

Laurie K. Loftin. WATER CHEMISTRY OF THE POCOSINS OF THE CROATAN NATIONAL FOREST, CARTERET, CRAVEN AND JONES COUNTIES, NORTH CAROLINA. (Under the direction of Dr. Lee J. Otte) Department of Geology, October 1985.

#### ABSTRACT

The Croatan National Forest, located on the central portion of the lower North Carolina Coastal Plain, contains one of the largest and least disturbed peat-bearing wetlands in the state. Within the Croatan system, three different water regimes have been chemically distinguished: (1) standing or flowing surface waters, (2) peat pore waters, and (3) mineral pore waters. Upon analysis for 27 ions, these water regimes were chemically differentiated, based on concentrations of the following dissolved ions: Al, Ca, K, Mg, Mn, Na,  $\text{NH}_4\text{-N}$ ,  $\text{NO}_3\text{-N}$ ,  $\text{SiO}_2\text{-Si}$ , total dissolved  $\text{PO}_4\text{-P}$ , total organic C, Ti, and V.

Optimum indicators of the three water regimes were total organic C, Si, and Ca. Mineral pore waters contained the highest amounts of dissolved Si (ave = 3.55 mg/l), intermediate levels of Ca (ave = 1.51 mg/l), and the lowest concentrations of total organic C (ave = 42.7 mg/l). Peat pore waters contained the highest concentrations of total organic C (ave = 212.5 mg/l) and Ca (ave = 2.09 mg/l), and intermediate Si concentrations (ave = 0.89 mg/l) of the three regimes. Standing surface waters contained the lowest concentrations of dissolved Si (ave = 0.45 mg/l) and Ca (ave = 0.20 mg/l) and had intermediate concentrations of total organic C (ave = 51.0 mg/l).

The seasonality of outflow waters was as follows: highest total

organic C, Ca, and Si concentrations corresponded to periods of lowest water table, when peat and mineral pore waters were draining. During the winter and spring, increased surface runoff and the subsequent addition of its chemical components caused total organic C, Ca, and Si concentrations in the drainage canals to decline. Potassium (K), although not an indicator species for any particular water regime, exhibited a seasonality in outflow waters. Concentrations of K in drainage waters increased during periods of low flow (summer and fall) and declined during periods of high flow (winter and spring). Other ions present in the outflow waters, as well as in the well waters, were not indicative of a specific water regime, nor did they exhibit a strong degree of seasonality in outflow.

WATER CHEMISTRY OF THE POCOSINS  
OF THE CROATAN NATIONAL FOREST  
CARTERET, CRAVEN, AND JONES COUNTIES,  
NORTH CAROLINA

A Thesis

Presented to

the Faculty of the Department of Geology  
East Carolina University

In Partial Fulfillment  
of the Requirements for the Degree  
Master of Science in Geology

by

Laurie K. Loftin

October, 1985

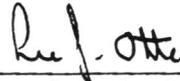
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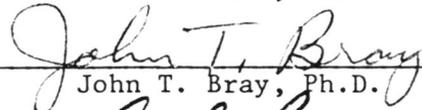
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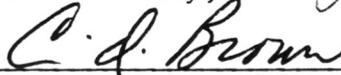


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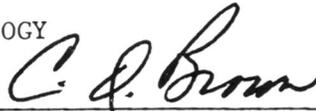


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## INTRODUCTION

The North Carolina Coastal Plain supports thousands of square miles of peat-forming wetland ecosystems (Figure 1). Excluding the coastal brackish marsh systems, most of these wetlands are in serious danger of being irreversibly altered by man. Tens of thousands of acres have already been ditched, drained, and cleared for agriculture and silvaculture (Otte and Loftin, 1983). Only two large freshwater wetland tracts (greater than 4047 hectares) remain that can be considered relatively undisturbed: the large open pocosin and freshwater marshes of southeastern Dare County, and the pocosins of the Croatan National Forest in Carteret, Craven, and Jones Counties.

Most research on coastal wetlands has focused on man's influence on the various aspects of these environments (Gambrell, Gilliam, and Weed, 1974; Kuenzler, Mulholland, Ruley, and Sniffen, 1977; Kirby-Smith and Barber, 1979; Gilliam and Skaggs, 1981). Unfortunately, these works cannot be put into perspective until the natural, undisturbed systems are understood. In the past 30 years, man has concentrated on developing the pocosin wetlands - the large, shrub-dominated systems underlain with varying thicknesses of peats and peaty mineral soils. The major concern over the development of these pocosins, however, does not appear to be the alteration of the land itself, but rather, the effects of water draining from these wetlands into the surrounding streams and estuaries. To better understand the influence of these waters as they leave the pocosin, a need exists to determine the exact source of the water within the pocosin.

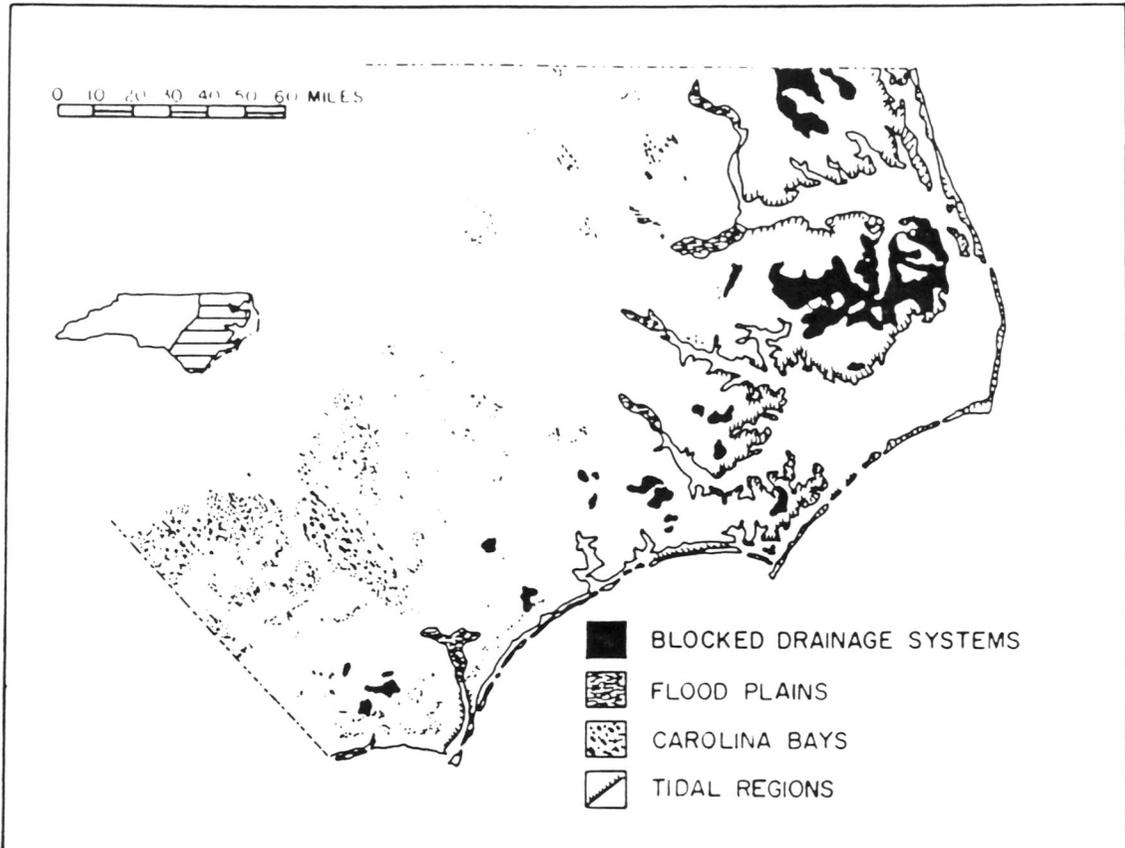


Figure 1. Environments of peat accumulation on the North Carolina Coastal Plain. (1 mile = 1.6 kilometers)

## OBJECTIVES

This project is designed to qualify and quantify the chemical parameters of the source waters in the pocosins of the Croatan National Forest. Preliminary field and lab investigations for this project indicated that three different water regimes exist in the pocosins of the Croatan National Forest: a) standing or flowing surface water, b) pore water in the peat soils, and c) pore water in the underlying and adjacent mineral soils. Because the physical conditions of each regime are distinct, one should also expect that different chemical characteristics exist for each regime. Standing or flowing surface waters should largely reflect the addition of rainwater, in that the concentrations of elements are appreciably less than those of peat pore water or mineral pore water. Water associated with the peat should be enriched in elements that either concentrate in the peat environment or elements that are released by the decay of organics. Water associated with the underlying and adjacent mineral soils should be less enriched in those ions directly associated with organic matter and richer in ions that might be derived from the minerals in the soils.

With the seasonal fluctuation of the water table (See Hydrology section), a typical occurrence in a pocosin, it is logical for a particular water regime to dominate or contribute more to drainage waters in the appropriate season. Therefore, in addition to determining the chemistry of the pocosin waters and documenting source regimes, this project is designed to detect the change in outflow source(s) on a seasonal basis.

## GEOGRAPHIC SETTING

The Croatan National Forest contains approximately 60,704 ha of land (Schumann, 1977), 14,164 ha of which are underlain with peat (Ingram and Otte, 1981). The Croatan is located in the Tidewater Region of the North Carolina Coastal Plain and is situated on the Talbot Terrace. According to Mixon and Pilkey (1976), the Talbot Terrace slopes gently southeastward, is of Pleistocene age, and ranges in elevation from 7.6 to 12.2 m above mean sea level.

The Croatan is located approximately 23.9 km south of New Bern and 12.7 km west of Havelock in Carteret, Craven, and Jones Counties (Figure 2). Primary access to the forest is along Catfish Lake Road (SSR 1100, 1105), but several Forest Service Roads branch from Catfish Lake Road and provide additional access (Figure 2).

Five lakes, the origin of which has not been fully documented, are found in the Croatan (Catfish, Ellis, Great, Little, and Long), and all are found along the margins of peat deposits (Figure 2). Tietz (1981) studied the sedimentation and evolution of Great Lake and suggested that this lake formed from the damming of Hunters Creek (method unknown) and the subsequent flooding of its upper tributaries. Based on  $^{14}\text{C}$  dating, Tietz interpreted this to have occurred within the last 4000 years, after and unrelated to the beginning of peat deposition in the Croatan pocosins (estimated at 11,000 years before present). (See Regional Geology section for information regarding peat deposition).

Peat is found in five areas in the Croatan National Forest: the Northwest Catfish Lake deposit, the Northwest Great-Long Lake deposit, the South Great Lake deposit, the South Ellis Lake deposit, and the

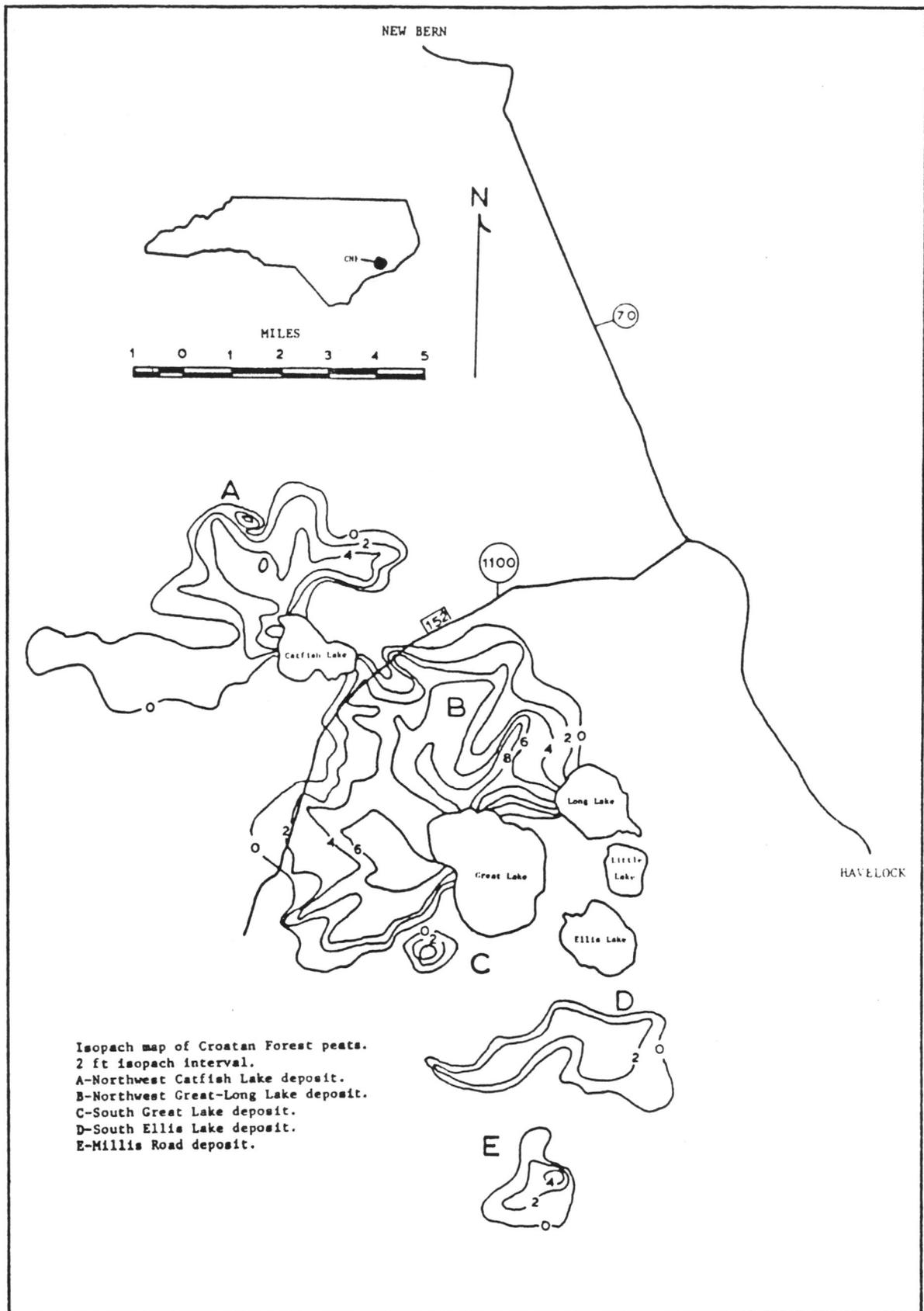


Figure 2. Location map of the Croatan National Forest with peat isopachs.  
 (2 feet = 0.6 meter and 1 mile = 1.6 kilometers)

Millis Road deposit (Figure 2). Surface elevations of the peatlands in the Croatan range from 12.2 m in the northeast to 9.1 m in the southeast (Ingram and Otte, 1981). The surface of the major deposit rises as a broad dome (elevation slightly greater than 12 m above mean sea level) just northwest of Great Lake (Ingram and Otte, 1981).

The study area for this project includes land west of Great and Long Lakes and east and north of Catfish Lake and Forest Service Road #152 (SSR 1100) (See Figure 2). This tract consists of approximately 7080 ha of peatland, with peat thicknesses ranging up to 2.5 m. The peat thins to the edge of the deposit and grades laterally into mineral soils (Ingram and Otte, 1981). In this tract, the only major, man-made disturbance is along its western edge, where approximately 51.0 km of canals and canal maintenance roads cut through about 15.5 km<sup>2</sup> of pocosin. These canals, dug 30 years ago, are small and shallow and now act as natural drainages rather than maintained, man-made drainages. While working in the area, it was noted that an area of vegetation in close proximity to the canals is usually slightly higher in stature than what would normally be expected. Minimal change in vegetation, however, occurs further away from the canals (roughly 10 m). Thus, the wetland system seems to have reached equilibrium with the canals, and wells were emplaced approximately 30 m away from them.

## PREVIOUS INVESTIGATIONS

Hydrological studies of coastal North Carolina have thus far concentrated on various aspects of fluvial systems and their related estuaries. Several approaches have been taken and may be broadly classified into groups as follows: (a) those studies concerned with nutrient levels in estuaries (Hobbie and Smith, 1975) and the impacts of coastal plain streams upon estuaries (Brinson, Noltemeier, and Jones, 1980); (b) analyses of agricultural effects on drainage waters and associated estuaries (Gambrell, et al., 1974; Kirby-Smith and Barber, 1979; Gilliam and Skaggs, 1981); and (c) studies dealing with the effects of channelization (Kuenzler et al., 1977). In another hydrological study, several North Carolina lakes were sampled and nutrient levels were determined between 1971 and 1975 (Weiss and Kuenzler, 1976). However, none of the five natural lakes of the Croatan National Forest was sampled.

These cited studies were concerned mostly with fluvial systems, not peatlands. This study's approach to understanding nutrient levels in a peatland is different in that the in situ waters of a pocosin ecosystem are observed, not just the drainage or outflow waters. This study attempts to document that the in situ waters are chemically different in response to differing physical parameters.

Peatland water studies have been performed in northern areas such as Minnesota and Canada (Heinselman, 1970; Verry, 1975; Richardson, Tilton, Kadlec, Chamie, and Wentz, 1978). The climatic and geological differences between North Carolina and these areas, however, are significant enough that comparison of data must be made cautiously.

Hydrological studies of North Carolina peatlands are, unfortunately, few in number. Peat Methanol Associates have monitored the drainage canals in a proposed peat mining area in Washington and Tyrell Counties, North Carolina in an attempt to assess the effects of peat mining on drainage waters. In addition, they monitored wells that collect water from peat environments and from areas dominated by mineral sediments. The unpublished well data are available as PMA documents (PMA, 1983) and may be compared to the subsurface water data from this project.

A study was conducted in the Pungo National Wildlife Refuge between the years 1977 and 1979 (Daniel, 1981) that is similar to this project for the Croatan pocosins. The Daniel work included a comparative analysis of peat pore waters and mineral pore waters between cultivated and natural areas in the refuge. A difference in water chemistries was observed in the study area and thus may serve as a reference for Ca, K, Mg, and Na data obtained in this project.

During the years 1978 and 1979, Noltemeier conducted a water quality study of Coastal Plain streams, in which peat-draining streams were compared to mineral soil-draining streams. The peat-draining streams in her study have their headwaters originating in the peat deposits of the Croatan National Forest. A peat-draining stream in Noltemeier's study refers to one in which a mixture of peat, peaty mineral soil, and mineral soil is present in the drainage basin. Of the peat-draining streams studied by Noltemeier, West Brice Creek was sampled in both her study and for this project. Noltemeier's sampling site was located downstream from the one in this study, however, and thus probably represents a greater degree of mixing between peat, mineral, and surface waters. Comparison of data is possible, however, and is of interest.

The Croatan National Forest has served as a research area for

various other projects, including vegetational analyses (Snyder, 1977,1978; Wilbur and Christensen, 1982) and a peat inventory conducted for the U.S. Department of Energy (Ingram and Otte, 1981). The research and conclusions of the Ingram and Otte study (1981) have been heavily relied upon in this study as it is the only existing report of its kind for the Croatan. The sedimentation of the Great Lake area of the Croatan was studied in 1981 by Tietz. Water chemistry was not included in Tietz's work, but stratigraphic and sedimentological data from the cores of Great Lake have been helpful in this study.

## CLIMATE

The North Carolina Coastal Plain experiences a humid, warm temperate climate, with cool winters and warm summers. On the average, North Carolina receives 127 cm of precipitation per year, with July being the wettest month (19.5 cm) and October the driest (8.3 cm). A histogram of average monthly precipitation data for the past 35 years at the Maysville 6 SW station is presented in Figure 3a. This is the closest weather station to the Croatan. A histogram of the rainfall data, by month, for this project's duration, June of 1983 through May of 1984 (Figure 3b), is also presented. Generally, the summer of 1983 was drier than the average, with the winter being somewhat wetter.

Monthly average temperatures for the Maysville station are presented in Figure 4 and are compared to those for the sampling year. For the long-term average, July and August are the warmest months, with average temperatures of 25.4°C and 25.1°C, respectively. January and February are the coolest months, having average temperatures of 6.4°C and 7.3°C, respectively. Temperatures for the summer of 1983 were slightly higher than the 31 year average.

The sampling year for this project can be characterized as having a drier than average summer with higher temperatures, and a wetter than average winter with temperatures that closely approximate the long-range mean.

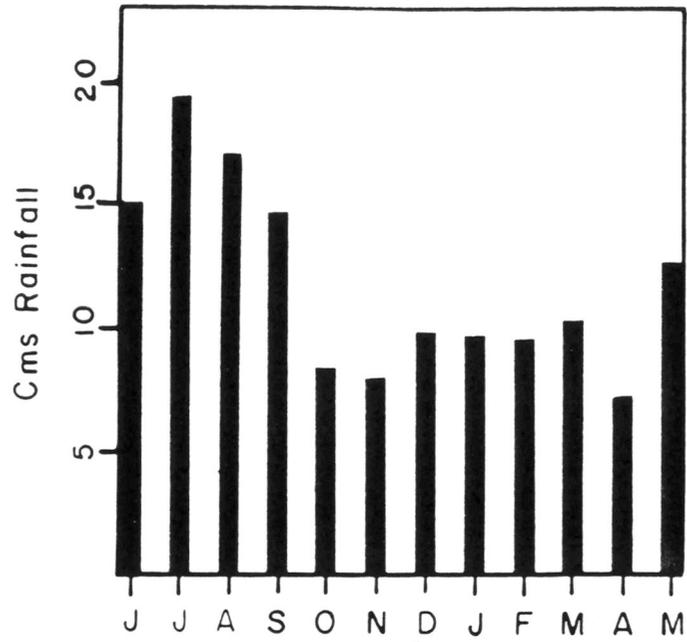


Figure 3a. 35 year average monthly precipitation (cm) from Maysville 6 SW station.

