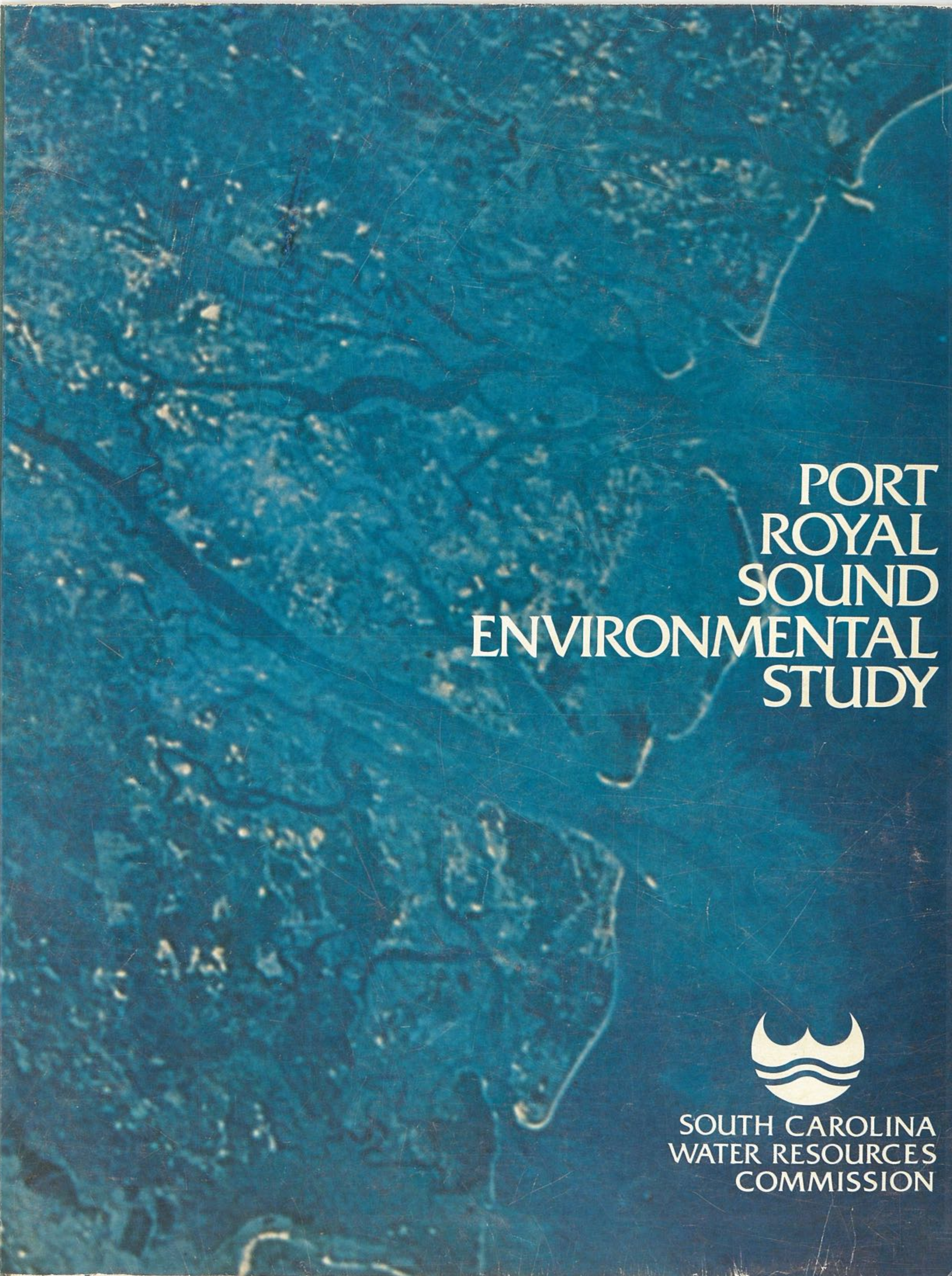
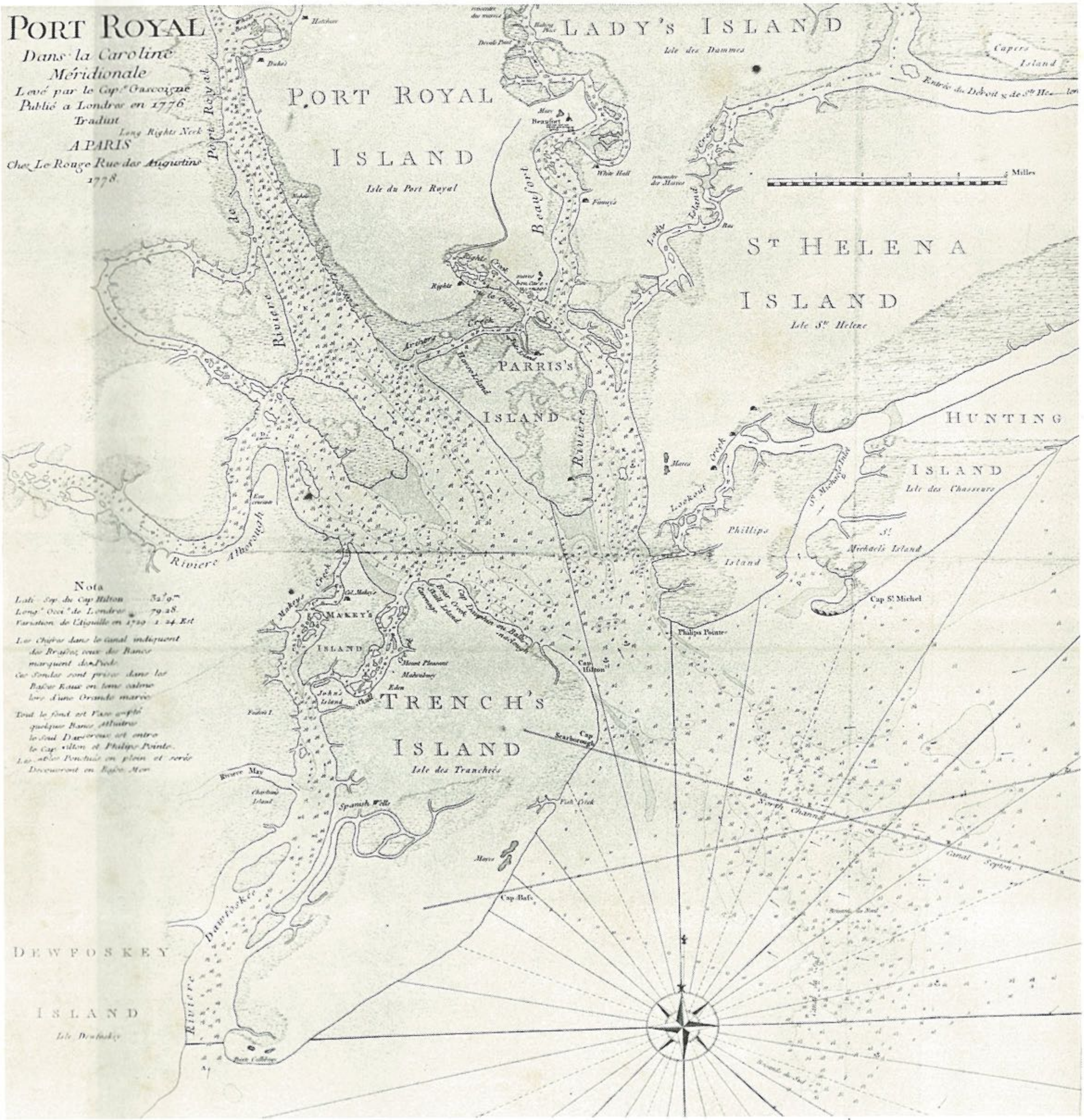


PORT ROYAL SOUND ENVIRONMENTAL STUDY

SOUTH CAROLINA
WATER RESOURCES
COMMISSION



Map of the Port Royal Sound area in 1776.

COVER PHOTO SUPPLIED BY NASA

Paul Foster
Figure 8 Island, N.C.

PORT ROYAL SOUND ENVIRONMENTAL STUDY

SOUTH CAROLINA
WATER RESOURCES
COMMISSION

THE STATE PRINTING COMPANY

Litho United States
2500 November, 1972

Table of Contents

Introduction

Background

The Port Royal Sound Environmental Study evolved from the controversy concerning the proposed construction of a petrochemical plant in the vicinity of Port Royal Sound, S. C. The plant was to be built by a German firm, Badische Anilin und Sodafabrik, (BASF) at Victoria Bluff on the Colleton River. The fishing and tourist interests on Hilton Head Island felt that if BASF were allowed to develop on that site, the environment would be greatly damaged, and as a result, these two industries, being directly or indirectly dependent upon the natural resources of the area, would suffer permanent and irreparable damage. However, other factions in the vicinity felt that BASF would provide badly needed jobs to bolster the economy.

A highly emotional conflict evolved on a basis of very few facts and a large amount of speculation. With national attention focused by the news media, the emotional climate of the conflict reached alarming proportions. Obviously, there was an urgent need to collect base line data on this estuary, as well as others in South Carolina so that future decisions could be based upon facts without the involved emotional conflicts.

The involvement of the South Carolina Water Resources Commission in this environmental study in the Port Royal Sound area began with a letter dated January 21, 1970, from then Governor Robert E. McNair to Mr. Clair P. Guess, Jr., Executive Director of the Water Resources Commission. In view of the proposed development in the Port Royal Sound vicinity and also the unfortunate scarcity of information concerning the environmental quality in the area, Governor McNair stated the following:

> It has become necessary, in my opinion, to conduct a comprehensive study of the environmental conditions as they exist in the coastal area of the State. This, of course, would be far-reaching and necessitate a considerable amount of time and expense. Because of the proposed industry at Victoria Bluff, I feel that the first step would be that you and the staff complement of the Water Resources Commission should collect and evaluate base line environmental quality information relating to the development of this type of industry. You should utilize the interdisciplinary inputs and facilities of the agencies of the State, such Federal assistance as may be available and, if necessary, employment of a private consulting firm.
>
> This first effort should commence immediately.

Upon receipt of this directive from Governor McNair, the Executive Director and Commission staff members began drafting preliminary study guidelines and developing recommendations for the imminent investigation. With the natural biological and physical processes operating relatively undisturbed in this area of South Carolina, these environmental studies offered the rare opportunity to thoroughly probe a system largely unaltered by man. This was an important aspect. The Port Royal Sound investigation could examine a system before, not after, it had been significantly disturbed. Only with such foresight can man fully appreciate the natural resources, natural processes and natural potential that an area may possess and thereby keep his involvement in harmony.

The controversy that arose between various factions concerning the use of the Victoria Bluff site, and utimately the entire Port Royal Sound area, demonstrated the lack of, and the need for, information upon which sound management plans for this area could be based. The Port Royal Sound Environmental Study was designed to gather such information. The knowledge gained and the vast amounts and various types of data that were collected during this investigation have made it possible to develop the conclusions and recommendations found in this report.

This study, which was conducted during the spring, summer and fall seasons of 1970, provides some tools for the wise management of this resource. This purpose has been accomplished. With the help of this knowledge and data, wise decisions about the sound utilization of this area can be made. However, these tools are not self-enacting; someone must use them; and they are not all inclusive, they should be frequently updated and possibly expanded. The Port Royal Sound Environmental Study is, and should be thought of as, just a beginning.

Scope

In designing the overall investigation, the Commission was not content to deal only with the obvious scientific disciplines that must be included in such an environmental study. Instead, the scope of the study was extended to include a myriad of scientific parameters and fields plus evaluations of the social, economic and political conditions existing within the study area.

The areas considered and investigated in this study included: surface water hydraulics, geology and ground water hydrology, biology, water chemistry, air quality, solid waste and economic, sociological and political considerations. These areas of interest were intensively investigated to evaluate the base line environmental conditions existing within the boundaires of the study area. Upon completion of the individual studies, each was evaluated to define its interrelationships with all aspects of the environment.

Organization of Study

To conduct an environmental study of this magnitude required expertise unavailable, to our knowledge, in any one agency, institution or private firm. Cognizant of this and at the same time of the scope and importance of the study, the South Carolina Water Resources Commission organized the Port Royal Sound Environmental Study as a task force investigation. Federal and State agencies, academic personnel from appropriate departments of the University of South Carolina and Clemson University and a private consulting firm contributed to the design and conduct of this study. While the Water Resources Commission coordinated the overall effort, each participant was responsible for collecting his data, analyzing this information and preparing his final report. With little or no modifications, the reports presented in this document are those submitted to the Water Resources Commission by the study participants. The Commission then embarked upon the arduous task of digesting, comprehending and combining these diversified elements. Using these reports and other sources, Commission staff members prepared the Review, Estuary, Reflections, Conclusion and Recommendations Chapters.

The task force approach, while perhaps not an original concept, worked remarkably well in such a large scale, diversified investigation. While future investigations may not warrant such an all-out scientific assault upon an area, whether it be Port Royal Sound or not, the task force design has demonstrated its usefulness, if not its necessity, in multidisciplined, environmental studies.

Study Area

Beaufort County is located in southwestern South Carolina on the coast. Victoria Bluff is on the Colleton River approximately ten miles southwest of the city of Beaufort and about eighteen miles northeast of Savannah, Georgia.

The study area lies within the Sea Island Section of the Coastal Plain province, which is a part of the Atlantic Plain. The Atlantic Plain consists of the emerged plain, or Coastal Plain and the submerged continental shelf. The Coastal Plain and the continental shelf have a combined width of about 200 miles and a southeastward gradient of about 3.6 feet per mile.

The study area is drained principally by Port Royal Sound and its many tributaries. The principle tributaries include Broad River, Beaufort River, the Chechessee River and Colleton River. The drainage of these streams is principally to the southeast into the Atlantic Ocean.

The climate of the Beaufort area is characterized by mild temperatures and abundant rainfall. Winters are short and mild, but usually include occasional cold periods of a few days duration. Summers are long and hot with maximum temperatures ranging from 95° to 100° F. during July and August. The U. S. Weather Bureau records show the average precipitation and temperatures at Savannah for the period 1874 to 1957 as 45.75 inches and 66.4° F. respectively. Rainfall is usually well distributed with the largest amounts occurring during the spring and summer months. The average frost-free growing season is 273 days. The average date for the last freeze in spring is February 26 and for the first freeze in fall is November 26.

The study area included Port Royal Sound, Colleton River, Broad River, Chechessee River, Mackay Creek, Skull Creek and the Beaufort River. Estimates indicate that the open water area encompassed by this study was approximately 42,000 acres.

This size estimate is a conservative value for no attempt was made to include the area covered by the countless tidal creeks and cuts within the study vicinity. Even so, this area is almost 13% as large as Beaufort County and only slightly smaller than several of South Carolina's large inland lakes, such as Lake Murray, approximately 50,000 acres; and Lake Moultrie, approximately 60,400 acres.

Acknowledgements

The Port Royal Sound Environmental Study, as presented here, is the result of a massive undertaking in both time and effort by a great many people, including a number of agencies, both State and Federal.

This study was originally guided by Mr. James T. Darby, Jr., Bio-Chemist, of the South Carolina Water Resources Commission under the direction of the Executive Director, Clair P. Guess, Jr. When Mr. Darby left the Commission, the guidance of the report was undertaken by Mr. Morrow B. Thompson, Bio-Chemist, of the South Carolina Water Resources Commission.

A study as comprehensive as this could not possibly have been done adequately by a single person or a single agency. Many agencies were called upon to obtain the best available knowledge on a particular section of the study. Many people, respected in their fields, contributed to this study in a number of ways, ranging from actual participation in the field work to consultation on problems that arose during the study.

Thanks are due to many agencies, both Federal and State, as well as to many individuals for their work in this undertaking. Special thanks go to the people and agencies who helped this study along, but whose names have been inadvertently omitted.

We also wish to acknowledge the financial assistance provided by the Coastal Plains Regional Commission and the South Carolina Planning and Grants Division.

Participating Agencies

Belle W. Baruch Research Institute, University of South Carolina

Bureau of Governmental Research and Service, University of South Carolina

Coastal Plains Regional Commission

Department of Agricultural Economics and Rural Sociology, Clemson University

Department of Biology, University of South Carolina

Department of Geology, University of South Carolina

Environmental Protection Agency

Hydrosurveys, Incorporated, of Fort Lauderdale, Florida

National Marine Fisheries Service

South Carolina Pollution Control Authority

South Carolina State Board of Health

South Carolina State Development Board

South Carolina State Highway Department

South Carolina State Ports Authority

South Carolina Water Resources Commission

South Carolina Wildlife & Marine Resources Department

United States Department of Health, Education and Welfare

United States Department of the Interior, Bureau of Sports Fisheries and Wildlife

United States Forestry Service

United States Geological Survey

United States Marine Corps, Parris Island, S. C.

United States Navy, Sixth Naval District, Charleston, S. C.

United States Water Resources Council, Washington, D. C.

Contributors

E. Andrews, Department of Geology, University of South Carolina, Columbia, South Carolina.

R. K. Ballentine, Environmental Protection Agency, Washington, D. C.

R. A. Baltzer, United States Geological Survey, Washington, D. C.

K. Basnett, Department of Biology, University of South Carolina, Columbia, South Carolina.

W. T. Batson, Department of Biology, University of South Carolina, Columbia, S. C.

C. M. Bearden, Marine Resources Division, South Carolina Wildlife Department, Charleston, S. C.

J. J. Blackard, Bureau of Sport Fisheries and Wildlife, Department of the Interior, Atlanta, Georgia.

B. C. Blackwelder, Department of Biology, University of South Carolina, Columbia, S. C.

J. Byrnes, Department of Geology, University of South Carolina, Columbia, South Carolina.

M. G. Carmichael, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C.

E. Chamberlain, Federal Aid Division, Department of the Interior, Atlanta, Georgia.

E. G. Cleveland, Environmental Control Administration, Department of Health, Education, and Welfare, Atlanta, Georgia.

D. J. Colquhoun, Department of Geology, University of South Carolina, Columbia, S. C.

D. Comer, Department of Geology, University of South Carolina, Columbia, South Carolina.

W. G. Crosby, South Carolina Pollution Control Authority, Columbia, S. C.

T. R. Cummings, United States Geological Survey, Washington, D. C.

H. K. Dickert, Solid Waste Section, Environmental Sanitation, South Carolina State Board of Health, Columbia, S. C.

D. A. Duncan, South Carolina Water Resources Commission, Columbia, S. C.

E. L. Falk, College of Architecture, Clemson University, Clemson, S. C.

C. H. Farmer, III, Marine Resources Division, South Carolina Wildlife Resources Department, Charleston, S. C.

K. D. Feigner, Systems Analysis and Economics Branch, Environmental Protection Agency.

G. Gardner, Operations Office, Environmental Protection Agency, Washington, D. C.

R. A. Gardner, Water Resources Division, United States Geological Survey, Columbia, S. C.

H. E. Gibson, South Carolina Pollution Control Authority, Columbia, S. C.

C. Hall, Fresh Water Protection Section, Environmental Protection Agency, Washington, D. C.

W. W. Hall, Jr., Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C.

D. B. Hicks, Environmental Protection Agency, St. Petersburg, Florida.

J. C. Hite, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C.

R. Hodges, Department of Geology, University of South Carolina, Columbia, S. C.

L. Holliday, Beaufort Resident Technical Center, Beaufort, S. C.

F. Johnson, United States Geological Survey, Columbia, S. C.

G. N. Johnson, National Marine Fisheries Service, Beaufort, N. C.

P. Johnson, United States Geological Survey, Columbia, S. C.

L. E. Keup, Biological Unit, Environmental Protection Agency, Washington, D. C.

F. A. Kilpatrick, United States Geological Survey, Washington, D. C.

E. A. Laurent, Environmental Resources Center, Georgia Institute of Technology.

D. W. Lear, Environmental Protection Agency, Annapolis Field Office, Annapolis, Maryland.

H. H. Macaulay, Department of Economics, Clemson University, Clemson, S. C.

R. McCormack, District Sanitarian, South Carolina State Board of Health, Ridgeland, S. C.

T. W. McKenney, National Marine Fisheries Service, Beaufort, N. C.

T. C. Meadows, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C.

D. Nelson, Department of Geology, University of South Carolina, Columbia, South Carolina.

J. O'Hara, South Carolina Water Resources Commission, Columbia, S. C.

N. K. Olson, Division of Geology, State Development Board, Columbia, S. C.

W. T. Parker, Bureau of Sport Fisheries and Wildlife, Department of the Interior, Atlanta, Georgia.

L. P. Parrish, Water Quality Office, Environmental Protection Agency, Cincinnati, Ohio.

R. M. Pope, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C.

L. E. Priester, Environmental Health Laboratory, South Carolina State Board of Health, Columbia, S. C.

J. Ragsdale, Beaufort, S. C.

S. Reznek, Fresh Water Pollution Section, Environmental Protection Agency, Washington, D. C.

D. L. Rich, College of Engineering, Clemson University, Clemson, S. C.

M. B. Richardson, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C.

C. Sansbury, Belle W. Baruch Coastal Research Institute, University of South Carolina, Columbia, S. C.

L. Settlemyre, Department of Geology, University of South Carolina, Columbia, S. C.

D. S. Shriner, Department of Biology, University of South Carolina, Columbia, S. C.

G. Siple, United States Geological Survey, Columbia, S. C.

S. K. Smith, Environmental Protection Agency, Annapolis Field Office, Annapolis, Maryland.

J. Stallings, United States Geological Survey, Columbia, S. C.

W. J. Steele, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C.

J. M. Stepp, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C.

F. Sumrell, Bureau of Sport Fisheries and Wildlife, Department of the Interior, Atlanta, Georgia.

D. Swink, Water Quality Protection Branch, Environmental Protection Agency, Washington, D. C.

N. A. Thomas, Environmental Protection Agency, Grosse Ile, Michigan.

M. B. Thompson, South Carolina Water Resources Commission, Columbia, S. C.

W. R. Turner, National Marine Fisheries Service, Beaufort, N. C.

F. J. Vernberg, Belle W. Baruch Coastal Research Institute, University of South Carolina, Columbia, S. C.

R. W. Warner, Division of Field Investigation, Environmental Protection Agency, Denver, Col.

H. J. Webb, South Carolina Pollution Control Authority, Columbia, S. C.

G. Welsh, Environmental Protection Agency, Atlanta, Ga.

H. Wickwar, Bureau of Governmental Research and Service, University of South Carolina, Columbia, S. C.

B. Wygal, Water Quality Protection Branch, Environmental Protection Agency, Washington, D. C.

CHAPTER ONE

STUDY OUTCOME

Conclusions and Recommendations

CONCLUSION 1.

