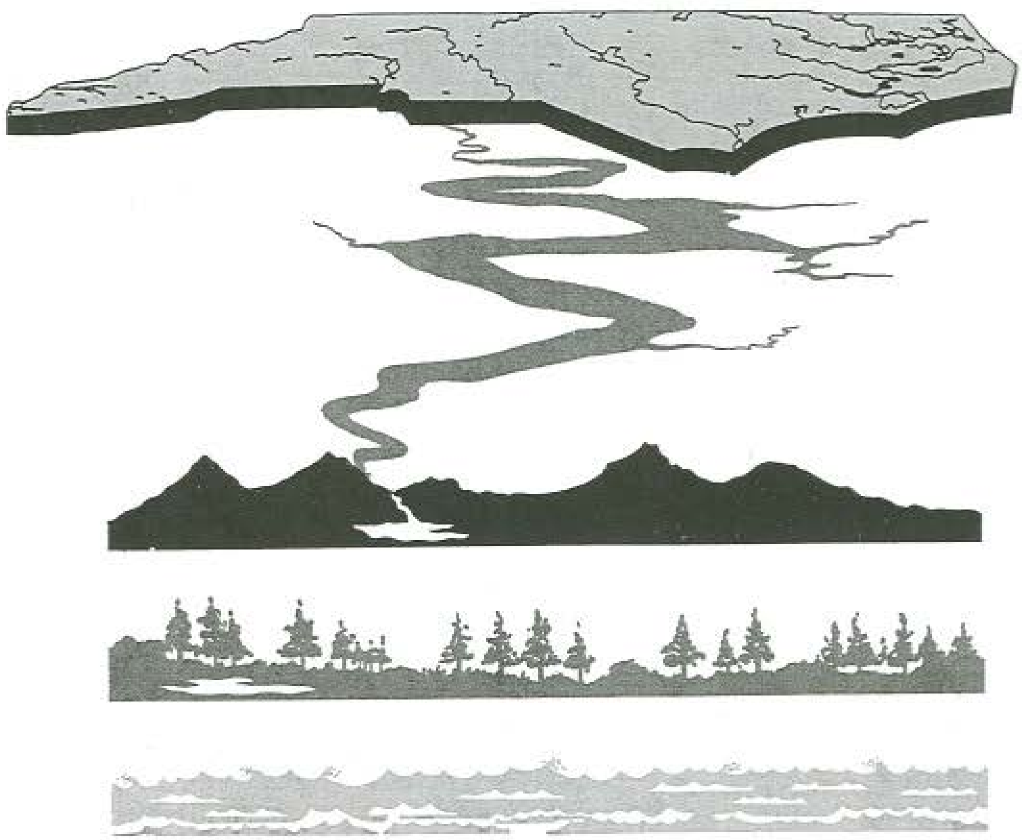
# ALBEMARLE-PAMLICO BASELINE WATER QUALITY MONITORING DATA SUMMARY 1988 - 1991



Report No. 92 - 01 January 1992

North Carolina Department of Environment, Health, and Natural Resources
Division of Environmental Management
Water Quality Section

# ALBEMARLE-PAMLICO BASELINE WATER QUALITY MONITORING DATA SUMMARY

1988-1991

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT,
HEALTH, AND NATURAL RESOURCES
Division of Environmental Management
Water Quality Section

# ALBEMARLE-PAMLICO BASELINE WATER QUALITY MONITORING DATA SUMMARY 1988-1991

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT, HEALTH, AND NATURAL RESOURCES
Division of Environmental Management
Water Quality Section

This report has been approved for release [signature]
Steve W. Tedder, Chief
Water Quality Section

Date 1/2/92

LIST OF FIGURES

LIST OF TABLES

## SUMMARY

In 1988 the Division of Environmental Management (DEM) began an expanded ambient water quality monitoring program in the Albemarle-Pamlico study area. The baseline information generated by this monitoring provides a network of physical, chemical and biological information with usefulness for researchers and water quality managers.

This report summarizes the water quality information for the Tar-Pamlico, Neuse, Roanoke, Chowan and Pasquotank river basins. When reviewing these results, it should be kept in mind that while the lower Pamlico and Neuse rivers are similar physically and hydrologically, the other basins in the Albemarle-Pamlico area have different salinity regimes and smaller drainage areas, and so can function in ways different from the Tar-Pamlico and Neuse.

In the Tar-Pamlico River basin, data indicate that tributaries to the Tar and Pamlico rivers, and the lower Pamlico River from Washington to Hickory Point, had the most frequent occurrences of hypoxia. Mean nitrogen concentrations were highest in the upper riverine stations and in some tributaries, while highest phosphorus values were found in the mainstem river stations from Tarboro to the Pamlico Sound. Algal blooms and elevated chlorophyll-a levels commonly occurred in the lower Tar-Pamlico estuary and tributaries throughout the year.

In the Neuse River basin, the productive phytoplankton community in the lower estuary is reflected in the elevated pH values, supersaturated dissolved oxygen conditions, and elevated chlorophyll-a values.

Stratified dissolved oxygen conditions rarely occurred in the Roanoke River basin. The pH values reflected the swamp-like nature of the Cashie River and tributary stations. Nutrient concentrations were generally low, as were chlorophyll-a values at all stations.

In the Chowan River basin, dissolved oxygen levels were lowest in the Wiccacon River, while stratification occurred at the lower Chowan River stations. Nutrient levels were highest during the winter season. Algal blooms occurred frequently in the summer and early fall in the Chowan River.

For the Pasquotank River basin, dissolved oxygen values were lower at most upstream stations (with adjacent swamps), while stratification occurred at several Albemarle Sound stations and on the Alligator River at Cherry Ridge Landing. Algal blooms were recorded at stations in Albemarle Sound, in Currituck Sound and at the lower Alligator River station.

Metals were generally below the laboratory detection level in the study area.

# INTRODUCTION

As part of the negotiated designation agreement between the U. S. Environmental Protection Agency (USEPA) and the Albemarle-Pamlico Estuarine Study (APES), a plan to acquire baseline water quality information throughout the APES area was finalized in March 1988. The combined expertise of state and federal staff (USEPA, US Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), APES, NC Division of Environmental Management (DEM), and NC Division of Marine Fisheries (DMF) were utilized in the development of this plan. DEM and USGS staff have invested significant time and resources in coordinating the project in response to EPA guidance. This coordination in project design has greatly improved the usefulness of collected information by both government agencies and researchers.

The project design accounts for spatial variability within the system with as much resolution as is feasible within fiscal limitations. Temporal variability can only be addressed through continuation of baseline data collection. Comprehensive baseline information is useful to researchers conducting intensive work within localized areas for interpreting their results relative to spatial and temporal variability within the system. Such data are also useful on a regional or national basis for comparisons of baseline data between large estuarine systems. Another primary benefit of this project is the acquisition of nutrient data within a major estuary in coordination with a relatively large effort by USGS to identify water movement. The combined information should improve efforts to develop nutrient budgets. The component parts of this study were carefully tailored in response to EPA's guidance to:

- construct a comprehensive baseline dataset to characterize the water quality and biological resources of the Albemarle-Pamlico system;
- develop by November 1992 a continuing monitoring program which is intended to evaluate the long-term status of this important estuarine system and measure success of management strategies.

Design of this baseline program was in accordance with a specific request of EPA in response to the Office of Marine and Estuarine Protection's interpretation of Clean Water Act requirements.

An extensive review of existing and historical water quality information was conducted to assess needs within the ambient network. The location of tide gages and continuous monitoring sites by USGS were also considered in selection of new sites and reactivation of old sites. New stations were transect arranged, in the areas of highest concern, to correspond with flow modeling efforts and maximize spatial coverage. The coordinated plan results in a network of physical, chemical, and biological information with maximum utility for researchers and managers.

## STATION LOCATIONS AND PARAMETRIC COVERAGE

This report provides a summary of the data collected by DEM from 1988 through September 1991 at the water quality stations in the A/P area. Figure 1 presents the sampling sites of this expanded ambient water quality network, and the following list identifies the parameters sampled at these stations.

| AMBIENT WATER QUALITY NETWORK PARAMETRIC COVERAGE | | | |
|---|---|---|---|
| Dissolved oxygen | Chloride | $PO^4$ | Iron |
| Temperature | Chlorophyll-a Tri | Aluminum | Lead |
| pH | Chlorophyll-a Corr | Arsenic | Manganese |
| Conductivity | Pheophytin a | Beryllium | Mercury |
| Salinity | $NH^3$ as N | Cadmium | Nickel |
| Residue Total | TKN as N | Chromium | Selenium |
| Residue Suspended | $NO^2 + NO^3$ | Copper | Silver |
| Turbidity | P Total | Cyanide | Zinc |

Sampling frequency varied with parametric coverage but generally involved collections once monthly throughout the network. Table 1 provides station locations and parameters sampled by river basin.

Water quality standards are developed and identified in the North Carolina Administrative Code (NCAC) to protect surface water quality for designated uses. The use of "standard" in this report will refer to those standards published in 15A NCAC 2B .0100 and 5A NCAC 2B .0200. The adopted water quality standards relate to the condition of waters as affected by the discharge of sewage, industrial wastes or other wastes including those from nonpoint sources and other sources of water pollution. Water quality standards are not considered violated when values outside the normal range are caused by natural conditions.

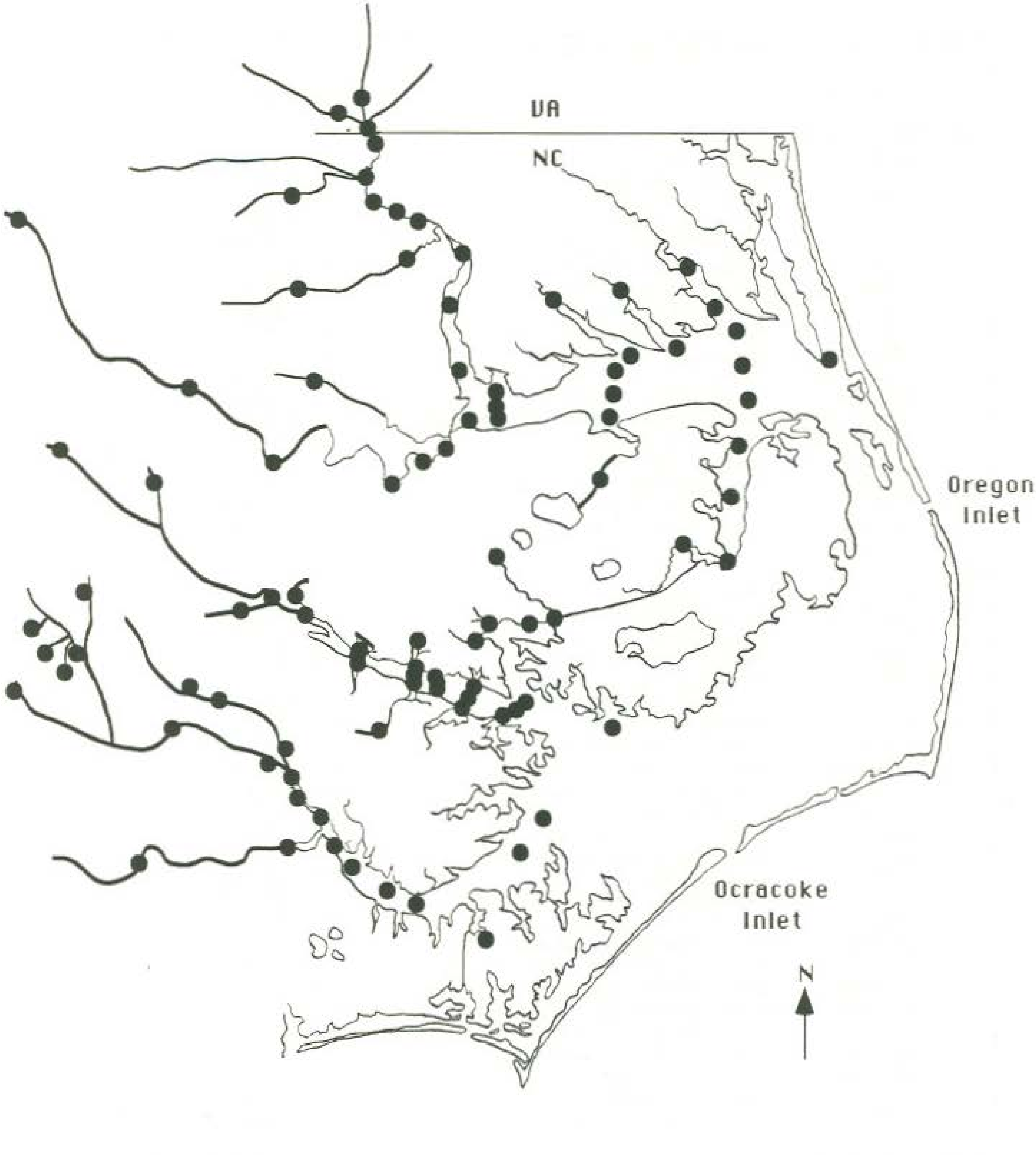



FIGURE 1. AMBIENT WATER QUALITY STATIONS
ALBEMARLE-PAMLICO STUDY AREA

TABLE 1. Station Locations and Parameters by River Basin

| STATION # | DESCRIPTION | PARAMETERS |
|---|---|---|
| TAR-PAMLICO RIVER BASIN | | |
| 02083500 | Tar R @ Tarboro | P,T,N |
| 02083800 | Conetoe Cr nr Bethel | P,T,N,M,F |
| 02084160 | Chicod Cr nr Simpson | P,T,B |
| 02084171 | Tar R nr Grimesland | P,T,N,M,BP,F |
| 02084392 | Tranters Cr nr Washington | P,T,N,M,BP,F |
| 02084472 | Pamlico R @ Washington | P,T,N,M,BP,F * |
| 0208451950 | Pamlico R @ mouth of Broad Cr | P,T,N,M,BP,F * |
| 02084534 | Bath Cr nr Bath (Hwy 92) | P,T,N,M,BP,F |
| TAR057G | Pamlico R @ Light 5 nr Cove Pt | P,T,N,M,BP,F * |
| 02084540 | Durham Cr @ Edwards | P,T,N |
| TAR0581A | Pamlico R @ Light 4 nr Gum Pt | P,T,N,M,BP,F * |
| 0208454450 | Pamlico R @ Hickory Pt | P,T,N,M,BP,F * |
| 0208457020 | Pungo Cr @ Hwy 92 @ Sidney Crossroads | P,T,N,M,F |
| 0208455850 | Pantego Cr @ Belhaven | P,T,N,M,F |
| 02084557 | Van Swamp @ Hwy 32 nr Hoke | P,T,N,M,F |
| 0208455650 | Pungo R @ Hwy 264 nr Ponzer | P,T,N,M,BP,F |
| TAR064 | Pamlico R @ Pungo | P,T,N,M,BP,F * |
| 02092690 | Pamlico Sound @ Great Island | P,T,N,M,BP,F * |
| NEUSE RIVER BASIN | | |
| 02089500 | Neuse R @ Kinston | P,T,N,M,B,BP |
| 02090380 | Contentnea Cr nr Lucama | P,T,N,M,B |
| 02090625 | Turner Swamp nr Eureka | P,T,N,M,B |
| 02091000 | Nahunta Swamp nr Shine | P,T,N,M,B |
| 02091500 | Contentnea Cr @ Hookerton | P,T,N,M,B |
| 02091700 | Little Contentnea Cr nr Farmville | P,T,N,M,B |
| 0209176690 | Contentnea Cr @ Grifton | P,T,N,M,B |
| 02091814 | Neuse R nr Fort Barnwell | P,T,N,M,BP |
| 02091836 | Neuse R @ Streets Ferry | P,T,N,M,B,BP * |
| 02091970 | Creeping Swamp nr Vanceboro | P,T,N,M,B |
| 02092000 | Swift Cr nr Vanceboro | P,T,N,M,B |
| 02092084 | Swift Cr @ mouth nr Askin | P,T,N,M,BP,F * |
| 02092092 | Neuse R below Swift Cr nr Askin | P,T,N,M,BP,F * |
| 02092109 | Neuse R @ Narrows | P,T,N,M,BP,F * |
| 02092162 | Neuse R @ New Bern | P,T,N,M,BP * |
| 02092500 | Trent R nr Trenton | P,T,N,M |
| 0209256050 | Trent R above Reedy Br nr Rhems | P,T,N,M,BP,F * |
| 0209257120 | West Prong Brice Cr nr Riverdale | P,T,N,M,B |
| 02092586 | Neuse R @ mouth of Broad Cr nr Thurman | P,T,N,M,BP * |
| NEU131F | Neuse R @ Light #22 nr Fairfield Harbor | P,T,N,BP |
| NEU131X | Neuse R @ Light #11 nr Riverdale | P,T,N,BP * |
| NEU139 | Neuse R nr Minnesott Beach | P,T,N,M,BP * |
| 0209266890 | Back Cr nr Merrimon | P,T,N,M |
| 02092674 | Neuse R nr Oriental | P,T,N,M,BP,F * |
| 02092682 | Neuse R @ mouth nr Pamlico | P,T,N,M,BP,F * |
| ROANOKE RIVER BASIN | | |
| 02080500 | Roanoke R @ Roanoke Rapids | P,T,M,B |
| 02081000 | Roanoke R nr Scotland Neck | P,T,N,M |
| 02081022 | Roanoke R nr Lewiston | P,T,M,B,F |
| 02081054 | Roanoke R @ Williamston | P,T,N,M,B |
| 02081101 | Cashie R nr Lewiston | P,T,N,M,B,F |
| 02081135 | Roanoke R nr Plymouth | P,T,N,M,BP,B * |

| | | |
|---|---|---|
| 02081141 | Roanoke R @ Sans Souci | P,T,N,M,BP,B * |
| 0208114330 | Albemarle Sound (Batchelor Bay) | P,T,N,F * |
| CHOWAN RIVER BASIN | | |
| 02047370 | Nottaway R nr Riverdale | P,T,N,F * |
| 02050065 | Blackwater R @ Horseshoe Bend | P,T,N,BP,F * |
| 0205007750 | Blackwater R nr Wyanoke | P,T,N,BP,F * |
| 02050079 | Chowan R nr Riddicksville | P,T,N,BP,F * |
| 02053200 | Potecasi Cr nr Union | P,T,N,BP |
| 0205321790 | Meherrin R (Parkers Ferry) nr Como | P,T,N,M,B,F * |
| 02053244 | Chowan R @ Winton | P,T,N,B,BP,F * |
| 0205325510 | Chowan R @ Channel Marker # 27 | P,T,N,B,BP,F * |
| 02053500 | Ahoskie Cr @ Ahoskie | P,T,N,M,B,BP |
| 02053574 | Chowan R nr Gatesville (Marker # 16) | P,T,N,BP,F * |
| 0205360615 | Chowan R below Holiday Island | P,T,N,M,BP,F * |
| 02053569 | Wiccacon R nr Harrelsville | P,T,N,BP |
| 02053632 | Chowan R @ Colerain | P,T,N,BP,F * |
| 02053652 | Chowan R @ Edenhouse | P,T,N,M,BP * |
| PASQUOTANK RIVER BASIN | | |
| 02042955 | Currituck Sound @ Point Harbor | P,T,N,BP * |
| 02043859 | Pasquotank R @ RR Bridge nr Elizabeth City | P,T,N,M * |
| 02043862 | Pasquotank R @ Elizabeth City | P,T,N,M,F * |
| 02043878 | Pasquotank R @ Buoy FL"5"Sec nr Old Trap | P,T * |
| 02043882 | Little R @ Woodville | P,T,N |
| 02043884 | Little R nr Weeksville (Buoy # 4) | P,T * |
| 02081179 | Albemarle Sound nr Frog Island | P,T,N,BP * |
| 02043892 | Perquimans R @ Hertford | P,T,N |
| 0208455655 | Intracoastal Waterway @ US Hwy 264 | P,T * |
| 02043906 | Perquimans R @ Harvey Point | P,T,N,F * |
| 02081172 | Albemarle Sound btwn Harvey Pt & Mill Pt | P,T,N,BP,F * |
| 02081145 | Albemarle Sound nr Edenton (Buoy #R"4") | P,T,N,BP,F * |
| 02081185 | Kendricks Cr @ Mackeys | P,T,N,M |
| 02081166 | Scuppernong R nr Columbia | P,T,N,BP |
| 0208117810 | Alligator R us Cherry Ridge Landing | P,T,N,BP * |
| 0208117820 | Alligator R @ Newport News Pt | P,T,N,BP * |
| 0208117830 | Alligator R 3 miles us Catfish Pt | P,T,N,BP * |
| 0208117840 | Alligator R @ US Hwy 6 | P,T,N,BP * |

P (Physical parameters - D.O., pH, temperature, conductivity)
T (Turbidity); N (Nutrients); M (Metals);
BP (Phytoplankton and/or chlorophyll-a), B (BOD), F (fecals), * (secchi depth)

*Dissolved oxygen.* The water quality standard for dissolved oxygen is 5.0 mg/l for all surface waters, except designated swamp waters which may have lower values if due to natural conditions. When dissolved oxygen is depleted to near zero levels the waters are said to be hypoxic. When dissolved oxygen is at zero in the water column the condition is called anoxia. Hypoxia and anoxia are commonly occurring conditions in estuaries throughout the world. Monthly sampling provides sketchy information on the frequency of hypoxia and anoxia; therefore, care must be taken when interpreting monthly dissolved oxygen sampling results. USGS has established several continuous monitoring stations in the Albemarle-Pamlico estuarine areas to provide information on the frequency and duration of hypoxic and anoxic events. Data from these continuous monitors will prove invaluable for documenting hypoxia and anoxia in the system.

*pH*. pH is the measure of the concentration of hydrogen ions in solution. The standard for pH is 6.0 to 9.0 standard units (s.u.) for freshwater and 6.8 to 8.5 s.u. for tidal saltwaters.

*Secchi depth and Turbidity*. Secchi depth and turbidity measurements give an indication of light penetration within a water body. This information is useful in determining potential for phytoplankton and aquatic macrophyte growth, especially the growth of submerged aquatic vegetation (SAV). Secchi depth is a measure of light penetration and is used to determine the photic zone or depth of water in which photosynthesis can occur. An increase in phytoplankton growth and siltation would decrease the secchi depth. Turbidity and phytoplankton populations both affect the secchi depth.

Turbidity depends on the amount of suspended materials, the production of organic matter, and the tidal currents and storms which can resuspend sediments (Gulicher 1967). Turbidity in estuaries is variable and higher than in neighboring marine waters (Darnell 1967). High turbidity limits the growth of most phytoplankton and rooted matter (Day 1952) and promotes the growth of surface algae such as Anabaena and Microcystis (Darnell 1967). Turbidity standards for both freshwater (50 Nephlometric Turbidity Units - NTU) and tidal saltwater (25 NTU) were used for assessing turbidity values.

*Metals*. Due to bioaccumulation and detrimental effects on different life history stages of aquatic fauna, metals analysis is important in the aquatic ecosystem. During 1988 through 1991 water column metal samples were taken on a quarterly basis. This type of sampling does not provide an assessment of all the metals that may be available to aquatic organisms as many of the metals in aquatic systems are bound up in the sediment and are released periodically during mixing and anoxic events. Water column metals may be increased due to allocthonous inputs and/or by autochthonous mechanisms.

*Nitrogen and Phosphorus*. Research has shown that overenrichment of nutrients (nitrogen and phosphorus) is the major cause of accelerated eutrophication. For most lake systems phosphorus has been identified as the limiting nutrient. In the estuarine system, nitrogen and to a lesser extent phosphorus usually appear to be the controlling factors. The most graphic examples of eutrophication are the green and blue-green scums seen on ponds and slow moving rivers and estuaries. In recognition of the role that nutrients play in the eutrophication process, DEM has set in-stream nutrient targets or upper limits that can be used for waste load modeling purposes. Target levels for nitrogen, where nitrogen would be a factor in phytoplankton growth if no other factor such as flow, turbidity, or phosphorus was limiting, were established as guidelines. The target level for a flowing river is 1.0 mg/l for TN. The target level for total phosphorus was established as 0.1 mg/l. These targets are used in fresh waters for situations where the retention time is seven or more days. Estuarine waters are more complex and evaluation of nitrogen and phosphorus concentrations relative to growth response needs to be conducted for specific zones.

*Biochemical Oxygen Demand.* Biochemical oxygen demand (BOD) is a measure of the amount of oxygen used in the biological process of degradation and decomposition of organic matter. Effluent from wastewater treatment plants, degradation of large algal populations, or direct delivery of organic matter from adjacent tributaries could result in elevated values of BOD. BOD is considered high when values exceed 5.0 mg/l and may indicate the presence of a source of organic matter.

*Phytoplankton and Chlorophyll-a.* Phytoplankton biovolume and density estimates along with supporting chlorophyll-a provide information about the primary productivity or trophic status of a waterbody. At phytoplankton biovolume estimates above 5,000 $mm^3/m^3$ and density estimates greater than 10,000 units/ml, algal bloom conditions are considered to exist. Chlorophyll-a values approaching or greater than the state standard of 40 ug/l also are indicative of algal blooms. During blooms or periods of increased algal activity, elevations in surface dissolved oxygen and pH values often occur as a result of photosynthesis during the day.

*Fecal Coliform Bacteria.* Fecal coliforms are important indicators of bacteria which may be detrimental to human health. The state standard for fecal coliforms for freshwaters and all tidal salt waters states that fecal coliforms are not to exceed geometric mean of 200 membrane filter fecal coliform colonies (MFFCC) per 100 ml based upon at least five consecutive samples examined during any 30-day period; and are not to exceed 400/100 ml in more than 20 percent of the samples examined during such period. For shellfishing (SA) waters the standard states: fecal coliform group not to exceed a median MF of 14/100 ml and not more than 10 percent of the samples shall exceed an MF count of 43/100 ml in those areas most probably exposed to fecal contamination during the most unfavorable hydrographic and pollution conditions (15A NCAC 2B .0200).

## METHODS

Temperature, dissolved oxygen, pH, salinity, and conductivity measurements were taken with a Hydrolab Surveyor II at 0.15 meter below the surface at all stations. In addition, depth profiles, where measurements were also taken at each successive one meter until the bottom, were conducted at stations where stratification might be expected. DEM's Chemical Physical Standard Operations Manual (NC DEHNR 1989) quality control procedures were followed.

Nitrogen and phosphorus series, turbidity, BOD, chlorophyll-a series, and phytoplankton samples were taken using a Labline sampler pulled slowly through the photic zone. The photic zone was considered to be twice the secchi depth. The average of the depths obtained by lowering a secchi disc from the shaded side of the boat until it disappeared and then raising it until it reappeared was considered the secchi depth. Samples were preserved, placed on ice, and transported to the laboratory.

Laboratory analyses of the chemical samples were performed at DEM's Chemistry Laboratory and Washington Regional Laboratory using EPA approved standard methods (American Public Health Association 1985). Phytoplankton samples were analyzed by the Biological Assessment Group in accordance with DEM's Standard Operating Procedures Biological Monitoring Manual (NC DEHNR 1990) using a modification of Utermohl's inverted microscope technique (Utermohl 1958).

Throughout the report, box and whisker plots are frequently used for graphical illustration of data using Statview II software on Macintosh computers. The top and bottom of the box represent the 75th and 25th percentiles respectively (which measures the distribution and variability of the bulk of the data), while the horizontal line, often occurring as a midline in the box, represents the median value. The distribution of remaining data points, between the 10th percentile and the 90th percentile, are indicated by vertical lines or whiskers. Extreme values below the 10th percentile and above the 90th percentile are denoted by dots.

## RESULTS AND DISCUSSION

Data will be discussed by river basin with separate sections for the Tar-Pamlico, Neuse, Roanoke, Chowan, and Pasquotank basins. Each section provides a watershed description, a figure showing sampling locations and discussion of physical data including metals, nutrients, and biological data collected.

# TAR-PAMLICO RIVER BASIN

As the fourth largest basin in North Carolina, the Tar-Pamlico has a drainage area of 5,400 square miles. The estuarine portion consists of 634,400 acres. The saltwater portion of the Tar-Pamlico is almost twice that of the Neuse. As the Tar River reaches Washington, it slows, widens and becomes the Pamlico River.