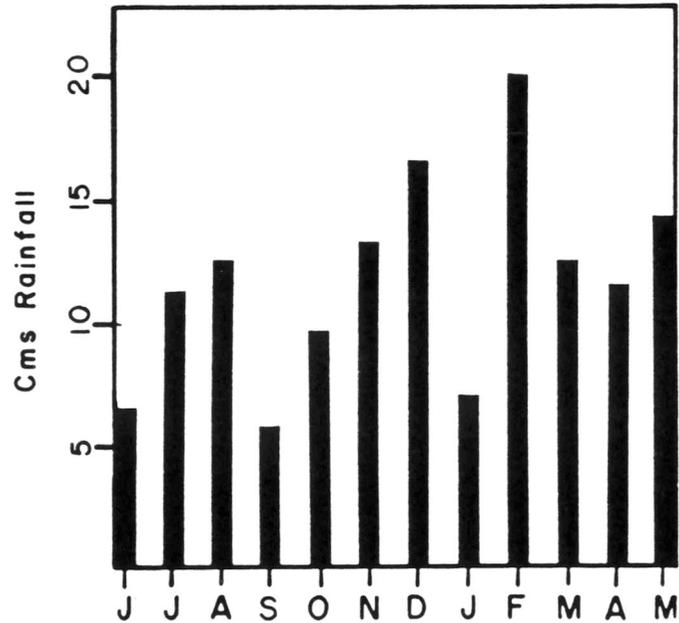


Figure 3b. Monthly average precipitation (cm) for Maysville 6 SW station sampling year (6/83 - 5/84).

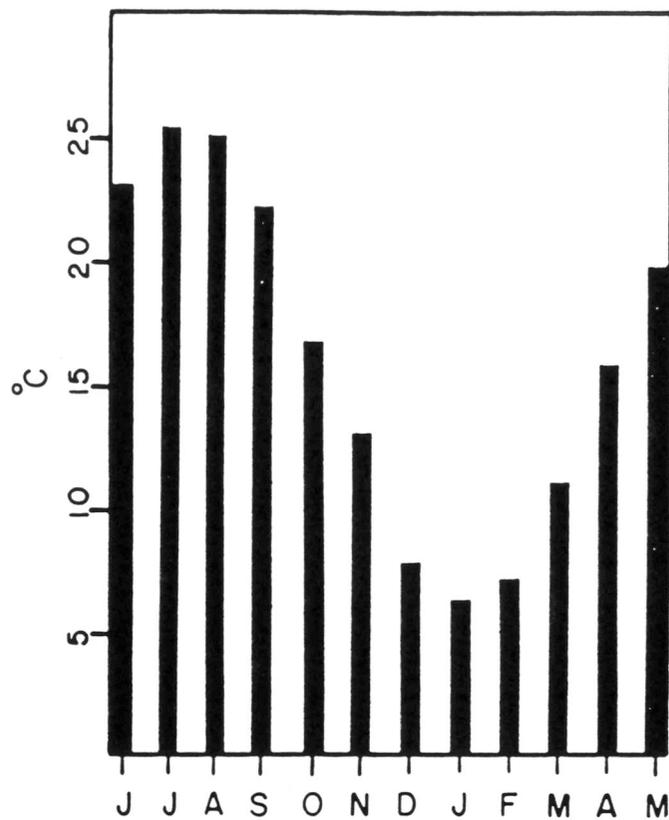


Figure 4a. 31 year average temperature (°C) for Maysville 6 SW station.

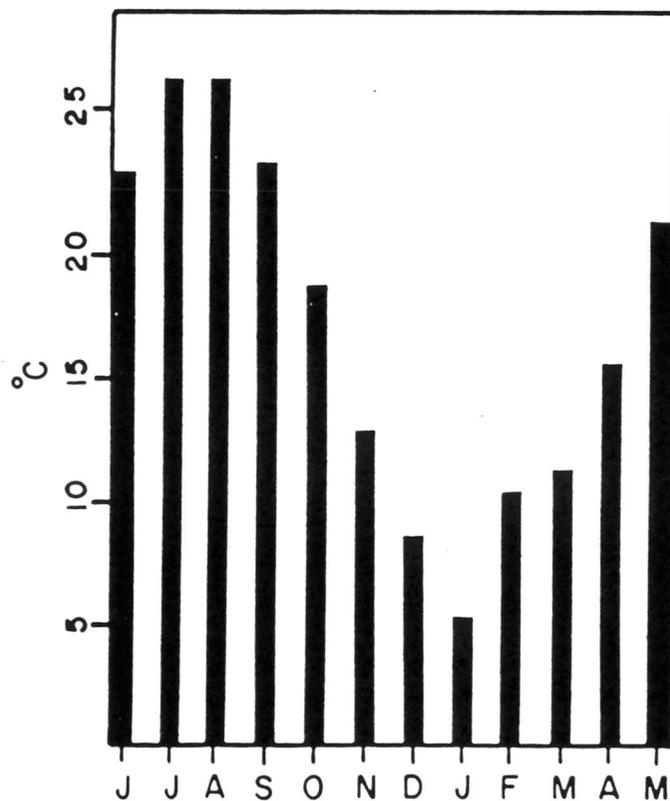


Figure 4b. Monthly average temperature (°C) for Maysville 6 SW station during sample year (6/83 - 5/84).

## REGIONAL GEOLOGY

Four major wetland geomorphological types can be found on the lower North Carolina Coastal Plain: coastal marshes, floodplains, Carolina bays, and blocked drainage systems (to which the Croatan pocosins belong) (Otte, 1981).

∩ The development of coastal marshes and sediment-filled floodplains occurred in direct response to flooding associated with the geologically recent rise in sea level. Available  $^{14}\text{C}$  dates indicate that the initial flooding responsible for the development of these systems occurred 5000 to 6000 years before present (Otte, 1981). Sea level, at this time, was approximately 5 m below its present level.

The cause of formation and development of Carolina Bays is not known. The development of blocked drainage systems occurred between 10,000 and 12,000 years before present, based on  $^{14}\text{C}$  dates of peats, as well as matching pollen profiles with known floral succession associated with glacial retreat (Otte, 1981). In Tietz's (1981) work on the Holocene evolution of Great Lake, two peat samples from the Croatan pocosin adjacent to the lake were age dated.  $^{14}\text{C}$  dates suggest that the start of organic build-up in the Croatan was between 10,000 and 11,000 years before present. This age correlates with other dates reported for the Dismal Swamp of North Carolina and Virginia (Whitehead, 1972) and Hofmann Forest in North Carolina (Daniels, Gamble, Wheeler, and Holzhey, 1977a).

At 11,000 years before present, sea level was approximately 25 m below its present level and roughly 38 km east of the present shoreline. Sea level at this time was so far removed, with respect to elevation and

distance, from these blocked drainage systems as well as Carolina Bays that Otte (1981) believed sea level unlikely to have been a major control in the formation of these wetlands. Had this type of wetland development been related to a rise in sea level, these systems should be more widespread over the entire coastal plain.

Otte (1981) suggested a model for the development of blocked drainage systems in which thicker peats fill a stream channel whereas thinner peats spread over the adjacent interstream divides. Downstream of peat-filled channels, areas of sandy sediment that mark the site of blockage are found. Free-flowing, open-water streams flow downstream from the blockages, indicating that some outflow still follows the original drainage pattern. The origin of these blockages is, as yet, unknown (Otte, 1981).

An impermeable, basal layer of clay which could account for a perched water table is found in most of the blocked channels. Perhaps the combination of basal clays with the blockage of drainage created a ponded environment in which peat accumulation could begin (Otte, 1981). In any case, the water-holding capacity of the peat probably allowed the peat deposits to maintain themselves with or without the aid of a water impermeable layer beneath the entire pocosin (Otte, 1981).

During 1979-1980, Ingram and Otte (1981) mapped the peat deposits of the Croatan National Forest. Peat was found in five, physically separated areas: Northwest Catfish Lake deposit, Northwest Great-Long Lake deposit, South Great Lake deposit, South Ellis Lake deposit, and Millis Road deposit (See Figure 2 for peat thicknesses).

Basically, two peat types occur in the Croatan: (1) brown, decomposed fibrous peat, and (2) black, fine-grained, highly decomposed humic peat. In the deeper parts of the filled stream channels, brown

fibrous peat can be found with thicknesses ranging up to 1.4 m. It is usually absent from the top 0.6 to 1.2 m of peat (Ingram and Otte, 1981). Black humic peat dominates most of the top 1.2 to 1.5 m of peat, overlying sands where the basal fibrous peat is absent (Ingram and Otte, 1981).

The Plio-Pleistocene stratigraphy underlying the peat deposits of the Croatan region can be generalized as follows: (1) the Lower Pliocene Yorktown Formation comprises the lowermost of these stratigraphic units. The Yorktown has been described by Snyder, Mauger, and Akers (1983) as being an unconsolidated, very muddy, quartz sand that thickens to the northwest and east of New Bern (Daniels, Gamble, Wheeler, and Holzhey, 1972). (2) The Plio-Pleistocene Croatan Formation overlies the Yorktown (Richards, 1950; Fallaw and Wheeler, 1969; and Daniels, Gamble, Wheeler, and Holzhey, 1977b). The Croatan Formation consists of fossiliferous, unconsolidated marine sands and silty sands and is equivalent to the James City Formation of Dubar and Solliday (1963) and to the Small Sequence of Daniels et al. (1972). (3) Upper Pleistocene sediments overlie the Croatan Formation, with the contact marked by the Horry Clay, a gray to olive-brown massive clay imbedded with cypress stumps and lacking marine fossils (Tietz, 1981). Overlying the Horry Clay in the Croatan region is the upper Pleistocene Flanner Beach Formation, which Tietz (1981) equates with the Talbot morphostratigraphic unit. This late Pleistocene deposit is composed of unconsolidated sand, clayey sand, and clay with some highly fossilized zones near the base (Tietz, 1981). The lithology of the Flanner Beach Formation is extremely variable laterally as well as vertically.

For this project, nine cores along two east-west transects were collected from the sediment layers adjacent to and underlying the Croatan

peat deposits (See Methods section for explanation and Figures 5 and 6 for cross-sections). In general, these sediments are very fine to fine quartz sands, silty sands, sandy clays, and clays with minor amounts of fine-grained opaques. X-ray diffraction analyses of some of the clay samples indicate that the clays are primarily composed of kaolinite, illite, vermiculite, and smectite. Vertical and lateral variation is so widespread that correlation between cores is difficult. Beyond large scale bedding features, a lack of recognition of sedimentary structures may be due to sampling techniques, but Tietz also noted a lack of structures in his study of the Great Lake area. These sediments are Pleistocene in age and correspond to those of Teitz's Talbot morphostratigraphic unit (= Flanner Beach Formation), which represents deposition in an estuarine environment during a marine transgression.

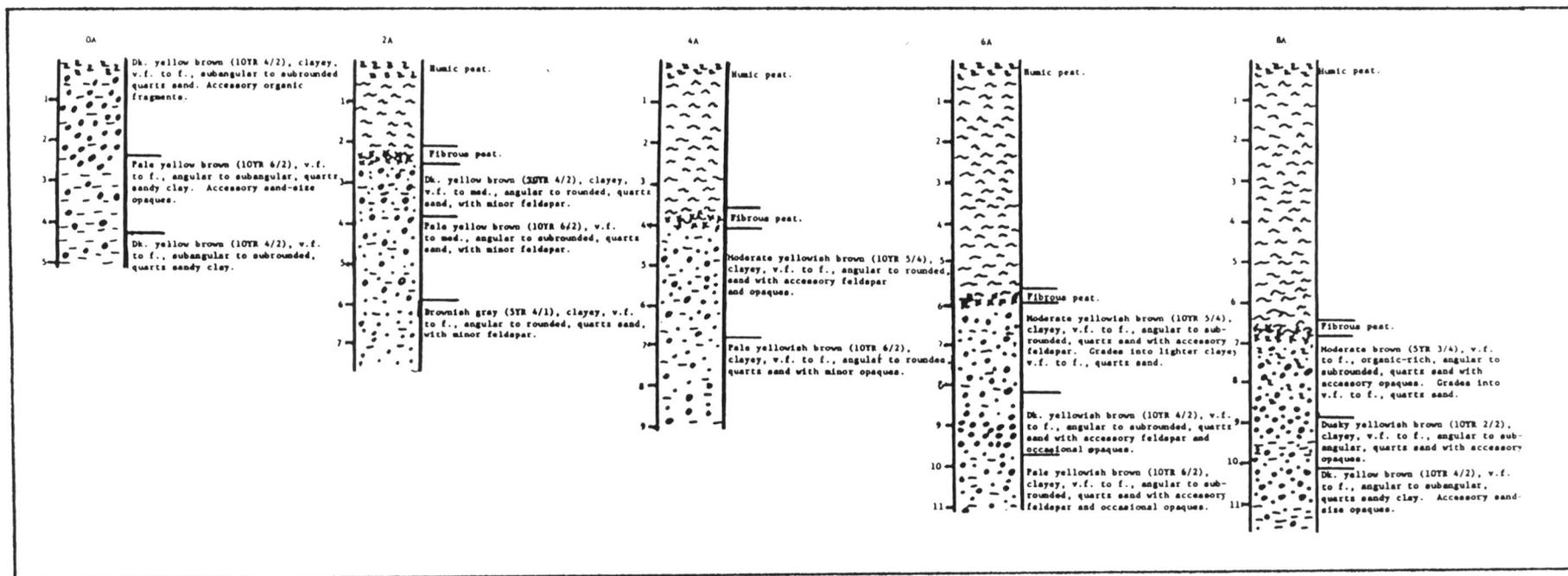


Figure 5. Soil profile prepared from mineral sediments collected along Transect A (Figure 7). Samples were collected at 1/2 foot intervals. (1 foot = 0.3 meter)

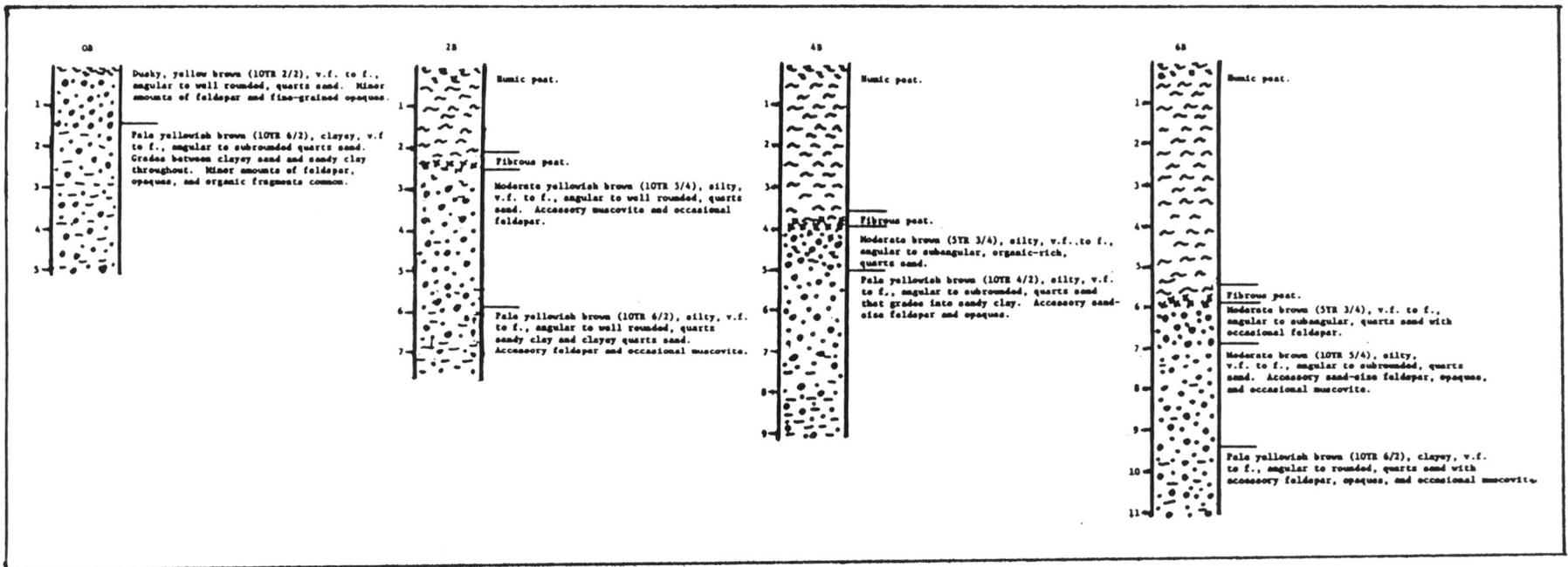


Figure 6. Soil profile prepared from mineral sediments collected along Transect B (Figure 7). Samples were collected at 1/2 foot intervals. (1 foot = 0.3 meter)

## HYDROLOGY

The term "pocosin" refers to a type of wetland system dominated by a mixture of sparse trees and shrubs, organic soils, high water tables, and poor drainage (Otte, 1981). An Algonquian Indian term, "pocosin" means "swamp-on-a-hill" (Tooker, 1899). Originally, it referred to wetlands believed to have developed on broad interstream flats that were topographically higher than the surrounding terrain. This interpretation has been modified based on recent work which indicates that the interstream flats are really peat domes that developed in blocked stream valleys. These peat domes grew both vertically and laterally until the valley filled, after which the domes spread over the adjacent interstream divides (Otte, 1981). As a result of this doming effect, water flows out of the pocosin, rather than into it, making precipitation the major source of water to the system.

Water tables fluctuate on a seasonal basis in pocosins. During the winter and early spring, the water table is at its highest and is near, at, or above ground surface. At this time standing surface water can be found in areas of deep peat, grading outward to the edges of the pocosin where the mineral-dominated soils are typically only water-saturated (Otte and Loftin, 1983). As temperatures increase in the spring and summer (Figure 4b), the vegetation begins to transpire and pumps a significant quantity of water out of the system. During this time, as the water table drops, surface waters disappear. Next, the water table descends through the underlying sediments, draining the surficial peats and peaty mineral sediments. Water tables typically drop 1.0 to 1.5 m below ground surface during the summer and fall months (Otte, 1981). In

the thinner peats and peaty mineral soils, the water table may descend through these soils and into the underlying mineral sediments. In the thicker peats, the underlying mineral sediments are rarely unsaturated. During late fall and winter, after evapotranspiration reaches a minimum, influx of water from precipitation raises the water table back to its spring-time high (Otte, 1981).

Most of the outflowing surface drainage during the spring-time high is by sheet flow. Extensive Sphagnum mats and dense shrub growth baffle water flow and aid in spreading this water evenly over the ground surface (Otte, 1981). Such features as these and the lack of steep elevational gradients hinder the development of channelized flow in a pocosin (Otte and Loftin, 1983).

Sheet flow in the Croatan pocosins eventually converges and forms the headwaters of several small creeks along the edges of the peat deposits. These creeks radiate to the west into White Oak River, to the east into Neuse River estuary, to the north into Trent River, and to the south into Bogue Sound (Ingram and Otte, 1981).

Five blackwater lakes are located in the Croatan National Forest. These include Catfish, Ellis, Great, Little, and Long Lakes, all of which occupy shallow depressions with maximum depths ranging from 1.5 to 3.0 m. Of these lakes, the maximum diameter is approximately 4.0 km for Great Lake, and the minimum diameter is roughly 1.2 km for Little Lake. Drainage into and out of Great Lake is predominantly by groundwater flow, the major influx coming from a northwest, topographically higher region in the pocosin. Discharge is to the south, eventually forming the headwaters of Hunters Creek en route to the White Oak River (Tietz, 1981).

In this study, Catfish Lake served as a lake sampling site. The maximum depth is approximately 1.5 m, and the maximum and minimum diameters are roughly 2.8 km east to west and 0.8 km north to south, respectively. The mineral sediments around the periphery and bottom of the lake are dominated by quartz sands, sandy clays, and clays. The reworking of sediments by wave action around the shoreline has led to the concentration of quartz sands at the lake's edge. In the deeper, quieter portions of the lake, a thin layer (up to 30 cm) of organic-rich sediments can be found overlying the sands and sandy clays. Several small creeks flow south and southeast into Catfish Lake, whereas one small outflow creek flows southeastward toward Great Lake (Ingram and Otte, 1981).

Fire-break canals, dug about 30 years ago, can also be found in the Croatan. Water flow in these canals fluctuates with the natural fluctuation in the water table. The pocosin soils further away (approximately 0.4 km) from the canals are slightly wetter than those immediately adjacent to the canals (Table 1) (Otte and Loftin, 1983). This difference is due to increased surface and subsurface drainage near the canals, which allows aeration and oxidation of the peat in the immediate area. Associated with the increased oxidation of soils adjacent to canals is the increased release of nutrients. The vegetation directly along the canals responds to better drainage by developing denser and, in some cases, taller growth. This creates an area of locally increased evapotranspiration and indirectly aids in subsurface drainage.

PEAT THICKNESS - IN FEET							
1	2	3	4	5	6		
75.3	77.3	76.3	79.7	80.5	80.8	0-1	
	78.6	77.5	81.5	82.3	83.5	1-2	
		78.0	81.1	83.2	83.5	2-3	
			79.5	81.4	82.6	3-4	
				81.6	81.1	4-5	
					85.8	5-6	
water content of peat within 100 feet of canals							depth below ground surface -in feet
PEAT THICKNESS - IN FEET							
1	2	3	4	5	6		
82.0	81.6	85.6	84.7	84.7	85.8	0-1	
	79.9	82.7	83.6	84.5	85.2	1-2	
		80.5	81.1	83.3	84.5	2-3	
			76.5	82.3	84.2	3-4	
				82.0	84.0	4-5	
					85.9	5-6	
water content of peat at least 1/4 mile from canals							depth below ground surface -in feet
PEAT THICKNESS - IN FEET							
1	2	3	4	5	6		
6.7	4.3	9.3	5.0	4.2	5.0	0-1	
	1.3	5.2	2.1	2.2	1.7	1-2	
		2.5	0.0	0.1	1.0	2-3	
			-3.0	0.9	1.6	3-4	
				0.4	2.9	4-5	
					0.1	5-6	
difference between water content of peats 1/4 mile from canals and those 100 feet from canals							depth below ground surface -in feet

Table 1. Comparison of water content of peat soils near drainage canals and away from drainage canals, in the Croatan National Forest of North Carolina. Numbers refer to % water content of total peat sample - as collected in the field. Data based on analyses of 440 samples. (1 foot = 0.3 meter)

## VEGETATION

Pocosins are tertiary mire systems, dominated by differing concentrations of evergreen, semi-evergreen, and deciduous shrubs, as well as pond pine (Pinus serotina) (Otte and Loftin, 1983). Three major environmental controls have direct influence over the distribution of vegetation in a pocosin: peat thickness, hydroperiod, and fire (Otte, 1981). In peat less than about 1.2 m in thickness, the water table can drop below the mineral/peat contact during the dry season; and roots can reach the more nutrient-rich underlying mineral sediments. In peat greater than 1.2 m in thickness, the water table rarely drops to the mineral/peat contact. The vegetation associated with these deeper peats is more likely to be limited in growth by low nutrients. As a result, the plants are more stunted.

