentine mouth; Matt Brown, Jen McLeod, Mark Mellyn

Boat 5—Islands and Eastern Shoreline; Miller Islands shorelines, Horn Hill development to pier in Brickett Point Cove; Dave Edelstein, Julie Eells, Kristen McMahon, Kendra Smith

Canoe 1—Northern Serpentine; North Pond dam, up tributaries of Clark and Sucker Brooks (as far as possible); Nicole St. John,
Ashley Weld

Canoe 2—Southern Serpentine; mouth of Serpentine to North Pond dam; Elaine Bueschan, Karen Wu

Below is a summary of the conditions observed within each region of East Pond. Site numbers refer to pictures taken in each area/location.

Boat 1

This section of East Pond had a large number of high density areas whose houses rested very close to the shoreline, where lush lawns were abundant and natural vegetation buffer zones were often scanty. Fire roads were often close to the shoreline and private dirt roads travelled straight into the lake at many houses. Steep, gravel slopes or well-maintained grass served as lawns, and small sandy beaches were also spotted in this area. Many decks and docks sprinkled the shoreline in this region. Overall, the area surveyed by boat 1 was densely developed with older residences (seasonality questionable) all occupying a small amount of shoreline property. Forested land was present only in small patches.

Boat 2

The area seen by this boat consisted of residential development, natural vegetation, and marshes. Many of the homes had lawns that extended to the water and the majority of older cottages in addition to some of the newer homes were less than 75 feet from the water (some as close as 2 feet from water's edge). In marsh areas: cattails, scented lily pads, watershields, and pickeral weeds were present. Trees such as maples, birch alder and pine dotted the shoreline. In terms of wildlife, numerous loons and cormorants were seen, as well as one crow, a kingfisher and one blue heron.

Boat 3

The mouth of the Serpentine appeared undeveloped at first glance. However, in the distance, a gravel pit and agricultural clearing were noted. These could possibly have a significant affect on the pond. The North end was relatively undeveloped. Some bank erosion was observed and some dirt roads were seen. As we headed Northeast, more development was evident.

An interesting observation was the development of many modern houses which were not marked on the map. Eventually we came upon a deserted camp (which was marked on the map provided). This camp was built at the water's edge and was quite dilapidated; no plans for cleanup were observable. We also came upon a summer camp (closed for the season) which included a cluster of buildings built close to the shore, a large sloping lawn, and paved roads to the water. A few red ribbons on trees, presumably indicating future clearing and development, were also noted.

Boat 4

On the Western shore, deforested areas were noted as well as residential development in close proximity with the water line. Some relatively undisturbed areas were also seen; marsh and wetlands. In the Serpentine mouth, agricultural activity was present and also a gravel pit was observed. Some residential development was seen in this region.

Boat 5

This boat crew discovered a high degree of development and clearing along the northeast corner of East Pond. Many well established lawns were present. Much of this region was devoid of natural buffer vegetation zones. The Miller islands were only sparsely populated. A few residential homes were seen as well as a high degree of forested land.

B. Points of interest along Miller islands

1. Well-established home located on southern shore of Miller island #1 only about 50 feet from shore (photo #1)
2. Marsh on southwestern shore of Miller island #2 with loons in foreground (photo #2).
3. Small house approximately 20 feet from shore on western side of Miller island #2 (photo #3).
4. Small amount of erosion on western shore of Miller island #2.
5. Another home on western shore of Miller island #2 close to shore (photo #4).
6. An additional home on southern shore of Miller island #1 (photo #5) which is a close proximity to the home in photo #1.
7. A third home (photo #6) in same area as photo #1 and #5.
8. Miller island #3 contains only one home which is not visible from shore.

C. Areas of concern from northern to southern portion of eastern shore of East Pond

1. Well-established home about 100 yards from shore (photo #7).
2. Large cluster of cottages about 30 feet from shore with lawn (photo #8).
3. View of the center portion of the cottages introduced in photo #8 (photo #9).
4. The southern portion of the same concentration of cottages in photos #8 and #9

(photo #10).
5. Broad view of cottages also shown in part in photos #8,#9, and #10 which includes about 8 cottages close to the shore and another 8 or so set back (photo #11).
6. Recently constructed home about 100 yards from shore (photo #12)
7. Another new home about 100 yards from shore including a spacious lawn(photo #13).
8. A very large lawn close to shore approximately 200 yards long (photo #14)
9. A driveway which runs right into the water, two homes, and a neighboring camper (photo #15).
10. Large, well-developed home and spacious lawn (photo #16).
11. home and driveway (photo #17)
12. Small home (photo #18).
13. Small shack at shore with protruding pipes which hang over water(photo #19).
14. A lawn, shack, and large dock (photo #20).
15. Small amount of erosion and flora creeping into pond and one fallen tree.
16. loons (photos #21,22)
17. Reconnaissance research scientists (photo #23)
18. Smithfield gravel pit between North Pond and East Pond (photo #24,25).

