1974

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Recommended Citation

Axelrad, D. M., Bender, M. E., & Moore, K. A. (1974) Function of marshes in reducing eutrophication of estuaries of the Middle Atlantic Region. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.25773/m1jj-sz31

Completion Report to

Office of Water Resources Research
Blacksburg, Virginia

Function of Marshes in Reducing Eutrophication of Estuaries of the Middle Atlantic Region

by

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February 1974

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SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

1. Report No.

2.

3. Accession No.

W

4. Title Function of Marshes in Reducing Eutrophication of Estuaries of the Middle Atlantic Region

5. Report Date

6.

8. Performing Organization Report No.

7. Author(s)

Axelrad, Donald M Bender, Michael E Moore, Kenneth A

10. Project No.

B-027-Va.

9. Organization

Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

11. Contract/Grant No.

13. Type of Report and Period Covered

12. Sponsoring Organization

15. Supplementary Notes

16. Abstract

Annual nitrogen, phosphorus and carbon budgets for two Virginia salt marshes were determined by monthly measurements of water discharge and constituent concentrations over tidal cycles.

Considering all three forms of phosphorus measured (total, dissolved organic and orthophosphate) there was a net loss from the estuary to the marshes. The data reveal a loss of particulate phosphorus of estuarine origin to marsh sediments and mineralization of this phosphorus in the marshes with subsequent export of dissolved inorganic and organic phosphorus back to the estuary.

Nitrogen flux data show a loss of nitrate and nitrite to the marshes. Particulate nitrogen is imported to the marshes where it is mineralized and returned to the estuary as ammonia and dissolved organic nitrogen. The magnitude of nitrogen export suggests significant fixation of atmospheric nitrogen by marsh flora with subsequent export as dissolved species.

Carbon flux data show significant contributions of both particulate and dissolved organic carbon to the estuary from the marshes. Estimates of export, based on marsh grass productivity, suggest a loss of 36 and 49% of a years primary production on the marshes as detritus for Ware and Carter Creeks respectively.

17a. Descriptors

nitrogen/phosphorus/detritus/budgeting/salt marshes/effects/water quality/eutrophication

17b. Identifiers

Same as above

17c. COWRR Field & Group

18. Availability

19. Security Class. (Report)

0. Security Class. (Page)

21. No. of Pages

Price

Send To:

WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

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SECTION I

PROJECT OBJECTIVES

Objectives

Many roles have been attributed to marshes in estuarine systems. They serve in many instances as buffers to erosional processes and thereby protect fastland areas. They provide valuable habitat for many species of wildlife which feed, nest and reside in them. Their greatest potential importance to the estuary, however, lies in their potential to provide organic matter in the form of detritus and their effect upon nutrient budgets. The influence of marshes on estuarine productivity has been largely ascribed to the high primary productivity of marsh plants, much of which is exported to the estuaries where it is the basis for the detritus food chain. However, as mentioned above, another means by which the marsh ecosystem can affect estuarine productivity and water quality is by its interaction with the plant nutrients, phosphorus and nitrogen, contained in the estuarine waters which flush through the marshes. Phosphorus and nitrogen are the nutrients most often restricting autotrophic productivity in aquatic systems and both have been demonstrated to be capable of limiting primary productivity in estuaries. Therefore qualitative and quantitative changes in the forms and levels of these nutrients in estuarine waters brought about by processes in the marshes can have a far reaching influence on estuarine productivity.

Although the general processes involved in nutrient transformations within marshes are known, the result of the interacting processes remains to be elucidated.

The processes of greatest importance in cycling of nitrogen are: nitrogen assimilation by bacteria, benthic algae, phytoplankton, and *Spartina*, as well as bacterial nitrification, denitrification and detrital degradation.

Processes having the greatest influence on phosphorus cycling in salt marshes are: assimilation of phosphorus by bacteria, benthic algae, phytoplankton, and *Spartina*; degradation of detritus by bacteria and fungi; *Spartina* "pumping" of subsurface phosphorus into the water; and physical phosphate-sediment interactions.

The objectives of our investigation were to determine the flux of nitrogen, phosphorus and carbon in Virginia marshes, and to assess the results obtained in light of estuarine water quality. In support of these flux studies, a determination of the primary production in the Ware and Carter creek marshes was made under a joint program sponsored by VIMS and NSF.

SECTION II

ATTAINMENT OF OBJECTIVES

Attainment of Objectives

The objective of this investigation was to determine the role of marshes in the nutrient budget of estuarine waters. Emphasis was placed upon those elements which are important in the eutrophication process, i.e. nitrogen, phosphorus and carbon.

Flux measurements of the various forms of nitrogen, phosphorus and carbon were made hourly over a tidal cycle and experiments were performed during all seasons.

Analysis of the data revealed the following major conclusions:

1) The marshes in all salinity regimes studied are contributing dissolved phosphorus to their river systems.

2) Considering all three phosphorus forms, there is a net loss of phosphorus to the marshes. This budget suggests a cycle of loss of estuarine particulate phosphorus to marsh sediments and mineralization in the marshes with subsequent export of dissolved inorganic and organic phosphorus to the estuary.

3) Nitrogen flux data show a loss of nitrate and nitrite to both marshes.

4) Particulate nitrogen appears to be imported from the estuary where it is mineralized and returned to the estuary as ammonia and dissolved organic nitrogen.

5) Large contributions of organic carbon to the river systems are made by the marsh creeks. The source of the carbon is decomposing marsh vegetation. Calculations show a contribution of between 36.4 and 49.6% of the marsh production to the estuary in a year.

The implication of these findings is that marsh systems influence estuarine primary productivity by mineralizing particulate organic nitrogen and phosphorus of estuarine origin, exporting these nutrients in dissolved form that can be assimilated by estuarine autotrophs. Thus the primary objective of the study has been attained and we conclude that marshes of the types studied serve to maintain estuarine productivity. There is no evidence to suggest that they function as sinks for either nitrogen or phosphorus compounds utilized by estuarine phytoplankton.

SECTION III

RESEARCH PROCEDURES

A - Literature Review

NITROGEN CYCLING IN SALT MARSHES

Nitrogen Cycles

In a North Carolina *Juncus roemerianus* dominated salt marsh, Byron (1968) found that forty-one percent of the nitrogen entering the system over several fall tidal cycles was not returned to the estuary. Flux calculations utilizing water discharge and nitrogen concentration data indicated that particulate nitrogen of estuarine origin was lost to the marsh. Low levels of nitrite and nitrate in marsh creek ebb tide waters suggested that this organic nitrogen was not mineralized in the marsh and subsequently returned to the estuary.

Nitrate concentrations of waters overlying two Delaware *Spartina alterniflora* dominated salt marshes were generally lower than concentrations within marsh creeks (Daiber, Gallagher, and Sullivan, 1970; 1971). Measurements in creeks draining these marshes revealed the presence of maximal nitrate levels in winter and minimal nitrate levels in summer (Daiber, Aurand, and Shlopak, 1969; Aurand and Daiber, 1973).

The occurrence of winter nitrate concentration peaks at high slack water and summer nitrate concentration peaks at low slack water led Aurand (1968) to speculate that the Delaware marsh systems imported nitrate in winter but exported small amounts of nitrate in summer.

Salt Marsh Sediment-Nitrogen Interactions

Sampling over a year in two Louisiana Spartina marshes indicated that sediment interstitial water ammonia concentrations were many times greater than levels in the corresponding water columns. Highest interstitial water ammonia concentrations were found August through November and were attributed to increased detrital decomposition rates. Parallel concentration trends in the water column suggested diffusion of ammonia from sediments to water (Ho and Lane, 1973).

Maye (1972) found the highest interstitial water ammonia concentrations in sediments beneath the thickest Spartina growth and also proposed mineralization of Spartina detritus as the mechanism supplying ammonia to marsh sediments. Sediment cores taken in a Georgia marsh also revealed increased ammonia concentration with depth.

Nitrogen Cycling by Salt Marsh Biota

Evidence of algal nitrogen fixation was found in two Florida salt marshes. Epiphytic blue-green algae on dead Spartina and Juncus stems exhibited greater nitrogen fixation rates than did algae of surface sediments; the water column seldom displayed any activity (Green and Edmisten, 1972). More than sixty percent of the bacteria in Delware salt marsh sediments were able to utilize molecular nitrogen as their sole nitrogen source. Large numbers of ammonifying nitrifying and denitrifying bacteria were also isolated from these marsh sediments (Daiber and Gooch, 1968).

It was theorized that bacteria using characteristically nitrogen poor Spartina detritus as an energy source must assimilate their nitrogen requirements from marsh waters (Thayer, 1969). Ustach (1969) supported this theory by demonstrating increased heterotrophic utilization of Spartina detritus upon addition of nitrate to a detritus estuarine water system.

PHOSPHORUS CYCLING IN SALT MARSHES

Phosphorus Cycles

The seasonal phosphorus cycle of several Delaware *Spartina* marsh creeks was characterized by elevated summer dissolved inorganic and organic phosphorus levels. Monthly measurements made over a year revealed higher dissolved phosphorus concentrations in marsh creeks at low slack than at high slack water, suggesting export of dissolved phosphorus from the marshes to the estuary (Reimold, 1969; Reimold and Daiber, 1970). Particulate phosphorus was the predominant phosphorus species of the Delaware marsh creeks and peak levels of this phosphorus form were also attained in summer and at low slack water (Daiber, Aurand, and Shlopak, 1969; Daiber, Gallagher, and Sullivan, 1970). Waters overlying the marshes in areas of tall *Spartina* growth had higher dissolved inorganic phosphorus concentrations than did creek waters, but displayed seasonal concentration fluctuations similar to those of the marsh creeks (Reimold, 1969; Daiber, Gallagher, and Sullivan, 1971).

Blum (1969) theorized that high marsh *Spartina patens* was adapted to rapid absorption of nutrients when flooded by spring high tides. It was further suggested that the mesh of dead leaves and stalks beneath live growth could act as a filter system and remove particulate nutrients brought to the high marsh by these tides. Measurements over a June tidal cycle revealed that the waters overlying the marsh during flood tide had significantly lower dissolved inorganic phosphorus concentrations and significantly higher total phosphorus concentrations compared to ebb tide.

Flux measurement over several fall tidal cycles utilizing phosphorus concentration, and water discharge data, indicated that two North Carolina Juncus dominated marshes exerted little effect on the estuary with respect to particulate and dissolved inorganic phosphorus. Dissolved organic phosphorus was the predominant phosphorus species of these marshes and calculations showed a small net export of this nutrient to the estuary (Byron, 1968).

Salt Marsh Sediment-Phosphorus Interactions

In two Louisiana Spartina marshes, yearly averages of sediment interstitial water dissolved inorganic phosphorus concentrations were many times greater than concentrations in corresponding water columns. Higher interstitial water phosphorus concentrations August through November were attributed to increased detrital decomposition rate. Parallel seasonal concentration trends in the water column suggested diffusion of phosphorus from sediments to water (Ho and Lane, 1973). Highest dissolved inorganic phosphorus concentrations in Georgia marsh sediment interstitial waters were found under thicker Spartina growth, again indicating detrital mineralization as the source of phosphorus to marsh sediments. Sediment cores taken in this marsh also revealed increased interstitial water phosphorus concentrations with increasing depth (Maye, 1972).

Gooch (1968) postulated a seasonal cycle of precipitation and solubilization of inorganic phosphorus from salt marsh sediments. In this cycle bacterial hydrogen sulfide production initiated inorganic phosphorus release from sediments. Thus it was believed that minimal hydrogen sulfide production in winter and maximal production in late spring caused dissolved inorganic phosphorus uptake in winter and release in spring.

Pomeroy, Smith, and Grant (1965) suggested that movement of dissolved inorganic phosphorus between undisturbed salt marsh - estuarine sediments and overlying water involved a two step ion exchange between clay and water, plus an exchange between interstitial microorganisms and water. In undisturbed sediments, abiotic exchange predominated, but in resuspended sediments biologically mediated exchange was of the same magnitude as physical exchange. Sediment - water exchange processes buffered estuarine water to a dissolved inorganic phosphorus level of about one microgram atom per liter.

Phosphorus Cycling by Salt Marsh Biota

Turnover rate of dissolved inorganic phosphorus was found to be significantly greater in salt marsh waters than in other aquatic environments (Pomeroy, 1960). High dissolved inorganic phosphorus levels in Georgia salt marsh waters were attributed to this rapid turnover rate. A cycle of uptake of sedimentary phosphorus by Spartina, with subsequent bacterial utilization of Spartina detritus, followed by assimilation of detritus and associated bacteria by detritivores and excretion by detritivores, introduces dissolved phosphorus to marsh waters (Pomeroy et al., 1969). Another explanation for the high concentrations of dissolved inorganic phosphorus in marsh waters has been suggested by Reimold (1972) who indicated that Spartina alterniflora pumps sedimentary phosphorus from rhizomes to leaves, where phosphorus is released to marsh waters upon Spartina inundation by high tides. Seasonal variation in dissolved inorganic phosphorus concentration of marsh waters was ascribed to changes in rate of uptake and release of phosphorus from Spartina, paralleling seasonal changes in rate of Spartina productivity.

In a Typha dominated tidal marsh, periphyton communities were primarily responsible for removal of phosphorus from marsh waters. Typha competed with periphyton for the phosphorus of shallow marsh sediments but the importance of the angiosperm in phosphorus cycling was mainly that it provided increased surface area for periphyton growth (Correll, 1973).

A phosphorus budget of a salt marsh mussel population indicated that the population removed particulate phosphorus from marsh waters with a turnover time of 2.6 days (Kuenzler, 1961). Investigation of phosphorus cycling by marsh arthropod communities revealed that the communities mineralized large amounts of organic phosphorus through their detrital and periphyton grazing activities (Marples, 1966; Pomeroy et. al., 1969).

The high carbon to phosphorus ratio of *Spartina alterniflora* detritus led Thayer (1969) to speculate that bacteria must assimilate phosphorus from marsh waters to completely utilize detrital carbon. Addition of dissolved inorganic phosphorus to estuarine water containing *Spartina* detritus increased detrital decomposition rate and thus supported this contention (Ustach, 1969).

DETRITUS: COMPOSITION, FORMATION AND FLUX

Decomposition of Marsh Grasses

The decomposition of marsh flora has been documented by numerous authors (Burkholder and Bornside, 1957; De la Cruz 1965; Waits, 1967; Heald, 1969; Ustach, 1969; Kirby, 1971). Most of these studies have utilized some variation of a litterbag method, in which known amounts of marsh grass are placed in nylon mesh bags at various locations in a marsh. Decomposition is measured as the rate of loss from the bags. Kirby indicates that the loss of material from the litterbags is a function of several factors: (1) the size of the litterbag mesh (2) the area in which the bags are placed (3) the amount of flushing received (4) the temperature. The last three of these factors along with two others, the species of plant decomposing and the salinity, appear important in controlling decomposition rates in tidal marsh areas.

De la Cruz found the most rapid decomposition of Spartina occurred in bags that were continuously submerged in a creek. While there was a fifty percent loss of material from these bags in three months, those placed in the high marsh during the same spring period required seven months to reach fifty percent decomposition. Kirby found more rapid initial decomposition in material placed out in the marsh in June than in January. He also found considerably more rapid loss of material from bags placed in a tidal channel as compared to material placed in a high marsh area. Ustach noted a relatively constant loss of one percent per day in his study area.

Kirby hypothesizes that grazing by amphipods and other invertebrates is initially responsible for reduction of the grasses to small particles. He cites as evidence, however, simply the abundance of amphipods in and around the bags. There is little documented evidence for mechanisms of biological degradation of marsh grasses. Heald (1969) and De la Cruz (1965) indicate as being important: simple fragmentation by tidal action with subsequent hydrolysis and oxidation of the particles, and microbial and fungal colonization. Burkholder and Bornside (1957) found aerobic, heterotrophic marine bacteria, analogous to those of freshwater lakes (Rodina, 1963; Paerl, 1973) to participate in the decomposition of Spartina with much of the loss in dry weight of the plant tissue taking place through diffusion of the metabolic products of the microorganisms.

In freshwater streams where a situation somewhat similar exists, that being the input of large amounts of allochthonous leaf-born organic material, there has been more extensive investigation of the degradation process (Nelson and Scott, 1962; Egglishaw, 1964; Minshall, 1967; Kaushik and Hynes, 1971; Cummins, et. al., 1973). Cummins, et.al., in studying the microbial, animal successional pattern on various leaf species recognize the importance of large particle detritivore "shredders". However, they indicate that the shredders, through mechanical and/or chemical stimuli, select leaves that are maximally colonized by fungi and bacteria. Kaushik and Hynes (1971) also evidenced differential decomposition rates for fallen leaves of different species of trees and noted that fungi appeared to be more effective than bacteria in the breakdown of the leaves.

The Importance of Detritus as a Food Source

The fragmented, semi-decomposed material found in such abundance in the waters of marshes and estuaries includes besides material from marsh grasses, invertebrates, algae, plankton and allochthonous estuarine and wind blown materials (Teal, 1962), and is termed "organic detritus". It has been defined by Darnell as: "...all types of biogenic material in various stages of microbial decomposition which represent potential energy sources for consumer species."

De la Cruz (1965) suggested detritus particles to be highly active spheres of microbial organisms and that the adsorption of nutrients onto the particles may increase their food value. His studies showed increased protein content in successive stages of decomposition from Spartina marsh grass to detritus. This was possibly due to bacterial growth; however, the suggestion is still speculative. Hall, et. al., in a later work (1970) indicates a tenfold decrease in percent protein with Spartina in ebbing tides from that found in the living plant leaves. Burkholder and Bornside (1957) suggested microbial degradation would result in a more favorable essential amino acid distribution. However, this was not confirmed by Hall, who indicated that suspended solids contain smaller percentages of essential amino acids, and fewer of them than living marsh grasses.

Whatever the nutritional value of estuarine detritus, numerous authors have cited its utilization by organisms. Darnell (1958, 1961, 1967) has evidenced consumption in a Louisiana estuary; W. Odum (1970) in a mangrove-dominated estuary; E. P. Odum and Smalley (1959), Kuenzler (1961) and Teal (1962) in S. alterniflora marshes. Johannes and Satomi (1966) have reported the nutritive value of fecal pellets found also in detritus, and Jannasch (1954) indicated that a particle of detritus may be ingested several times by organisms before exhaustion of its microfauna.

Detritus, by Darnell's definition, also includes dissolved and colloidal material. Because of their nature and quantity it is these fractions that may be of most importance to the estuary. Dissolved and colloidal organic materials in seawater are discussed by Kahailov and Finenko (1970) and the major works in this area reviewed by Riley (1970). It has been suggested that particles can be produced by the adsorption of dissolved matter on bubbles (Sutcliffe, et.al., 1963; Menzel, 1966) and that both dissolved and bubble-formed particulate material can be a source of nutrition for organisms (Stephens, 1967; Stephens and Schinske, 1961; Fox, 1952).