In a peatland, most of the nutrients fixed in plants are removed from circulation and stored in accumulating peat (Smith, 1980). Decomposition is so slow that these nutrients are only slowly recycled. Fire can be a very important controlling factor in determining plant growth in the pocosins, as it can rapidly recycle stored nutrients. The vegetational succession pattern following a fire is short-lived, however, in that the vegetation of a burned area soon returns to that of the pre-burn system (Wilbur and Christensen, 1982).

Within a pocosin ecosystem, four vegetation types are recognized: (1) Pond Pine Forest, (2) Pond Pine Woodland, (3) Tall Pocosin, and (4) Short Pocosin (Otte, 1981). Within the Pond Pine Forest, plants are rooted in soil that grades between peaty sand to about 0.6 m of sandy peat. The shrub layer is closed and ranges from 3 to 6 m in height.

Pond pines typically form a closed canopy which is less than 15 m in height. The subcanopy is composed of the bay species: loblolly bay (Gordonia lasianthus), red bay (Persea borbonia), and sweet bay (Magnolia virginiana), plus additional species such as red maple (Acer rubrum) and loblolly pine (Pinus taeda) (Otte, 1981). Site 2A of this project is located in a Pond Pine Forest. (See Figure 7 for location of sample sites.)

The trees of a Pond Pine Woodland may also be rooted in mineral soil, depending on the depth of the peat which ranges from 0.3 to 0.6 m in thickness. Shrub roots can reach the underlying mineral soil, and the shrub layer is usually closed, ranging from 1.8 to 4.6 m in height. The bay species are more restricted to this shrub layer, whereas in the Pond Pine Forest, they compose the subcanopy. The pond pines are taller and larger than those of the Pond Pine Forest. The canopy is typically less than 50% closed (Otte, 1981). Sites 4A and 2B can be categorized as Pond Pine Woodland (Figure 7).

Tall Pocosins are underlain by 0.6 to 1.2 m of peat thus plant roots typically can not reach the underlying mineral soils. With less nutrient availability, the pond pines and bay species are widely scattered, and the pines are gnarled at the tops due to past fires. The shrubs are 1.2 to 2.4 m in height and form a closed layer except in old burn sites (Otte, 1981). Sites 6A and 4B are located in a Tall Pocosin (Figure 7).

Within a Short Pocosin, peat thickness is usually greater than 1.2 m; thus, plant roots can rarely reach the underlying mineral sediment. The shrubs range from 0.6 to 1.2 m in height and are usually rooted in the top 0.3 m of peat. Pond pines are widely scattered and stunted (approximately 3 m in height), implying low nutrient availability (Otte, 1981). In this study, sites 8A and 6B are typical areas that may be

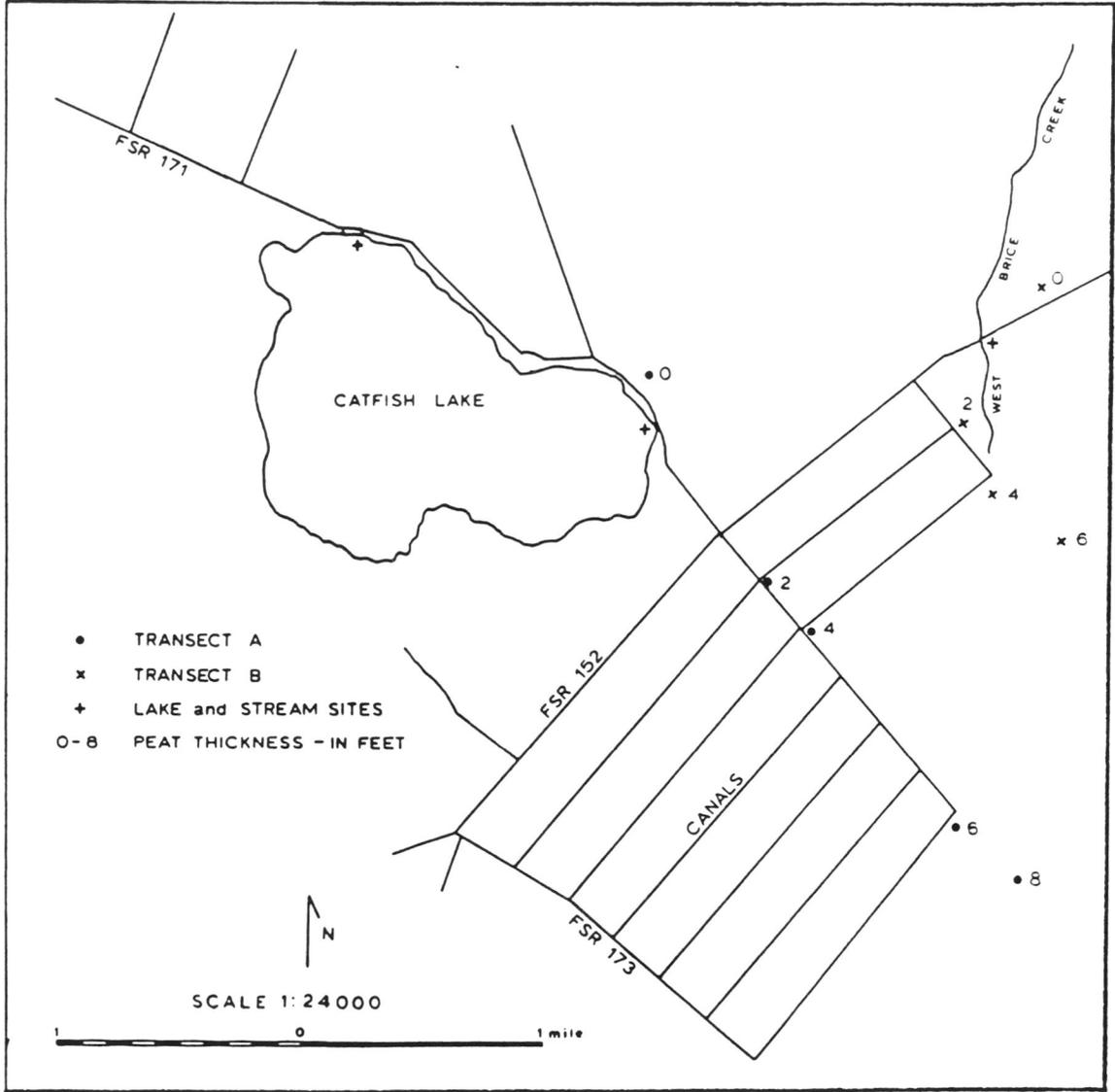


Figure 7. Location of study area and sampling sites, in association with the natural and man-made drainage systems in this section of the Croatan National Forest. (2 feet = 0.6 meter and 1 mile = 1.6 kilometers)

classified as a Short Pocosin (Figure 7).

Sites OA and OB (Figure 7) of this project are representative areas where peat is absent and mineral soils dominate. The vegetation community at site OA is a bay forest, which contains a mixture of pond pine, Atlantic White cedar (Chamaecyparis thyoides), sweetgum (Liquidambar styraciflua), and the three bay species. The soil at site OA is dominated by clays and clayey sands. Site OB, dominated by sandy soil, is located in a pine forest in which loblolly pine (Pinus taeda) is the dominant canopy species.

During the development of a pocosin ecosystem, sites of peat accumulation expand laterally as vertical deposition occurs. Associated with this expansion, the four pocosin types shift with the changing patterns of peat thickness, hydroperiod, and nutrient availability. The Pond Pine Forest and Pond Pine Woodland, which occupy the outer areas of the pocosin, are transient. They occupy an area only as long as conditions are proper for their existence. The Tall Pocosin can possibly exist for a longer period of time in one area, but it too is categorized with the Pond Pine Forest and Pond Pine Woodland. The Short Pocosin is the only true climax community of pocosin types. Once peat accumulation is of sufficient thickness that plant roots no longer reach the underlying mineral soils, the Short Pocosin will remain a permanent community, if not subjected to a major fire (Otte, 1981).

## PROCEDURES

### Field Methods

Seventeen locations were established to collect water samples, including West Brice Creek, five canal sites, two sites on Catfish Lake, and nine well sites (Figure 7). At each well site, two wells were emplaced, one to collect peat pore water and a second to collect pore water from the underlying mineral soils. The well sites range from areas of mineral soils to areas of deep peat up to 2.4 m in thickness and were positioned to form two parallel transects, here named transects A and B. Each site (along both transect A and transect B) was situated wherever a 0.6 m increase in peat thickness was observed (Figure 7). Standing surface water was collected next to the well sites located in the deeper peats (1.8 to 2.4 m in thickness). Canal sites are located adjacent to each well site along both transects. A soil profile for each well site was constructed (from samples collected with a soil auger) in anticipation of relating change in water chemistry to change in soil characteristics (Figures 5 and 6).

Data were collected for one year (June 1983 to May 1984). Well water was collected during the summer months of June, July, and August, 1983 to establish the chemical character of the mineral and peat pore waters. Wells were again sampled in December of 1983 and January of 1984 to determine if any measurable changes in chemical parameters had occurred with change in season. Standing surface water at each site was collected when available. No surface water was present during mid-summer to late fall due to the seasonal drop in water table below ground surface. The canals, lake, and stream were monitored every month to

identify any mixing of regimes and to recognize any flux of dissolved ions that might occur on a seasonal basis.

All water samples were collected and stored in 250 ml Nalgene bottles that were acid washed in the lab and rinsed with canal water in the field. Three 250-ml bottles were collected for each sample. Samples were kept on ice until they were returned to the lab, where one 250-ml bottle of each sample was centrifuged for 30 min at 4080 g and then filtered, using 0.45 um filter paper on a Millipore filtering system. The filtered portion and the two unfiltered portions for each sample were kept at 4°C until lab analyses were performed. Originally, pH measurements were to be taken in the field; however, due to the questionable accuracy of the field pH meter, laboratory pH readings were made instead, within 24 h of collection time.

#### Laboratory Methods

In order to identify the water chemistry of each regime, a variety of wet chemical and instrumental methods of analyses were conducted for the determination of pH and the quantification of the following dissolved ions: Ag, Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, NH<sub>4</sub>-N, NO<sub>3</sub>-N, Pb, Se, SiO<sub>2</sub>-Si, total dissolved PO<sub>4</sub>-P (TDP), total organic C (TOC), Ti, V, and Zn.

The analyses for NH<sub>4</sub>-N (Solorzano, 1969), NO<sub>3</sub>-N (Jones, 1984), SiO<sub>2</sub>-Si (Stainton, Capel, and Armstrong, 1974), and TDP (EPA, 1976) were performed on filtered samples in the Central Environmental Laboratory of the East Carolina University Biology Department, utilizing a Bausch and Lomb Spectronic 88 spectrophotometer. Precision and accuracy data are presented in Table 1 in the Appendix. Approximately 125 ml of filtered sample were left after the analyses for these ions. This remaining

amount was then acidified with  $\text{HNO}_3$  (to facilitate solution of cations and serve as a preservative) and stored at  $4^\circ\text{C}$  until analyses could be conducted for Ca, K, and Mg. Prior to cation analyses, each preserved sample was split into two aliquots. To suppress ionization interferences, lanthanum oxide was added to the samples used for Ca and Mg analyses, and lithium sulfate was added to those used for K analyses. Quantification of Ca, K, and Mg concentrations was performed in the geochemistry lab of the ECU Geology Department, using an atomic absorption spectrophotometer (Instrumentation Laboratory 457).

Total organic carbon was determined, using unfiltered samples, on an Oceanography International organic carbon analyzer in the Institute for Coastal and Marine Resources. Testing for Ag, Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Se, Si, Ti, V, and Zn was performed on approximately 100 samples with an inductively coupled argon plasma emission spectrometer (ICAPES) in the Elemental Analytical Lab of the Shared Research Resources Laboratories, ECU School of Medicine. Samples for ICAPES analysis were centrifuged for 30 min at 4080 g and filtered through a 0.45  $\mu\text{m}$  filter paper on a Millipore filtering system. For each sample, 200 ml were then preserved with 15 ml of double-distilled  $\text{HNO}_3$ , and 150 ml were concentrated to 5 ml. Of the 24 elements analyzed, only Al, Ca, Mg, Mn, Na, Ti, and V were found in detectable amounts. This limited number of detectable elements is due partly to contamination problems in the labs and partly to the naturally very low concentrations in the samples.

#### Statistical Methods

To test for significant chemical differences between the three water regimes (mineral, peat, and surface) and to determine the effect, if any,

of transect location, seasonal variation, and peat thickness, several randomized, incomplete, block analyses of variance were computed (SAS) : one for each element detected. Fisher's F-test was used for the comparison of the three water regimes, with transect, season, and peat thickness also considered as factors. Sidak t-tests were then applied for pairwise comparisons between the three water regimes to find which pairs of regimes differed significantly. The Scheffe method for comparisons was utilized to contrast well water types (mineral and peat), seasons, and peat thicknesses. When peat thickness was determined a varying factor, further pairwise comparisons were made to indicate which sites varied significantly. To determine the relationship between monthly canal data and water regimes, correlations were calculated between respective monthly averages by using the Pearson product-moment correlation coefficient.

Statistical analyses were performed on the following detected elements: Ca, K, Mg,  $\text{NH}_4\text{-N}$ ,  $\text{NO}_3\text{-N}$ , TDP,  $\text{SiO}_2\text{-Si}$ , and TOC. These analyses can be found in Tables 2, 3, and 4 in the Appendix. However, because of the seasonal sampling of well waters and the lack of surface waters at certain times of the year, the interpretation of the statistical analyses must be approached with caution. The test statistics should only be considered as "approximations" due to the considerable imbalance and number of missing observations. For the other detected elements, Al, Mn, Na, Ti, and V, no statistical methods were applied due to an even greater amount of missing data. In the cases of Al, Mn, Ti, and V, mineral, stream, and/or lake waters were the only water regimes that contained detectable concentrations. Sodium (Na) was found in all three regimes, but due to equipment problems in the lab, Na data was missing for all but three months of the sampling year. Therefore, no statistical methods were attempted for this element.

## RESULTS AND DISCUSSION

Because of the unique nature of an ombrotrophic system, special processes control the elemental concentrations in the ecosystem's waters. The major input of nutrients to the system is via precipitation and the obvious export is by surface runoff. During the interval between arriving and exiting the system, constituents in the water are subjected to several possible elemental alterations. The loss of nutrient ions from rainwater by plant uptake often results in a long-term storage of elements since organic decay is very slow. However, during times of low water table, the rate of organic decay can increase, releasing nutrient ions and affecting the composition of drainage waters. The weathering of silicate minerals, which predominate in the sandy clays and sands adjacent to and underlying the peat deposits, is another source of ions for the waters of this system. Ion exchange, whether by the colloidal action of the underlying clays, the peat, or by the surface vegetation (specifically Sphagnum), is another process which affects the pocosin's waters. In addition, the precipitation and dissolution of ions due to changes in concentration, pH, and redox conditions will affect the waters of an ecosystem. It is the interaction of all these processes, and perhaps of some not presented here, that affects and controls the composition of the hydrosystem. With respect to a particular element or ion, some specific processes play greater roles than others; and when it was possible to determine these factors they are described.

The data presented in this section denote ionic and elemental concentrations expressed in mg/l. Yearly average concentrations for each of the three regimes (mineral, peat, and standing surface) and monthly

averages for flowing surface waters are discussed. The raw data collected from each site and for each element may be found in the Appendix, as can the results of statistical analyses computed for the appropriate elements. Table 2 presents a summary of the total number of samples collected for each month from each regime. When possible, comparisons between average concentrations determined here and those reported by Verry (1975), Daniel (1981), Peat Methanol Associates (1983), and Noltemeier (1984) are made (Table 3). The reader will note that Peat Methanol Associates' (PMA) data are consistently higher in value than those reported in the other studies. This is possibly because some of the PMA wells were located in areas that had been fertilized. While comparisons with the PMA data may not be entirely applicable, some of the trends may be real and the comparisons are of interest.

The ions discussed under "Indicator Species" represent those in which an apparent difference in concentration between regimes occurs. In each case, the differences are supported by statistical analyses. The indicator species for specific regimes are (1) total organic carbon (an indicator for peat pore waters), (2) dissolved silica (an indicator for mineral pore waters), and (3) dissolved calcium (an indicator for surface waters). Those ions and elements classified as "Non-indicator Species" have been so classified for two reasons. For the inorganic forms of N, total dissolved  $\text{PO}_4\text{-P}$ , Mg, and K, there is neither an apparent nor a statistically significant difference between the average concentrations in the various regimes. For Na and the trace metals Al, Mn, Ti, and V, there are insufficient data on which to perform valid statistical analyses. For ease of discussion, the results of the major cations Mg, K, and Na are presented together as are the results for the trace metals Al, Mn, Ti, and V.

Table 2. Number of water samples from pocosin environments during the twelve month period June 1983 through May 1984.

ENVIRONMENT	J	J	A	S	O	N	D	J	F	M	A	M	TOTAL
Mineral	8	9	9	-	-	-	9	9	-	-	-	-	44
Peat	5	4	4	-	-	-	6	6	-	-	-	-	25
Standing Surface	6	-	-	-	-	-	4	4	6	6	6	4	36
Canal	5	5	5	4	-	5	5	5	5	5	5	5	54
Lake	2	2	2	2	2	2	2	2	2	2	2	2	24
Stream	1	1	1	1	1	1	1	1	1	1	1	1	12
TOTAL	27	21	21	7	3	8	27	27	14	14	14	12	195

Table 3. Comparison of water chemistry in surface, peat, and mineral waters of Croatan National Forest, peat and mineral waters of Pungo National Wildlife Refuge (Daniel, 1981), peat and mineral waters in Peat Methanol Associates area (PMA, 1983), Minnesota perched bog streams (Verry, 1975), and West Brice Creek (Noltemeier, 1984). Averages of concentrations are expressed in mg/l.

SITES	pH	TOC	SiO <sub>2</sub> -Si	Ca	NO <sub>3</sub> -N	NH <sub>4</sub> -N	TDPO <sub>4</sub> -P	Mg	K	Na	Mn
<u>This study</u>											
mineral ave.	3.8	42.7	3.55	1.51	0.03	0.15	0.03	0.61	0.64	3.72	0.00
peat ave.	3.8	212.5	0.89	2.09	0.12	0.34	0.06	0.76	0.43	2.99	0.00
surface ave.	3.7	51.0	0.45	0.20	0.02	0.02	0.02	0.51	0.12	2.14	0.00
West Brice Cr.	3.8	65.7	1.47	0.36	0.02	0.01	0.01	0.54	0.22	2.75	0.00
canal ave.	3.7	52.2	0.48	0.27	0.04	0.03	0.01	0.49	0.20	2.44	0.00
<u>Daniel, 1981</u>											
mineral ave.				8.00				2.43	0.78	5.51	
peat ave.				0.66				0.43	0.00	4.00	
<u>PMA, 1983</u>											
mineral ave.	6.5	41.8	34.6	49.1	0.02		0.15	8.93	1.19	10.89	0.27
peat ave.	5.1	233.5	10.4	24.2	0.02		0.39	10.95	7.68	13.25	0.23
<u>Noltemeier, 1984</u>											
West Brice Cr.	4.4			2.14	0.12	0.03	0.02	0.47	0.27	2.78	
<u>Verry, 1975</u>											
perched bog stream ave.	3.6			2.40	0.20	0.45		0.97	1.30	0.60	

## pH

The pH data collected during this study were determined with a laboratory meter nearly 24 hours after sampling. It should be mentioned that although pH can be measured accurately in the lab, the obtained results depend upon sampling conditions which can not always be controlled, and that the pH of water samples may change during storage. The carbon dioxide-bicarbonate-carbonate equilibrium and buffer system is most easily disturbed by loss of carbon dioxide (CO<sub>2</sub>). It is impossible to obtain a truly accurate lab pH from groundwater samples because some CO<sub>2</sub> will be lost before it is even possible to get a sample (Hem, 1959). The CO<sub>2</sub> content is lowered as temperature rises (Rainwater and Thatcher, 1960). In addition, the predominance of oxidized or reduced forms of some ions depends upon the environment of the water. With the contact of air, a reduced form may change to an oxidized state and pH can change as a result (Hem, 1959).

These uncertainties involved in using the laboratory pH determinations have caused some investigators to favor field determinations made in situ before some of the possible changes can occur. However, laboratory data also have a place of importance (Hem, 1959).

Because of the questionable reliability of the field pH meter available for this study, a laboratory pH meter was used and pH data was obtained within 24 hours of collection time. Samples were kept in the dark and refrigerated until time of analysis. Although these precautions were taken, the lab pH data of this study is not used as an indicator for any particular water regime and is only presented for completeness.

For all of the waters sampled, pH varied only slightly. Mineral and peat pore waters both had an average pH of 3.8; while both standing surface and flowing canal waters had an average pH of 3.7. Catfish Lake had an average pH of 3.9, and West Brice Creek had an average pH of 3.8.

Noltemeier (1984) reported an average pH of 4.1 for precipitation collected in the Croatan National Forest, and an average pH of 4.4 for her sampling site on West Brice Creek. Noltemeier's sampling site on the creek was downstream from the one in this study. Her pH value may have been higher because of a greater input of mineral soil waters. Verry (1975) found an average pH of 3.6, a comparable value to that determined here, for a stream in Minnesota whose headwaters originate in a perched bog. Peat Methanol Associates (1983) reported a pH average of 6.5 for wells in their fine sand unit and an average pH of 5.1 for wells in their peat unit. Both values are much higher than those determined for the well waters of this study.

In most natural systems exposed to the atmosphere, pH is controlled by reactions involving the carbonate system (carbonic acid and solvated carbon dioxide) (Drever, 1982). In addition, several other factors influence the pH of pocosin soils. Acidic substances are produced by vegetation as by-products of oxidative metabolism (Moore and Bellamy, 1974). Living plants release carboxyl-associated hydrogen (H<sup>+</sup>) ions, which are exchanged for nutrient cations contributed by rainfall or groundwater. Thus, the acidity of soil waters increases (Wetzel, 1983). In addition, organic acids (humic, fulvic, and tannic) are released with decomposition (Moore and Bellamy, 1974). These compounds accumulate in the system with the continued accretion of peat (Moore and Bellamy, 1974). Organic acids can be leached from peat as water exits the system by runoff or base flow.