In the upper section of the Tar-Pamlico basin where cropland constitutes 15 percent of all land use, erosion rates are higher than the state average. In the coastal plain, agriculture and forestry are the main land uses. An increase in agricultural activities has resulted in the draining of large expanses of land into the Pamlico's brackish waters. Water quality problems have been caused by the resulting agricultural runoff and there is concern that freshwater intrusion may be harmful to inhabitants of the primary nursery areas. Effluent from municipal WWTPs constitute another major cause of water quality degradation in the Pamlico. There are 128 permitted surface water dischargers to both fresh and saltwater in the basin. Of these, 21 are municipal WWTPs and 127 are nonmunicipal WWTPs (NC DEHNR 1990a). There were 18 sampling stations in the Tar-Pamlico River Basin and these are shown in Figure TP-A and listed below:

| STATION # | DESCRIPTION | PARAMETERS |
|---|---|---|
| TAR-PAMLICO RIVER BASIN | | |
| 02083500 | Tar R @ Tarboro | P,T,N |
| 02083800 | Conetoe Cr nr Bethel | P,T,N,M,F |
| 02084160 | Chicod Cr nr Simpson | P,T,B |
| 02084171 | Tar R nr Grimesland | P,T,N,M,BP,F |
| 02084392 | Tranters Cr nr Washington | P,T,N,M,BP,F |
| 02084472 | Pamlico R @ Washington | P,T,N,M,BP,F * |
| 0208451950 | Pamlico R @ mouth of Broad Cr | P,T,N,M,BP,F * |
| 02084534 | Bath Cr nr Bath (Hwy 92) | P,T,N,M,BP,F |
| TAR057G | Pamlico R @ Light 5 nr Cove Pt | P,T,N,M,BP,F * |
| 02084540 | Durham Cr @ Edwards | P,T,N |
| TAR0581A | Pamlico R @ Light 4 nr Gum Pt | P,T,N,M,BP,F * |
| 0208454450 | Pamlico R @ Hickory Pt | P,T,N,M,BP,F * |
| 0208457020 | Pungo Cr @ Hwy 92 @ Sidney Crossroads | P,T,N,M,F |
| 0208455850 | Pantego Cr @ Belhaven | P,T,N,M,F |
| 02084557 | Van Swamp @ Hwy 32 nr Hoke | P,T,N,M,F |
| 0208455650 | Pungo R @ Hwy 264 nr Ponzer | P,T,N,M,BP,F |
| TAR064 | Pamlico R @ Pungo | P,T,N,M,BP,F * |
| 02092690 | Pamlico Sound @ Great Island | P,T,N,M,BP,F * |

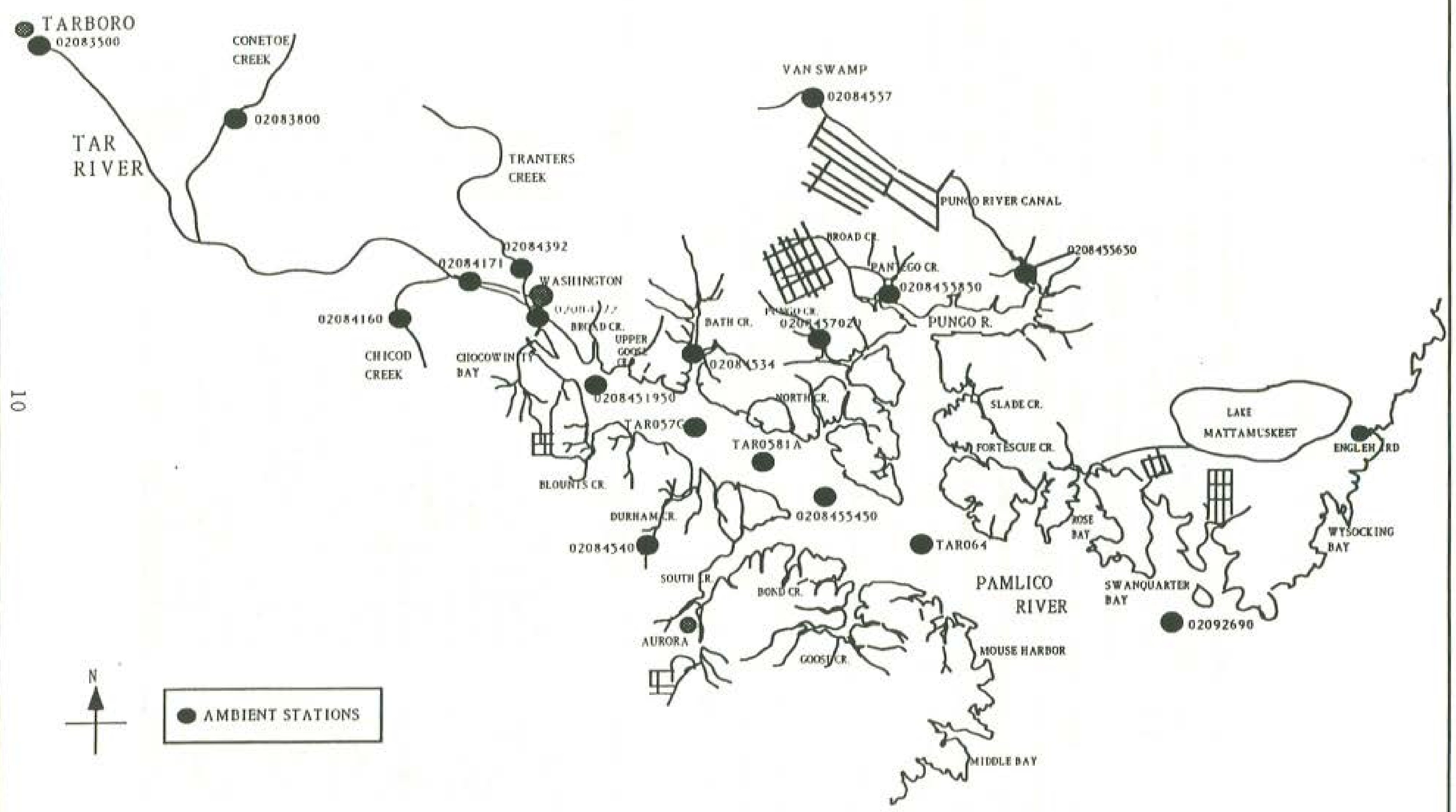



FIGURE TP-A AMBIENT STATIONS IN THE TAR-PAMLICO RIVER BASIN

Physical Data

*Flow.* Following wide fluctuations in January and February 1988, river flows were below normal during the remainder of 1988 until mid-February 1989. River flow increased at that time and continued to stay above average until June of 1990. August 1990 experienced high flows after a dry mid-summer. In the fall of 1990, river flow fell below normal and remained below average through the fall of 1991, with the exception of January and March 1991.

*Temperature and Dissolved Oxygen.* Surface temperatures ranged from 0 to 31°C, with January through March 1988 being the coldest months. Depth profile information was only collected from Washington to the Sound; therefore thermal stratification in the upper Tar River could not be measured. From Washington to the Sound, top and bottom temperature differences were never greater than 3°C.

Surface dissolved oxygen concentrations ranged from 0.2 mg/l in Chicod Creek (890914) to 12.8 mg/l in the Pamlico River at the mouth of the Pungo (5%) (900103 and 900201). Forty-nine percent of the dissolved oxygen concentrations taken at Chicod Creek were below 5 mg/l. Chicod Creek is slow moving and swamp-like with naturally low dissolved oxygen; therefore, the state standard for dissolved oxygen (15A NCAC 2B.0211b) is not applicable. Benthic macroinvertebrate sampling at this site in 1990 resulted in a poor bioclassification due to organic loading from poultry and swine operations (NC DEHNR 1991).

Highest dissolved oxygen concentrations and percent saturation occurred in the Pamlico River below Washington. Photosynthetic activity associated with algal populations can result in increased DO and pH concentration during the day. Table TP1 lists stations, number of DO samples taken, number of DO samples greater than or equal to 110 percent saturation and percent of samples at or below 5 mg/l. Dissolved oxygen concentrations below 5 mg/l may be detrimental to aquatic life. The data indicate that tributaries to the Tar and Pamlico rivers had the most frequent occurrences of hypoxia. As noted above Chicod Creek is affected by nonpoint sources. Conetoe Creek, although not classified swamp waters, is similar to the Chicod with slow moving waters. Tranters Creek and Van Swamp are classified swamp waters allowing for naturally low dissolved oxygen levels. Pantego Creek, Pungo Creek and Pungo River drain swamps; however, they also drain agricultural areas (NC DEHNR 1990a). The Pamlico River from Washington to Light 4 near Gum Point is where most algal activity is occurring, resulting in increased incidence of supersaturation.

Low dissolved oxygen in the Tar-Pamlico River occurred most frequently in the lower Pamlico from Washington to Hickory Point. At Washington, the Pamlico River slows, widens and has more salt wedges. The density gradient between salt and fresh waters inhibits mixing of the bottom waters with the oxic surface waters. In 95 out of 114 occurrences of bottom dissolved oxygen concentrations less than 5 mg/l a salt wedge was present with a difference of 3 to 5 ppt between the surface and bottom waters.

Table TP 1. Tar-Pamlico basin sites with dissolved oxygen values<=5mg/l

| STATIONS | N | # DO <= 110% Saturation | % DO <= 5 mg/l |
|---|---|---|---|
| RIVER | | | |
| Tar R @ Tarboro* | 49 | 0 | 0 |
| Tar R @ Grimesland* | 37 | 0 | 8 |
| Pamlico Cr @ Washington | 155 | 2 | 14 |
| Pamlico R @ Broad Cr (T) | 291 | 20 | 13 |
| Pamlico R @ light 5 | 373 | 15 | 15 |
| Pamlico R @ Hickory PT | 351 | 6 | 11 |
| Pamlico R @ Pungo | 399 | 5 | 5 |
| Pamlico Sound @ Great Island | 55 | 0 | 0 |
| TRIBUTARIES | | | |
| Conetoe Cr* | 34 | 0 | 9 |
| Chicod Cr nr Simpson* | 35 | 0 | 49 |
| Tranters Cr nr Washington* | 18 | 1 | 17 |
| Bath Cr nr Bath | 81 | 6 | 12 |
| Durham Cr @ Edwards* | 13 | 0 | 62 |
| Pungo Cr @ Hwy 92 | 114 | 3 | 29 |
| Pantego Cr @ Belhaven | 85 | 0 | 16 |
| Van Swamp @ Hwy 32* | 33 | 0 | 27 |
| Pungo R @ Hwy 264 | 110 | 0 | 41 |

* indicates DO was sampled at the surface only.

There is some concern that the incidences of hypoxia and anoxia are increasing in the Pamlico River. Stanley (1988) found that anoxia in the Pamlico is wind dependent, and anoxia disappears as fast as it appears, making monthly samples unsuitable for determination of the duration of anoxia.

Between years, there were no major variations in mean temperatures and dissolved oxygen concentrations.

*pH*. The standard for pH is 6.0 to 9.0 standard units (s.u.) for freshwater and 6.8 to 8.5 s.u. for tidal saltwaters. The pH values in the Tar-Pamlico Basin ranged from 3 to 9.5 s.u. with highest values occurring in the lower Pamlico River and lowest values occurring in Durham Creek and Van Swamp. Both Durham Creek and Van Swamp are tannic waters, which commonly have low pH. The higher pH values in the Pamlico River were usually associated with elevated DO and chlorophyll-a concentrations. Table TP 2 presents data from the Pamlico River with the number of pH values at or above 8.5, number of chlorophyll-a concentrations greater than or equal to 20 µg/l, and number of DO observations greater than 110 percent saturation. For the eight stations exhibiting pH values above 8.5, chlorophyll-a concentrations were above 20 µg/l and percent saturation greater than 110 percent in at least 50 percent of the samples from the river and tributary stations.

TABLE TP 2. pH values exceeding 8.5 SU with associated chlorophyll-a concentrations and percent saturation, Tar-Pamlico River Basin

| LOCATION | N | pH >= 8.5 ()=% of N | CHLA >=20 ()= % of pH | %SAT>=110% ()= % of %SAT |
|---|---|---|---|---|
| RIVER | | | | |
| Pamlico R @ Broad Cr. | 87 | 12 (14) | 11 (92) | 9 (75) |
| Pamlico R @ Light 5 | 84 | 23 (27) | 17 (74) | 14 (61) |
| Pamlico R @ Light 4 | 65 | 19 (29) | 10 (53) | 15 (79) |
| Pamlico R @ Hickory Pt | 87 | 8 (9) | 6 (75) | 5 (62) |
| Pamlico R @ mouth Pungo | 63 | 6 (10) | 3 (50) | 4 (67) |
| Pamlico Sound @ Great Island | 11 | 1 (9) | 1(100) | 0 (0) |
| TRIBUTARY | | | | |
| Bath Cr nr Bath | 39 | 7 (18) | 6 (86) | 5 (62) |
| Pungo Cr @ Hwy 92 | 28 | 2 (7) | 2 (100) | 2 (100) |

*Conductivity and Salinity.* At Washington the Pamlico River becomes brackish water as is evidenced by the salinity and conductivity box plots in Figure TP 1A. Saltwater may travel upstream as far as Grimesland (02084171) as was evident on October 4 and November 2, 1988, when the surface salinity was one ppt. The summer of 1988 was very dry, and resultant low inflows of freshwater allowed salt wedges to travel further upstream. Depth profile information was not taken above Washington, therefore the exact extent of salt wedges during this low flow period is not known.

Conductivities in the Tar River ranged from 57 to 142 µmhos with Conetoe and Chicod creeks ranging from 72 to 867 µmhos. The value of 867 µmhos was measured at Chicod Creek on September 14, 1989, and appears to be due to high turbidity (120 NTU), probably attributable to rainfall.

Salinity and conductivity varied on a seasonal and yearly basis with lowest spring salinities and conductivities occurring in the spring (April and May) each year (Figure TP 1B). Late winter and early spring are usually periods of high flow and rainfall which decreases salinities in the upper estuary.

As would be expected, highest salinities and conductivities were usually seen in the Pamlico Sound at Great Island. Salinities at this station ranged from 11 to 21.5 ppt; while conductivities were from 17500 to 31000 µmhos. Salinities within the Pamlico River from Washington to the Sound ranged from 0 to 19 ppt with conductivities of 62 to 37600 µmhos.

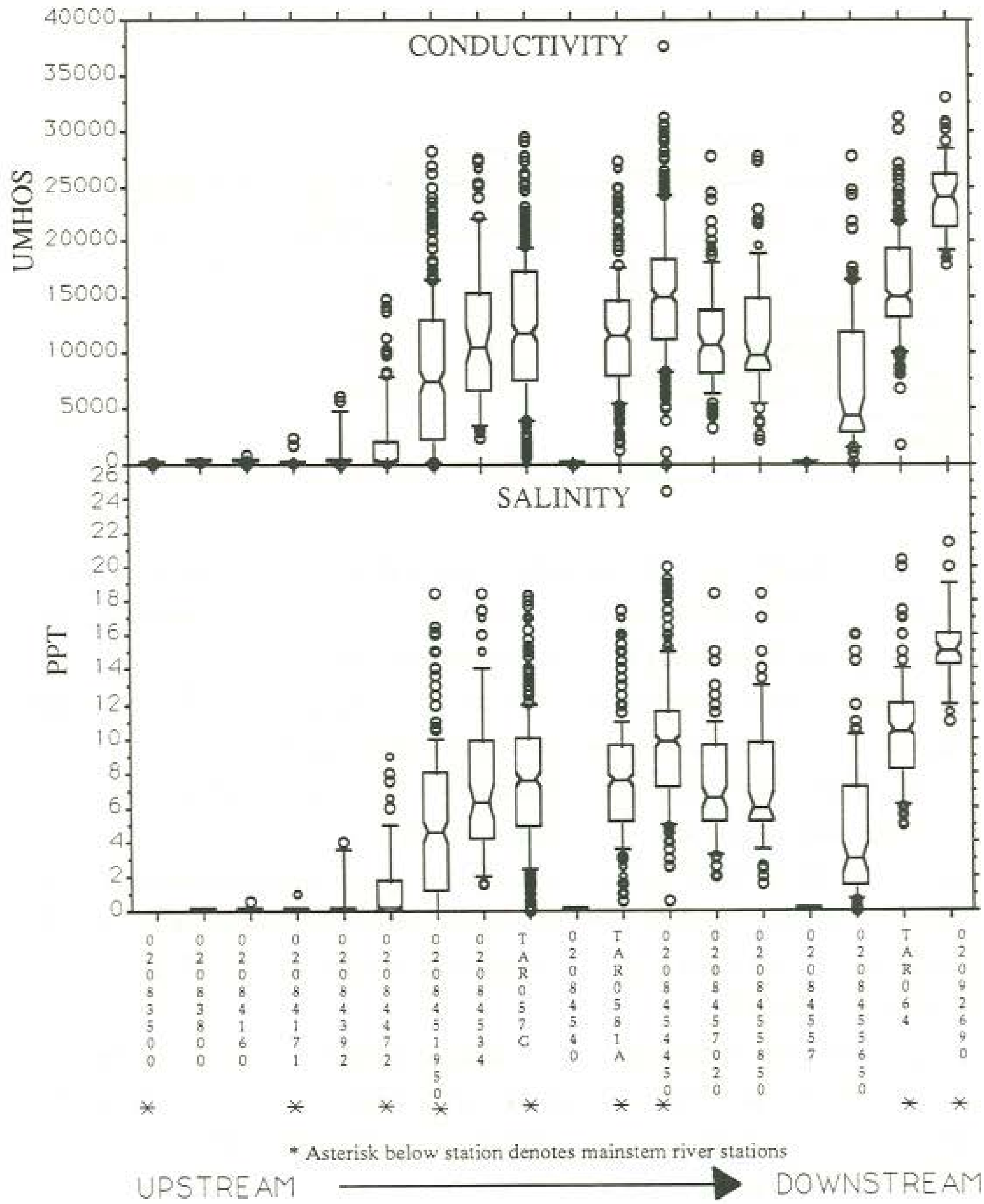



**Figure TP1A. CONDUCTIVITY AND SALINITY VALUES IN THE TAR-PAMLICO RIVER SYSTEM 1988 - 1991**

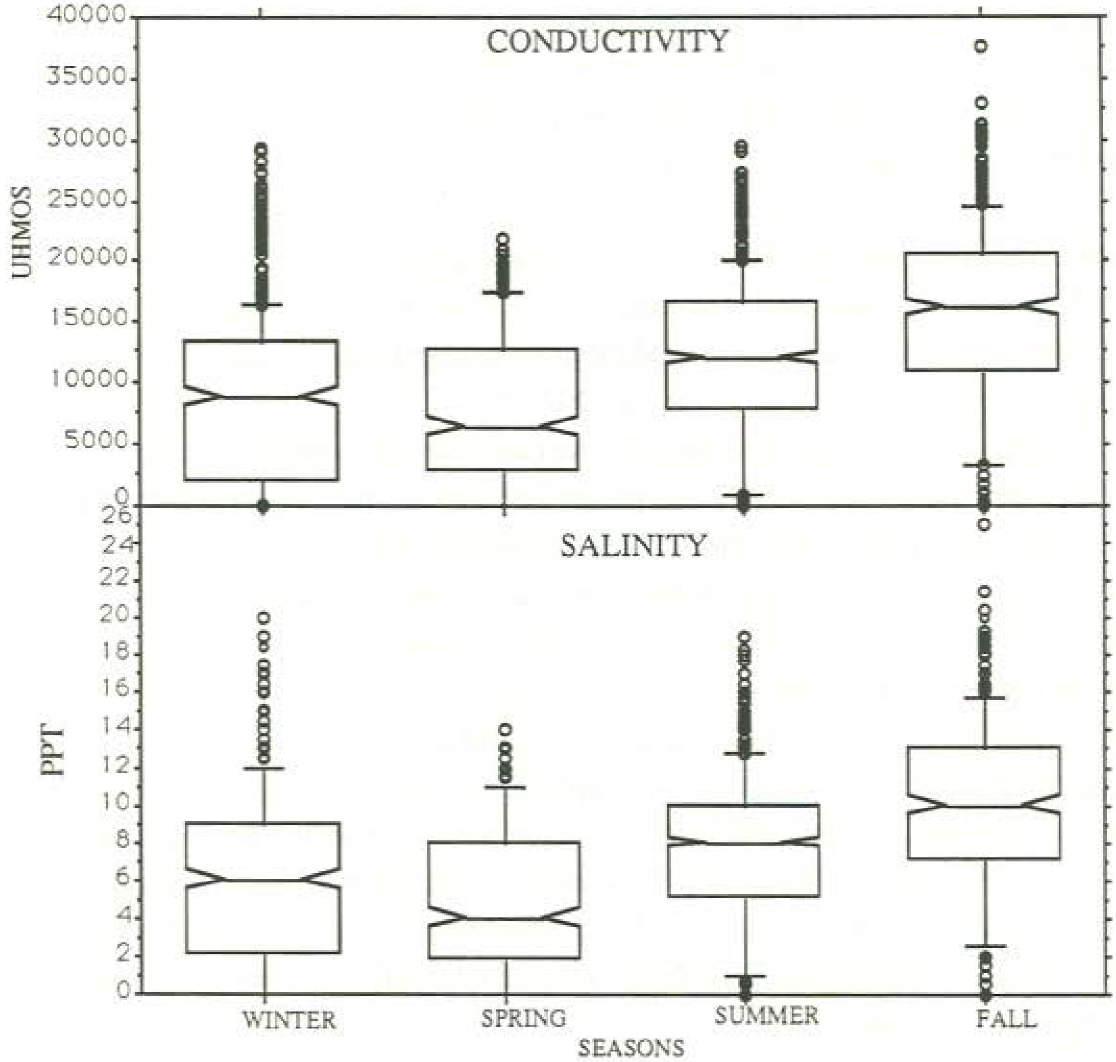



**FIGURE TP1B. SEASONAL CONDUCTIVITY AND SALINITY VALUES IN THE TAR-PAMLICO RIVER BASIN, 1988 - 1991**

Bath Creek near Bath, Pungo Creek at Hwy 92, Pantego Creek at Belhaven, and Pungo River at Hwy 264 had salinities similar to the Pamlico River stations. Van Swamp which flows into Pungo Creek is a freshwater swamp with no salinity values recorded during this sampling. Conductivities in Van Swamp ranged from 43 to 180 μmhos. Durham Creek at Edwards is also freshwater.

*Secchi Depth and Turbidity.* Turbidity values ranged from one to 240 NTU (Figure TP2), with the maximum turbidity value occurring in Conetoe Creek near Bethel in May 1989. Chicod Creek near Simpson exhibited the highest mean turbidity value of 32 NTU while values at this station ranged from one to 120 NTU.

Values exceeding the turbidity standard occurred mainly in the tributaries, probably attributable to sediment runoff or elevated algal growth. The two turbidity exceedences in Bath Creek coincided with elevated phytoplankton numbers. Van Swamp (02084557) also exhibited elevated turbidity readings, probably a result of natural conditions. In the mainstem Tar-Pamlico River, the highest mean turbidity values occurred at the upper, more riverine stations at Tarboro, Grimesland and Washington as would be expected.

Mean Secchi depth readings and box and whisker plots of turbidity values are illustrated in Figure TP 2. The average secchi depth for the Pamlico including tributary stations was 0.7 meters. Deepest secchi depth readings were taken at the Pamlico Sound at Great Island on November 1, 1989, and at Pamlico River at Hickory Point on January 17, 1989. Chlorophyll-a concentrations, phytoplankton, and turbidity for these samples were very low. Pantego Creek and the Pungo River exhibited relatively low mean secchi values because they are black water rivers.

*Metals.* Table TP 3 provides a summary of the water column metals data collected during 1988 through 1991. Of the seven metals sampled, four metals (copper, lead, nickel, and zinc) had values above the laboratory reporting level.

These data are in agreement with data collected during the APES Synoptic study on July 25, 1989. In addition, mercury was also found above the reporting level in Rose Bay while aluminum and manganese were above the detection limit at Washington during the synoptic study.

Copper concentrations above reporting level were present in 38 percent of the samples. Of those samples above reporting level, 12 percent of the samples in freshwater were above the state water quality action level of 7 μg/l. Forty percent of the saltwater samples were above the action level of 3 μg/l. Copper is used in antifoulant agents in marine

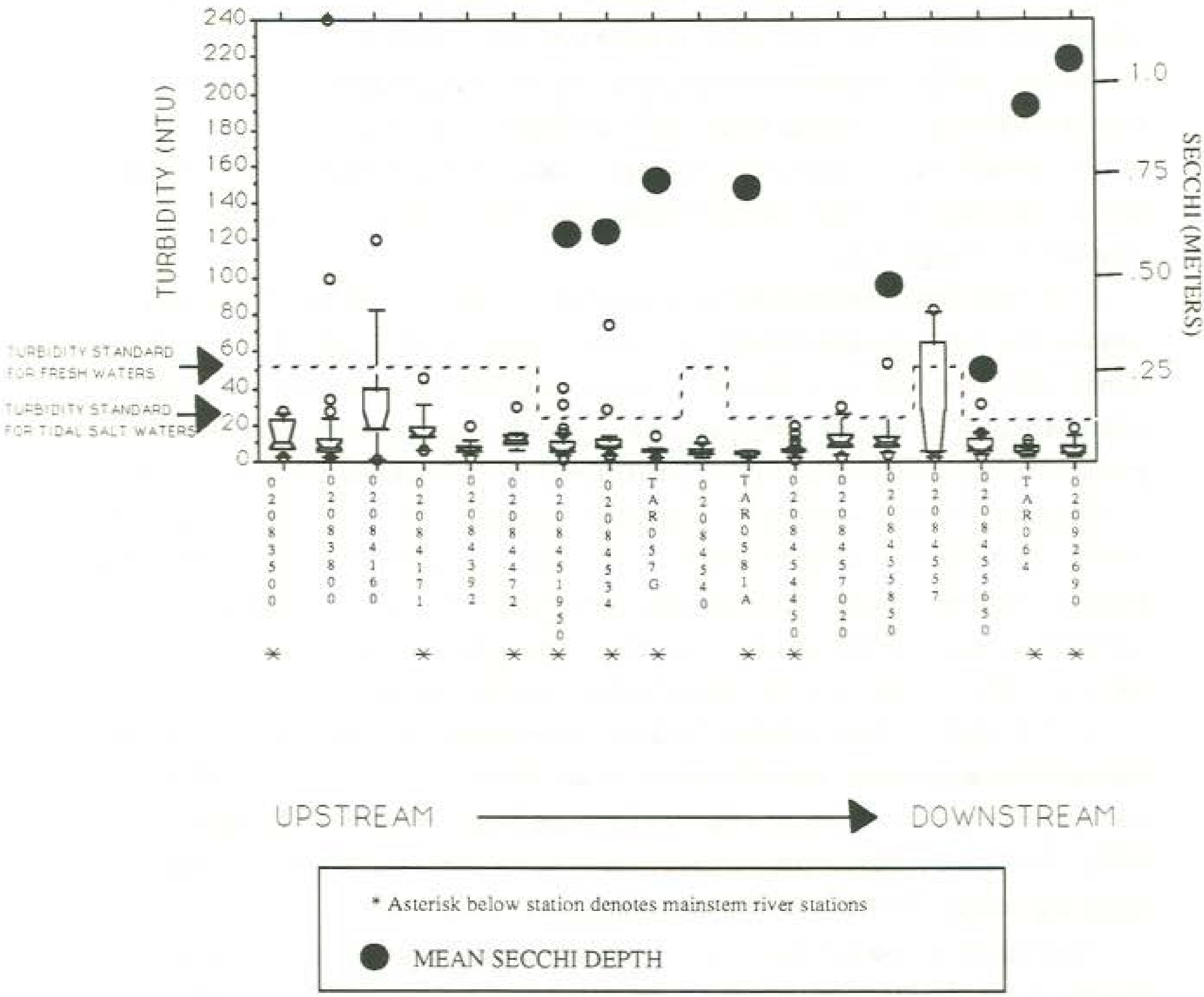



**Figure TP2. TURBIDITY AND MEAN SECCHI VALUES IN THE TAR-PAMLICO RIVER AND TRIBUTARIES, 1988-1991**

applications and is frequently found in elevated concentrations around marinas in North Carolina and other areas (NC DEHNR 1991a). The highest copper concentrations were found in Chicod Creek (31 µg/l), Bath Creek (20 µg/l) and Pungo Creek (12 µg/l). Twenty-five copper samples have been collected in Chicod Creek since 1983. Of those samples four were above 7 µg/l and all of those samples occurred after 1985. There are no dischargers into Chicod Creek; however, increasing development in the area and runoff may have elevated these values. Bath Creek and Pungo Creek are both heavily used by boaters possibly explaining the elevated copper concentrations. Riggs et al. (1989) found no significant metal enrichment in the sediments from Bath Creek and only nickel enrichment in Pungo Creek.

Lead concentrations were above the state standard in only one sample. That sample was from the Tar River near Grimesland with a concentration of 33 µg/l. Only one other sample was above detection at this site. Combustion of lead-containing fuel is the major source of lead in the environment (Riggs et al. 1989). Recent rain storms may have provided the lead by washing it off roadways or out of the marina near the sampling site.

Nickel concentrations were below reporting level in 98 percent of the samples and were below state standards at all freshwater sites. However, two samples from Pantego Creek at Belhaven had concentrations above the saltwater standard of 8.3 µg/l. In April of 1989 a nickel concentration of 20 µg/l was found and in January 1990 a concentration of 17 was taken. No other samples from this station were above reporting level.

Dr. Stan Riggs has been contracted to do sediment metals analysis in the A/P study area and has documented some "areas of concern" in the Pamlico River area. For a review of his data please refer to Albemarle - Pamlico Estuarine Study Project 89-06 (Riggs et al. 1989). This report found elevated sediment nickel concentrations in this area of Pantego Creek and indicated that no source was evident.

Zinc was the only other metal which had measurements above the reporting level; however, none of these measures were above state action levels for fresh or salt waters.

Table TP 3. DEM laboratory reporting levels and state standards for heavy metals sampled from 1988-1991, Tar-Pamlico Basin.

| METAL | N | REPORTING LEVEL (RL) | % SAMPLES BELOW RL | WATER QUALITY STANDARD (fresh/salt) | % SAMPLES ABOVE STANDARD (fresh/salt) |
|---|---|---|---|---|---|
| Arsenic | 175 | 10 | 100 | 50 | 0 |
| Chromium | 174 | 25 | 100 | 50/20 | 0/0 |
| Cadmium | 165 | 2 | 100 | 2/5 | 0/0 |
| | 12 | 10 | 100 | | |
| Copper | 123 | 2 | 62 | 7/3* | 12/40 |
| | 54 | 10 | 96 | | |
| Lead | 164 | 10 | 98 | 25 | 1 |
| | 12 | 50 | 100 | | |
| Nickel | 121 | 10 | 98 | 88/8.3 | 0/2 |
| | 55 | 50 | 100 | | |
| Zinc | 175 | 10 | 86 | 50/86* | 0/0 |

All reporting levels are in ug/l. * - values represent action levels

Nutrients

*Nitrogen and Phosphorus.* Overenrichment of nutrients, especially nitrogen and phosphorus, is the major cause of accelerated eutrophication. Nutrient levels in the Tar-Pamlico River system were generally high with exceedances of the target values for total nitrogen and total phosphorus at most stations.

Values for total nitrogen in the Tar-Pamlico River system ranged from 0.24 mg/l to 5.0 mg/l in Pantego Creek at Belhaven (0208455850). Mean nitrogen concentrations were highest in the upper riverine stations at Tarboro, Grimesland, Washington and in the tributary stations including Van Swamp, Pungo River and Durham, Pungo and Pantego Creeks as depicted in Figure TP3. Even with the elevated nitrogen levels in the upper Tar River near Tarboro and Grimesland, a short retention time prevented excessive phytoplankton growth. Both point and non-point sources contribute to these nitrogen inputs. As the Pamlico River reaches the Sound, settling, assimilation and dilution with nitrogen poor seawater account for the lowest levels of nitrogen which were found at the most downstream station. Seasonally, the highest values of nitrogen occurred during the wetter seasons, winter and spring, suggesting that the source of nitrogen stems from non-point runoff such as agricultural and animal operations. There are also considerably more nutrient inputs stemming from the Tar River during the wet season.