Transport of Detritus

There are numerous studies which cite the importance of marshlands as sources of organic material for coastal areas. Teal (1962), for example, has estimated that 45 percent of the net production of a Georgia salt marsh is exported as organic detritus. There are few studies, however, that have actually attempted to measure this transport. De la Cruz (1965) is perhaps the most referenced work. His study indicated that the export of detritus from a Georgia salt marsh to be 3.4 tons ha^{-1} yr^{-1}, though one might easily criticize his rather limited sampling program. Mid-flood and mid-ebb tide detritus concentrations in a tidal creek obtained several times during a year were simply compared, and water discharges were only estimated. Nadeau (1972) measured water discharge and particulate carbon concentrations in a tidal creek draining a New Jersey salt marsh but found no significant particulate export. He did conclude that there was generally a loss of floating debris from the creek.

SECTION III

RESEARCH PROCEDURES

B - Methods

Description of Study Areas

Two marshes in the York River watershed were selected to serve as the primary study sites in the investigation. The areas were chosen because: 1) they were undisturbed; 2) they represented different salinity regimes and hence were dominated by different species of marsh plants; 3) background data on marsh grass production was being collected and 4) both were surrounded on three sides by higher ground which effectively minimized any unmeasured transport of water to or from the study areas.

A third marsh located in the James River watershed was to be utilized to make comparisons with the undisturbed systems because it received effluent from the Williamsburg waste treatment plant. Although several studies were conducted at this site, the effluent was diverted to a new treatment plant before sufficient data could be collected.

Carter Creek

Carter Creek marsh covered an area of 25 acres, had a yearly mean high tide salinity of 12‰ and was dominated by saltmarsh cordgrass, salt grass and salt meadow hay. The remaining vegetation consisted of threesquare, narrow leaved cattail, wood sage, saltmarsh aster, sea lavender, arrowhead and rushes.

Ware Creek

Ware Creek marsh was 35 acres in size, had a mean high tide salinity of 7‰ and was dominated by giant cordgrass. Among the associated vegetation were rushes, smartweed, saltmarsh cordgrass, threesquares, saltgrass, wood sage, rice cutgrass, narrow leaved cattail, pickerel weed, marsh hibiscus, marsh mallow and salt meadow hay.

College Creek

The marsh within the College Creek drainage was 411 acres in extent, had an average high tide salinity of about 1‰ and was dominated by arrow arum. The remaining vegetation consisted of giant cordgrass as a subdominant with wild rice, cattail, pickerel weed, water dock, softstem bulrush, marsh mallow, marsh hibiscus, smartweed, swamp milkweed, water hemp, water millow, jewel weed and Walter's millet covering about 10% of the area.

Field Measurements

A sampling platform was constructed in the major creek draining each marsh, located such that all tidal waters entering and leaving the marsh passed by the sampling station. Cross sectional profiles at the sampling sites were measured before and during the sampling year by determining creek depth below fixed marks at half meter intervals across the creek. No significant change in creek cross section profiles was detected over the study period.

Preliminary Measurements

To determine constituent concentration variation within the creeks, water samples were taken over a tidal cycle at various points on the creek cross section at the surface and one foot above the bottom. It was found that at any given time the water column was homogeneous with respect to nutrient and detritus concentrations.

In addition, to determine if the seston (detritus) could adequately be represented by sampling with a water bottle, experiments were conducted in each creek to determine the size distribution of seston particles. Triplicate one hundred liter water samples were taken at ebb tide from each creek and strained through 264µ and 64µ plankton nets. Water passing the 64µ net was filtered through 0.45µ millipore filters. In Carter Creek the percentages of seston within these size ranges were: 0.7% (>264µ); 1.5% (64 to 264µ) and 97.8% (0.45 to 64µ). In Ware Creek the percentages were: 0.2% (>264µ), 0.7% (64 to 264µ), and 99.1% (0.45 to 64µ). From these results it was presumed that sampling with a bottle would effectively capture the major portion of the suspended material in the water.

Another series of the tests was undertaken to determine if sample storage in crushed ice would affect the determination of ATP and organic carbon. Samples were taken and analyzed for these two parameters at 1, 3, 6, 12, 24 and 48 hours after sampling with subsequent storage in crushed ice.

Statistical analysis of the data revealed no significant difference ($\alpha = .05$) in the concentrations of either parameter as a function time.

Field Measurements and Sampling Procedures

Ware and Carter creek marshes were sampled for tidal constituents transport over day time tidal cycles several times during 1971 and approximately monthly from January 1972 to January 1973. In so far as possible, sampling periods were chosen to correspond to spring tides as predicted by National Ocean Survey tide tables.

During a survey period, water samples for nutrient and chlorophyll 'a' analysis were taken hourly from the marsh creek from low slack to high slack to second low slack water. Samples were taken in clean, one liter polyethylene bottles. The samples were stored at 0°C after preservation with 40 mg of $HgCl_2$. Samples for ATP and carbon determinations were also taken hourly but were not preserved.

Air and water temperatures were measured hourly to the nearest 0.5°C with a mercury thermometer. Samples for dissolved oxygen were taken hourly while salinity samples were collected every twenty minutes over a tidal cycle.

Current velocity was determined coincidental with the nutrient sampling and at twenty minute intervals over the tidal cycle using a ducted-impeller type current speed indicator (Byrne and Boon, 1973). The current speed sensor was centered in the marsh creek with respect to creek width and depth, while current speed determinations were made. Simultaneous with current speed measurement, a reading of tide height was taken to the nearest millimeter from a meter stick fixed at a known elevation above creek bottom.

Water for phytoplankton productivity determination was taken every two hours over a tidal cycle beginning at first low slack water. Three 125 ml glass bottles (two light bottles and one dark bottle) were filled to 100 ml from a well mixed liter sample. One milliliter of a stock solution containing one microcurie per milliliter activity of carbon-14 (^{14}C) as $NaH^{14}CO_3$, buffered to pH 9.5 with 10 mg/liter Na_2CO_3, was pipetted into each of the bottles. The light bottles were placed into the light compartment of an incubator illuminated by Westinghouse twenty watt "cool white","warm white", and "plant gro" fluorescent lamps. The dark bottle was placed into the dark compartment of the incubator. Both incubator compartments were maintained at ambient temperature by water pumped from the marsh creek. After three hours the productivity samples were fixed with 1 ml 10% buffered formalin and stored in the dark at 0°C (Strickland and Parsons, 1968).

Laboratory Measurements

The morning following sampling, 500 ml of each of the nutrient samples were filtered first through a Gelman type A glass fiber filter and then a Millipore type HA 0.45 micron membrane filter. The 500 ml filtered and unfiltered fractions were then stored in a refrigerator at 4°C until analyzed. Glass fiber filters through which a measured 200 ml sample had been filtered were wetted with $MgCO_3$ slurry, then placed in a dessicator and refrigerated at 4°C for later chlorophyll analysis. Light and dark bottle primary productivity samples were each filtered through a Millipore type HA 0.45 micron membrane filter, the filters rinsed with 50 ml distilled water and stored in scintillation vials at room temperature.

Dissolved inorganic phosphorus concentration was determined on duplicate filtered samples using a Technicon Autoanalyzer II system employing the single reagent method (EPA, 1971; Technicon, 1972). Total dissolved phosphorus concentration of filtered samples and total phosphorus concentration of unfiltered samples were determined, following persulfate digestion, by single reagent analysis of duplicate 50 ml sample aliquots (EPA, 1971). A Klett-Summerson photoelectric colorimeter calibrated with the standards of the autoanalyzer phosphorus method was used in the analysis. Particulate phosphorus concentrations were obtained by subtracting total dissolved phosphorus from total phosphorus measurements. Dissolved organic phosphorus was obtained by taking the difference between total dissolved and dissolved inorganic phosphorus.

Nitrate and nitrite concentrations were determined on duplicate filtered samples using the Technicon Autoanalyzer II system. Nitrite was determined directly by colorimetry while nitrate was determined by cadmium-copper reduction of nitrate followed by colorimetric measurement of nitrite produced. Nitrate and nitrite standards were included in sample runs (EPA, 1971; Technicon, 1972). Fifty milliliter unfiltered water samples for total Kjeldahl nitrogen analysis, and filtered samples for dissolved Kjeldahl nitrogen analysis were digested with a sulfuric acid-mercuric sulfate mixture. Fifty milliliter filtered water samples for ammonia determination and the digested Kjeldahl samples were then analyzed by the distillation-titration technique (EPA, 1971). Ammonia standards were analyzed along with samples and several samples from each run were measured in duplicate. Standard titrant used was 0.001 n HCl. Particulate nitrogen concentrations were obtained by subtracting dissolved Kjeldahl nitrogen from total Kjeldahl nitrogen. Dissolved organic nitrogen was obtained by taking the difference between dissolved Kjeldahl nitrogen and ammonia.

Salinity was determined using a Beckman Model RS-7B portable induction salinometer. Dissolved oxygen concentration was measured using a modified Winkler titration (Strickland and Parsons, 1968).

Chlorophyll 'a' concentration uncorrected for phaeophytin was analyzed by the fluorimetric method (Strickland and Parsons, 1968). Glass fiber filters with their chlorophyll load were mixed with 90% acetone in a tissue grinder and pulverized. The product was centrifuged, the extract brought to volume, and read on a Turner Model 111 fluorimeter calibrated for chlorophyll 'a' determination against a Cary 15 scanning spectrophotometer.

Phytoplankton production was measured by liquid scintillation counting of phytoplankton carbon-14 uptake. Ten milliliters of scintillation cocktail consisting of 100g napthalene and 5 grams PPO (2, 5 diphenyloxazole) per liter of dioxane was added to each Millipore filter and its phytoplankton load in a 20 ml scintillation vial. Activity of the cells was measured on a Beckman LS-150 Liquid Scintillation System. Counting efficiency was determined by spiking samples with known activity carbon-14 hexadecane. Productivity was calculated using light and dark bottle phytoplankton carbon-14 uptake, counting efficiency, and the dissolved inorganic carbon concentration of the samples as obtained by Moore (1973), by use of the formula:

Phytoplankton Productivity (mg carbon/liter-hour)

$$= \frac{\left(\frac{L_1 + L_2}{2} - D\right) (C) \quad 1.05}{RTE}$$

where L_1= counts per minute of light bottle #1

L_2= counts per minute of light bottle #2

D= counts per minute of dark bottle

R= disintegrations per minute carbon-14 added to light and dark bottles

T = time (hours)

E = counting efficiency

C = dissolved inorganic carbon (mg/l)

1.05 = isotope correction factor

Carbon analysis was performed on whole water samples to determine particulate organic carbon, dissolved organic carbon, and inorganic carbon using a dual-channel Dow-Beckman Carbonaceous Analyzer (Model No. 915). The procedure followed is outlined in "Methods for Chemical Analysis of Water and Wastes", EPA, 1971.

ATP determinations were performed following the method outlined by Holm-Hansen and Booth (1966) using both a Beckman Liquid Scintillation Counter and a JRD Inc., ATP Photometer. Estimation of living carbon associated with ATP measurements was done by multiplying the ATP concentration by a factor of 250 (Hamilton and Holm-Hansen, 1967).

Tidal Nutrient Transport Calculation

For purposes of water discharge determination the creek cross sectional profiles at the sampling stations were drawn to a fraction of scale and the cross sectional area of water planimetrically determined at 10 cm tide height intervals from lowest to highest observed tide height. The data obtained were used to construct a regression line of water cross sectional area as a function of tide height. All tide height observations were converted to water cross sectional values in this manner. Water cross sectional area data were multiplied by corresponding current velocity data to produce instantaneous water discharge values. Water discharge data were matched with nutrient concentration and salinity data. Additional nutrient concentration data were generated by interpolating nutrient concentration against time so that all water discharge values had corresponding nutrient concentration values. With this data the tidal fluxes of water, salinity, and nutrients were calculated for each sampled tidal cycle using an IBM 1130 computer and a spline fit program (Boon, 1974) which:

1. multiplied nutrient concentration and salinity by instantaneous water discharge to produce instantaneous nutrient and salinity discharge;
2. plotted graphs of instantaneous nutrient and salinity discharge versus time and integrated the area under the flood tide and ebb tide halves of the curve;
3. subtracted flood tide nutrient and salinity transport from ebb tide transport and gave net flux for the complete tidal cycle.

Because salinity and water transport data indicated absence of significant non-tidal water input to the marshes, inequalities between flood tide and ebb tide water transport were attributed to a shift in the location of mean current velocity within the marsh creek channel as a consequence of the shift in direction of water flow, thus causing constant sampling bias. Therefore flood and ebb water transport were multiplied by factors to equate them to the mean of the measured flood and ebb tide water transport. Tidal salinity and nutrient transport were also corrected in this manner.

For calculation of nutrient flux over a year the sampling year was divided into approximately twelve month long periods, each containing a sampled tidal cycle. Nutrient transport over each period was calculated using two methods. In one calculation the assumption was made that every tidal cycle within a given period produced a net transport of nutrients into or out of the marsh equal to the net transport of the tidal cycle sampled within that period. In the second calculation the assumption was made that net nutrient transport over a tidal cycle was directly proportional to tidal prism. By calculating mean York River high water tide heights for each period from data supplied by a continuously recording tide gauge, and from regression equations relating marsh tidal prism to York River high water tide height, mean marsh tidal prisms were calculated for each period. Measured tidal prism, mean tidal prism, and number of tidal cycles within each period were then used to calculate nutrient flux. Because data suggest that the two calculations represent lower and upper limits of true flux, net tidal transport was estimated by taking the mean of the transports of the two calculations.

Statistical Analysis

To determine possible relationships between nutrient concentrations and physical parameters, a correlation matrix including nutrient concentrations, water temperature, salinity, tide height, and water discharge was calculated for each month using an IBM 360-50 computer (Dixon, 1968).

Multiple regression analysis for determination of effect of marsh induced nutrient transformations or estuarine phytoplankton productivity was also performed with the IBM 360-50. For comparison of flood tide versus ebb tide, phytoplankton productivity-nutrient relationships, simple and partial correlations were calculated between phytoplankton productivity, water temperature, chlorophyll 'a', ATP, nitrate, ammonia, dissolved inorganic phosphorus and dissolved inorganic carbon concentrations over each half tidal cycle (Dixon, 1968; Snedecor and Cochran, 1967).

SECTION III

RESEARCH PROCEDURES

C - RESULTS

General Comments

Although the actual sampling of the study areas was completed in January of 1973, analysis of stored samples, subsequent data reduction, and the development of flux calculations methodologies extended throughout 1973. In fact due to the large amount of data collected, we have not been able, within the time constraints of the completion report deadline, to complete the final drafting of figures. This is due more than anything to our inability to decide upon the best methods of presentation. We must also point out, however, that even though some aspects of the evaluation are not polished for final presentation, a thorough analysis of the data has been made.

College Creek

A partial tabulation of the results on College Creek are shown in Tables 1, 2 and 3. Several other sampling runs were conducted; however, freshets which increased normal freshwater input precluded their analysis because it was felt that conclusions drawn from the data would be unreliable.

Nutrient flux calculations based on two sampling dates in College Creek are tabulated in Tables 4 and 5. The magnitude of flux in both directions was quite different on the two dates, with about three times the material moving through the system during the December sampling date. This difference results directly from a greater magnitude of flow during that period. The differences in total phosphorus flux were small and variable on the two sampling dates, with the direction of total phosphorus flux being reversed on the two dates. Dissolved orthophosphate was contributed to the river by the marsh on both dates while particulate phosphate was supplied to the marsh from the river. The flux of total nitrogen was toward the marsh on both dates; however, the direction of flux of the various nitrogen fractions was variable. A large flux of organic carbon was observed toward the river on both sampling dates with a net flux of 5712 KG in December and 1674 KG in January.

Although not conclusive, the studies completed on this system which was receiving secondary sewage effluent at the time of study, indicated the following:

1) A significant flux of organic carbon can be expected from marsh creeks of this type;

2) With regards to plant nutrients at least during the dormant period for marsh plants, phosphorus seems little influenced by passage through the marsh. Essentially the same can be said for nitrogen except that the differences in net flux indicate that the river may be functioning as a nitrogen source for the marsh.

Further studies of this perturbed system were planned; however, the sewage discharge was discontinued in February thus making the site unsuitable for comparative study.

Table 1. Tidal Cycle Data
College Creek
7 Dec. 1971

Time Est.	Tide ht. cm below ref. notch	Tide Stage	Current cm/sec	Cross section area M^2	Water flux M^3/sec	Sal ‰	DO mg O_2/1	TKN mg N/1	DKN	NH_3	PON	DON	NO_x	NO_2	NO_3	TN
0920	120.5	Low														
0930	119.5		9	124.6	11.2	.70	10.4	.80	.50		.30		.728	.0021	.726	1.53
1000	114.5		32	125.6	40.2											
1030	108.5		49	126.8	62.2	.63	10.7	.60	.52	.14	.08	.38	.738	.0073	.731	1.34
1100	102	R	63	128.2	79.5											
1130	94.5	i	75	129.8	97.3	.65	10.9	.60	.41	.14	.19	.27	.771	.0084	.763	1.37
1200	86.5	s	83	131.5	109.8											
1230	79.5	i	92	133	122.3	.61	10.9	.56	.49	.13	.07	.36	.785	.0081	.777	1.34
1300	73.5	n	91	134.2	122.1											
1330	68	g	88	135.4	119.1	.63	7.5	.62	.49	.13	.13	.36	.771	.0081	.763	1.39
1400	62.5		82	136.5	111.1											
1430	58		75	137.5	103.2	.81	11.1	.60		.17			.779	.0073	.772	1.38
1500	54		49	138.2	67.7											
1530	53	High	0	138.5	0	.79	11.2	.47	.37	.14	.10	.23	.772	.0073	.765	1.24
1600	58.5		52	137.2	80.3											
1630	64.5		85	136	115.6	.69	9.9	.47	.45	.13	.02	.32	.600	.0063	.594	1.07
1700	72	F	96	134.5	129.8											
1730	78	a	102	133.2	135.9	.57	10.4	.41	.41	.20	0	.21	.778	.0081	.770	1.17
1800	85	l	102	131.8	135.0											
1830	92	l	100	130.4	131.0	.57	10.0	.90	.49	.07	.41	.42	.720	.0081	.712	1.62
1900	98.5	i	91	129	117.4	.58	10.9	.69	.41	.24	.28	.17	.718	.0081	.710	1.41
		n				.57	8.5	.56	.47	.14	.09	.33	.734	.0081	.726	1.29
1930	106	g	73	127.4	93.6	.60	8.2	.71	.49	.17	.22	.32	.727	.0087	.719	1.44
2000	112		56	126.1	71.3											
2030	117		39	125.1	49.4	.65	8.7	.54	.50	.14	.04	.36	.719	.0126	.706	1.26
2100	120		24	124.5	29.9											
2130	122	Low	8	124	9.9	.67	8.5	.64	.56	.17	.08	.39	.646	.0168	.629	1.29

Table 1. Part 2.