Canoe 1

Starting at the dam between East Pond and North pond, this boat traveled north towards Clark Brook. On the East bank of the river, there were a fair amount of residential homes. On the West bank, the area was mostly wooded, except for one house which was under construction.

Further upstream, we encountered a large marsh, which had many islands and inlets. Vegetation seen included cotton grass, lily pads, tape grass, and other bog and pond species. In the swamp's watershed, there was a very large farm on a long, sloping hill. There was also a large gravel pit. We were unable to find Clark brook from here. Pictures were taken of the vegetation, the farm and housing, noting comparisons between the east and west banks, the dam, and peaks of the gravel pit.

Canoe 2

We were able to confirm that there were in fact 10 homes which existed on the area of Serpentine which was covered. There were also 2 motor homes. On the other side of the 10 developed homes, we saw only 1 house which was about 100 yards from the gravel pit. Most of the homes we saw had indoor plumbing. Of those that we saw that did have outdoor plumbing, the structures were placed a good (safe) distance away from the Serpentine.

We also passed an agricultural field which was on the the road adjacent to the Serpentine. A large white chicken barn could be seen from our canoe. After making the semi-sharp right turn, vegetation was noted as follows: cotton grass, a pitcher plant, and leatherleaf, cranberry plant, lilies, arrowhead and sweet gale.

Appendix B: Testing Procedures

Water Sampling: The water samples were taken from boats on the lake. For each surface water sample, a clean water bottle was placed into the water upside-down. Once the bottle was approximately half a meter beneath the surface, it was turned to allow water to enter. When the bottle filled, it was brought to the surface and the bottle was closed. The bottle was then placed into a cooler with ice and remained in the cooler until refrigeration was available. The bottles were then kept at 4°C until tests were conducted on the water samples.

Water samples were collected at mid-depth and half a meter from the bottom of the lake with an Alpha water sampler. When these samples were brought to the surface, a small amount of water was drained out of the water sampling device and then the sample was placed in a bottle.

Filter Treatment for Orthophosphates: To prepare the water samples for orthophosphate testing, we filtered the test samples in the field. The sample was prefiltered with a glass microfiber filter using a manual vacuum pump. The filtered sample was then poured through a membrane filter of .45µm and once again a manual vacuum was used. After the second filtration was completed, the sample was placed on ice and kept refrigerated until testing was conducted in the lab.

Acidification Procedure for Total Phosphorus and Ammonia: To prepare the water samples for total phosphorus and ammonia testing, we acidified the test samples in the field. Once the water sample was collected, concentrated sulfuric acid (H_2SO_4) was added to the sample drop by drop and the pH level was monitored until it dropped to two. Once this acidity level was reached, the sample was placed on ice and kept refrigerated until testing was conducted in the lab.

Maximum Holding Times: The maximum holding time allowed prior to testing varied with the different types of tests. Most of our tests were conducted well before the maximum holding time was reached. The maximum holding times for the tests that we conducted are listed below in time order:

Maximum holding times for the tests that were conducted.

Maximum holding times for the tests that were conducted.

Test	Maximum Holding Time
Nitrates	48 Hours
Orthophosphate	48 Hours
Turbidity	48 Hours
Ammonia	14 Days
Total Phosphorus	28 Days
Chlorophyll a	30 Days in Dark

Appendix C: Water Budget and Flushing Rate Calculations

Using the Zeiss Interactive Digital Analysis System and the 1982 U.S. Geological Survey map of known scale, area values were calculated and equations performed. Areas were measured twice and the values were averaged.

East Pond watershed:

Total watershed area incl. East pond= 30,761.5 mm^2
East Pond area incl. Islands= 12,025 mm^2
Area of Islands= 272.2 mm^2

East Pond:

Lake

12,025 mm^2-272.2 mm^2=11,752.8 mm^2

11,752.8 mm^2 x $(24,000)^2$= 6.7696x10^{12}/1,000,000

=6,769,624 m^2

Watershed

30,761.5 mm^2-11,752.8 mm^2= 19,008.7 mm^2

19,008.7 mm^2 x $(24,000)^2$=1.0949 x10^{13}/1,000,000

=10,949,000 m^2

Inet= (.622 m x (10,878,117 m^2)) + (1.02 m x (6,769,624^2))-

(0.56 m x (6,769,624 m^2))= 9,880,216 m^3 x 264

=2,608,377,024 gallons

Serpentine watershed:
Total area of Serpentine w/ stream= 28,328 mm^2
Area of Serpentine Stream= 503.8 mm^2