Total phosphorus values ranged from below the detection limit to 0.62 mg/l at Pungo Creek (0208457020). Total phosphorus and orthophosphate values were generally highest in the mainstem Pamlico River from Tarboro to the Pamlico Sound. Concentrations of total phosphorus and orthophosphate exhibited similar patterns as shown in Figure TP4. The

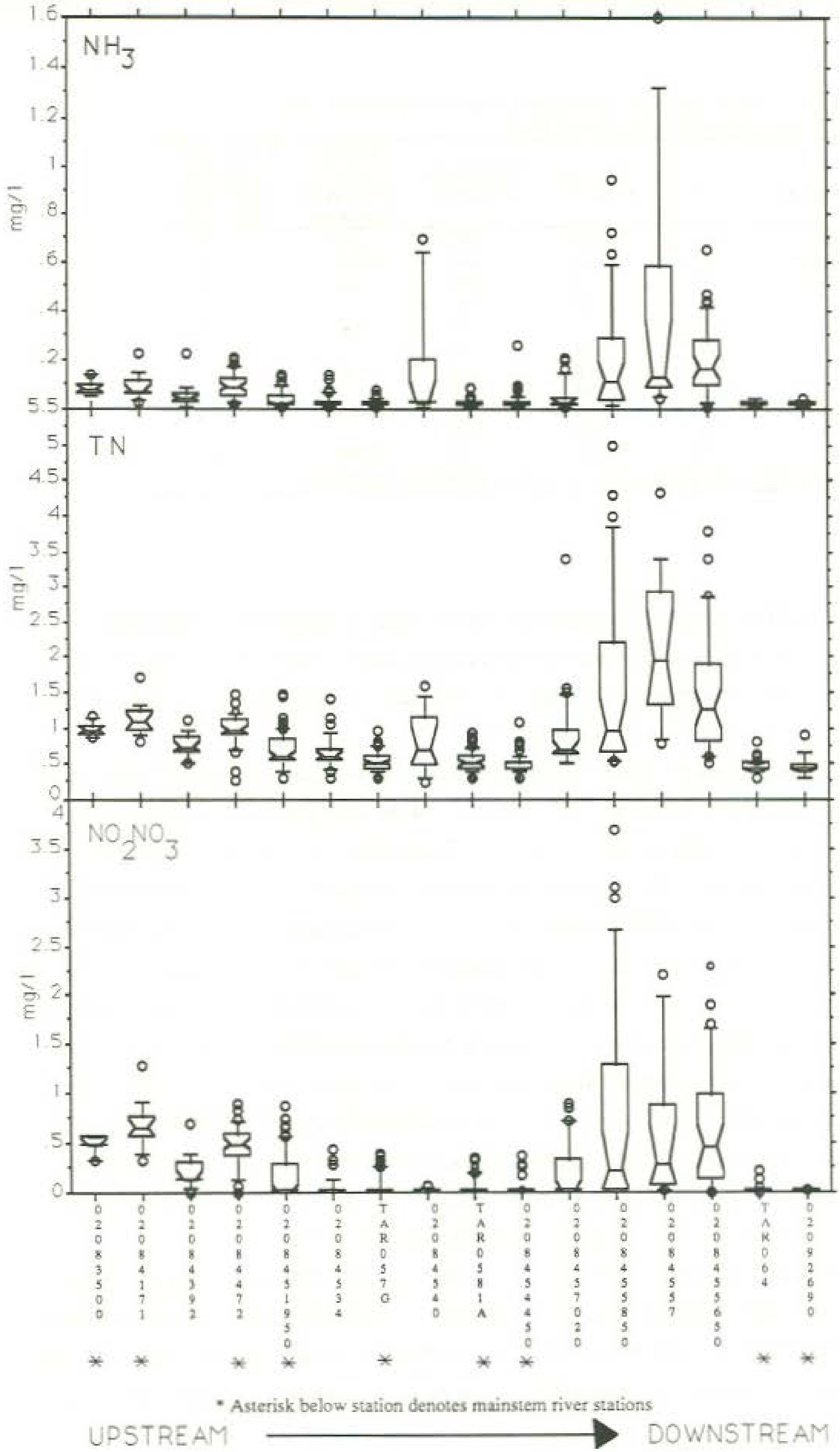
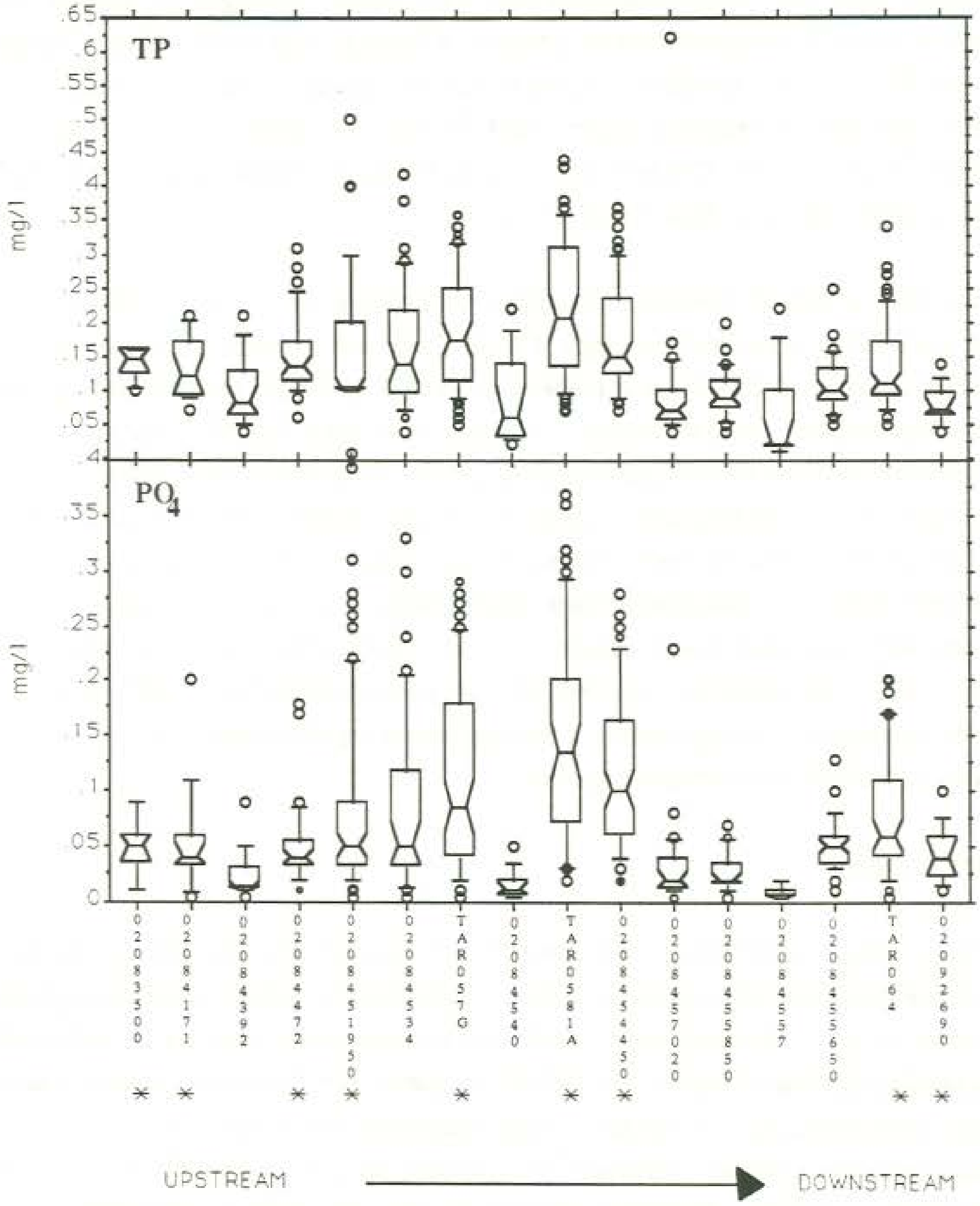



**Figure TP3. AMMONIA/AMMONIUM, TOTAL NITROGEN AND NITRITE/NITRATE VALUES IN THE TAR-PAMLICO RIVER BASIN, 1988-1991**




* Asterisk below station denotes mainstem river stations

**Figure TP4. TOTAL PHOSPHORUS AND ORTHOPHOSPHATE IN THE TAR-PAMLICO RIVER BASIN, 1988-1991**

highest mean concentrations of total phosphorus and orthophosphate (0.22 and 0.15 mg/l, respectively) were found just downstream of Texasgulf at station, TAR0581A.

Seasonal peaks in total phosphorus occurred during the summers as summer weather is generally drier with little dilution for point sources dischargers. In the Pamlico River during dry years, most phosphorus stems from point sources. Texasgulf in particular may contribute as much as 64 percent of the phosphorus loading to the Pamlico River during a dry year (Nixon 1989). In addition, during the summer in the Pamlico River estuary, bottom water hypoxia frequently occurs, which increases the release of phosphate from the sediments (Stanley 1988). The lowest phosphorus values occurred during the winter and spring seasons when river flow was greatest.

*Biochemical Oxygen Demand.* Throughout the sampling period, seven stations contained BOD values exceeding 5 mg/l. Chicod Creek near Simpson in particular had high BOD values with 33 percent of BOD values exceeding 5 mg/l. Organic loading from upstream poultry and swine operations is the likely cause of the high BOD values.

Other elevated BOD values occurred on October 4, 1988, at Tranters Creek near Washington and just downstream at the Pamlico River at Washington on the same date. The Pamlico River near the mouth of Broad Creek, the Pamlico River near Hickory Point, Bath Creek (02084534), and Pungo Creek (0208457020) all contained one BOD measurement greater than 5 mg/l (ranging from 5.5 to 8.6 mg/l) during the sampling period. These high values may have been caused by degradation of large amounts of organic matter such as an algal bloom or resuspension of organic matter in sediments originating from point or non-point sources.

Biological Data

*Phytoplankton and Chlorophyll-a.* Phytoplankton samples collected from the Tar River near Grimesland contained low levels of algal populations and corresponding chlorophyll-a. A combination of decreased water velocity and adequate nutrients resulted in increased phytoplankton growth at Washington (02084472), particularly during the summer months. Farther downstream, algal 'bloom' levels of dinoflagellates (Dinophyceae), diatoms (Bacillariophyceae), and cryptophytes (Cryptophyceae) along with elevated chlorophyll-a concentrations commonly occurred in the lower Tar-Pamlico estuary and tributaries throughout the year.

The Tar River at Washington contained a diversity of algal populations dominated by bacillariophytes (Cyclotella species 3), cryptophytes (Chroomonas caudata, C. minuta, Cryptomonas ovata, Cryptomonas erosa), a diversity of chlorophytes, and xanthophytes (Olisthodiscus carterae). During June through October, this station contained elevated levels of phytoplankton, with high chlorophyll-a concentrations averaging 44 ug/l.

Large populations of dinoflagellates such as Heterocapsa triquetra and Prorocentrum minimum, usually associated with low water temperatures, contributed to elevated chlorophyll-a levels during the late fall and winter months and caused reddish to brownish colored water in the Pamlico River from near Broad Creek to the mouth of the Pungo River.

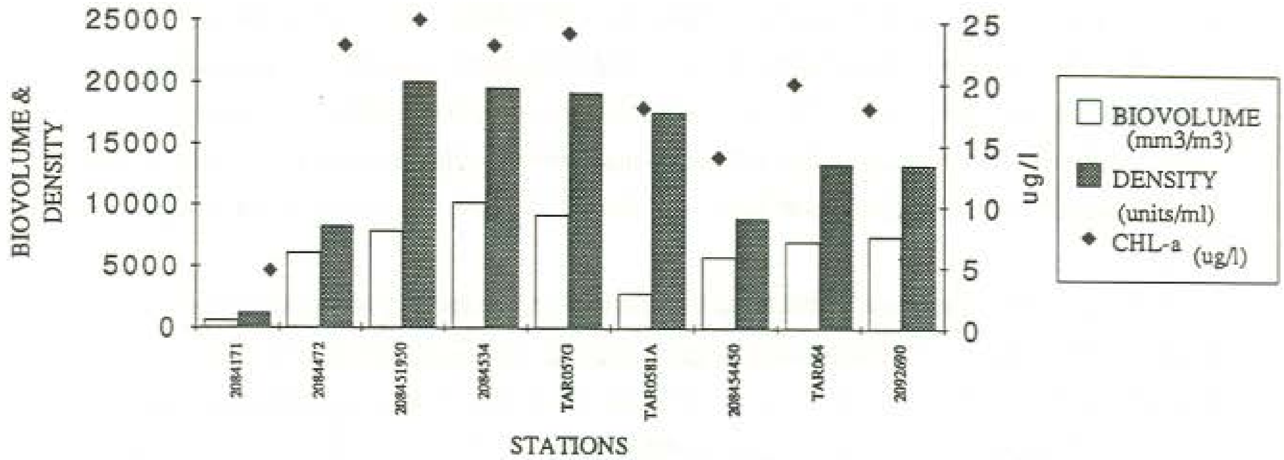
Spring, summer, and early fall algal populations in the estuary were most often dominated by various dinoflagellates (Gymnodinium spp, Gyrodinium spp. and Peridinium spp.), small centric diatoms, (Cyclotella species 2, and Skeletonema spp.) and cryptophytes (Chroomonas spp, Cryptomonas spp). Small cyanophytes or blue-green algae (Lyngbya spp. and Phormidium angustissima) were often a dominant component of algal density estimates.

Figure TP5 represents mean algal biovolume, density and corresponding chlorophyll-a concentrations measured in the Pamlico River. This figure illustrates relatively high algal growth in the mainstem river stations from the Pamlico River at Washington to the Pamlico Sound near Great Island as well as in tributary stations. The Biological Assessment Group's algal bloom reporting program has also documented occurrences of algal blooms occurring in tributaries such as the Pungo River, Chocowinity Bay, and Pantego, Pungo, Kennedy, and Durham creeks as well as in the mainstem Pamlico River (NC DEHNR 1989b, 1990b, 1991c).

Highest mean chlorophyll-a concentrations occurred in Pungo Creek at U.S. Highway 92. This high value partially stems from a massive algal bloom consisting of large brackish water dinoflagellates (Gyrodinium uncatenum) with a resultant chlorophyll-a concentration of 640 ug/l. Several blooms that occurred in tributaries may have been precipitated by runoff from upstream animal operations and agricultural operations. Nutrient levels in the Pamlico River system were also sufficient to sustain algal blooms in the mainstem river as well.

Seasonal values for chlorophyll-a concentrations measured in the Tar-Pamlico River system are illustrated in Figure TP 6. In contrast to Figure TP5 which contained only chlorophyll-a values which were associated with phytoplankton samples, Figure TP6 includes all chlorophyll-a values sampled, resulting in slightly different summations. Phytoplankton numbers and resultant chlorophyll-a values were often inversely associated

Figure TP5. Mean Phytoplankton Biovolume, Density and Chlorophyll-a Concentrations for the Tar-Pamlico River, 1988 - 1991



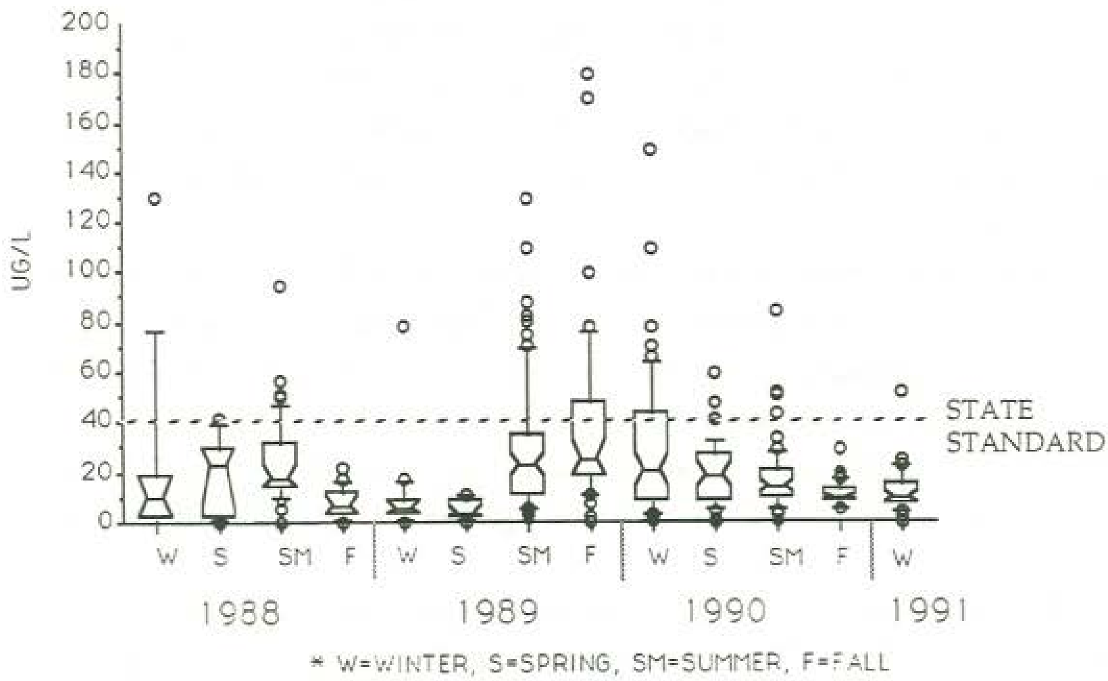




FIGURE TP6. SEASONAL CHLOROPHYLL-a CONCENTRATIONS IN THE TAR-PAMLICO RIVER BASIN, 1988 - 1991 with river flow. The lower values in the winter of 1989 occurred during a period of higher than normal flow.

Algal blooms in the Pamlico River estuary often occurred in association with salt wedges and resultant hypoxic bottom waters as well as with fish kills. There is research currently underway by North Carolina State University personnel evaluating the connection between a toxic dinoflagellate found in the Pamlico River estuary and episodes of fish kills.

*Fecal Coliform Bacteria.* Fecal coliforms measured greater than 200 colonies/100ml during routine monitoring on 11 occasions in the Tar-Pamlico watershed. These values ranged from 220 to 2100 colonies/100 ml. The Tar River near Grimesland and the Pungo River at U.S. Highway 264 each had high fecal coliform values on four occasions. The Pamlico River near the mouth of Broad Creek had two high values while Van Swamp had one high value for fecal coliforms.

## NEUSE RIVER BASIN

The Neuse River basin encompasses 6,192 square miles in the lower piedmont and coastal plain, contains 328,700 acres of saltwater, and is the third largest river basin in North Carolina. Major tributaries to the Neuse River in the coastal plain are the Little River, Swift Creek, Contentnea Creek and the Trent River. The basin contains 429 permitted surface water dischargers, with 34 of these having discharges exceeding 0.5 MGD (NC DEHNR 1990a).

Land use in the lower Neuse basin consists mainly of forest, wetlands, and agriculture. Above New Bern, the Neuse River is fairly narrow (about 0.9 miles wide at New Bern) and winding, with an average depth of about 2 meters. Below New Bern, the river widens to 6.3 miles and has an average depth of 5 meters at its mouth near Maw Point (Giese et al., 1979). Tidal effects are seen as far up the river as Fort Barnwell (approximately 65 miles upstream from Maw Point). In December 1983 the watershed above the Falls of the Neuse Reservoir dam was classified as Nutrient Sensitive Waters. In May 1988 the entire Neuse River basin was reclassified as NSW. Figure N-A shows the locations of all 25 ambient stations in the Neuse River Basin, listed as follows:

| STATION # | DESCRIPTION | PARAMETERS |
|---|---|---|
| NEUSE RIVER BASIN | | |
| 02089500 | Neuse R @ Kinston | P,T,N,M,B,BP |
| 02090380 | Contentnea Cr nr Lucama | P,T,N,M,B |
| 02090625 | Turner Swamp nr Eureka | P,T,N,M,B |
| 02091000 | Nahunta Swamp nr Shine | P,T,N,M,B |
| 02091500 | Contentnea Cr @ Hookerton | P,T,N,M,B |
| 02091700 | Little Contentnea Cr nr Farmville | P,T,N,M,B |
| 0209176690 | Contentnea Cr @ Grifton | P,T,N,M,B |
| 02091814 | Neuse R nr Fort Barnwell | P,T,N,M,BP |
| 02091836 | Neuse R @ Streets Ferry | P,T,N,M,B,BP * |
| 02091970 | Creeping Swamp nr Vanceboro | P,T,N,M,B |
| 02092000 | Swift Cr nr Vanceboro | P,T,N,M,B |
| 02092084 | Swift Cr @ mouth nr Askin | P,T,N,M,BP,F * |
| 02092092 | Neuse R below Swift Cr nr Askin | P,T,N,M,BP,F * |
| 02092109 | Neuse R @ Narrows | P,T,N,M,BP,F * |
| 02092162 | Neuse R @ New Bern | P,T,N,M,BP * |
| 02092500 | Trent R nr Trenton | P,T,N,M |
| 0209256050 | Trent R above Reedy Br nr Rhems | P,T,N,M,BP,F * |
| 0209257120 | West Prong Brice Cr nr Riverdale | P,T,N,M,B |
| 02092586 | Neuse R @ mouth of Broad Cr nr Thurman | P,T,N,M,BP * |
| NEU131F | Neuse R @ Light #22 nr Fairfield Harbor | P,T,N,BP |
| NEU131X | Neuse R @ Light #11 nr Riverdale | P,T,N,BP * |
| NEU139 | Neuse R nr Minnesott Beach | P,T,N,M,BP * |
| 0209266890 | Back Cr nr Merrimon | P,T,N,M |
| 02092674 | Neuse R nr Oriental | P,T,N,M,BP,F * |
| 02092682 | Neuse R @ mouth nr Pamlico | P,T,N,M,BP,F * |

P (Physical parameters), T (Turbidity); N (Nutrients); M (Metals); BP (Phytoplankton and/or chlorophyll-a), B (BOD), F (fecals), * (secchi depth)

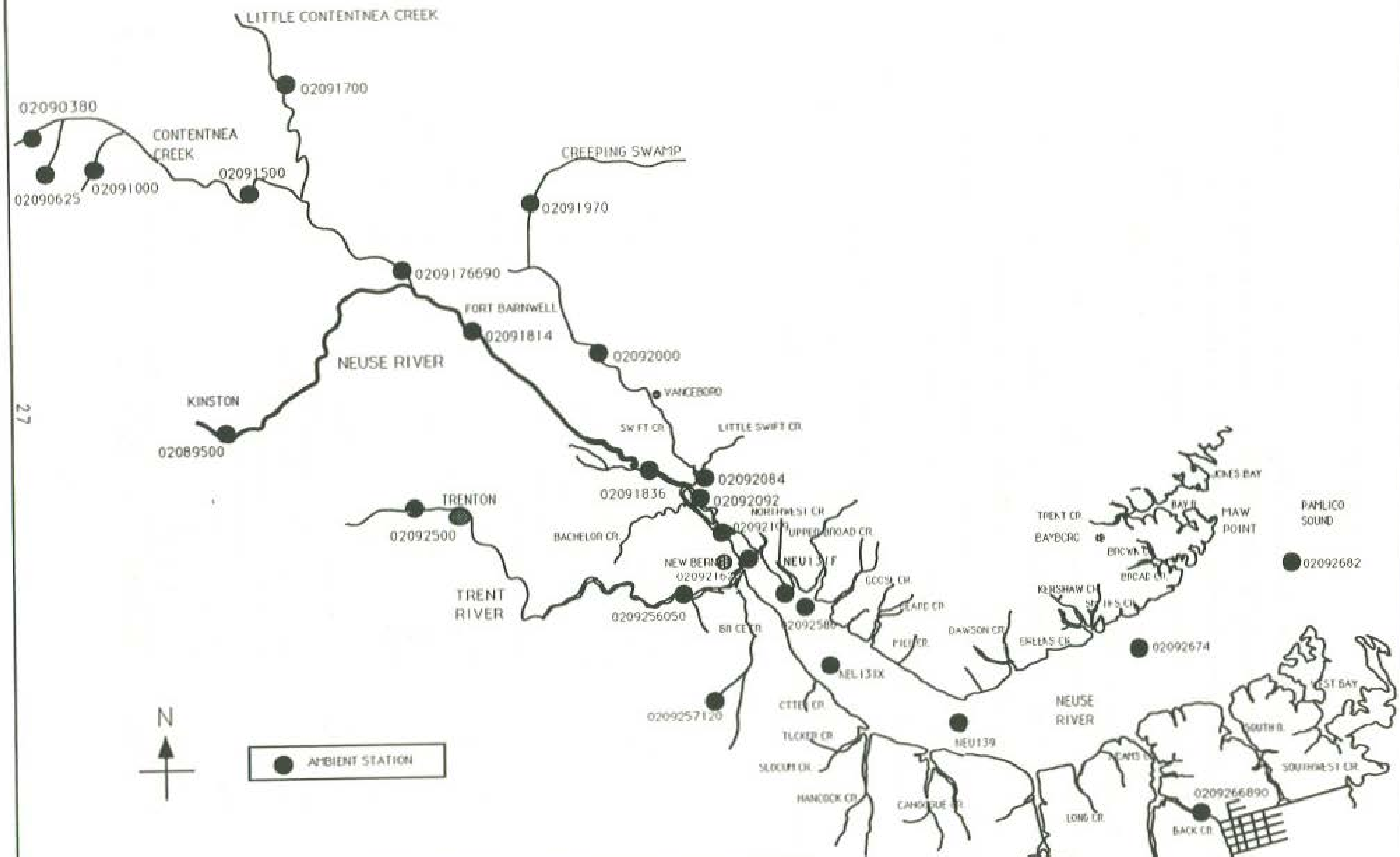



FIGURE N-A. AMBIENT STATIONS IN THE NEUSE RIVER BASIN

Physical Data

*Flow.* During 1988, flow measured at the Neuse River at Kinston was generally below average from January through August. River flows in the fall through the end of 1988 were above average. After a dry winter in early 1989, river flow was usually above the 10 year daily mean value from March 1989 through May 1990. Near normal flows were measured from June 1990 through July 1991. Late summer and fall flows during 1991 were higher than average.

*Temperature and Dissolved Oxygen.* Monthly surface temperatures in the mainstem Neuse River ranged from 3 to 31°C, with a mean temperature of 18.4°C. Surface temperatures at Neuse River tributary stations ranged from 2.5 to 33°C. The maximum temperature of 33° C was found at Contentnea Creek near Lucama.

Mean surface temperatures inversely corresponded with mean dissolved oxygen (DO) concentrations. Overall, highest mean DO concentrations were found during the cooler seasons, winter and fall. However, during the summer when excessive levels of algae were present, surface levels of DO were elevated, resulting in supersaturated dissolved oxygen conditions.

Surface DO concentrations reached supersaturated conditions at several Neuse River stations along with elevated pH levels, signifying algal blooms. Supersaturated conditions (greater than the state standard of 110 percent saturation) occurred in as much as 41 percent of the surface samples from the middle Neuse River station, NEU131X. Downstream near Minnesott Beach, station NEU139 reached a maximum saturation point of 177 percent. These excessively high dissolved oxygen levels stem from algal photosynthesis occurring with high levels of algae.

The water column exhibited conditions of stratified dissolved oxygen levels, frequently from New Bern (02092162) to near Minnesott Beach (NEU139). This pronounced stratification occurred intermittently from summer through fall and winter usually in association with salt wedges. Salt wedges commonly occur during periods of low flow, when dense hypolimnetic saline waters resist mixing with less dense fresh waters. As bacterial respiration and phytoplankton degradation consume oxygen on the river bottom, the bottom of the water column becomes hypoxic. Tributaries including the Trent River (0209256050) and Swift Creek (02092084) also exhibited DO stratification in conjunction with salt wedges. Stratification by temperature was much less frequent, with temperature differences of 5°C measured infrequently in this fairly shallow estuarine system. The USGS continuous monitoring stations will provide better resolution of the extent of stratification and mixing associated with salinity and temperature and bottom water hypoxia.

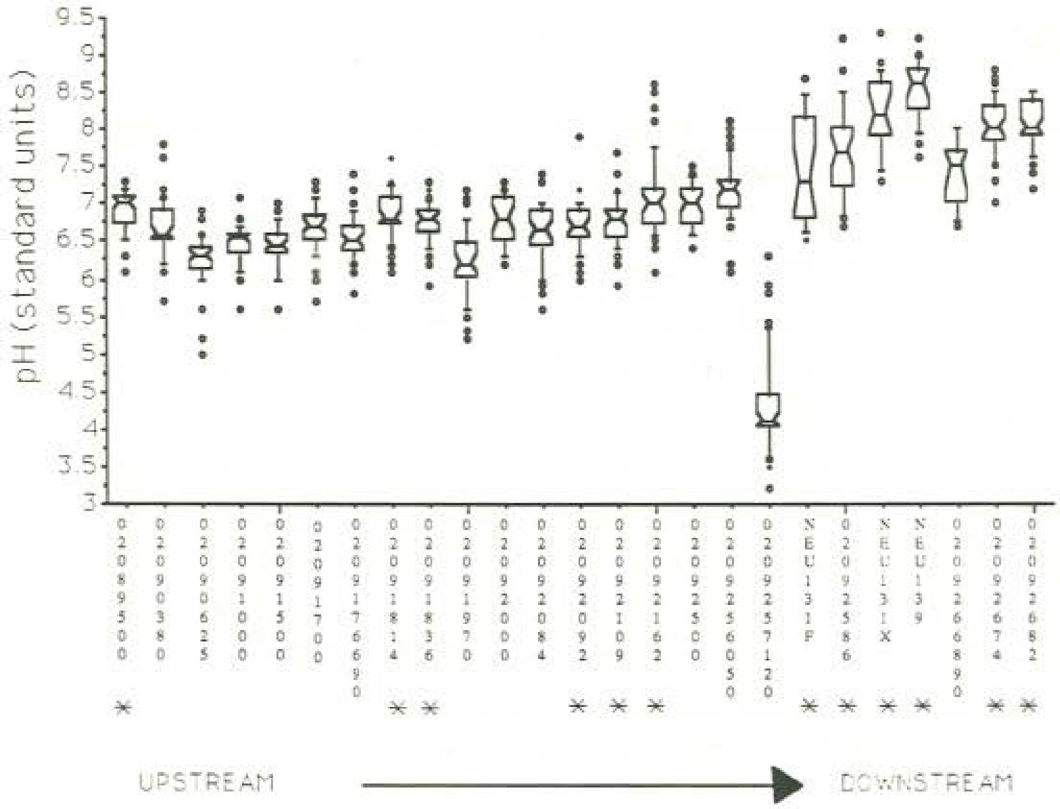
On a temporal scale, mean temperature values and dissolved oxygen concentrations did not show any major differences between years.