Time Est.	TP mg P/1	TDP	oP	PP	DUP	TC mg C/1	TDC	PC	TIC	DIC	DOC	Chlor. a ug/1
0920												
0930	.2117	.0972	.0756	.1145	.0216	19.2	17.5	1.7	8.0	6.0	11.5	6.3
1000												
1030	.1944	.0648	.0540	.1296	.0108	15.7	15.0	0.7	5.3	4.5	10.5	5.6
1100												
1130	.2354	.0626	.0497	.1728	.0129	15.9	13.0	2.9	5.0	3.5	9.5	2.7
1200												
1230	.2073	.0583	.0454	.1490	.0129	16.5	14.0	2.5	4.5	4.5	9.5	3.2
1300												
1330	.2268	.0540	.0346	.1728	.0194	15.4	11.5	3.9	4.5	3.0	8.5	3.2
1400												
1430	.1836	.0540	.0410	.1296	.0130	18.1	14.0	4.1	4.0	3.5	10.5	2.2
1500												
1530	.1750	.0475	.0432	.1275	.0043	16.0	12.0	4.0	4.5	3.5	8.5	3.9
1600												
1630	.1944	.0432	.0389	.1512	.0043	14.8	6.5	8.3	5.0	0	6.5	2.7
1700												
1730	.1901	.0540	.0454	.1361	.0086	17.0	12.5	4.5	4.5	2.5	10.0	4.6
1800												
1830	.1966	.0583	.0497	.1383	.0086	18.0	15.5	2.5	5.5	4.5	11.0	5.8
1900	.2074	.0583	.0562	.1491	.0021	17.0	14.0	3.0	5.3	3.5	10.5	4.6
	.2182	.0626	.0562	.1556	.0064	17.0	13.5	3.5	4.0	4.0	9.5	3.4
1930	.2268	.0691	.0605	.1577	.0086	21.9	15.0	6.9	4.5	4.5	10.5	6.8
2000												
2030	.2333	.0842	.0648	.1491	.0194	20.3	19.0	1.3	8.0	6.0	13.0	7.3
2100												
2130	.2441	.1080	.0929	.1361	.0151	21.2	19.5	1.7	9.5	6.5	13.0	11.9

Table 2. Tidal Cycle Data
College Creek
7 Jan. 1972

Time Est.	Tide ht. cm below ref. notch	Tide Stage	Current cm/sec	Cross section area M^2	Water Flux M^3/sec	Sal ‰	DO mg O_2/1	TKN mg N/1	DKN	NH_3	PON	DON	NO_x	NO_2	NO_3	TN
1045	120	Low	0	124.5	0	1.09	12.5	.65	.60	.13	.05	.47	.588	.015	.572	1.24
1115	118		15.3	124.9	19.1											
1145	115	R	28.0	125.5	35.1	1.11	12.7	.83	.51	.13	.32	.38	.602	.015	.587	1.43
1215	110.5	i	34.4	126.5	43.5											
1245	105	s	42.3	127.6	54.0	.95	11.6	.63	.63	.25	0	.38	.721	.013	.707	1.35
1315	100	i	36.0	128.7	46.3											
1345	95	n	39.6	129.7	51.4	.96	11.1	.75	.62	.17	.13	.45	.700	.002	.698	1.45
1415	93	g	19.8	130.1	25.8											
1445	92		0.4	130.4	0	1.00	11.2	.67	.65	.20	.02	.45	.735	.005	.730	1.40
1515	90.5	High	8.9	130.7	11.6											
1545	92.5		5.9	130.2	7.7	1.00	14.3	.96	.23	0	.73	.23	.525	.015	.509	1.48
1615	96		11.1	129.5	14.4											
1645	100	F	19.3	128.7	24.8	1.02	11.8	.76	.50	.18	.26	.32	.672	.014	.658	1.43
1715	105	a	25.5	127.6	32.5											
1745	110	l	31.7	126.6	40.1	.99	11.7	.72	.68	.07	.04	.61	.658	.014	.644	1.38
1815	115	l	25.1	125.5	31.5											
1845	119.5	i	19.3	124.6	24.0	.98	11.0	.76	.67	.10	.09	.57	.630	.014	.615	1.39
1915	124.5	n	20.5	123.5	25.3											
1945	128	g	9.8	122.8	12.0	.97	8.8	.97	.59	0	.38	.59	.560	.016	.544	1.53
2015	132.5		8.6	121.8	10.5											
2045	135		5.5	121.4	6.7	.96	10.7	.97	.62	.06	.35	.56	.483	.016	.466	1.45
2115	137.5		4.5	120.8	5.4											
2145	138.5	Low	2.1	120.6	2.5	.96	11.9	.98	.49	0	.49	.49	.476	.016	.459	1.46
2215	138.5		0	120.6	0											

Table 2. Part 2

Time Est.	TP mg P/1	TDP	oP	PP	DUP	TC mg C/1	TDC	PC	TIC	DIC	DOC	Chlor. a ug/1
1045	.161	.104	.040	.057	.064	16.8	13.5	3.3	7.1	2.8	10.7	8.0
1115												
1145	.177	.094	.039	.083	.055	18.9	14.5	4.4	7.5	2.8	11.7	7.3
1215												
1245	.183	.096	.030	.087	.066	13.7	10.5	3.2	4.7	2.4	8.1	1.7
1315												
1345	.189	.099	.032	.090	.067	18.4	8.5	9.9	5.7	0.5	8.0	2.2
1415												
1445	.155	.089	.033	.066	.056	11.6	9.5	2.1	4.2	2.4	7.1	1.5
1515												
1545	.181	.094	.047	.087	.047	20.5	18.5	2.0	7.5	9.0	9.5	14.8
1615												
1645	.133	.095	.032	.038	.063	14.7	14.5	0.2	5.7	6.1	8.4	4.1
1715												
1745	.177	.099	.033	.078	0.66	18.9	16.5	2.4	5.2	7.1	9.4	5.6
1815												
1845	.163	.104	.037	.059	.067	18.4	17.5	0.9	5.7	5.2	12.3	10.0
1915												
1945	.183	.112	.050	.071	.062	18.5	18.5	0	7.1	7.5	11.0	25.5
2015												
2045	.210	.126	.049	.084	.077	17.4	17.0	0.4	6.1	7.5	9.5	38.4
2115												
2145	.196	.117	.063	.079	.054	24.2	18.0	6.2	5.2	8.5	9.5	1.7
2215												

Table 3. Tidal Cycle Data
College Creek
19 Jan. 1972

Time Est.	Tide ht. cm below ref. notch	Tide Stage	Current cm/sec	Cross section area M^2	Water flux M^3/sec	Sal ‰	DO mg $O_2/1$	TKN mg N/1	DKN	NH_3	PON	DON	NO_x	NO_2	NO_3	TN
0815	161	Low	0	116	0	.59	12.9	1.07	.49	.08	.58	.41	.658	.0116	.646	1.73
0845	158		9.3	116.6	10.85											
0915	153		19.1	117.6	22.46	.53	12.9	1.00	.64	.24	.36	.40	.742	.0118	.730	1.74
0945	145	R	26.0	119.3	31.03											
1015	134.5	i	32.1	121.5	39.00	.38	12.8	.91	.77	.29	.14	.48	.840	.0112	.829	1.75
1045	124.3	s	35.3	123.5	43.60											
1115	114.5	i	33.9	125.6	42.60	.36	12.9	.91	.66	.25	.25	.41	.861	.0113	.850	1.77
1145	106.5	n	30.3	127.3	38.58											
1215	99.5	g	27.8	128.8	35.80	.32	12.8	.88	.72	.18	.16	.54	.910	.0122	.898	1.79
1245	94		26.4	130.0	34.32											
1315	90.7		19.4	130.6	25.34	.38	12.1	1.41	.45	.34	.96	.11	.875	.0120	.863	2.28
1345	89	High	9.8	131.0	12.84											
1415	91		13.6	130.5	17.75	.40	12.5	.89	.62	.28	.27	.34	.868	.0119	.856	1.76
1445	995		32.8	129.7	42.65											
1515	101	F	33.3	128.5	42.80	.37	12.3	.92	.88	.34	.04	.54	.875	.0112	.864	1.79
1545	108.8	a	43.5	126.8	55.16											
1615	116	l	34.6	125.3	43.37	.39	12.3	.88	.74	.18	.14	.56	.847	.0120	.835	1.73
1645	124	l	28.3	123.6	35.00											
1715	131	i	35.8	122.2	43.76	.43	13.0	.81	.65	.20	.16	.45	.966	.0125	.954	1.78
1745	139	n	18.4	120.5	22.17											
1815	144	g	16.4	119.5	19.60	.45	12.8	.82	.61	.22	.21	.39	.798	.0120	.786	1.62
1845	149.5		13.4	118.3	15.85											
1915	154		9.5	117.4	11.15	.51	13.2	.89	.64	.14	.25	.50	.763	.0127	.750	1.65
1945	157		7.8	116.8	8.99											
2015	159.5	Low	3.6	116.3	4.19	.54	13.9	.94	.68	.13	.26	.55	.630	.0130	.617	1.57

Table 3. Part 2.

Time Est.	TP mg P/1	TDP	oP	PP	DUP	TC mg C/1	TDC	PC	TIC	DIC	DOC	Chlor. a ug/1
0815	.125	.075	.051	.050	.024	22.1	11.8	10.3	8.4	3.6	8.2	22.4
0845												
0915	.205	.075	.044	.130	.031	20.0	16.9	3.1	7.6	7.6	9.3	13.8
0945												
1015	.180	.061	.035	.119	.026	16.9	13.8	3.1	5.6	6.0	7.8	5.6
1045												
1115	.098	.049	.033	.049	.016	15.9	13.8	2.1	5.2	6.0	7.8	4.7
1145												
1215	.144	.043	.033	.101	.010	15.4	12.8	2.6	5.6	5.6	7.2	3.5
1245												
1315	.148	.057	.035	.091	.022	16.4	13.8	2.6	5.2	5.2	8.6	4.5
1345												
1415	.164	.062	.035	.102	.027	16.4	13.8	2.6	5.2	5.6	8.2	5.8
1445												
1515	.163	.051	.051	.112	0	16.9	13.8	3.1	5.2	5.6	8.2	5.0
1545												
1615	.094	.057	.037	.037	.020	16.9	13.8	3.1	5.6	5.6	8.2	7.3
1645												
1715	.099	.060	.039	.039	.021	19.5	18.5	1.0	5.6	6.0	12.5	12.1
1745												
1815	.107	.069	.041	.038	.028	19.0	14.9	4.1	6.4	6.8	8.1	14.4
1845												
1915	.185	.068	.046	.117	.021	23.1	17.4	5.7	7.2	7.6	9.8	14.8
1945												
2015	.214	.070	.052	.144	.018	23.1	19.0	4.1	8.8	8.4	10.6	31.5

Table 4

College Creek 12/7/71
Kg/hr

	TP	DIP	PP	NO_3	NO_2	NH_3	DON	PON	TN
Flood	8.5	3.1	4.6	29.3	0.1	5.6	20.2	12.1	61.7
	43.5	12.1	29.0	163.4	1.6	31.3	116.4	17.9	300.1
	82.5	17.4	60.5	270.1	2.9	49.0	94.6	66.5	479.9
	91.3	19.9	65.6	342.1	3.5	57.2	158.5	30.8	589.9
	97.2	14.8	74.1	327.1	3.4	55.7	154.4	55.7	595.9
	68.2	15.2	48.1	286.8	2.7	63.2	133.7	48.3	512.7
Total	391.2	82.5	281.9	1418.8	14.2	262.0	677.8	231.3	2540.2
Ebb	80.9	16.2	62.9	247.2	2.6	54.1	133.1	8.3	445.3
	93.0	22.2	66.6	376.7	3.9	97.8	102.7	-	572.4
	92.7	23.4	65.2	335.8	3.8	33.0	198.1	193.4	763.9
	76.4	20.4	53.1	242.3	2.9	57.3	107.8	74.1	485.2
	41.5	11.5	26.5	125.6	2.1	24.9	64.0	7.1	224.1
	8.7	3.3	4.8	22.4	0.6	6.1	13.9	2.8	45.9
Total	393.2	97.0	279.1	1350.0	15.9	273.2	619.6	285.7	2536.8

Table 5

College Creek 1/19/73
Kg/hr

	TP	DIP	PP	NO_3	NO_2	NH_3	DON	PON	TN
Flood	16.6	3.6	10.5	59.0	.9	19.4	32.3	29.1	140.7
	25.3	4.9	16.7	116.4	1.6	40.7	67.4	19.6	245.7
	15.0	5.1	7.5	130.4	1.7	38.3	62.9	38.3	271.4
	18.6	4.3	13.0	115.7	1.5	23.2	69.6	20.6	230.7
	13.5	3.2	8.3	78.6	1.1	30.9	10.0	87.4	207.6
Total	89.0	21.1	55.5	500.1	6.8	152.5	242.2	195.0	1096.1
Ebb	10.5	2.2	6.5	54.7	0.7	17.9	21.7	17.3	112.5
	25.1	7.8	17.3	133.1	1.7	52.4	83.2	6.2	275.8
	14.7	5.8	5.8	130.4	1.8	28.1	87.4	21.9	270.1
	15.6	6.1	6.1	150.3	2.0	31.5	70.9	25.2	280.4
	7.5	2.9	2.7	55.4	0.8	15.5	27.5	14.8	114.3
Total	73.4	24.8	38.4	523.9	7.0	145.4	290.7	85.4	1053.1

Ware and Carter Creek Marshes

Tidal and Temporal Nutrient Concentration Trends

(Tables 6-28)

Dissolved Inorganic Phosphorus

The seasonal variation in dissolved inorganic phosphorus concentration of Ware and Carter creek marsh waters was atypical compared with seasonal phosphorus trends observed in most other aquatic environments. Highest phosphorus levels were found in summer and lowest concentrations occurred in winter. Seasonally, dissolved inorganic phosphorus concentrations varied from 0.3 to 5 ug at/l. Throughout the sampling year, phosphorus levels were highest at low slack water and decreased towards high slack water with maximal phosphorus concentration ranges during summer tidal cycles.

Dissolved Organic Phosphorus

The marshes seasonal and tidal dissolved organic phosphorus concentration trends were similar to those of dissolved inorganic phosphorus as evidenced by the high correlation between the two phosphorus species. Seasonally dissolved organic phosphorus concentrations ranged from 0.2 - 1.4 ug at/l. Dissolved organic phosphorus concentrations peaked in summer and were lowest in winter. Over the year concentrations were generally highest at low slack water and decreased towards high slack water.

Particulate Phosphorus

In both marshes highest levels of particulate phosphorus were found in summer months and concentrations ranged over the year from 0.5 - 19.5 ug at/1. Peak phosphorus concentrations over tidal cycles often occurred near low slack water but also occurred at times of maximum water discharge. Minimum phosphorus concentrations were generally found at high slack water.

The highest sustained particulate phosphorus levels found during the study occurred during a storm.

Nitrate

Nitrate concentrations ranged from 0.2 to 27 ug at/1 over the year with maximal concentrations in winter and minimal concentrations in summer. Low slack water nitrate concentrations were greater than high slack water concentrations during May through September in Ware Creek and in June through November in Carter Creek. At other times high slack nitrate concentrations were greater than low slack water concentrations.

Nitrite

Nitrite concentrations varied seasonally in the marshes from 0.1 to 1.8 ug at/1. In general this transitory nitrogen species followed the seasonal trends of nitrate but concentrations did not fluctuate widely over a tidal cycle or over the year.

Ammonia

The seasonal ammonia cycle strongly contrasts with cycles of other aquatic environments. Over the year ammonia concentrations ranged from 1 - 26 ug at/l with highest concentrations occurring in summer months. Generally, highest ammonia levels over a tidal cycle were found at low slack water.

Dissolved Organic Nitrogen

Dissolved organic nitrogen concentrations peaked in summer and were lowest in winter months ranging from 3 - 82 ug at/l over the year. Concentrations over a tidal cycle were generally higher at low slack water decreasing towards high slack water.

Particulate Nitrogen

Particulate nitrogen followed a seasonal cycle similar to that of particulate phosphorus. Highest nitrogen concentrations were measured in summer and lowest levels were found in winter. Seasonally particulate nitrogen ranged from 4 - 175 ug at/l. Peak nitrogen concentrations over tidal cycles either occurred near low slack water or at times of maximum water discharge.

Table 6

Ware Creek 1/23/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
12.25	0	0.78	0.40	1.70	4.99	0.28	8.0	30.0	47.0	1.44
12.67	+ 155.686									
12.92	+ 319.084									
13.25	+ 879.200	0.65	0.39	1.88	7.68	0.32	4.0	27.0	21.0	1.08
13.58	+ 1,143.087									
14.05	+ 1,278.704									
14.25	+ 1,332.504	0.63	0.41	1.91	7.27	0.30	4.0	29.0	28.0	1.59
14.70	+ 1,976.776									
14.92	+ 2,037.882									
15.25	+ 1,136.212	0.55	0.29	1.96	7.02	0.28	3.0	30.0	30.0	3.07
15.58	+ 1,213.732									
15.92	+ 1,216.784									
16.75	+ 1,252.597	0.49	0.24	1.95	7.13	0.27	3.0	31.0	25.0	5.28
16.58	+ 1,215.680									
16.92	+ 999.380									
17.25	+ 716.210	0.51	0.27	1.44	7.37	0.29	3.0	39.0	8.0	7.23
17.58	0	0.51	0.29	1.12	7.41	0.24	2.0	41.0	5.0	7.42
17.92	- 807.260									
18.25	- 1,090.320									
18.58	- 1,095.682	0.48	0.30	1.42	6.97	0.29	6.0	34.0	26.0	5.96
19.00	- 1,257.450									
19.25	- 1,239.768									
19.58	- 1,236.300	0.51	0.30	1.85	5.95	0.32	4.0	33.0	29.0	3.88
19.92	- 1,283.120									
20.25	- 1,237.456									
20.58	- 1,147.176	0.55	0.33	1.92	5.73	0.34	4.0	32.0	31.0	2.42
20.92	- 1,023.360									
21.25	- 983.940									
21.58	- 869.295	0.62	0.39	2.27	4.67	0.33	3.0	41.0	32.0	1.77
21.92	- 701.100									
22.25	- 625.860									
22.58	- 530.352	0.69	0.39	1.96	3.23	0.34	4.0	36.0	20.0	1.43
22.92	- 398.780									
23.25	- 291.360									
23.58	- 153.584									
23.75	0	0.82	0.40	1.94	2.92	0.34	5.0	37.0	17.0	1.01

Table 7

Ware Creek 3/4/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
09.00	0	1.00	0.60	4.22	1.59	0.28	8.0	4.0	26.0	0.42
09.33	+ 177.240									
09.67	+ 410.856									
10.00	+ 544.152	0.57	0.45	1.12	3.44	0.32	6.0	3.0	14.0	0.19
10.33	+ 583.604									
10.67	+ 627.260									
11.00	+ 921.270	0.54	0.45	1.31	2.70	0.28	3.6	3.4	13.0	0.25
11.33	+ 977.235									
11.67	+ 1,051.178									
12.00	+ 1,245.158	0.59	0.45	1.63	2.44	0.31	4.0	5.0	13.0	0.41
12.33	+ 1,385.494									
12.67	+ 1,525.600									
13.00	+ 1,490.760	0.65	0.41	2.02	2.35	0.32	4.6	4.4	15.0	0.57
13.33	+ 1,443.022									
13.67	+ 1,216.384									
14.00	+ 880.630	0.69	0.31	1.89	2.65	0.31	3.4	4.6	18.0	0.87
14.33	0				3.19	0.29				
14.67	- 902.340	0.58	0.32	1.69			3.8	8.2	17.0	1.02
15.00	- 1,222.188									
15.33	- 1,453.868	0.68	0.40	1.73	2.31	0.29	4.4	7.6	11.0	0.74
15.67	- 1,586.850									
16.00	- 1,738.008									
16.33	- 1,689.314	0.77	0.45	1.48	2.31	0.28	5.2	9.8	11.0	0.48
16.67	- 1,607.856									
17.00	- 1,660.158									
17.33	- 1,488.350	0.83	0.44	1.42	1.86	0.29	6.2	9.8	10.0	0.44
17.67	- 1,257.210									
18.00	- 1,099.080									
18.33	- 925.248	1.09	0.47	0.76	1.76	0.30	6.4	7.6	11.0	0.40
18.67	- 673.608									
19.00	- 526.656									
19.33	- 377.136	1.37	0.47	1.12	1.40	0.28	7.2	5.8	16.0	0.41
19.67	- 242.676									
20.00	- 52.767									
20.33	0	1.40	0.72	0.98	1.65	0.33	7.8	3.8	18.0	0.41