The Port Royal Sound Environmental Study is fundamental to responsible future development of this region. The scientific, economic, and sociologic data collected during this investigation provide base line information against which proposed alterations can be assessed and evaluated, and the effects of future changes, compared. The mathematical model (U.S.G.S., Interim Report, this volume) which is being developed in conjunction with this study, for example, will be a valuable management tool for the waters of Port Royal Sound.

Recommendation 1.

This study should not be terminated, but rather it should be expanded and periodically updated.

Recommendation 2.

A comprehensive management plan including zoning should be developed and implemented for the entire study area. As suggested in the succeeding section (Reflections), specific land use classes should be assigned to the area using the information developed from the Port Royal Sound Environmental Study and additional investigations. Such a classification scheme should consider the following (and perhaps other) land use categories:

1. Conservation and Preservation
2. Agriculture
3. Passive Recreation
4. Active Recreation
5. Residential Development
6. Commercial and Industrial Development

CONCLUSION 2.

With few exceptions, the waters of Port Royal Sound are clean and typical of a salt marsh estuarine environment as would be expected under natural conditions.

Recommendation 1.

To retain the almost pristine conditions of the waters, no hazardous or toxic materials should be discharged into the system.

Recommendation 2.

Limited amounts of non-toxic organic wastes can be absorbed by the waters without significant deterioration in the existing water quality. The resulting enrichment might be beneficial to the productivity of the area, but care must be taken that extensive eutrophication does not occur, that valuable shellfishing areas are not jeopardized, and that South Carolina water quality standards are not violated.

Recommendation 3.

Outfalls should be designed and constructed to provide for the maximum possible mixing and removal of an effluent into areas of high current transport toward the sea. If at all feasible, wastes should be confined in holding ponds and released on ebb tides.

CONCLUSION 3.

The salt marshes of Port Royal Sound are vital to the maintenance of the fishery, seafood and recreational industries of the area.

Recommendation 1.

There should be no dredging, filling, or other destruction of the marsh area unless such alterations can be demonstrated to the appropriate State agency to be in the public interest and that no viable alternative exists. All efforts should be made to preserve the valuable marshes of the area.

CONCLUSION 4.

Economically, the general region around Port Royal Sound is depressed and highly dependent upon local military bases. The economic base can be expanded by diverse programs to promote development that would be compatible with the human and natural resources of the area.

Recommendation 1.

The recreation and tourism industry should be expanded through a progressive program developed by an existing local agency which has such authority, or, if necessary, through the creation of a local Recreation and Tourism Commission. Emphasis should be directed toward the middle income segment of the population. Consideration should be given to promoting the historical, cultural, and recreational value and appeal of the entire area. Increased public facilities and the possibility of a historical-zoological-botanical park should attract additional tourists and income to the vicinity.

Recommendation 2.

Non-polluting industries should be encouraged into the area. A less desirable alternative would be expansion of those industries whose final effluent is organic and non toxic.

CONCLUSION 5.

Ground-water resources are good on the south of Port Royal Sound and adequate for limited use on the north side.

Recommendation 1.

A Capacity Use Study under the provisions of the Ground Water Use Act of 1969 should be conducted in this area.

Recommendation 2.

No further dredging should be allowed in the Beaufort River unless reliable investigations can demonstrate that additional dredging to deepen the shipping channel can be conducted without jeopardizing the ground-water resource. Seismic surveys indicate that the aquifer is extremely shallow and may already have been breached in portions of the River.

REFLECTIONS

Not unlike most coastal areas of these United States, Port Royal Sound is faced with the possibility of increased commercialization and industrialization of the shores. This, along with a subsequent growth in population, would increase use of the waters, filling of the marshes, and the threat of pollution. Fortunately, a source of domestic pollution in the Port Royal Sound area is to be corrected by the construction of a municipal sewage treatment system for Beaufort, South Carolina.

Currently, Port Royal Sound is primarily used for fisheries and recreation. Because of the economic needs of the area, the pristine conditions of the area are the basis for conflict. Beaufort and Jasper Counties are economically depressed and must rely on utilization of their natural resources to attract developmental money. Obviously, Port Royal Sound and its associated rivers are a major natural resource. The problem to be resolved is how best to use these resources without conflicting or interfering with the other interests of the area.

Industrialization of Port Royal Sound would be the fastest economic boom for the area, but the record of some industries is deplorable in the anti-pollution field. There have been too many mistakes resulting in gradual environmental deteriorations along the coast of America. Scientists are apprehensive of any change in the extremely complex estuarine ecosystem. Slight alterations in the ecosystem can have disastrous results. Base line studies, such as the Port Royal Sound Environmental Study, provide data against which future alterations can be evaluated. Such studies are invaluable and should be insisted upon.

It appears unlikely that any coastal area in the eastern United States will be able to escape the influence or domination of development in the next decade. Examples of beautiful areas being decimated are far too common to need elucidation here. Port Royal Sound is one of the few unspoiled areas left. In fact, most of Port Royal Sound and the associated St. Helena Sound constitute a large part of South Carolina's remaining unpolluted coastal area. The cleanliness of these areas—in a time when pollution is rampant—should be regarded as a natural resource for the nation.

Environmental pollution is the common enemy of the 1970's. The problem is world wide, and, at the time of this writing, the first United Nations conference on pollution is being held in Stockholm, Sweden, to consider an international program to halt the deterioration of the environment.

On the national level, U. S. Senate Bill S. 3507 has passed and is in the House Committee on Merchant Marine and Fisheries. This bill would assist the coastal states in developing a coastal zone management program. A state management agency would establish acceptable uses for public and private lands in the coastal zones so as to minimize the adverse impact of utilization on the coastal waters. This bill calls for approval of a state comprehensive management plan by the Secretary of Commerce and it provides funds to implement the provisions of the plan.

The Land Use Policy and Planning Assistance Act of 1972, was approved by the Senate Interior and Insular Affairs Committee on June 5, 1972. This proposed bill would grant $100 million annually in federal funds to the states to finance 90% of the cost of developing state land use programs. An Office of Land Use Policy Administration would be established within the Interior Department which would, among other things, maintain a study of land resources and their use; assist states in developing methods and classifications for collection of land use data; and administer the grant-in-aid program established under the Act. The state programs would be concerned with critical areas (such as beaches, lakes, and parks), key facilities (such as major highways and airports), developments of regional benefit (such as power plants), and large scale development (such as industrial parks and subdivisions).

The South Carolina Senate recently (May 18, 1972) amended and passed S. 977 which is known widely as the Tidelands Bill. Among other things, this bill provides for an Interagency Council on

Tidelands which would be responsible for management of the intertidal and submerged areas. The bill was referred to the House of Representatives for consideration.

In view of the proposed Federal Bills, coastal zone management of some sort, if not land management in general, will probably become a reality in the near future. The South Carolina Legislature is in a potential position of leadership in providing for the protection and management of this zone. Unlike the pending Federal Bill (S. 3507), the South Carolina Tidelands Bill provides only for management of the intertidal and submerged areas, not of the entire coastal zone which, according to the Federal Bill, extends inland "to the extent necessary to control shorelands, the uses of which have a direct and significant impact on the coastal water." If the Tidelands Bill is extended to cover management of the upland areas which influence the intertidal zone and submerged lands, the mechanism would exist for an enlightened program of land use zoning.

Apparently, Port Royal Sound and other coastal zones throughout the State and Nation will have to be managed. Management of an area is a complex concept and process. It involves much more than the permit system for regulation of development within coastal areas that has emerged in recent years. The permit system is not, and cannot pretend to be, land use management. It is a stopgap attempt at preventing wholesale destruction of our valuable marshlands and coastal areas.

A classic example of how sound management for an area should be developed was prepared and discussed by the noted landscape architect and planner, Ian McHarg (1969). McHarg, in developing his Staten Island Study, employed what he termed a "rational method" in that he derived the evidence for his study from exact sciences.

Over thirty factors falling under the major categories of climate, geology, physiography, hydrology, soils, vegetation, wildlife habitats, and land use were thoroughly investigated on Staten Island. Each factor was evaluated on a gradient scale (such as: Quality, Scarcity, Vulnerability) and the degree of suitability of each factor was then determined for each specific land use class (Conservation, Passive Recreation, Active Recreation, Residential Development, and Commercial and Industrial Development). Using base maps of the study area and the knowledge derived from the factor evaluations as to the suitability of given locations for certain types of land uses, McHarg delineated on separate overlays those areas best suited for conservation, passive recreation, etc. From these, a master map was prepared which combined all the different possible land uses.

Applying McHarg's factors to Victoria Bluff, for example, indicates that it could qualify for a conservation area (high-quality forest, high-quality marshes, water associated wildlife habitats, intertidal wildlife habitats, scenic land features, scenic water features, and scarce ecological associations), as passive and active recreation areas (scenic water features, high quality forests, high quality marshes, scenic land features, scarce ecological associations, water-associated wildlife habitats, field and forest wildlife habitats, open water for pleasure craft, fresh water areas, riparian lands, flat land, and existing and potential recreation areas), as residential areas (scenic land features, riparian lands, good bedrock foundations, and good soil foundations), or as commercial-industrial areas (good soil foundation, good bedrock foundations, and navigable channels). All of the land uses listed could be applied to Victoria Bluff, but the determination of which use is the best for the environment and society (if they can be separated) would require a complete land (and water) use evaluation of the entire study area along with the difficult task of judging the supply and demand for a particular type of use.

The Port Royal Sound Environmental Study cannot provide the means whereby land-use determinations can be made. Rather in demonstrating that generally the waters and air are clean; the fish, shellfish, and wildlife, abundant; the area is economically depressed, and that locally the desire, ability, and/or foresight to wisely manage these resources and simultaneously improve the lot of the local residents is lacking, the Study has provided essential background data — a foundation upon which broad recommendations were made and a base line against which future changes can be assessed. These recommendations all point towards the need for management of the entire Port Royal Sound Study area. Hopefully, a McHargian land use study can be conducted in this and all areas of our coastal zone in the near future. If this information is coupled with the knowledge provided by a competent environmental investigation and placed in the hands of a responsible institution, these areas can be utilized to the benefit of the ecosystem of which man is still a member.

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CHAPTER TWO

WHAT IS AN ESTUARY?

Morrow B. Thompson
South Carolina Water Resources Commission
Columbia, South Carolina

A Definition

What is an Estuary? Strictly from a physical standpoint, it generally can be defined as that coastal zone between the open sea and land which usually serves as a mixing zone for fresh water and sea water. Pritchard (1967) developed the following definition that has become widely accepted:

> An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage.

Physical Conditions

This definition implies that the following requirements be met by a system in order to be designated as an estuary:

1. "semi-enclosed coastal body of water" — The lateral boundaries or sides of an estuary are important in establishing water circulation patterns within the system. Pritchard intends for his definition to imply that an estuary is a feature *of* the coast and does not *form* the coast. This is an arbitrary decision, but the intent is to limit the size of the system so that the lateral boundaries still play an important part in affecting circulation patterns.

2. "a free connection with the open sea" — This phrase implies that the connection between the ocean and the estuary must be sufficient to transmit tidal energy and sea salts. The free connection must be adequate to allow an exchange of water between the estuary and the ocean during all tidal stages.

3. "sea water is measurably diluted with fresh water derived from land drainage" — This dilution of sea water is an important process in estuaries for it contributes to the density gradients which help form the circulation patterns found in estuaries. Fresh water inflow and tidal currents are primarily responsible for determining circulation patterns.

Depending upon the pattern of fresh water flow in relation to the tidal flow, estuaries can generally be classified as belonging in one of the following categories:

1. Highly Stratified (Salt Wedge) Estuary — In this type of estuary, the ratio of fresh water flow to tidal flow is relatively large and the ratio of the width of the system to its depth is fairly small. As a result, the less dense fresh water flows out over the more dense inflowing salt water creating a stratified estuary with a well-defined interface between the two layers. Slight upward mixing of the salt water into the fresh water zone, however, does occur (see Figure 1).

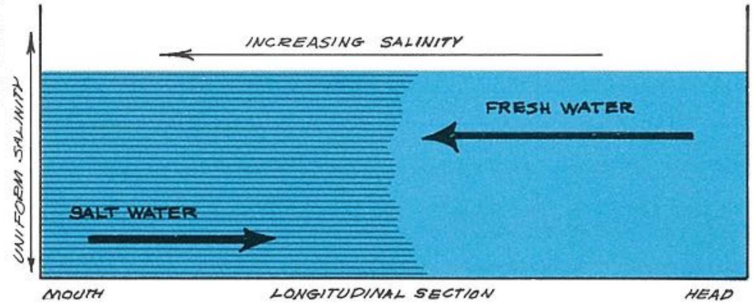

Figure 1.
Diagramatic Sketch of a Stratified Estuary

An example of a stratified estuary in South Carolina is the Charleston Harbor - Cooper River system. During average discharge conditions (approximately 15,000 to 16,000 cubic feet per second) from Lake Moultrie into the Cooper River, the upper limit of the salt water wedge (delineated by a conductivity reading of 125 micromhos/cm) is generally located in the Cooper River between Slack Back Reach and the confluence of the diked Back River with the Cooper.

2. Partially Mixed Estuary — In a system which possesses a moderate fresh water inflow and a large tidal current, a partially mixed estuary can develop. In this particular kind of estuary, the well-defined transition zone or interface between the salt and fresh water zones is largely dispersed. This is due mainly to the turbulence created by the relatively large tidal flow. Not only does salt water mix with the upper fresh water zone, but fresh water mixes downward thereby diluting the lower salt water zone. A vertical-salinity gradient, however, is still present increasing in concentration from top to bottom, and further, the salinity of both the upper and lower layers increases seaward (see Figure 2).

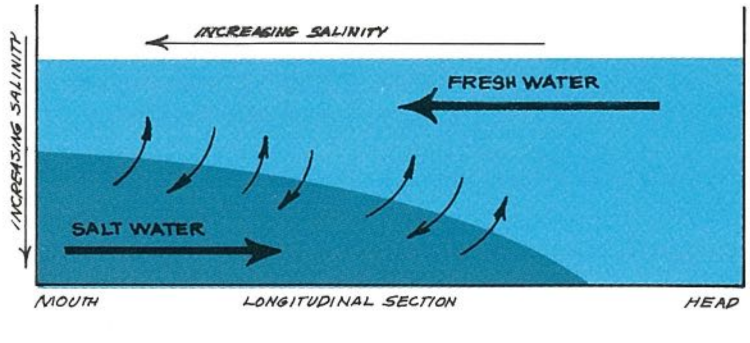

Figure 2.
Diagramatic Sketch of a Partially-Mixed Estuary

3. Homogeneous Estuary — When the ratio of fresh-water inflow is relatively insignificant in comparison with the tidal current, a vertically homogenous system results. The tidal turbulence thoroughly mixes the fresh and salt water creating an estuary wtih a uniform salinity gradient increasing from the upper reaches of the estuary towards the open sea (see Figure 3).

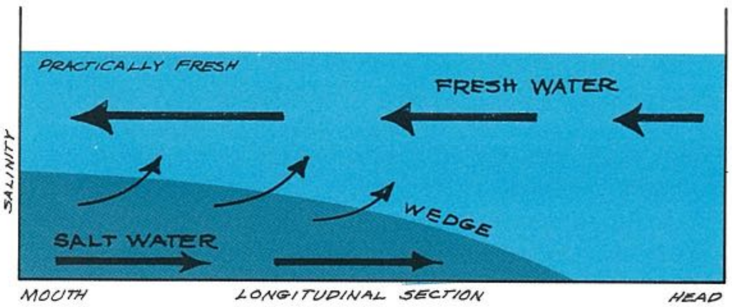

Figure 3.
Diagramatic Sketch of A Homogeneous Estuary

The Port Royal Sound estuary in South Carolina is an excellent example of a homogeneous estuary. Maximum flows at the entrance to the Sound range from 1.5 to 2.0 million cubic feet per second (cfs) (Kilpatrick and Cummings, this volume). The largest surface fresh water flow into the system (Coosawhatchie River) averages less than 300 cfs. Other sources of fresh water entering the system, such as smaller rivers and ground-water seepage, have not been measured and the physical significance of their presence is not known. The mean tidal range in the Sound is approximately 7.5 feet. The combined mixing effects of these factors contribute to the maintenance of a well-mixed system in Port Royal Sound. Salinities of 23 to 25‰ (parts per thousand) in the upper reaches of the system increase to around 30 to 35‰ (the approximate salinity of sea water) at the mouth. These values are in keeping with the expected seaward increase in salinity that occurs in a homogeneous system.

Biological Considerations

Few people consider definitions, circulation patterns, salt water wedges or salinity gradients of estuaries. However, many are aware of the opportunities to boat, swim and fish in such an area. Most people probably visualize an estuary as being a conglomeration of fish, gulls, ducks, egrets, shrimp, oysters, crabs, clams, marsh grasses, mudflats and, of course, water. Most of these considerations are biological. The mudflats contain large amounts of decaying vegetation. The water in such an area can be thought of as a biological soup—enriched with decaying organic matter and teeming with life.

Estuaries are ecosystems, and as Kormondy (1969) points out, ecosystems are real systems comprised of the abiotic (non-living) segments of the environment and the biotic (living) segments, such as plants, animals and microbes, in which an ecological relationship is demonstrated. A pond is an ecosystem, as is a field, a forest, or an ocean. Although ecosystems are real and identifiable, they are not isolated units. Ecosystems are invariably influenced by other systems. Ponds and lakes receive runoff from adjacent fields and forests; inhabitants of one ecosystem migrate to another; the seas are affected by the rivers discharging into them; forests encroach upon meadows and estuaries are washed by rivers and tides. Additionally, all ecosystems must depend upon some external source for energy, which is ultimately the sun.

The estuarine ecosystem represents one of nature's most productive biomes. In simple terms, productivity is merely an estimate of the number of living organisms a system supports. Specifically, primary production is an estimate of the amount and rate of autotrophic (green plant) energy fixation measured in such terms as kcal/m^2/yr (kilocalories per square meter per year). Kormondy (1969) discussed the earlier work of D. F. Westlake, who in comparing the primary production of various ecosystems, revealed some interesting estimates. For example, the annual net primary productivity of a salt marsh was estimated to be roughly 12,000 kcal/m^2/yr. This areas was estimated to be approximately 30 times more productive than a desert, 15 times more than the ocean and a temperate zone lake, 5 times more than a polluted lake, 2½ times more than a temperate zone deciduous forest, about the same as temperate zone perennial and tropical zone annual agricultural plants, 3/5 as much as a tropical rain forest, and about 2/5 as much as tropical zone agricultural plants and a tropical zone reed swamp. The saltmarsh, as demonstrated by these values, represents a highly productive environment.

In his definition of an estuarine ecosystem, Hedgpeth (1967) identified a prime reason for the productive sucess of estuaries:

> The estuarine ecosystem is a mixing region between sea and inland water of such shape and depth that the net resident time of suspended materials exceeds the flushing. Thus the system constitutes . . . a nutrient trap.

Scenic view of marshland; photo by M. Thompson, S. C. Water Resources Commission.

Generally, such fertile waters provide the necessary ingredients to support a wide variety of life forms. The great productivity of this system is due largely, therefore, to its ability to concentrate nutrients and minerals.

According to Ketchum (1967), an estuary can be fertilized in three primary ways:

1. River waters leech plant nutrients from the soil and carry a constant supply through the estuary.
2. Pollution, either locally within the estuary, or indirectly through the river, may enrich the waters and increase productivity.
3. The subsurface counter current, which is a unique characteristic of many estuarine circulations, may enrich the estuary when the sea water is drawn from below the euphotic zone where nutrient concentrations are higher than at the surface.

The relative importance of each of these three methods by which fertilization of an estuary can occur depends primarily upon the characteristics of the particular system in question.

These nutrients, such as nitrogen and phosphorous compounds, concentrated in estuaries by the filtering action of the marsh and some of its inhabitants and probably more importantly by the tidal circulation patterns, can be considered the first phase in the cyclic movement of minerals through an estuarine food chain, or for that matter, through any type of food chain. These inorganic compounds are primarily utilized by the so-called producers in a system. These producers or autotrophs, are green chlorophyll-bearing organisms (plants) which convert radiant energy via the process of photosynthesis into chemical energy in the form of organic carbon compounds. In the estuarine ecosystem, these producers include marsh grasses, trees and algae.

Estuarine producers can be, and frequently are, consumed by other members of the estuarine ecosystem. As depicted in Figure 4, herbivores or plant-eating animals graze upon green organisms. These animals may in turn be eaten by omnivores, animals which eat both animals and plants, or by carnivores, flesh-eating animals that occasionally feast upon an unfortunate omnivore. These three methods of obtaining nutritional requirements belong to animals which constitute that group of organisms that ingest, in part, or in whole, other organisms.

These animals, along with saprotrophs and parasites are members of that larger classification of organisms known as the consumers. Consumers obtain their nutrients (organic and inorganic metabolites) and consequently their energy from the physical and biological environment. Unlike green plants, they cannot manufacture their food from inorganic minerals and sunlight and they must depend to some extent upon other organisms, dead or alive, for these essential supplies. Herbivores, carnivores and omnivores eat other organisms; saprotrophs, primarily fungi, bacteria and protozoa, are the decomposers that live upon dead and decaying matter; and parasites derive their sustenance in or upon a living host organism.

In an estuary, the plant-eating herbivores are faced with boundless opportunities, and as to be expected, in nature, the opportunists are many. Crustaceans and microscopic animals graze upon the algae in these coastal waters. Oysters and clams filter their food, largely phytoplankton and detritus, from the surrounding waters and from the bottoms. Small fish, insects and snails obtain their sustenance from algae and aquatic and marsh plants. The fiddler crabs rely heavily upon decaying vegetative matter as their staple food.