*pH*. Surface pH values in the mainstem Neuse River ranged from 5.9 s.u. at upper station 02091836 (Streets Ferry) to 9.3 s.u. at lower Neuse River station, NEU131X. The tributaries, many of which drain swamplands, exhibited much lower pH values. The West Prong of Brice Creek (0209257120) for example contained a minimum pH value of 3.2 s.u. The mean pH at this station is 4.3 s.u, probably due to natural causes as this station is located in the Croatan National Forest and there are no dischargers into the creek. Values of pH were elevated in the lower Neuse River because of increased algal activity. Figure N1 illustrates this range of pH values with highest mean pH values occurring in the Neuse River proper, particularly at downstream stations where algal growth was highest. Table N 1 represents data from the Neuse River with the number of pH values greater than or equal to 8.5 s.u., corresponding mean chlorophyll-a values, the number of chlorophyll-a concentrations greater than or equal to 20 µg/l, and the number of D.O. observations with greater than 110 percent saturation.

TABLE N 1. Values of pH exceeding 8.5 s.u. with associated chlorophyll-a concentrations and percent saturation, Neuse River Basin

| LOCATION | N | pH >= 8.5 ( )=% of N | CHLA >=20 ( )= % of pH | Mean Chla - ug/l ( )=# samples | %SAT>=110% ( )= % of %SAT |
|---|---|---|---|---|---|
| Neuse R. @ New Bern | 37 | 1 (3) | 1 (100) | 57 (1) | 1 (100) |
| Nesue R. @ Fairfield Harbor | 21 | 2 (10) | 2(100) | 52 (2) | 2 (100) |
| Neuse R.near Thurmon | 34 | 4 (12) | 4 (100) | 55 (4) | 1 (25) |
| Neuse R.near Riverdale | 20 | 7(35) | 4(57) | 77 (7) | 6 (86) |
| Neuse R. near Minnesott Bch. | 19 | 12 (63) | 9 (75) | 42 (12) | 10 (83) |
| Neuse R. near Oriental | 33 | 5(14) | 2(40) | 20 (5) | 2 (40) |
| Neuse R. near mo.of Pamlico | 33 | 5(15) | 1(20) | 13 (5) | 2 (40) |

*Conductivity and Salinity*. Conductivity values ranged from 37 to 314 umhos at freshwater stations and peaked at 34,220 uhmos at the most saline station, Neuse River near Pamlico (02092682). Lowest mean conductivities were found at the tributary station, Contentnea Creek near Lucama. Several high conductivity values were recorded on August 25, 1988 at stations which are normally freshwater. These high conductivities occurring at




* Asterisk below station denotes mainstem river stations

**Figure N1. VALUES OF pH IN THE NEUSE RIVER BASIN 1988 - 1991**

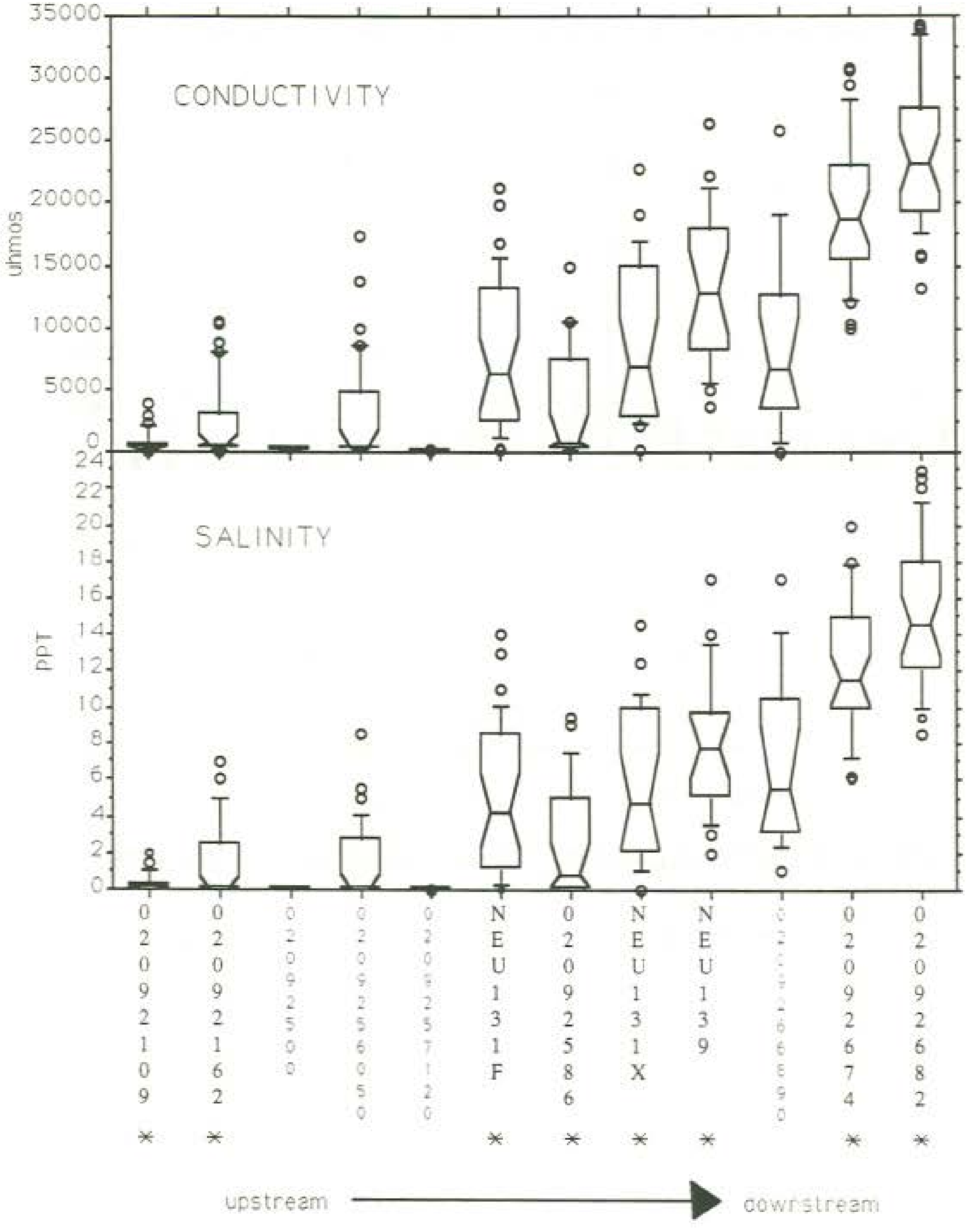
Neuse River at Streets Ferry ( 02091836) and at two stations on Swift Creek were most likely caused by salt water intrusion, since flow had been very low the previous few months. During sampling on this date, corresponding salinity was not measured. Other instances of high conductivities on the creek bottom in Swift Creek near Askin corresponded to brackish waters during the fall seasons of 1988, 1989 and 1990. Figure N 2 depicts conductivity and salinity in the lower Neuse River.

*Secchi Depth and Turbidity*. Turbidity values in the Neuse River were generally low and most were below the state standard. Turbidity standards (50 NTU) for both freshwater and tidal saltwater (25 NTU) were used for assessing turbidity values according to appropriate designated use. There were a few exceedances of the state standards as depicted in Figure N 3. However some exceedances occurred in areas designated as swampwaters which may naturally have higher turbidity values, and therefore are not considered violations of the turbidity standard.

The elevated turbidity values may be caused by increased phytoplankton growth, sediment runoff, or resuspension from sediments or other biotic or abiotic factors. In March 1989, three stations from Neuse - Narrows to Thurmon exhibited elevated turbidity values. River flows recorded at Kinston show higher than average flows during this period, suggesting that sediment runoff was responsible for the elevated readings. Turbidity values generally decreased from the faster flowing upper Neuse to the slower downstream river stations. Secchi values were inversely correlated to turbidity as depicted in Figure N4.

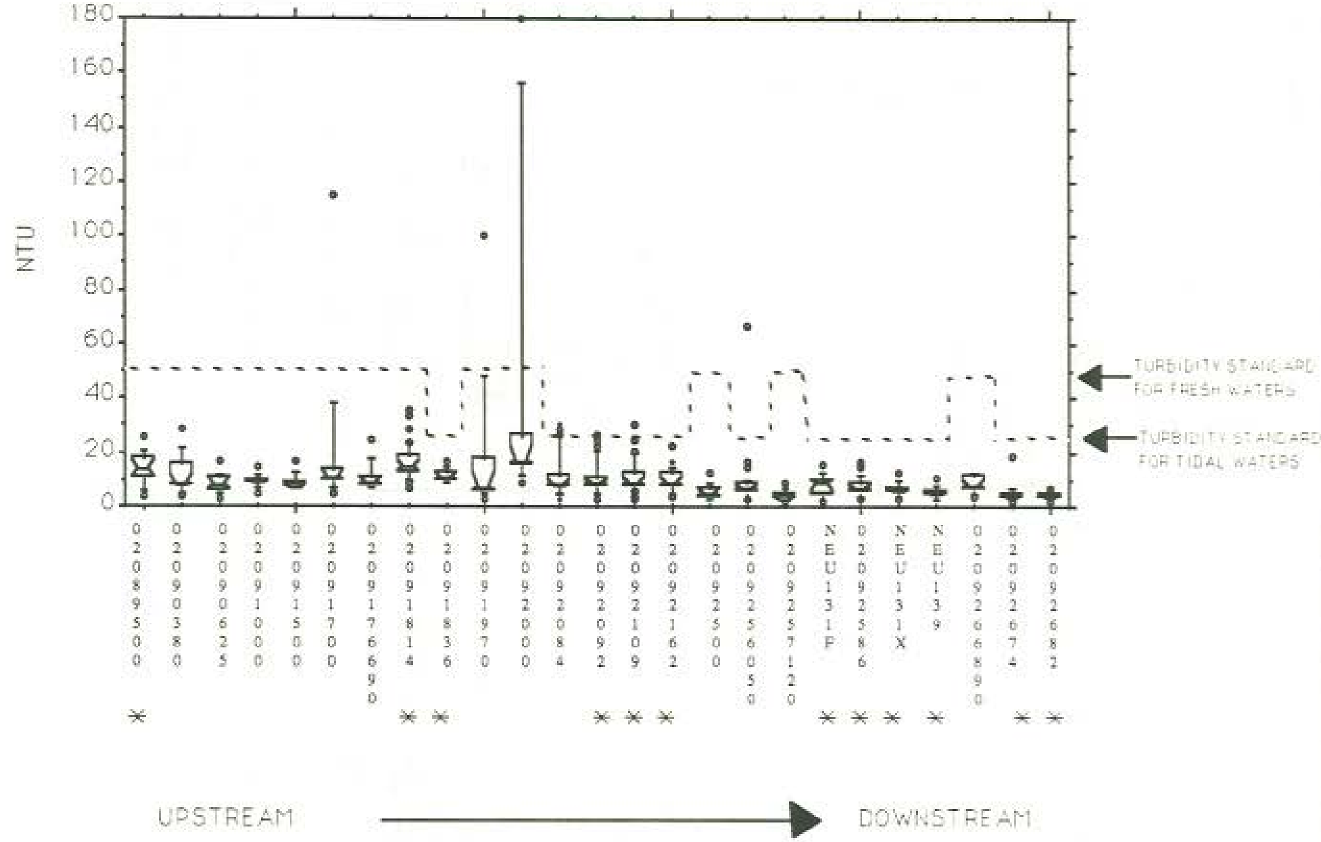
*Metals*. Heavy metals are usually present in bodies of water although inputs from anthropogenic sources often result in levels higher than normal. Urban runoff, industrial wastes and marinas all may contribute higher than normal concentrations of metals to waterbodies. Samples were analysed for fifteen heavy metals at Neuse River stations. Very low concentrations of 10 metals were found. Ninety-eight percent or more of these 10 metals were below the reporting level or detection limit. Table N1 shows the distribution of samples below the reporting level and above the state standards.

Although zinc and manganese were found above the detection level in 12 percent and 11percent of the samples, respectively, less than 1percent of the samples showed levels above the state standard. Copper was above the reporting level in 28 percent of the samples and 3 percent of the samples were above the state action level. Elevated concentrations of both zinc and copper have been found in conjunction with boats and marinas. The majority of samples analysed for iron and aluminum were above the reporting level as piedmont and coastal plain sediments contain large amounts of these elements.




* Asterisk below station denotes mainstem river stations

**Figure N2. SURFACE CONDUCTIVITY AND SALINITY VALUES FOR THE LOWER NEUSE RIVER AND TRIBUTARIES, 1988-1991**




* Asterisk below station denotes mainstem river stations

**Figure N3. TURBIDITY VALUES IN THE NEUSE RIVER BASIN, 1988-1991**

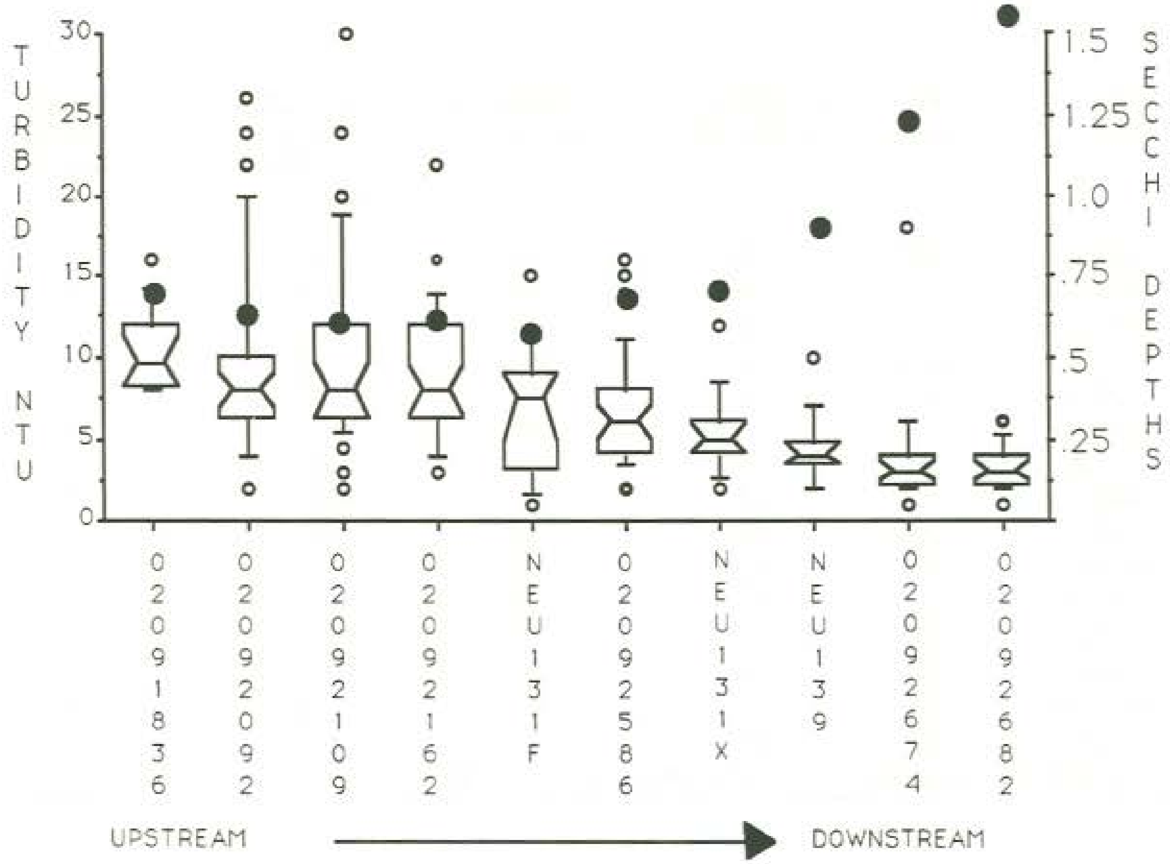



**Figure N4. BOX AND WHISKER PLOTS OF TURBIDITY AND MEAN SECCHI DEPTHS IN THE NEUSE RIVER 1988-1991**

Table N2. DEM laboratory reporting levels and state standards for heavy metals sampled from 1988-1991, Neuse Basin.

| METAL | # of samples | REPORTING LEVEL (RL) | % SAMPLES BELOW RL | WATER QUALITY STANDARD (fresh/salt) | % SAMPLES ABOVE STANDARD (fresh/salt) |
|---|---|---|---|---|---|
| Arsenic | 165 | 10 | 98 | 50 | 1 |
| Chromium | 265 | 25 | 100 | 50/20 | 0 |
| Beryllium | 7 | 25 | 100 | 6.5 | 0 |
| Cadmium | 267 | 2 | 100 | 2/5 | 0 |
| Copper | 255 | 2 | 72 | 7/3* | 3 |
| Cyanide | 2 | | 100 | 5/1 | 0 |
| Lead | 255 | 10 | 100 | 25 | 0 |
| Mercury | 255 | 0.2 | 98 | .012/.025 | 2 |
| Nickel | 269 | 10 | 99 | 88/8.3 | 2 |
| Selenium | 42 | 0.5 | 100 | 5/71 | 0 |
| Silver | 7 | 0.5 | 100 | .06/0.1* | 0 |
| Zinc | 270 | 10 | 88 | 50/86* | 0 |
| Iron | 23 | 50 | 0 | 1000* | 17 |
| Manganese | 18 | 25 | 89 | 200 | 0 |
| Aluminum | 30 | 50 | 3 | none | |

All reporting levels are in ug/l. * - values represent action levels

## Nutrients

*Nitrogen and Phosphorus.* Nitrogen species sampled in the Neuse River include nitrate/nitrite ($NO_2$+$NO_3$), ammonia/ammonium ($NH_3$+$NH_4$) and total kjeldahl nitrogen (TKN). Total nitrogen (TN) also mentioned here is the sum of TKN and $NO_2$+$NO_3$. Total phosphorus (TP) and orthophosphate ($PO_4$) were also measured in the Neuse River. Much of the nutrient input into the Neuse River may stem from non-point sources in the upper Neuse basin (Contentnea Creek and tributaries) as this area is largely agricultural. Research Triangle Institute is currently conducting a study to determine the sources of nutrient inputs into the Neuse River Basin.

Values for $NO_2$+$NO_3$ at most mainstem river stations were generally above 0.5 mg/l until reaching the slower, wider section of the Neuse near Fairfield Harbor (NEU131F), where algal assimilation and settling could have accounted for the lower values of

$NO_2$+$NO_3$ measured. The inorganic constituents of nitrogen ($NO_2$+$NO_3$) along with $PO_4$ are most readily used by phytoplankton. Seasonally throughout the Neuse River nitrate/nitrite concentrations increased in winter and fall when algal growth was somewhat reduced and decreased in spring and summer probably due to a combination of decreased loading and phytoplankton uptake. Figure N-5 illustrates the seasonal fluctuation of nitrate/nitrite in the Neuse River.

Values for TN ranged from a minimum of .015 mg/l at Neuse River near Oriental to 3.8 mg/l at Swift Creek near Vanceboro. Total nitrogen and $NH_3$+$NH_4$ followed similar patterns as depicted in Figure N-6. Swift Creek near Vanceboro (02092000) consistently exhibited the highest mean nitrogen values as illustrated in Figure N-6. There are no known dischargers located upstream which may have contributed to the source of nitrogen. The topographic map shows many small rectangular reservoirs. The Washington Regional Office will be investigating the land use in this watershed to locate the source of nitrogen loading to the Neuse River.

Phosphorus values were also generally high in the Neuse River and its tributaries with total phosphorus values ranging from 0.02 mg/l in Creeping Swamp near Vanceboro to 1.6 mg/l at Little Contentnea Creek near Farmville. Several tributary stations and the lowermost Neuse River stations contained relatively low levels of phosphorus. As depicted in Figure N-7, consistently high levels of $PO_4$ and total phosphorus were recorded at Little Contentnea Creek near Farmville (02091700). The town of Farmville's wastewater treatment plant is located approximately three miles upstream from this ambient station. Elevated levels of total phosphorus as high as 3.5 mg/l have been found at the treatment plant discharge, exceeding the 2.0 mg/l outfall target value for dischargers in the Neuse River basin. Phosphorus limits will be included in future permits according to the Nutrient Sensitive Waters management plan. Non-point sources may also have contributed to these high values found at station.

Seasonally, increases in orthophosphate concentrations during the spring each year may originate from agricultural runoff brought by spring rains. Figure N-8 illustrates the concentrations of $PO_4$ graphed by year and season.

*Biochemical Oxygen Demand.* Five out of 175 BOD measurements or approximately 3 percent exceeded 5 mg/l. These values were found in the Neuse River at Streets Ferry (02091836) and Thurman (02092585) and in Little Contentnea Creek (02092500) and Creeping Swamp near Vanceboro (02081970) on separate dates. These higher values, ranging from 5.2 to 23 mg/l, may have been caused by degradation of large amounts of organic matter such as an algal bloom or pulses of organic wastes.

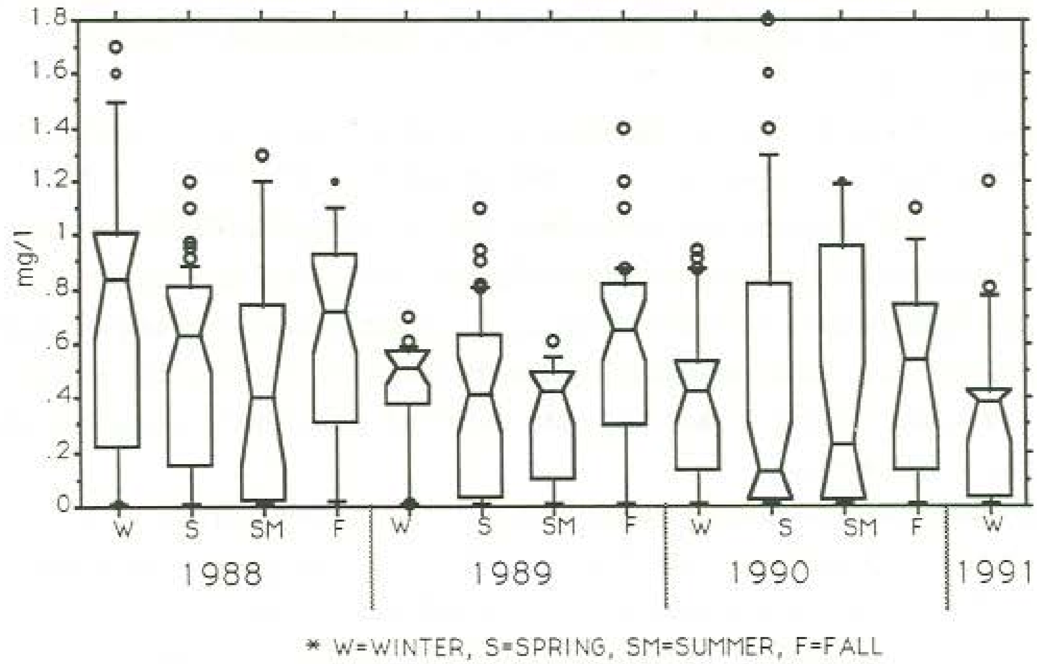
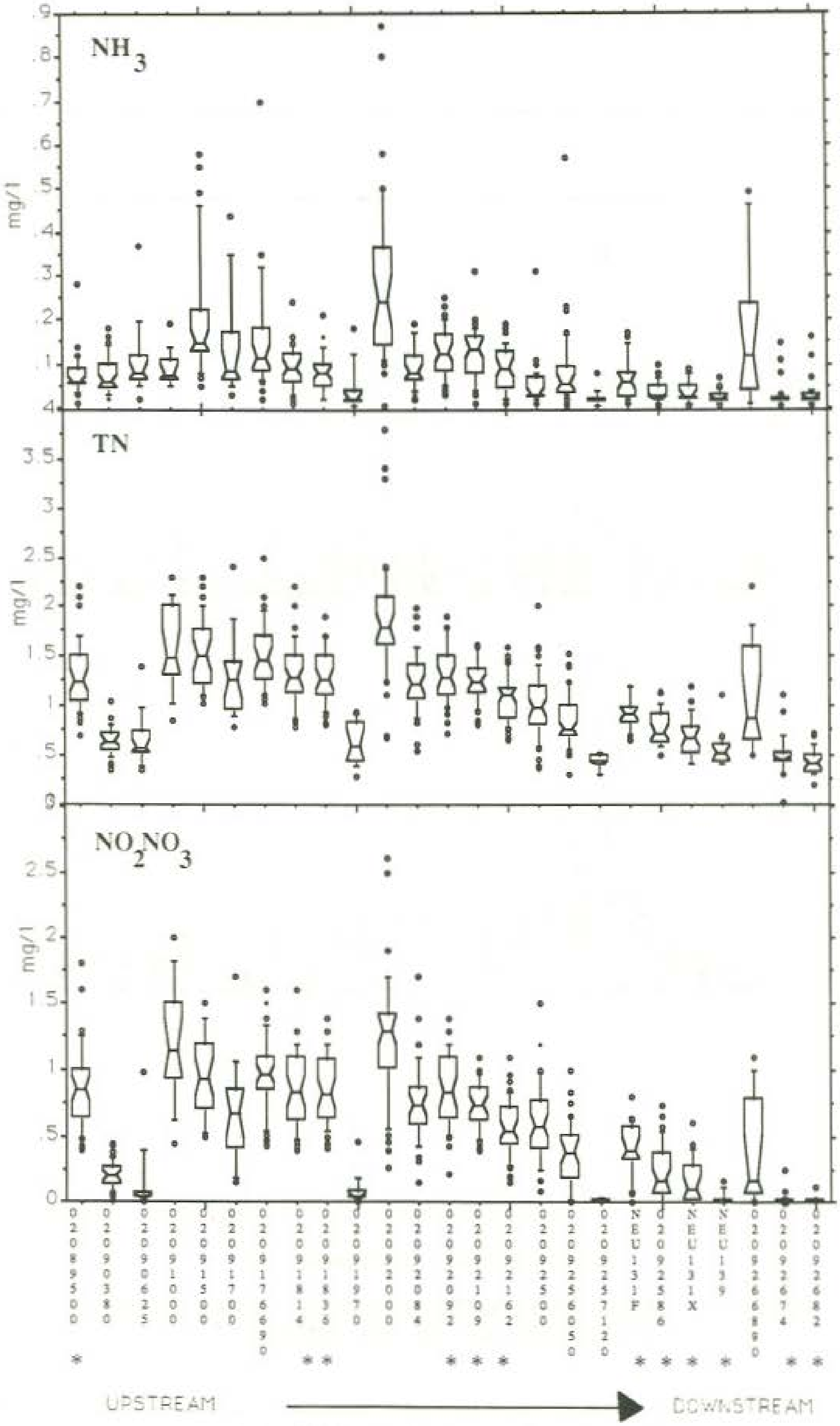
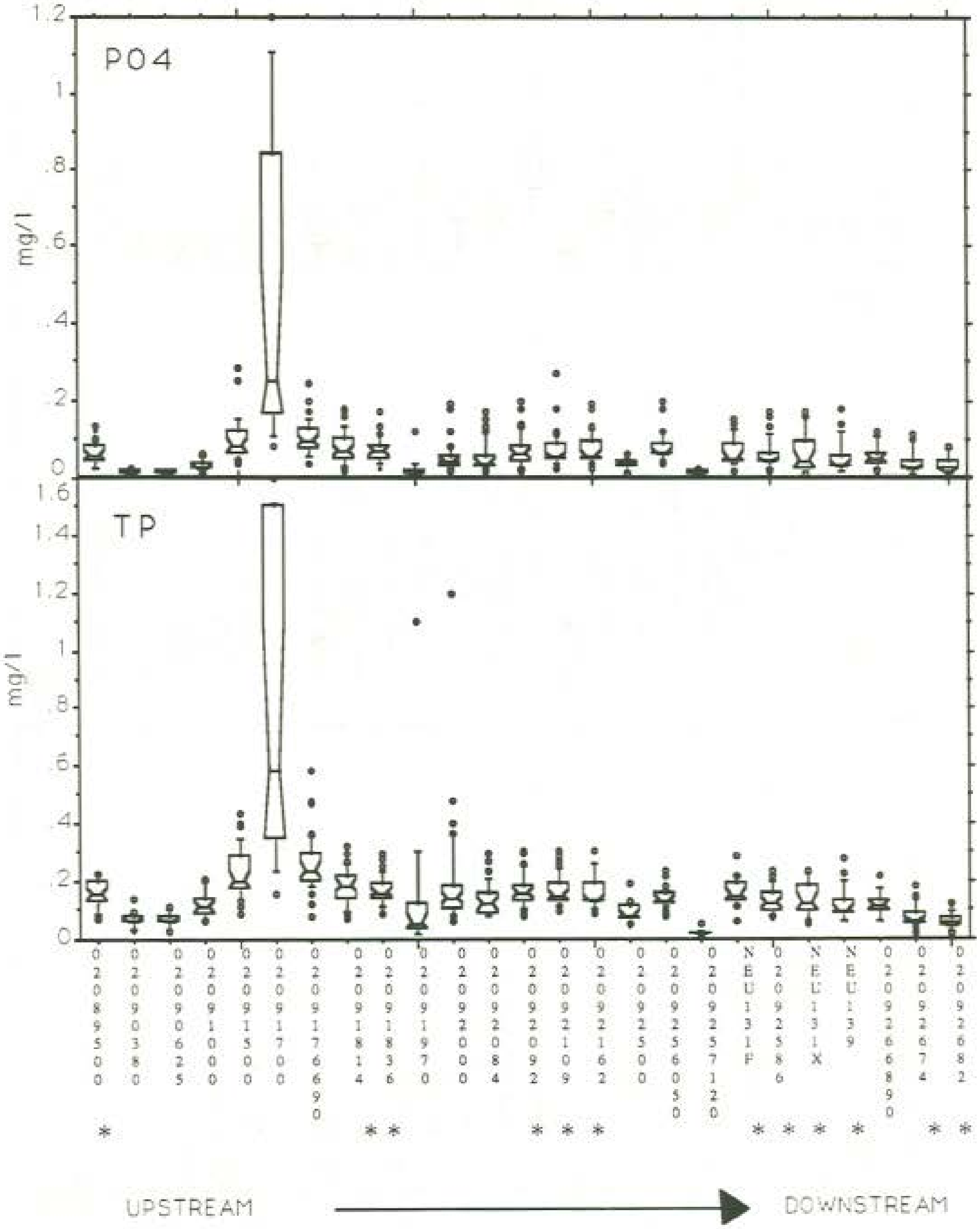



**Figure N5. SEASONAL NITRATE/NITRITE CONCENTRATIONS IN THE NEUSE RIVER BASIN, 1988-1991**




* Asterisk below station denotes mainstem river stations

**Figure N6. AMMONIA/AMMONIUM, TOTAL NITROGEN AND NITRITE/NITRATE VALUES IN THE NEUSE RIVER BASIN, 1988-1991**




* Asterisk below station denotes mainstem river stations

**Figure N7. ORTHOPHOSPHATE AND TOTAL PHOSPHORUS IN THE NEUSE RIVER AND TRIBUTARIES, 1988-1991**

Biological Data

*Phytoplankton and Chlorophyll-a.* Mean algal biovolume, density and corresponding chlorophyll-a values are illustrated in Figure N-9. Increases in algal growth occurred at New Bern as the Neuse River widens and slows down. Below New Bern at station NEU131F to downstream at Minnesott Beach (NEU139), where the river turns northeast, algal populations and corresponding chlorophyll-a values are greatest as shown in Figure N 9. In addition, the majority of algal blooms reported to DEM's Biological Assessment Group occurred in this area.