Table 8

Ware Creek 4/17/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
09.62	0	0.70	1.18	2.10	0.96	0.17	6.0	22.0	20.0	1.97
09.95	+ 1,010.350									1.40
10.28	+ 644.800									1.37
10.62	+ 838.500	0.42	0.62	2.00	0.64	0.22	3.0	24.0	16.0	1.47
10.95	+ 1,335.800									1.57
11.28	+ 1,609.300									1.78
11.62	+ 1,800.000	0.37	0.43	2.64	0.61	0.15	7.0	25.0	16.0	2.04
11.95	+ 1,990.660									2.30
12.28	+ 2,210.670									2.62
12.62	+ 2,360.960	0.29	0.31	3.00	0.89	0.15	4.0	20.0	20.0	3.02
12.95	+ 2,477.520									3.65
13.28	+ 2,463.390									4.07
13.62	+ 2,502.400	0.25	0.37	2.68	1.22	0.18	6.0	24.0	14.0	4.95
13.95	+ 2,532.600									5.88
14.28	+ 2,246.760									7.11
14.62	+ 1,944.120	0.31	0.43	3.56	2.73	0.17	1.0	29.0	18.0	8.06
14.95	+ 1,367.080									8.83
15.28	+ 493.480									8.98
15.50	0	0.37	0.35	1.90	3.70	0.17	5.0	15.0	15.0	8.34
15.83	- 1,771.740									7.63
16.17	- 2,229.520									7.39
16.50	- 2,415.440	0.26	0.40	2.64	1.80	0.15	2.0	15.0	18.0	6.49
16.83	- 2,574.880									5.22
17.17	- 2,735.680									4.69
17.50	- 2,707.540	0.26	0.46	3.90	0.83	0.14	12.0	17.0	23.0	4.14
17.83	- 2,842.258									3.63
18.17	- 2,768.150									3.29
18.50	- 2,721.180	0.31	0.51	3.88	0.55	0.14	11.0	20.0	24.0	2.95
18.83	- 2,550.240									2.70
19.17	- 2,397.300									2.47
19.50	- 2,157.600	0.43	0.52	4.01	0.49	0.15	14.0	17.0	23.0	2.29
19.83	- 1,773.440									2.13
20.17	- 1,439.200									2.07
20.50	- 1,076.320	0.65	0.65	3.36	0.56	0.13	9.0	18.0	22.0	1.98
20.83	- 683.200									1.77
21.17	- 215.600									1.43
21.33	0	1.01	0.81	2.28	0.89	0.17	11.0	20.0	20.0	1.69

Table 9

Ware Creek 5/17/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
11.25	0	2.02	0.65	3.33	0.87	0.29	3.0	33.0	25.0	0.41
11.58	+ 492.768									0.20
11.92	+ 715.564									0.21
12.25	+ 872.792	1.64	0.63	1.90	2.96	0.48	2.0	28.0	15.0	0.21
12.58	+ 1,091.324									0.22
12.92	+ 1,346.404									0.27
13.25	+ 1,757.754	1.68	0.72	1.80	2.54	0.43	2.2	30.8	14.0	0.32
13.58	+ 2,021.823									0.40
13.92	+ 2,213.028									0.50
14.25	+ 2,540.314	1.47	0.68	2.32	2.19	0.39	2.0	29.0	14.0	0.62
14.58	+ 2,727.936									0.79
14.92	+ 2,777.040									1.16
15.25	+ 2,823.480	1.09	0.56	2.13	1.45	0.29	1.4	18.6	16.0	1.92
15.58	+ 2,829.486									2.84
15.92	+ 2,703.476									4.58
16.25	+ 2,268.715	0.35	0.42	1.23	0.98	0.13	1.4	19.6	12.0	5.87
16.58	+ 1,701.295									6.44
16.92	+ 348.798									6.62
17.00	0	0.26	0.49	1.05	0.33	0.13	1.6	22.4	9.0	6.27
17.33	- 1,712.120									5.37
17.67	- 2,374.312									5.01
18.00	- 2,641.320	0.53	0.57	1.83	0.58	0.19	2.0	28.0	16.0	4.25
18.33	- 2,938.580									3.14
18.67	- 2,855.804									2.36
19.00	- 2,770.146	1.08	0.72	2.07	1.05	0.28	2.4	32.6	15.0	1.76
19.33	- 2,576.860									1.32
19.67	- 2,656.794									1.01
20.00	- 2,409.750	1.53	0.61	2.25	1.61	0.30	2.4	33.6	18.0	0.85
20.33	- 2,256.000									0.70
20.67	- 2,098.091									0.60
21.00	- 1,742.760	1.78	0.67	2.88	0.84	0.34	1.8	26.2	29.0	0.56
21.33	- 1,542.446									0.51
21.67	- 1,502.970									0.46
22.00	- 940.347	2.24	0.66	2.23	0.72	0.33	12.0	28.0	17.0	0.45
22.33	- 773.608									0.45
22.67	- 377.925									0.57
22.92	0	2.43	0.69	1.75	0.82	0.38	17.0	26.0	37.0	0.46

Table 9

Ware Creek 5/17/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
11.25	0	2.02	0.65	3.33	0.87	0.29	3.0	33.0	25.0	0.41
11.58	+ 492.768									0.20
11.92	+ 715.564									0.21
12.25	+ 872.792	1.64	0.63	1.90	2.96	0.48	2.0	28.0	15.0	0.21
12.58	+ 1,091.324									0.22
12.92	+ 1,346.404									0.27
13.25	+ 1,757.754	1.68	0.72	1.80	2.54	0.43	2.2	30.8	14.0	0.32
13.58	+ 2,021.823									0.40
13.92	+ 2,213.028									0.50
14.25	+ 2,540.314	1.47	0.68	2.32	2.19	0.39	2.0	29.0	14.0	0.62
14.58	+ 2,727.936									0.79
14.92	+ 2,777.040									1.16
15.25	+ 2,823.480	1.09	0.56	2.13	1.45	0.29	1.4	18.6	16.0	1.92
15.58	+ 2,829.486									2.84
15.92	+ 2,703.476									4.58
16.25	+ 2,268.715	0.35	0.42	1.23	0.98	0.13	1.4	19.6	12.0	5.87
16.58	+ 1,701.295									6.44
16.92	+ 348.798									6.62
17.00	0	0.26	0.49	1.05	0.33	0.13	1.6	22.4	9.0	6.27
17.33	- 1,712.120									5.37
17.67	- 2,374.312									5.01
18.00	- 2,641.320	0.53	0.57	1.83	0.58	0.19	2.0	28.0	16.0	4.25
18.33	- 2,938.580									3.14
18.67	- 2,855.804									2.36
19.00	- 2,770.146	1.08	0.72	2.07	1.05	0.28	2.4	32.6	15.0	1.76
19.33	- 2,576.860									1.32
19.67	- 2,656.794									1.01
20.00	- 2,409.750	1.53	0.61	2.25	1.61	0.30	2.4	33.6	18.0	0.85
20.33	- 2,256.000									0.70
20.67	- 2,098.091									0.60
21.00	- 1,742.760	1.78	0.67	2.88	0.84	0.34	1.8	26.2	29.0	0.56
21.33	- 1,542.446									0.51
21.67	- 1,502.970									0.46
22.00	- 940.347	2.24	0.66	2.23	0.72	0.33	12.0	28.0	17.0	0.45
22.33	- 773.608									0.45
22.67	- 377.925									0.57
22.92	0	2.43	0.69	1.75	0.82	0.38	17.0	26.0	37.0	0.46

Table 10

Ware Creek 6/14/72

Time	l/sec Discharge	μg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
10.33	0	2.04	0.82	6.99	2.90	0.55	4.8	45.0	47.0	0.51
10.67	+ 263.940									0.85
11.00	+ 620.400									0.33
11.33	+ 800.400	1.36	0.85	4.67	1.72	0.46	8.6	55.4	23.0	0.37
11.67	+ 973.840									0.42
12.00	+ 1,156.000									0.53
12.33	+ 1,227.400	1.10	0.79	5.31	1.02	0.38	6.2	51.2	24.0	0.68
12.67	+ 1,479.720									0.73
13.00	+ 1,626.400									0.86
13.33	+ 1,779.540	1.06	0.77	5.42	1.31	0.43	5.4	58.0	29.0	1.01
13.67	+ 1,972.800									1.28
14.00	+ 2,013.600									1.60
14.33	+ 2,029.110	0.82	0.76	3.92	1.18	0.40	3.0	55.0	22.0	2.08
14.67	+ 1,673.100									3.00
15.00	+ 1,417.350									3.89
15.33	0	0.60	0.55	2.67	0.90	0.39	3.4	49.4	20.6	5.38
15.67	- 1,369.400									4.19
16.00	- 1,784.000									3.16
16.33	- 1,989.000	0.73	0.70	3.46	1.00	0.32	6.0	43.6	26.0	3.12
16.67	- 2,033.850									2.12
17.00	- 1,945.400									1.54
17.33	- 1,981.700	1.16	1.10	5.06	0.72	0.42	6.6	56.6	30.0	1.23
17.67	- 1,718.750									1.09
18.00	- 1,524.840									0.89
18.33	- 1,662.250	1.60	1.30	5.80	0.47	0.45	6.8	56.0	36.0	0.81
18.67	- 1,290.140									0.73
19.00	- 1,066.900									0.65
19.33	- 811.800	2.15	1.26	6.10	0.49	0.47	4.0	58.0	32.0	0.59
19.67	- 654.500									0.51
20.00	- 554.400									0.48
20.33	- 505.300	2.39	1.40	6.04	1.32	0.55	6.2	54.0	36.0	0.50
20.67	- 354.000									0.49
21.00	- 206.000									0.58
21.33	- 110.750	2.95	1.27	6.52	1.12	0.60	6.2	61.6	35.0	0.59
21.67	0	1.88	1.31	4.08	0.82	0.55	8.2	49.0	23.0	0.25

Table 11

Ware Creek 6/14-15/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
21.67	0	1.88	1.31	4.08	0.82	0.55	8.2	49.0	23.0	0.25
22.00	+ 409.200									0.17
22.33	+ 640.200									0.22
22.67	+ 756.500	1.43	0.99	3.85	1.17	0.52	6.2	49.8	24.0	0.25
23.00	+ 923.100									0.29
23.33	+ 1,098.200									0.36
23.67	+ 1,196.800	1.60	0.80	4.88	0.73	0.34	7.0	52.2	24.0	0.43
24.00	+ 1,414.890									0.49
00.33	+ 1,714.500									0.62
00.67	+ 1,760.000	1.45	0.76	4.79	0.70	0.33	5.6	52.2	32.0	0.78
01.00	+ 2,159.750									0.93
01.33	+ 2,433.900									1.23
01.67	+ 2,346.120	1.07	0.75	4.38	0.94	0.57	8.2	52.8	26.0	3.96
02.00	+ 2,316.840									4.80
02.33	+ 2,350.380									5.79
02.67	+ 2,307.500	0.88	0.60	4.08	0.86	0.50	7.2	58.8	23.0	6.79
03.00	+ 2,129.520									7.16
03.33	+ 1,870.000									7.28
03.67	+ 742.400	0.49	0.30	2.29	0.41	0.45	3.4	43.4	13.6	7.55
03.92	0	0.48	0.41	2.03	0.34	0.48	5.2	39.8	12.0	7.27
04.25	- 1,502.800									7.02
04.58	- 1,831.800									6.51
04.92	- 2,277.000	0.69	0.49	3.23	0.54	0.61	5.6	45.6	17.4	5.92
05.25	- 2,186.880									4.89
05.58	- 2,514.600									3.74
05.92	- 2,424.240	0.99	0.60	5.29	0.88	0.61	9.6	40.0	19.4	2.66
06.25	- 2,440.800									1.78
06.58	- 2,118.760									1.43
06.92	- 2,116.530	1.28	0.73	6.34	0.52	0.61	8.2	57.8	36.0	1.14
07.25	- 1,799.880									0.99
07.58	- 1,502.800									0.78
07.92	- 1,353.600	1.95	0.86	6.42	0.85	0.26	6.6	65.2	33.0	0.68
08.25	- 1,209.600									0.57
08.58	- 962.850									0.53
08.92	- 789.800	2.52	0.98	7.29	0.81	0.66	5.4	60.2	35.0	0.50
09.25	- 612.360									0.48
09.58	- 498.300									0.50
09.92	- 249.000									0.53
10.17	0	2.88	1.03	7.70	0.95	0.71	5.2	57.8	46.8	0.55

Table 12

Ware Creek 7/28/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
08.75	0	2.35	0.82	3.62	1.90	0.37	18.0	35.4	27.0	0.65
09.08	+ 543.910									0.42
09.42	+ 830.060									0.28
09.75	+ 971.388	1.85	0.70	2.77	2.88	0.42	18.0	29.0	22.2	0.33
10.08	+ 1,180.080									0.36
10.42	+ 1,490.325									0.40
10.75	+ 1,862.867	1.77	0.75	3.11	1.61	0.37	9.0	34.0	28.0	0.53
11.08	+ 2,112.602									0.71
11.42	+ 2,450.123									0.97
11.75	+ 2,710.164	1.41	0.64	4.40	1.09	0.59	16.4	29.4	36.6	1.30
12.08	+ 2,938.414									1.88
12.42	+ 2,717.916									2.84
12.75	+ 3,162.456	0.87	0.46	4.82	1.26	0.36	12.4	34.6	39.6	4.20
13.08	+ 3,142.382									5.82
13.42	+ 2,838.330									7.37
13.75	+ 2,741.168	0.74	0.34	4.33	1.02	0.23	13.0	26.2	43.6	7.88
14.08	+ 2,151.424									8.11
14.42	+ 1,658.748									8.36
14.75	+ 351.828									8.42
14.83	0	0.57	0.39	1.81	0.74	0.17	11.2	26.0	23.8	8.43
15.17	- 1,992.706									8.14
15.50	- 2,376.000									7.41
15.83	- 2,959.846	0.66	0.34	3.21	0.78	0.18	12.4	34.8	26.0	6.79
16.17	- 3,058.785									6.11
16.50	- 3,055.468									5.33
16.83	- 3,419.325	0.71	0.40	3.75	0.68	0.19	17.0	28.0	32.0	4.59
17.17	- 3,255.318									3.75
17.50	- 3,039.857									2.00
17.83	- 2,834.573	1.00	0.49	4.35	1.03	0.25	15.4	33.6	31.2	1.85
18.17	- 2,612.300									1.70
18.50	- 2,345.500									1.55
18.83	- 2,147.500	1.36	0.58	4.90	0.89	0.28	14.2	34.2	35.2	1.28
19.17	- 1.791.620									1.04
19.50	- 1,573.983									0.90
19.83	- 1,317.896	1.84	0.62	3.99	1.25	0.30	18.0	24.0	38.0	0.80
20.17	- 928.896									0.64
20.50	- 496.100									0.59
21.00	0	2.01	0.72	3.35	1.21	0.34	22.2	27.0	23.8	0.65

Table 13

Ware Creek 8/26/72

Time	1/sec Discharge	µg at/1 DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
08.00	0	1.09	0.54	3.42	1.00	0.19	9.6	34.4	8.0	1.46
08.33	+ 393.737									0.94
08.67	+ 557.848									0.95
09.00	+ 557.826	0.64	0.54	2.27	0.57	0.18	2.0	30.0	12.0	1.03
09.33	+ 782.964									1.13
09.67	+ 990.654									1.31
10.00	+ 1,315.300	0.62	0.52	2.74	0.55	0.19	1.8	35.2	10.6	1.55
10.33	+ 1,620.230									1.90
10.67	+ 1,966.640									2.34
11.00	+ 2,138.535	0.51	0.57	3.18	0.67	0.20	1.6	32.4	34.6	2.87
11.33	+ 2,456.600									3.57
11.67	+ 2,774.551									4.34
12.00	+ 2,837.768	0.51	0.54	3.64	0.46	0.19	2.2	32.8	30.6	5.62
12.33	+ 2,956.300									7.34
12.67	+ 2,457.215									9.10
13.00	+ 2,534.224	0.64	0.47	3.92	0.44	0.17	2.2	26.8	42.4	9.57
13.33	+ 2,619.086									9.70
13.67	+ 2,287.552									9.76
14.00	+ 1,372.000	0.70	0.48	2.84	0.44	0.21	10.8	23.2	22.0	9.83
14.33	+ 352.716									9.85
14.50	0	0.80	0.50	2.11	0.43	0.23	4.1	30.2	21.6	9.87
14.83	- 2,304.588									9.68
15.17	- 2,613.013									9.13
15.50	- 3,167.442	0.62	0.55	2.79	0.38	0.21	6.6	29.4	20.0	8.80
15.83	- 3,284.484									8.36
16.17	- 3,269.546									7.69
16.50	- 3,332.940	0.56	0.58	3.75	0.43	0.23	3.2	34.8	37.0	7.00
16.83	- 3,393.696									6.04
17.17	- 3,187.766									5.14
17.50	- 3,147.228	0.56	0.54	4.01	0.47	0.22	10.4	37.2	21.0	4.41
17.83	- 2,690.338									3.79
18.17	- 2,347.095									3.50
18.50	- 1,978.368	0.59	0.60	4.86	0.39	0.23	6.0	34.2	29.8	2.86
18.83	- 1,625.627									2.52
19.17	- 1,233.109									2.16
19.50	- 1,014.000	0.82	0.65	3.93	0.48	0.25	7.2	34.4	26.6	2.03
19.83	- 676.940									1.78
20.17	- 339.080									1.63
20.66	0	1.25	0.62	2.86	1.01	0.30	8.6	33.8	15.6	1.49