In addition to the herbivores, the carnivores are well represented in an estuary. As noted, these animals derive their nutritional requirements by eating other animals. In an estuary, the smaller animals that ingested the algae are probably preyed upon by small fish. These small fish may also fall victim to larger fish, or ducks, or egrets, or herons, or ospreys or other fish-eating inhabitants of the system. Likewise, many of these predators can fall victim to larger and more powerful predators—possibly alligators, bobcats, foxes or man. Other carnivores in this habitat include: otters which feast upon fish, oysters and clams; marsh hens which patrol the banks of the tidal creeks looking for crabs, shrimp, snails and small fish; and the raccoons which feed upon snails, eggs, clams, oysters, crabs and other small animals.

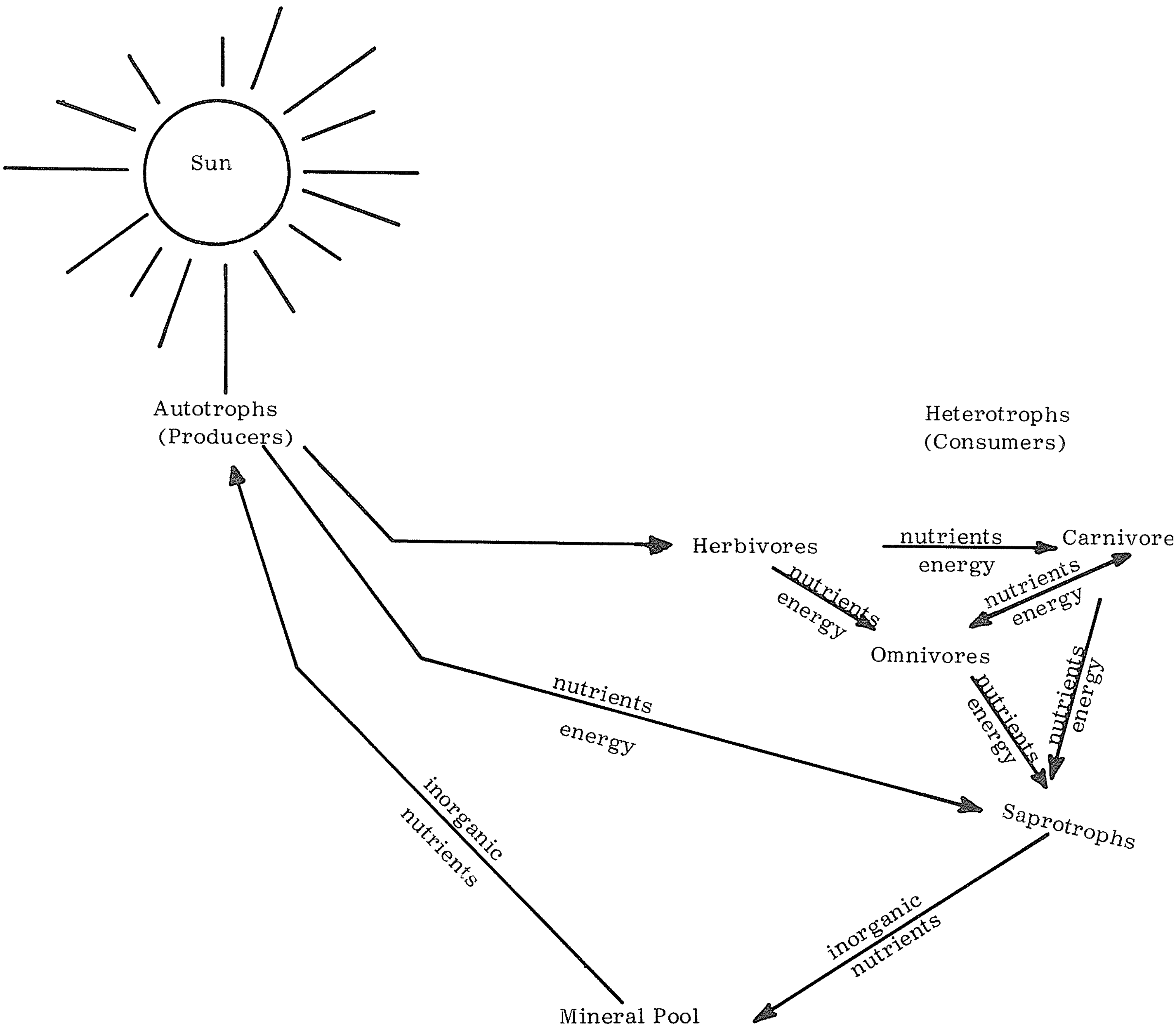

FIGURE 4. Simplified Diagram of Energy and Nutrient Flow in an Ecosystem.

Tracks of a predator; photo by M. Thompson, S. C. Water Resources Commission.

The omnivores of an estuary should also be recognized. This group includes those animals whose diets include both plants and animals. Several estuarine inhabitants with this type of dietary design include some of the marsh crabs which feed upon marsh grasses and which also occasionally spice up their menu with smaller crustaceans; and the shrimp, which not unlike many of the crabs, can be considered omnivorous scavengers, feeding upon smaller animals, plants and decaying plant and animal matter.

One point to keep in mind in this brief look at producer-consumer relationships is that the number or amount of organisms on a given level required to support life on a higher level greatly exceeds that which it supports. This implies that, in any food web, in any ecosystem, *X* pounds of autotrophs can produce fewer pounds of herbivores, which in turn can support so many fewer pounds of carnivores. An example of this diminishing relationship in an estuarine food chain was presented in a United Nations report (No. E/C. 7/2 Add. 7): "1000 pounds of phytoplankton (can) produce 100 pounds of shellfish, 50 pounds of small fish, 10 pounds of small carnivores and one pound of carnivores harvested by man."

A food pyramid is produced (see Figure 5) with the autotrophs forming the foundation; the herbivores the middle section; and the carnivores the zenith.

The food pyramid results from the inefficient transfer of energy through a food chain. As Kormondy (1969) revealed in his discussion of energy flow in ecosystems, of the total amount of energy fixed by producers in an ecosystem, only about 10 to 15% is utilized by herbivores. The energy fixed by the autotrophs but not utilized by the herbivores is lost to decomposers, or used in the metabolic activities of the autotrophs themselves, or just simply not utilized. Of this 10 to 15% energy value acquired by the herbivores, probably only 10 to 20% of this value will be utilized by the carnivores. Metabolic activity, nonutilization, and decomposition are responsible again for this loss of energy along a food chain. During the period of time that green plants convert radiant energy into chemical energy in the form of organic compounds, and the plants are eaten by a small herbivore, which is in turn eaten by a small crustacean, the energy in the food chain can be depleted by as much as 99%.

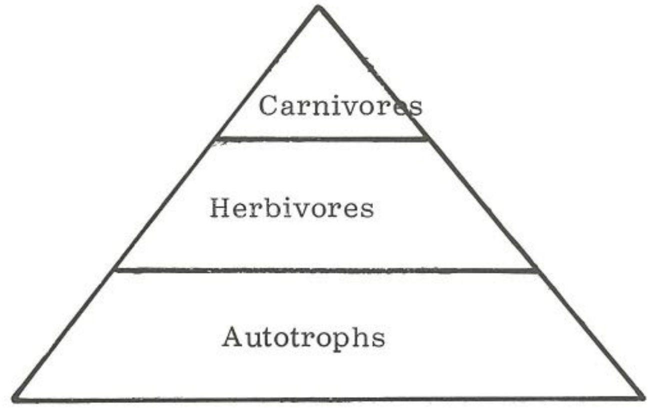

Figure 5.
Food Pyramid

Coupled with this low efficiency of energy transfer is the fact that energy flow in an ecosystem is also unidirectional. The radiant energy fixed by plants cannot be transferred back to the sun, and neither can energy acquired by herbivores and carnivores be reutilized by autotrophs or herbivores respectively.

Energy transfer in the system, is inefficient, unidirectional and noncyclic. The last step in energy transfer occurs with the decomposers. Nonliving plant and animal tissue is subject to decay or decomposition. The decomposers (bacteria, fungi and protozoa) derive their nutritional requirements and therefore their energy requirements from dead tissues and organic by-products. Decomposers represent the endpoint of energy flow in an ecosystem. They also, represent the last step in the cyclic flow of minerals through an ecosystem (see Figure 4). The end products of their processes, minerals, are once again returned to the mineral pool.

Hopefully, it has been thus far established that an estuary is a complex concoction of salinities, currents, organisms, food webs, energy patterns and more. It is a dynamic and yet a delicate system in which the organisms have adapted to conditions that are constantly changing. These conditions can include salinity fluctuations from almost fresh water to pure sea water in a day's time; or tidal fluctuations that twice a day can alternately flood an organism and then expose it to the drying sun; or temperature variations in excess of forty degrees in one tidal exchange period which can result when the cool waters recede and the bright sun heats the shallow pools and exposed flats. Nature has indeed made this a versatile and dynamic environment.

The Importance of Estuaries

The value of a resource is usually expressed in man-made terms. In the case of an estuary, these terms may be pounds of fish or shellfish, tons of shipping, gallons of water, acres of land or man-days of recreation. Seldom is such a natural resource considered valuable simply because it exists, but rather its value lies in what one can extract from it.

Man, through the years has located his megalopolises near the sea. Seven of the world's ten largest cities are situated on major coastal estuaries (New York, Tokyo, London, Buenos Aires, Shanghai, Osaka and Los Angeles).

Human beings obviously have an affinity for water. Millions flock to coastal resorts, attracted by the natural beauty and the recreational developments of the area. Responding to the law of supply and demand, coastal real estate is now an expensive commodity.

Other reasons, have contributed to the appeal of estuaries. The geographic location of estuaries, between the open seas and the inland waterways, along with their semi-enclosed nature make them natural harbors and centers of transportation. The abundance of water is also an attractive feature of these coastal zones. The estuaries and adjacent offshore regions provide convenient areas for sewage and solid waste disposal, while abundant ground water and surface water supplies prove to be enticing to large water-using industries and municipalities.

Perhaps, however, the most important asset of estuaries in terms that man can readily understand and directly associate with was alluded to earlier in this report, that asset being the natural productivity of these systems. Man is and has been attracted to estuaries because of their tremendous ability to produce food such as algae, clams, oysters, shrimp, crabs and fish. Estuaries are a vitally important and indispensable link in our continued efforts to harvest food from these near shore waters, the continental shelves and the open oceans. In fact, Ricker (1969) estimated that by the year 2000, over 20% of the world's needs for food protein could be derived from the sea. This is possible, however, only if the estuaries remain healthy. The importance of maintaining healthy estuaries and coastal zones becomes more evident in that approximately 80 to 90% of the catch of the United States' commercial fishery industry, which is rather typical of world fisheries in general (in terms of species composition), are marine fish, most of which depend upon estuarine waters during some phase of their life cycles (McHugh, 1967).

In Port Royal Sound in 1970, 107 different species of fish and 18 species of macro-invertebrates were caught and identified. The organisms were there for various reasons. They may have been just passing through the system; they may have been breeding in the estuary; or they may have just dropped in to feed. McHugh's following classification scheme for estuarine fishes, which demonstrates various ways that fish utilize these ecosystems, may be interpreted to show the importance of maintaining healthy estuaries in supporting viable fisheries:

1. Freshwater fishes that occasionally enter brackish water.
2. Truly estuarine species, which spend their entire lives in the estuary.
3. Anadromous and catadromous species.
4. Marine species which pay regular seasonal visits to the estuary, usually as adults.
5. Marine species which use the estuary primarily as a nursery ground, usually spawning and spending most of their adult life at sea, but often returning seasonally to the estuary.
6. Adventitious visitors, which appear irregularly and have no apparent estuarine requirements.

The one thing that most natural resources need not be concerned with today is a lack of attention. Estuaries are not exceptions. The concern of estuaries should be that they are too popular and too much in demand. Many of the demands placed upon them are basically incompatable. Fish cannot breed on filled marsh, and houses, roads and industries cannot be built on pluff mud.

In the past, society has had the option of determining which alternative uses for estuaries or for any of our natural resources were most desirable. Often, these various uses were at the expense of the natural system. Perhaps in the future, society will realize that a healthy environment is not only desirable, but essential for the continued existence and refinement of society and life upon our small and delicate planet.

Closing Thoughts

> Man's past effects on estuaries have been poorly and incompletely planned, unimaginative and frequently destructive. In view of the many important uses served by these waters, and the size of the growing pressures on them, it is imperative that a new major human force be utilized in the future—the force of intelligent management.
> Cronin, 1967

The future for estuaries as viable, functioning ecosystems is dim. Scientists know that pesticides, heavy metals, sewage, filling, dumping and dredging seriously harm these areas. Increasing pesticide concentrations have been linked with reproductive failures in brown pelicans, bald eagles, ospreys and oysters, as well as some fish. Certain pesticides are known to be toxic to zooplankton and to certain commercially important shrimp and crabs. Heavy metals such as mercury, cadmium, zinc, copper, chromium and lead tend to accumulate in estuarine sediments and are very toxic to both plants and animals. Many commercially important species of animals are very succeptible to these elements.

Bacterial contamination from sewage outfalls has been responsible for the closure of many recreational and shellfishing areas. The additional nutrients released or retained in an estuary from sewage outfalls or runoffs may result in increased primary production in the ecosystem, but excessive amounts of nutrients can also produce prolific growths of undesirable weed organisms. Through their growth and eventual death and decay, these organisms create conditions that are not favorable to the maintenance of the normal biota. Desirable plant species which provide food for the primary consumers (including in this case shellfish and fish) are unable to compete with the undesirables (such as certain species of algae) and the value of the area as a natural resource is diminished.

The effects of dredging, filling, and dumping on this ecosystem can also be quite deleterious. Each in varying degrees reduces the amount of natural habitat available to the estuarine organisms.

With these remarks in mind and assuming that man is not going to abandon the coastal zones, we are reminded of Cronin's opening statement—that the future of estuaries depends upon sound management. This statement should imply to all that indiscriminate destruction of coastal zones must be stopped and replaced with orderly, carefully conceived programs which provide for the utilization of these areas. The term management itself implies that development is controlled and directed. Intelligent management should include the zoning of certain coastal areas for recreational, residential, conservational, industrial, urban and other uses. Furthermore, it would promote the need for additional research. The complex physical, chemical and biological interrelationships which exist in coastal and especially estuarine areas and the impact that man has upon these systems are still poorly known.

Knowledge and its proper utilization are important ingredients in sound management. Knowledge about estuaries and the entire coastal zone must be obtained and disseminated. Scientific and technical personnel can handle these two responsibilities. To make these tasks worthwhile, however, this acquired knowledge must be utilized, and, more importantly, it must be utilized with wisdom. This latter responsibility falls not only to the planners, but also to the politicians, developers, conservationists and the general public. Collectively, these people help form society, and society will determine, by its whims and wishes, the fate of these ecosystems. Let's wish them both a healthy, prosperous future.

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CHAPTER THREE

THE ECOSYSTEM

Surface Water Hydraulics

Mathematical Simulation of The Flow Dynamics And Constituent Transport In Port Royal Sound, South Carolina: An Interim Report[1]

R. A. Baltzer
U.S. Geological Survey
Washington, D.C.
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1. Approved for publication by the Director, U.S. Geological Survey.

Abstract

Research leading to the development of general purpose, mathematical/numerical models with which to simulate the flow dynamics and constituent transport of well-mixed estuaries and coastal embayments is in progress. A description of one of these models, its scope, its capabilities, and its implementation to specifically represent Port Royal Sound, South Carolina, is presented briefly. The vertically integrated equations for fluid continuity and momentum conservation, together with the vertically integrated mass-balance, constituent-transport equation are the basis for model development in the two-dimensional, areal sense. Constituent reaction terms are included in the transport equation. For the particular model being implemented in Port Royal Sound a finite-difference, implicit numerical process is used to achieve successive solutions with respect to time. An extensive field-data collection program was specifically designed and instrumented to provide adequate, high-quality, prototype information with which to implement the model. The data collection program was carried out between April 1, 1970, and March 1, 1971. Precisely timed water stages were recorded digitally at seven selected field sites. Auxiliary stage data were collected as required at six other field locations. Tidal-cycle discharge measurements were made in six selected channel cross-sections, and three pairs of simultaneous tidal-cycle discharge measurements were made in six other cross-sections. Infrared and ordinary color aerial photographic coverage of the sound at high tide and at low tide provided information with which to delineate the extent of high-water inundation in the tidal-marsh regions and the degree of low-water dewatering of the marshes. Bathymetric data for Port Royal Sound were obtained from copies of the original manuscript field survey charts furnished by the National Ocean Survey, National Oceanic and Atmospheric Administration. These data were verified, updated, and augmented by field soundings; their interpretation was greatly enhanced by comparison with the low-water aerial photography.

The mathematical/numerical model of Port Royal Sound is intended to permit time-sequential simulation of the movement and concentration of nonconservative as well as conservative constituents injected into the embayment. However, it can also be used for a variety of other investigative purposes. The model is presently being parameterized and calibrated for a subregion of the embayment. When this has been accomplished, the model will be extended to cover the full embayment. Output from the model is in the form of film or hard-copy graphical displays of the flow vector field and contoured constituent concentration patterns at successive time intervals throughout the modeled region. It is anticipated that the model will become operationally available during the summer of 1972.

Introduction

Port Royal Sound is located on the continental Atlantic coastline between Charleston, South Carolina, and Savannah, Georgia. The mathematical simulation of the flow dynamics and constituent transport in the Sound is being undertaken by the U.S. Geological Survey in cooperation with the State Water Resources Commission, South Carolina, and is part of a comprehensive investigation of this embayment and the region surrounding it.

The specific purpose of the modeling effort is to permit simulation of the movement and dispersal of one or more conservative or nonconservative solute constituents injected concurrently into the Sound at one or more geographical locations. Within the context of this report, excess heat may be considered as a possible constituent. The Port Royal Sound simulation model should prove useful, however, for a variety of other purposes. It could be used to study the probable effects of potential, man-made modifications to the embayment configuration or to the bathymetry of the Sound. Such modifications might result from navigational dredging and the construction of spoil islands, from the diking and/or filling of marshlands, or from the construction of road causeways. The model might be used to assist with an areal investigation of the productivity of the tidal marshes or to investigate the movement and dispersal of a potential waste-heat loading. It could be used to delineate existing as well as hypothetical currents throughout a navigation channel, and to aid with the safe and economical design of an improved navigation channel. With some modification it could be used to determine the region that would be adversely affected by the dispersal and deposition of fine materials placed in suspension by a proposed dredging operation. The model could also be employed to determine the effects of extreme events such as the occurence of unusual flooding (or dewatering) in the sound caused by the proximity of a tropical-storm depression.

The general-purpose mathematical model being used in this investigation is one of two currently under development by the Water Resources Division, U.S. Geological Survey. Both models are two-dimensional in the areal sense and are intended for simulation of the flow dynamics in well-mixed estuaries and embayments. The model in use is an outgrowth of a two-dimensional flow-dynamics model first developed by Leendertse (1967). This model, significantly modified and expanded to include the transport and reactions of constituent solutes, is being used to simulate the flow dynamics and water quality conditions in Jamaica Bay on Long Island, New

York (Leendertse, 1970; Leendertse and Gritton, 1971). The U.S. Geological Survey, working jointly with J. J. Leendertse and the Rand Corporation, has undertaken further refinement, generalization, and development of this model. The version being employed currently in Port Royal Sound embodies the latest refinements.

This investigation marks the first time that implementation of a sophisticated, two-dimensional, mathematical model of a water body as large and complex as Port Royal Sound has been attempted. Implementation of the fully parameterized model is still in progress. Hence, it is both appropriate and timely to present this interim report summarizing briefly certain aspects of the undertaking. This report provides a brief description of the fundamental concepts used in the development of the mathematical/numerical model. It reviews the collection and processing of the field data needed for implementation of the model, as well as the actual implementation process. The report concludes with a summary of the computational requirements of the simulation model and a description of the form of the results typically produced by the model. Upon completion of the investigation a full and detailed report on the modeling effort in Port Royal Sound will be prepared.

The mathematical simulation effort being reported here is complemented by another study by the U.S. Geological Survey. The study is described in a report entitled, "A Tracer Simulation Study of Potential Solute Movement in Port Royal Sound, South Carolina," by Kilpatrick and Cummings (1972). In this other study the movement and dispersal of a fluorescent tracer dye injected at one particular geographic location under a single set of prevailing field conditions were observed in the field over an extended time period. Some of the findings of this study will be used to help verify the model.

Some Concepts of Mathematical Simulation

In recent years investigators of technical solutions to water-management and water-quality-control problems found in estuaries and embayments generally have come to recognize the value of and to depend increasingly upon mathematical modeling as a tool. Largely as a result of the introduction and rapid development of large-capacity digital computers, it is possible to build increasingly sophisticated mathematical models with which to investigate water-quality problems. For a particular problem situation, such models can then be used to predict the probable consequences of the various solution alternatives that appear worthy of consideration. By using the predictions obtained from such models, together with other appropriate information, one is able to evaluate technical solution alternatives and draw conclusions regarding the most desirable course of action. In summary, mathematical modeling provides a powerful means by which to analyze and compare solution alternatives and thereby to reach a more rational course of action than might otherwise be possible.

One must be cautioned, however, that mathematical modeling must be intelligently employed by knowledgeable persons fully aware of both its capabilities and limitations with respect to a particular prototype situation. Misuse of a mathematical/numerical model can lead to inaccurate conclusions and serious blunders. Moreover, mathematical modeling is not a substitute for the managerial function; it remains the duty of management to take appropriate action with due regard to associated sociopolitical, legal, and economic constraints, in addition to the optimal technical solution revealed by modeling.

It is the intent of the U.S. Geological Survey that the Port Royal Sound model shall evolve as a result of its general-purpose, estuarine simulation research effort, wherein high transfer value to several of the Nation's estuarine systems is sought. To meet this objective, the model must embody in mathematical/numerical form the physical and interacting chemical/biological properties, which, when taken collectively, constitute the total mechanism commonly identified as estuarine flow. The mathematical expressions describing the conservation of physical quantities, namely, fluid mass and momentum, together with those representing the conservation and rates-of-reaction of individual solute constituents within the flow are the fundamental building blocks used in model development.