The winter phytoplankton samples were generally dominated by cool weather dinoflagellates (Dinophyceae) such as Heterocapsa triquetra and Prorocentrum minimum. Summer algal populations were most often dominated by various dinoflagellates (Gymnodinium spp, Gyrodinium spp, and Peridinium spp.) and small centric diatoms, Cyclotella species 2 (Bacillariophyceae). Between seasons, chlorophyll-a values were also similar with highest chlorophyll-a values indicating the greatest algal growth again occurring in the middle Neuse River area as shown in Figure N10.

*Fecal Coliform Bacteria.* Fecal coliforms only measured greater than 200 colonies/100ml during routine monitoring on three occasions. These three samples contained ranges of 210 to 630 colonies/100 ml and all were collected on August 25, 1988. Because weather had been dry the past three months and river flow greatly reduced, the high fecal coliform values are unexplainable. Typically, elevated fecal coliform levels occur after heavy rains.

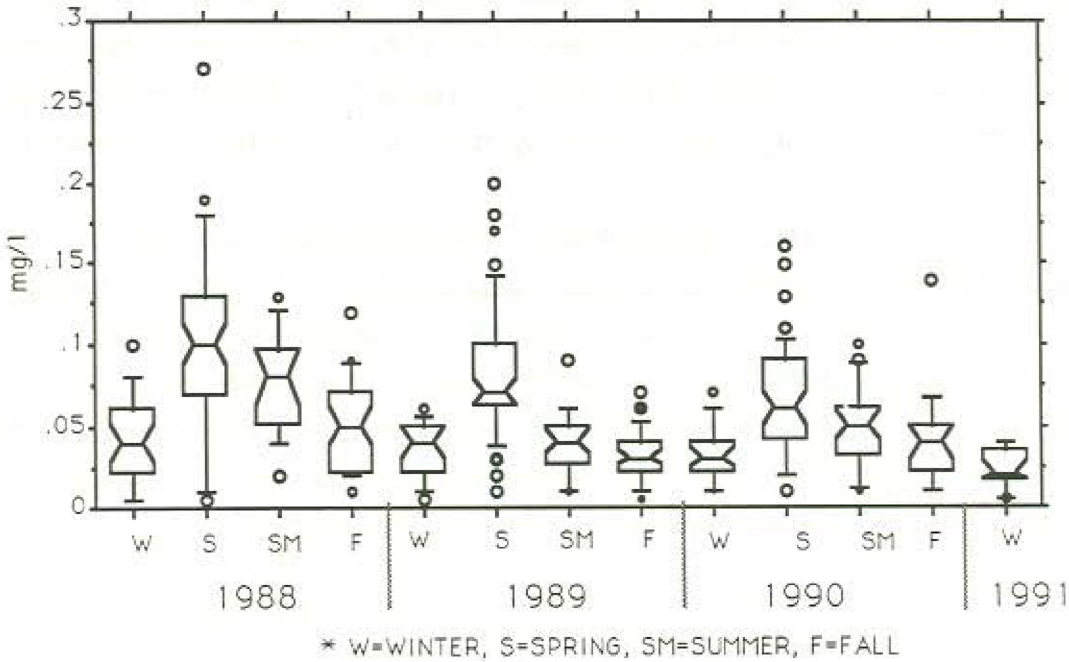



**Figure N8. SEASONAL ORTHOPHOSPHATE CONCENTRATIONS IN THE NEUSE RIVER BASIN, 1988-1991**

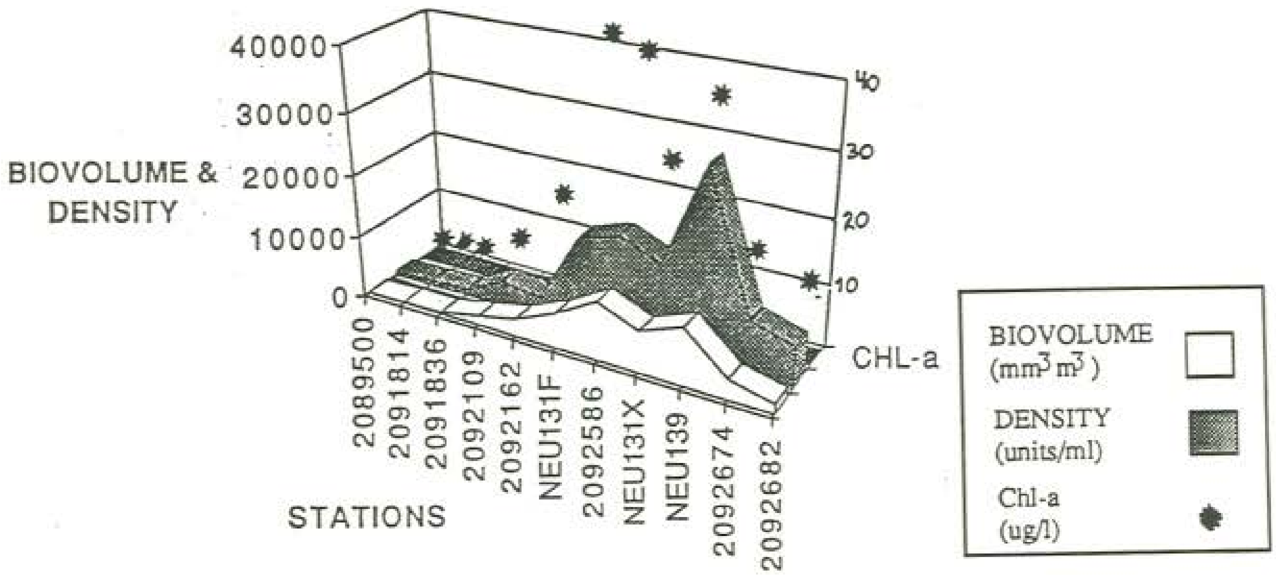



Figure N9. MEAN PHYTOPLANKTON BIOVOLUME, DENSITY, AND CHLOROPHYLL-a FOR THE NEUSE RIVER, 1988 - 1991

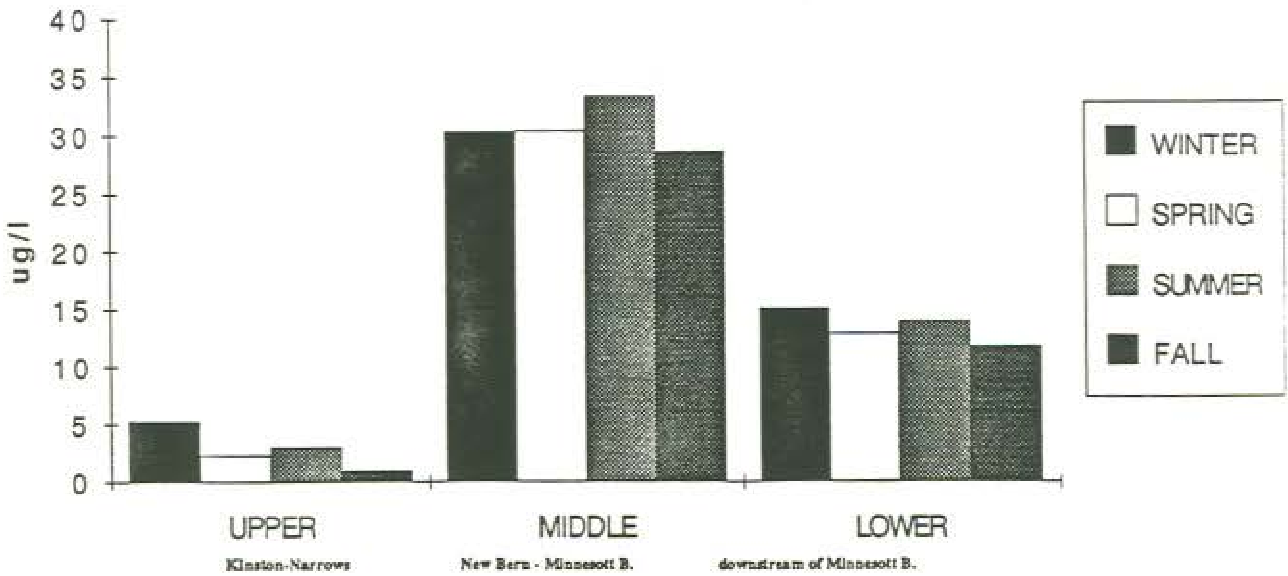



Figure N10. CHLOROPHYLL-a VALUES FOR THE UPPER, MIDDLE AND LOWER NEUSE RIVER, 1988 - 1991

ROANOKE RIVER BASIN

The Roanoke River basin encompasses 3,603 square miles in 17 counties located in the piedmont and inner coastal plain regions of the state. It also includes an additional 4,783 square miles of mountain and piedmont regions in Virginia. The Roanoke River below Roanoke Rapids, N. C. is characterized by variable water levels and flow rate fluctuations due to changes in discharge rates from upstream dams. There are 276 active dischargers in the basin, with 19 having permitted flows greater than 0.5 MGD (NC DEHNR 1990). Figure R-A shows the locations of the eight ambient water quality stations in the Roanoke River basin, listed as follows:

| STATION # | DESCRIPTION | PARAMETERS |
|---|---|---|
| ROANOKE RIVER BASIN | | |
| 02080500 | Roanoke R @ Roanoke Rapids | P,T,M,B |
| 02081000 | Roanoke R nr Scotland Neck | P,T,N,M |
| 02081022 | Roanoke R nr Lewiston | P,T,M,B,F |
| 02081054 | Roanoke R @ Williamston | P,T,N,M,B |
| 02081101 | Cashie R nr Lewiston | P,T,N,M,B,F |
| 02081135 | Roanoke R nr Plymouth | P,T,N,M,BP,B * |
| 02081141 | Roanoke R @ Sans Souci | P,T,N,M,BP,B * |
| 0208114330 | Albemarle Sound (Batchelor Bay) | P,T,N,F * |

P (Physical parameters - D.O., pH, temperature, conductivity)
T (Turbidity); N (Nutrients); M (Metals);
BP (Phytoplankton and/or chlorophyll-a), B (BOD), F (fecals), * (secchi depth)

Physical Data

*Flow.* During 1988, the Roanoke River flow was low, especially during spring and summer months. River flow remained mostly below normal until March of 1989. From the spring of 1989 to November of 1990, flows remained consistently above the average. From January to June of 1990, river flow fluctuated but was above normal during most of the period. Flow continued to fluctuate from June of 1990 until March of 1991, but the flow during this period was predominantly low. After a dry winter in early 1991, the spring and summer experienced higher than normal flows.

*Temperature and Dissolved Oxygen.* The box and whisker plot in Figure R-1 illustrates the distribution of temperatures at each station in the Roanoke Basin. Seasonal trends were evident, with temperatures ranging from 2° to 33°C. The highest surface temperature was recorded on July 24, 1989, at the Albemarle Sound at Batchelor Bay

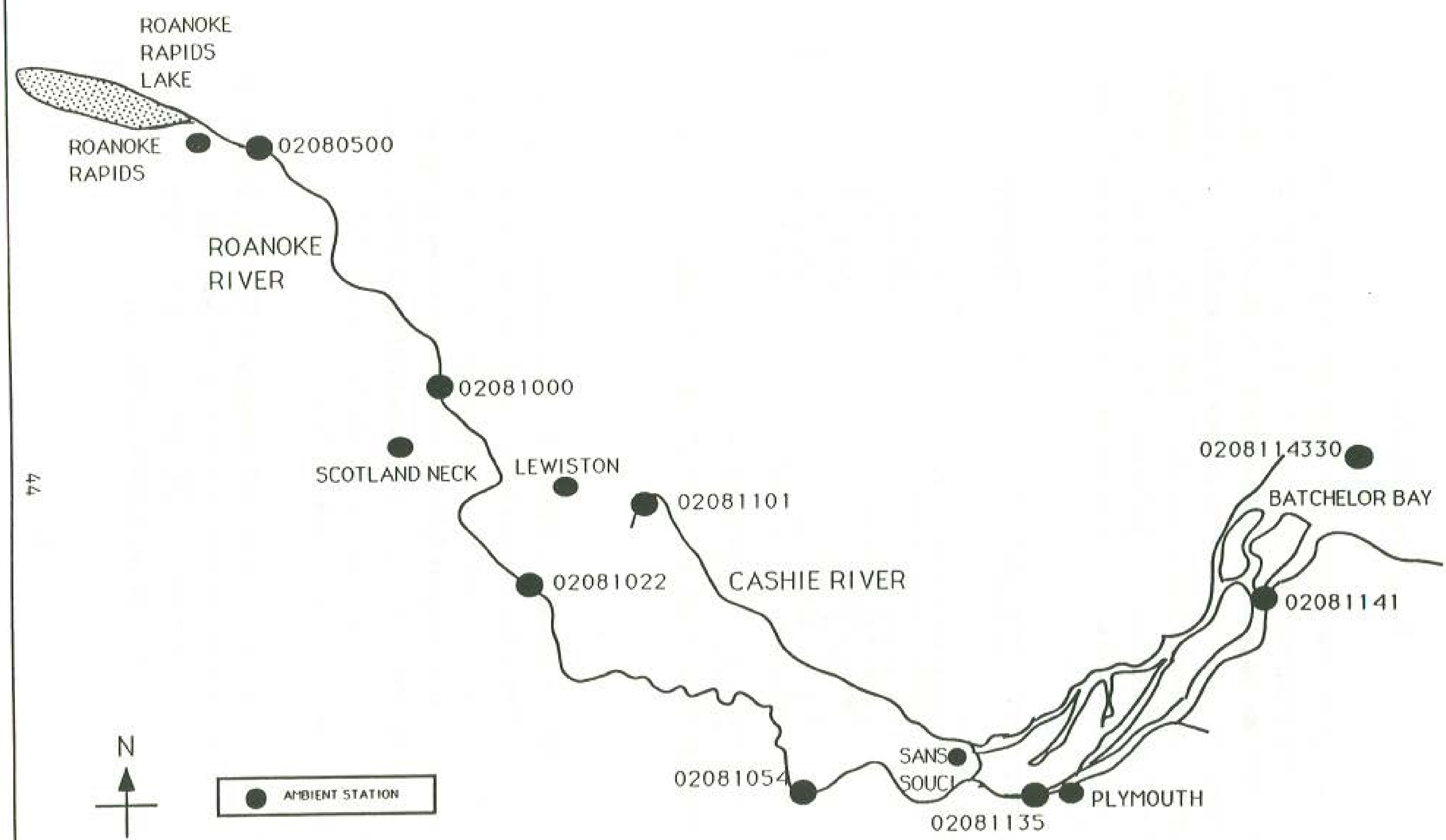



FIGURE R-A. AMBIENT STATIONS IN THE ROANOKE RIVER BASIN

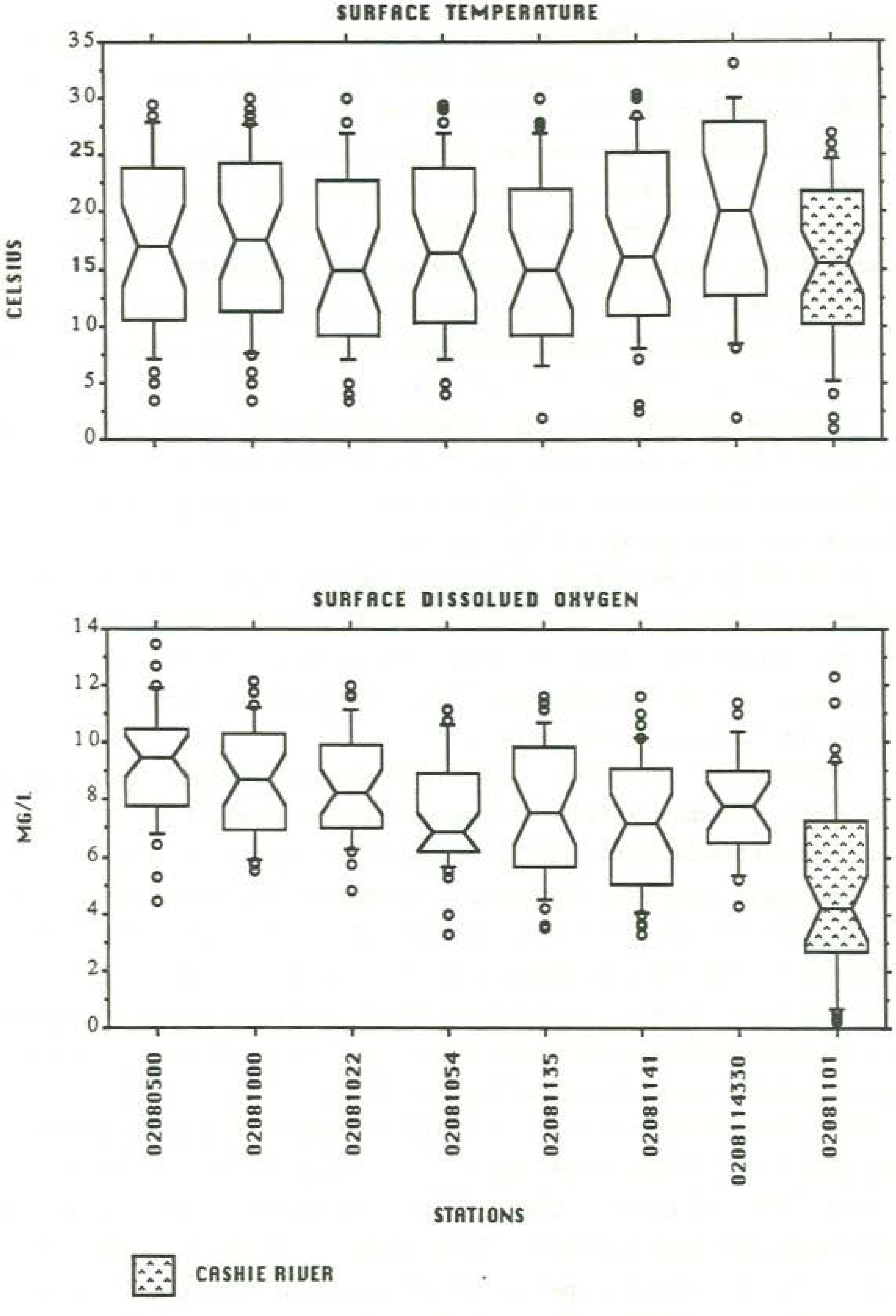



Figure R1. Box plots of surface temperature and dissolved oxygen for the Roanoke and Cashie Rivers, 1988-1991.

station (33°C). Surface temperatures for the Cashie River near Lewiston (02081101) were similar to the Roanoke River temperatures. The lowest surface temperature of 1°C was recorded during December at the Cashie River near Lewiston.

Surface dissolved oxygen averaged 7.60 mg/l in the Roanoke River (all stations). The box and whisker plot in Figure R1 illustrates the distribution of dissolved oxygen from Roanoke River at Roanoke Rapids to the Albemarle Sound (Batchelor Bay). The highest mean DO values were recorded at Roanoke Rapids station (02080500). Dissolved oxygen at this station was higher than all other stations as indicated by the box and whisker plot in Figure R1. This higher concentration of DO may be a result of aeration associated with dam release of water from Roanoke Rapids Lake.

The highest surface DO (13.5 mg/l) occurred in the Roanoke at Roanoke Rapids on November 2, 1989. At a temperature of 8°C and a DO concentration of 13.5 mg/l the surface waters at this station were at approximately 113% saturation. By state standard, dissolved gases shall not exceed 110% saturation.

On July 24, 1989, depth profile readings indicated that the water column was stratified with regard to temperature and dissolved oxygen at the mouth of the Roanoke River at the Albemarle Sound (0208114330). There was a 8°C and a 4.5 mg/l DO difference between the top and the bottom of the water column. No strong thermal or dissolved oxygen stratification was seen at any other stations.

Dissolved oxygen concentrations equal to or less than 5 mg/l occurred most frequently in the Cashie River near Lewiston , the Roanoke River near Plymouth (02081135), the Roanoke River near San Souci (020811411), and the Albemarle Sound (Batchelor Bay). These stations are classified as swampwaters, and lower DO concentrations are considered natural occurrences. The lowest surface DO (0.2 mg/l) occurred in the Cashie River on November 21, 1988. Sixty-two percent of the DO concentrations measured for the Cashie River were below 5.0 mg/l. Oxygen-deficient waters stored in the adjacent swamps may have depressed dissolved oxygen concentrations as they entered the Cashie River as a result of declining instream flows (Rulifson et al. 1990).

For the Roanoke River, 32 percent of the DO concentrations measured near Sans Souci were below 5 mg/l. Twenty-two percent and 9 percent of the DO concentrations near Plymouth (02081135) and at the Albemarle Sound (0208114330), respectively, were also below 5 mg/l. Dissolved oxygen levlels for these stations were above 5.0 mg/l during the winter months, but dropped in April and May and remained low throughout the summer into October. For the Roanoke River basin, dissolved oxygen was lowest during the summer of 1989. These low DO concentrations corresponded with high flow.

*pH*. Mean surface pH for the Roanoke River was 6.9. The surface pH ranged from 6.0 to 7.8. Values for pH were lowest at the Roanoke River near Plymouth site. This station was within the 95% confidence interval of all other stations except Roanoke River at Roanoke Rapids and Roanoke River near Scotland Neck . However, all pH values were within the range of 6.0 to 9.0 established as the standard for fresh water in the state.

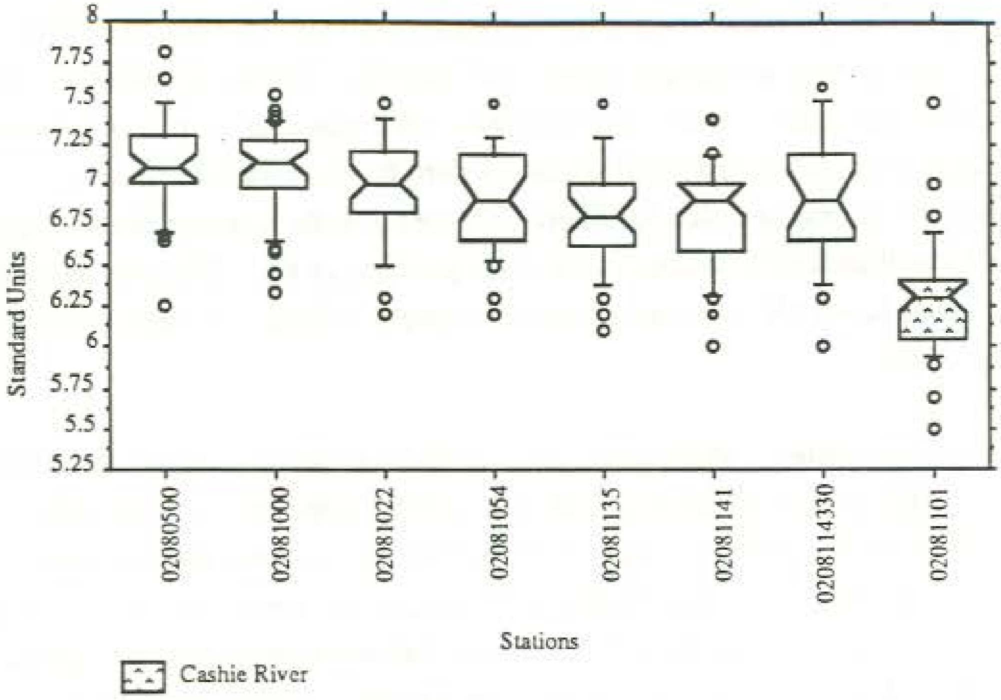
The Cashie River near Lewiston had lower pH values than the Roanoke River, ranging from 5.5 to 7.5 as illustrated in the box and whisker plot (Figure R2). The mean surface pH was 6.3. Such lower pH values are common for rivers, such as the Cashie, associated with swamp waters.

*Conductivity and Salinity*. Mean conductivity in the Roanoke River ranged from 79.8 umhos for the Roanoke at Roanoke Rapids in 1991 to 507.3 umhos on the Albemarle Sound (Batchelor Bay) in 1988 (Fig. R2). In 1988, river flow was low and salt water entered the Roanoke from the Albemarle Sound. The result was a mean salinity of 0.39 ppt for the year and a mean conductivity of 507.3 umhos. Salt water was measurable upstream on the Roanoke to Plymouth. The mean salinity for this station in 1988 was 0.06 ppt and the mean conductivity was 112.56 umhos. In 1989, salt water was detectable at both stations, but concentrations were much lower. For the Roanoke near Plymouth and at the Albemarle Sound, mean salinity and conductivity were 0.02 ppt, 102.6 umhos, 0.03 ppt and 180.90 umhos, respectively.

In 1988, throughout the Roanoke River from Roanoke Rapids to the Albemarle Sound (Batchelor Bay), river flow was lower and mean conductivity was correspondingly higher than in 1989, 1990, and 1991. Mean conductivity for the Cashie River near Lewiston was consistently lower than the Roanoke River stations from 1988-1991. For both the Roanoke River and the Cashie near Lewiston, salinity remained below 1.0 ppt for all stations in this study.

*Turbidity*. Turbidity measurements for the Roanoke River ranged from 1.4 NTU at Roanoke Rapids to 34 NTU near Scotland Neck. All turbidity values were below the state standard of 50 NTU. Turbidity values were lowest at Roanoke Rapids, where Roanoke Rapids Lake above the dam acts as a settling pool. Turbidity measurements were higher downstream near Scotland Neck and leveled off near Lewiston . Turbidity was lower at the mouth of the Roanoke at Albemarle Sound. Turbidity values were below the state standard on the Cashie River near Lewiston. All but one sample were below 20 NTU. A turbidity reading of 42 NTU was sampled on April 6, 1989.

SURFACE pH FOR ROANOKE RIVER BASIN (1988-1991)




MEAN CONDUCTIVITY FOR ROANOKE RIVER BASIN (1988-1991)

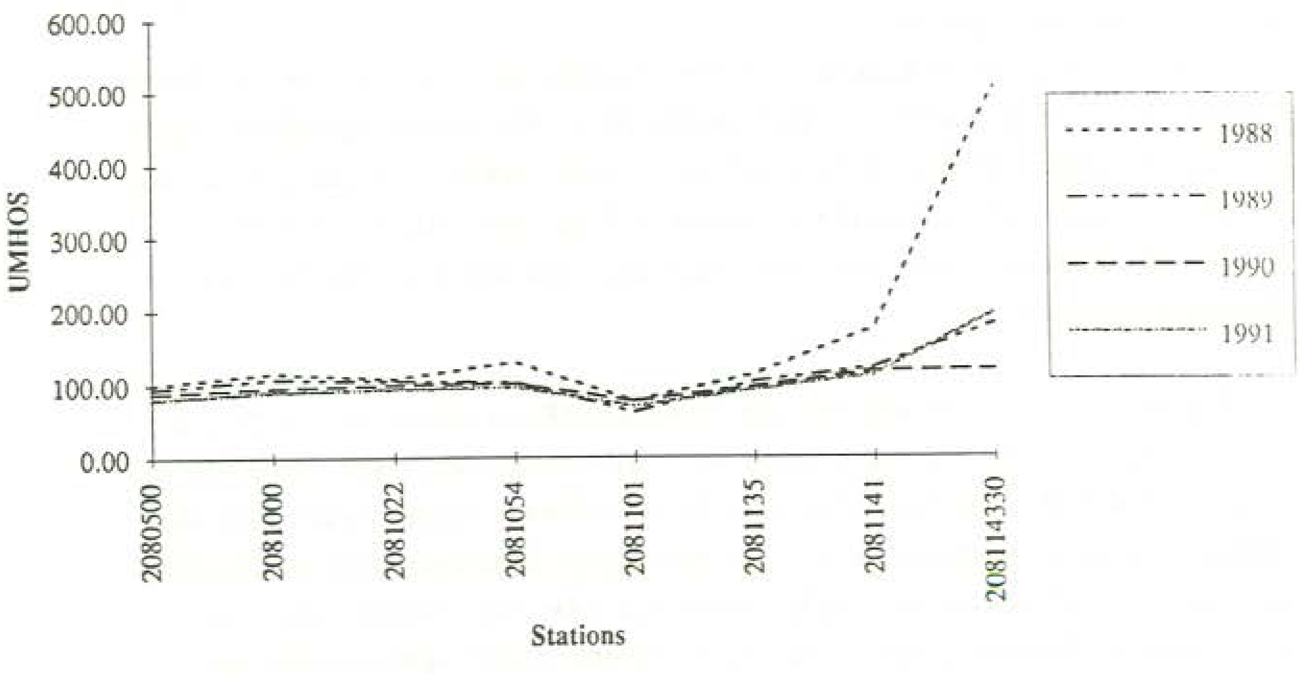



Figure R2. Surface pH and conductivity for the Roanoke and Cashie Rivers, 1988-1991.