Noltemeier (1984) also noted that the low pH of surface waters in the Croatan may be influenced by acid rainfall (ave = 4.1). Waters with low dissolved solids, such as rain, tend to become increasingly acidic in contact with peat (Gosselink and Turner, 1978). Therefore, rainfall may be a contributing factor, along with the influence of vegetation, to the acidity of pocosin waters.

### Indicator Species

#### Total Organic Carbon

Total organic carbon (TOC) associated with peat pore waters (ave = 212.5 mg/l) was higher than that in the other environments (Figure 12a). Standing surface waters and mineral pore waters contained average concentrations of 51.0 and 42.7 mg/l, respectively. Catfish Lake, West Brice Creek, and the canals had average concentrations of 42.9, 65.7, and 52.2 mg/l TOC for the sampled year.

The histogram (Figure 8a) comparing monthly average TOC concentrations for each regime, supported by statistical analyses (Tables 2 and 3 in the Appendix), dramatizes the differences between water types. Because of the agreement between statistical data and the obvious differences between average concentrations for each regime, high concentrations of TOC are interpreted to be an indicator of peat waters. Data also indicate that, with increasing peat thickness, there is an increase in TOC concentration of peat waters (Figure 8b). Overall, an increase does occur. The increase in TOC may reflect a reduced flushing rate, and thus greater accumulation in pore water with increasing thickness (Noltemeier, 1984).

Figure 8a. Monthly average TOC concentrations (mg/l) for the three water regimes. See the Appendix for explanation of missing data.

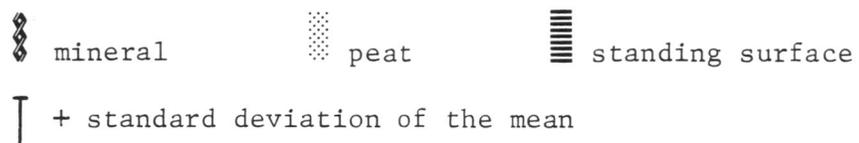
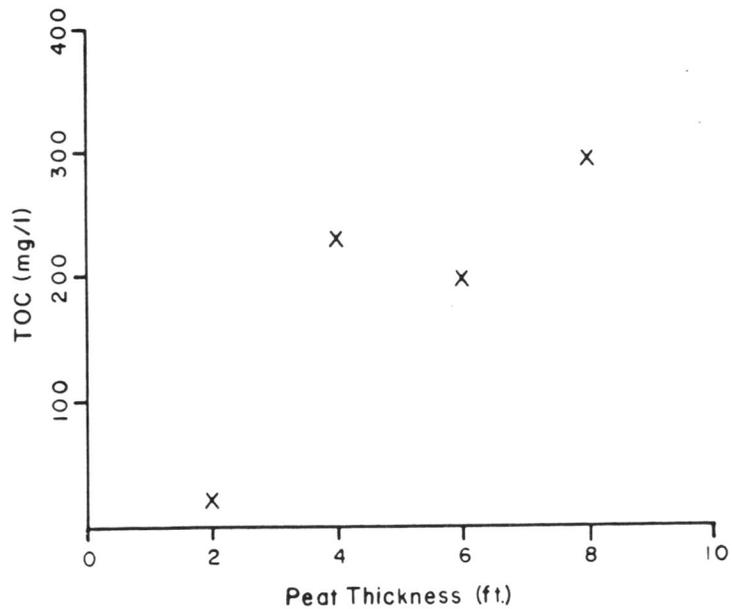
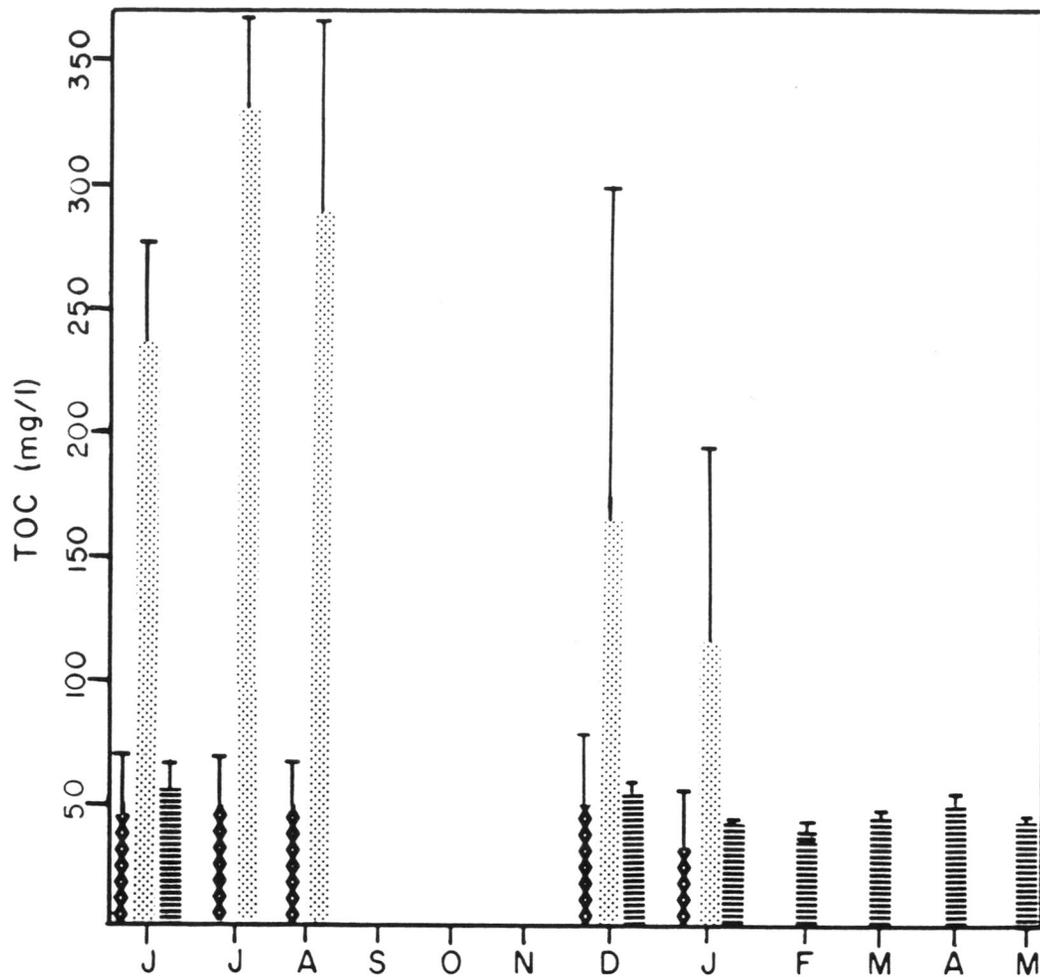
 mineral      peat      standing surface  
+ standard deviation of the mean

Figure 8b. Average TOC concentrations (mg/l) for peat waters compared to peat thicknesses (feet). (2 feet = 0.6 meter)



Positive correlations (ranging from .921 to 1.000) for TOC occurred between peat and canal waters during the summer months of June to August through December (Table 4 in the Appendix). By March, a negative correlation (-.962) existed between standing surface and canal waters. West Brice Creek also followed this trend of increasing TOC during the dry summer and fall months as peat-water drainage increased. TOC concentration of the creek declined in the winter months as increased surface drainage diluted the creek waters. This trend is consistent with Noltemeier's (1984) findings of highest TOC concentrations for peat-draining streams occurring during low flows.

The TOC data of Catfish Lake also showed an increase in concentration with the dry fall months. According to Gorham (1967), organics and associated carbon may be concentrated with the lowering of water level. As water level rises during the winter and spring months, TOC concentration declines. (See Figure 9 for monthly trends of standing and flowing surface waters.)

The high TOC concentrations of peat pore waters (ave = 212.5 mg/l) are consistent with those reported by Peat Methanol Associates (1983) (ave = 233.5 mg/l) for peat waters. The pore water of the peat has longer contact time with the carbon-rich organics than does any other water regime. Therefore, the peat pore waters would be expected to have greater concentrations of TOC. The underlying mineral pore waters contained an average TOC concentration of 42.7 mg/l, which is also similar to the 41.8 mg/l average found by Peat Methanol Associates (1983) for their fine sand unit. It is possible that carbon from the overlying peat unit migrates downward (via both diffusion and mass transport) into the mineral layers, thus accounting for the TOC concentrations of the mineral sediments. These mineral sediments could contain some original

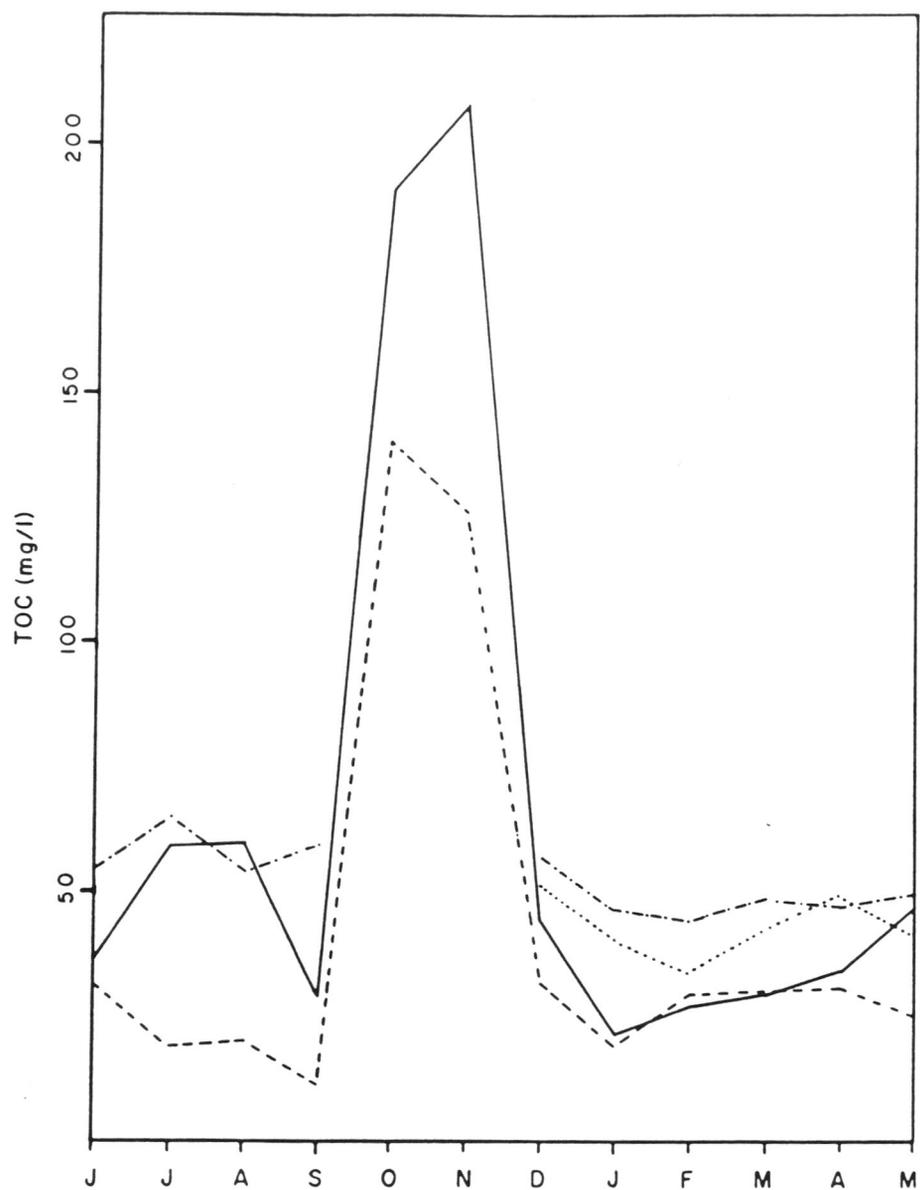


Figure 9. Monthly average TOC concentrations (mg/l) for standing and flowing surface waters.

— stream water                      - - - canal water  
 - - - lake water                      ..... standing surface water

colloidal organics, however, which would mean that the organic carbon is "authigenic" to the mineral sediments.

Standing surface waters contained an average of 51.0 mg/l TOC, possibly the result of minimal contact time between these waters and peat. With the lowering of the water table in summer and fall, flowing surface waters became more concentrated in organic carbon, as can be seen in Figure 9. With the rise of the water table during the winter and spring months, TOC concentration declined from the summer high and fluctuated very little.

### Silica

Dissolved silica (Si) was most concentrated in the mineral pore waters (ave = 3.55 mg/l). Peat pore waters contained a yearly average of 0.89 mg/l Si, approximately three-fourths less than that of the underlying and adjacent mineral soils. Catfish Lake, standing surface waters, and water draining by way of the canals contained the least amount of Si, averaging yearly concentrations of 0.41, 0.45, and 0.48 mg/l, respectively. West Brice Creek averaged 1.47 mg/l Si, but ranged in Si content from 0.61 to 2.50 mg/l during the sampling year. Noltemeier (1984) did not determine Si concentrations in her study, so no comparisons are possible for stream data.

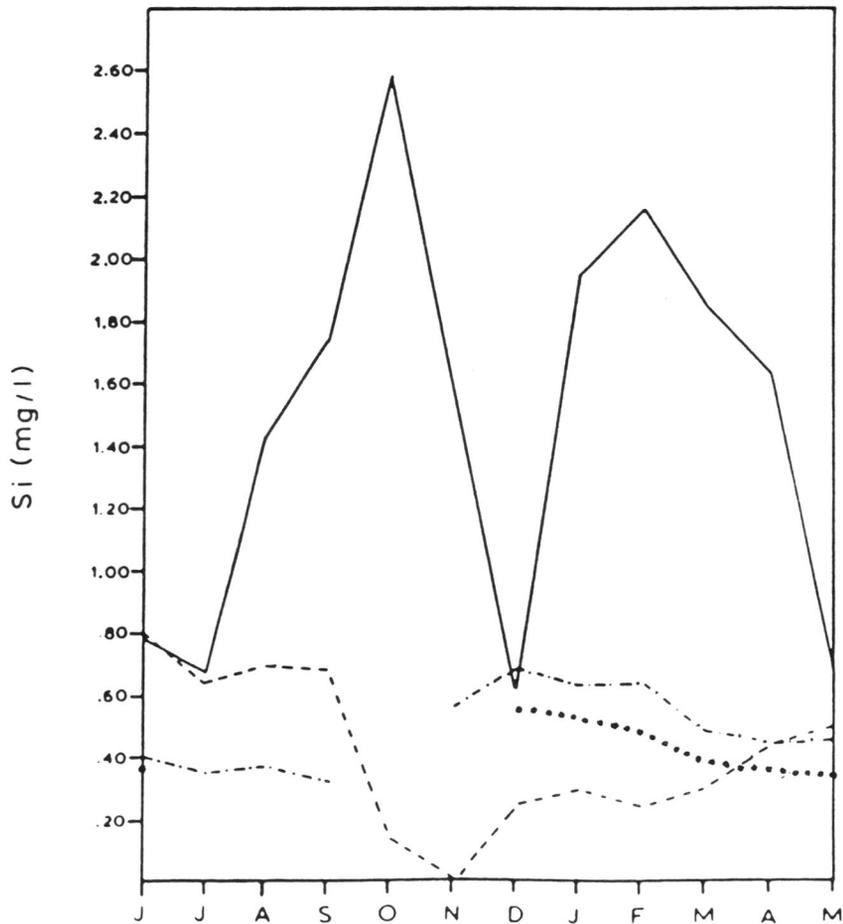
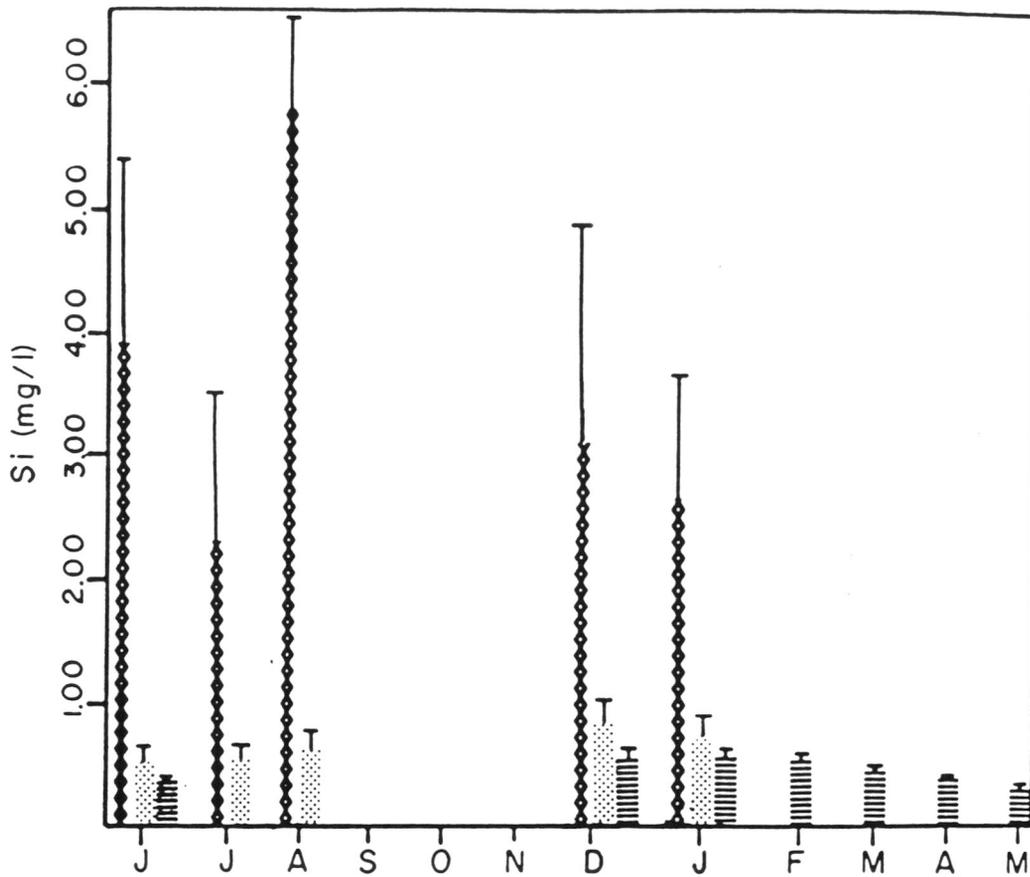
A histogram of monthly average Si concentrations for each regime (mineral, peat, and surface waters) exemplifies the contrast in concentrations (Figure 10a), and is supported by statistical analyses (Tables 2 and 3 in the Appendix). Therefore, Si is considered to be an indicator element for mineral pore waters.

Figure 10a. Monthly average Si concentrations (mg/l) for the three water regimes. See the Appendix for explanation of missing data.

 mineral       peat       standing surface  
 + standard deviation of the mean

Figure 10b. Monthly average Si concentrations (mg/l) for standing and flowing surface waters.

———— stream water      -.-.- canal water  
--- lake water      .....standing surface water



Positive relationships, indicated by correlation coefficients of 1.00, 1.00, and .885, between peat and canal waters occurred during the months of July, August, and December (Table 4 in the Appendix). For January, a positive correlation between both peat and mineral waters with the canal waters occurred (.889, .724, respectively). During February and March, positive correlations existed between surface and canal waters (.984 and .958, respectively). This information is interpreted to mean, and supports the hypothesis, that peat water is predominant in the drainage waters during times of low water table. With the rise of the water table, drainage from the areas of no peat that are dominated by mineral soil increases. This mixing is represented by both peat and waters being positively correlated with canal waters. Again, these statistical interpretations support the observed behavior of the rise and fall of the water table, draining the respective environments. As the water table rises above ground surface, surface waters dominate the drainage waters, indicated by the dilution of Si in the canals. This is supported by the positive correlation between surface and canal waters for February and March. (See Figure 10b for monthly trends of canal and surface waters and Table 4 in the Appendix for correlation data.)

The Si content in West Brice Creek fluctuated in much the same way as in the canals. Si concentration increased during the dry summer and fall months, followed by a decline in the winter months (See Figure 10b). West Brice Creek flows through an area of mineral-dominated soils upstream from the sampling site, thus accounting for the high concentrations in Si of the summer and fall. With increased surface runoff during the winter and spring, Si concentrations in the creek were diluted. There was a sharp decrease in Si concentration in December

(Figure 10b) between the summer /fall high and the winter/spring decline, which is unexplainable at this time.

Catfish Lake is directly underlain by quartz sands and sandy clays. With the decline of water level during the summer and fall, one would expect an increase in Si content due to a concentration of Si ions already present (Gorham, 1967). However, Si concentration took a sharp decline during the fall months. One possible explanation for this decline could be uptake by a diatom bloom (Schelske, Stoermer, Conley, Robbins, and Glover, 1983). (See Figure 10b for monthly trends of lake water.) However, chlorophyll concentrations and other necessary data were not obtained and thus, insufficient supportive evidence is available to document a bloom.

The Si found in all the systems is derived from chemical weathering of silicate minerals (Stumm and Morgan, 1981), which dominate the mineral component of the non-peat soils and the non-peat fraction of the peat soils. Peat Methanol Associates (1983) found Si concentrations in the peat and in the fine sand units to be 10.4 mg/l and 34.6 mg/l, respectively. Although their Si values are much higher than those reported here, their data exhibit the notable difference in Si content between mineral and peat waters.

### Calcium

Standing and flowing surface waters contained the least amounts of dissolved calcium (Ca). West Brice Creek, Catfish Lake, and the canals had yearly averages of 0.36 mg/l, 0.66 mg/l, and 0.27 mg/l Ca, whereas standing surface waters averaged 0.20 mg/l Ca. Peat pore waters

contained the highest levels of Ca, averaging 2.09 mg/l, and mineral pore waters the second highest levels, averaging 1.51 mg/l dissolved Ca.

A histogram of monthly average Ca concentrations (Figure 11a) for each regime (mineral, peat, and surface waters) contrasts the difference in Ca content between standing surface waters and both types of well waters. The significance of this difference is confirmed by statistical analyses (Tables 2 and 3 in the Appendix) which compare the three water regimes with respect to transect. Low concentrations of Ca therefore, are considered an indicator for surface waters. Positive correlation coefficients (ranging from 1.00 to .742) between surface waters and drainage canal waters for December through May support the observation that surface waters were draining from the pocosin during the time when the water table was at its highest (Table 4 in the Appendix).