Mathematical modeling, however, encompasses much more. Because the mathematical expressions mentioned above are generally complex, nonlinear, partial-differential equations, which cannot be solved by analytic means, they must be solved by some numerical process, in this instance, a finite-difference process. The transformation of the mathematical expressions into numerical, finite-difference expressions, the selection of a suitable areal grid system, and the development of an efficient numerical-integration procedure suitable for a high-speed digital computer are all extremely important aspects of model development. It is essential, of course, that the functioning of the whole model be thoroughly tested. No mass or energy should be created or destroyed in proceeding step-by-step through the numerical-integration process. The stability and the mathematical-dispersive properties of the numerical-computation process must also be considered. In summary, the model must be verified to insure that its numerical form and the attendant numerical-integration process used to exercise it do, indeed, retain the various properties embodied in the original mathematical expressions.

The implementation of a mathematical model includes the parameterization and calibration of the general purpose model so as to uniquely represent a specific, prototype water body. Parameterization, sometimes referred to as schematization, is the process by which the specific magnitudes of the appropriate field values — water-level histories, bathymetry, water temperatures and salinities, wind vectors, energy dissipation coefficients, etc.—constituting the initial and time-dependent boundary conditions particularizing the prototype region are incorporated in the generalized model. Calibration is the process by which the model is adjusted to reproduce within acceptable tolerances the quantitative and qualitative conditions observed in the prototype.

Finally, it is important to thoroughly test the functioning of the general purpose model under a wide range of field conditions. This can best be done by attempting to simulate conditions in two or more dissimilar estuarine systems. Port Royal Sound is characterized by its high-amplitude semidiurnal tidal pattern, dendritic channel structure, and extensive regions of tidal marshlands. In sharp contrast, Tampa Bay in Florida is characterized by its low-amplitude mixed diurnal/semidiurnal tidal pattern, lobate shape, shallow depth, and high susceptibility to wind surge. Data from both Tampa Bay and Port Royal Sound are being used in the model-evaluation process.

THE COMPUTATIONAL MODEL

The flowing water in an estuary or embayment is not only the vehicle by which solute constituents are transported, but also the medium within which solute reactions and interactions take place. The flow model is of fundamental importance in the development of a water-quality-simulation model for well-mixed estuaries and embayments.

Vertical integration of the continunity and momentum equations for fluid flow in the areal sense yields the following basic equations for two-dimensional flow in a well-mixed estuary (Leendertse and Gritton, 1971) :

$$\frac{\partial \zeta}{\partial t} + \frac{\partial (HU)}{\partial x} + \frac{\partial (HV)}{\partial y} = 0 \quad (1)$$

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} - fV + g\frac{\partial \zeta}{\partial x} + g\frac{U(U^2+V^2)^{\frac{1}{2}}}{C^2H} - \frac{1}{\rho H}\tau_x^s = 0 \quad (2)$$

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + fU + g\frac{\partial \zeta}{\partial y} + g\frac{V(U^2+V^2)^{\frac{1}{2}}}{C^2H} - \frac{1}{\rho H}\tau_y^s = 0 \quad (3)$$

where

f = the Coriolis parameter, as determined from geographical latitude,

g = acceleration of gravity,

ρ = water density,

ζ = water-level elevation with respect to the reference plane,

h = distance from the reference plane to the embayment bottom,

$H = h + \zeta$,

C = Chezy coefficient,

τ_x^s = surface wind-stress component in the x-direction,

τ_y^s = surface wind-stress component in the y-direction,

t = time.

The variables U and V are the vertically averaged velocities of flow defined as

$$U = \frac{1}{H}\int_{-h}^{\zeta} u \, dz \quad (4)$$

$$V = \frac{1}{H}\int_{-h}^{\zeta} v \, dz \quad (5)$$

where u and v are the point-flow velocities in the positive x and y directions, respectively. The wind-stress components are given by Dronkers (1964) as

$$\tau_x^s = \theta \rho_a w^2 \sin \psi$$

and

$$\tau_y^s = \theta \rho_a w^2 \cos \psi$$

where

θ = wind-stress coefficient,

ρ_a = air density,

w = wind velocity,

ψ = angle between wind vector and y axis.

Although the flow equations are defined using the Chezy coefficient this coefficient is actually treated as a variable as it is redetermined periodically using the Manning n coefficient and total depth H in the expression $C = (1.49\ H^{1/6})/n$. This procedure avoids the repetitive use of the Manning equation with its computationally unwieldy fractional exponents.

Transport of a solute constituent in well-mixed estuaries and embayments is given by the vertically integrated mass-balance equation for two-dimensional flow:

$$\frac{\partial(HP)}{\partial t} + \frac{\partial(HUP)}{\partial x} + \frac{\partial(HVP)}{\partial y} - \frac{\partial\left(HD_x \frac{\partial P}{\partial x}\right)}{\partial x} - \frac{\partial\left(HP_y \frac{\partial P}{\partial y}\right)}{\partial y} - HS_A = 0 \qquad (6)$$

where

D_x = dispersion coefficient, flow in the x-direction,

D_y = dispersion coefficient, flow in the y-direction,

S_A = source and sink function, including the rate of injection of constituent A.

As with the velocities U and V, P is the integrated average mass concentration of the constituent in the vertical given by

$$P = \frac{1}{H}\int_{-h}^{\zeta} p_A \, dz \qquad (7)$$

where p_A is the local mass concentration of a particular constituent substance, A. However, in order to deal with more than one constituent injected at one location, equation 6 must be generalized to include the simultaneous transport of several solutes. Moreover, because these constituents may be undergoing chemical, physical, and/or biochemical transformation during their transport, a reaction capability must be included. In matrix notation the generalized mass-balance equation for i constituents is written

$$\frac{\partial(H\overline{P})}{\partial t} + \frac{\partial(HU\overline{P})}{\partial x} + \frac{\partial(HV\overline{P})}{\partial y} - \frac{\partial\left(HD_x \frac{\partial \overline{P}}{\partial x}\right)}{\partial x} - \frac{\partial\left(HD_y \frac{\partial \overline{P}}{\partial y}\right)}{\partial y} + [K]H\overline{P} - H\overline{S} = 0 \qquad (8)$$

where

$\overline{P}$ = mass-concentration vector for i constituents,

[K] = reaction matrix in which the K terms are the reaction rates,

$\overline{S}$ = source/sink vector.

Equations 1, 2, 3, and 8 are the fundamental mathematical expressions used in the development of the model being implemented for Port Royal Sound. The transformation of these equations into numerical form and the development of the digital-computer oriented numerical-simulation procedure is far beyond the scope of this report. However, in order to understand the prototype data requirements better it is worth noting that in the finite difference approximation of these equations, the discrete values of the variable are described on the space-staggered grid illustrated in Figure 1. The velocities, U, are computed at the half-integer values of j and integer values of k, whereas the velocities, V, are computed at the integer value of j and the half integer value of k. The water levels, ζ , and the mass, P, are computed at integer values of j and k. The values of water depth, h, are given at half-integer values of j and k. Note that the water levels and water depths do not coincide geographically.

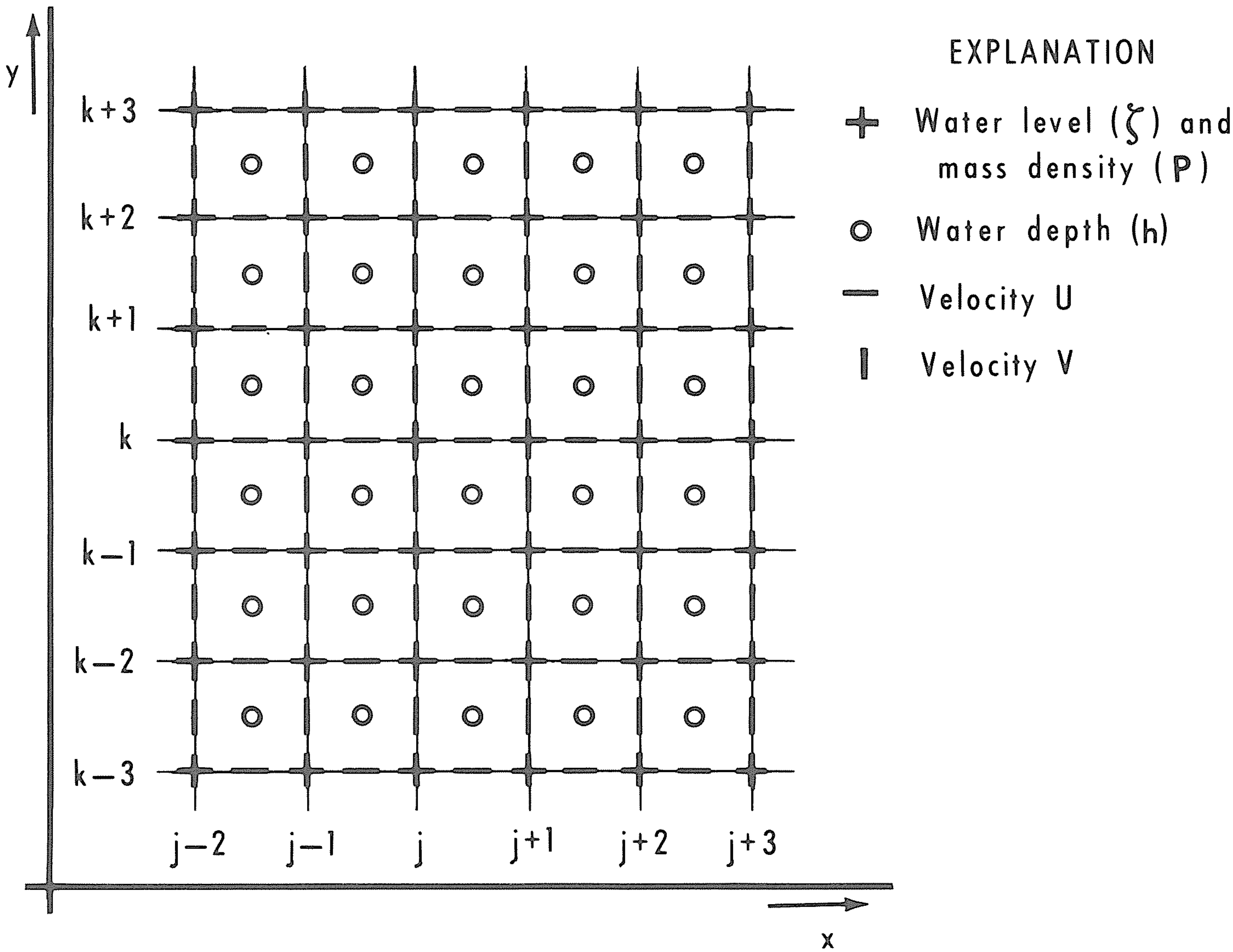

Figure 1. Space-staggered grid for numerical integration model.

Port Royal Sound Embayment

The map presented in Figure 2 shows the location and some of the significant features of Port Royal Sound. The Sound, typical of many of the estuaries and embayments along the southeastern Atlantic coast of the United States, is characterized by rather high tidal amplitudes, very extensive areas of semi-diurnally flooded-and-dewatered marshlands, and a dendritic channel structure. The main channel of the embayment, identified in its upper reaches as the Broad River, extends inland approximately 24 miles from the coast. At mean tide the mouth of the sound is approximately 3 miles wide.

The region immediately surrounding Port Royal Sound is rural, composed largely of farmland, wooded acreage, and open countryside. Hilton Head Island on the southeast side of the entrance to the sound is an extensively developed island resort. Parris Island Marine Base is located on Parris Island directly south of the town of Port Royal.

By virtue of the fact that, hydrologically speaking, Port Royal Sound is wedged between the Savannah River drainage system to the southwest and the Combahee River drainage system to the north and northwest, the upland region contributing fresh surface water into the sound is very small. The Coosewhatchie River, the principle source of fresh surface water to the sound, has had an annual average discharge of less than 300 cubic feet per second during the past 20 years of record. The rate of fresh surface-water drainage entering the sound from other small tributary streams is not significant.

Fresh ground-water inflow to the embayment may be a source of minor dilution. An artesian aquifer having a potentionmetric surface ranging from approximately 10 feet above mean sea level in the upper reaches of the embayment to sea level at its mouth, underlies the region at a depth ranging from 50 to 100 feet below mean sea level. Several shallower aquifers of very limited areal extent and capacity overlie the artesian aquifer and may crop out in the deeper parts of the sound near the mouth. Hence, dilution of the ocean water in Port Royal Sound by either fresh surface-water or fresh ground-water inflow is inconsequential.

Because of the lack of significant fresh water discharges to the sound, the fresh-water/salt-water mixing and other attendant features typical of a river estuary are not evident. It is for this reason that Port Royal Sound may be more accurately referred to as an embayment.

The Colleton and Chechessee Rivers, major waterways in their own right, are really tidal subreaches of the main embayment. The Beaufort River and Whale Branch connect Port Royal Sound to the Coosaw River and St. Helena Sound to the northeast, whereas Skull and Mackay Creeks connect it to Calibogue Sound to the southwest. However, as will become evident later in the report, the physical identities of many of these waterways become grossly different at high tide (with respect to the mean low-water map delineations, Fig. 2) when the marshlands are fully inundated and the region assumes a lakelike appearance.

The natural channel depts in Port Royal Sound are great. The depths in the lower reaches of the embayment average about 40 feet, whereas those in the Chechessee, Beaufort, Colleton, and upper Broad Rivers average 25 to 30 feet (mean low water). However, numerous sand bars, banks, and shoals characterize the sound, particularly the confluences of the subreaches with other subreaches or the main channel. Despite the dynamic character of the flow in the sound, these features seem to be in a state of long-term dynamic equilibrium.

The mean range of the semidiurnal tide in the sound varies from about 7.0 feet at the mouth to about 8.1 feet in the upper reaches. However, spring tides in excess of 10.3 feet have been recorded during this study in the upper reaches of the embayment.

Field data verify that the water in the sound is very well mixed vertically. No appreciable vertical variation in specific conductance or in dissolved oxygen was observed (Kilpatrick and Cummings). Although specific conductance in the lower reaches was found to be generally slightly higher than in the upper reaches, the water throughout the embayment is sea water. Thus, the sound is well mixed both vertically and areally.

COLLECTION OF FIELD DATA

The preceding sections of this report introduced certain of the concepts of mathematical modeling of estuarine systems and described the fundamental mathematical expressions being employed in the modeling effort. The report has also presented a hydrologic description of Port Royal Sound. The succinct object of the simulation effort bears repeating: it is to produce an areal representation of the time-varying flow and constitutent distribution patterns in a well mixed estuary or embayment. Therefore, the areal representation itself must be dynamic and a function of time. Large numbers of input field data are required in order to simulate and represent the real-world, time-varying prototype processes. The collection of the data to meet the requirements of model implementation is the subject of this section.

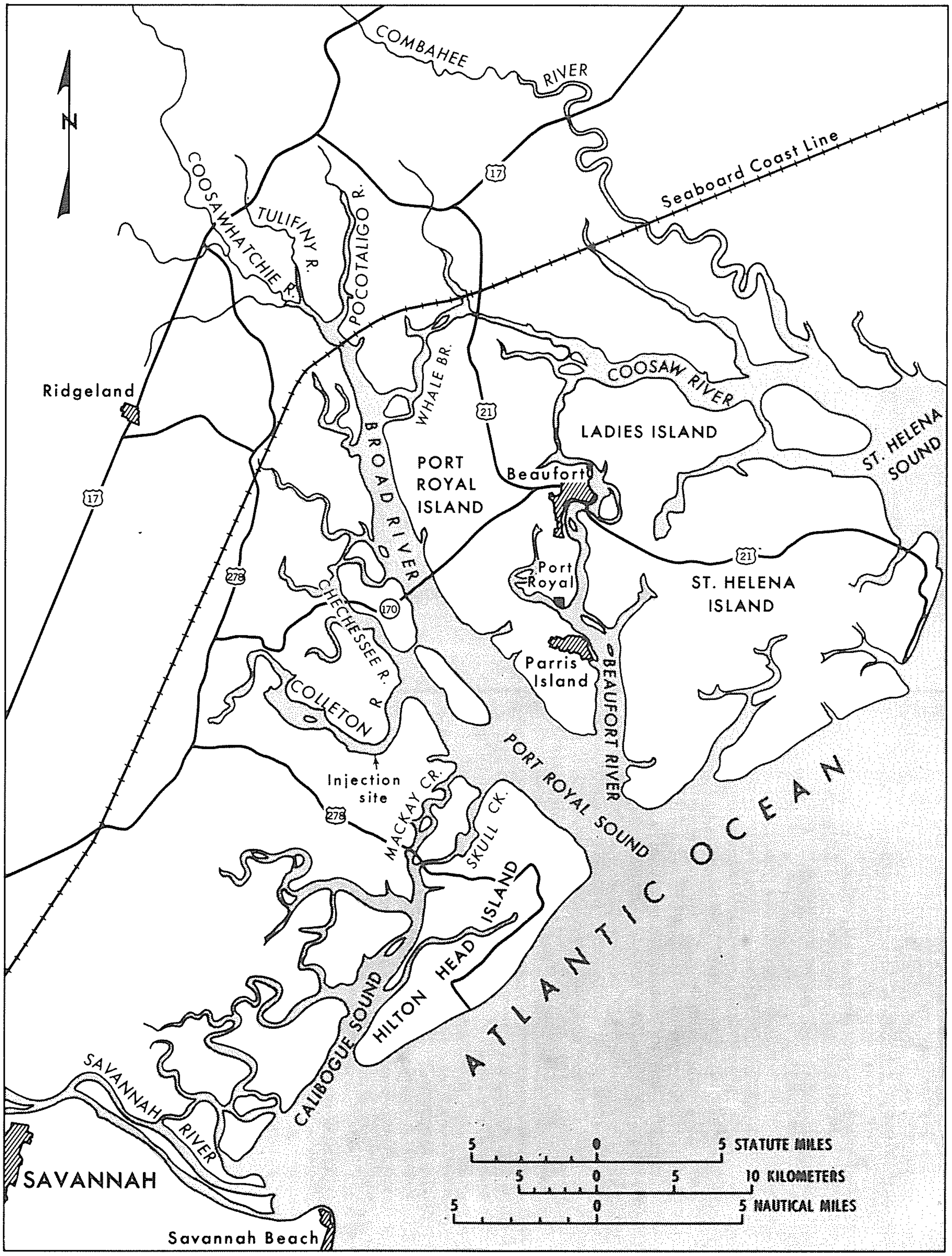
N
COMBAHEE RIVER
Seaboard Coast Line
COOSAWHATCHIE R.
TULIFINY R.
POCOTALIGO R.
17
WHALE BR.
COOSAW RIVER
LADIES ISLAND
ST. HELENA SOUND
Ridgeland
21
BROAD RIVER
PORT ROYAL ISLAND
Beaufort
17
278
CHECHESSEE R.
170
Port Royal
ST. HELENA ISLAND
Parris Island
BEAUFORT RIVER
COLLETON R.
Injection site
278
MACKAY CR.
SKULL CK.
PORT ROYAL SOUND
ATLANTIC OCEAN
HILTON HEAD ISLAND
CALIBOGUE SOUND
SAVANNAH RIVER
SAVANNAH
Savannah Beach
5 0 5 STATUTE MILES
5 0 5 10 KILOMETERS
5 0 5 NAUTICAL MILES

Figure 2

Examples of the types of prototype data that may be required to implement a mathematical model simulating the flow dynamics and constituent transport of well-mixed estuaries and embayments can be classified under four principle headings, as follows:

(1) Geographical boundary data — bathymetry, topography, latitude, bathymetric roughness.

(2) Water data — temperatures, densities, tidal water-level histories, selected measured flow rates, upland drainage rates.

(3) Atmospheric data — surface wind-vector histories, air temperatures, net radiation rates, precipitation rates, barometric-pressure histories.

(4) Constituent data — dissolved oxygen contents, biological oxygen demands, waste heat loadings, solute-injection rates, suspended-solids concentrations, solute-reaction rates.

Fortunately, not all of the individual types of data listed above need be collected for each modeling effort; the particular field conditions and the simulation objective of the modeling effort will determine which types of data must be collected and often the manner in which collection is best accomplished.

Figure 3 shows the topographic map coverage available for Port Royal Sound. As a first step toward defining the bathymetry of the channels and of the extensive tidal marshlands adjacent to the channels, an aerial photographic survey of the Sound was made. On April 7, 1970, two complete photographic missions were flown over approximately the same region as that covered by the topographic quadrangle maps, Figure 3. One mission was flown at high tide and the other at low tide. Vertical infrared and Ektachrome color imagery was produced from both missions. Flight lines were specifically oriented in a northeast/southwest direction across the Sound. Each mission was coordinated with the movement of the tide-wave crest or trough so that the time at which the photographs were taken along each successive flight line would coincide as nearly as possible with the time of the local high or low tide, respectively. Figures 4 and 5 are example infrared views of a part of Lemon Island between the Broad and Chechessee Rivers, whereas Figures 6 and 7 are example views of a region including the upper Colleton River near Bailey's Landing. The photographic coverage has proved of great value, not only in defining the inundation and dewatering of the tidal marshlands, but also when used together with the bathymetric data in defining the detailed flow patterns.

The bulk of the bathymetric data has been obtained from photocopies of the original field manuscript charts furnished by the National Ocean Survey. Additional soundings at cross sections and at specific points were made to verify and, in some instances, update or augment these data.

In order to obtain tidal water-level histories that could be used as the time-dependent boundary condition with which to drive the model, eight precisely timed digital water-stage recording stations were established. (See Fig. 3.) These stations were located so as to provide tidal-stage information on the various channels at approximately the positions where, ultimately, the boundaries of the model would subtend the channels. Construction of the water-stage gaging station on the southwest side of the entrance to Port Royal Sound is shown in Figure 8.