*Metals*. The concentrations of arsenic, chromium, beryllium, cadmium, nickel, selenium, silver, and manganese were all below detection level or reporting level (Table R1). Concentrations of lead, mercury, and zinc were below detection level in over 98 percent of the samples. Two lead concentrations above detection level, 19 and 20 ug/l, were found on the Roanoke at Williamston (02081054). Both values were below the state standard of 25 ug/l. A concentration of 0.2 ug/l of mercury was measured near Plymouth. This measurement was above the state standard of 0.012 ug/l and was the only sample above detection. Two positive zinc concentrations, 21 and 16 ug/l, which were measured at Roanoke Rapids and near Scotland Neck, respectively, were below the state action level of 50 ug/l.

Table R1. DEM laboratory reporting levels and percent of samples below the reporting level for heavy metals sampled between 1988 and 1991, Roanoke River Basin.

| Metal | Reporting Level (RL) | % Samples Below RL | Metal | Reporting Level (RL) | % Samples Below RL |
|---|---|---|---|---|---|
| Arsenic | 10 | 100 | Nickel | 10* | 100 |
| Chromium | 25 | 100 | Selenium | 0.5 | 100 |
| Beryllium | 25 | 100 | Silver | 5 | 100 |
| Cadmium | 2 | 100 | Zinc | 10 | 98 |
| Copper | 2* | 62 | Iron | 50 | 0 |
| Lead | 10 | 98 | Manganese | 25 | 0 |
| Mercury | 0.2 | 99 | Cobalt | 50 | 100 |
| Aluminum | 50 | 8 | | | |

All reporting levels are in ug/l.
* Reporting levels for 1988 were high level.

Copper, aluminum, iron, and manganese concentrations were more commonly found above the reporting level. Copper concentrations ranged from 2 to 15 ug/l, with the highest concentrations found in the Roanoke River at Williamston and the Cashie near Lewiston. Iron, manganese, and aluminum concentrations were only available for the Roanoke at Roanoke Rapids and near Scotland Neck. For these metals, the concentrations were above detection level for the majority of the samples. Aluminum concentrations ranged from 72 to 1000 ug/l, and iron ranged from 140 to 650 ug/l in the surface water. Aluminum and iron occur naturally in the sediments of the piedmont and coastal plain. Manganese concentrations ranged from 25 to 270 ug/l, with the highest concentration (270 ug/l) sampled at Roanoke Rapids. Like iron and aluminum, manganese is also naturally occurring in sediments of the piedmont of North Carolina and Virginia.

Nutrients

*Nitrogen and Phosphorus.* Ammonia/ammonium ($NH_3/NH_4$), nitrate/nitrite ($NO_2/NO_3$), and total kjeldahl nitrogen (TKN) were sampled on the Roanoke River and the Cashie River near Lewiston. Total nitrogen (TN) was determined by adding the total kjeldahl nitrogen and nitrate/nitrite.

The mean total nitrogen concentration for the Roanoke River was 0.48 mg/l. The highest TN concentration of 0.84 mg/l was found on the Roanoke River at Sans Souci. However, all TN concentrations were well below the target level of 1.0 mg/l.

TN concentrations for the Cashie River near Lewiston were generally higher than those measured from stations on the Roanoke River. The mean TN concentration for the Cashie River station was 0.7 mg/l. The highest TN concentration (1.2 mg/l) was sampled on July 13, 1988. The Cashie is a blackwater river and light probably is a limiting factor in phytoplankton growth.

For the Cashie River, TN concentrations were highest in the summer months (June, July, August, and September). This seasonal trend was most prevalent during the summers of 1988 and 1989. No distinguishable seasonal trend was observed in the Roanoke River from Roanoke Rapids to the Albemarle Sound.

Mean nitrate/nitrite concentration for the Roanoke River was 0.18 mg/l. The concentrations for the Roanoke River ranged from 0.03 mg/l on the Roanoke at Williamston (02081054) to 0.36 mg/l at Roanoke Rapids.

The Cashie River near Lewiston had lower $NO_2/NO_3$ concentrations than the Roanoke as illustrated in the box and whisker plot in Figure R3. The mean concentration for the Cashie was 0.06 mg/l. Concentrations ranged from 0.01 to 0.2 mg/l.

Ammonia/ammonium ($NH_3/NH_4$) concentration for the Roanoke ranged from 0.01 mg/l to 0.28 mg/l. The highest concentration (0.28 mg/l) was sampled on the Roanoke at Sans Souci.

The two forms of phosphorus that were analyzed in this study were orthophosphate ($PO_4$) and total phosphorus (TP). The TP concentration in the Roanoke River ranged from 0.01 to 0.85 mg/l. The mean total phosphorus was 0.06 mg/l. The highest TP concentration (0.85 mg/l) measured on the Roanoke River was sampled at San Souci (02081141).

Total phosphorus was higher on the Cashie River near Lewiston. Total phosphorus concentrations in the Cashie near Lewiston ranged from 0.04 to 0.61 mg/l. The mean orthophosphate concentration was 0.025 mg/l, with a highest $PO_4$ concentration of 0.06. This form of phosphorus is considered as available to phytoplankton. The mean

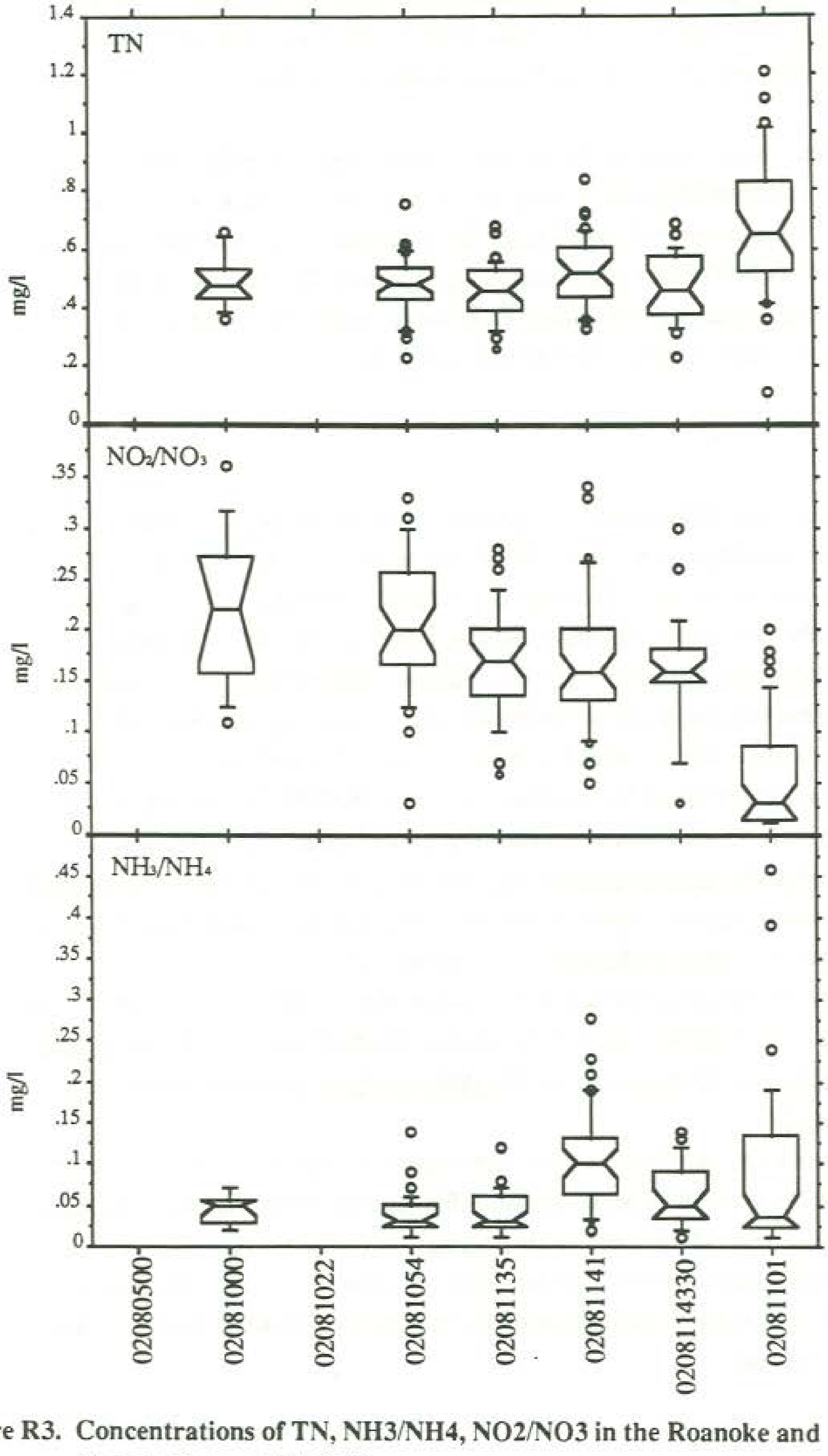



**Figure R3. Concentrations of TN, NH3/NH4, NO2/NO3 in the Roanoke and Cashie Rivers, 1988-1991.**

orthophosphate concentration for the Roanoke River was 0.01 mg/l, with a highest concentration of 0.05 mg/l at Sans Souci (02081141). There was little difference in $PO_4$ concentrations between stations on the Roanoke River (Figure R4).

*Biochemical Oxygen Demand.* BOD concentrations were low in the Roanoke, with mean concentrations ranging from 0.9 mg/l to 1.5 mg/l. The Cashie River near Lewiston had a slightly higher mean BOD of 2.2 mg/l. Of 37 samples taken, only two had a BOD above 5.0 mg/l. A BOD of 6.4 mg/l occurred on November 21, 1988, and a BOD of 7.1 mg/l occurred on August 6, 1990. However, all other samples (35) were low in comparison to 5.0 mg/l, ranging from 0.7 mg/l to 4.9 mg/l.

Biological Data

*Phytoplankton and Chlorophyll-a* Chlorophyll-a was measured at three stations on the Roanoke River, near Plymouth, at Sans Souci, and in Batchelor Bay. Chlorophyll-a values were low at all stations. The mean concentrations were 5.1 ug/l, 4.0 ug/l and 2.0 ug/l, respectively. The highest chlorophyll-a concentration of 28 ug/l was sampled on February 25, 1988, near Plymouth. No phytoplankton samples were taken at that time.

Phytoplankton biovolume and density measurements were only available for the Roanoke at Sans Souci station. Both biovolume and density were low. The highest biovolume measurement was 3,596 $mm^3/m^3$ on March 28,1988. The density on that day was 4,647 units/ml. The chlorophyll-a concentration was 8 ug/l. This sample was dominated by Melosira granulata angustissima (Bacillariophyceae), Melosira italica alpigena (Bacillariophyceae), Chlorella species (Chlorophyceae), Ankistrodesmus falcatus miralbilis (Chlorophyceae) and Cryptomonas ovata (Chryptophyceae).

The greatest phytoplankton density was found on May 31, 1988. The biovolume was 2,658 $mm^3/m^3$ and the density was 5,391 units/ml. The dominant species were Melosira granulata angustissima, Chlorella species, Cryptomonas minuta (Cryptophyceae), and Cryptomonas ovata.

For the Roanoke at Sans Souci, typical assemblages of phytoplankton were present. Throughout the four-year study period, diatoms (Bacillariophyceae), especially Melosira species, were dominant. Greens, especially Chlorella (Chlorophyceae) were dominant in the spring, summer, and early fall. Chryptophytes (Crytophyceae) were consistently dominant. Blue-green (Cyanophyceae) populations were low, but were more prevalent in late spring and summer.

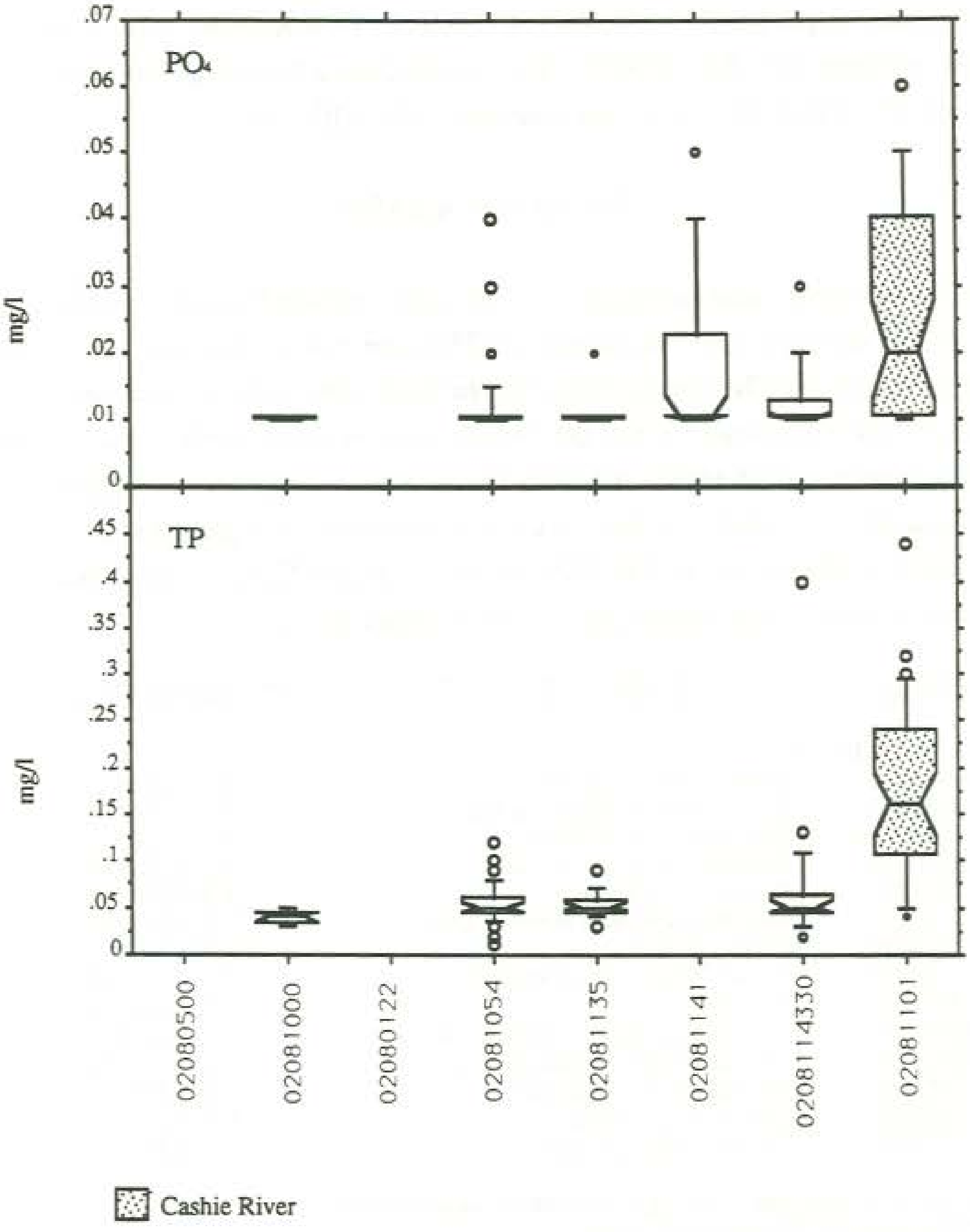



**Figure R4. Concentrations of TP and PO4 in the Roanoke and Cashie Rivers, 1988-1991.**

*Fecal Coliform Bacteria.* Fecal coliform counts that exceeded 200 MFFCC/100 ml were found on the Roanoke near Lewiston and on the Cashie near Lewiston. Fecal coliform counts ranged from 10 to 400 MFFCC/100 ml on the Roanoke River near Lewiston, and from 10 to 840 MFFCC/100 ml on the Cashie River near Lewiston. The fecal count of 840 MFFCC/100 ml was measured on July 10, 1990.

## CHOWAN RIVER BASIN

The Chowan River basin encompasses 1,315 square miles in five counties in the coastal plain of North Carolina and includes 3,575 square miles in Virginia. Major rivers in the basin include the Chowan, the Meherrin, the Blackwater and the Wiccacon rivers. There are 29 active dischargers within the Chowan basin in North Carolina, but only three have flows greater than 0.5 MGD. All North Carolina stream segments in the basin have been designated as "Nutrient Sensitive Waters". This classification provides regulatory authority to limit nutrient inputs (NC DEHNR 1990a). Figure C-A shows the locations of the 14 ambient water quality stations in the Chowan River Basin.

| STATION # | DESCRIPTION | PARAMETERS |
|---|---|---|
| CHOWAN RIVER BASIN | | |
| 02047370 | Nottaway R nr Riverdale | P,T,N,F * |
| 02050065 | Blackwater R @ Horseshoe Bend | P,T,N,BP,F * |
| 0205007750 | Blackwater R nr Wyanoke | P,T,N,BP,F * |
| 02050079 | Chowan R nr Riddicksville | P,T,N,BP,F * |
| 02053200 | Potecasi Cr nr Union | P,T,N,BP |
| 0205321790 | Meherrin R (Parkers Ferry) nr Como | P,T,N,M,B,F * |
| 02053244 | Chowan R @ Winton | P,T,N,B,BP,F * |
| 0205325510 | Chowan R @ Channel Marker # 27 | P,T,N,B,BP,F * |
| 02053500 | Ahoskie Cr @ Ahoskie | P,T,N,M,B,BP |
| 02053574 | Chowan R nr Gatesville (Marker # 16) | P,T,N,BP,F * |
| 0205360615 | Chowan R below Holiday Island | P,T,N,M,BP,F * |
| 02053569 | Wiccacon R nr Harrelsville | P,T,N,BP |
| 02053632 | Chowan R @ Colerain | P,T,N,BP,F * |
| 02053652 | Chowan R @ Edenhouse | P,T,N,M,BP * |

P (Physical parameters - D.O., pH, temperature, conductivity)
T (Turbidity); N (Nutrients); M (Metals);
BP (Phytoplankton and/or chlorophyll-a), B (BOD), F (fecals), * (secchi depth)

Physical Data

*Flow.* Flows in the Chowan River basin were generally below normal for 1988, particularly during the first months of the year, and then in late summer through February

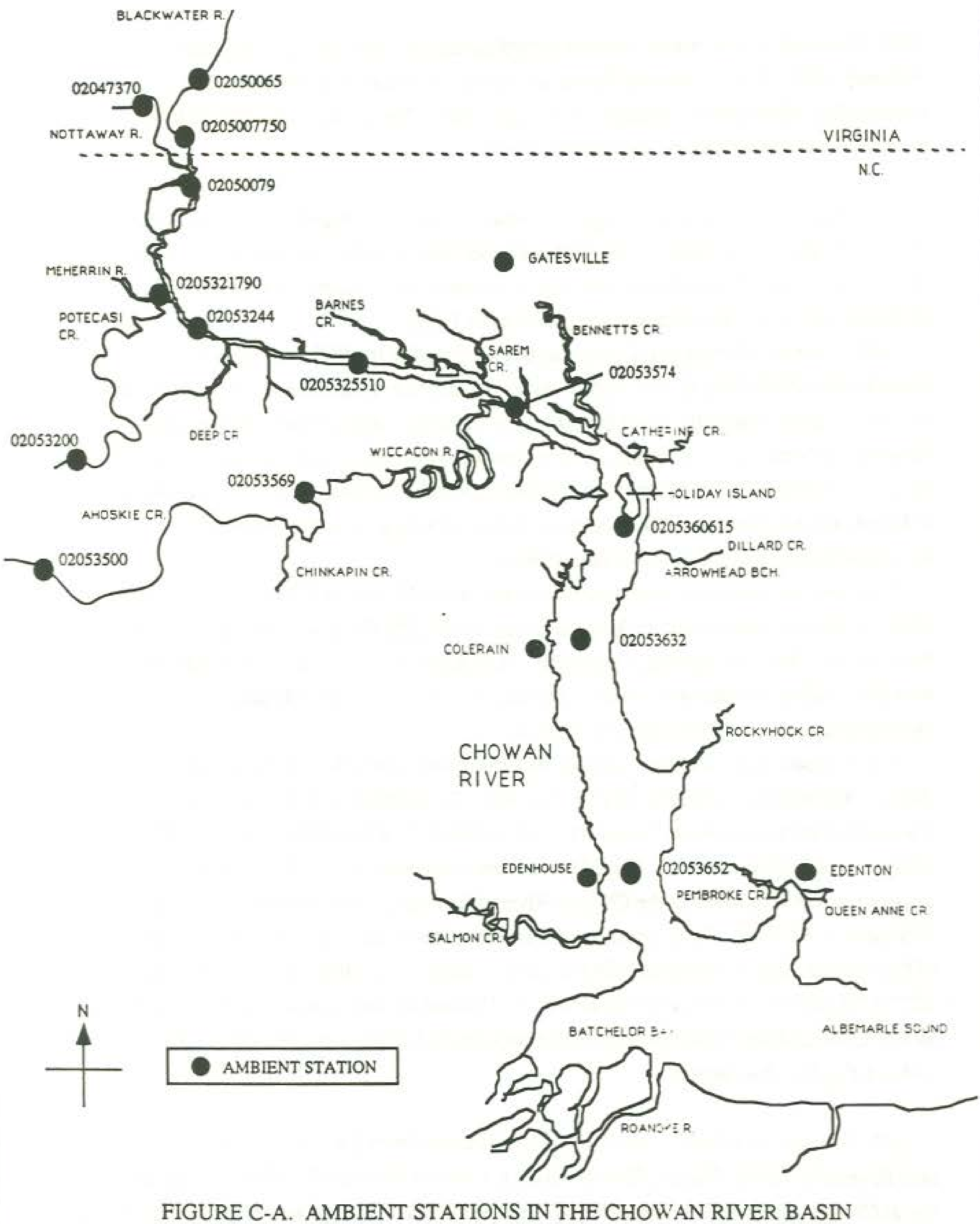



FIGURE C-A. AMBIENT STATIONS IN THE CHOWAN RIVER BASIN

1989. However, above normal flows occurred during the remainder of 1989 through February 1990. Flows fluctuated during the spring and summer of 1990 and then decreased to below normal through the spring of 1991. The summer and fall of 1991, however, experienced higher than normal flows.

*Temperature and Dissolved Oxygen*. Surface temperature ranged from 0°C to 31°C and varied seasonally. Figure C-1 provides an overview of surface temperature at each station within the Chowan Basin. The highest temperatures occurred in August 1988, and the lowest temperatures occurred during December 1989.

Surface dissolved oxygen (DO) ranged from 1.4 mg/l in the Wiccacon River near Harrellsville (02053569) to 12.4 mg/l in the Chowan River at Edenhouse (02053652). The DO levels varied seasonally, exhibiting the typical inverse correlation with temperature. However, supersatuated conditions (greater than 100 percent), occurred in the Chowan River at Colerain (02053632) on May 22, 1989, and July 12, 1990, and at Chowan River at Edenhouse on June 19, 1990, as a result of excessive algal growth. Figure C-1 illustrates the range of DO levels at each station.

Dissolved oxygen levels were generally lowest at the Wiccacon River station. All the ambient tributary stations except Ahoskie Creek (02053500) along with the upper Chowan River stations down to Gatesville, experienced DO levels less than 5 mg/l on at least two occasions during the summer months. This may have occurred naturally due to the swamp-like conditions in that part of the basin.

Stratification within the water column occurred at the lower Chowan River stations (Marker #27 and Colerain) only on May 22, 1989. Temperature was most stratified at the Chowan River below Holiday Island station (0205360615) with a difference of 7.5°C within a profile of five meters. The DO difference at this station was 2.3 mg/l. Dissolved oxygen was most stratified at the Chowan River at Colerain station (02053632) with a difference of 4.0 mg/l. The temperature difference at this station was 6.5°C within a profile of four meters. The lowest bottom DO levels (4.8 mg/l) on this date occurred at Gatesville (02053574) and Holiday Island (0206360615). Thermal statification occurred one other time at Chowan River below Holiday Island on March 13, 1990 with a difference of 6°C within a depth of five meters.

*pH*. Surface pH values in the Chowan basin ranged from 5.4 s.u. at Nottaway River near Riverdale (02047370) and Chowan River at Channel Marker #27 (0205325510) to 9.1 s.u. at Chowan River at Colerain (02053632). The highest pH value was associated with an algal bloom on July 12, 1990, accompanied by high chlorophyll-a and dissolved

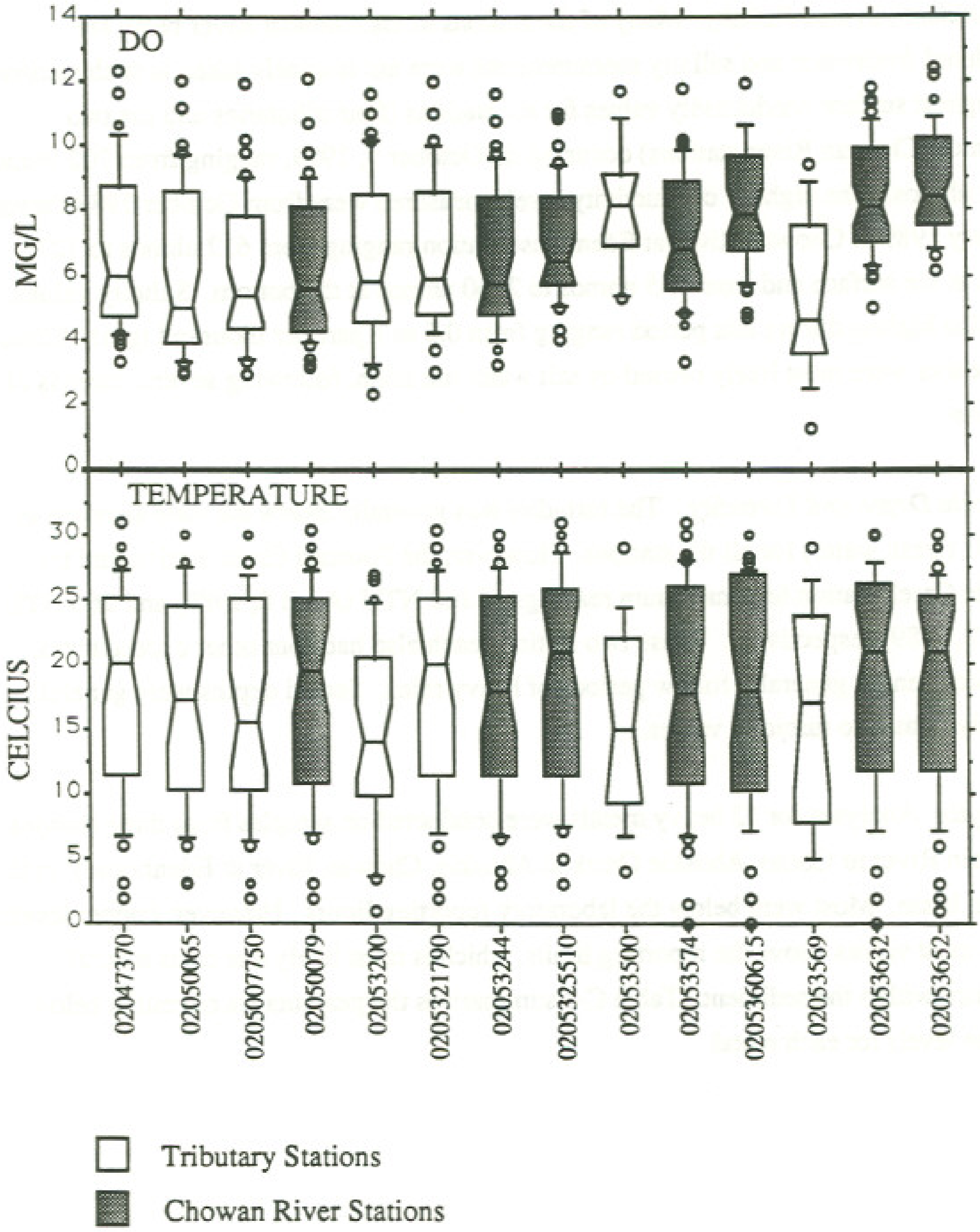



Figure C1. Surface temperature and dissolved oxygen for the Chowan River Basin, 1988-1991.

oxygen levels. Figure C-2 illustrates the ranges for each station. It can be noted that the median values for all stations were generally similar and close to 6.5, except for the Wiccacon River.

*Conductivity and Salinity.* Many of the stations in the Chowan River basin are considered freshwater and salinity measurements were not routinely taken at such stations. The highest surface conductivity values for six stations (four tributaries and the two uppermost Chowan River stations) occurred on October 9, 1989, ranging from 702 uhmos to 833 uhmos. The highest conductivity levels measured were from October 1988 through February 1989 at Chowan River at Edenhouse station ranging from 612 uhmos to 1273 uhmos at the surface and from 945 uhmos to 2160 uhmos at the bottom. Salinity values were also highest during this period ranging from 0.5 to 1 part per thousand (ppt). These occurrences were most likely caused by salt water intrusion, following several months of low flow.

*Secchi Depth and Turbidity.* The turbidity was generally below the state standard of 50 NTU (fresh water) for all the stations. However, the Potecasi Creek station and the Ahoskie Creek station had maximum readings of 160 NTU (April 6, 1989) and 260 NTU (July 17, 1989) respectively. These two stations each also had four other exceedances. Such occurrences generally follow periods of heavy rains. Secchi depths were generally inversely related to turbidity values.

*Metals.* Analyses for 12 heavy metals were conducted on samples from three stations (Meherrin River nr Como, Ahoskie Creek at Ahoskie, Chowan River at Edenhouse) in the Chowan basin. Most were below the laboratory reporting limits. However, copper levels had the most values above the reporting limits, which is most likely due to its natural abundance within the sediment. Table C-1 summarizes the percentages of results below detection levels for each metal.