Serpentine:

Stream

503.8 mm^2 x (24,000)^2= 2.9016 x10^{11}/1,000,000=

=290,160 m^2

Land

23,328 mm^2-503.75 mm^2 x (24,000)^2=

=1.6027 x 10^{13}/1,000,000

=16,026,768 m^2

Inet= (.622 m x (15,961,000 m^2)) + (1.02 m x (290,160 m2))-

(0.56 m x (290,160 m^2))= 10,061,216 m^3 x 264

=2,656,161,024 gallons

Flushing Rate for East Pond:
DEP reported average depth for East Pond= 5 meters
Measured Surface area of East Pond= 6,769,624 meters^2
Measured net gallon annual addition to East Pond= 2,608,377,024 gal.

Flushing Rate= 6,769,624 meters^2 x 5 meters= 33,848,120 m^3
=33,848,120 m^3 x 264 gal. in 1 m^3=8,935,903,680
=2,608,377,024/8,935,903,680
=.29 flushes per year

Appendix D: Results of East Pond water quality tests conducted in October, 1991.

Test	Site 14			Site 15			Site 16			Site 17			Site 18			Site 19			Site 20		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Temperature (°C)	15.1	14.9	14.9	15.3	14.8	14.4	15.1	14.6	14.2	15.3	14.7	14.4	15.1	-	15.1	15	14.4	14.3	15.1	14.6	14.4
Dissolved Oxygen (ppm)	9.2	9.4	9.5	9.5	9.8	9.9	9.7	9.7	9.7	9.6	9.7	9.8	9.6	-	9.6	9.6	9.8	9.8	9.6	9.8	9.9
pH (ppm)	7.0	7.0	7.0	7.1	7.1	6.9	7.0	-	6.9	7.3	7.1	7.2	7.0	-	7.0	6.9	-	7.2	7.126	7.1	7.0
Turbidity (FTU)	4	5	8.5	4	6	4	5	-	4	4	4	5	5	-	5	5	-	4	3	4	5
Conductivity (µmhos/cm)	29	30	30	30	27	30	40	30	28	30	29	28	29	-	25	29	26	27	29	28	29
Nitrate (ppm)	.03	-	.03	.03	-	.04	.04	-	.02	.03	-	.03	.03	-	.02	.02	-	.03	.02	-	.03
Ammonia (ppm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	-	0.0	0.0	0.0	0.0
Ortho-phosphate (ppb)	23	-	-	22	-	24	18	-	16	24	-	13	31	-	20	26	-	26	25	-	15
Reactive Phosphorus (ppb)	8	-	-	7	-	8	6	-	5	8	-	4	10	-	7	9	-	9	8	-	5
Total Phosphorus (ppb)	7	7	7	14	9	-	8	-	-	4	3	3	10	-	5	-	-	14	9	4	8

*A=surface, B=mid depth, C=bottom

Appendix E: Road Evaluation Key

Category	Description
Road Number	road number or name
Road Type	describe road type St = state Mu = municipal Fi = fire Pv = private
Section Length	estimate section length (ft)
Section Width	measure section width widest point (ft)
Surface Material	state whether road is paved or dirt Pd = paved Dt = dirt
Crown Rating	rate on basis of height : width (scale of 1-5) 1 = 1/2" height for 1' width 5 = 1/2" height for > 2' width
Surface Rating	rate on base of pavement condition or sediment compaction and coarseness (scale of 1-5) 1 = newly paved or sed. size < 1/4" 5 = cracks, potholes present or sed. size > 2"
Road Conditions	describe road conditions using below key As = steep topography leading to lake Bo = road has been recently graded; correctly Bd = road has been recently graded; incorrectly Co = crown is in good condition Cc = crown is cracked and/or sunken Do = lack of ditches where there should be some Er = erosion of roadside is occurring Fg = construction occurs; good erosion control Fb = construction occurs; poor erosion control Pe = potholes present in road section Sp = surface material well packed Sl = surface material muddy or eroding Va = good vegetational buffer zone Vo = poor vegetational buffer zone
Ditch Presence	state whether ditches are present Yy = present on both sides of section Ye = present on one side of section No = present on neither side of section
Ditch Length	estimate ditch length in section (ft)
Ditch Width	measure ditch width at widest point (ft)