This seasonality in Ca content for outflowing waters is shown in Figure 11b. Both the creek and canals increased in Ca concentration during the driest months of July to September, reflecting the concentration of Ca ions with the lowering of water level in the drainage channels (Gorham, 1967). With increased surface runoff during the winter and spring months, Ca content of the canals and creek declined. This is suggested by the positive correlation between surface and canal data. Noltemeier (1984) reported a higher average concentration of 2.14 mg/l Ca for West Brice Creek, compared to the 0.36 mg/l average reported here. However, in general her peat draining streams exhibited higher Ca concentrations during periods of low flow, the same trend observed here. Catfish Lake exhibited a similar trend in which Ca concentration increased during the driest months with the lowering of water level and subsequent concentration of Ca ions.

Figure 11a. Monthly average Ca concentrations (mg/l) for the three water regimes. See the Appendix for explanation of missing data.

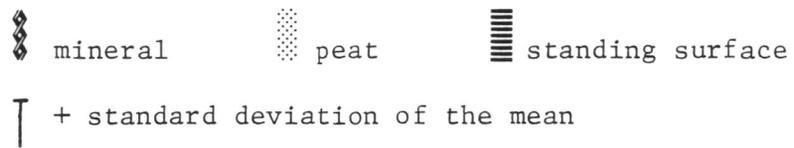
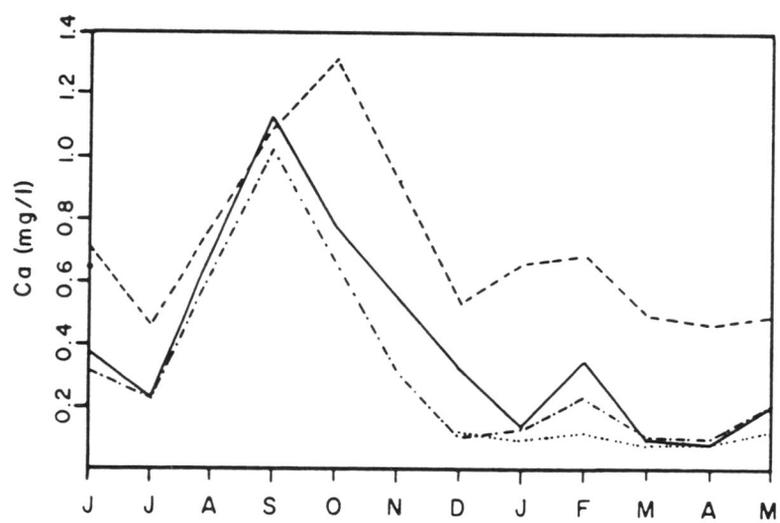
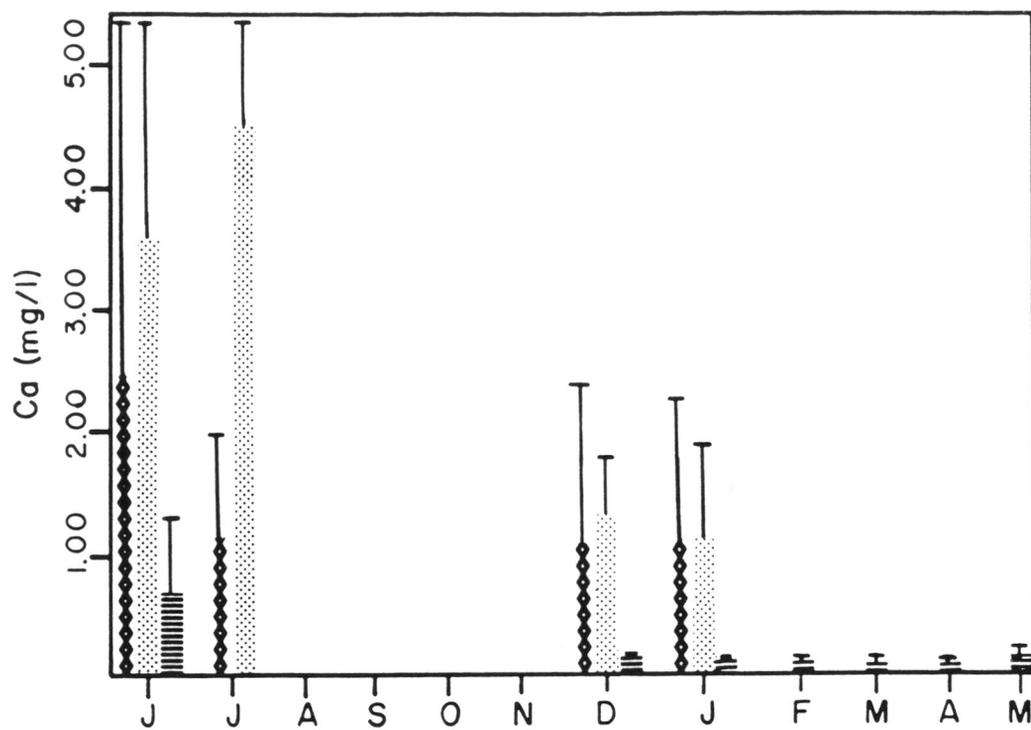
 mineral      peat      standing surface  
+ standard deviation of the mean

Figure 11b. Monthly average Ca concentrations (mg/l) for standing and flowing surface waters.

— stream water      -.-.- canal water  
- - - lake water      ..... standing surface water



Since precipitation is the major ionic contributor to surface waters, these waters are naturally low in ionic concentrations. Noltemeier (1984) reported an average Ca concentration of 1.26 mg/l for precipitation in the Croatan. Standing surface waters collected in this study from the low pocosin areas contained the lowest level of Ca (ave = 0.20 mg/l) compared to other waters in the system. In these low pocosin areas, extensive Sphagnum mats are found. Sphagnum mats behave as cation exchangers because of their high concentration of polymerized unesterified uronic acids (Wetzel, 1983). Cations (Ca and Mg) are absorbed by the moss, resulting in the release of hydrogen (H<sup>+</sup>) ions and organic acids (Clymo, 1963). The Ca ions in surface waters not adsorbed by Sphagnum serve as plant nutrients for the pocosin vegetation (Richardson et al, 1978) or are lost in runoff (Hemond, 1980). Thus, surface waters contain low levels of Ca due to a combination of factors.

Daniel (1981) reported Ca concentrations for organic soil waters and underlying mineral soil waters of 0.66 mg/l and 8.00 mg/l, respectively. Peat Methanol Associates (1983) reported even higher concentrations of 24.2 mg/l and 49.1 mg/l Ca for wells in the peat unit and fine sand unit. The trend observed from both PMA and Daniel's data is that mineral waters contain higher levels of dissolved Ca than do peat waters. This trend contradicts the one detected here, where peat waters contain higher levels of Ca than mineral waters. As of yet, I do not have a good explanation for this contradiction. It may be that mineral sediments in the PMA and Daniel studies contained higher concentrations of CaCO<sub>3</sub> shell debris, in which case, mineral pore waters would probably contain higher concentrations of Ca than peat pore waters. In explanation of the trend observed here, it may be possible that some Ca, associated with the organic peat, is slowly being released by decomposition, allowing the Ca

concentration for peat waters to be greater than that of mineral waters. According to Damman (1978), an increase in Ca concentration resulting from organic matter breakdown can result without any additions from other sources.

### Non-Indicator Species

#### Nitrogen

Nitrate. Standing surface waters and mineral pore waters contained less dissolved nitrogen in the form of nitrate ( $\text{NO}_3\text{-N}$ ) (ave = 0.02 and 0.03 mg/l) than peat pore waters (ave = 0.12 mg/l). Catfish Lake, West Brice Creek, and canal waters had yearly averages of 0.08 mg/l, 0.02 mg/l, and 0.04 mg/l, respectively.

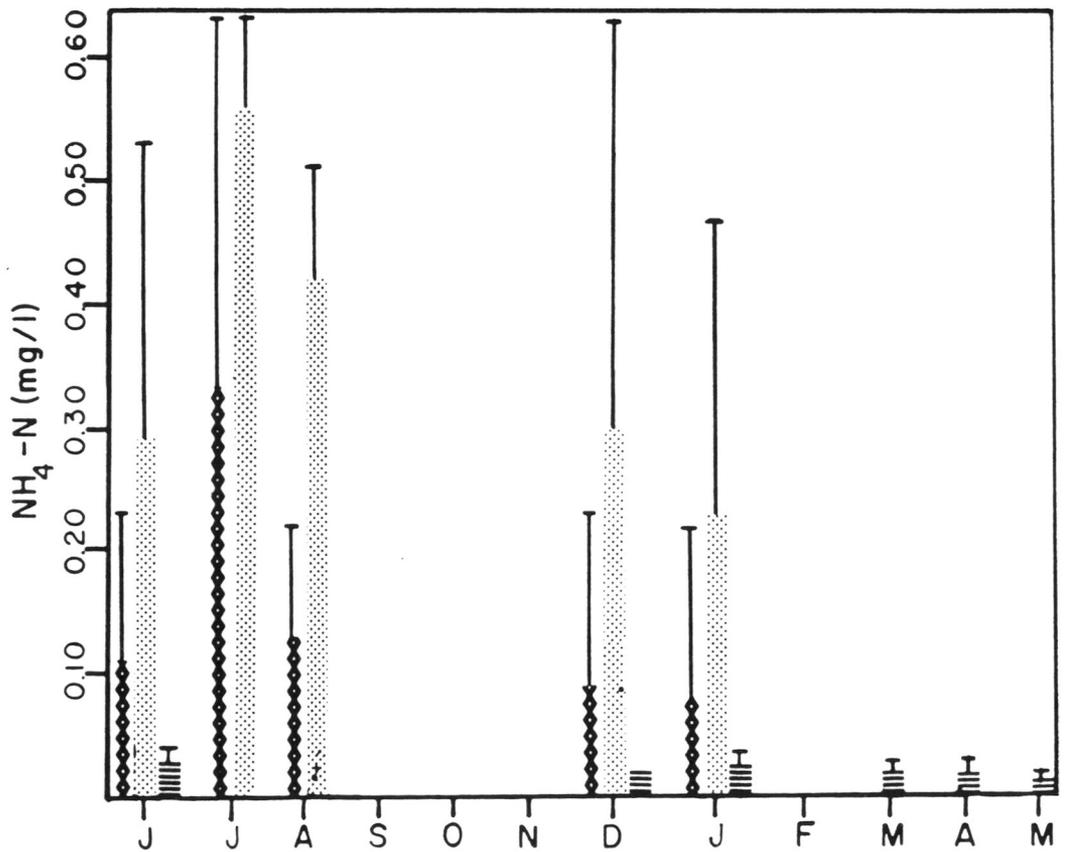
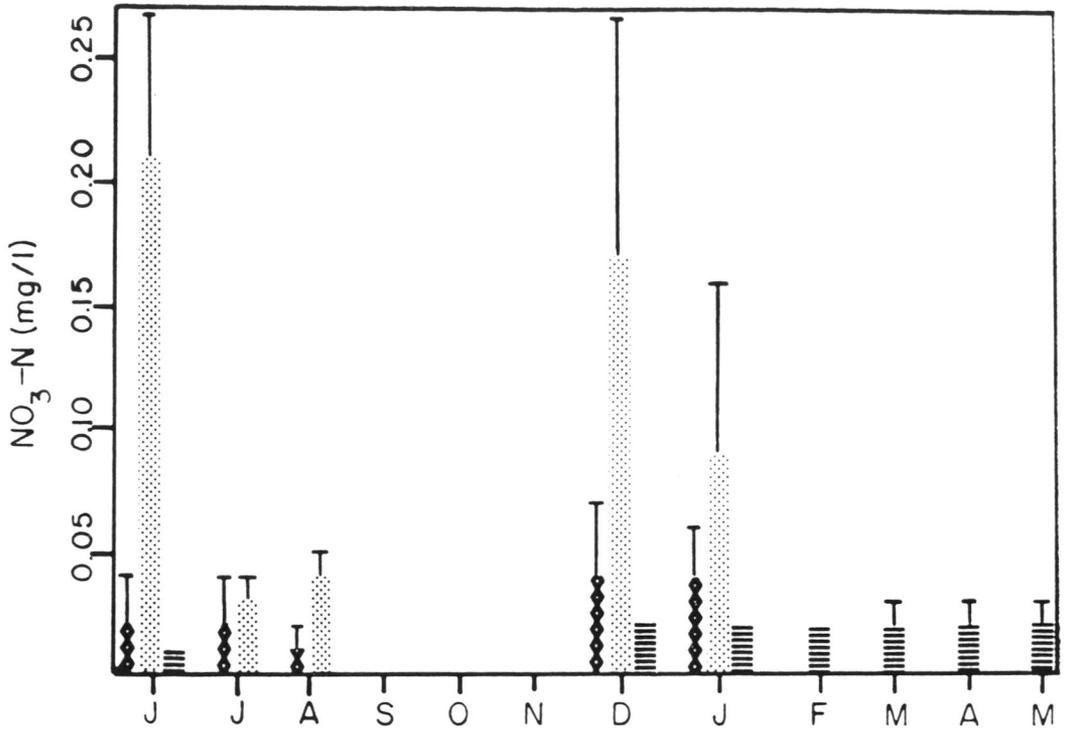
A histogram (Figure 12a) contrasting monthly averages for each regime (mineral, peat, and standing surface waters) illustrates that peat waters appear to have much greater  $\text{NO}_3\text{-N}$  concentrations than either mineral or surface waters. Statistical analyses (Tables 2 and 3 in the Appendix), however, do not support the apparent differences noted in Figure 12a. There is a wide range in  $\text{NO}_3\text{-N}$  concentrations at any one time for peat waters which affects the statistical analyses to a greater degree than what the histogram depicts. The statistical data actually indicate that there is a significant difference in  $\text{NO}_3\text{-N}$  concentrations between mineral and surface waters. However, since neither mineral nor surface waters are significantly different (according to statistical analyses) from peat waters,  $\text{NO}_3\text{-N}$  can not be considered a good indicator species for any specific water regime.

Figure 12a. Monthly average NO<sub>3</sub>-N concentrations (mg/l) for the three water regimes. See the Appendix for explanation of missing data.

 mineral       peat       standing surface  
 + standard deviation of the mean

Figure 12b. Monthly average NH<sub>4</sub>-N concentrations (mg/l) for the three water regimes. See the Appendix for explanation of missing data.

 mineral       peat       standing surface  
 + standard deviation of the mean



Standing surface waters were lowest in  $\text{NO}_3\text{-N}$  concentrations. The average  $\text{NO}_3\text{-N}$  concentration for West Brice Creek in this study (ave = 0.02 mg/l) is less than that found by Noltemeier (1984) (ave = 0.12 mg/l). Noltemeier's sampling site is a few miles downstream of the one in this study and is influenced by a larger area and diversity of soils. Noltemeier also used a different analytical method for  $\text{NO}_3$  determination, which may also account for the difference in  $\text{NO}_3$  concentration.

Peat pore waters were highest in  $\text{NO}_3\text{-N}$  concentrations of the three regimes. With the lowering of the water table during the summer months, allowing aeration of shallow peats, aerobic nitrifiers can convert ammonium ( $\text{NH}_4$ ) to  $\text{NO}_3$  (van Cleemput, Patrick, and McIlhennig, 1975). Thus, peat waters range in  $\text{NO}_3\text{-N}$  concentrations from relatively low (0.02 mg/l) levels in the deeper peats to higher (0.28 mg/l) levels in the shallow, periodically aerated peats. This range in concentrations has led to a higher overall average (ave = 0.12 mg/l) for  $\text{NO}_3\text{-N}$  concentrations in peat waters. Peat Methanol Associates (1983) reported a lower average concentration of 0.02 mg/l.

Mineral pore waters were consistently lower in  $\text{NO}_3\text{-N}$  concentration than peat pore waters. A continuously anaerobic environment is reflected by these low concentrations, as a significant conversion of  $\text{NH}_4$  to  $\text{NO}_3$  does not occur (van Cleemput et al., 1975). Peat Methanol Associates (1983) reported an average  $\text{NO}_3\text{-N}$  concentration of 0.02 mg/l for wells in the fine sand unit. This concentration is consistent with the  $\text{NO}_3\text{-N}$  average (0.03 mg/l) found in this study.

Ammonium Nitrogen. Except for the peat pore waters (ave = 0.34 mg/l), all the environments contained relatively low levels of  $\text{NH}_4\text{-N}$ :

mineral pore waters 0.15 mg/l, standing surface waters 0.02 mg/l, canal waters 0.03 mg/l, lake waters 0.02 mg/l, and stream water 0.01 mg/l.

The histogram of monthly  $\text{NH}_4$  averages for mineral, peat, and standing surface waters (Figure 12b) exemplifies the higher  $\text{NH}_4\text{-N}$  concentration of peat waters. All statistical analyses (Tables 2 and 3 in the the Appendix) indicate that no significant difference exists between water regimes. The extreme variation in  $\text{NH}_4\text{-N}$  concentrations at any one sampling time for each regime affects the statistical analyses in such a way that no significant differences occur. Because the statistical data do not support the hypothesis of a  $\text{NH}_4\text{-N}$  difference among the regimes,  $\text{NH}_4\text{-N}$  is not considered an indicator species for any water regime.

The concentration of  $\text{NH}_4\text{-N}$  in flowing surface waters did not fluctuate dramatically on a seasonal basis. An average  $\text{NH}_4\text{-N}$  concentration of 0.01 mg/l was determined for West Brice Creek in this study, which is comparable to that found by Noltemeier (1984) (0.03 mg/l) further downstream.

In comparison to mineral and peat pore waters, standing surface waters were lowest in  $\text{NH}_4$  concentration. Anaerobic and aerobic microbes are responsible for the production of inorganic  $\text{NH}_4$  from organic N (Smith, 1980). Conversion of  $\text{NH}_4$  to  $\text{NO}_3$  by aerobic nitrifiers occurs rapidly in an oxygenated surface environment (Klopatek, 1975). The  $\text{NH}_4$  not converted to  $\text{NO}_3$  is probably not an appreciable amount, and this may be reflected in the low  $\text{NH}_4$  concentrations in surface waters.

The higher  $\text{NH}_4$  concentrations in peat pore waters reflect an accumulation of  $\text{NH}_4$  ions produced in the conversion of organic N to inorganic  $\text{NH}_4$  by anaerobic bacteria (Richardson et al., 1978). The  $\text{NH}_4$  concentrations present in mineral pore waters (ave = 0.15 mg/l) are also

in response to the conversion of organic N to inorganic  $\text{NH}_4$ . The lower  $\text{NH}_4$  levels reflect the lack of abundant organic matter in the mineral sediments as opposed to the abundance of organics composing peat. There may be more  $\text{NH}_4\text{-N}$  present in the mineral pore waters than is detected because cation exchange sites of the clay minerals can be occupied by  $\text{NH}_4\text{-N}$  ions. PMA did not determine  $\text{NH}_4$  levels in their analyses, so no comparisons are possible.

#### Total Dissolved Phosphorus

Total dissolved phosphorus (TDP) content was low, ranging from less than 0.01 mg/l to 0.18 mg/l, in all of the environments samples. Mineral waters averaged 0.03 mg/l; peat waters averaged 0.06 mg/l; and surface waters averaged 0.02 mg/l. Catfish Lake, West Brice Creek, and canal waters all averaged 0.01 mg/l TDP.

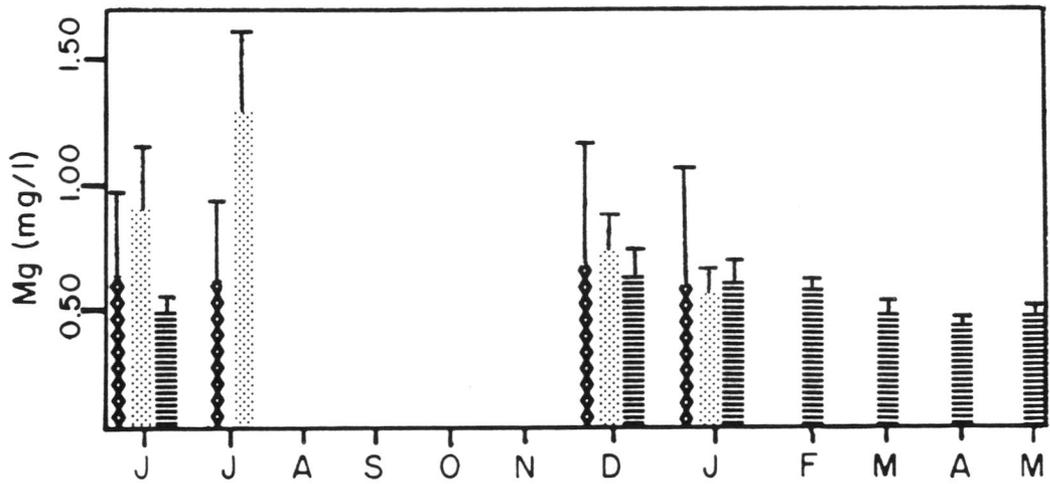
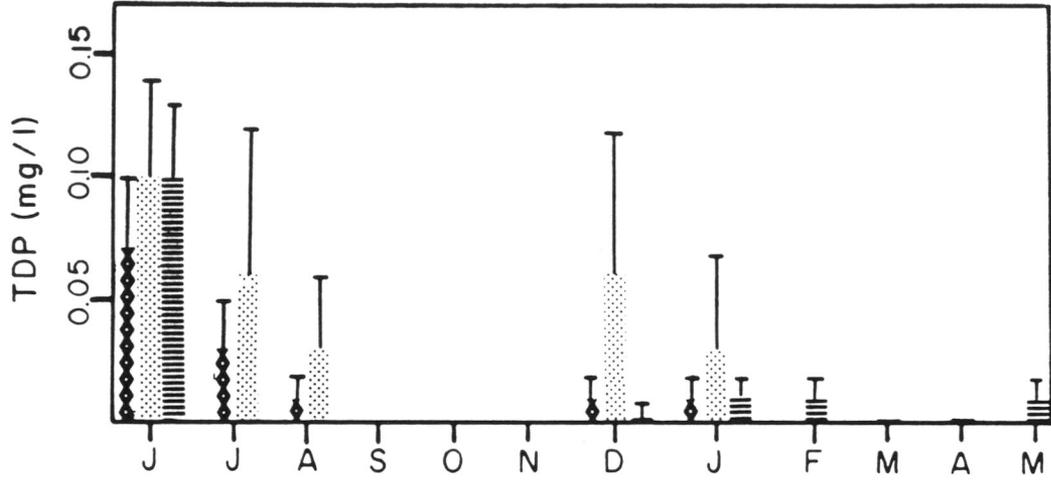
The histogram of monthly average TDP concentrations for each regime (Figure 13a) exemplifies the difference between peat and surface water concentrations. As can be seen in the figure, there is an overlap of ranges among regimes, and the statistical data (Tables 2 and 3 in the Appendix) indicate this. According to one set of analyses (Table 2 in the Appendix), only mineral and surface waters are significantly different. The results from a second statistical analysis (Table 3 in the Appendix) indicate that only peat and mineral waters are significantly different. Because of this lack of agreement between the two statistical tests and because of the range overlap between regimes, TDP is not considered a good indicator for any specific water regime.