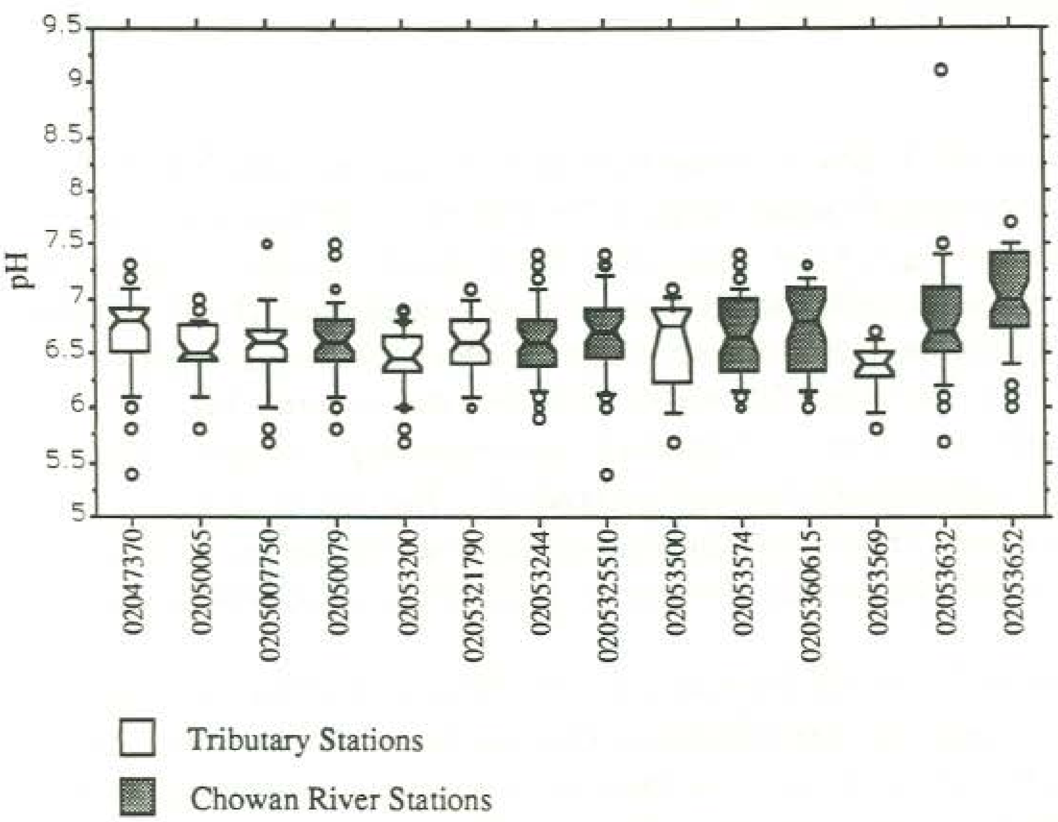



Figure C2. Surface pH for the Chowan River Basin, 1988-1991.

Table C1. DEM Laboratory reporting levels (RL) and percent of samples below the reporting levels for heavy metals sampled between 1988 and 1991 in the Chowan River Basin.

| Metal | Reporting Level (RL) | % Samples Below RL | Metal | Reporting Level (RL) | % Samples Below (RL) |
|---|---|---|---|---|---|
| Arsenic | 10 | 100 | Mercury | 0.2 | 100 |
| Chromium | 25 | 100 | Nickel | 10* | 100 |
| Beryllium | 25 | 100 | Selenium | 0.5 | 94 |
| Cadmium | 2 | 100 | Silver | 5 | 100 |
| Copper | 2* | 68 | Zinc | 10 | 85 |
| Lead | 10 | 95 | Cobalt | 50 | 100 |

All reporting levels are in ug/l.
*Reporting levels for 1988 were high level.

Nutrients

*Nitrogen and Phosphorus.* Seasonally, most of the stations experienced the highest nutrient levels during the winter and spring. The levels may be attributed to nonpoint source inputs during high flow. Figures C-3 - C-5 illustrates the ranges of nutrient levels for each station. The surface total nitrogen (TN) levels ranged from 0.13 mg/l at Chowan River at Riddicksville (02050079) to 2.18 mg/l at Blackwater River near Wyanoke (0205007750). The highest TKN and $NH_3/NH_4$ levels also occurred at Blackwater River near Wyanoke with values of 1.7 mg/l and 1.1 mg/l respectively. The highest $NO_2/NO_3$ level of 1.1 mg/l occurred at Ahoskie Creek at Ahoskie. The mean TN concentration was highest at Ahoskie Creek followed by Blackwater River near Wyanoke with values of 0.58 mg/l and 0.50 mg/l respectively. The other nitrogen species generally followed the same trend.

The highest TP and $PO_4$ levels along with TN, TKN and $NH_3/NH_4$ levels were recorded on January 26, 1988 at Blackwater River near Wyanoke. This station is located below the discharge canal from Union Camp, and on that date much lower values were measured at the upstream station on the Blackwater River (02050065). The discharge is sent to a settling pond and then released during the early part of the winter when flow is generally highest. The TP and $PO_4$ means, like the TN, TKN, and $NO_2/NO_3$ means, were highest at the Ahoskie Creek station. Nutrient concentrations measured at Blackwater near Wyanoke and Ahoskie Creek at Ahoskie were high relative to Chowan River stations.

*Biochemical Oxygen Demand.* Only the stations at Chowan River at Riddicksville, Meherrin River near Como, Chowan River at Winton, Chowan River at Channel Marker #27, and Ahoskie Creek were sampled for BOD measurements. Maximum values for these five stations ranged from 1.6 mg/l to 4.3 mg/l.

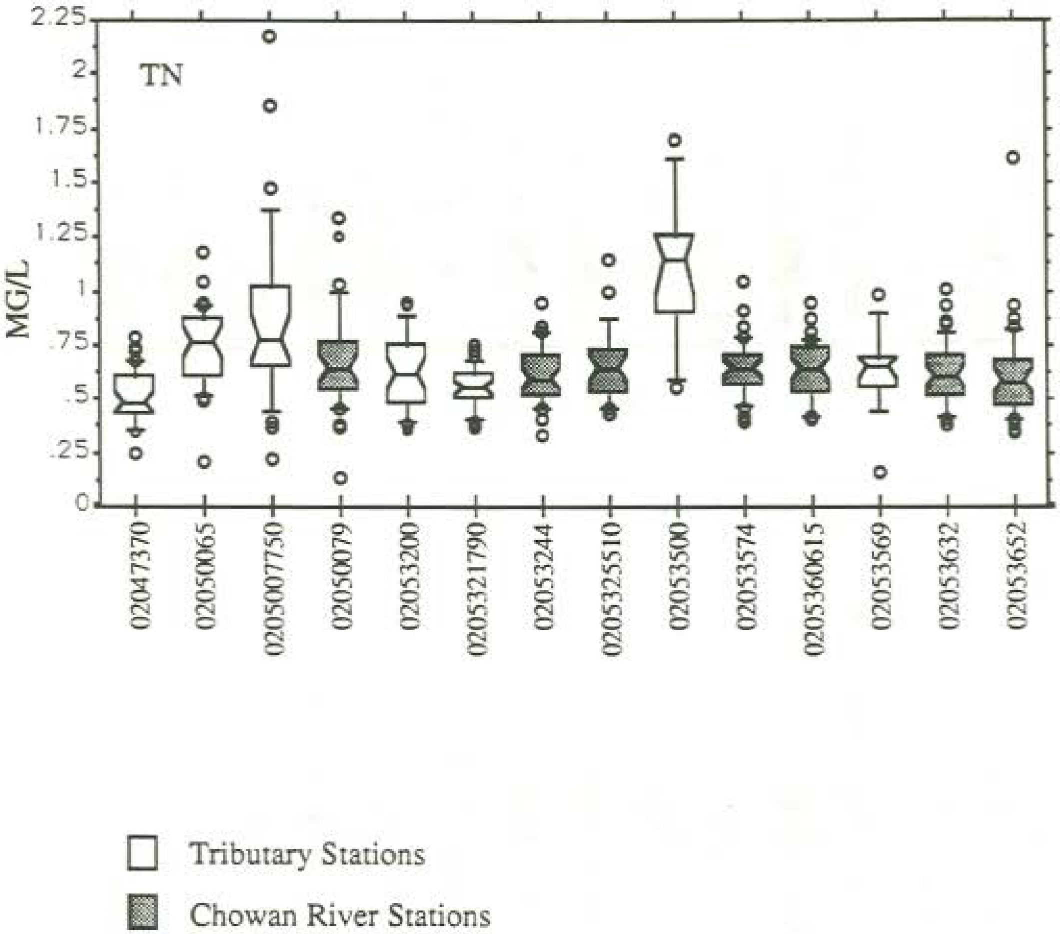



Figure C3. Total nitrogen levels for the Chowan River Basin, 1988-1991.

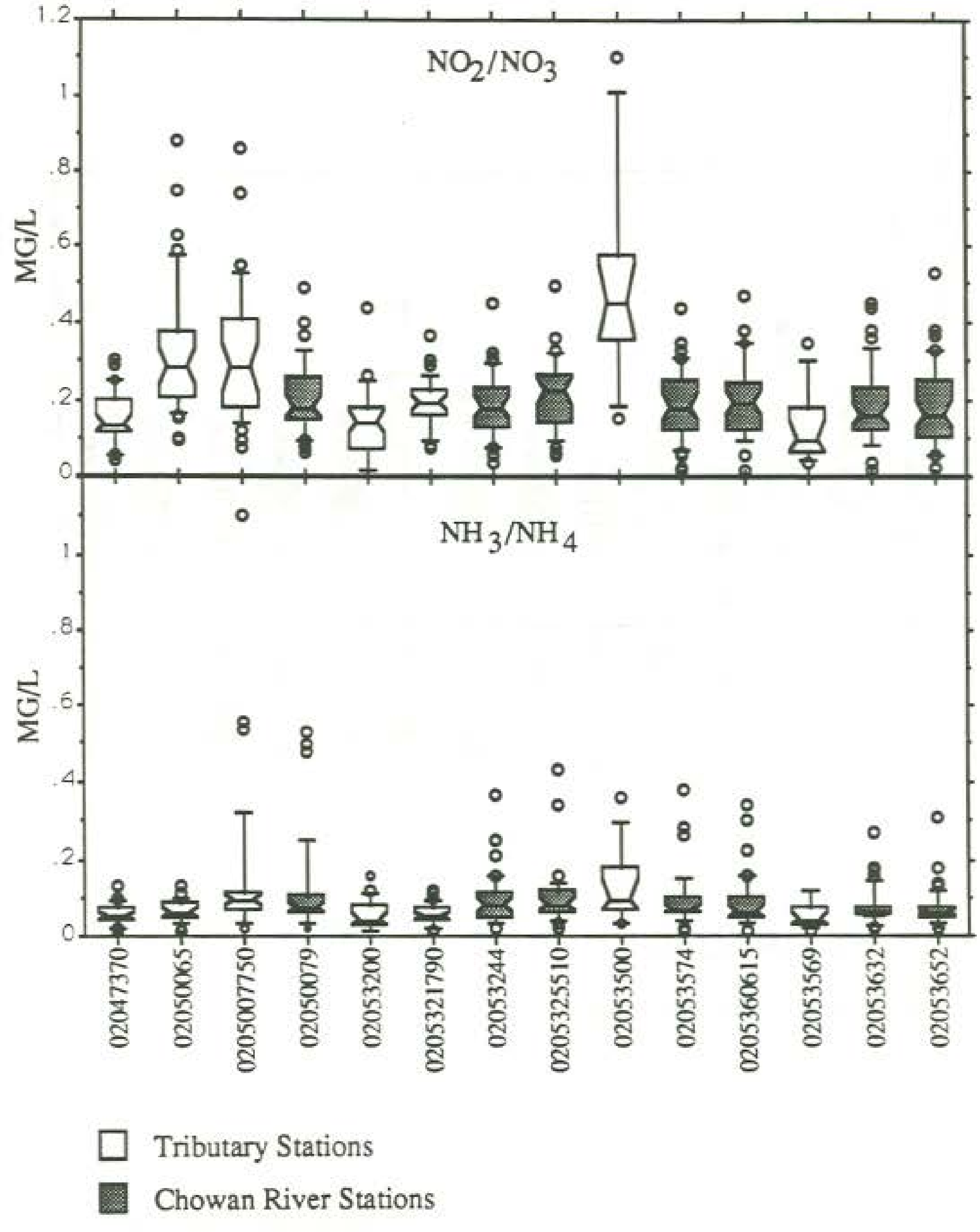



Figure C4. Nitrate/Nitrite and Ammonia/Ammonium levels for the Chowan River Basin, 1988-1991

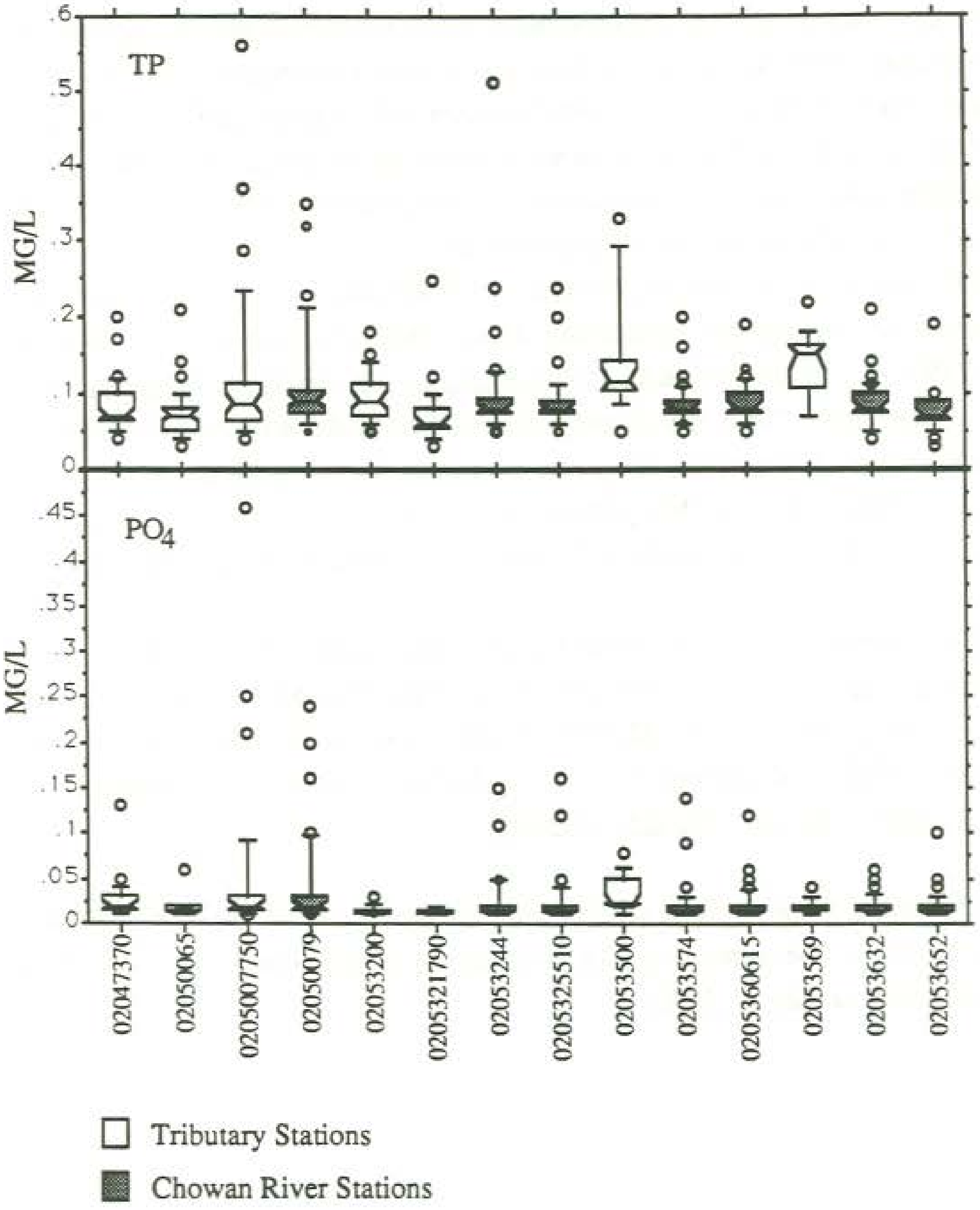



Figure C5. Total phosphorous and orthophosphate levels for the Chowan River Basin, 1988-1991.

Biological Data

*Phytoplankton and Chlorophyll-a.* Algal blooms in the Chowan basin are controlled by meteorology. Wet springs resulting in nonpoint source runoff followed by dry summers, creating increased retention time, often result in algal bloom conditions. These favorable conditions existed for both 1989 and 1990. However both 1988 and 1991 experienced lower than normal spring flow conditions which decreased availability of nutrients for phytoplankton assimilation during the summer. A wet summer in 1991 also inhibited algal growth for that year by decreasing the retention time.

The Chowan River experienced blue-green blooms in July and August of 1989 and 1990 and the blooms extended intermittently through October of both years (NCDEHNR 1990b & 1991c). The dominant algal species Anabaena spp. and Anacystis cyanea formed visible surface scums. The blooms mainly extended from Holiday Island (0205360615) to as far as Edenhouse (02053652). Many slow moving tributaries to the Chowan also had thick surface growths of algae. Many of these blooms were accompanied by elevated chlorophyll-a levels ranging from 54 ug/l to 400 ug/l in 1989 and 100ug/l to 400 ug/l in 1990.

A bloom dominated by dinoflagellates (Peridinium cinctum), chrysophytes (Mallomonas majorensis), and cryptophytes (Chroomonas sp.) on the Chowan River at Colerain was documented on May 22, 1989. Another bloom on the Chowan River near Gatesville (02053574) on October 16, 1990, was dominated by chloromonadophytes such as Gonystomum semen and Vacuolaria virescens.

*Fecal Coliform Bacteria.* Fecal coliforms measured greater than 200 colonies/100ml only once during routine monitoring. The station on the Chowan River near Gatesville had a count of 340/ml on July 12, 1990.

## PASQUOTANK RIVER BASIN

The Pasquotank River basin covers an area of 3,697 square miles in nine counties in the outer coastal plain region, including 527,900 acres of saltwater. The watersheds that form the Pasquotank basin drain into sections of the Albemarle, Currituck, Croatan, Roanoke and Pamlico sounds. There are 53 active permitted surface water dischargers (seven municipal and 46 nonmunicipal) within the basin (NC DEHNR 1990a). Figure P-A shows the location of the 25 ambient water quality stations in the Pasquotank River basin, listed as follows:

| PASQUOTANK RIVER BASIN | | |
|---|---|---|
| 02042955 | Currituck Sound @ Point Harbor | P,T,N,BP * |
| 02043859 | Pasquotank R @ RR Bridge nr Elizabeth City | P,T,N,M * |
| 02043862 | Pasquotank R @ Elizabeth City | P,T,N,M,F * |
| 02043878 | Pasquotank R @ Buoy FL"5"Sec nr Old Trap | P,T * |
| 02043882 | Little R @ Woodville | P,T,N |
| 02043884 | Little R nr Weeksville (Buoy # 4) | P,T * |
| 02081179 | Albemarle Sound nr Frog Island | P,T,N,BP * |
| 02043892 | Perquimans R @ Hertford | P,T,N |
| 0208455655 | Intracoastal Waterway @ US Hwy 264 | P,T * |
| 02043906 | Perquimans R @ Harvey Point | P,T,N,F * |
| 02081172 | Albemarle Sound btwn Harvey Pt & Mill Pt | P,T,N,BP,F * |
| 02081145 | Albemarle Sound nr Edenton (Buoy #R"4") | P,T,N,BP,F * |
| 02081185 | Kendricks Cr @ Mackeys | P,T,N,M |
| 02081166 | Scuppernong R nr Columbia | P,T,N,BP |
| 0208117810 | Alligator R us Cherry Ridge Landing | P,T,N,BP * |
| 0208117820 | Alligator R @ Newport News Pt | P,T,N,BP * |
| 0208117830 | Alligator R 3 miles us Catfish Pt | P,T,N,BP * |
| 0208117840 | Alligator R @ US Hwy 6 | P,T,N,BP * |

Physical Data

*Temperature and Dissolved Oxygen.* Figure P1 depicts the full distribution of surface temperatures and dissolved oxygen at each station. Surface temperature in the Pasquotank River ranged from 3 to 30° C, with the maximum temperature found at Elizabeth City (02043859). The maximum temperature of 31° C was measured on the Albemarle Sound near Edenton (02081145).

There was an inverse correlation between surface temperature and dissolved oxygen concentration (Fig. P2). Mean surface DO concentration was lowest in the summer and highest in the winter. However, during the summer, there were occurrences of elevated surface dissolved oxygen concentrations which resulted in supersaturated conditions.

Surface DO concentrations reached supersaturated conditions (greater than the state standard of 110% saturation) on July 18, 1990 in the Pasquotank at Elizabeth City and near

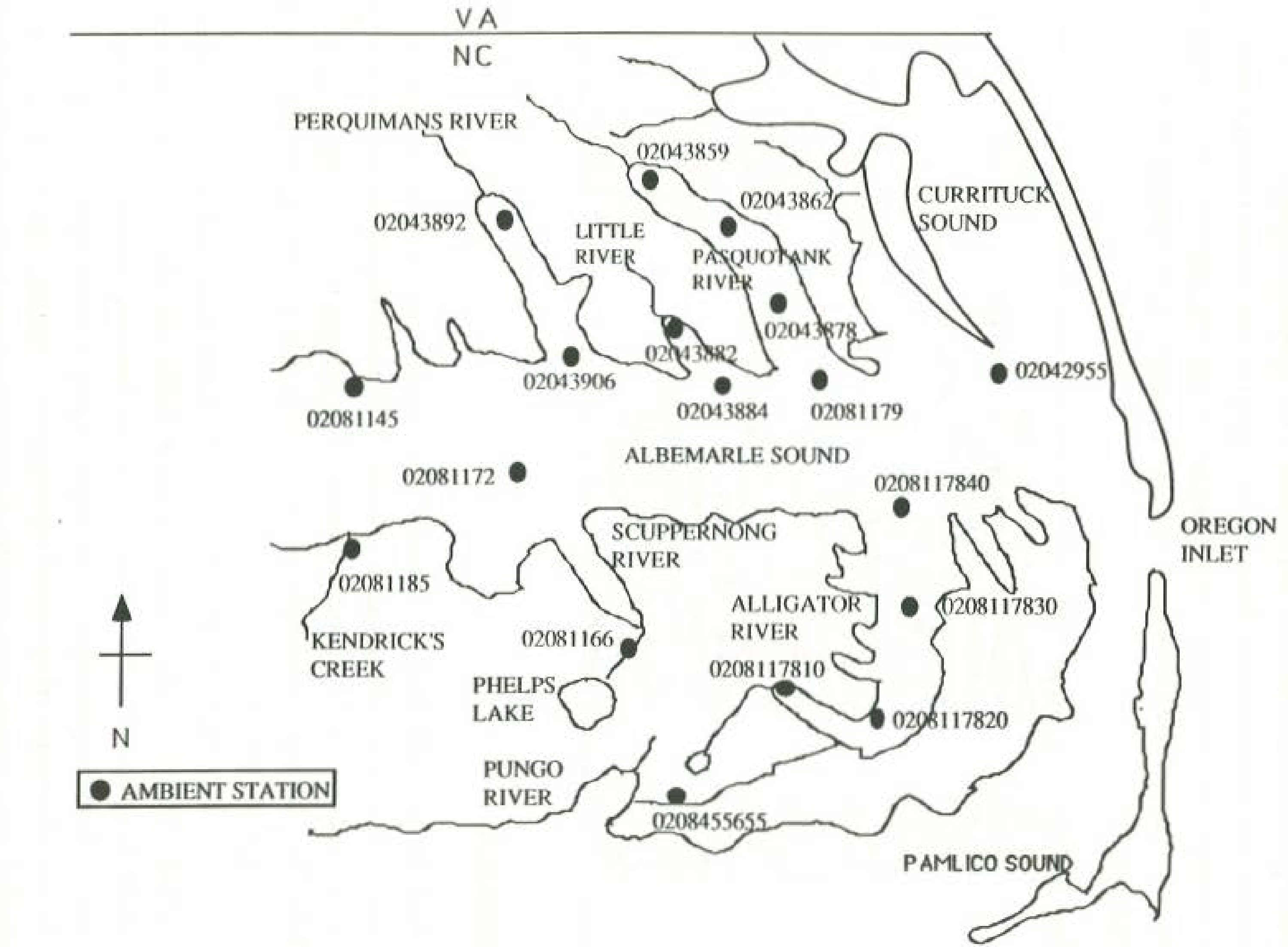



**FIGURE P-A. AMBIENT STATIONS IN THE PASQUOTANK RIVER BASIN**

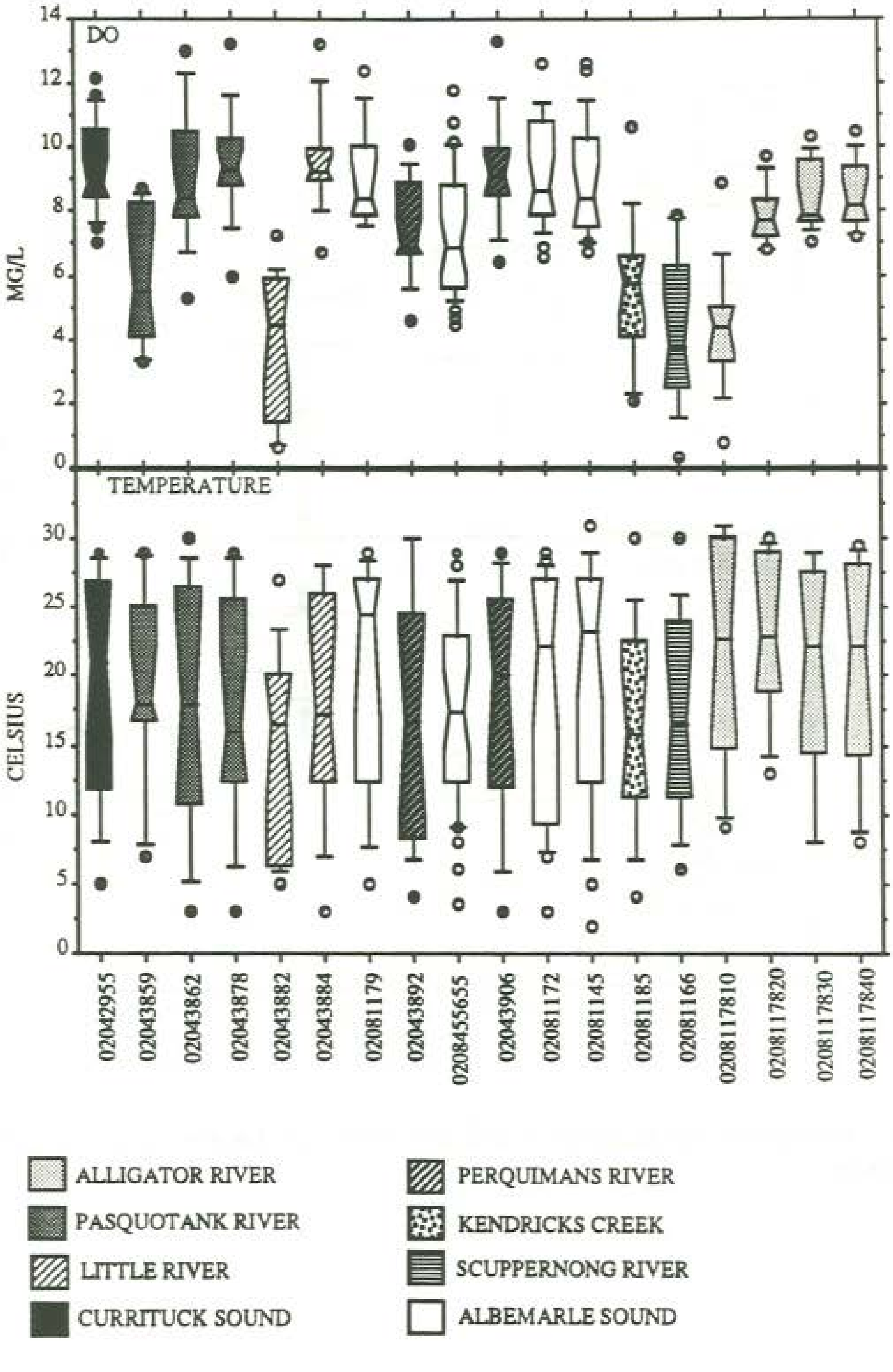



**Figure P1. Surface temperature and dissolved oxygen for the Pasquotank River Basin, 1988-1991.**

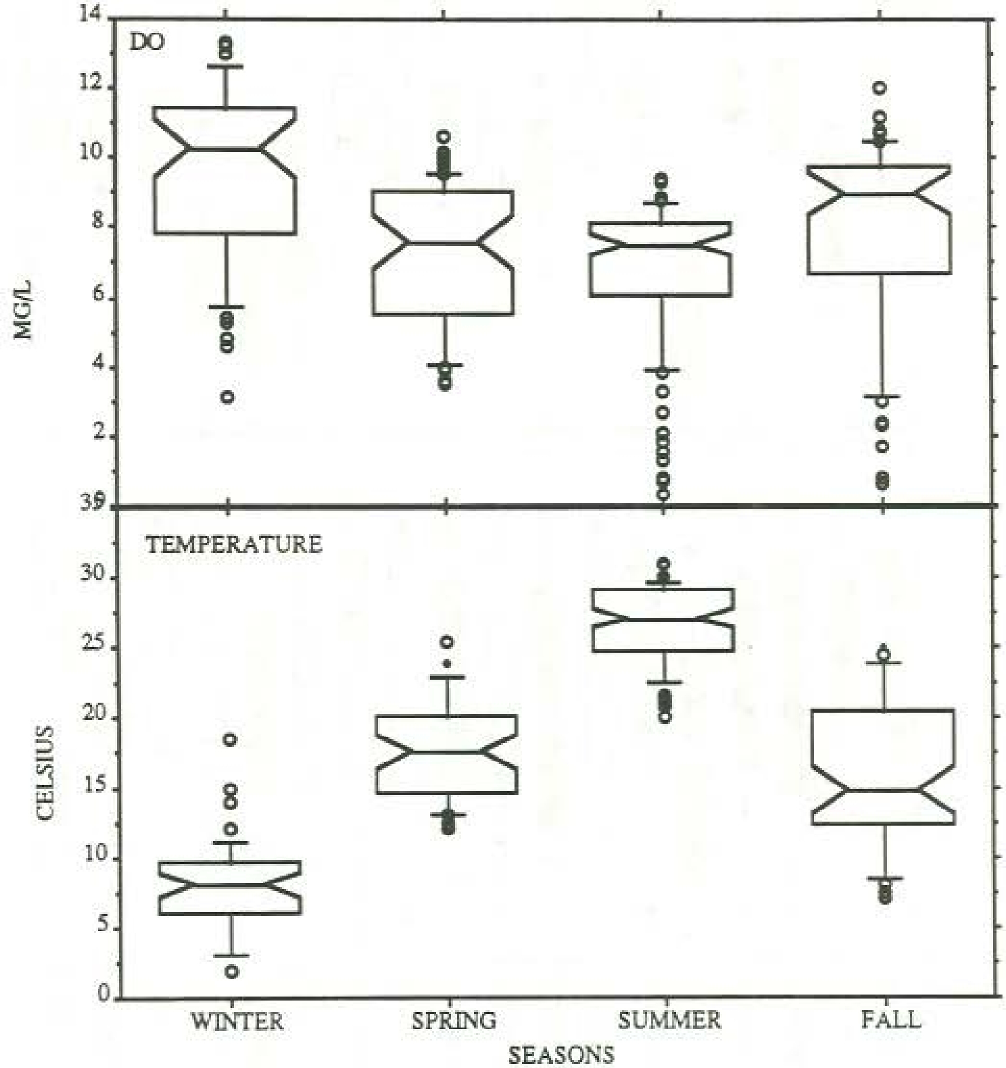



**Figure P2. Seasonal surface temperature and dissolved oxygen for the Pasquotank River Basin, 1988-1991.**

Old Trap (02043878) and in the Albemarle Sound near Frog Island (02081179). The pH and chlorophyll-a values were moderate for each station on this date, indicating increased levels of phytoplankton growth. Supersaturated conditions were also reached on July 18, 1988, on Little River near Weeksville (02043884); on July 24, 1989, on the Albemarle Sound near Edenton; on July 26, 1989, on Perquimans River at Hertford (02043892); and on October 8, 1990, on the Pasquotank at Elizabeth City.