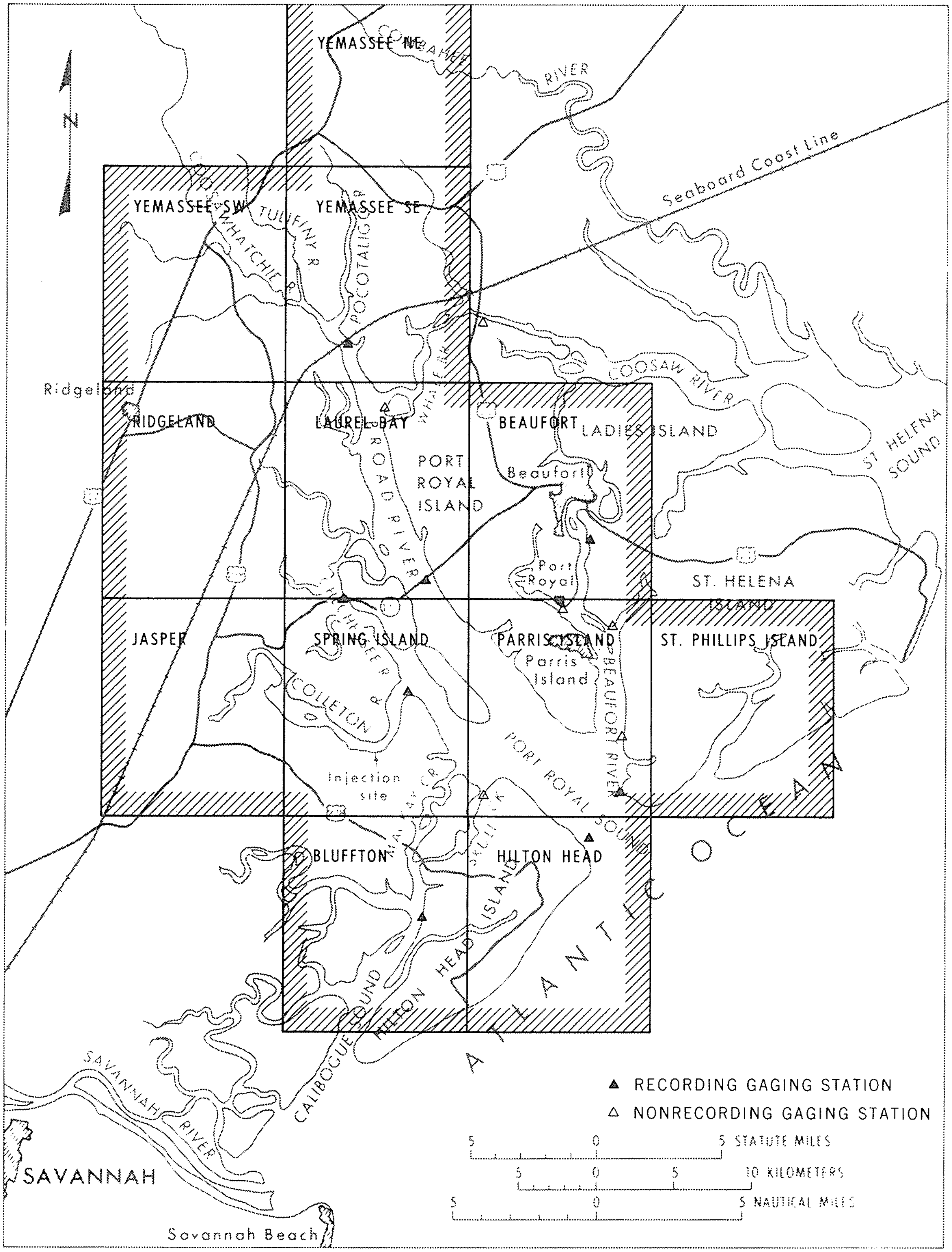

Figure 3. Topographic map coverage, Port Royal Sound; each 7½-minute quadrangle is identified by its map name.

Figure 4. False-color infrared, aerial view of region surrounding highway SC-170 on Lemon Island, Port Royal Sound; photograph was taken vertically from an altitude of 9,000 feet on April 7, 1970, at 0951 hours, e.s.t., and just prior to high tide; note inundation of marshlands between Broad River (left) and Chechessee River.

Figure 5. False-color infrared, aerial view of region surrounding highway SC-170 on Lemon Island, Port Royal Sound; photograph was taken vertically from an altitude of 6,000 feet on April 7, 1970, at 1549 hours, e.s.t., and just prior to low tide; note detailed drainage configuration in the dewatered tidal marshlands.

Figure 6. False-color infrared, aerial view of upper Colleton River and adjacent region near Bailey's Landing, Port Royal Sound; photograph was taken vertically from an altitude of 9,000 feet on April 7, 1970, at 0947 hours, e.s.t., and prior to high tide; note suspended matter in water and large-scale flood-tide turbulence patterns around submerged shoals.

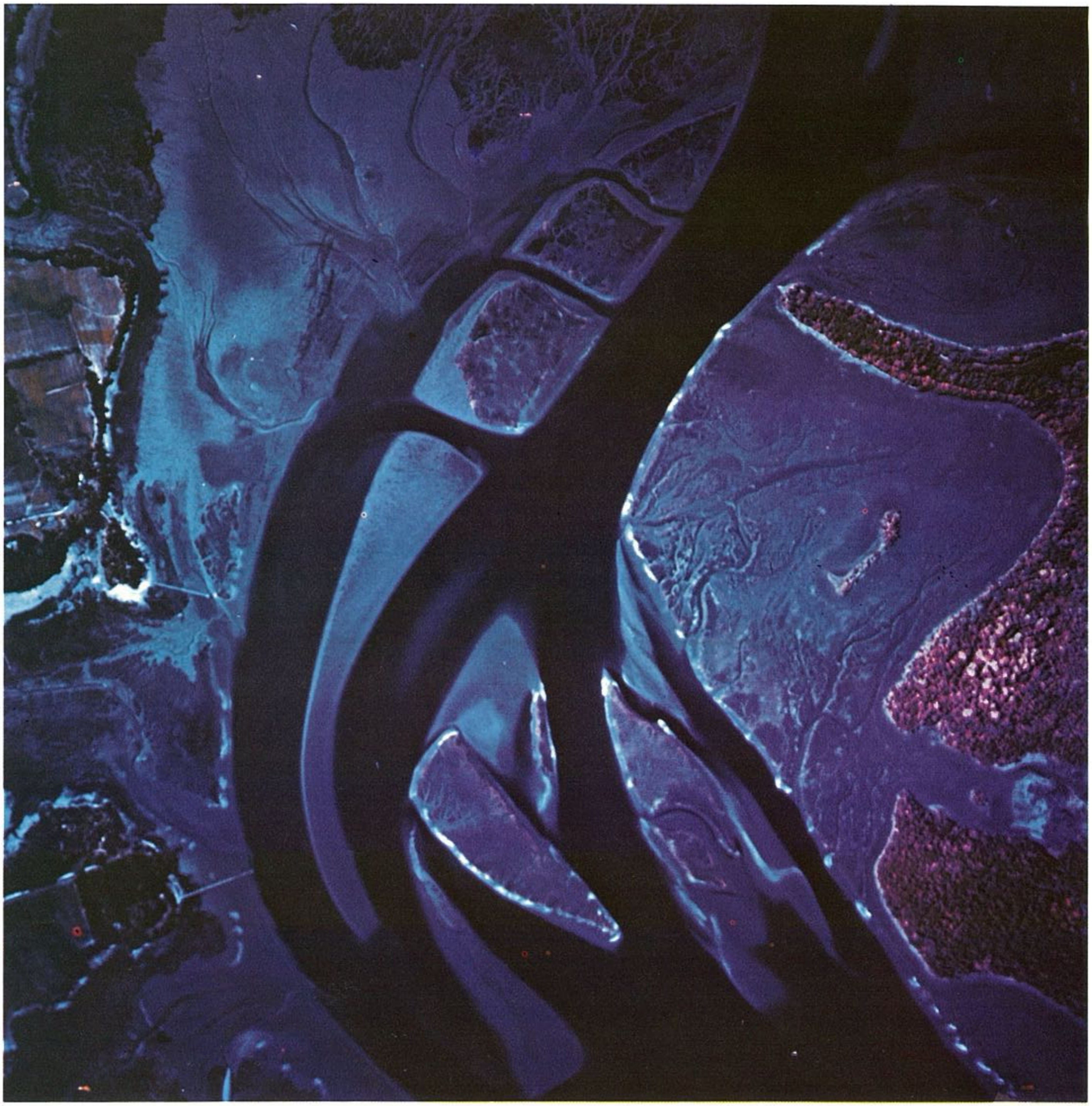

Figure 7. False-color infrared, aerial view of upper Colleton River and adjacent region near Bailey's Landing, Port Royal Sound; photograph was taken vertically from an altitude of 6,000 feet on April 7, 1970, at 1543 hours, e.s.t., and prior to low tide; note complex channel configuration and drainage pattern of tidal marshlands.

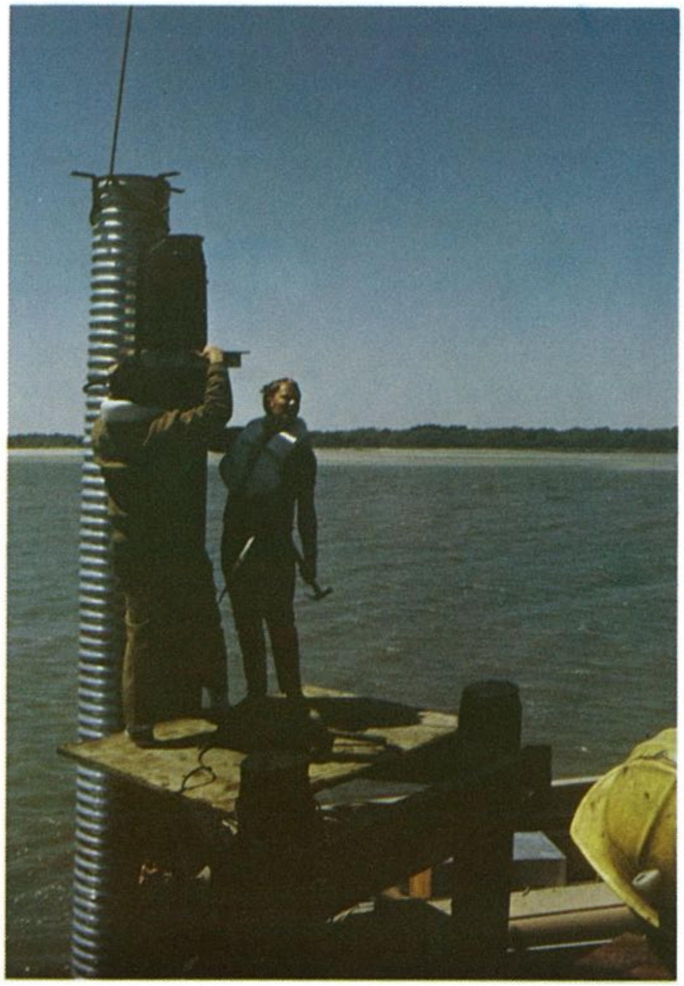

Figure 8. Construction of water-level gaging station on the southwest side of entrance to Port Royal Sound; station located offshore of Hilton Head Island.

It is imperative that recorded stage data be precisely timed; a discrepancy in timing results in an apparent change in the propagation rate of the tide wave and a very appreciable distortion of the flow and circulation patterns produced in the model (Baltzer and Lai, 1968). To insure precise timing of the digital recorders, all of the gaging stations were equipped with battery-operated, temperature-compensated, precision, crystal timers, having a rated accuracy of less than ±5 seconds variation from reference time per month. Standard time signals broadcast by shortwave radio station WWV, operated by the National Bureau of Standards, Fort Collins, Colorado, were used as the time reference. In this manner the recording of water stages was synchronized throughout the embayment. Water stage data were digitally recorded to the nearest hundredth of a foot on punched paper tape every 15 minutes. Each of the gaging stations was referenced to −10.00 feet mean sea level.

An intense local ocean storm wrought havoc in Port Royal Sound in the late spring of 1970. Both of the recording gaging stations located at the entrance to the sound were substantially damaged by the storm and valuable water-level records lost. The station on the southwest side of the entrance to the sound was immediately reestablished. However, the station across the entrance was never successfully reestablished, and only a fragmentary water-stage record is available for this location. Virtually complete records for the period of the field study (April 7, 1970, to March 1, 1971) are available for all of the other gaging locations.

In order to be able to verify the flow rates through the various channel cross sections, as simulated by the model, comparable data from the field are needed. In anticipation of this need a series of tidal-cycle-discharge measurements were made at selected cross-sections. Six nonrecording auxiliary water-stage stations were established to provide additional stage data to be used in the model calibration. The locations of these stations are shown in Figure 3. The site locations and dates of the tidal-cycle-discharge measurements are given in Table 1. The tidal-cycle discharge measured in Whale Branch at the highway bridge was accomplished using standard current meter techniques. All of the other measurements were made using moving-boat techniques (Smoot and Novak, 1969). During the time of each of these measurements, water stages, carefully referenced with respect to time and datum, were observed and recorded at the auxiliary stations in the vicinity of the measuring site.

Field observations describing the movement and dispersal of a solute constituent under a particular set of known field conditions would clearly be an asset in the parameterization and calibration of the model. As a result of a separate but complementary investigation conducted in Port Royal Sound by the U.S. Geological Survey, such data are available. The water-soluble fluorescent dye, rhodamine WT, was injected into the Colleton River at Victoria Bluff, a site located 2.8 miles above the confluence of the Colleton and Chechessee Rivers. (See Fig. 2.) The field-injection technique was specifically designed to simulate a continuous line-source introduction of dye across the channel. The actual injection of dye was begun with the start of ebb tide at 2240 hours on April 7, 1970, and was continued uninterrupted for one lunar day until 2320 hours on April 8. A very extensive water-sample-collection program was conducted to monitor the movement and dispersal of the dye throughout the embayment during the next 43 days. Water samples, collected at predesignated field sites by boats, helicopter, and anchored automatic samplers, were analyzed by carefully controlled fluorometric techniques. In addition, water temperature, conductivity, and dissolved-oxygen data were also collected throughout the Port Royal Sound embayment during this time period, but on a less comprehensive scale areally and timewise. The scope, the field program, the data-analysis technique, and the findings of this investigation are the subject of a report by Kilpatrick and Cummings. All of these data are available to aid the model implementation.

Model Implementation

Model implementation as discussed here is interpreted broadly to include not only the processes for model parameterization and calibration, but also the processes for preparation of the prototype data for input into the model. This section begins with a discussion of the more important aspects of model implementation, following which, certain of the specific procedures being used to parameterize the generalized simulation model to represent Port Royal Sound are described. Also included in the section is a cursory review of some of the data-processing techniques used in conjunction with the implementation processes and with application of the simulation model itself.

The comprehensive computer program that performs the actual numerical simulation of the flow dynamics and constituent transport, though being of fundamental importance and the focal point of the modeling effort, is but one program in a whole system of computer programs. The other programs—many of which are very sophisticated in their own right—are best described as supporting programs.

TABLE 1. List of tidal-cycle-discharge measurements, Port Royal Sound

Field Measurement Location	Date
Battery Creek at mouth	June 24, 1970
Chowan Creek at mouth	June 25, 1970
Colleton River at mouth	July 15, 1970
Whale Branch near Corning Landing	July 16, 1970
Whale Branch at U.S. 21 bridge	July 16, 1970
Chechessee River at SC-170 bridge	July 28, 1970
Broad River at SC-170 bridge	July 29, 1970
Skull Creek near Calibogue Sound	July 30, 1970
Beaufort River near Spanish Point (below Beaufort)	August 13, 1970
Beaufort River at mouth	August 13, 1970
Broad River at SC-170 bridge	August 26 and September 9, 1970
Port Royal Sound entrance	August 26 and September 9, 1970

They perform various tasks such as the digital filtering and editing of the raw field data, the creating and updating of various data files, the creating and checking of a particular set of input data to be used in the flow/transport simulation program, and the plotting of the output data from that program by either optical or mechanical digital plotter. Although it is beyond the scope of this report to describe the details of the various computer programs and the supporting functions they perform, it is important that the reader understand that this integrated system of supporting programs exists, that it is widely used in both the model-implementation function and in prototype flow/transport simulation, and that it is of fundamental importance to the development of an operational mathematical-modeling capability. Without these supporting computer programs, the numerical-simulation model would be of little more than academic interest.

Implementation of the Port Royal Sound model is still underway. Much work yet remains to be accomplished. Because of these facts, certain of the decisions pertaining to the model implementation are subject to change. Some of the techniques, which are still under development, will be modified. Thus, the discussions contained in this section of the report should be viewed as reflecting the state-of-the-art as of this writing (February 1972) and not necessarily a finished effort. All data presented herein are provisional and subject to change, pending further analysis.

The intricate and complex physiography of Port Royal Sound and the variable, highly dynamic character of its flow regimen, make implementation of the general purpose mathematical/numerical simulation model representing this embayment both formidable and challenging. The task of implementing the model is being undertaken jointly by J. J. Leendertse, of the Rand Corporation, and by the author. This effort marks the first time that parameterization and calibration of a highly developed, two-dimensional model of a water body as large and complex as Port Royal Sound has been attempted.

The boundaries of the region to be modeled, the orientation of the region, and the size of the computational grid are among the first items to be set forth in the model-implementation process. Several important criteria must be considered in choosing these parameters.

As a consequence of the fact that the numerical simulation scheme is premised upon a square grid, the modeled region will be necessarily of rectangular shape and will have overall dimensions that are integral multiples of the spatial grid size selected. However, when selecting a suitable grid size, one is confronted by two conflicting constraints: (1) the computational accuracy and fidelity of the model, and (2) the degree of the computational effort measured in terms of dollar cost. If the grid size selected is too large the model becomes difficult to calibrate and both the approximation of the flow and the constituent transport in the channels become inaccurate and of dubious value, especially during low tide. Clearly then, selection of a grid size greater than a certain threshold dimension would result in totally meaningless computations. Nevertheless, one must not lose sight of the fact that the dispersive properties of the numerical-computation scheme are related to the time-step interval at which successive areal computations are to be made, specifically, to the ratio of this interval to the spatial grid size. A decrease in the spatial dimension between adjacent grid points consequently requires a proportional decrease in the computational time-step interval. Thus, the computational effort is inversely proportional to the third power of the grid size. One ultimate constraint to diminishing the spatial grid size, which was not previously mentioned, is the maximum capacity of the high-speed memory of the digital computer that one anticipates using in the numerical-computation process. Obviously, this capacity cannot be exceeded. To summarize from the mathematical viewpoint, one may visualize the region to be modeled as being comprised of a two-dimensional, spatially oriented array of points at which the parameters depicting certain of the prototype characteristics must be defined and at which the unknown quantities are to be computed at successive time-step intervals.

The orientation of the gridded region must be adjusted rotationally so that the flow vectors at the various open-water boundaries are as parallel as practicable to one of the grid axes. This is desirable in order to simplify, if possible, the special computational procedures that must be employed at each of the open-water boundaries.

The detailed and complex character of the physiography of Port Royal Sound and the dynamic variability of its flow regimen require that a relatively fine grid size be adopted for model implementation. A grid size of 600 feet has been selected for the initial modeling effort. This grid size is believed by the author to be adequate to maintain the computational accuracy and fidelity of the model.

The task of implementing the mathematical simulation model representing Port Royal Sound is an immense undertaking. In order to simplify the task and to reduce both the time and computational costs associated with it, the process is being done in two steps. The simulation model is being implemented, first, for a subregion of the final model. The geographical boundaries of the regions included in both the preliminary and final versions of the simulation model are shown in Figure 9. The smaller size of the arrays used in the preliminary version of the model reduces both the digital computer costs and computer turnaround time substantially. Moreover, the experience being gained parameterizing and calibrating the preliminary version of the model is expected to aid implementation of the final version appreciably. Once implementation of the preliminary version of the model is well in hand, the dimensions of the spatial arrays can be simply increased to their full extent and the parameterization and calibration of the remainder of the model begun. The dimensions of the arrays for the preliminary version of the model are 104 by 126 grid steps; the physical dimensions of the rectangular region modeled are 11.8 by 14.3 miles. The array dimensions and physical dimensions of the final model are 141 by 192 grid steps and 16.1 by 21.9 miles, respectively. Note that the alinement of the model is such that the flow vectors at the open-water boundaries at the mouth of the sound and at the upper end of Broad River remain approximately normal to the model boundaries during ebb and flood tide.

In order to simulate the flow dynamics within the modeled regions, certain prototype conditions observed in the field must be imposed at the open-water boundaries of the model. These conditions serve to tie the modeled region into the flow dynamics of the real world surrounding it. Theoretically speaking, one could use either time sequential rates-of-flow or water-stage levels for this purpose. However, rates-of-flow are both difficult and expensive to obtain and are so seldom available in prototype situations that recorded water stages are the data normally used for this purpose. The reader will note from figure 9 that recording water-stage gaging stations are situated near each of the open-water boundaries, with the exception of Whale Branch. At this site the waterway is sufficiently small that synthesized stages, determined from one or more of the other nearby water-level records, could be used to supply the information needed at this particular boundary site without introducing appreciable error. When hypothetical flow and constituent-transport situations are to be investigated, the water-stage data required at all the open-water boundaries must be synthesized from existing records. Those water-stage records available at interior points within the modeled region serve to help calibrate the model and to verify its subsequent performance. The digitally recorded water stages collected in the field, after being subjected to a rather extensive digital filtering and editing process, are stored on a mountable magnetic disc pack for high-speed retrieval by the computer. Figures 10A and 10B are time-sequential plots showing the water-stage levels recorded at the SC-170 highway bridge on January 1, 1971. The data used in these plots were retrieved from the disc file and are representative of all of the water-stage data collected in Port Royal Sound and now on this file.