Table 14

Ware Creek 9/24/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
08.00	0	0.81	0.27	3.42	0.40	0.07	2.6	27.4	7.2	1.52
08.33	+ 884.988									1.20
08.67	+ 984.075									1.29
09.00	+ 1,144.022	0.73	0.34	3.59	0.96	0.18	1.4	29.6	11.0	1.59
09.33	+ 1,581.150									1.64
09.67	+ 1,871.584									2.98
10.00	+ 2,268.024	0.58	0.39	7.76	0.74	0.11	1.8	28.2	56.0	2.35
10.33	+ 2,429.133									2.91
10.67	+ 2,965.515									3.83
11.00	+ 3,185.056	0.43	0.24	8.79	1.50	0.36	1.8	30.8	62.4	4.94
11.33	+ 3,378.320									6.32
11.67	+ 3,287.412									10.28
12.00	+ 3,300.352	0.71	0.21	6.67	4.76	1.64	2.6	32.4	60.0	12.10
12.33	+ 3,117.235									12.48
12.67	+ 2,829.706									12.60
13.00	+ 2,677.950	0.80	0.21	5.39	5.19	1.80	2.8	35.2	48.0	12.68
13.33	+ 2,365.252									12.79
13.67	+ 1,914.174									12.96
14.00	+ 1,181.488	0.85	0.20	3.25	5.46	1.83	2.6	41.4	18.0	13.09
14.33	0	0.84	0.31	2.45	5.75	1.82	1.8	44.2	19.0	13.13
14.67	- 2,285.996									12.65
15.00	- 2,557.818									12.46
15.33	- 2,749.398	0.66	0.28	2.68	4.01	1.44	1.6	38.4	26.0	12.16
15.67	- 3,317.376									11.51
16.00	- 3,303.056									11.16
16.33	- 3,134.950	0.49	0.19	4.15	2.82	1.05	1.2	38.8	25.0	10.58
16.67	- 2,904.930									9.69
17.00	- 3,122.065									8.68
17.33	- 3,067.416	0.36	0.25	4.14	1.24	0.52	1.4	36.6	59.0	7.71
17.67	- 3,112.110									6.83
18.00	- 2,960.100									6.05
18.33	- 2,791.220	0.36	0.23	5.45	0.46	0.29	2.8	34.6	74.6	5.43
18.67	- 2,961.216									4.82
19.00	- 2,601.500									4.34
19.33	- 2,328.192	0.38	0.25	4.39	0.30	0.19	1.8	32.2	42.0	3.88
19.67	- 2,003.850									3.61
20.00	- 1,627.296									3.28
20.33	- 1,160.824	0.44	0.28	3.83	0.41	0.22	2.4	33.6	30.0	3.23
20.67	- 403.300									2.34
20.92	0	0.64	0.35	2.23	0.26	0.20	2.6	27.8	6.6	2.35

Table 15

Ware Creek 10/24/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
08.00	0	0.69	0.60	2.21	1.28	0.23	10.0	12.0	10.0	1.65
08.33	+ 323.252									1.18
08.67	+ 456.370									1.02
09.00	+ 594.490	0.45	0.77	1.20	1.02	0.20	7.6	17.4	6.0	1.11
09.33	+ 730.780									1.28
09.67	+ 1,063.198									1.52
10.00	+ 1,449.660	0.42	0.57	2.84	1.01	0.21	8.2	13.8	16.0	1.76
10.33	+ 1,616.800									2.20
10.67	+ 1,791.910									2.67
11.00	+ 2,228.218	0.42	0.53	3.12	2.05	0.27	5.0	22.4	19.6	3.36
11.33	+ 2,483.532									4.22
11.67	+ 2,651.672									5.26
12.00	+ 2,933.806	0.43	0.76	3.24	3.25	0.28	5.4	20.6	31.0	6.94
12.33	+ 2,712.120									10.39
12.67	+ 2,574.000									11.71
13.00	+ 2,486.484	0.78	0.65	2.18	8.50	0.38	7.2	21.8	12.0	11.64
13.33	+ 2,452.808									11.73
13.67	+ 2,338.614									11.75
14.00	+ 1,811.691	0.82	0.48	1.70	8.94	0.38	7.6	19.8	14.6	11.80
14.33	+ 841.007									11.93
14.63	0	0.85	0.68	0.61	9.03	0.41	5.4	20.0	7.6	11.93
15.00	- 1,992.706									11.72
15.33	- 2,663.920									11.22
15.67	- 3,065.184	0.61	0.84	0.80	6.45	0.35	6.0	22.4	7.6	10.69
16.00	- 3,030.468									10.30
16.33	- 2,609.274									9.82
16.67	- 2,507.736	0.41	0.81	1.71	3.71	0.35	8.2	15.8	14.6	8.85
17.00	- 2,594.592									7.86
17.33	- 2,611.102									6.89
17.67	- 2,212.360	0.30	0.57	2.74	1.43	0.25	4.0	21.6	17.4	6.03
18.00	- 2,371.408									5.25
18.33	- 2,126.680									4.71
18.67	- 1,897.266	0.32	0.63	2.89	0.42	0.31	1.0	22.2	20.0	4.12
19.00	- 1,714.395									3.49
19.33	- 1,431.324									3.13
19.67	- 1,472.784	0.37	0.52	3.28	0.39	0.14	5.0	17.4	25.4	2.75
20.00	- 1,284.717									2.68
20.33	- 907.137									2.43
20.67	- 507.025	0.44	0.75	2.29	0.38	0.09	6.6	18.2	16.8	2.20
21.25	0	0.61	0.69	1.50	0.53	0.10	5.4	21.0	8.0	1.61

Table 16

Ware Creek 11/24/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
08.67	0	1.08	0.37	2.42	1.36	0.16	15.0	15.0	12.4	1.03
09.00	+ 346.522									0.54
09.33	+ 375.493									0.37
09.67	+ 453.348	0.86	0.40	1.89	9.20	0.29	13.6	10.4	13.4	0.53
10.00	+ 573.990									0.45
10.33	+ 903.408									0.49
10.67	+ 1,207.374	0.83	0.39	2.06	6.52	0.25	14.6	9.4	22.4	0.60
11.00	+ 1,628.275									0.71
11.33	+ 1,799.520									0.85
11.67	+ 2,088.702	0.75	0.43	2.80	3.76	0.21	13.0	11.2	23.2	1.05
12.00	+ 2,212.875									1.27
12.33	+ 2,329.309									1.60
12.67	+ 2,443.413	0.61	0.29	3.04	2.76	0.19	10.8	13.6	20.2	2.09
13.00	+ 2,698.000									2.86
13.33	+ 2,576.815									4.80
13.67	+ 2,440.350	0.48	0.25	1.79	5.01	0.14	7.0	17.4	10.6	5.50
14.00	+ 2,294.470									5.68
14.33	+ 1,921.248									5.78
14.67	+ 1,264.792	0.45	0.26	1.11	5.24	0.16	9.0	14.8	9.2	5.81
15.00	+ 134.730									5.85
15.13	0	0.45	0.21	0.88	5.10	0.17	7.0	13.2	11.2	5.83
15.50	- 1,692.260									5.69
15.83	- 2,053.866									5.34
16.17	- 2,251.179	0.45	0.28	1.21	4.26	0.13	9.8	11.4	11.2	4.83
16.50	- 2,476.480									4.49
16.83	- 2,683.454									4.04
17.17	- 2,701.029	0.48	0.35	1.87	3.01	0.15	6.4	16.2	17.2	3.44
17.50	- 2,842.321									2.81
17.83	- 2,691.564									2.27
18.17	- 2,475.590	0.64	0.34	2.58	2.49	0.19	8.2	15.0	24.4	1.88
18.50	- 2,522.548									1.62
18.83	- 2,327.673									1.37
19.17	- 1,962.111	0.79	0.36	2.99	2.88	0.22	12.0	10.4	26.4	1.18
19.50	- 1,779.848									1.03
19.83	- 1,568.160									0.94
20.17	- 1,189.608	0.85	0.47	3.07	2.42	0.24	13.0	12.0	24.0	0.84
20.50	- 948.510									0.79
20.83	- 673.466									0.80
21.17	- 326.106	1.21	0.41	3.29	1.64	0.23	10.2	18.4	31.0	0.80
21.50	- 119.460									0.80
21.75	0	1.50	0.42	2.65	1.33	0.26	12.6	7.8	17.2	0.80

Table 17

Ware Creek 1/7/73

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
7.67	0	0.65	0.43	2.42	23.55	0.43	13.0	19.0	14.0	0.43
8.00	+ 111.360									0.44
8.33	+ 210.273									0.14
8.67	+ 339.268	0.76	0.41	2.35	24.39	0.49	7.0	22.0	18.0	0.15
9.00	+ 364.500									0.16
9.33	+ 485.889									0.16
9.67	+ 405.582	0.85	0.39	2.15	21.83	0.51	8.6	18.6	17.0	0.16
10.00	+ 527.240									0.19
10.33	+ 494.648									0.20
10.67	+ 514.960	0.87	0.41	2.05	22.81	0.47	7.0	20.0	16.0	0.21
11.00	+ 693.925									0.23
11.33	+ 1,063.608									0.23
11.67	+ 1,127.984	0.88	0.46	2.42	19.51	0.46	9.0	18.0	18.0	0.28
12.00	+ 1,321.452									0.28
12.33	+ 1,368.000									0.30
12.67	+ 1,174.668	0.86	0.45	2.50	18.55	0.45	5.0	18.0	18.0	0.33
13.00	+ 1,082.832									0.38
13.33	+ 758.286									0.42
13.67	+ 232.518									0.48
13.83	0	0.84	0.43	2.51	18.06	0.44	12.0	17.0	18.0	0.67
14.17	- 1,067.930									0.69
14.50	- 1,352.334									0.45
14.83	- 1,525.760	0.87	0.40	2.32	16.37	0.47	6.4	18.6	18.0	0.38
15.17	- 1,719.620									0.35
15.50	- 1,559.404									0.32
15.83	- 1,624.078	0.86	0.41	3.00	20.04	0.46	12.4	15.6	24.0	0.29
16.17	- 1,423.670									0.28
16.50	- 1,285.758									0.27
16.83	- 1,128.732	0.95	0.45	2.89	17.28	0.45	7.6	14.4	21.2	0.27
17.17	- 901.140									0.27
17.50	- 700.812									0.29
17.83	- 589.992	1.24	0.44	3.79	17.55	0.31	7.6	23.4	22.0	0.31
18.17	- 526.220									0.33
18.50	- 399.359									0.35
18.83	- 298.704	1.38	0.51	4.07	6.16	0.30	11.4	23.6	30.0	0.37
19.17	- 222.222									0.38
19.50	- 171.380									0.40
19.83	- 111.706									0.42
20.17	0	1.50	0.50	4.90	6.44	0.30	13.0	15.0	34.0	0.42

Table 18

Carter Creek 3/7/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
10.50	0	2.03	0.43	3.78	9.33	0.40	7.0	9.0	30.0	1.62
11.25	+ 40.560									
11.50	+ 57.120	0.59	0.41	5.58	18.63	0.46	5.6	12.4	47.0	9.95
12.50	+ 205.380	0.49	0.41	9.48	8.78	0.39	5.0	11.0	87.0	10.48
12.75	+ 260.190									
13.50	+ 548.640	0.48	0.33	7.05	8.64	0.40	4.0	10.0	78.0	9.00
14.50	+ 567.910									
14.67	0	0.50	0.35	3.35	8.14	0.39	4.0	10.0	30.0	9.10
14.83	- 181.170									
15.25	- 358.190									
15.50	- 447.795									
15.67	- 509.292	0.48	0.29	1.83	7.36	0.42	3.6	12.4	28.0	9.15
16.00	- 225.446									
16.17	- 284.200									
16.33	- 374.035									
16.67	- 167.455	0.61	0.39	4.14	7.36	0.43	4.4	16.6	42.0	9.50
17.17	- 216.750									
17.33	- 138.330									
17.67	- 80.864	1.62	0.25	6.29	7.63	0.43	5.6	16.4	59.0	4.15
18.00	- 30.720									
18.67	- 19.670	2.09	0.41	5.24	7.99	0.49	5.6	18.4	48.0	3.23
19.25	- 19.800									
19.67	- 11.825	1.87	0.31	7.00	7.85	0.50	5.4	18.6	64.0	2.39
20.17	- 14.730									
20.67	- 13.380	1.72	0.17	9.17	6.85	0.52	4.8	16.2	88.0	2.36
21.67	- 9.800	1.78	0.24	7.38	6.13	0.54	5.8	15.2	71.0	2.25
22.67	0	2.10	0.27	5.37	5.88	0.51	7.4	14.6	40.0	1.89

Table 19

Carter Creek 3/23/72

Time	l/sec Discharge	μg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
10.83	0	0.78	0.70	2.50	1.84	0.26	5.0	21.0	16.0	4.98
11.17	+ 84.180									4.39
11.50	+ 228.690									4.09
11.83	+ 316.800	0.38	0.48	1.66	3.82	0.28	3.6	15.4	8.0	4.42
12.17	+ 262.700									4.11
12.50	+ 75.200									4.27
12.83	+ 37.350	0.41	0.51	1.00	4.22	0.26	3.0	14.0	7.0	4.50
13.17	+ 458.640									4.71
13.50	+ 398.395									5.41
13.83	+ 402.600	0.33	0.49	1.38	3.69	0.29	2.0	13.0	13.0	5.89
14.17	+ 1,233.580									6.72
14.50	+ 829.980									7.61
14.72	+ 82.350	0.27	0.50	1.05	3.06	0.26	2.0	15.0	10.0	6.74
14.88	+ 172.020									7.10
15.17	+ 721.140									7.57
15.50	+ 263.895									7.97
15.83	+ 1,745.170	0.33	0.52	0.93	2.12	0.26	1.6	12.4	14.0	7.62
16.17	+ 610.000									7.67
16.50	+ 954.975									8.22
16.83	+ 136.620	0.26	0.50	0.80	2.42	0.28	1.6	12.4	12.0	8.04
17.25	+ 112.950									7.82
17.30	+ 1,517.775	0.25	0.49	0.91	2.31	0.25	2.2	15.8	12.0	8.13
17.75	+ 358.930									8.10
17.83	0									8.04
17.92	- 480.000	0.22	0.62	1.36	1.90	0.28	2.6	15.4	8.0	8.10
18.25	- 1,533.840									8.18
18.58	- 454.155									7.61
18.92	- 807.270	0.29	0.59	0.84	1.84	0.28	3.0	15.0	7.0	8.09
19.25	- 1,257.585									8.07
19.58	- 709.475									8.46
19.92	- 985.150	0.26	0.50	0.82	1.89	0.26	3.0	16.0	7.0	8.08
20.25	- 843.200									7.75
20.58	- 695.500									6.94
20.92	- 457.710	0.53	0.55	0.82	2.14	0.11	3.4	16.6	8.0	6.44
21.25	- 150.150									5.94
21.58	- 60.255									5.40
21.92	- 121.940	0.93	0.47	0.94	1.93	0.07	3.6	15.4	8.0	5.09
22.25	- 188.825									4.67
22.58	- 67.680									4.19
22.92	0	0.90	1.06	0.86	1.73	0.25	6.0	13.0	21.0	4.70

Table 20

Carter Creek 4/19/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
09.00	0	1.15	0.53	2.48	2.12	0.24	10.0	22.0	19.0	4.78
09.33	+ .585									4.92
09.67	+ 50.150									9.93
10.00	+ 176.800	0.50	0.42	7.96	1.98	0.26	11.0	26.0	56.0	10.95
10.33	+ 243.000									10.68
10.67	+ 341.550									10.54
11.00	+ 436.050	0.43	0.47	5.88	3.28	0.30	4.0	33.0	41.0	10.78
11.33	+ 504.000									11.19
11.67	+ 636.300									11.49
12.00	+ 797.580	0.43	0.41	4.91	4.67	0.36	4.0	28.0	30.0	12.36
12.33	+ 900.900									12.98
12.67	+ 1,045.380									13.29
13.00	+ 761.250	0.37	0.45	3.27	2.87	0.31	1.0	28.0	23.0	13.50
13.33	+ 751.900									13.61
13.67	+ 499.610									13.76
14.00	+ 488.250	0.35	0.43	2.88	2.70	0.31	1.0	23.0	19.0	13.79
14.33	0	0.36	0.48	2.36	2.46	0.33	1.0	33.0	17.0	13.83
14.67	- 350.790									13.67
15.00	- 947.600									13.58
15.33	- 855.360	0.30	0.46	2.12	2.32	0.31	2.0	31.0	12.0	13.46
15.67	- 877.100									13.32
16.00	- 1,011.500									13.20
16.33	- 1,005.750	0.32	0.48	2.22	2.54	0.31	2.0	30.0	25.0	12.84
16.67	- 946.660									12.17
17.00	- 793.650									11.69
17.33	- 920.620	0.31	0.53	2.44	2.32	0.27	6.0	30.0	28.0	11.43
17.67	- 482.400									11.21
18.00	- 384.580									10.09
18.33	- 254.600	0.66	0.58	5.40	1.94	0.29	6.0	34.0	45.0	8.94
18.67	- 203.050									7.49
19.00	- 114.400									5.95
19.33	- 81.950	1.25	0.45	13.12	2.45	0.41	6.0	33.0	118.0	5.32
19.67	- 46.800									4.54
20.00	- 34.650									4.59
20.33	- 29.370	1.30	0.46	14.23	2.40	0.42	10.0	39.0	111.0	4.60
20.67	0	1.24	0.50	9.06	2.38	0.42	10.0	38.0	72.0	4.46

Table 21

Carter Creek 5/19/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
10.00	0	0.98	0.70	2.27	0.20	0.50	4.8	34.2	11.0	7.47
10.33	+ 251.125									7.15
10.67	+ 407.000									8.60
11.00	+ 354.270	0.88	0.82	1.95	0.40	0.30	3.2	22.8	31.0	7.07
11.33	+ 632.100									9.28
11.67	+ 370.487									9.52
12.00	+ 730.100	0.71	0.72	2.01	0.45	0.25	2.8	21.2	34.0	8.78
12.33	+ 1,016.305									9.39
12.67	+ 1,466.745									10.63
13.00	+ 1,265.600	0.67	0.64	2.03	0.41	0.24	2.6	18.4	32.0	11.03
13.33	+ 1,405.300									11.43
13.67	+ 2,370.225									11.92
14.00	+ 2,882.560	0.73	0.57	2.31	0.37	0.25	3.6	26.4	30.0	12.38
14.33	+ 4,160.422									12.44
14.67	+ 4,926.442									12.76
15.00	+ 3,365.842	0.43	0.39	1.76	0.29	0.27	2.0	14.0	22.0	13.15
15.33	+ 4,361.940									13.33
15.67	+ 5,055.562									13.35
16.00	+ 2,662.044	0.30	0.39	1.42	0.71	0.30	2.0	15.0	11.0	13.46
16.33	+ 1,908.869									13.42
16.67	+ 1,015.109									13.33
17.00	0	0.26	0.41	1.27	0.34	0.39	2.0	14.0	12.0	13.02
17.33	- 2,109.315									13.17
17.67	- 3,342.812									12.95
18.00	- 2,778.960	0.63	0.57	2.02	0.29	0.29	2.0	21.0	21.0	12.77
18.33	- 3,586.830									12.95
18.67	- 4,026.745									12.74
19.00	- 4,235.860	0.65	0.62	1.56	0.41	0.25	3.0	26.2	16.0	12.41
19.33	- 2,775.040									12.22
19.67	- 2,207.520									12.00
20.00	- 1,864.610	0.58	0.66	1.63	0.31	0.30	3.6	25.6	21.0	11.69
20.33	- 893.760									11.59
20.67	- 929.812									11.25
21.00	- 958.160	0.72	0.67	1.69	0.25	0.32	3.4	23.8	27.0	10.94
21.33	- 439.890									10.69
21.67	- 434.875									10.52
22.00	- 552.240	0.75	0.62	1.31	0.17	0.39	3.2	22.0	23.0	10.03
22.33	- 328.635									9.78
22.67	- 322.260									9.45
23.00	0	1.21	0.78	1.19	0.16	0.52	2.8	21.2	16.0	9.12