Surface DO concentrations were lower at the most upstream stations for the Pasquotank, Little, Perquimans, and Alligator rivers. Dissolved oxygen concentrations below the state standard of 5.0 mg/l were measured at these stations, but remained above the state standard at the other stations in each river. Oxygen-deficient waters stored in adjacent swamps may have depressed dissolved oxygen concentrations as they entered each river at its upstream station. Little River at Woodville (02043882), the Scuppernong River near Columbia (02081166), and the Alligator River at Cherry Ridge Landing (0208117810) are classified as swampwaters, which means dissolved oxygen concentrations below 5 mg/l would not be violations of the state standard.

The water column exhibited conditions of stratified dissolved oxygen levels during late summer and fall on the Albemarle Sound near Frog Island, between Harvey Point and Mill Point (02043906), and on the Alligator River at Cherry Ridge Landing (0208117810). This stratification occurred in association with salt wedges on the Albemarle Sound near Frog Island. No strong thermal stratification was evident.

*pH*. The water quality standard for surface pH in a saltwater system is 6.8 to 8.5 s.u. The surface pH ranged from 4.9 to 8.7 s.u. on the Pasquotank River. The lowest surface pH was sampled on the upper station, at the railroad bridge near Elizabeth City. This station was not within the 95% confidence interval of the other two stations (Figure P3). The Dismal Swamp drains into the Pasquotank upstream of Elizabeth City and may have contributed to the lower pH values.

Lower pH values were also found in the Scuppernong River (02081166), Kendrick's Creek at Mackeys (02081185), and the Alligator River at Cherry Ridge Landing. The mean pH for each station respectively was 6.3, 6.4, and 5.5 s.u. The Alligator and Scuppernong rivers both drain swamplands, which may account for their lower pH. Kendrick's Creek drains peat deposits, which accounts for its lower pH. All stations associated with swamplands exhibited a low pH.

Measurement of pH in the Albemarle Sound ranged from 6.4 s.u. between Harvey Point and Mill Point to 8.7 s.u. near Frog Island. There was one freshwater station, Little

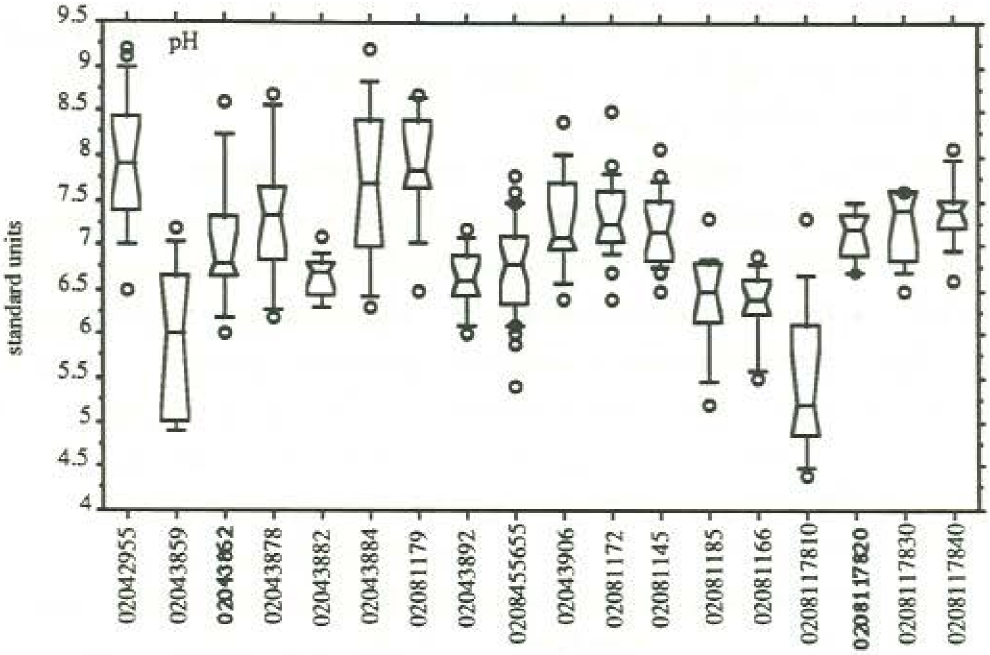



**Figure P3. Surface pH in the Pasquotank Basin, 1988-1991.**

River at Woodville. The pH values for this station were within the range for freshwater (6.0 to 9.0 s.u.).

*Conductivity and Salinity*. Conductivity values ranged from 68 umhos on the Albemarle Sound near Edenton (02081145) to 27,830 umhos on the Intracoastal Waterway at US Highway 264 (0208455655). This high conductivity corresponded with high salinity on the Intracoastal Waterway at Highway 264 (0208455655). Figure P-4 depicts the range of conductivity and salinity at each station.

The freshwater station, Little River at Woodville, had correspondingly low conductivities and low salinities. Several stations classified as saltwater stations but infrequently inundated with saltwater exhibited characteristics of a freshwater system. Consequently, these stations had low conductivities.

*Secchi Depth and Turbidity*. There were a few values exceeding the state turbidity standards in the Pasquotank basin, but most of these occurred in designated swampwaters which naturally have higher turbidity values. These included the Intracoastal Waterway at US Highway 264, the Scuppernong River at Columbia, and the Alligator River at Newport News Point. Secchi depths inversely correlated to the turbidity values, resulting in the lowest secchi depths at these swampwater stations as depicted in Figure P5. The greatest secchi depths were measured on the Perquimans River at Harvey Point, the Albemarle Sound between Harvey Point and Mill Point and near Edenton.

*Metals*. Samples from the pasquotank basin were analyzed for nine heavy metals. Low concentrations were found for six of the metals analyzed (all below the detection or reporting level) as depicted in Table P1. Ninety-five percent of the nickel samples were also below detection level; however the two samples (5 percent) above detection level also exceeded the state standard. Both violations were measured in Kendricks Creek at Mackeys. Zinc was above the reporting level in 29 percent of the samples; however, none of these exceeded the state action level. Copper was above the reporting level in 45 percent of the samples and above the state action level in 16 percent of the samples.

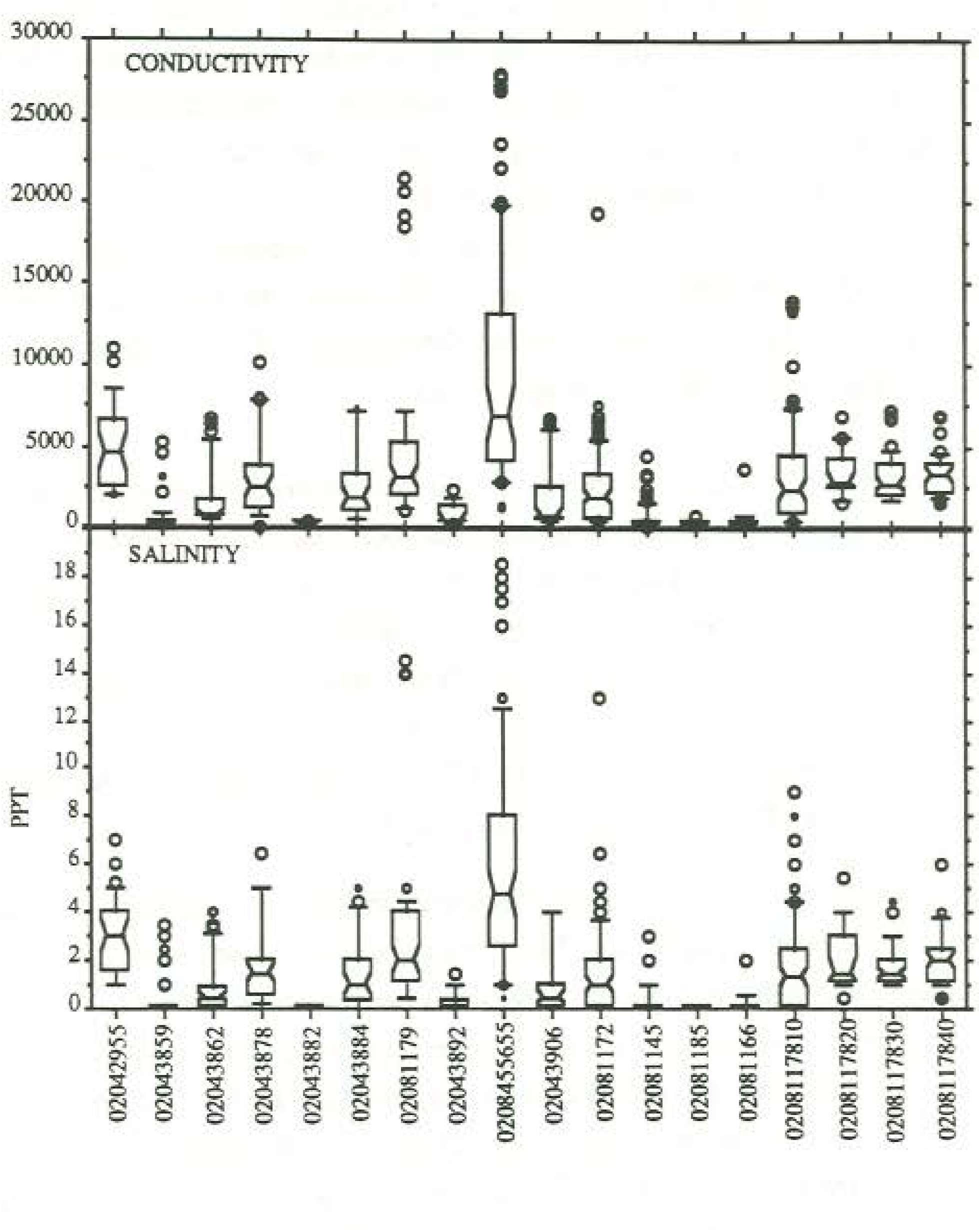



Figure P4. Conductivity and salinity in the Pasquotank Basin, 1988-1991.

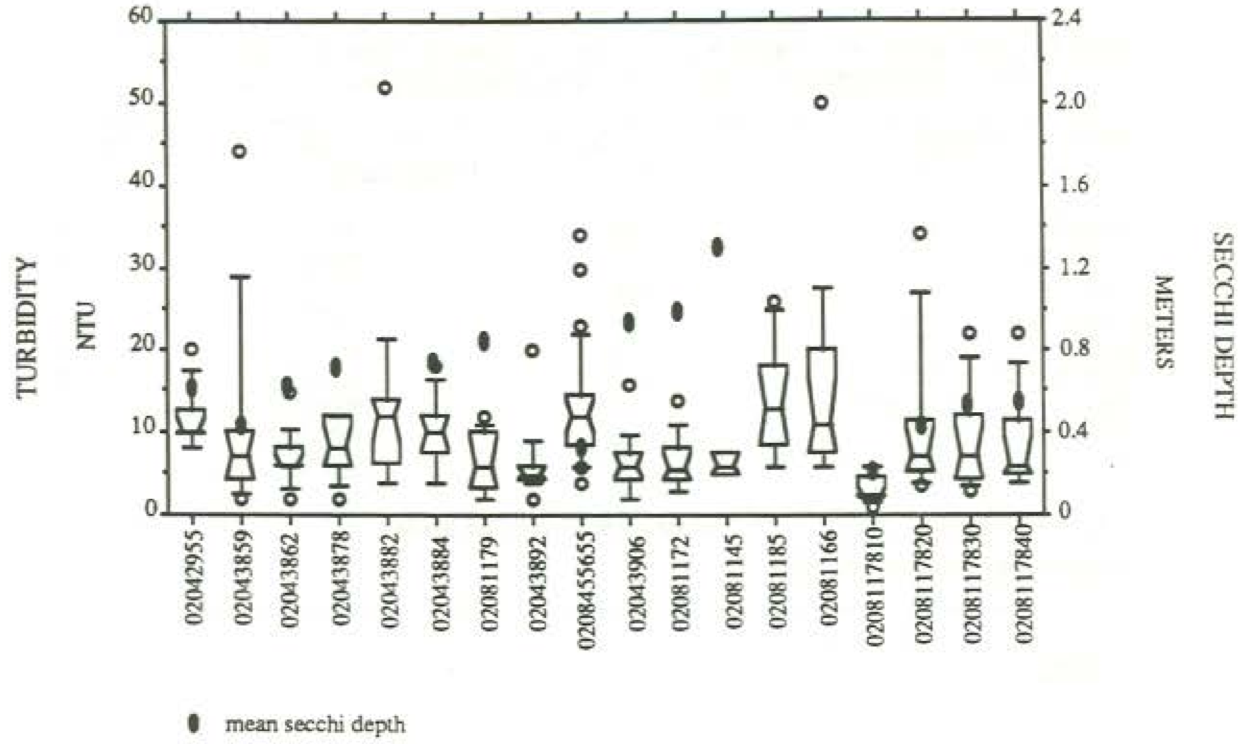



Figure P5. Turbidity and mean secchi depth in the Pasquotank Basin, 1988-1991.

Table P1. DEM laboratory reporting levels and percent of samples below the reporting level for heavy metals sampled between 1988 and 1991 in the Pasquotank basin.

| Metal | Reporting Level (RL) | % Samples Below RL | Water Quality Standard (fresh/salt) | % Sample Above Standard |
|---|---|---|---|---|
| Arsenic | 10 | 100 | 50 | 0 |
| Chromium | 25 | 100 | 50/20 | 0 |
| Cadmium | 2 | 100 | 2/5 | 0 |
| Copper | 2 (10)* | 55 | 7/3** | 16 |
| Lead | 10 | 100 | 25 | 0 |
| Mercury | 0.2 | 100 | .012/.025 | 0 |
| Nickel | 10 (50)* | 95 | 88/8.3 | 5 |
| Selenium | 0.5 | 100 | 5/71 | 0 |
| Zinc | 10 | 71 | 88** | 0 |

* Reporting levels for 1988. ** - values represent action levels
All reporting levels were in ug/l.

Nutrients.

*Nitrogen and Phosphorus.* Ammonia/ammonium ($NH_3/NH_4$), nitrate/nitrite ($NO_2+NO_3$), and total kjeldahl nitrogen (TKN) were sampled in the Pasquotank River Basin. Total nitrogen (TN) was determined by adding total kjeldahl nitrogen and nitrate/nitrite. The two forms of phosphorus that were analyzed in this study were orthophosphate (($PO_4$) and total phosphorus (TP).

The box and whisker plot in Figure P6 depicts the distribution of nutrients in the Pasquotank basin. Waste water treatment plant discharges from the Elizabeth City, the Columbia, and the Hertford waste water treatment plants may have contributed to the high total nitrogen inputs into the Pasquotank, the Scuppernong, and the Perquimans Rivers, respectively. Total nitrogen levels reached 3.6 mg/l on the Pasquotank near Elizabeth City, 4.8 mg/l on the Scuppernong River at Columbia, and 3.4 mg/l on the Perquimans at Hertford. There was little difference in TN concentrations over the four-year study period in the Perquimans River, except for slightly higher concentrations in 1989 and the spring of 1991. Mean total nitrogen concentration (0.64 mg/l) in the Pasquotank River was lowest in 1988. Total phosphorus concentrations were also elevated at these stations.

Slightly elevated total nitrogen concentrations at the Alligator River at Cherry Ridge Landing may be attributed to low light penetration into the water column, inhibiting phytoplankton growth. Mean secchi depth reading at this station was 0.2 m. The Alligator

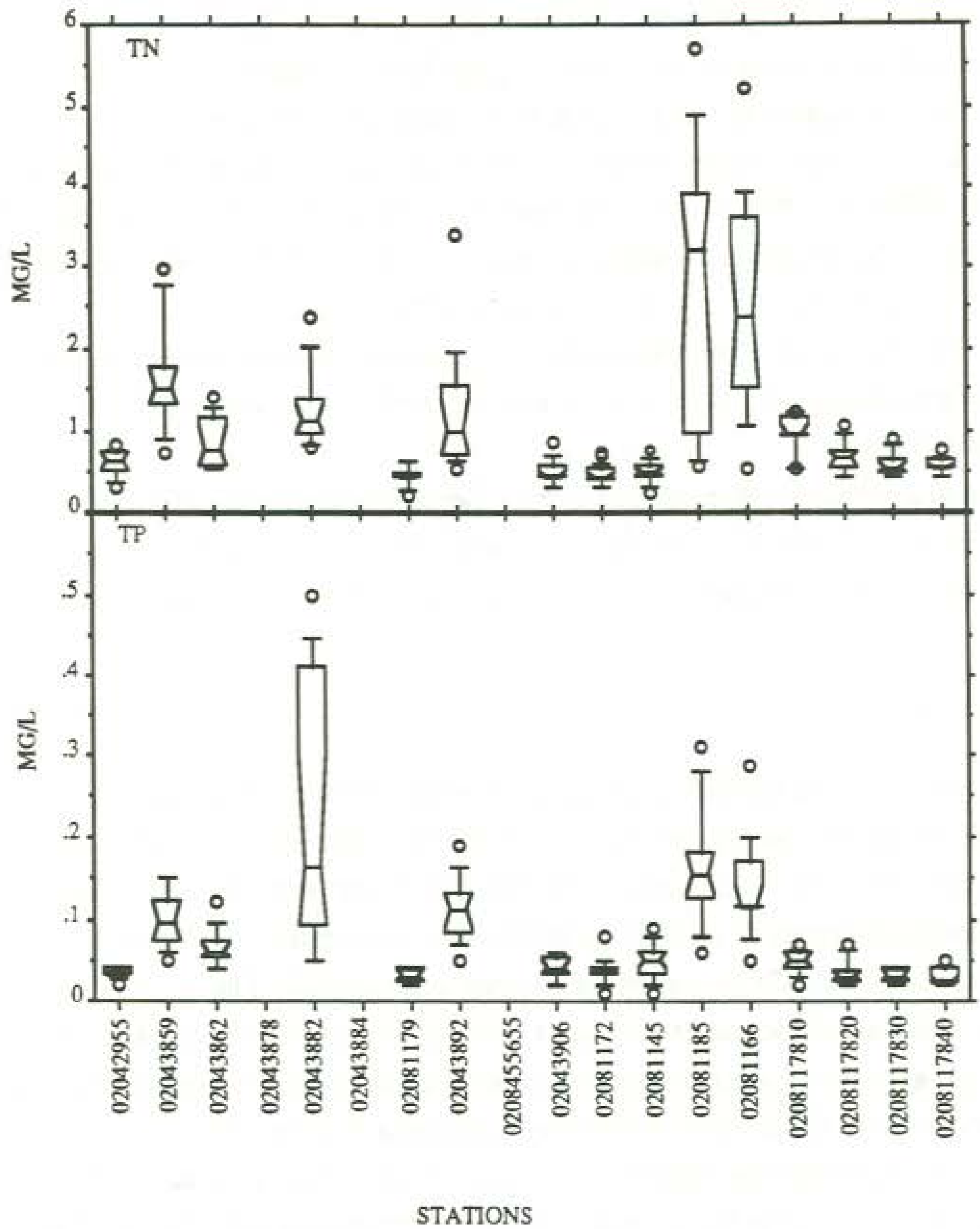



Figure P6. Total nitrogen and total phosphorus concentrations in the Pasquotank Basin, 1988-1991.

River receives tanic waters from adjacent swamps, keeping transparency low. Low light levels limit phytoplankton growth, and consequently there is little utilization of nutrients in the water column by phytoplankton. There was little change in total nitrogen concentrations in the Alligator River between 1988 and 1991. Total phosphorus concentrations were relatively low in the Alligator River at Cherry Ridge Landing.

High total nitrogen and total phosphorus concentrations were also sampled in Little River at Woodville and Kendricks Creek at Mackeys. High orthophosphate concentrations were also sampled at these stations; the mean $PO_4$ concentrations were 0.08 mg/l and 0.05 mg/l respectively. Mean total nitrogen concentrations for Little River were highest during 1989 and the spring of 1991, possibly as a result of the increased precipitation during those periods. This is indicative of nutrient input from nonpoint runoff. Superfarm canals draining farmland adjacent to Little River and Kendricks Creek were present on the topographic maps.

Mean total nitrogen concentrations in the Albemarle Sound near Edenton and between Harvey Point and Mill Point were highest during 1989, with means of 0.53 mg/l and 0.50 mg/l, respectively. The mean TN concentrations for 1988 and 1990 were similar for both stations.

Biological Data

*Phytoplankton and Chlorophyll-a.* Phytoplankton and chlorophyll-a data were collected at Albemarle Sound between Harvey Point and Mill Point, Albemarle Sound near Frog Island, all the Alligator River stations, and Currituck Sound at Point Harbor (02042955). Algal blooms occurred at all stations, except the two most upstream Alligator River stations (0208117810 & 0208117820) during the summer and early fall. The highest phytoplankton biovolume and density values were reported at the Currituck Sound station. Chlorophyll-a values were relatively low, however the chlorophyll-a concentrations did correspond with the phytoplankton biovolume estimates (Figure P-7).

Figure P-7 illustrates the trend on the Alligator River with no algal bloom conditions existing in upstream waters but increased algal growth occurring further downstream in wider shallow waters. The presence of dark water, limiting light penetration, in the Alligator River may also contribute to the minimal algal growth found at the upstream stations.

Most of the algal blooms consisted of filamentous blue-greens, dominated by Anabaenopsis raciborskii, Phormidium angustissimum, and/or Lyngbya sp. The small size and high numbers of these species found accounted for the high density/low biovolume ratio illustrated by Figure P-7. The relatively low chlorophyll-a values accompanying the phytoplankton data may also be explained by the low chlorophyll-a content of the blue-greens.

*Fecal Coliform Bacteria.* For 1988 through 1991, fecal coliform counts were available for the Pasquotank River at Elizabeth City (02043862), the Perquimans River at Harvey Point (02043906), the Albemarle Sound between Harvey Point and Mill Point (02081172), and the Albemarle Sound near Edenton (02081145). There were no values exceeding the state standard for fecal coliforms (200 MFFCC). A fecal count of 100 MFFCC was sampled on July 25, 1990, in the Albemarle Sound between Harvey Point and Mill Point (02081172), and a count of 140 MFFCC was measured near Edenton (02081145) on January 12,1988. All other fecal counts ranged between 10 and 60 MFFCC, and most samples were below detection.

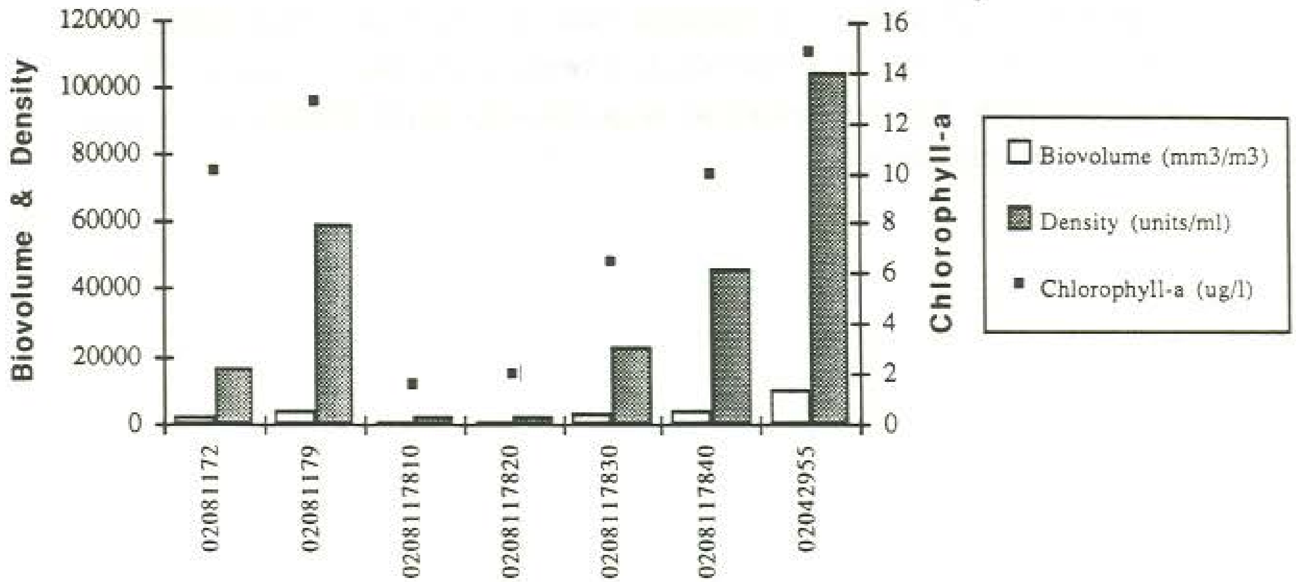



Figure P7. Phytoplankton biovolume and density means and chlorophyll-a means for the Pasquotank River Basin, 1988-1990.

# BIBLIOGRAPHY


American Public Health Association. 1985. Standard methods for the examination of water and wastewater. 16th edition. American Public Health Association, Washington, DC.

Copeland, B. J., R. G. Hodson, & S. R. Riggs. 1984. The ecology of the Pamlico River, North Carolina: an estuarine profile. U.S. Fish & Wildlife Service. FWS/OBS-82/06.

Darnell, R. M. 1967. The organic detritus problem. In Estuaries. George Lauff (Editor). American Association for the Advancement of Science Pub 83. Washington, D. C.

Day, J. J. 1952. The ecology of South African estuaries. I. A review of estuarine conditions in general. Trans. Roy. Soc. S. Africa 33: 53-91.

Giese, G. L., H. B. Wilder, and G. G. Parker Jr. 1979. Hydrology of major estuaries and sounds of North Carolina. U.S. G. S., Water Resources Investigations 79-46.

Gulicher, A. 1967. Origins of sediments in estuaries. In Estuaries. George Lauff (Editor). American Association for the Advancement of Science Pub 83. Washington, D. C.

Nixon, Scott W. 1989. Water quality in the Pamlico River Estuary with special attention to the possible impact of nutrient discharges from Texasgulf Inc. A report prepared for Texasgulf Inc.

North Carolina Department of Environment, Health, and Natural Resources. 1991. Biological assessment of water quality in North Carolina streams: Benthic macroinvertebrate data base and long term changes in water quality, 1983-1990. 118 pp.

North Carolina Department of Environment, Health, and Natural Resources. 1991a. Coastal Marinas, Field Survey of Contaminants and Literature Review. Report No. 91-03.

North Carolina Department of Environment, Health, and Natural Resources. Division of Environmental Management. 1991b. Nutrient criteria: Review and assessment for North Carolina waters.

North Carolina Department of Environment, Health, and Natural Resources. Division of Environmental Management. 1991c. 1990 Algal bloom reports.

North Carolina Department of Environment, Health, and Natural Resources. Division of Environmental Management. 1990. Standard operating procedures manual - Biological Assesment.

North Carolina Department of Environment, Health, and Natural Resources. 1990a. Water Quality Progress in North Carolina 1988-1989 305(b) Report. Report No. 90-07.

North Carolina Department of Environment, Health, and Natural Resources. Division of Environmental Management. 1990b. 1989 Algal bloom reports.

North Carolina Department of Environment, Health, and Natural Resources. Division of Environmental Management. 1989. Standard operating procedures manual - Chemical Physical Group.

North Carolina Department of Environment, Health, and Natural Resources. Division of Environmental Management. 1989a. Tar-Pamlico River Basin Nutrient Sensitive Waters designation and nutrient management strategy.

North Carolina Department of Environment, Health, and Natural Resources. Division of Environmental Management. 1989b. 1988 Algal bloom reports.

North Carolina Department of Natural Resources and Community Development. Division of Environmental Management. 1984. Special study of the Lewiston-Woodville wastewater treatment plant on the Cashie River.

Riggs, S.R., E. R. Powers, J. T. Bray, P.M. Stout, C. Hamilton, D. Ames, S. Lucas, R. Moore, J. Watson and M. Williamson. 1989. Heavy metal pollutants in organic-rich muds of the Pamlico River estuarine system: Their concentration, distribution, and effects upon benthic environments and water quality. Albemarle-Pamlico Estuarine Study Project 89-06.

Rulifson, R.A., R.B. Herrmann, J.T. Bray, and W.M. White. 1990. Water quality as a function of discharge from the Roanoke Rapids resevoir during hydropower generation. Albemarle-Pamlico Estuarine Study Project 90-12.

Stanley, D.W. 1988. Water quality in the Pamlico River estuary 1967-1986. Institute for Coastal and Marine Resources, East Carolina University. Report No. 88-01.

Utermohl, H. Zur. 1958. Vervollkimmurug der quantitative phytoplankton methodki. Mitt. Int. Verein. Limnol. Vol. 0.