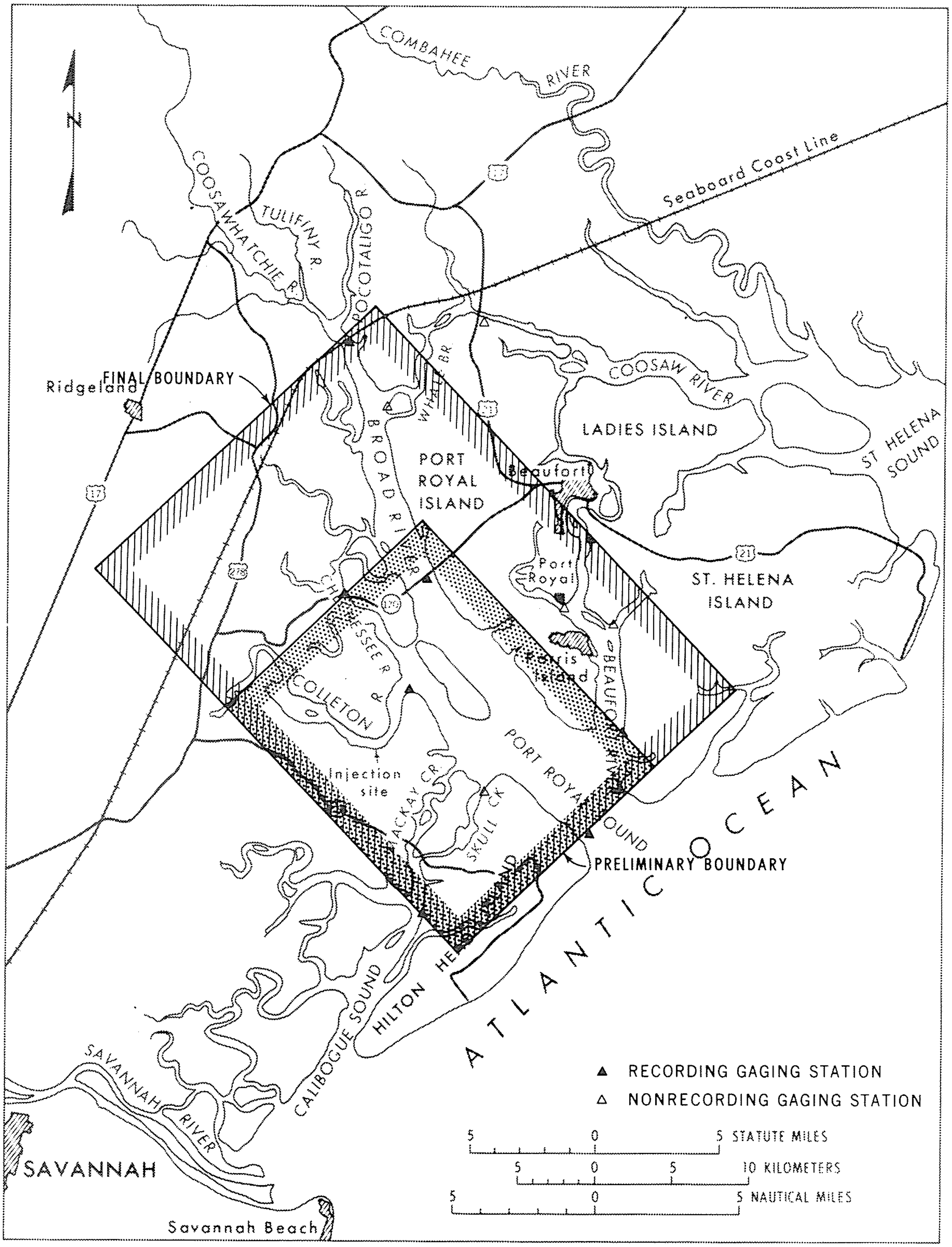

Figure 9. Map showing boundaries of the geographical regions included in the preliminary version and final version of the Port Royal Sound mathematical simulation model.

In Port Royal Sound the dynamic variability of the flow regimen is attributable largely to the complex and intricate character of the physiography of the embayment. Very extensive regions of tidal marshlands and flats adjoin the main channels. Examination of aerial photographs of these marshlands reveals that they are composed of a progression or hierarchy of bifurcating channels, subchannels, and tributaries to subchannels. The dewatered tidal marsh with its meandering drainage gully shown in Figure 11 is typical of the tidal marshlands found throughout the region being modeled. The tidal marshlands and flats adjacent to the permanently inundated waterways and channels were observed to be occasionally edged by a low rim or berm composed largely of shells and cobbles. However, these berms are intermittent in extent and are penentrated frequently by marshland drainage channels breaking through to a confluence with the permanently inundated waterways. The significance of this feature is that in many instances flooding of a marshland region first occurs in the interior as a result of the initial flood-flow filtering through the channels. Finally, a water level is reached at which flow passes directly over the berm. The process is reversed during ebb tide. The areal pattern of flow is clearly affected by this condition. In many other instances flow over the tidal flats and marshlands interconnects adjacent waterways and main channels above a threshold level of the tide. Therefore, it is important that the inundated regions modeled by the mathematical-simulation program not only expand and contract with the passage of each tide wave, but also that the parameterization of the model captures the essence of the manner in which the flooding and dewatering of the marshlands actually occurs.

As a first step toward the development of the bathymetry needed in the model, the high- and low-tide infrared photography of the embayment was projected upon the topographic map bases of the modeled region. (See Fig. 3.) The high-water and low-water inundation boundaries were determined and transcribed onto the individual map quadrangles. The result of this process is illustrated in Figure 12. The high-water and low-water inundation boundaries for the Spring Island quadrangle are defined by the dashed lines and dotted lines, respectively. Similar maps were developed for each of the other topographic quadrangles. An overlay grid, scaled 600 feet on each side and oriented in the manner of the model, was then placed over each inundation-boundary map. Figure 13 is an example showing the grid superimposed upon the Laurel Bay inundation map.

The specific bathymetric data needed in the simulation model are the depths at the centers of each of the grid squares lying on or within the high-water inundation boundaries. Copies of the original manuscript charts showing the detailed bathymetry of Port Royal Sound were obtained from the National Ocean Survey. For certain regions of the embayment the bathymetry shown on the charts was verified, updated, and augmented using recent soundings obtained in the field. To determine the appropriate model depth for each grid-square center, transparent copies of the inundation-boundary maps with the superimposed grids are placed over the appropriate bathymetric chart converted to the same map scale, after which the values can be determined one by one. This is an arduous task requiring assiduous attention to properties of both model and prototype: it requires detailed familiarity with the numerical simulation techniques employed in the model, as well as experienced insight into the dynamics of the flow/transport process. When selecting appropriate grid depths, one must consider not only the local average bathymetry within each grid square, but also the manner in which each selected grid depth will integrate with the adjacent grid depths such that the flow/transport regimen produced in the model will most nearly duplicate the flow/transport regimen observed in the prototype. The appropriate aerial photographs, when used to augment the information on the bathymetric charts, have proven to be a particularly useful aid in the selection of grid depths in the marshland regions.

The energy introduced into the embayment by the propagating tide wave cascades to waves of shorter and shorter wavelengths and is finaly dissipated through viscous action. In order to accomplish energy dissipation in the simulation model, the traditional hydraulic engineering approach is followed:

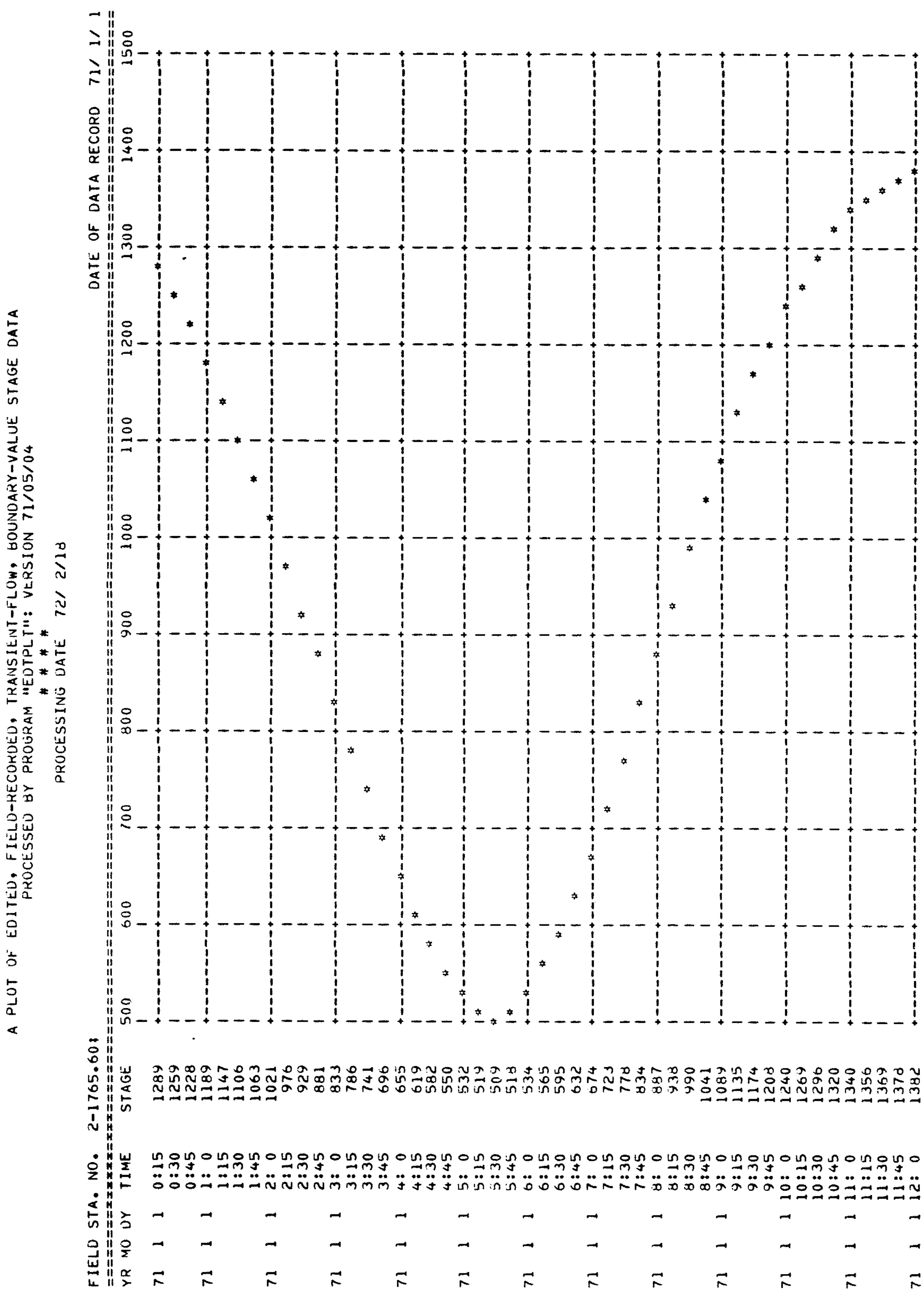

Figure 10A. An example plot of the edited stage data rcorded at gaging station No. 02-1765.60, located on the Broad River at the SC-170 highway bridge, 0015 to 1200 hours, e.s.t., Jan. 1, 1971; stages are in hundredths of feet and referenced to −10.00 feet mean sea level.

A PLOT OF EDITED, FIELD-RECORDED, TRANSIENT-FLOW, BOUNDARY-VALUE STAGE DATA
PROCESSED BY PROGRAM "EDTPLT": VERSION 71/05/04
# # # #
PROCESSING DATE 72/ 2/18

FIELD STA. NO. 2-1765.60; DATE OF DATA RECORD 71/ 1/ 1

YR	MO	DY	TIME	STAGE
			12:15	1381
			12:30	1373
			12:45	1354
71	1	1	13: 0	1329
			13:15	1301
			13:30	1267
			13:45	1236
71	1	1	14: 0	1199
			14:15	1160
			14:30	1120
			14:45	1079
71	1	1	15: 0	1036
			15:15	991
			15:30	943
			15:45	895
71	1	1	16: 0	845
			16:15	797
			16:30	749
			16:45	701
71	1	1	17: 0	654
			17:15	613
			17:30	577
			17:45	548
71	1	1	18: 0	529
			18:15	521
			18:30	528
			18:45	554
71	1	1	19: 0	595
			19:15	636
			19:30	682
			19:45	731
71	1	1	20: 0	784
			20:15	841
			20:30	899
			20:45	954
71	1	1	21: 0	1005
			21:15	1051
			21:30	1093
			21:45	1131
71	1	1	22: 0	1167
			22:15	1199
			22:30	1228
			22:45	1254
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			23:15	1292
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			23:45	1316
71	1	1	24: 0	1322

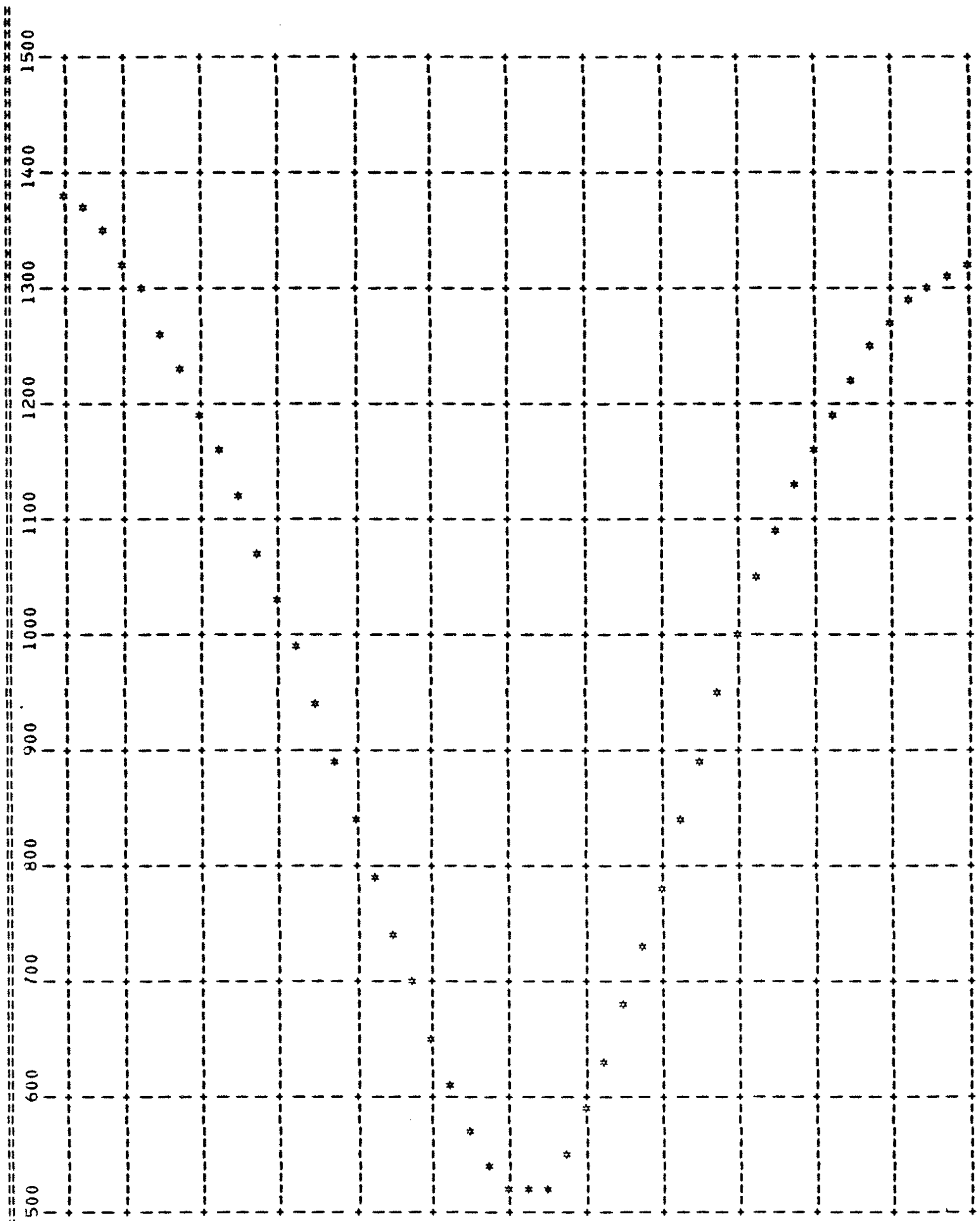

Figure 10B. An example plot of the edited stage data rcorded at gaging station No. 02-1765.60, located on the Broad River at the SC-170 highway bridge, 1215 to 2400 hours, e.s.t., Jan. 1, 1971; stages are in hundredths of feet and referenced to −10.00 feet mean sea level.

Figure 11. Photograph of the dewatered tidal marshlands near Seaboard Coast Line railroad bridge/causeway, Port Royal Sound.

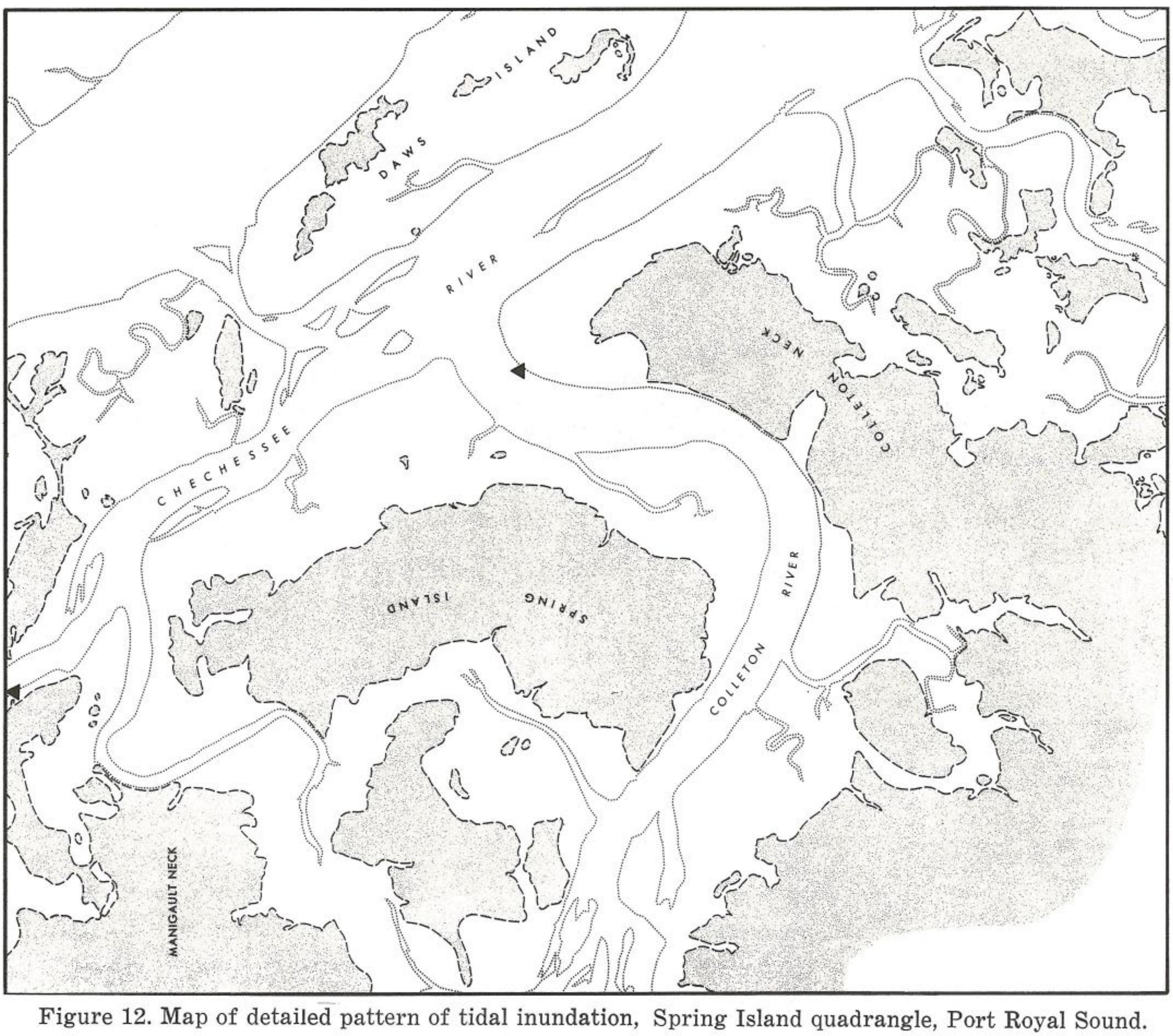

Figure 12. Map of detailed pattern of tidal inundation, Spring Island quadrangle, Port Royal Sound.

Figure 13. Modeling grid superimposed on detailed pattern of tidal inundation, Laurel Bay quadrangle, Port Royal Sound.

namely, the assumption is made that this energy can be extraced parametrically from the high-frequency wave spectrum in terms of turbulent shear stress. Thus, the mathematical simulation model requires that values of the Manning and/or Chezy coefficients be introduced at each of the grid intersection points within the modeled region. Similarly, the dispersive transport can be treated by also assigning a dispersion coefficient to each intersection point.

Prototype information regarding the magnitudes of the energy dissipation and the flow-dispersion coefficients is always inadequate. The selection of values for these coefficients at grid intersection points for use in the model is very much a matter of engineering judgment. In Port Royal Sound, results available from the several tidal cycle discharge measurements and the fluorescent dye-tracer study are of considerable help in making the proper initial selection of the areal values of these coefficients. Nevertheless, the coefficients must be adjusted in an iterative manner by comparing computed results with actual field measurements. This operation constitutes calibration of the model. The rate at which the model can be calibrated to resemble the prototype depends in large measure on the quantity and quality of the available field data and upon the experience of the engineer and his insight into the physics of the problem.

Wind-vector data—air speed and direction—can be introduced as a regional or subregional function of time in order to determine the appropriate wind-stress term in the momentum equation. Wind-vector data obtained from the U.S. Naval Air Station located near Beaufort are being used for this purpose.

Concluding Remarks

This report has presented a synopsis of the concepts and fundamentals of mathematical simulation of the flow dynamics and constituent transport in well-mixed estuaries and embayments. The report is an interim report, as the implementation of the general-purpose simulation model representing Port Royal Sound is still in progress. The model of this embayment is expected to become operational during the summer of 1972 and will be made available, thereafter, for a variety of investigative purposes through cooperative agreement with the U.S. Geological Survey.