Figure 13a. Monthly average TDP concentrations (mg/l) for the three water regimes. See the Appendix for explanation of missing data.

 mineral       peat       standing surface  
 + standard deviation of the mean

Figure 13b. Monthly average Mg concentrations (mg/l) for the three water regimes. See the Appendix for explanation of missing data.

 mineral       peat       standing surface  
 + standard deviation of the mean



Correlation data (Table 4 in the Appendix) for drainage waters is not very meaningful as the canals fluctuated between 0.00 (below detection limits) and 0.03 mg/l TDP. Creek waters varied only 0.01 mg/l between months, averaging 0.01 mg/l. This is close to the 0.02 mg/l average TDP content reported by Noltemeier (1984). Total dissolved phosphorus in all drainage and surface waters is quite low, suggesting that pocosins are very phosphorus poor systems.

Peat pore waters contained the highest amounts of TDP (ave = 0.06 mg/l). This is to be expected as TDP is associated with the slowly decaying plant material. A large portion of TDP that is released by decomposition may not be lost in runoff but possibly retained by the high ion exchange capacity of the colloidal peat (Moore and Bellamy, 1974). TDP may, therefore, either be bound within the organic structures of the decaying peat, or retained superficially by ion exchange (Moore and Bellamy, 1974). Noltemeier (1984) reported that for West Brice Creek, approximately 50% of the TDP was reactive, meaning that it is in a form available for plants, the other 50% probably being organically bound. Most of the TDP that enters the system via rainwater is probably in the reactive form. In any case, peat pore waters contain greater amounts of TDP than do surface waters.

Mineral pore waters contained less TDP than did peat waters (ave = 0.03 mg/l). The TDP content of the mineral layers is possibly related to the organic material associated with the fine grained sediments. The colloidal nature of not only the organics, but of the clays which are common in the mineral sediments, allows TDP to be easily bound within this layer (Moore and Bellamy, 1974).

Peat Methanol Associates (1983) reported TDP concentrations for wells in the fine sand unit and in the peat unit to be 0.15 mg/l and 0.39 mg/l, respectively. Their data are notably higher in concentration than that of this study. However, the average TDP content in the peat water was greater than the average of mineral water, which is consistent with the trend observed in this study.

#### Magnesium/Potassium/Sodium

The magnesium (Mg) concentration in all environments was similar. The average for peat pore waters was 0.76 mg/l; for mineral pore waters was 0.61 mg/l; and for standing surface waters was 0.51 mg/l. The averages for Catfish Lake, West Brice Creek, and the canals were 0.56 mg/l, 0.54 mg/l, and 0.49 mg/l, respectively. The histogram of monthly average Mg concentrations (Figure 13b), supported by statistical data (Tables 2 and 3 in the Appendix), illustrates that Mg levels are not significantly different between regimes. Therefore, Mg is not an indicator element for any particular water regime.

Magnesium content for flowing surface waters did not vary significantly on a seasonal basis. West Brice Creek and the canals averaged 0.54 mg/l and 0.49 mg/l, ranging from 0.31 to 0.80 mg/l. Noltemeier (1984) reported a comparable average of 0.47 mg/l Mg for the stream. Peat Methanol Associates (1983) reported higher Mg values for peat and sand waters (ave = 10.95 and 8.93 mg/l, respectively) than those reported here (peat ave = 0.76 mg/l and mineral ave = 0.61 mg/l). Although the PMA averages are higher by an order of magnitude than those

determined during this study, a similar trend exists in which peat waters contain slightly higher Mg concentrations than mineral waters. Daniel (1981) observed the opposite trend, however, in which mineral waters had higher average Mg concentrations (ave = 2.43 mg/l) than peat waters (ave = 0.43 mg/l).

Mineral pore waters had higher average concentrations of dissolved potassium (K) than did peat pore waters (ave = 0.64 mg/l and 0.43 mg/l, respectively). Standing and flowing surface waters contained lesser amounts of dissolved K, with standing waters averaging 0.12 mg/l, Catfish Lake averaging 0.30 mg/l, West Brice Creek averaging 0.22 mg/l, and drainage canals averaging 0.20 mg/l.

Monthly K averages for each regime are presented in Figure 14a. As is the case with the other "non-indicator" species, the overlapping of ranges between regimes is so great that statistical differences can not be demonstrated. Therefore, K can not be considered a good indicator for any particular water regime. Statistical analyses (Tables 2 and 3 in the Appendix) reflect the variation in K concentrations and, therefore, support this conclusion.

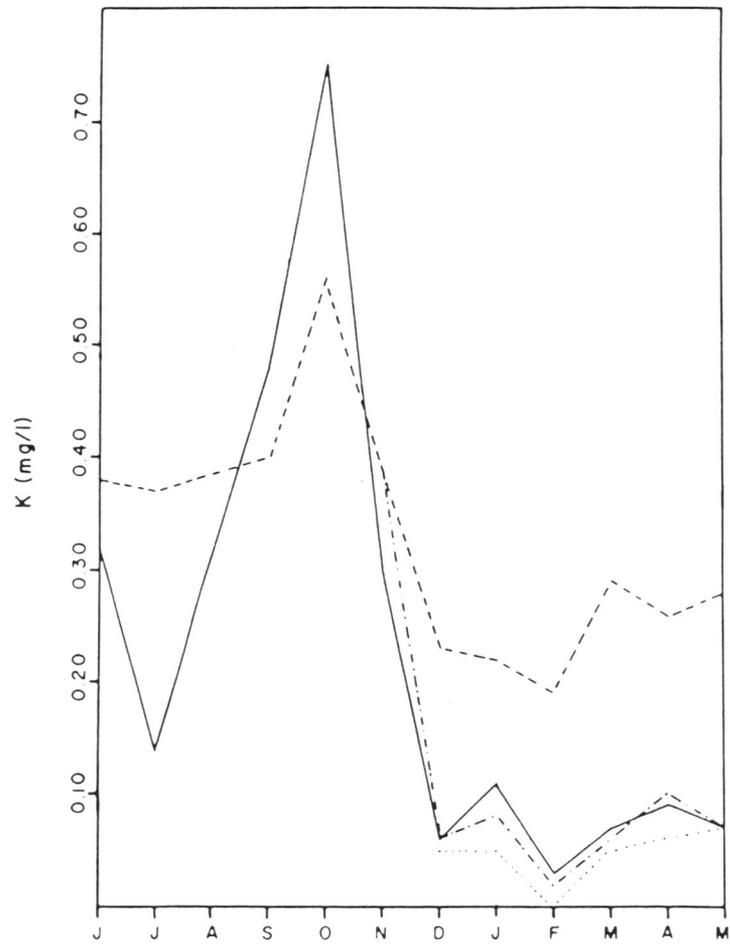
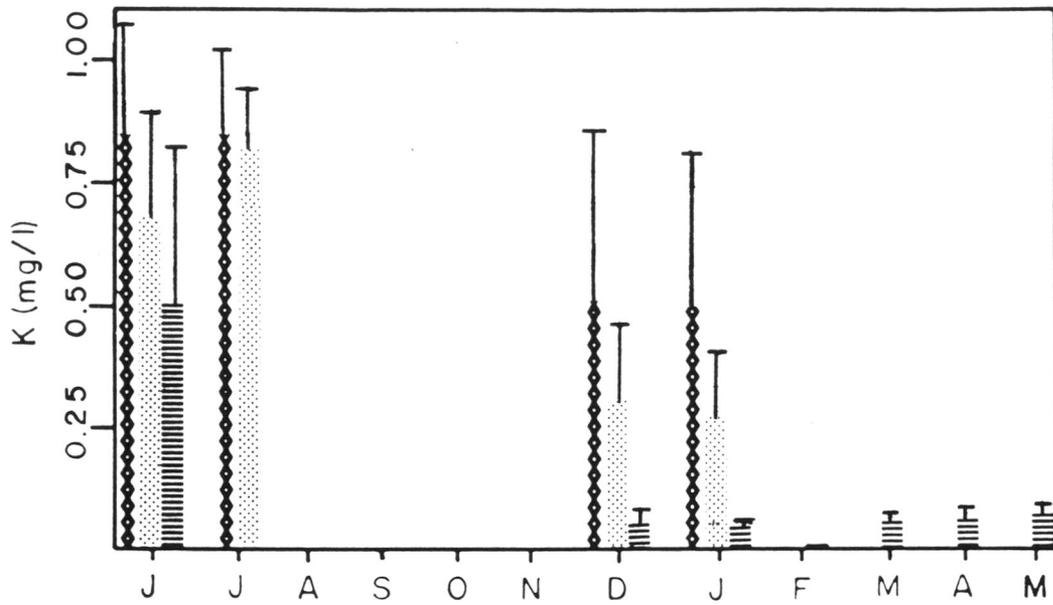
Drainage waters and Catfish Lake exhibited a seasonal trend in K concentration. The lake, canals, and stream all increased in K concentration during the driest months of August to October (Figure 14b). This trend was also observed by Noltemeier (1984) in her water quality/flow study for peat draining streams, in which periods of low flow were associated with an increase in K concentration. According to Gorham (1967), with increased evapotranspiration and the subsequent decline in water level during summer months, cation concentrations may increase. The average K concentrations of West Brice Creek and the

Figure 14a. Monthly average K concentrations (mg/l) for the three water regimes. See the Appendix for explanation of missing data.

 mineral       peat       standing surface  
 + standard deviation of the mean

Figure 14b. Monthly average K concentrations (mg/l) for standing and flowing surface waters.

 stream water       canal water  
 lake water       standing surface water



drainage canals (0.22 mg/l and 0.20 mg/l) are similar to the average K concentration of 0.27 mg/l reported by Noltemeier.

The trend of higher K concentrations in mineral waters, compared to peat waters, as observed in this study, is similar to Daniel's (1981) observation. Daniel reported slightly higher concentrations in mineral waters (ave = 0.78 mg/l as opposed to 0.64 mg/l reported here), but did not detect K in peat waters, whereas the average for peat waters in this study was 0.43 mg/l K. Peat Methanol Associates (1983) not only reported significantly higher concentrations in both water regimes (ave = 1.19 mg/l K in waters from their fine sand unit and 7.68 mg/l k in waters from their peat unit), but also noted the opposite trend, in which peat waters contained higher K levels than mineral waters.

Sodium (Na) was present in all of the environments in comparable concentrations. The average for mineral pore waters was 3.72 mg/l; for peat pore waters was 2.99 mg/l; and for standing surface waters was 2.14 mg/l Na. Catfish Lake, West Brice Creek, and the canals had averages of 2.78 mg/l, 2.75 mg/l, and 2.44 mg/l Na, respectively. A histogram of monthly average Na concentrations for each of the three regimes (mineral, peat, and standing surface waters) is presented in Figure 15. Although mineral waters contained higher levels of dissolved Na, the difference in concentrations between regimes does not appear to be significant. The lack of sufficient well water data prohibits the use of statistical analyses in order to test significance between regimes. Therefore, Na can not be considered a good indicator element for any of the water types.

The Na concentrations of drainage waters (canals and creek), as well as of lake waters, did not indicate any seasonal trends in outflow.

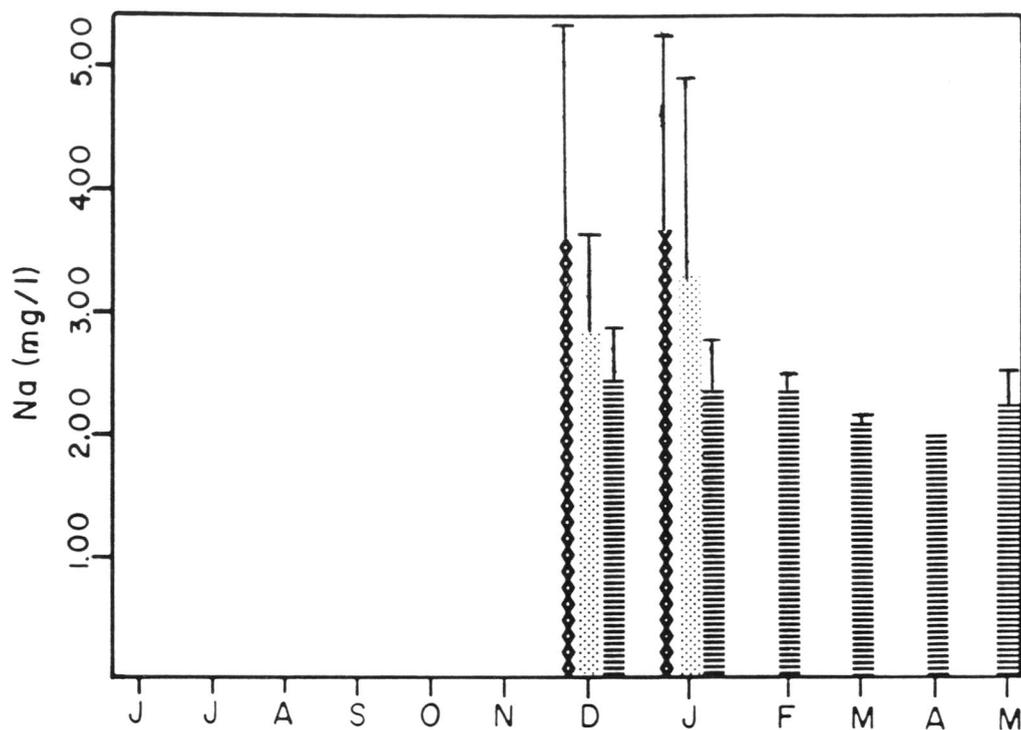


Figure 15. Monthly average Na concentrations (mg/l) for the three water regimes. See the Appendix for explanation of missing data.

 mineral     
  peat     
  standing surface

 + standard deviation of the mean

Noltemeier (1984) reported an average Na concentration of 2.78 mg/l for West Brice Creek, comparable to the 2.75 mg/l Na recorded in this study.

Daniel (1981) reported Na concentrations for peat and mineral waters collected in Pungo National Wildlife Refuge to be 4.00 and 5.51 mg/l, respectively. Although these values are nearly twice as high as those reported here, a similar trend exists in which mineral waters contained higher average Na concentrations than peat waters. Peat Methanol Associates (1983) recorded average Na concentrations of 13.25 mg/l and 10.89 mg/l for peat and sand units. Not only are their data more than twice greater than those reported here and by Daniel, but a contrast in trends exists in which peat waters had higher average Na levels than mineral waters.

In ombrotrophic systems, such as the Croatan pocosins, the major input of nutrients to the system is via precipitation (Moore and Bellamy, 1974). Thus, the low concentrations of the major cations (Mg, K, Na) in standing surface waters are a result of this phenomenon. Sodium is a good example of the close correlation between rainwater and surface waters. The average Na levels in precipitation collected in the area by Noltemeier (1984) was 2.21 mg/l, and the average for standing surface waters collected in this study was 2.14 mg/l Na. The low concentrations of Mg in surface waters is due in part to a low input of Mg and possibly to cation exchange by Sphagnum mats (Wetzel, 1983). Standing surface waters contained lower levels of K compared to well waters, again reflecting a low level of K input. Also, some K is lost to plant uptake as K is considered an important nutrient, though seldom a limiting one (Moore and Bellamy, 1974).

Cation concentrations in peat pore waters are most possibly related to peat decomposition and to ion exchange. Living plants require nutrient cations. With the later decomposition of organics, cations are released. The colloidal nature of peat may also affect cation concentrations by simple exchange.

Concentrations of Mg, K, and Na in mineral pore waters are related to the solubility of the minerals and to the cation exchange capacity of colloidal clays, meaning the cation exchange capacity of clays can lead to the binding and release of cations into the interstitial pore waters (Matthess, 1982). The K dissolved in the mineral waters may be derived from the illite component of the clays associated with the mineral sediments (Stumm and Morgan, 1981). Sodium ions may be released from the crystalline structure of smectite, a sometimes Na-bearing clay also present in the mineral soils. Some of the clays of the mineral soils are comprised of vermiculite, a Mg-bearing mineral. The exchange of cations (Mg for Ca) may account for the Mg content in mineral pore waters (Stumm and Morgan, 1981).

#### Aluminum/Manganese/Titanium/Vanadium

Aluminum (Al) was present in detectable amounts only in the water regimes associated with mineral sediments. Mineral pore waters contained an average of 1.02 mg/l Al; Catfish Lake an average of 0.28 mg/l Al; and West Brice Creek an average of 0.51 mg/l Al. The Al concentrations of both the creek and lake waters fluctuated very little seasonally, and so no trends were evident. Aluminum data were not reported by Noltemeier (1984), PMA (1983), or Daniel (1981); thus comparisons are not possible.

Manganese (Mn) was present in detectable concentrations only in lake waters (ave = 0.006 mg/l). Peat Methanol Associates (1983) reported anomolous Mn concentrations of 0.27 mg/l and 0.23 mg/l for the fine sand unit and peat unit, respectively. Manganese is detectable in most groundwaters. Under reducing conditions, however, concentrations greater than 1.0 mg/l are rare (Matthess, 1982).

Titanium (Ti) and vanadium (V) were present in detectable concentrations in mineral pore waters only, with averages of 0.010 mg/l and 0.004 mg/l, respectively. Noltemeier (1984), Peat Methanol Associates (1983), and Daniel (1981) did not test for Ti or V in their waters.

The Al present in all the environments can be attributed to the weathering of the alumino-silicates kaolinite, illite, vermiculite, smectite and various feldspars (Stumm and Morgan, 1981), which are found in the clay and sand size fractions of the mineral sediments. The mineral sediments underlying the peat unit generally are either clayey sands or sandy clays (Figures 5 and 6). The mineral pore waters contain Al that is possibly derived from the chemical weathering of these sediments. Catfish Lake is also underlain by clayey sands in some areas, and West Brice Creek drains mineral-dominated soils as well as peat-dominated soils. The waters of these two systems also contain Al in detectable concentrations. It would seem logical for Al to be considered an indicator for mineral waters. However, since there is insufficient Al data to compute valid statistical analyses, coupled with the contamination problems associated with the trace element analyses, Al can not be considered an indicator for mineral pore waters.

Manganese is associated with various minerals, such as pyrolusite ( $MnO_2$ ) and the manganiferous garnet, spessarite ( $Mn_3Al_2(SiO_4)_3$ ) (Jones, 1945). The sand-size, detrital sediments underlying the lake and peat deposits are derived from the weathering of crystalline rocks further to the west. It is possible that the trace amounts of Mn in the lake waters are related to the slow chemical weathering of these stable minerals. If this is so, it seems likely that the mineral pore waters would contain detectable Mn concentrations. However, due to contamination problems in the lab, Mn concentrations in mineral pore waters are not reliable values. Therefore, it was not possible to determine accurate Mn concentrations in mineral pore waters.

Titanium (Ti) occurs in minerals such as rutile ( $TiO_2$ ) and ilmenite ( $FeTiO_3$ ) (Jones, 1945). Detrital ilmenite and rutile, both chemically and physically stable minerals, are common accessory minerals in local beach sands. The mineral sediments of the study area do contain very fine grained opaque minerals, some of which may be ilmenite. Therefore, trace amounts of Ti in the pore waters might be expected.

Vanadium (V) is incorporated in minerals such as vanadinite ( $Pb_5(VO_4)_3Cl$ ) and carnotite ( $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$ ) (Jones, 1945). If these and other V-bearing minerals are associated with the mineral sediments underlying the peat deposits, then the trace amounts of V reported could be accounted. However, no such minerals were observed by visual or microscopic inspection in the cores or grab samples during sediment analyses. Since it was beyond the scope of this project, no attempt was made to look for traces of V-bearing minerals by other more sensitive methods. It is interesting to note that V is commonly present in organic remains in varying amounts (Jones, 1945). Therefore, it is a

possibility that some V is present in the peat, but that it is tightly bound to the organics and not detectable in the pore waters.

The trace elements detected in the mineral and lake waters (Mn, Ti, and V) are all widely distributed in igneous and sedimentary rocks, but only in small quantities (Jones, 1945). It is feasible, then, to detect trace amounts of these elements in groundwater as the result of slow chemical weathering of detrital sediments.

## SUMMARY

"The chemistry of water draining wetlands reflects the source of water, whether from direct precipitation, surface inflow, groundwater, or in some cases mixing of water from these different sources" (Daniel, 1981). Because of the nature of an ombrotrophic system, the regionally elevated topography of accumulated organic remains tends to isolate a pocosin from the influence of the regional groundwater system (Daniel, 1981). When peat accumulation forms an elevated surface, the water table within the peat also becomes slightly elevated above the regional groundwater system and removes itself from the chemical influence of groundwater in the underlying mineral sediments (Daniel, 1981).

The objectives of this study were (a) to determine the chemical characteristics of three water regimes (mineral, peat, and surface waters) of the Croatan National Forest, and (b) to document any seasonal fluctuations of those parameters in the outflow waters. In answer to the first objective, three elements (TOC, Si, and Ca) appear to act as indicator species for the three major water regimes. Mineral pore waters contain the highest amounts of dissolved Si (ave = 3.55 mg/l), intermediate levels of Ca (ave = 1.51 mg/l), and the lowest concentrations of TOC (ave = 42.7 mg/l). Peat pore waters contain the highest concentrations of TOC (ave = 212.5 mg/l) and Ca (ave = 2.09 mg/l), and the lowest Si content (ave = 0.89 mg/l) of the three regimes. Standing surface waters contain the lowest concentrations of dissolved Si (ave = 0.45 mg/l) and Ca (ave = 0.20 mg/l) and have intermediate concentrations of TOC (ave = 51.0 mg/l).