Table 22

Carter Creek 6/17/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
10.00	0	4.20	0.87	6.05	2.17	0.57	10.8	82.2	31.4	3.97
10.33	+ 111.564									5.52
10.67	+ 104.460									7.06
11.00	+ 176.385	1.11	1.14	4.29	0.99	0.22	6.4	60.2	41.2	6.69
11.33	+ 362.700									6.61
11.67	+ 446.630									7.13
12.00	+ 422.670	1.06	1.19	4.22	1.68	0.21	4.8	66.4	38.0	7.35
12.33	+ 624.250									7.59
12.67	+ 1,012.491									8.37
13.00	+ 908.995	0.60	0.65	2.95	0.72	0.21	2.2	47.2	30.4	8.60
13.33	+ 1,014.848									8.89
13.67	+ 1,057.485									9.62
14.00	+ 1,145.320	0.54	0.68	2.14	0.72	0.23	5.0	48.0	22.2	10.30
14.33	+ 1,410.892									10.46
14.67	+ 1,265.425									10.80
15.00	+ 1,342.096	0.38	0.48	1.60	0.73	0.24	3.8	52.4	13.2	11.03
15.33	+ 1,153.440									10.90
15.67	0	0.38	0.60	1.23	0.93	0.32	5.2	48.8	8.6	10.75
16.00	- 867.240									10.76
16.33	- 749.235									10.26
16.67	- 772.850	0.49	0.57	1.37	1.27	0.27	3.4	56.4	15.2	9.69
17.00	- 1,122.375									10.13
17.33	- 1,238.328									10.05
17.67	- 467.950	0.66	0.57	1.91	0.99	0.29	3.0	54.6	16.4	9.67
18.00	- 460.100									9.73
18.33	- 443.700									9.37
18.67	- 740.350	0.89	0.70	2.79	1.43	0.19	6.6	57.0	30.8	8.36
19.00	- 707.600									8.09
19.33	- 419.040									7.75
19.67	- 461.390	1.61	0.72	3.65	1.70	0.42	8.6	56.8	28.6	7.15
20.00	- 351.655									6.89
20.73	- 236.991									5.85
20.67	- 151.696	3.02	0.84	3.74	2.50	0.61	14.8	69.6	30.6	5.18
21.00	- 98.046									4.83
21.33	- 46.400									4.48
21.67	0	3.56	0.92	4.01	2.80	0.77	15.0	71.4	32.0	4.68

Table 23

Carter Creek 7/31/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
08.67	0	5.06	1.04	11.57	1.90	0.38	16.2	31.8	174.6	3.82
09.00	+ 533.790									5.81
09.33	+ 694.500									5.98
09.67	+ 684.000	1.09	0.47	5.27	2.81	0.32	19.8	33.8	38.6	6.48
10.00	+ 980.352									7.20
10.33	+ 955.550									7.56
10.67	+ 1,105.000	0.68	0.36	3.64	2.84	0.42	23.4	33.2	28.2	8.04
11.00	+ 1,088.340									8.13
11.33	+ 1,779.330									8.39
11.67	+ 2,477.790	0.42	0.30	2.14	2.78	0.44	18.2	32.8	24.0	9.62
12.00	+ 2,324.160									10.01
12.33	+ 2,083.980									10.36
12.67	+ 4,507.900	0.38	0.28	1.96	2.36	0.45	23.0	26.8	26.0	10.65
13.00	+ 3,543.792									10.88
13.33	+ 2,766.420									11.16
13.67	+ 1,029.600	0.30	0.23	1.57	2.21	0.47	23.0	24.2	24.0	11.15
14.00	0	0.53	0.41	2.05	2.08	0.46	16.8	31.6	31.8	11.22
14.33	- 508.625									11.15
14.67	- 2,283.915									11.04
15.00	- 2,622.600	0.35	0.36	1.82	2.05	0.45	16.8	32.4	25.2	10.73
15.33	- 3,469.200									10.36
15.67	- 2,692.200									10.35
16.00	- 3,308.211	0.46	0.37	1.43	1.56	0.34	11.4	37.0	21.8	9.92
16.33	- 2,269.376									9.51
16.67	- 1,976.910									9.48
17.00	- 2,140.380	0.45	0.30	6.61	2.16	0.42	8.2	45.0	53.0	10.38
17.33	- 2,730.600									8.05
17.58	0									7.49
17.90	+ 7,087.561									6.53
17.94	0									6.48
18.00	- 6,814.650	0.67	0.41	7.89	3.41	0.33	14.8	30.0	75.2	6.22
18.33	- 2,604.208									3.53
18.67	- 1,086.967									2.77
19.00	- 830.790	1.63	0.60	11.23	5.58	0.44	12.4	51.8	92.6	1.96
19.33	- 508.200									1.37
19.67	- 264.440									1.16
20.00	- 169.008	2.01	0.73	13.71	6.14	0.56	16.8	51.6	13.00	0.94
20.33	- 42.375									0.92
20.67	- 157.480									0.90
21.00	- 128.016									0.87
21.28	0	2.79	0.82	6.82	6.11	0.58	14.4	53.4	108.0	0.87

Table 24

Carter Creek 8/29/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
08.33	0	3.33	0.69	6.44	1.34	0.34	18.6	39.4	46.0	8.02
08.67	+ 110.250									10.07
09.00	+ 199.520									9.83
09.33	+ 230.625	1.25	0.64	4.98	0.91	0.29	10.0	44.0	38.4	10.02
09.67	+ 418.443									10.24
10.00	+ 619.482									10.57
10.33	+ 847.600	0.90	0.66	4.44	0.55	0.38	3.8	45.2	38.0	10.94
10.67	+ 1,024.765									11.40
11.00	+ 1,024.650									11.80
11.33	+ 1,380.270	0.69	0.69	3.53	0.53	0.30	3.8	44.2	33.0	12.13
11.67	+ 1,549.440									12.75
12.00	+ 1,792.236									13.39
12.33	+ 2,488.100	0.52	0.59	2.58	0.41	0.30	2.6	33.4	22.6	14.14
12.67	+ 4,265.680									14.53
13.00	+ 3,427.776									14.10
13.33	+ 1,612.070	0.42	0.55	2.10	0.29	0.25	2.8	29.2	25.0	14.33
13.67	0	0.48	0.64	2.05	0.28	0.29	1.8	37.8	17.4	14.59
14.00	- 292.665									14.39
14.33	- 1,409.895									14.40
14.67	- 3,530.375	0.43	0.63	1.85	0.52	0.15	2.4	30.8	21.8	14.22
15.00	- 3,223.350									14.27
15.33	- 2,004.640									14.14
15.67	- 1,859.528	0.67	0.63	2.15	0.34	0.33	2.2	35.8	19.8	13.76
16.00	- 1,643.6 5									13.34
16.33	- 574.926									13.20
16.67	- 883.116	0.85	0.60	2.31	0.35	0.30	1.6	38.4	23.0	12.53
17.08	- 563.010									12.17
17.33	- 707.678									11.85
17.67	- 731.640	1.23	0.58	3.05	0.52	0.35	3.8	38.4	22.8	11.43
18.00	- 475.800									10.72
18.33	- 457.875									10.20
18.67	- 331.551	2.22	0.68	3.23	0.65	0.36	4.2	37.8	30.0	9.31
19.00	- 206.000									8.59
19.33	- 83.790									8.10
19.67	- 32.800	2.69	0.69	4.67	0.79	0.44	9.6	37.8	29.2	10.08
20.00	0	2.60	0.65	5.48	0.63	0.42	12.8	35.6	45.4	7.93

Table 25

Carter Creek 9/27/72

Time	l/sec Discharge	μg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
07.83	0	1.68	0.36	4.05	1.37	0.47	22.6	15.4	44.0	10.91
08.25	+ 64.880									13.42
08.50	+ 107.379									13.16
08.83	+ 229.284	0.84	0.33	4.64	0.78	0.31	6.8	21.2	36.4	13.49
09.17	+ 336.690									13.99
09.50	+ 417.745									14.15
09.83	+ 852.175	0.65	0.40	4.90	0.98	0.33	3.4	19.6	39.0	14.34
10.17	+ 1,181.670									14.55
10.50	+ 1,223.694									14.82
10.83	+ 1,256.850	0.83	0.52	3.34	0.81	0.30	2.4	20.6	26.0	15.05
11.17	+ 1,035.860									15.29
11.50	+ 2,086.245									15.39
11.83	+ 2,291.400	0.55	0.38	2.16	0.70	0.13	2.0	17.0	23.8	15.54
12.17	+ 2,491.470									15.62
12.50	+ 2,821.170									15.83
12.83	+ 2,934.382	0.48	0.35	1.93	0.59	0.14	1.8	10.2	23.0	16.24
13.17	+ 1,982.040									16.36
13.67	0	0.50	0.33	1.81	0.55	0.16	1.6	29.4	9.0	16.56
14.00	- 1,873.035									16.31
14.33	- 2,509.308									16.29
14.67	- 2,840.271	0.60	0.40	2.09	1.22	0.06	2.8	29.2	14.0	16.11
15.00	- 2,961.480									15.93
15.33	- 2,122.624									15.77
15.67	- 1,717.170	0.70	0.40	2.57	0.15	0.07	1.0	33.0	18.0	15.59
16.00	- 1,336.784									15.46
16.33	- 1,306.426									15.23
16.67	- 1,074.870	0.85	0.41	2.90	0.33	0.11	1.2	33.8	24.0	15.02
17.00	- 959.100									14.88
17.33	- 821.730									14.57
17.67	- 684.600	1.01	0.31	2.10	0.43	0.14	2.6	35.4	12.0	14.18
18.00	- 458.640									13.62
18.33	- 613.800									11.76
18.67	- 398.180	1.32	0.37	11.24	5.82	0.38	9.0	38.0	84.0	10.61
19.00	- 213.651									9.15
19.33	- 184.428									7.93
19.67	- 137.785	1.07	0.42	19.52	11.35	0.39	19.0	46.0	150.0	6.84
20.00	- 77.794									6.49
20.33	- 38.499									6.18
20.50	0	1.49	0.46	8.56	11.88	0.87	21.	38.6	57.6	6.26

Table 26

Carter Creek 10/27/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
08.00	0	1.80	0.68	1.55	2.20	0.28	8.0	23.6	10.4	9.10
08.42	+ 35.496									10.64
08.67	+ 50.464									10.66
09.00	+ 229.284	1.05	0.71	0.62	1.76	0.23	7.0	18.6	5.0	10.21
09.33	+ 324.292									12.64
09.67	+ 354.662									13.04
10.00	+ 639.450	0.69	0.55	0.43	1.34	0.27	5.4	13.4	5.2	13.36
10.33	+ 515.112									13.34
10.67	+ 738.804									13.33
11.00	+ 1,130.025	0.54	0.60	0.32	1.41	0.27	4.4	11.2	4.4	13.86
11.33	+ 1,350.720									13.89
11.67	+ 1,406.680									13.01
12.00	+ 1,826.250	0.6	0.71	0.18	1.00	0.26	2.6	16.0	3.4	14.18
12.33	+ 2,329.245									14.70
12.67	+ 3,492.800									14.99
13.00	+ 3,669.596	0.43	0.71	0.33	0.49	0.20	3.4	12.6	5.0	15.28
13.33	+ 3,224.100									15.27
13.67	+ 2,097.454									15.44
14.00	+ 1,128.600	0.40	0.64	0.19	0.14	0.22	1.4	13.4	5.2	15.65
14.33	0	0.55	0.90	0.45	0.07	0.27	3.0	12.2	4.8	15.71
14.67	- 911.200									15.90
15.00	- 2,545.240									15.41
15.33	- 2,355.325	0.49	0.77	0.40	0.24	0.17	1.2	17.0	5.8	15.63
15.67	- 2,596.815									15.57
16.00	- 2,549.260									15.47
16.33	- 2,114.384	0.51	0.66	0.54	0.28	0.16	5.0	19.8	8.2	15.45
16.67	- 1,662.384									15.09
17.00	- 1,011.968									14.94
17.33	- 1,079.585	0.63	0.57	0.67	0.44	0.19	3.0	22.6	11.4	14.68
17.67	- 873.300									14.52
18.00	- 833.760									14.29
18.33	- 619.100	0.78	0.63	0.37	0.61	0.17	3.8	21.6	8.3	13.91
18.67	- 692.860									13.51
19.00	- 236.060									13.12
19.33	- 283.328	1.16	0.61	0.39	0.67	0.19	3.0	25.2	4.8	12.93
19.67	- 187.650									11.96
20.00	- 115.560									11.13
20.33	0	1.42	0.86	0.52	0.72	0.23	3.4	19.6	8.0	10.80

Table 27

Carter Creek 11/27/72

Time	l/sec Discharge	µg at/l DIP	DOP	PP	NO$_3$	NO$_2$	NH$_3$	DON	PKN	o/oo Sal
10.33	0	2.40	0.52	5.81	11.04	0.21	22.5	43.8	43.4	2.37
10.67	+ 57.744									3.81
11.00	+ 88.816									3.31
11.33	+ 214.230	1.07	0.53	7.90	16.11	0.31	26.0	33.0	66.0	4.21
11.67	+ 274.000									4.19
12.00	+ 179.760									4.60
12.33	+ 154.368	0.94	0.40	6.32	16.39	0.30	17.2	17.0	62.6	5.55
12.67	+ 436.590									7.28
13.00	+ 557.127									8.10
13.33	+ 345.173	0.74	0.28	3.05	14.97	0.25	16.6	16.6	40.0	8.97
13.67	+ 158.208									8.73
14.00	+ 565.295									8.87
14.33	+ 161.100	0.72	0.31	2.02	13.66	0.24	10.8	20.0	22.2	8.89
14.67	+ 601.350									8.97
15.00	0	0.64	0.29	1.82	13.86	0.22	11.4	16.0	26.6	9.05
15.33	- 82.170									8.92
15.67	- 120.825									8.85
16.00	- 316.500	0.69	0.24	1.44	13.91	0.21	8.2	15.8	28.8	8.83
16.33	- 569.258									8.63
16.67	- 315.018									7.19
17.00	- 290.646	0.77	0.33	1.46	15.88	0.24	14.8	15.6	15.6	6.94
17.33	- 456.570									5.23
17.67	- 181.472									4.56
18.00	- 195.296	1.63	0.50	1.65	13.54	0.26	14.6	19.4	18.0	4.48
18.33	- 259.182									4.51
18.67	- 313.131									3.57
19.00	- 128.250	2.09	0.53	5.75	12.92	0.30	16.0	19.8	40.0	3.70
19.33	- 54.576									3.32
19.67	- 21.808									2.70
20.00	- 10.353	2.20	0.51	4.96	13.01	0.27	16.0	21.6	39.4	2.34
20.33	- 8.560									2.98
20.67	- 5.760									1.81
21.00	- 5.355	2.57	0.50	3.71	12.17	0.26	16.0	21.0	37.0	2.13
21.33	- 1.350									1.79
21.67	- 1.080									2.13
22.00	- 0.900	2.80	0.48	6.75	11.36	0.27	21.2	18.0	51.8	2.16
22.33	- 0.900									2.10
22.67	0	3.23	0.42	4.61	11.28	0.29	22.6	17.2	39.2	2.26

Table 28

Carter Creek 1/11/73

Time	1/sec Discharge	µg at/l DIP	DOP	PP	NO_3	NO_2	NH_3	DON	PKN	o/oo Sal
9.00	0	1.97	0.41	2.22	24.89	0.34	19.6	17.4	10.0	2.90
9.33	+ 96.096									2.32
9.67	+ 230.160									3.01
10.00	+ 472.800	1.16	0.29	0.76	25.91	0.35	14.8	14.2	6.0	3.93
10.33	+ 288.600									4.27
10.67	+ 460.600									4.57
11.00	+ 805.620	0.91	0.27	0.56	25.75	0.31	11.8	12.2	5.0	6.48
11.33	+ 714.970									6.69
11.67	+ 446.522									6.03
12.00	+ 914.370	0.90	0.25	0.59	23.28	0.32	16.0	8.0	5.0	6.26
12.33	+ 948.720									6.58
12.67	+ 0									7.02
13.00	+ 869.550	0.86	0.25	0.61	23.68	0.31	12.4	7.6	4.4	7.24
13.33	+ 753.270									7.29
13.67	+ 186.656									8.06
14.00	+ 199.640									7.09
14.33	0	0.89	0.22	0.58	23.78	0.33	9.8	8.2	4.8	7.00
14.67	- 646.300									7.67
15.00	- 472.512									6.48
15.33	- 818.376	0.90	0.25	0.63	25.15	0.31	11.6	12.4	6.0	6.84
15.67	- 627.000									6.28
16.00	- 737.748									6.00
16.33	- 816.046	1.01	0.35	0.57	26.86	0.32	13.2	11.8	6.0	6.35
16.67	- 706.550									5.40
17.00	- 662.330									5.31
17.33	- 561.996	1.28	0.34	0.86	23.39	0.34	15.0	11.0	10.0	4.81
17.67	- 407.320									4.04
18.00	- 222.480									4.04
18.33	- 145.440	1.93	0.45	1.27	20.39	0.32	7.2	20.8	15.0	3.25
18.67	- 97.263									2.39
19.00	- 43.860									1.94
19.33	- 24.299	1.92	0.45	2.09	22.07	0.34	6.8	30.2	12.0	1.79
19.67	- 12.160									1.75
20.00	- 9.380									1.64
20.33	0	2.04	0.48	1.58	23.55	0.35	8.0	30.0	10.0	1.79

Net Tidal Nutrient Flux

(Tables 29-32)

Dissolved Inorganic Phosphorus

Over the sampling year there was significant export of dissolved inorganic phosphorus from both marshes. Ware Creek exhibited a general export of this phosphorus form but data indicate import of estuarine phosphorus to the marsh in the fall. Carter Creek exports dissolved inorganic phosphorus year round and the net annual quantity exported is greater than that exported from Ware Creek.

Dissolved Organic Phosphorus

There is a export of dissolved organic phosphorus from both marshes throughout the year. Ware Creek exports more of this phosphorus species than does Carter Creek marsh.

Particulate Phosphorus

There was strong net import of estuarine particulate phosphorus to both marshes during the study. Seasonal trends are, however, unclear. Ware Creek appears to import phosphorus in fall while Carter Creek imports phosphorus in winter and spring. While there appears to be a greater import of phosphorus to Ware Creek, in both creeks the import of particulate phosphorus is greater than the combined export of dissolved inorganic and dissolved organic phosphorus.

Nitrate

Estuarine nitrate was lost to Ware Creek throughout the year and imported to Carter Creek in all but three months of the year. Annual import to Ware Creek was greater than import to Carter Creek. However, loss of estuarine nitrate to the marshes was significant in both cases.

Nitrite

Nitrite of estuarine origin was imported to the marshes throughout the year.