Mathematical simulation modeling of the type described in this report requires extensive digital-computer hardware and software support. The main simulation program described herein is written in Fortran IV and is currently designed to run on any large-scale IBM 360 or 370 digital computer using standard job-control-language (JCL) conventions and the appropriate operating system (OS version 20 or better). Because of the desirability for a high-speed memory of large capacity, as well as for a very fast central processor, the Port Royal Sound simulation model is being implemented for operational processing on an IBM 360/91 computer. Those supporting-operations programs for which stream-type, data handling techniques are best suited to accomplishing certain of the field-data, editing functions are coded in Program Language One (PL/I, IBM version). The remainder of the supporting programs are written in Fortran IV. All of the supporting programs are currently implemented for processing on an IBM 360/65[J] or larger computing system. Because of the fact that most of these programs perform various integrated data processing and data storage and retrieval functions, their implementation requires thorough familiarity with the operating systems and job-control language used at large-scale, IBM digital-computer installations.

It is essential to the success of this type of effort that the results produced by both the mathematical-simulation model and by certain of the supporting programs be in a format easily and quickly comprehended. For this reason most of the results are produced in graphical form. Whereas some of the plotting is accomplished using the on-line digital-computer printer (see, for example, Figs. 10A and 10B), most of the plotting is done off-line, using mechanical or optical plotters. For example, a user of the simulation model might request that a graph showing the time sequential variation of the velocity, the water stage, or the constituent concentration at one or more selected points be produced. On the other hand, a user might desire a sequential, time series of synoptic maps showing the flow vector fields and isolines of the velocity and/or constituent concentrations throughout part or all of the embayment. In either instance the plots would be produced using the SC-4060 (Stromberg-Carlson Corp.) or using the comparable FR-80 (Information International, Inc.) plotters. Both machines are magnetic-tape driven, high-speed, cathode-ray plotters from which either hard copy prints or movie film can be made.

In addition to being able to investigate the movement and dispersal of a particular solute constituent injected at a specific point in the embayment, the Port Royal Sound simulation model should prove useful for a variety of other purposes. Some of these purposes have already been mentioned. Others may become evident as familiarity with the model increases and as needs for means for comparing solution alternatives to new water-management problems arise.

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A Tracer Simulation Study of Potential Solute Movement in Port Royal Sound

F. A. Kilpatrick and T. R. Cummings
United States Geological Survey, Washington, D. C.

Abstract

A tracer study was conducted in Port Royal Sound to simulate the movement and ultimate pattern of concentration of a solute continuously injected into the flow. A total of 750 pounds of Rhodamine WT dye was injected by boat, during a period of 24 hours, in a line across the Colleton River. During the following 43 days, samples of water were taken at selected points in the Sound and the concentration of dye in the samples was determined by fluorometric analysis.

The data obtained in the field study were used with theoretical models to compute the ultimate pattern of concentration of non-conservative and conservative solutes for a hypothetical continuous injection at the site on the Colleton River. The information developed in the study can be used to determine ultimate patterns of concentrations that would result from continuous injection of solutes at other locations in the Sound.

Introduction

This report describes a study of the movement of injected solutes in Port Royal Estuary in South Carolina. This study was conducted as a part of a comprehensive investigation of the physical, chemical, and biological characteristics of the waters of this estuary.

The estuary consists of a broad deep channel which is three miles wide at the confluence with the ocean; 4 tributary rivers, the Broad, Chechessee, Beaufort and Colleton, and small channels which interconnect the estuary to other coastal waters (See Figure 1). The estuary is filled primarily with ocean water because of the relatively small volume of fresh water inflow.

The objective of this study was to simulate the movement and the ultimate pattern of concentration of a solute continuously injected into the Colleton River at a point 13.75 miles upstream from the ocean. The objective was attained by a combination of field tests and theoretical analysis. Rhodamine WT dye was injected into the Colleton River during a period of 24.8 hours and the movement of the dye in the estuary was traced during the following 43 days. This information when used with the principle of superposition permits the computation of the pattern of concentration that would exist at anytime for alternate rates of injection of solutes at the site on the Colleton River or at other sites in the estuary system.

Method of Study

Several tools are available to evaluate the movement of solutes introduced into a water course. The two chosen for this study are the mathematical-model and tracer-simulation method. The first method mathematically combines the flow and dispersion characteristics of the estuary. It involves extensive hydraulic calibration of the estuary and is the subject of a subsequent report. Some of the data collected as a part of the model study will be utilized to acquaint the reader with the study area and to explain results of the tracer simulation study.

The second method, and the subject of this report, involves imitating the movement of a waste solute by simulating it with a fluorescent dye tracer. The chief advantage of the method is the fact that the tracer imitates exactly the movement of a like solute without the necessity of measuring the various hydraulic parameters of the estuary.

The principle of superposition on which this method is based can be better understood if the case of continuous injection into a flowing stream is understood first. If, as shown in Figure 2A, a slug of tracer W_a, is injected instantaneously into a flowing stream, there results at an observation point, x, downstream the typical bell-shaped time-concentration curve, *a*. This curve is the response to a single slug injection or impulse. If repeated slug injections of the same amounts of tracer at uniform, closely spaced time intervals follows, there is buildup of concentration to some ultimate plateau level. A series of closely spaced slug injections thus amounts to a continuous injection and yields an ultimate concentration level dependent on the stream discharge and amount or rate of tracer injection. The ultimate level, as shown in Figure 2A, may be simulated by superimposing concentrations from a series of unit response curves as described by Linsley *et al.* (1958) in unit hydrograph theory; or it may be simulated by numerically integrating the response curve produced by a single slug injection.

A more complex situation exists in an estuary. Significant tidal flow, both seaward and shoreward, as well as freshwater inflow exist. The response curve resulting from an instantaneous slug injection in an estuary would thus vary in shape, magnitude and location, depending on the existing flow conditions. An entire series of different response curves could be obtained at anytime during the normal 12.4 hour tidal cycle. This is best remedied by assuming that a tidal cycle represents a quasi-steady-state period. The tracer can then be injected continuously over at least one tidal wave cycle (See Figure 2B). The resulting curves would then be observed at one-tidal-cycle intervals. This injection may still be considered a slug injection when the long period of observation required is considered.

For an estuary where there is no fresh water inflow (see Figure 2B), the response curve observed at $T=1\triangle t$ shows the tracer cloud at the end of the injection when the same tidal-conditions as when the injection began returns. The tracer mass remains centered about the point of injection in the absence of fresh water flow, even though it becomes

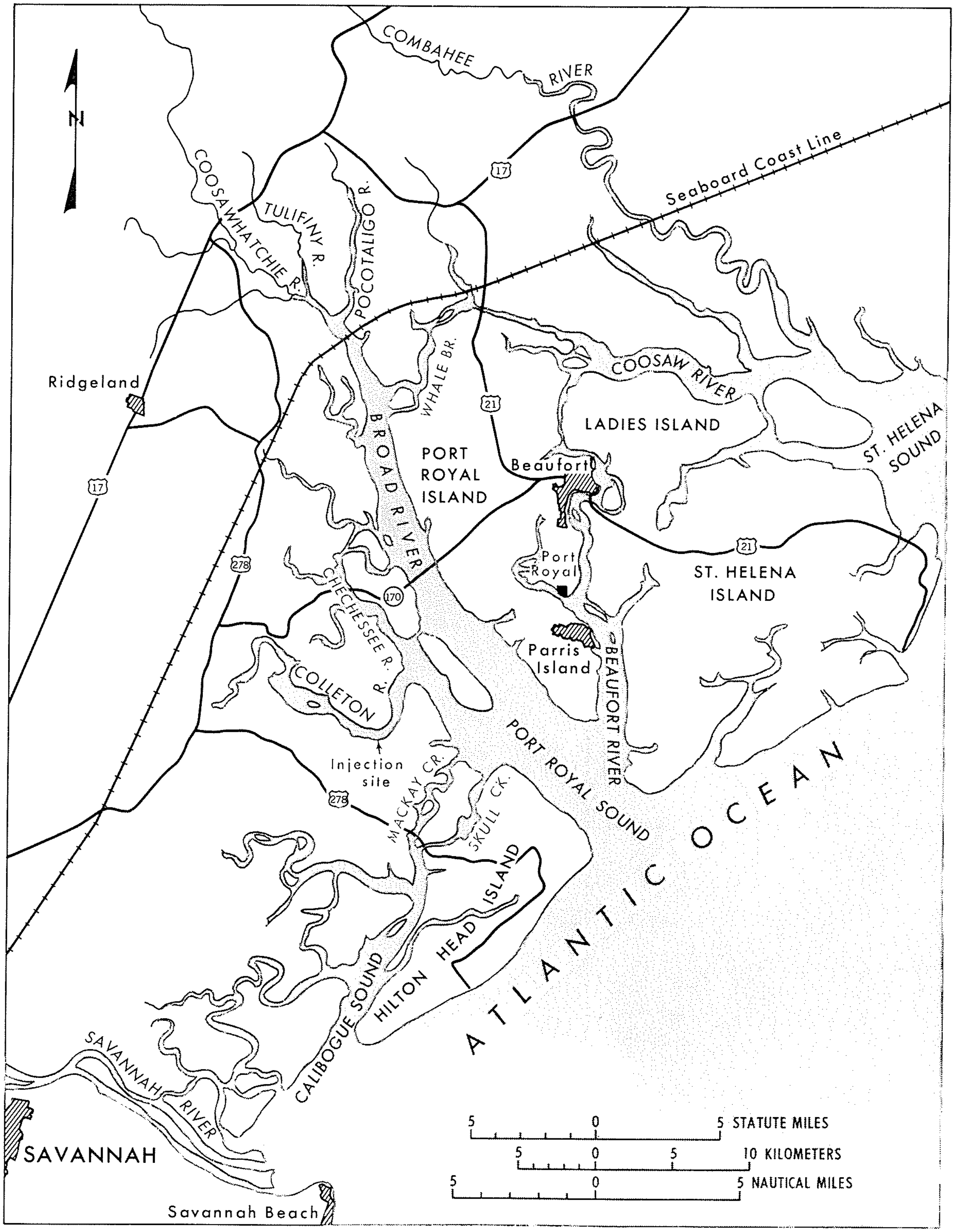

Figure 1—Port Royal Sound and vicinity.

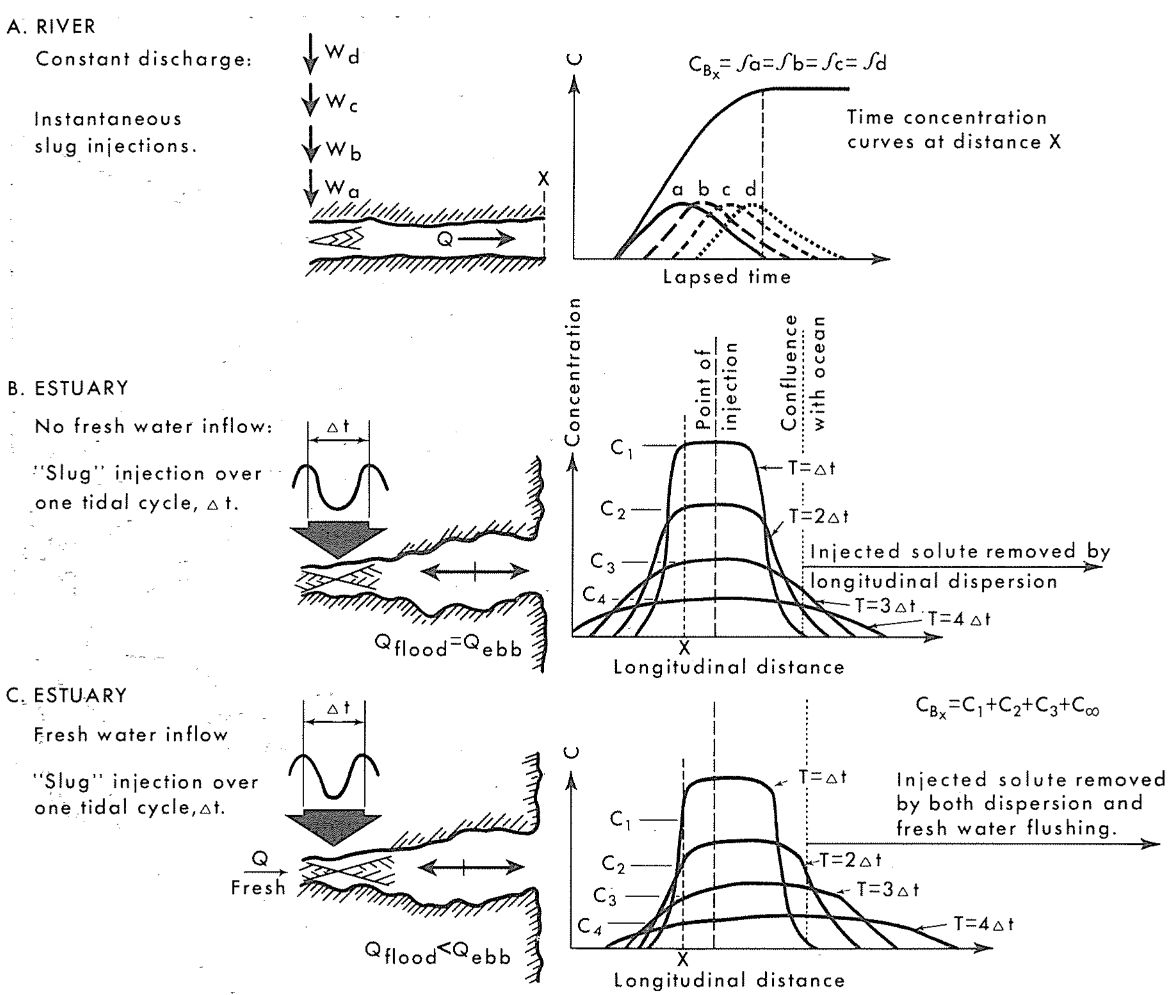

Figure 2. - Illustration of superposition principle as applied to rivers and estuaries.

more elongated with each tidal period. Some tracer is dispersed eventually into the adjoining ocean; longitudinal dispersion being the principle flushing agent.

If the injection point is close to the ocean, and the tidal excursion is sufficiently long, a part of the tracer injected on the ebb tide may reach the ocean and be flushed out. Such flushing would cause additional attenuation of concentration on the seaward side of the cloud, presenting a nonsymmetric cloud form.

The response curves shown in Figure 2B at various tidal-cycle intervals, result from single, tidal-cycle-long "slug" injection. It may readily be visualized that the response to a continuous injection may be simulated by merely summing these response curves. Thus the curve at $2\triangle t$ is the response to injection which took place two tidal cycles previous; the curve at $3\triangle t$ is the response due to injection three tidal cycles ago; and so on. The ultimate concentration at any location X may be obtained by summing each concentration as observed at $\triangle t$ intervals. This is, in essence, the principle of superposition used by Yotsukura (1968), and Bailey *et al.* (1966). As can be seen, the rate of buildup is rapid until the tracer cloud has become reduced and elongated by dispersion.

In estuaries where steady fresh water inflow exists, the response curves are shifted seaward (See Figure 2C). Furthermore, the concentrations may be reduced by dilution. The ultimate concentrations resulting from a continuous injection may still be simulated by the superposition principle by summing the response curves. The measured response curve reflects both the effects of fresh water transport and tidal dispersion and flushing, since the tracer is an exact imitator of a potential waste solute having similar characteristics. Fresh water inflow may reduce the buildup concentrations at certain locations, and facilitate earlier flushing, as may be seen in Figure 2C.

Study Area

Figure 3 is a more detailed hydrologic map of Port Royal Sound, showing the existing extremely complex waterway network. The locations of data collection points pertinent to the study are also shown, and some typical velocities in the estuarine system are shown. Mileages from the mouth of the Sound upstream along the flow thalweg lines are shown for reference purposes.

This estuary is virtually undeveloped at the present time (1970). Aside from oyster fishing boats and pleasure craft navigating the intercoastal waterway via Skull Creek and the Beaufort River, only limited ship traffic exists on the Beaufort River to the town of Port Royal. Parris Island Marine Base occupies the lower portion of the island just to the south of the town of Port Royal. Hilton Head Island on the south bank bordering the Atlantic Ocean is extensively developed as a resort area. Summer homes and camps are to be found scattered along most creeks and waterways that branch off the Sound.

Type of Estuary

Mean depths in the estuary vary from about 40 feet near the confluence with the Atlantic Ocean, to 20 and 30 feet in the upper Broad, Chechessee, Beaufort, and Colleton Rivers. The mean tidal range in the Sound is 7.5 feet with tides occasionally in excess of 9 feet.

The principle source of fresh surface water into the Sound is the Coosawhatchie River, for which 19 years of record show an average flow of less than 300 cubic feet per second. No significant fresh water enters the other arms of the estuary.

Vertical mixing in the estuary should be rapid since the depths and tidal ranges are large. Also, the contents may be expected to be almost entirely seawater due to the absence of major fresh water inflows. Figure 4 shows the range in specific conductance, dissolved oxygen, and pH, as measured during one tidal cycle at selected locations in Port Royal Sound. Seawater immediately off the South Carolina Coast has a specific conductance of about 45,000 micromhos; as can be seen, high values of specific conductance exist throughout the estuary. The lower values in the upper reaches indicate some dilution by fresh water.

Fresh ground-water discharge into the estuary and fresh surface inflow may be the source of minor dilution. The piezometric surface of the principle artesian aquifer ranges from about 10 ft. above mean sea level to −100 ft. mean sea level in the study area. Overlying this aquifer are several shallow water-bearing units, some of which outcrop in the deeper parts of the estuary, some of which have a limited areal extent or distribution.

The data also showed no significant vertical variation in specific conductance indicating a very homogeneous, well-mixed estuary. The dissolved oxygen was also found not to vary significantly in the vertical, confirming estuarine homogeneity. Their absolute values also confirm the lack of pollution.

Tidal Hydraulics

The stage and estimated discharge hydrographs for the Colleton River at its mouth at the start of the tracer test are shown in Figure 5. The normal semidiurnal type of reversing current is seen to exist with flow seaward or downstream (ebb tide) for approximately 6.2 hours, and then upstream (flood tide) for about 6.2 hours. High or low tide (stage) precedes slack water, or the time of zero current, by about 2 hours. A tidal day is composed

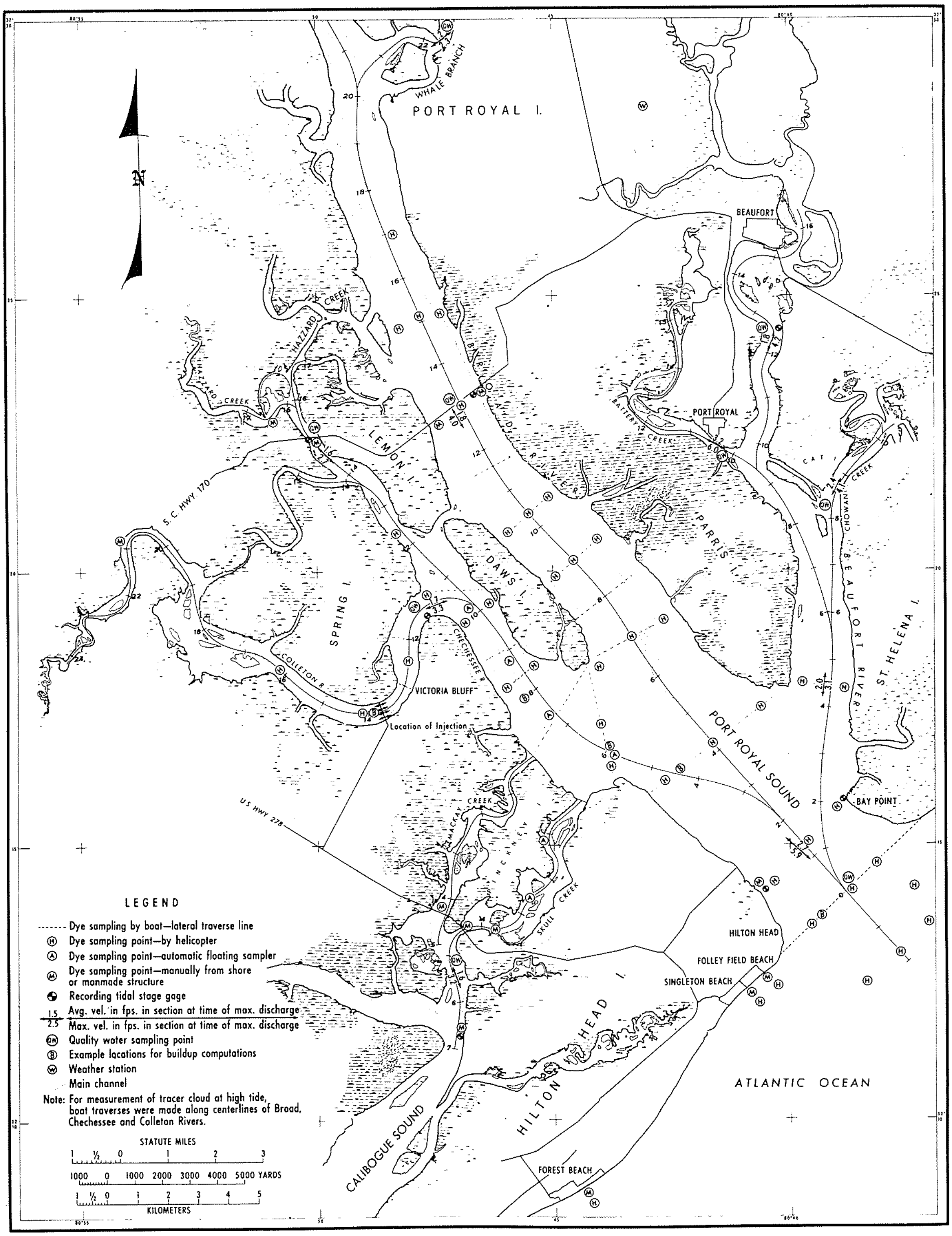

Figure 3. - Hydrologic map of Port Royal Sound.