As an aid in determining seasonal trends in outflow waters, Pearson product-moment correlation coefficients were used on the indicator species to test for correlations between water regimes and drainage waters. The statistical data indicate that during the times of lowest water level (summer and fall), peat and mineral pore waters are the major contributors to canal drainage. With the rise in water table during the winter and spring months, related to the decline in evapotranspiration, increased surface runoff dilutes the waters of the canals; and surface water becomes the major contributor to drainage waters. The seasonality of outflow waters (concerning the three indicator elements) is as follows: Highest TOC, Ca, and Si concentrations correspond to periods of lowest water table when peat and mineral pore waters are draining. During the winter and spring, increased surface runoff and the subsequent addition of its chemical components causes TOC, Ca, and Si concentrations in the drainage canals to decline.

Potassium (K), although not an indicator species for any particular water regime, exhibits a seasonality in outflow waters. Concentration of K in drainage waters increases during periods of low flow (summer and fall) and declines during periods of high flow (winter and spring). Noltemeier (1984) also reported this trend for K. Gorham (1967) noted a similar trend in the English Lake District and suggests that during periods of lowered water table associated with increased evapotranspiration, the K already present in drainage waters is concentrated. As surface runoff increases, the K content of drainage channels is diluted, and K concentrations of the canals decrease.

Other ions ( $\text{NO}_3\text{-N}$ ,  $\text{NH}_4\text{-N}$ , TDP, Mg, Na, and trace metals) present in the outflow waters, as well as in the well waters, are not indicative of a specific water regime, nor do they exhibit a strong degree of

seasonality in outflow. Had this study been conducted somewhat differently, these ions and perhaps some others not tested, might be found to be indicator species. As an example, more frequent sampling (every two weeks as opposed to the monthly sampling done here) would have resulted in a larger number of samples as well as in a closer look at fluctuations in water chemistries.

Based on the results obtained from this project, some recommendations for further study can be suggested and are as follows:

- (1) To do a thorough stratigraphic work-up on the underlying mineral soil, including detailed petrographic and clay analyses, in order to possibly relate mineral pore water chemistry to changing lithologies.
- (2) To concentrate solely on peat pore waters and analyze not only the pore waters, but also the non-filterable colloids to determine the relationships between the colloidal organics and the interstitial waters.

This project did not include either detailed petrographic work or organic geochemistry; but hopefully with the results of this baseline study, additional interest in wetland environments will be generated.

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## APPENDIX

Statistical data and raw data for detectable elements and ions.

Sampling sites are expressed as "peat thickness", "transect", and "water type".

Examples:

OAM	site of 0 feet peat along transect A, mineral water
4BP	site of 4 feet peat along transect B, peat water
2AC	site of 2 feet peat along transect A, canal water adjacent to wells 2AM and 2AP
STR	West Brice Creek
LAI	lake water from site 1 on Catfish Lake

Table 1A. Precision and accuracy data for water analyses. Precision is expressed as the standard deviation of the mean of "n" samples. Accuracy is expressed as % recovery of a known concentration control or of a spiked sample.

<u>Method</u>	<u>Ion</u>	<u>sd</u>	<u>n</u>	<u>% Recovery</u>
Jones, 1984	NO <sub>3</sub> -N	+0.04 <sup>1</sup>	12	96% <sup>2</sup>
Solorzano, 1969	NH <sub>4</sub> -N	+0.01 <sup>1</sup>	8	94% <sup>3</sup>
Stainton, etal, 1974	S102-S1	+0.03 <sup>1</sup>	13	98% <sup>2</sup>
EPA, 1976	TDPO <sub>4</sub> -P	+0.01 <sup>1</sup>	11	100% <sup>2</sup>
	Ca <sup>4</sup>	—	—	—
	Mg <sup>4</sup>	—	—	—
	K <sup>4</sup>	—	—	—
	TOC	+1.0 <sup>1</sup>	8	99% <sup>5</sup>

1 as determined in this study based on "n" samples.

2 as reported in cited reference.

3 as reported in McGlynn, 1974.

4 Precision/accuracy data not available. AA spectrophotometer was calibrated in the concentration mode. When the analysis of standards and blank showed more than a 0.02 mg/l discrepancy, the calibration curve was updated with three readings of all standards.

5 as reported by Oceanography International Corporation.

Table 2A. Anova tables where data are derived from comparison of surface, peat, and mineral waters, considering transect and water types as factors. F-ratio represents  $F = \frac{ss(\text{factor})/df}{ss(\text{error})/df}$

P-value is the probability of observing a difference as great or greater than that observed if the null hypothesis ( $H_0$ ) is true.

$H_0$ : no difference between water regimes.

	<u>Source</u>	<u>SS</u>	<u>df</u>	<u>F-ratio</u>	<u>P-value</u>
TOC	Transect	10969.48	1	2.68	0.1050
	Type	541243.50	2	66.05	0.0001*
	Transect*Type	6850.69	2	0.84	0.4365
	Error	405609.59	99		
$\frac{SiO_2-Si}{2}$	<u>Source</u>	<u>SS</u>	<u>df</u>	<u>F-ratio</u>	<u>P-value</u>
	Transect	1.85	1	0.72	0.3995
	Type	224.32	2	43.43	0.0001*
	Transect*Type	5.80	2	1.12	0.3294
Error	268.60	104			
$\frac{NH_4-N}{4}$	<u>Source</u>	<u>SS</u>	<u>df</u>	<u>F-ratio</u>	<u>P-value</u>
	Transect	0.15	1	0.50	0.4816
	Type	0.98	2	1.66	0.1955
	Transect*Type	0.99	2	1.69	0.1896
Error	30.61	104			
$\frac{NO_3-N}{3}$	<u>Source</u>	<u>SS</u>	<u>df</u>	<u>F-ratio</u>	<u>P-value</u>
	Transect	0.00	1	0.01	0.9311
	Type	1.79	2	3.54	0.0326*
	Transect*Type	0.13	2	0.25	0.7763
Error	26.32	104			
$\frac{TDPO-P}{4}$	<u>Source</u>	<u>SS</u>	<u>df</u>	<u>F-ratio</u>	<u>P-value</u>
	Transect	0.01	1	0.05	0.8214
	Type	1.97	2	3.94	0.0225*
	Transect*Type	0.08	2	0.16	0.8514
Error	26.07	104			
Ca	<u>Source</u>	<u>SS</u>	<u>df</u>	<u>F-ratio</u>	<u>P-value</u>
	Transect	1.36	1	0.64	0.4277
	Type	38.25	2	8.96	0.0003*
	Transect*Type	7.14	2	1.67	0.1942
Error	170.73	80			
K	<u>Source</u>	<u>SS</u>	<u>df</u>	<u>F-ratio</u>	<u>P-value</u>
	Transect	0.33	1	0.89	0.3486
	Type	0.90	2	1.22	0.3001
	Transect*Type	0.03	2	0.04	0.9602
Error	30.16	82			
Mg	<u>Source</u>	<u>SS</u>	<u>df</u>	<u>F-ratio</u>	<u>P-value</u>
	Transect	0.40	1	1.38	0.2431
	Type	0.60	2	1.06	0.3526
	Transect*Type	0.35	2	0.61	0.5475
Error	22.91	80			

\*significant at 0.05 level

Table 3A. Anova tables where data are derived from comparison of peat and mineral pore waters, considering water type, season (time), and peat thickness as factors. F-ratio represents  $F = \frac{ss(\text{factor})/df}{ss(\text{error})/df}$  and P-value is the probability of observing

a difference as great or greater than that observed if the null hypothesis ( $H_0$ ) is true.

$H_0$ : no difference between water regimes.

	Source	SS	df	F-ratio	P-value
TOC	Type	262636.63	1	103.81	0.0001*
	Time	24081.70	1	9.52	0.0033
	Thickness	24973.77	3	3.29	0.0276*
	Error	129029.20	51		
SiO <sub>2</sub> -Si	Source	SS	df	F-ratio	P-value
	Type	100.69	1	24.42	0.0001*
	Time	3.85	1	0.93	0.3385
	Thickness	10.27	3	0.83	0.4858
Error	218.57	53			
Ca	Source	SS	df	F-ratio	P-value
	Type	14.33	1	6.76	0.0141*
	Time	6.74	1	3.18	0.0842
	Thickness	1.25	3	0.20	0.8976
Error	65.67	31			
NO <sub>3</sub> -N	Source	SS	df	F-ratio	P-value
	Type	0.06	1	9.29	0.0036*
	Time	0.00	1	0.12	0.7251
	Thickness	0.02	3	1.27	0.2943
Error	0.34	53			
NH <sub>4</sub> -N	Source	SS	df	F-ratio	P-value
	Type	0.19	1	2.19	0.1447
	Time	0.01	1	0.07	0.7915
	Thickness	0.24	3	0.91	0.4432
Error	4.62	53			
TDPO <sub>4</sub> -P	Source	SS	df	F-ratio	P-value
	Type	0.01	1	6.58	0.0131*
	Time	0.00	1	0.08	0.7786
	Thickness	0.00	3	0.36	0.7841
Error	0.07	53			
Mg	Source	SS	df	F-ratio	P-value
	Type	0.84	1	9.94	0.0036*
	Time	0.18	1	2.12	0.1557
	Thickness	0.16	3	0.64	0.5922
Error	2.62	31			
K	Source	SS	df	F-ratio	P-value
	Type	0.33	1	5.06	0.0317*
	Time	0.01	1	0.16	0.6917
	Thickness	0.41	3	2.09	0.1216
Error	2.30	31			

\*significant at 0.05 level

Table 4A. Pearson product-moment correlation coefficients. Values in parentheses denote number of pairs used in calculating the statistic.

		June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April	May
TOC	M,C	-.345(8)	.646(9)	.588(9)	-	-	-	1.000(4)	-.616(9)	-	-	-	-
	P,C	.921(7)	1.000(6)	1.000(4)	-	-	-	1.000(4)	-.500(8)	-	-	-	-
	S,C	.408(5)	-	-	-	-	-	-	-	.632(5)	-.962(6)	-.251(6)	-
SiO <sub>2</sub> -Si	M,C	-.004(9)	-.335(9)	.316(9)	-	-	-	-.702(9)	.724(9)	-	-	-	-
	P,C	-.160(7)	1.000(6)	1.000(4)	-	-	-	.885(8)	.889(8)	-	-	-	-
	S,C	-.362(5)	-	-	-	-	-	-	-	.984(6)	.958(6)	.243(6)	-
Ca	M,C	.271(9)	.000(3)	-	-	-	-	.061(9)	.571(9)	-	-	-	-
	P,C	.000(4)	.000(3)	-	-	-	-	.057(8)	.500(8)	-	-	-	-
	S,C	.369(5)	-	-	-	-	-	-	-	.751(6)	.840(3)	.742(5)	-
NO <sub>3</sub> -N	M,C	.224(9)	-.828(9)	.250(9)	-	-	-	-.309(9)	-.750(9)	-	-	-	-
	P,C	.779(7)	.000(6)	.000(4)	-	-	-	.000(8)	.858(8)	-	-	-	-
	S,C	-.372(5)	-	-	-	-	-	-	-	-.448(6)	-.333(6)	-1.000(6)	-
NH <sub>4</sub> -N	M,C	-.554(9)	-.349(9)	.022(9)	-	-	-	.451(9)	.864(9)	-	-	-	-
	P,C	.971(7)	.000(6)	.000(4)	-	-	-	-.562(8)	-.411(8)	-	-	-	-
	S,C	-.372(5)	-	-	-	-	-	-	-	.000(6)	.000(6)	.000(6)	-
TDPO <sub>4</sub> -P	M,C	-.762(9)	-.643(9)	.000(9)	-	-	-	-.378(9)	.000(9)	-	-	-	-
	P,C	-.125(7)	.000(6)	.000(4)	-	-	-	.447(8)	.000(8)	-	-	-	-
	S,C	.371(5)	-	-	-	-	-	-	-	.894(6)	.000(6)	.000(6)	-
Mg	M,C	.391(9)	-	-	-	-	-	.272(9)	.061(9)	-	-	-	-
	P,C	1.000(4)	-	-	-	-	-	.642(8)	.801(8)	-	-	-	-
	S,C	-.361(5)	-	-	-	-	-	-	-	.827(6)	.000(3)	.963(5)	-
K	M,C	.206(9)	-	-	-	-	-	-.240(9)	.939(9)	-	-	-	-
	P,C	-1.000(4)	-	-	-	-	-	.511(8)	.692(8)	-	-	-	-
	S,C	.368(5)	-	-	-	-	-	-	-	.000(6)	.000(3)	.112(6)	-

Table 5A. Raw elemental data

TOC  
(mg/l)

SITES	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY
OAM	76.9	43.4	40.1	*	*	*	90.5	18.9	*	*	*	*
2AM	34.1	30.7	29.0	*	*	*	24.1	15.6	*	*	*	*
4AM	***	74.0	81.0	*	*	*	65.3	45.7	*	*	*	*
6AM	59.4	59.2	55.4	*	*	*	41.3	39.4	*	*	*	*
8AM	63.2	74.6	65.2	*	*	*	80.9	82.9	*	*	*	*
OBM	11.5	25.6	13.6	*	*	*	13.4	18.2	*	*	*	*
2BM	15.6	18.3	14.3	*	*	*	58.3	10.9	*	*	*	*
4BM	51.9	57.3	56.3	*	*	*	54.4	43.9	*	*	*	*
6BM	***	40.2	23.7	*	*	*	9.1	10.3	*	*	*	*
4AP	212.8	**	382.0	*	*	*	26.0	45.8	*	*	*	*
6AP	195.9	262.5	259.0	*	*	*	216.3	154.3	*	*	*	*
8AP	274.7	267.4	302.1	*	*	*	368.6	252.1	*	*	*	*
2BP	**	**	**	*	*	*	4.8	36.8	*	*	*	*
4BP	284.7	582.1	**	*	*	*	218.4	78.3	*	*	*	*
6BP	209.5	211.5	204.4	*	*	*	149.1	113.9	*	*	*	*
2AC	51.7	54.8	53.2	**	**	***	***	54.3	48.1	52.2	48.8	55.2
4AC	54.0	68.9	56.9	62.7	**	***	***	42.1	41.9	45.5	44.4	46.1
6AC	54.7	70.5	59.3	61.9	**	***	54.3	43.2	40.5	45.6	44.4	46.2
2BC	58.9	64.6	49.4	59.3	**	***	60.2	46.6	46.0	48.9	50.3	49.9
4BC	56.2	65.4	52.9	52.0	**	***	***	46.6	44.9	49.6	49.4	49.6
STR	37.4	58.9	59.5	29.3	190.5	207.8	45.3	21.8	27.4	29.2	33.7	47.4
LA1	29.5	21.9	19.9	11.8	150.8	135.9	11.8	14.3	30.7	28.8	33.8	23.0
LA2	36.1	15.4	20.8	12.5	129.1	115.3	52.1	23.1	27.3	30.8	27.7	27.3
6AS	**	**	**	**	**	**	**	41.1	*	42.5	53.2	42.8
6AS2	**	**	**	**	**	**	**	*	39.5	42.6	47.7	*
6AS3	**	**	**	**	**	**	**	*	39.9	42.7	47.8	*
8AS	69.9	**	**	**	**	**	52.9	40.6	*	*	*	42.4
8A2S	47.5	**	**	**	**	**	**	*	*	*	*	*
4BS	54.6	**	**	**	**	**	**	39.3	40.4	43.3	50.6	41.9
4BS2	34.6	**	**	**	**	**	**	*	40.4	43.6	46.7	*
4BS3	*	**	**	**	**	**	**	*	42.9	43.7	48.6	*
6BS	56.4	**	**	**	**	**	50.0	41.9	*	*	*	41.5

\*no water collected

\*\*no water present

\*\*\*lab problem

Table 5A. (continued)

 $\text{SiO}_2\text{-Si}$   
(mg/l)

SITES	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY
OAM	2.96	2.96	3.32	*	*	*	2.40	2.37	*	*	*	*
2AM	3.63	3.36	3.66	*	*	*	3.35	2.94	*	*	*	*
4AM	0.64	0.29	0.71	*	*	*	0.77	0.70	*	*	*	*
6AM	5.34	2.54	6.62	*	*	*	5.76	2.52	*	*	*	*
8AM	5.24	2.07	6.52	*	*	*	5.29	2.85	*	*	*	*
0BM	4.27	3.56	3.86	*	*	*	2.19	1.52	*	*	*	*
2BM	5.03	1.66	7.70	*	*	*	2.49	3.47	*	*	*	*
4BM	3.46	0.84	14.75	*	*	*	1.02	3.62	*	*	*	*
6BM	4.63	3.43	5.14	*	*	*	4.51	3.81	*	*	*	*
4AP	0.58	**	0.51	*	*	*	0.78	0.70	*	*	*	*
6AP	0.46	0.46	0.53	*	*	*	0.57	0.57	*	*	*	*
8AP	0.68	0.68	0.88	*	*	*	1.05	1.06	*	*	*	*
2BP	**	**	**	*	*	*	0.87	0.84	*	*	*	*
4BP	0.46	0.60	**	*	*	*	1.04	0.71	*	*	*	*
6BP	0.39	0.35	0.51	*	*	*	0.59	0.55	*	*	*	*
2AC	0.35	0.29	0.46	**	**	0.40	0.67	0.61	0.58	0.48	0.43	0.48
4AC	0.37	0.30	0.27	0.13	**	0.35	0.59	0.53	0.53	0.41	0.39	0.40
6AC	0.35	0.26	0.29	0.10	**	0.33	0.57	0.53	0.51	0.40	0.38	0.38
2BC	0.51	0.55	0.44	0.38	**	1.31	0.82	0.80	0.87	0.57	0.50	0.50
4BC	0.42	0.35	0.38	0.67	**	0.41	0.77	0.68	0.68	0.56	0.49	0.50
STR	0.78	0.67	1.43	1.74	2.58	1.58	0.61	1.95	2.16	1.85	1.64	0.66
LA1	0.78	0.66	0.69	0.71	0.14	0.00	0.02	0.16	0.21	0.27	0.44	0.46
LA2	0.81	0.62	0.68	0.65	0.13	0.00	0.45	0.41	0.27	0.30	0.42	0.51
6AS	**	**	**	**	**	**	0.58	0.53	0.51	0.40	0.38	0.40
6AS2	**	**	**	**	**	**	*	*	0.49	0.40	0.40	*
6AS3	**	**	**	**	**	**	*	*	0.48	0.41	0.39	*
8AS	0.37	**	**	**	**	**	0.47	0.50	*	*	*	0.33
8A2S	0.32	**	**	**	**	**	*	*	*	*	*	*
4BS	0.36	**	**	**	**	**	0.63	0.61	0.59	0.48	0.39	0.35
4BS2	0.35	**	**	**	**	**	*	*	0.59	0.45	0.39	*
4BS3	*	**	**	**	**	**	*	*	0.59	0.47	0.40	*
6BS	0.41	**	**	**	**	**	0.60	0.59	*	*	*	0.36

\*no water collected

\*\*no water present

\*\*\*lab problem

Table 5A. (continued)

Ca  
(mg/l)

SITES	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY
0AM	2.09	0.93	***	*	*	*	1.08	1.03	*	*	*	*
2AM	2.39	***	***	*	*	*	0.72	0.69	*	*	*	*
4AM	0.83	***	***	*	*	*	0.10	0.12	*	*	*	*
6AM	0.58	0.73	***	*	*	*	0.47	0.35	*	*	*	*
8AM	2.89	2.34	***	*	*	*	1.20	1.10	*	*	*	*
0BM	9.66	***	***	*	*	*	4.35	4.09	*	*	*	*
2BM	0.63	***	***	*	*	*	0.44	0.35	*	*	*	*
4BM	1.69	***	***	*	*	*	1.13	1.18	*	*	*	*
6BM	1.13	***	***	*	*	*	0.35	0.72	*	*	*	*
4AP	1.22	**	***	*	*	*	1.60	0.25	*	*	*	*
6AP	***	2.64	***	*	*	*	0.75	0.80	*	*	*	*
8AP	5.83	6.38	***	*	*	*	1.08	0.52	*	*	*	*
2BP	**	**	**	*	*	*	1.07	0.92	*	*	*	*
4BP	3.14	**	***	*	*	*	2.10	1.46	*	*	*	*
6BP	4.09	**	***	*	*	*	1.33	2.54	*	*	*	*
2AC	0.48	***	***	**	**	0.46	0.12	0.17	0.19	0.12	0.06	0.20
4AC	0.23	***	***	1.13	**	0.23	0.08	0.13	0.10	0.04	***	0.03
6AC	0.28	***	***	0.63	**	0.35	0.08	0.08	0.28	***	0.04	0.20
2BC	0.38	***	***	1.89	**	0.35	0.18	0.12	0.46	0.07	0.24	0.13
4BC	0.23	***	***	0.33	**	0.20	0.10	0.14	0.10	0.19	0.05	0.50
STR	0.38	0.23	***	1.13	0.78	0.55	0.33	0.14	0.35	0.09	0.08	0.21
LA1	0.73	0.46	***	1.24	0.88	1.00	0.72	0.66	0.64	0.47	0.51	0.50
LA2	0.68	0.46	***	0.93	1.74	0.85	0.35	0.65	0.74	0.52	0.42	0.50
6AS	**	***	**	**	**	**	0.13	0.08	0.07	***	0.06	0.02
6AS2	**	***	**	**	**	**	*	*	0.19	0.15	0.03	*
6AS3	**	***	**	**	**	**	*	*	0.08	0.02	***	*
8AS	1.13	***	**	**	**	**	0.10	0.05	*	*	*	0.25
8AS2	1.54	***	**	**	**	**	*	*	*	*	*	*
4BS	0.13	***	**	**	**	**	0.14	0.09	0.11	0.04	0.10	0.04
4BS2	0.28	***	**	**	**	**	*	*	0.14	0.16	0.07	*
4BS3	*	***	**	**	**	**	*	*	0.11	0.05	0.15	*
6BS	0.43	***	**	**	**	**	0.10	0.19	*	*	*	0.21

\*no water collected

\*\*no water present

\*\*\*lab problem

Table 5A. (continued)