Ammonia

Ware Creek marsh exported ammonia to the estuary in winter, spring and summer but imported ammonia during fall. Carter Creek exported ammonia in spring and summer and imported ammonia in fall and winter. Annual budgets show a large net export of ammonia from Ware Creek and a small import of ammonia to Carter Creek.

Dissolved Organic Nitrogen

There was a general net export of dissolved organic nitrogen throughout the year from both marshes. Carter Creek exported more of this nitrogen form than did Ware Creek, but both marshes exported significant quantities of dissolved organic nitrogen.

Particulate Nitrogen

Seasonal trends in particulate nitrogen flux are difficult to discern. Ware Creek appears to export nitrogen in spring and winter and import nitrogen in summer and fall.

Carter Creek exhibits a general import of particulate nitrogen throughout the year with greatest import in spring. Annual budgets for the marshes show Carter Creek with a very significant import of particulate nitrogen and Ware Creek with an extremely small export of this nitrogen species.

Table 29

Ware Creek Marsh
Nitrogen Budget

		NO_3 grams N	NO_2 grams N	NH_3 grams N	DON grams N	PN grams N
1/15/72	- 2/12/72	+ 22,348	- 371	- 10,181	- 62,416	- 31,875
2/13	- 3/26	+ 13,825	+ 560	- 34,115	- 120,942	+ 90,003
3/27	- 5/2	+ 9,086	+ 979	- 187,387	+ 241,881	- 176,042
5/3	- 5/31	+ 27,432	+ 1,557	- 47,054	- 163.521	- 125,895
6/1	- 7/5	+ 13,801	- 97	- 22,538	+ 59,980	- 153,402
7/6	- 8/11	+ 20,236	+ 6,362	- 67,707	- 25,857	+ 183,803
8/12	- 9/10	+ 2,852	- 1,273	- 121,402	- 121,185	+ 97,151
9/11	- 10/8	+ 43,016	+ 9,044	+ 14,775	- 153,588	+ 203,650
10/9	- 11/9	+ 48,555	+ 313	+ 44,940	+ 4,897	+ 98,288
11/10	- 12/16	+ 56,284	+ 453	+ 57,337	- 4,238	- 107,001
12/17/72	- 1/14/73	+ 63,995	+ 664	- 34,222	+ 20,154	- 82,445
TOTAL		+ 321,420	+ 18,191	- 407,554	- 324,835	- 3,765

+ = into marsh
- = out of marsh

Table 30
Ware Creek Marsh
Phosphorus Budget

	DIP grams P	DOP grams P	PP grams P
1/15/72 - 2/12/72	+ 381	- 183	+ 2,009
2/13 - 3/26	- 14,037	- 992	+ 19,149
3/27 - 5/2	- 2,420	- 6,047	- 55,789
5/3 - 5/31	- 4,813	- 2,940	- 14,768
6/1 - 7/5	- 21,196	- 17,681	- 5,822
7/6 - 8/11	+ 17,554	+ 6,501	+ 14,252
8/12 - 9/10	- 2,623	- 3,765	- 26,472
9/11 - 10/8	+ 15,252	+ 1,189	+ 194,036
10/9 - 11/9	+ 9,052	- 5,431	+ 41,104
11/10 - 12/16	+ 634	- 1,493	+ 5,112
12/17/72 - 1/14/73	- 4,635	+ 330	- 25,530
TOTAL	- 6,851	- 30,512	+ 147,281

+ = into marsh
- = out of marsh

Table 31
Carter Creek Marsh
Nitrogen Budget

	NO_3 grams N	NO_2 grams N	NH_3 grams N	DON grams N	PN grams N
2/9/72 - 3/15/72	+ 12,061	- 230	+ 83	- 32,156	+ 194,793
3/16 - 4/6	+ 8,385	+ 230	- 8,669	- 16,434	+ 37,853
4/7 - 5/4	+ 11,771	+ 189	- 3,839	- 33,396	+ 32,061
5/5 - 6/3	+ 2,757	- 690	- 6,594	- 128,464	+ 106,354
6/4 - 7/9	- 7,807	- 1,343	- 24,296	- 75,532	+ 60,478
7/10 - 8/14	+ 1,010	+ 559	- 2,840	- 214,336	- 251,738
8/15 - 9/13	- 32	+ 727	+ 17,744	+ 31,565	+ 118,859
9/14 - 10/12	- 8,791	+ 1,674	- 6,933	- 315,377	+ 67,229
10/13 - 11/12	+ 9,233	+ 1,125	+ 4,061	- 121,678	- 61,255
11/13 - 12/20	+ 8,406	+ 225	+ 36,627	+ 30,697	+ 210,127
12/21/72 - 2/8/73	- 5,802	- 69	+ 23,321	- 50,159	- 49,337
TOTAL	+ 31,191	+ 2,397	+ 28,665	- 925,270	+ 465,424

\+ = into marsh

\- = out of marsh

Table 32
Carter Creek Marsh
Phosphorus Budget

		DIP grams P	DOP grams P	PP grams P
2/9/72	- 3/15/72	- 4,667	+ 877	+ 48,424
3/16	- 4/6	- 543	- 1,220	+ 2,832
4/7	- 5/4	+ 614	- 1,451	+ 37,811
5/5	- 6/3	- 5,513	- 6,324	+ 10,036
6/4	- 7/9	- 11,429	+ 2,482	+ 13,305
7/10	- 8/14	- 6,834	- 6,423	- 78,078
8/15	- 9/13	- 5,735	- 651	+ 33,536
9/14	- 10/12	- 6,398	+ 321	- 19,532
10/13	- 11/12	- 4,745	- 1,212	- 8,754
11/13	- 12/20	- 7,756	- 499	+ 47,531
12/21/72	- 2/8/73	- 7,485	- 2,530	- 3,288
TOTAL		- 60,491	- 16,630	+ 83,823

+ = into marsh
- = out of marsh

Tidal and Temporal Seston Concentration Trends

(Tables 33-42)

Dissolved Inorganic Carbon

Dissolved inorganic carbon levels were generally lower in the early spring in both marshes. The range in concentration of DIC over a tidal cycle was greater in Carter Creek than in Ware reflecting the influence of salinity on this parameter. Seasonally DIC concentrations varied from 6 to 35 mg/1.

Dissolved Organic Carbon

In both marshes, peak DOC levels were recorded in the summer. Seasonally DOC concentrations ranged from 3.5 to 14 mg/1 in Ware Creek and from 2 to 17 mg/1 in Carter Creek.

Particulate Organic Carbon

Levels of POC were generally higher in Carter Creek than in Ware. Peak concentrations were observed in June in Ware Creek and in late summer in Carter. Seasonally POC levels ranged from 0.5 to 24 mg/1.

Chlorophyll 'a'

Phytoplankton biomass as reflected by measurements of chlorophyll 'a' peaked in Carter Creek in July and during August in Ware Creek. Average concentrations ranged from 3 to 17 μg/1 in Ware and from 3 to 22 μg/1 in Carter (excluding the July sample for Carter which was recorded during a storm).

ATP

Seasonal changes in ATP concentration closely paralleled the chlorophyll 'a' levels indicating that much of the living material present in the seston was phytoplankton. Peak ATP concentrations were recorded during July in Ware Creek and in August for Carter Creek.

Table 33

Ware Creek - 1/23/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a μg/l	Discharge l/sec
1215	11.5	7.0	3.0	1.58	5.3	0
1315	11.2	5.8	3.7	0.39	6.7	+ 879.200
1415	12.0	6.0	3.5	0.20	5.9	+ 1332.504
1515	12.2	5.8	2.2	0.68	5.3	+ 1136.212
1615	12.2	5.8	2.5	0.43	4.8	+ 1252.597
1715	12.2	5.3	2.5	0.27	5.1	+ 716.210
1735	12.4	5.1	2.4	0.32	3.9	0
1835	12.2	5.8	1.2	0.89	4.1	- 1095.682
1935	12.6	6.4	1.1	0.55	4.0	- 1236.300
2035	11.5	7.0	3.5	1.09	4.6	- 1147.176
2135	11.3	6.2	3.3	1.44	4.7	- 869.295
2235	11.5	5.5	3.5	1.69	5.1	- 530.352
2345	11.2	6.3	2.7	2.50	3.0	0

Ware Creek - 3/4/72

0900	7.4	8.8	2.8	1.08	2.7	0
1000	7.0	8.6	0.4	0.90	3.4	+ 544.152
1100	6.3	8.0	0.7	5.46	2.9	+ 921.270
1200	7.4	7.6	0.4	4.38	3.7	+ 1245.158
1300	7.2	7.4	1.5	4.50	2.9	+ 1490.760
1400	8.7	7.0	1.8	3.02	4.1	+ 880.630
1420	7.9	7.3	1.2	6.00	3.9	0
1520	8.2	7.5	1.2	6.60	3.2	+ 1453.868
1620	7.7	8.0	0.8	8.70	3.7	+ 1689.314
1720	7.4	7.5	1.2	6.00	3.2	+ 1488.350
1820	7.4	8.3	2.9	7.25	3.2	+ 925.248
1920	7.1	9.2	2.0	8.70	2.2	+ 377.136
2020	7.4	8.3	2.3	11.30	2.2	0

Ware Creek - 4/17/72

0937	9.9	7.6	2.2	18.6	9.3	0
1037	9.9	3.3	4.9	15.9	8.5	+ 912.600
1137	9.9	7.6	1.7	9.8	9.0	+ 1800.000
1237	9.5	3.3	5.3	15.9	10.7	+ 2360.960
1337	8.9	7.6	1.1	14.8	9.3	+ 2502.400
1437	9.4	6.0	2.7	14.8	16.0	+ 1944.120
1530	9.4	7.6	0.5	18.6	14.3	0
1630	9.4	7.1	1.6	12.8	9.5	- 2415.440
1730	9.4	7.6	2.7	5.2	11.9	- 2707.540
1830	9.4	8.1	2.9	10.6	11.9	- 2721.180
1930	9.4	8.6	4.0	10.4	10.9	- 2157.600
2030	8.9	9.7	1.5	20.6	10.0	- 1076.320
2120	9.4	11.5	1.5	20.2	6.3	0

Table 34

Ware Creek - 5/17/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a µg/l	Discharge l/sec
1115	9.9	3.3	10.9	10.8	10.9	
1215	8.3	4.9	2.8	5.2	10.0	+ 872.792
1315	8.3	7.1	2.2	5.8	10.0	+ 1757.754
1415	8.3	6.7	1.5	8.9	10.7	+ 2540.314
1515	8.3	6.5	1.2	9.9	13.4	+ 2823.480
1615	8.3	3.8	1.5	14.6	18.0	+ 2268.715
1700	7.9	4.2	1.1	19.5	18.0	0
1800	7.2	3.8	3.2	6.1	17.2	- 2641.320
1900	8.3	6.0	1.5	3.8	12.4	- 2770.946
2000	8.3	6.5	3.6	6.8	11.4	- 2409.750
2100	8.3	6.5	2.4	8.7	9.7	- 1742.760
2200	9.4	7.3	4.4	16.6	8.5	- 940.347
2255	9.4	8.6	1.1	27.0	7.5	0

Ware Creek - 6/14/72

First Tidal Cycle

1020	14.6	8.9	7.1	16.2	9.6	0
1120	13.0	6.8	10.4	14.5	7.8	+ 800.400
1220	14.6	6.8	6.6	10.6	5.9	+ 1227.400
1320	15.2	8.3	6.1	8.5	5.9	+ 1779.540
1420	12.5	6.7	2.5	8.1	8.1	+ 2029.110
1520	12.5	6.1	2.3	13.1	10.4	0
1620	14.1	7.9	3.8	21.8	10.0	- 1989.000
1720	15.2	8.3	4.5	14.2	9.3	- 1981.700
1820	15.7	7.8	5.5	7.0	10.7	- 1662.250
1920	14.6	8.9	6.0	4.6	8.1	- 811.800
2020	14.6	10.1	4.9	11.0	7.6	- 505.300
2120	14.6	10.6	4.9	11.3	8.9	- 110.750
2140	15.6	10.5	5.6	9.0	9.6	0

Second Tidal Cycle

2240	11.0	7.6	3.5	5.0	10.5	+ 756.500
2340	12.5	8.9	2.7	-	10.2	+ 1186.800
0040	15.2	7.8	4.4	-	11.7	+ 1760.000
0140	16.2	9.0	4.4	-	12.2	+ 2346.120
0240	15.2	9.5	4.3	-	12.6	+ 2307.500

Table 35

Ware Creek - 6/15/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a μg/l	Discharge l/sec
Second Tidal Cycle						
0340	11.3	6.2	4.8	-	11.9	+ 742.400
0355	10.5	7.0	1.7	-	10.2	0
0455	11.5	8.3	2.2	-	12.0	- 2277.000
0555	10.5	7.0	1.8	-	10.4	- 2424.240
0655	15.2	7.8	7.1	-	10.9	- 2116.530
0755	16.2	8.5	6.1	-	13.4	- 1353.600
0855	15.7	9.5	5.5	-	16.3	- 789.800
1010	15.7	10.1	4.3	-	21.1	0

Ware Creek - 7/28/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a μg/l	Discharge l/sec
0845	13.0	13.9	0.4	21.34	8.0	0
0945	12.0	11.5	2.8	22.38	6.1	+ 971.388
1045	14.7	13.3	1.6	22.50	10.6	+ 1862.867
1145	15.7	13.3	2.9	22.52	15.8	+ 2710.164
1245	11.5	11.0	4.3	17.68	17.5	+ 3162.456
1345	12.5	9.5	4.7	17.56	21.1	+ 2741.168
1450	12.0	8.4	1.3	21.36	17.7	0
1550	13.0	10.0	2.4	20.54	20.2	- 2959.846
1650	14.1	11.7	2.7	23.28	19.2	- 3419.325
1750	15.7	11.6	5.0	19.28	17.0	- 2834.573
1850	15.1	12.9	2.9	23.38	18.2	- 2147.500
1950	14.1	13.3	2.5	19.84	16.8	- 1317.896
2050	11.0	12.0	2.6	24.48	12.1	0

Ware Creek - 8/26/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a μg/l	Discharge l/sec
0800	11.5	10.0	3.1	11.46	9.6	0
0900	16.2	7.9	1.1	11.48	8.8	+ 557.826
1000	16.2	9.6	0.8	13.32	11.4	+ 1315.300
1100	16.8	8.4	3.3	13.76	14.2	+ 2138.535
1200	15.1	8.4	5.0	12.80	19.6	+ 2837.768
1300	13.0	8.0	1.6	11.32	23.6	+ 2534.224
1400	12.5	6.7	2.8	15.15	23.0	+ 1372.000
1430	9.0	8.0	1.1	22.82	20.2	0
1530	13.0	8.5	2.0	16.64	23.0	- 3167.442
1630	14.1	8.9	5.0	14.68	22.4	- 3332.940
1730	10.5	8.7	2.2	12.36	22.2	- 3147.228
1830	15.1	10.1	6.0	12.93	17.4	- 1978.368
1930	16.2	10.6	2.8	10.48	14.0	- 1014.000
2040	18.3	9.7	0.2	10.41	11.0	0

Table 36

Ware Creek - 9/24/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a µg/l	Discharge l/sec
0800	13.6	9.9	0.2	4.16	5.0	0
0900	12.0	7.6	1.8	4.70	5.0	+ 1144.022
1000	12.5	10.5	1.7	6.10	4.4	+ 2268.024
1100	14.6	7.9	5.4	4.75	5.8	+ 3185.056
1200	15.7	6.3	3.1	6.73	5.0	+ 3300.352
1300	15.7	6.3	3.8	6.18	4.6	+ 2677.950
1400	15.7	6.8	1.2	8.49	5.8	+ 1181.400
1420	15.7	5.7	1.6	8.32	6.0	0
1520	16.2	5.8	1.8	4.98	6.8	- 2749.398
1620	15.7	6.3	3.5	6.04	5.4	- 3134.950
1720	15.1	6.9	4.3	3.97	5.0	- 3067.416
1820	14.6	7.9	5.0	7.27	4.4	- 2791.220
1920	14.6	7.4	4.9	10.42	10.2	- 2328.192
2020	15.7	6.8	6.6	7.04	5.8	- 1160.824
2055	14.6	7.9	0.7	4.41	4.8	0

Ware Creek - 10/24/72

0800	15.7	8.7	2.0	3.15	6.8	0
0900	13.6	7.4	0.7	2.59	5.8	+ 594.490
1000	13.6	7.9	2.7	4.36	8.0	+ 1449.660
1100	14.6	7.9	4.4	7.86	8.0	+ 2228.218
1200	15.1	7.4	5.5	3.40	9.2	+ 2933.806
1300	15.7	6.8	2.9	5.85	9.6	+ 2486.484
1400	15.1	6.4	2.1	5.61	9.4	+ 1811.691
1438	14.6	6.9	1.0	7.31	10.6	0
1540	13.6	7.9	1.1	6.16	9.4	- 3065.184
1640	14.1	7.4	2.1	4.83	9.2	- 2507.736
1740	13.6	8.4	2.3	3.2	9.2	- 2212.360
1840	14.1	8.4	3.9	4.09	8.2	- 1897.266
1940	14.1	8.9	2.9	3.23	7.8	- 1472.784
2040	15.7	8.4	2.4	3.74	6.4	- 507.025
2115	13.6	7.4	1.5	2.56	4.6	0

Table 37

Ware Creek - 11/24/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a μg/l	Discharge l/sec
0840	14.1	8.7	2.4	0.95	4.2	0
0940	12.0	6.7	1.7	0.41	3.4	+ 453.348
1040	12.0	8.4	0.7	0.38	3.8	+ 1207.374
1140	12.5	8.5	2.0	0.64	4.2	+ 2088.702
1240	12.0	8.6	4.4	0.85	4.8	+ 2443.413
1340	11.0	7.1	2.3	1.40	4.8	+ 2440.350
1440	11.0	7.1	2.3	1.73	3.6	+ 1264.792
1508	10.5	8.2	0.6	2.99	3.6	0
1610	11.0	8.3	3.2	2.24	4.4	- 2251.179
1710	10.5	9.3	2.7	2.84	4.4	- 2701.029
1810	12.0	8.9	4.1	3.29	5.4	- 2475.590
1910	12.0	8.4	4.8	1.78	5.4	- 1962.111
2010	12.5	9.0	3.7	0.88	5.2	- 1189.608
2110	12.5	10.0	2.7	0.99	5.0	- 326.106
2145	13.6	9.4	1.7	1.12	3.8	0

Ware Creek - 1/7/73

0740	9.4	5.5	5.5	5.38	7.8	0
0840	8.9	3.2	1.1	2.79	7.8	+ 339.268
0940	8.9	3.2	1.7	4.18	6.0	+ 405.592
1040	8.9	3.2	2.3	1.95	6.4	+ 514.960
1140	8.3	4.3	1.1	2.64	6.4	+ 1127.984
1240	8.9	4.3	0.6	1.55	5.0	+ 1174.668
1350	9.4	3.8	1.7	1.42	6.0	0
1450	8.9	3.7	3.3	1.67	5.0	- 1525.760
1550	8.3	3.8	2.7	2.07	6.0	- 1624.078
1650	8.9	3.7	2.3	4.48	5.2	- 1128.732
1750	8.9	4.3	2.8	4.74	7.8	- 589.992
1850	8.9	4.8	2.8	4.21	8.2	- 298.704
2010	8.9	4.8	3.3	5.02	8.2	0