Category	Description
Ditch Depth	measure ditch depth top/bottom (ft)
Turnout Number	count number of ditch turnouts in section
Ditch Conditions	describe ditch conditions using below key
	Dd = should be ditches on both sides of road
	Er = erosion of ditch is occurring
	Ll = distance between ditches > 100-200'
	Ls = Ll for steeper slopes > 100'
	Mr = rounded ditch shape
	Mt = trapezoidal ditch shape
	Mv = V-shaped ditch
	Ts = steep slope of ditch sides
	Va = abundant vegetation lining ditch
	Vo = lack of sufficient vegetation lining ditch
	Wn = bottom width too narrow; channel-like
Culvert Presence	count number of culverts in section
Culvert Size	measure culvert diameter (in)
Culvert Conditions	describe culvert conditions using below key
	Eu = erosion on outlet side of culvert
	Ei = erosion on inlet side of culvert
	Er = rusting culvert; culvert needs replacement
	Kx = culvert size too small for water load
	Pr = culvert doesn't protrude enough from road

Appendix F: Construction sites within the East Pond Watershed for 1991.

Town [1]	Map #	Lot #	Date Approved	Name	Alterations
Oakland	44	32	1991	Champagne, D.	construct permanent dock
Oakland	44	38	1991	Averill, R.	addition to seasonal home
Oakland	44	29	1991	Fortin, R.	level land, add parking and area for trailer
Oakland	44	10	1991	Karter, M.	add concrete slab
Oakland	44	63	1991	Reese, F.	new foundation to existing permanent home
Oakland	44	21	1991	Pooler, M.	construct seasonal dwelling
Oakland	44	129	1991	Sarazin, R.	reconstruct permanent dock and pathway to it
Oakland	44	95	1991	Guerette, P.	construct seasonal dwelling
Oakland	44	65	1991	Irvin, G.	seasonal to permanent residence conversion
Oakland	44	47	1991	Bessey, C.	five-lot subdivision
Oakland	44	64	1991	Wiggins, K.	construction of garage
Oakland	44	135	1991	Mcadam, G.	addition to home
Oakland	44	59	1991	Lanctot, J.	addition of glass to screened porch
Oakland	44	79-1	1991	Labreck, Jr., L.	construction of deck
Oakland	44	32	1991	Champagne, D.	addition to home
Smithfield [2]	22	20	5/7/91	Pratt, M.	construction of storage building and boathouse

[1] All construction occurring in Belgrade was outside the East Pond Watershed

[2] The information for Smithfield may be incomplete because the building permits are listed by name rather than by date. Therefore, tracing construction in Smithfield during the past year was difficult.

Appendix G: System for Rating Erosion on Construction Sites.

A rating system was established to evaluate construction sites on their effectiveness in preventing erosion. The following factors were considered:

1) Amount of Vegetative Clearing (square feet). This was measured using a standard tape measure, determining the area of a rectangle most closely fitting the cleared area.

2) Percentage of Bare Soil. This was a rough estimate to show the amount of soil left prone to erosion.

3) Length of Time Spent without Grass Cover. This was determined by asking when clearing on the site actually began and noting the date of visitation and the rate of grass growth up to that point.

4) Progress of Grass Growth. On a system of one to five (five being the highest amount of grass growth), the construction sites were rated subjectively.

5) Erosion Prevention Techniques Employed. All the methods of preventing erosion used on the site were noted.

6) Areas of Specific Erosion. Areas of specific erosion on the site were noted.

Appendix H Personal Communications.

Bouchard, Roy. Maine Department of Environmental Protection.

Bessey

Butler, Sally SCS

Charles, F. Independent farmer.

Chartrand, E. Independent farmer.

Dennis, J. Maine Department of Environmental Protection.

Dirkman, Jack. Maine State Forest Service.

Dumont, G. Maine State Department of Fisheries and Wildlife.

Feegal, T. Independent farmer.

Firmage, D. Colby College Biology Professor.

Gordon, T. Cobbossee Water District.

Gurney, D. East Pond gravel pit co-owner.

Hoey, R. Maine Department of Environmental Protection (land use bureau).

Joly, B. East Pond Lakes Association, Year-round East Pond Resident.

Long, D. Soil Conservation Service.

Lowell, P. Lakes Environmental Association.

Mairs, D. Maine Department of Environmental Protection.

Nelson, R. Department of Geology, Colby College.

Olson, C. Environmental Department, Maine Department of Transportation.

Smith, Rick

Sturtevant, D. Oakland Town Council.

Staples, R. Independent farmer.

Thompson, P. North Kennebec Regional Planning Commission.

Tipper, E. Year-round East Pond Lake Resident.

Turner, P. Soil Conservation Service.

Walton, C. Erosion and Sediment Control Department, Maine Department of Transportation

Wentworth, W. Alden Camps Owner.

Whitten, J. Maintenance Department, Maine Department of Transportation.

Zarcone, M. Smithfield Plumbing Inspector.