SITES	NO <sub>3</sub> -N (mg/l)											
	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY
0AM	0.01	0.00	0.01	*	*	*	0.01	0.02	*	*	*	*
2AM	0.01	0.00	0.01	*	*	*	0.02	0.02	*	*	*	*
4AM	0.04	0.03	0.03	*	*	*	0.02	0.02	*	*	*	*
6AM	0.03	0.01	0.01	*	*	*	0.05	0.04	*	*	*	*
8AM	0.06	0.04	0.02	*	*	*	0.05	0.06	*	*	*	*
0BM	0.01	0.04	0.02	*	*	*	0.10	0.08	*	*	*	*
2BM	0.01	0.01	0.01	*	*	*	0.04	0.02	*	*	*	*
4BM	0.03	0.03	0.01	*	*	*	0.02	0.02	*	*	*	*
6BM	0.01	0.00	0.00	*	*	*	0.03	0.05	*	*	*	*
4AP	0.08	**	0.06	*	*	*	0.04	0.02	*	*	*	*
6AP	0.22	0.04	0.04	*	*	*	0.10	0.07	*	*	*	*
8AP	0.28	0.02	0.04	*	*	*	0.08	0.07	*	*	*	*
2BP	**	**	**	*	*	*	0.04	0.03	*	*	*	*
4BP	0.30	0.04	**	*	*	*	0.58	0.18	*	*	*	*
6BP	0.16	0.02	0.03	*	*	*	0.16	0.19	*	*	*	*
2AC	0.06	0.03	0.03	**	**	0.05	0.05	0.04	0.05	0.02	0.04	0.05
4AC	0.05	0.02	0.03	0.06	**	0.04	0.04	0.02	0.03	0.02	0.04	0.04
6AC	0.05	0.02	0.03	0.04	**	0.04	0.04	0.02	0.02	0.01	0.02	0.02
2BC	0.04	0.03	0.03	0.06	**	0.04	0.04	0.03	0.04	0.03	0.02	0.03
4BC	0.07	0.01	0.02	0.04	**	0.03	0.04	0.04	0.04	0.03	0.04	0.04
STR	0.03	0.01	0.03	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.02
LA1	0.09	0.11	0.07	0.11	0.09	0.05	0.06	0.07	0.10	0.09	0.07	0.09
LA2	0.07	0.11	0.07	0.11	0.09	0.05	0.05	0.07	0.09	0.08	0.09	0.09
6AS	**	**	**	**	**	**	0.02	0.02	0.02	0.02	0.02	0.02
6AS2	**	**	**	**	**	**	*	*	0.02	0.01	0.02	*
6AS3	**	**	**	**	**	**	*	*	0.02	0.02	0.02	*
8AS	0.01	**	**	**	**	**	0.02	0.02	*	*	*	0.03
8A2S	0.01	**	**	**	**	**	*	*	*	*	*	*
4BS	0.01	**	**	**	**	**	0.02	0.02	0.02	0.01	0.01	0.02
4BS2	0.01	**	**	**	**	**	*	*	0.02	0.02	0.01	*
4BS3	*	**	**	**	**	**	*	*	0.01	0.01	0.01	*
6BS	0.01	**	**	**	**	**	0.02	0.02	*	*	*	0.02

\*no water collected

\*\*no water present

\*\*\*lab problem

Table 5A. (continued)

NH<sub>4</sub>-N  
(mg/l)

SITES	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY
0AM	0.19	0.24	0.19	*	*	*	0.14	0.00	*	*	*	*
2AM	0.01	0.54	0.16	*	*	*	0.44	0.40	*	*	*	*
4AM	0.08	0.07	0.09	*	*	*	0.02	0.02	*	*	*	*
6AM	0.40	0.21	0.23	*	*	*	0.03	0.02	*	*	*	*
8AM	0.14	0.16	0.11	*	*	*	0.12	0.25	*	*	*	*
0BM	0.04	0.19	0.27	*	*	*	0.02	0.03	*	*	*	*
2BM	0.01	0.03	0.00	*	*	*	0.01	0.00	*	*	*	*
4BM	0.08	1.48	0.12	*	*	*	0.01	0.01	*	*	*	*
6BM	0.04	0.02	0.00	*	*	*	0.00	0.00	*	*	*	*
4AP	0.09	**	0.11	*	*	*	0.04	0.02	*	*	*	*
6AP	0.27	0.15	0.10	*	*	*	0.09	0.20	*	*	*	*
8AP	0.16	0.35	0.33	*	*	*	0.30	0.23	*	*	*	*
2BP	**	**	**	*	*	*	0.03	0.04	*	*	*	*
4BP	0.71	0.47	**	*	*	*	1.02	0.68	*	*	*	*
6BP	0.24	1.26	1.14	*	*	*	0.29	0.21	*	*	*	*
2AC	0.08	0.03	0.13	**	**	0.02	0.03	0.03	0.02	0.04	0.03	0.02
4AC	0.06	0.03	0.00	0.03	**	0.02	0.02	0.01	0.01	0.03	0.02	0.02
6AC	0.06	0.03	0.00	0.01	**	0.01	0.03	0.01	0.00	0.02	0.01	0.01
2BC	0.06	0.04	0.01	0.01	**	0.01	0.02	0.02	0.01	0.04	0.02	0.02
4BC	0.09	0.03	0.00	0.01	**	0.01	0.02	0.01	0.01	0.04	0.02	0.02
STR	0.03	0.02	0.01	0.00	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.01
LA1	0.04	0.02	0.01	0.03	0.00	0.00	0.01	0.80	0.01	0.02	0.01	0.04
LA2	0.05	0.02	0.00	0.03	0.02	0.00	0.02	0.03	0.01	0.01	0.01	0.01
6AS	**	**	**	**	**	**	0.02	0.01	0.00	0.02	0.01	0.00
6AS2	**	**	**	**	**	**	*	*	0.00	0.02	0.02	*
6AS3	**	**	**	**	**	**	*	*	0.00	0.02	0.02	*
8AS	0.05	**	**	**	**	**	0.02	0.02	*	*	*	0.02
8A2S	0.02	**	**	**	**	**	*	*	*	*	*	*
4BS	0.03	**	**	**	**	**	0.02	0.01	0.00	0.02	0.02	0.02
4BS2	0.03	**	**	**	**	**	*	*	0.00	0.02	0.01	*
4BS3	*	**	**	**	**	**	*	*	0.00	0.02	0.02	*
6BS	0.01	**	**	**	**	**	0.02	0.02	*	*	*	0.01

\*no water collected

\*\*no water present

\*\*\*lab problem

Table 5A. (continued)

TDPO<sub>4</sub>-P  
(mg/l)

SITES	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY
0AM	0.06	0.04	0.01	*	*	*	0.01	0.01	*	*	*	*
2AM	0.03	0.08	0.01	*	*	*	0.01	0.01	*	*	*	*
4AM	0.10	0.02	0.03	*	*	*	0.01	0.01	*	*	*	*
6AM	0.04	0.01	0.01	*	*	*	0.00	0.01	*	*	*	*
8AM	0.09	0.03	0.02	*	*	*	0.02	0.02	*	*	*	*
0BM	0.04	0.01	0.01	*	*	*	0.01	0.03	*	*	*	*
2BM	0.07	0.02	0.01	*	*	*	0.01	0.01	*	*	*	*
4BM	0.10	0.03	0.01	*	*	*	0.01	0.02	*	*	*	*
6BM	0.06	0.01	0.00	*	*	*	0.00	0.00	*	*	*	*
4AP	0.06	**	0.01	*	*	*	0.02	0.01	*	*	*	*
6AP	0.12	0.02	0.02	*	*	*	0.02	0.01	*	*	*	*
8AP	0.12	0.07	0.03	*	*	*	0.06	0.01	*	*	*	*
2BP	**	**	**	*	*	*	0.02	0.02	*	*	*	*
4BP	0.15	0.02	**	*	*	*	0.18	0.11	*	*	*	*
6BP	0.06	0.14	0.07	*	*	*	0.04	0.04	*	*	*	*
2AC	0.02	0.01	0.01	**	**	0.01	0.01	0.01	0.01	0.00	0.00	0.01
4AC	0.01	0.02	0.01	0.01	**	0.01	0.00	0.01	0.01	0.00	0.00	0.01
6AC	0.02	0.03	0.01	0.00	**	0.01	0.01	0.01	0.00	0.00	0.01	0.01
2BC	0.03	0.03	0.01	0.00	**	0.01	0.00	0.01	0.01	0.01	0.01	0.01
4BC	0.01	0.03	0.01	0.00	**	0.01	0.01	0.01	0.01	0.02	0.00	0.01
STR	0.01	0.01	0.01	0.00	0.02	0.00	0.00	0.01	0.01	0.01	0.00	0.00
LA1	0.01	0.01	0.02	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.00	0.01
LA2	0.01	0.01	0.02	0.00	0.01	0.00	0.06	0.02	0.01	0.01	0.00	0.01
6AS	**	**	**	**	**	**	0.01	0.00	0.00	0.00	0.00	0.01
6AS2	**	**	**	**	**	**	*	*	0.00	0.00	0.00	*
6AS3	**	**	**	**	**	**	*	*	0.00	0.00	0.00	*
8AS	0.14	**	**	**	**	**	0.00	0.00	*	*	*	0.00
8A2S	0.13	**	**	**	**	**	*	*	*	*	*	*
4BS	0.07	**	**	**	**	**	0.00	0.01	0.01	0.00	0.00	0.01
4BS2	0.08	**	**	**	**	**	*	*	0.01	0.00	0.00	*
4BS3	*	**	**	**	**	**	*	*	0.02	0.00	0.00	*
6BS	0.09	**	**	**	**	**	0.00	0.01	*	*	*	0.01

\*no water collected

\*\*no water present

\*\*\*lab problem

Table 5A. (continued)

Mg  
(mg/l)

SITES	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY
0AM	0.96	0.89	***	*	*	*	1.84	1.78	*	*	*	*
2AM	1.11	***	***	*	*	*	0.75	0.73	*	*	*	*
4AM	0.91	***	***	*	*	*	0.59	0.51	*	*	*	*
6AM	0.25	0.24	***	*	*	*	0.23	0.19	*	*	*	*
8AM	0.64	0.68	***	*	*	*	0.52	0.51	*	*	*	*
0BM	0.89	***	***	*	*	*	0.58	0.61	*	*	*	*
2BM	0.23	***	***	*	*	*	0.82	0.29	*	*	*	*
4BM	0.32	***	***	*	*	*	0.33	0.33	*	*	*	*
6BM	0.27	***	***	*	*	*	0.16	0.15	*	*	*	*
4AP	0.63	***	***	*	*	*	0.92	0.49	*	*	*	*
6AP	***	1.05	***	*	*	*	0.52	0.50	*	*	*	*
8AP	1.22	1.52	***	*	*	*	0.53	0.41	*	*	*	*
2BP	**	**	***	*	*	*	0.75	0.58	*	*	*	*
4BP	1.01	***	***	*	*	*	0.86	0.58	*	*	*	*
6BP	0.75	***	***	*	*	*	0.68	0.65	*	*	*	*
2AC	0.42	***	***	**	**	0.70	0.59	0.50	0.53	0.44	0.37	0.46
4AC	0.33	***	***	0.36	**	0.60	0.53	0.48	0.47	0.39	***	0.39
6AC	0.31	***	***	0.32	**	0.60	0.53	0.45	0.54	***	0.37	0.43
2BC	0.43	***	***	0.50	**	0.69	0.66	0.70	0.68	0.49	0.50	0.46
4BC	0.34	***	***	0.35	**	0.68	0.66	0.55	0.55	0.50	0.43	0.48
STR	0.34	0.42	***	0.33	0.31	0.74	0.80	0.68	0.75	0.56	0.48	0.55
LA1	0.55	0.33	***	0.65	0.68	0.79	0.68	0.60	0.68	0.68	0.66	0.58
LA2	0.51	0.33	***	0.65	0.68	0.78	0.55	0.68	0.65	0.70	0.56	0.62
6AS	**	**	***	**	**	**	0.55	0.50	0.51	***	0.39	0.42
6AS2	**	**	***	**	**	**	*	*	0.53	0.43	0.39	*
6AS3	**	**	***	**	**	**	*	*	0.50	0.40	***	*
8AS	0.57	**	***	**	**	**	0.52	0.50	*	*	*	0.45
8A2S	0.49	**	***	**	**	**	*	*	*	*	*	*
4BS	0.38	**	***	**	**	**	0.72	0.68	0.55	0.50	0.45	0.45
4BS2	0.37	**	***	**	**	**	*	*	0.58	0.50	0.43	*
4BS3	*	**	***	**	**	**	*	*	0.63	0.49	0.45	*
6BS	0.49	**	***	**	**	**	0.68	0.68	*	*	*	0.51

\*no water collected

\*\*no water present

\*\*\*lab problem

Table 5A. (continued)

K  
(mg/l)

SITES	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY
0AM	0.90	0.66	***	*	*	*	0.32	0.33	*	*	*	*
2AM	1.59	***	***	*	*	*	1.26	1.22	*	*	*	*
4AM	0.52	***	***	*	*	*	0.12	0.06	*	*	*	*
6AM	0.61	1.02	***	*	*	*	0.65	0.49	*	*	*	*
8AM	0.83	0.83	***	*	*	*	0.67	0.68	*	*	*	*
0BM	0.56	***	***	*	*	*	0.30	0.43	*	*	*	*
2BM	0.56	***	***	*	*	*	0.26	0.43	*	*	*	*
4BM	0.60	***	***	*	*	*	0.44	0.34	*	*	*	*
6BM	1.37	***	***	*	*	*	0.57	0.44	*	*	*	*
4AP	0.43	***	***	*	*	*	0.17	0.08	*	*	*	*
6AP	***	0.73	***	*	*	*	0.30	0.22	*	*	*	*
8AP	0.89	0.90	***	*	*	*	0.51	0.47	*	*	*	*
2BP	**	**	***	*	*	*	0.11	0.24	*	*	*	*
4BP	0.82	***	***	*	*	*	0.48	0.31	*	*	*	*
6BP	0.57	***	***	*	*	*	0.24	0.27	*	*	*	*
2AC	0.29	***	***	**	**	0.77	0.06	0.11	0.07	0.07	0.13	0.13
4AC	0.22	***	***	0.76	**	0.26	0.07	0.06	0.01	0.06	***	0.07
6AC	0.26	***	***	0.89	**	0.20	0.03	0.08	0.02	***	0.11	0.05
2BC	0.39	***	***	0.85	**	0.43	0.04	0.07	0.02	0.05	0.09	0.06
4BC	0.20	***	***	0.06	**	0.31	0.08	0.08	0.00	0.06	0.07	0.05
STR	0.32	0.14	***	0.48	0.75	0.30	0.06	0.11	0.03	0.07	0.09	0.07
LA1	0.39	0.38	***	0.40	0.81	0.38	0.25	0.22	0.20	0.30	0.24	0.29
LA2	0.36	0.35	***	0.39	0.30	0.38	0.20	0.21	0.18	0.28	0.28	0.27
6AS	**	**	***	**	**	**	0.06	0.06	0.00	***	0.10	0.08
6AS2	**	**	***	**	**	**	*	*	0.00	0.07	0.07	*
6AS3	**	**	***	**	**	**	*	*	0.00	0.06	***	*
8AS	0.76	**	***	**	**	**	0.01	0.03	*	*	*	0.06
8A2S	0.64	**	***	**	**	**	*	*	*	*	*	*
4BS	0.18	**	***	**	**	**	0.04	0.05	0.00	0.04	0.05	0.06
4BS2	0.12	**	***	**	**	**	*	*	0.00	0.03	0.05	*
4BS3	*	**	***	**	**	**	*	*	0.00	0.03	0.05	*
6BS	0.79	**	***	**	**	**	0.07	0.06	*	*	*	0.07

\*no water collected

\*\*no water present

\*\*\*lab problem

Table 5A. (continued)

Na  
(mg/l)

SITES	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY
0AM	***	***	***	*	*	*	4.81	4.75	*	*	*	3.06
2AM	***	***	***	*	*	*	5.64	5.61	*	*	*	5.31
4AM	***	***	***	*	*	*	2.31	***	*	*	*	***
6AM	***	***	***	*	*	*	2.94	2.86	*	*	*	2.32
8AM	***	***	***	*	*	*	2.39	***	*	*	*	***
0BM	***	***	***	*	*	*	5.87	***	*	*	*	6.31
2BM	***	***	***	*	*	*	***	2.22	*	*	*	3.09
4BM	***	***	***	*	*	*	2.47	2.70	*	*	*	***
6BM	***	***	***	*	*	*	2.20	***	*	*	*	***
4AP	***	***	***	*	*	*	***	***	*	*	*	2.73
6AP	***	***	***	*	*	*	***	3.07	*	*	*	2.41
8AP	***	***	***	*	*	*	3.66	3.81	*	*	*	3.62
2BP	***	***	***	*	*	*	2.13	***	*	*	*	2.75
4BP	***	***	***	*	*	*	***	2.65	*	*	*	2.16
6BP	***	***	***	*	*	*	2.66	3.66	*	*	*	3.57
2AC	***	1.88	***	***	***	***	2.17	2.05	2.35	***	2.66	***
4AC	***	2.37	***	***	***	2.34	2.57	2.83	***	***	***	2.61
6AC	***	***	***	***	***	***	2.33	***	2.74	2.69	1.90	1.98
2BC	***	***	***	***	***	***	2.96	3.19	***	***	***	3.03
4BC	***	***	***	***	***	***	***	2.55	***	1.83	2.29	***
STR	***	***	***	***	2.39	2.77	3.19	3.89	3.62	0.03	2.60	3.49
LA1	***	3.10	***	***	3.33	2.88	3.28	3.12	***	***	***	2.94
LA2	***	3.69	***	***	***	0.62	***	2.58	***	***	***	2.34
6AS	**	**	***	**	**	**	2.02	1.75	***	***	***	**
6AS2	**	**	***	**	**	**	*	*	2.42	2.11	*	*
8AS	**	**	***	**	**	**	***	2.52	***	**	*	2.00
4BS	**	**	***	**	**	**	2.39	2.41	*	*	***	2.11
4BS3	**	**	***	**	**	**	*	*	2.32	2.07	1.99	*
6BS	**	**	***	**	**	**	2.81	2.66	*	*	*	2.51

\*no water collected

\*\*no water present

\*\*\*lab problem

Table 5A. (continued)

<u>SITES</u>	<u>AI</u> (mg/l)											
	<u>JUNE</u>	<u>JULY</u>	<u>AUG</u>	<u>SEPT</u>	<u>OCT</u>	<u>NOV</u>	<u>DEC</u>	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>	<u>APRIL</u>	<u>MAY</u>
0AM	***	***	***	*	*	*	1.76	1.95	*	*	*	1.36
2AM	***	***	***	*	*	*	2.00	1.84	*	*	*	1.70
4AM	***	***	***	*	*	*	0.11	***	*	*	*	***
6AM	***	***	***	*	*	*	0.36	0.49	*	*	*	0.42
8AM	***	***	***	*	*	*	0.45	***	*	*	*	***
0BM	***	***	***	*	*	*	0.53	***	*	*	*	3.53
2BM	***	***	***	*	*	*	**	0.17	*	*	*	0.40
4BM	***	***	***	*	*	*	0.23	0.58	*	*	*	***
6BM	***	***	***	*	*	*	0.36	***	*	*	*	***
STR	***	***	***	***	0.32	0.21	0.34	0.85	0.82	0.01	0.67	0.84
LA1	***	0.32	***	***	0.25	0.22	0.32	0.35	***	***	***	0.32
LA2	***	0.33	***	***	0.00	0.09	***	0.29	***	***	***	0.27

Mn  
(mg/l)

<u>SITES</u>	<u>JUNE</u>	<u>JULY</u>	<u>AUG</u>	<u>SEPT</u>	<u>OCT</u>	<u>NOV</u>	<u>DEC</u>	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>	<u>APRIL</u>	<u>MAY</u>
LA1	***	0.009	***	***	0.009	0.009	0.009	0.014	***	***	***	0.008
LA2	***	0.010	***	***	0.000	0.001	0.000	0.031	***	***	***	0.005

\*no water collected

\*\*no water present

\*\*\*lab problem

Table 5A. (continued)

TI  
(mg/l)

<u>SITES</u>	<u>JUNE</u>	<u>JULY</u>	<u>AUG</u>	<u>SEPT</u>	<u>OCT</u>	<u>NOV</u>	<u>DEC</u>	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>	<u>APRIL</u>	<u>MAY</u>
0AM	***	0.000	***	*	*	*	0.002	0.001	*	*	*	0.001
2AM	***	0.000	***	*	*	*	0.002	0.001	*	*	*	0.001
4AM	***	0.000	***	*	*	*	0.003	0.000	*	*	*	0.000
6AM	***	0.000	***	*	*	*	0.003	0.004	*	*	*	0.002
8AM	***	0.000	***	*	*	*	0.001	0.000	*	*	*	0.000
0BM	***	0.000	***	*	*	*	0.020	0.000	*	*	*	0.126
2BM	***	0.000	***	*	*	*	0.000	0.001	*	*	*	0.001
4BM	***	0.000	***	*	*	*	0.007	0.013	*	*	*	0.000
6BM	***	0.000	***	*	*	*	0.001	0.000	*	*	*	0.000

V  
(mg/l)

<u>SITES</u>	<u>JUNE</u>	<u>JULY</u>	<u>AUG</u>	<u>SEPT</u>	<u>OCT</u>	<u>NOV</u>	<u>DEC</u>	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>	<u>APRIL</u>	<u>MAY</u>
0AM	***	0.000	***	*	*	*	0.004	0.004	*	*	*	0.002
2AM	***	0.000	***	*	*	*	0.009	0.009	*	*	*	0.007
4AM	***	0.000	***	*	*	*	0.000	0.000	*	*	*	0.000
6AM	***	0.000	***	*	*	*	0.008	0.008	*	*	*	0.008
8AM	***	0.000	***	*	*	*	0.004	0.000	*	*	*	0.000
0BM	***	0.000	***	*	*	*	0.001	0.000	*	*	*	0.005
2BM	***	0.000	***	*	*	*	0.000	0.001	*	*	*	0.001
4BM	***	0.000	***	*	*	*	0.001	0.001	*	*	*	0.000
6BM	***	0.000	***	*	*	*	0.001	0.000	*	*	*	0.000

\*no water collected

\*\*no water present

\*\*\*lab problem