Table 38

Carter Creek - 3/7/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a µg/l	Discharge l/sec
1030	18.3	7.5	3.5	1.6	4.7	+ 000.000
1130	13.0	5.0	6.0	1.9	11.0	+ 54.670
1230	12.5	5.0	12.5	3.0	15.1	+ 169.050
1330	13.6	5.6	10.2	1.4	13.0	+ 491.250
1440	14.1	7.2	2.7	4.1	7.3	+ 000.000
1540	13.6	5.6	2.8	4.6	4.6	- 401.850
1640	13.6	5.1	3.7	3.7	8.5	- 283.500
1740	15.8	7.2	4.8	2.5	8.3	- 95.760
1840	15.8	7.7	4.3	2.2	7.0	- 16.640
1940	17.3	7.3	1.5	2.7	7.2	- 12.500
2040	18.9	6.9	6.8	2.9	9.2	- 14.000
2140	18.4	6.2	5.4	5.0	9.8	- 9.240
2240	17.9	7.3	5.5	2.9	7.8	- 0.000

Carter Creek - 3/23/72

1050	16.2	7.9	2.2		6.1	0.00
1150	16.2	5.8	1.0		4.4	+ 199.640
1250	15.8	5.1	2.1		6.3	+ 229.350
1350	15.2	5.0	2.3		3.9	+ 576.710
1443	14.7	5.5	1.5		10.5	+ 669.700
1550	15.2	4.0	0.6		9.0	+ 862.100
1650	13.6	6.2	0.6		9.3	+ 455.400
1718	14.7	5.1	0.6		10.5	000.000
1755	14.1	4.0	1.7		6.3	- 623.500
1855	14.1	4.5	1.6		5.6	- 1048.500
1955	13.6	5.0	1.6		5.8	- 901.000
2055	15.2	5.7	1.6		2.2	- 382.570
2155	16.8	6.2	1.6		2.4	- 118.300
2255	16.2	7.9	2.9		2.9	000.000

Table 39

Carter Creek - 4/19/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a µg/l	Discharge l/sec
0900	7.3	4.2	1.3	4.42	4.1	0
1000	4.6	5.9	4.6	4.55	11.9	+ 176.800
1100	3.5	4.3	4.5	5.51	10.2	+ 436.050
1200	8.9	5.4	2.4	5.85	11.4	+ 797.580
1300	4.5	5.7	0.4	8.97	10.5	+ 761.250
1400	11.5	6.5	2.0	9.32	12.9	+ 488.250
1420	4.6	4.2	1.3	12.25	12.9	0
1520	4.6	2.1	3.4	16.2	16.8	- 855.360
1620	4.5	3.5	1.0	17.22	12.4	- 1005.750
1720	4.6	4.2	1.3	16.62	16.8	- 920.620
1820	6.8	6.4	0.7	11.90	17.7	- 254.600
1920	12.0	7.2	8.8	4.50	15.3	- 81.950
2020	7.9	5.3	11.7	4.60	13.4	- 29.370
2040	6.1	4.9	7.7	4.32	10.9	0

Carter Creek - 5/19/72

1000	11.5	5.5	3.1	13.25	2.8	0
1100	16.8	4.1	4.6	15.68	3.1	+ 354.270
1200	14.6	3.4	2.5	14.23	4.1	+ 730.100
1300	12.5	4.5	4.4	15.06	15.0	+ 1265.600
1400	13.0	2.4	4.3	17.67	23.5	+ 2882.560
1500	12.0	3.0	3.4	14.60	13.4	+ 3365.842
1600	12.0	3.0	5.3	9.17	10.5	+ 2662.044
1700	12.0	2.3	2.2	11.30	10.9	0
1800	12.0	2.3	2.7	10.72	17.2	- 2778.950
1900	12.0	3.4	3.8	16.13	22.4	- 4235.860
2000	13.0	2.4	4.1	13.81	12.9	- 1864.610
2100	13.0	3.0	5.0	15.50	10.7	- 958.160
2200	13.6	2.4	3.5	18.77	10.2	- 552.240
2300	14.1	2.4	2.7	18.38	8.5	0

Table 40

Carter Creek - 6/17/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a µg/l	Discharge l/sec
1000	33.6	9.7	5.3	16.2	12.2	0000.000
1100	23.5	8.4	5.4	17.0	23.5	+ 176.385
1200	23.1	8.2	6.1	13.8	24.8	+ 422.670
1300	21.0	7.5	3.4	15.5	14.6	+ 908.995
1400	17.8	7.4	1.2	16.8	12.2	+ 1145.320
1500	17.3	6.3	1.2	13.0	10.5	+ 1342.096
1540	17.3	6.3	1.7	14.5	11.5	0000.000
1640	17.8	7.0	0.5	16.4	11.5	- 772.850
1740	18.9	7.4	2.2	23.5	15.8	- 467.950
1840	20.0	8.0	3.4	23.6	18.7	- 740.350
1940	22.0	8.7	3.8	16.7	17.2	- 461.390
2040	26.8	10.6	2.6	12.5	12.9	- 151.696
2140	29.4	10.0	2.6	12.3	7.6	0000.000

Carter Creek - 7/31/72

0840	25.8	14.2	9.6	10.22	202.4	0
0940	22.0	9.8	5.3	24.4	30.8	+ 684.000
1040	9.3	10.5	1.0	19.0	17.0	+ 1105.000
1140	19.0	6.2	9.4	22.8	13.3	+ 2477.790
1240	17.3	9.6	0.6	17.8	11.2	+ 4507.900
1340	17.8	7.7	2.4	15.1	12.0	+ 1029.600
1400	16.8	9.5	0.6	21.8	17.0	0
1500	16.8	9.0	0.5	22.9	16.2	- 2622.600
1600	17.3	9.0	0.3	28.8	11.2	- 3308.211
1700	12.0	10.0	7.9	21.7	23.6	- 2140.380
1800	11.5	8.5	15.2	28.3	26.8	- 6814.650
1900	13.5	12.8	14.2	12.5	29.6	- 830.790
2000	11.0	17.0	23.9	16.9	43.8	- 169.008
2117	14.1	14.4	7.0	25.4	69.4	0

Table 41

Carter Creek - 8/29/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl. a µg/l	Discharge l/sec
0820	34.8	12.2	0.5	20.4	22.8	0
0920	24.6	9.9	2.5	33.5	31.6	+ 110.250
1020	22.0	9.8	2.7	33.8	27.6	+ 847.600
1120	19.6	8.4	3.2	37.3	28.2	+ 1380.270
1220	17.5	7.7	1.1	36.0	23.8	+ 2488.100
1320	17.2	8.6	1.2	37.7	18.0	+ 1612.070
1340	17.2	7.4	1.7	31.6	76.8	0
1440	17.2	7.4	2.0	31.7	19.6	- 3530.375
1540	15.0	8.0	1.6	37.6	24.0	- 1859.528
1640	19.4	8.6	2.0	31.5	21.4	- 883.116
1740	22.0	9.8	2.9	35.5	18.4	- 731.640
1840	25.3	11.9	1.3	23.0	15.0	- 331.551
1940	27.3	13.7	1.7	10.5	14.2	- 32.800
2000	20.0	7.0	2.4	15.5	13.2	0

Carter Creek - 9/27/72

0750	31.5	6.9	2.2	25.30	18.0	0
0850	23.1	5.4	3.9	18.94	17.2	+ 229.284
0950	22.0	6.5	3.9	15.92	15.2	+ 852.175
1050	21.0	7.0	4.9	23.31	25.2	+ 1256.850
1150	21.0	6.5	2.5	21.80	19.0	+ 2291.400
1250	19.5	5.7	2.8	26.92	19.4	+ 2934.382
1340	19.5	5.3	3.7	27.30	18.6	0
1440	20.0	6.0	3.5	38.18	18.0	- 2840.271
1540	21.0	5.3	4.5	21.16	22.4	- 1717.170
1640	21.5	6.0	4.3	21.72	21.0	- 1074.870
1740	22.5	7.5	1.8	21.08	17.0	- 684.600
1840	24.7	8.3	14.6	9.96	20.8	- 398.180
1940	22.0	10.4	15.5	5.15	36.0	- 137.785
2030	20.0	11.8	5.7	12.87	26.4	0

Table 42

Carter Creek - 10/27/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl a µg/l	Discharge l/sec
0800	30.0	9.0	1.6	3.56	5.2	0
0900	29.4	9.0	1.6	3.4	5.4	+ 229.284
1000	22.0	7.6	1.2	8.0	5.8	+ 639.450
1100	21.5	7.0	1.7	8.32	6.6	+ 1130.025
1200	20.0	7.0	1.0	4.42	6.4	+ 1826.250
1300	18.9	7.5	1.1	7.28	11.4	+ 3669.596
1400	18.4	5.4	2.6	5.85	8.0	+ 1128.600
1420	17.3	7.4	2.2	7.0	20.8	0
1520	17.5	7.7	2.4	10.58	16.0	- 2355.325
1620	18.4	7.4	3.5	10.30	13.8	- 2114.384
1720	18.4	9.6	2.0	11.52	12.0	- 1079.585
1820	20.4	8.1	2.5	10.01	8.6	- 619.100
1920	22.5	9.3	1.0	3.82	5.0	- 293.328
2020	24.6	10.5	1.2	6.67	4.6	0

Carter Creek - 11/27/72

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl a µg/l	Discharge l/sec
1020	25.8	12.6	4.5	2.18	6.8	0
1120	26.8	10.2	6.3	1.80	9.6	+ 214.230
1220	24.7	8.8	8.1	1.70	10.8	+ 154.368
1320	20.5	8.5	2.3	3.14	8.6	+ 345.173
1420	20.5	8.5	1.5	5.29	6.6	+ 161.100
1500	20.5	7.5	3.3	3.28	6.8	0
1600	19.4	10.8	1.7	5.33	7.0	- 316.500
1700	21.5	10.0	1.5	4.66	5.2	- 290.646
1800	24.7	10.8	3.4	3.54	4.0	- 195.296
1900	24.7	11.8	7.3	2.36	7.4	- 128.250
2000	23.7	13.1	7.0	1.69	7.2	- 10.353
2100	25.1	11.9	7.0	1.61	8.2	- 5.355
2200	26.2	11.3	12.2	1.83	8.8	- 900
2240	27.3	12.4	7.1	1.24	6.0	0

Carter Creek - 1/11/73

Time	DIC mg/l	DOC mg/l	POC mg/l	ATP 10^{-4}mg/l	Chl a µg/l	Discharge l/sec
0900	18.4	6.3	2.8	2.38	4.0	0
1000	18.4	5.2	1.1	1.81	2.6	+ 472.800
1100	16.2	4.7	1.0	1.30	3.0	+ 805.620
1200	15.7	6.3	0.5	1.34	2.6	+ 914.370
1300	16.3	5.2	0.5	1.49	3.0	+ 869.550
1420	16.3	4.7	1.1	2.12	2.6	0
1520	16.3	5.2	1.0	1.38	2.6	- 818.376
1620	15.8	5.7	0.5	1.49	2.6	- 816.046
1720	15.8	6.2	1.6	1.64	3.0	- 561.996
1820	15.8	7.2	1.7	2.19	3.0	- 145.440
1920	16.2	6.8	1.1	2.17	4.0	- 24.289
2020	16.2	6.8	1.7	1.88	4.0	0

Net Tidal Detritus Flux

(Tables 43 and 44)

As indicated from the flux calculations presented in Tables 43 and 44, both marshes exported significant quantities of organic carbon to the estuary.

Based on estimates of marsh grass productivity made during 1972, 40.7% of the annual net productivity was exported from Carter Creek in the particulate form and 8.9% as dissolved organic carbon. In Ware Creek 12.4% was exported as particulate while 28.0% was exported in the dissolved form.

Living carbon as estimated from the ratio of ATP to cellular carbon accounted for 8.4% and 8.7% of the export from Ware and Carter creeks respectively.

Table 43

WARE CREEK MARSH DETRITUS BUDGET

Time Period	POC (kgC)	DOC (kgC)	DIC (kgC)	ATP (10^{-4}kg)	Chl. a (g)
1/15/72 - 2/12/72	+ 575.6	- 453.9	+ 55.4	- 653.2	+ 1075.2
2/13 - 3/26	- 853.6	- 421.8	- 823.5	- 6396.9	+ 70.3
3/27 - 5/2	+ 799.4	- 5595.4	+ 201.5	+ 9068.2	- 510.5
5/3 - 5/31	- 2407.5	+ 472.6	+ 939.6	+ 4887.2	- 189.1
6/1 - 7/5	+ 779.3	- 205.8	+ 450.2	- 10833.4	- 4571.0
7/6 - 8/11	+ 1082.1	- 399.3	- 3162.4	- 4186.4	- 7303.7
8/12 - 9/10	- 1556.9	- 1971.2	+ 3746.5	- 2665.6	- 6602.6
9/11 - 10/8	- 1680.0	+ 1883.3	- 1534.7	- 769.8	- 2822.6
10/9 - 11/9	+ 3140.1	- 1862.2	+ 2178.2	- 744.9	- 254.0
11/10 - 12/16	- 2652.1	- 2652.1	+ 656.4	- 3494.1	- 1339.3
12/17 - 1/15	- 2172.1	+ 49.6	+ 24.8	- 826.9	- 124.1
TOTAL	- 4945.7	- 11156.2	+ 2732.0	- 16615.8	- 22571.4

\+ into marsh
\- out of marsh

Table 44

CARTER CREEK MARSH DETRITUS BUDGET

Time Period		POC (kgC)	DOC (kgC)	DIC (kgC)	ATP (10^{-4}kg)	Chl. a (g)
2/9/72	- 3/15/72	+ 3243.6	- 148.2	- 362.2	- 1214.2(1)	+ 3128.4
3/16	- 4/6	- 341.0	+ 156.1	+ 549.6	- 9720.8(2)	+ 1823.6
4/7	- 5/4	+ 168.2	+ 1444.9	+ 818.0		- 3356.2
5/5	- 6/3	+ 922.0	+ 438.0	+ 465.3	- 295.0	- 5426.0
6/4	- 7/9	+ 189.4	- 688.0	- 674.0	- 7826.4	- 1216.4
7/10	- 8/14	- 12297.3	- 1191.2	- 1191.2	- 13388.4	- 17842.8
8/15	- 9/13	- 156.2	+ 295.0	+ 295.0	+ 4570.2	+ 5472.6
9/14	- 10/12	- 1933.2	+ 88.9	+ 88.9	- 6171.6	- 355.5
10/13	- 11/12	- 1967.0	- 1190.2	- 1190.2	- 5405.3	- 6849.0
11/13	- 12/20	+ 934.6	- 1178.8	- 1178.8	- 1013.3	+ 20783.4
12/21	- 2/8	- 417.6	- 561.6	- 705.6	- 129.6	+ 288.0
TOTAL		- 11654.6	- 2535.1	- 3085.2	- 40594.4	- 3549.9

\+ into marsh

\- out of marsh

(1) - Time interval 2/9/72 - 3/25/72

(2) - Time interval 3/26/72 - 5/4/72

SECTION IV

CONCLUSIONS

Conclusions

Annual nitrogen, phosphorus and carbon budgets for two Virginia salt marshes were determined by monthly measurements of water discharge and constituent concentrations over tidal cycles.

Phosphorus Cycle

In both *Spartina cynosuroides* dominated Ware Creek marsh and *Spartina alterniflora* dominated Carter Creek marsh, the phosphorus cycle was characterized by elevated summer phosphorus concentrations. Dissolved inorganic phosphorus was exported from Carter Creek to the estuary throughout the year and from Ware Creek except during fall. Over a year there was net dissolved inorganic phosphorus export from both marshes to the York River estuary. Dissolved organic phosphorus was exported from both marshes at all times during the year, but on an annual basis particulate phosphorus was lost from the estuary to the marshes. Considering all three phosphorus forms, there was net phosphorus loss from the estuary to the marshes. This phosphorus budget suggests a cycle of both loss of estuarine particulate phosphorus to marsh sediments and mineralization of estuarine particulate phosphorus in the marshes with subsequent export of dissolved inorganic and organic phosphorus to the estuary.

Nitrogen Cycle

The salt marsh nitrogen cycle was characterized by elevated winter nitrite and nitrate levels and elevated summer ammonia, dissolved organic nitrogen, and particulate nitrogen concentrations. Nitrate and nitrite were lost to both marshes from the estuary throughout the year. Ammonia was exported from Ware Creek except during fall and imported to Carter Creek except during spring. On an annual basis there was a strong export of ammonia from Ware Creek and a slight import of ammonia to Carter Creek. Dissolved organic nitrogen was exported from both marshes at all times during the year while particulate nitrogen was exported only during fall and winter. Annually there was a strong net export of dissolved organic nitrogen from both marshes and a net import of particulate nitrogen into Carter Creek from the estuary, while in Ware Creek there was a small net export of particulate nitrogen.

Nitrogen flux data thus indicate a cycle of loss of nitrate and nitrite to both marshes via denitrification and conversion to molecular nitrogen. Particulate nitrogen imported to the marshes from the estuary is mineralized and returned to the estuary as ammonia and dissolved organic nitrogen. Ammonia entering the marshes from the estuary is nitrified to produce nitrate and then perhaps denitrified. Considering all nitrogen species, there is a strong net export of nitrogen from the marsh to the estuary. This suggests significant fixation of atmospheric nitrogen by marsh flora and subsequent export of some of this nitrogen.

Detritus

Concentrations of seston in the water generally followed seasonal trends. Particulate organic carbon, dissolved inorganic carbon and dissolved organic carbon levels were highest in the summer and early fall and lowest in the late winter and early spring. ATP levels and chlorophyll 'a' concentrations indicated that much of the standing crop of living material in the water was autotrophic.

Flux calculations indicated a net export of carbon from the marshes. In Ware Creek the majority of the carbon was exported in the dissolved organic form, while the major portion exported from Carter Creek was in the particulate form.

Impact on Water Quality

The salt marsh ecosystem thus influences estuarine primary productivity by mineralizing particulate organic nitrogen and phosphorus of estuarine origin, exporting these nutrients in a dissolved form that can be assimilated by estuarine autotrophs.

Organic carbon is exported to the estuary in both dissolved and particulate form. The extent to which this material is utilized by specific autotrophs, heterotrophs and other consumers is not known. However, it would seem reasonable to assume that this contribution adds significantly to the productive potential of the estuary by supplying a source of energy.

SECTION V

PUBLICATIONS AND THESES

Publications and Theses

The work completed under this grant will form the basis for two theses:

1) Donald M. Axelrad, Ph.D. Function of Salt Marshes in Determining the Nutrient Budgets of Estuaries (completion date June 1974).
2) Kenneth A. Moore, M.S. Seston Contributions from Two Virginia Salt Marshes (completion date June 1974).

Matching effort has been provided in part through the study of marsh grass productivity which provided the basis for the thesis of Mr. Irving A. Mendelssohn entitled: Angiosperm Production in Three Virginia Marshes in Various Salinity and Soil Nutrient Regimes.

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