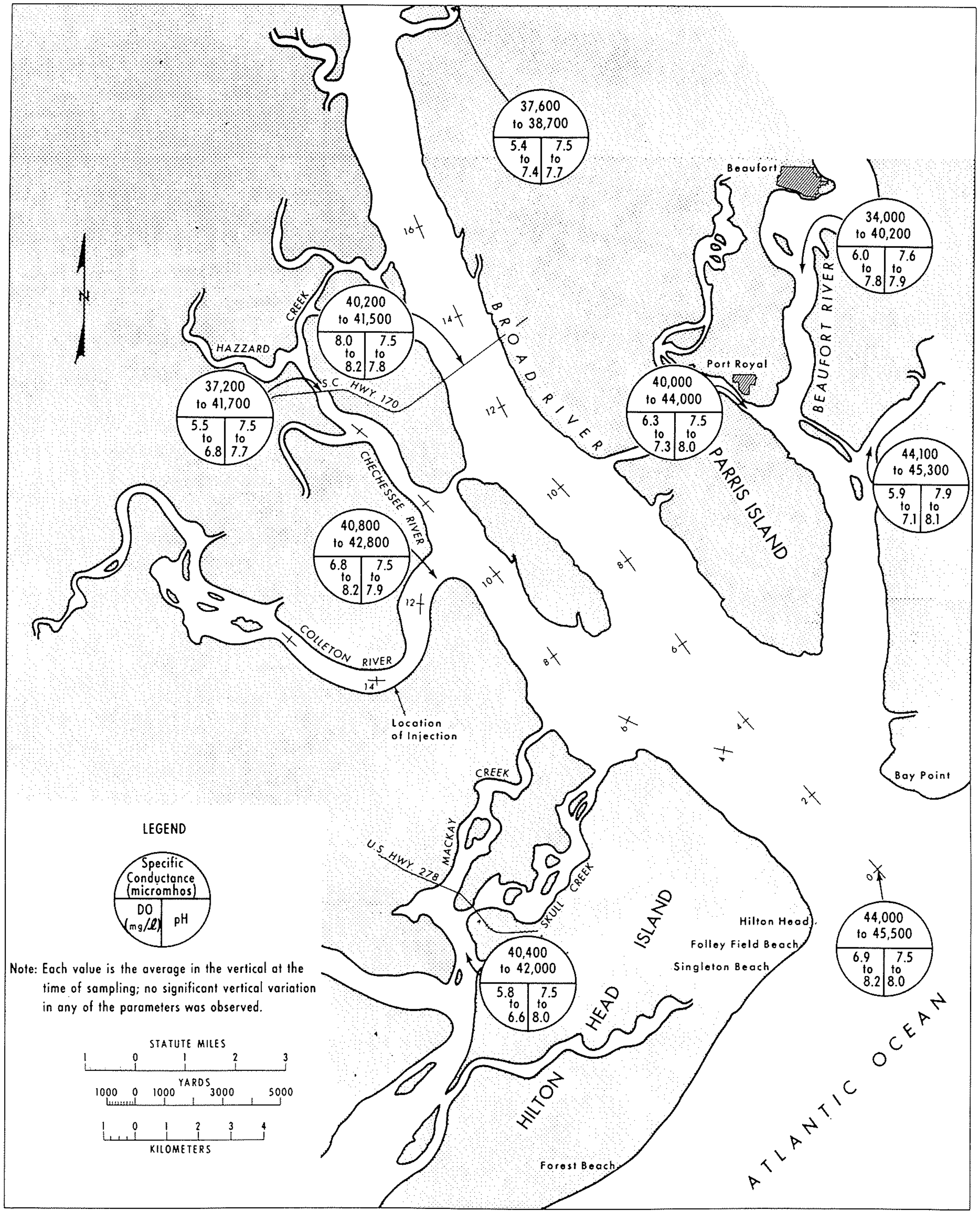

Figure 4. - Maximum variation in specific conductance, dissolved oxygen, and pH during one tidal cycle at selected locations in Port Royal Sound.

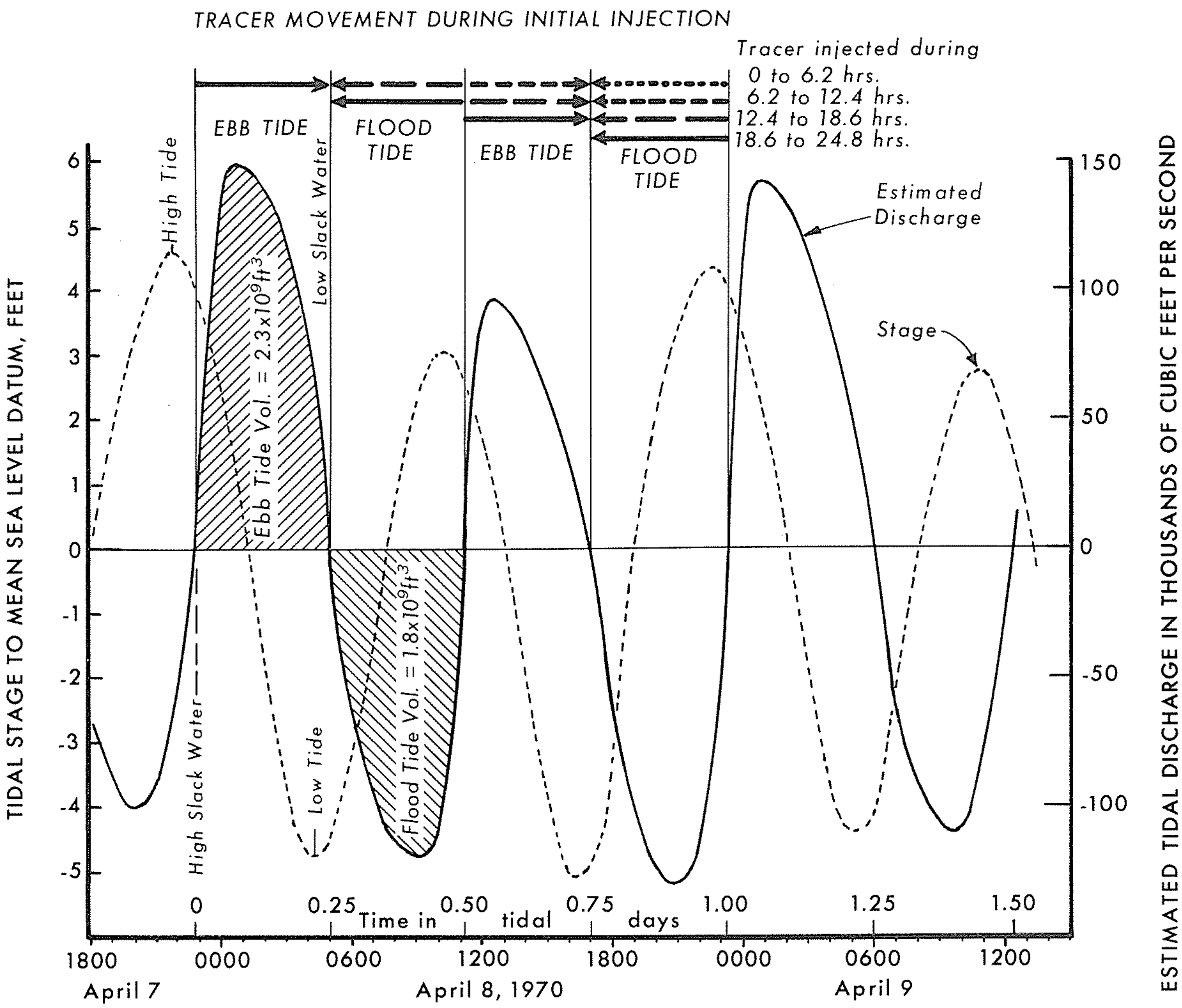

Figure 5—Recorded stage and estimated discharge hydrographs for Colleton River at confluence with the Chechessee River showing tracer injection schedule and initial movement.

of two high tides and two low tides and is approximately 24.8 hours long. In Port Royal Sound, the two high tides and two low tides do not vary greatly in amplitudes. The maximum tidal discharges in and out of the Colleton River are shown to vary from 100 to 150 thousand cubic feet per second. By contrast, maximum flows at the entrance to the Sound, mile 0, vary from 1.5 to 2 million cubic feet per second. These discharge values are based on actual measurements made in the summer of 1970 throughout the estuary. The areas under the discharge hydrograph sketched in Figure 5 indicate that tidal volume exchanges at the mouth of the Colleton River are on the order of 2 x 10^9 cubic feet. These large volumes represent water moving into and out of storage in the main channel, and in marshy areas upstream, and vary with absolute tidal stage. Such large tidal flows produce comparably large tidal velocities; some shown in Figure 3 are in excess of 6.0 feet per second.

The flow pattern in Port Royal Sound is complicated by the many interchanges with adjoining waterways. As seen in Figures 1 and 3, the Sound is connected with the Coosaw River and with St. Helena Sound by Whale Branch and by the Beaufort River on the east, and with Calibogue Sound by Mackay and Skull Creeks to the southeast. Many smaller connections exist throughout the system, and at extreme high tide much of the region becomes a common lake. In each of these connecting waterways, tidal-flow null points exist, varying in location with wind direction and absolute tide stage.

Tracer Test

Tracer Injection

Application of the superposition principle in simulating the continuous injection of a solute into an estuary is best accomplished by injecting the tracer continuously over at least one tidal cycle. This quasi-steady-stage period, $\triangle t$, also determines the sampling interval. As can be seen in Figure 5, there was some difference in amplitudes between the first and second tidal cycles occurring on April 8, 1970. While this nonuniformity was not great, continuous injection over two tidal cycles would assure more quasi-steady simulation and permit the observation interval to be greater. For this reason, $\triangle t$ for the actual test was chosen as 24.8 hours, or a tidal day.

From 2240 hours on April 7, 1970, to 2320 hours, April 8, 1970 (see lower abscissa of Figure 5), a total of 750 lbs. of Rhodamine WT dye, a fluorescent water-soluble tracer, was injected by boat across the Colleton River at mile 13.75. Ten pounds of dye were poured out every 20 minutes in a line injection, as seen in Figure 6A. This dye has a specific gravity of 1.19 but because of its high solubility and the existing turbulence, mixes rapidly into the flow. Injection began with the start of ebb tide, T = 0, and ceased one tidal day later. From T = 0 to 0.25, and from 0.50 to 0.75 tidal days, the tracer moved seaward; from T = 0.25 to 0.50, and from 0.75 to 1.00 tidal days, flood tide existed and the tracer moved upstream in the Colleton River. Figure 6B is an aerial view during flood tide (about 1000 hours on April 8) showing the individual line injections moving upstream. These tracer lines soon dispersed longitudinally such that, within a few miles, they overlapped and became indistinguishable as separate clouds, much as illustrated in Figure 2A.

Sampling

The aerial photograph in Figure 6B, taken on the flood tide, shows that the surrounding marshland is extensively flooded at high slack water. At such times the tracer cloud may be spread over many square miles of inaccessible marsh. At low slack water, conversely, water and the tracer cloud drain out of the marshlands and occupy the more accessible, more confined main channels. For this reason, and because of the experience of Dyar and others (written communication) in measuring a tracer in an estuary, it was decided to measure primarily at low slack water. Tracer cloud observations are shown in Figure 7 to have been made mostly at such periods. A few high slack water measurements were made periodically to define the outer limits of the tracer cloud.

Figure 7 shows the dye injection and subsequent sampling schedule for the first two weeks. Thereafter the frequency of sampling decreased, with the last samples being collected on May 20, 1970, at T = 41.25 tidal days after the start of injection.

The tidal discharges shown in Figure 7 are estimated from stage record to show relative magnitudes between cycles for the initial two week period. Dye injection and initial sampling took place during a period of relatively large-amplitude tides, as seen in Figure 7. Tidal amplitudes subsequently diminished, and then grew large again. Similar cyclic tidal amplitude variations were experienced through May 20, thus indicating that a representative period was chosen for the tracer simulation test. The same may be said for other climatic conditions experienced during the test period (see Figure 7), with rainfall, and wind direction and speed being typical of the area. Another reason that April 8 was chosen for the injection was because low slack water occurred during the daylight hours for the next three weeks. This expedited the sampling of the tracer cloud.

Grab water samples were obtained by boat along previously marked lateral traverse lines located as shown in Figure 3. The extremities of these traverse lines were marked with large, painted plywood panels supplemented with anchored bouys in the

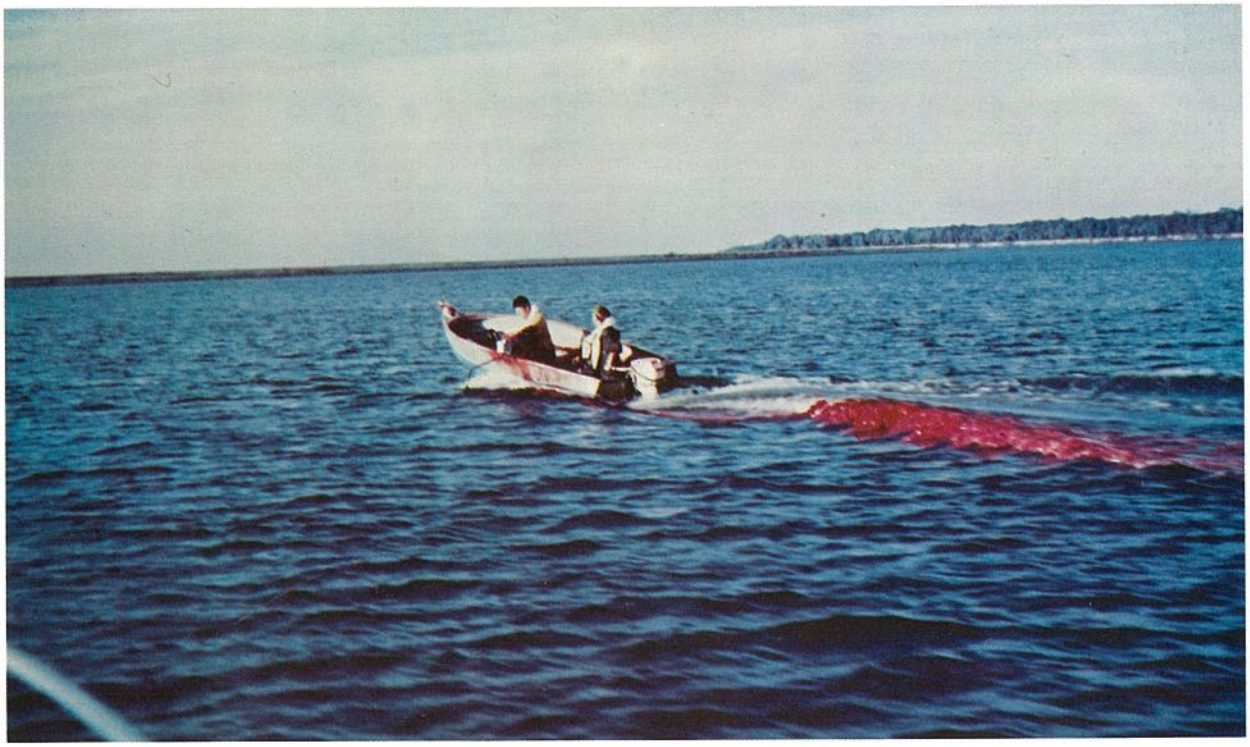

Figure 6A.—Line injection of dye tracer by boat across Colleton River at mile 13.75; view is eastward in direction of Port Royal Sound; Victoria Bluff is on the right bank and low marshland visible on the left bank.

Figure 6B.—Aerial view of dye injection on the Collection River; line of tracer is being distorted and swept upstream on the floodtide; view is southward with access road visible at top of picture.

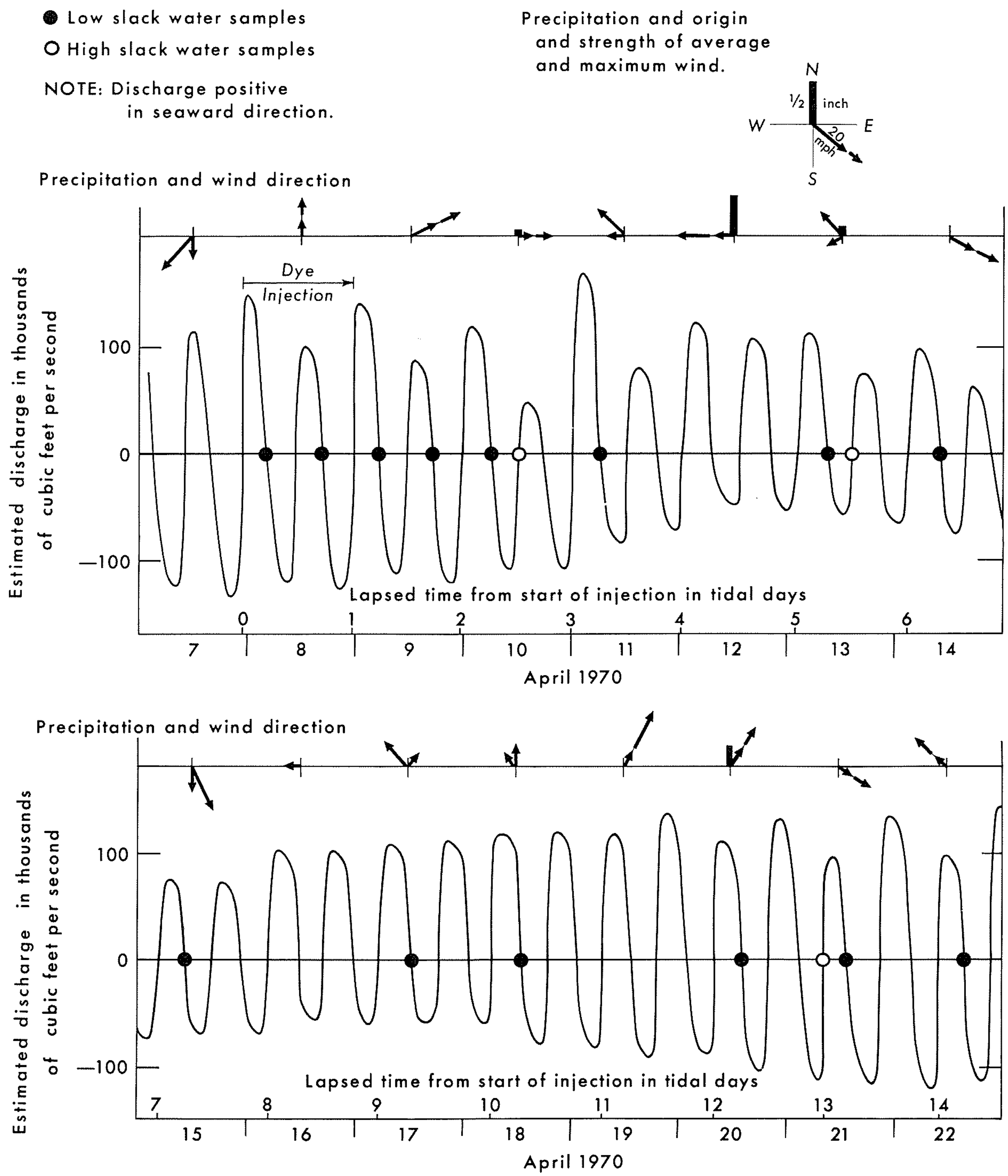

Figure 7—Precipitation and wind direction and strength, for Port Royal Sound; estimated discharge hydrograph for Colleton River showing injection and sampling schedule for the first two weeks of the tracer test.

main channels. Grab samples were also taken manually from bridges, docks, and other man-made structures. Where nighttime sampling was hazardous, and during the first two days when it was desirable to observe the complete movement of the dye cloud with time, automatic floating samplers were utilized, as seen in Figure 8A. These units automatically collected samples at 45-minute intervals at four mid-channel locations during the early morning hours of April 8 (T = 0.25 tidal days). They aided in defining the extent of the initial seaward movement of the tracer cloud.

The duration of low slack water, the length of time in which the tracer cloud is essentially immobile, is, for practical purposes, from 1 to 2 hours. The time of low slack water differs with location; at the mouth of the Colleton River it occurs 20 to 30 minutes later than it does at the mouth of the Sound. Grab water samples were therefore collected by starting just prior to low slack water at the downstream edge of the tracer cloud, and by thereafter moving upstream with the occurrence of low slack water.

As the tracer cloud became more dispersed and more uniform in concentration, fewer but more wide spread samples were needed. The helicopter shown in Figure 8B proved to be advantageous in rapidly collecting samples over what eventually amounted to 50 square miles of water.

Laboratory Analysis

The large number of water samples collected, and the need for concurrence in their analyses so that subsequent sampling could be scheduled, dictated that a laboratory be located near the study area. A Turner Model 111 filter type fluorometer, and precise temperature bath, along with supporting laboratory accessories, were conveniently located at a motel on Hilton Head Island.

The fluorometer measures concentration by measuring fluorescence; the principles and techniques in its use are described by Wilson (1968). Dye standards were carefully prepared in duplicate from distilled water and a sample of the dye retained for this purpose. The fluorometer was completely calibrated several times during the study, with frequent intervening checks. New dye standards were prepared at the end of the test as a double check, and the fluorometer calibration was determined anew. No significant calibration variations were observed.

Samples were brought to the laboratory immediately, placed in the temperature bath, and analyzed within 12 hours of collection. As the test progressed and concentrations became low, samples were allowed to settle for at least 24 hours in the temperature bath prior to fluorometer analysis to lessen background interference due to sediment. As a result of careful fluorometic techniques, dye concentrations were determined to be accurate within $\pm 0.02\ \mu g/l$.

Data Analysis and Interpretation
Low Slack Water Isoconcentration Maps

Water samples were extensively collected in the estuary from April 8 to May 20, 1970, during 25 periods of low slack water and 7 periods of high slack water. These data were plotted on base maps, and lines of equal concentration were drawn to give a picture of the movement of the tracer cloud with successive tides. Seven such isoconcentration maps for low slack tide periods are shown in Figures 9A through 9G, to give a picture of the initial and long term movements of the tracer cloud.

The maximum seaward movement of the tracer cloud at the time of the first low slack water, T = 0.25 tidal days, is shown in Figure 9A. Only one fourth of the dye has been injected and has moved downstream on the ebb tide. At T = 0.25, movement upstream is impending, tracer going up the Colleton from T = 0.25 to 0.50 tidal days. Not only does this tracer move upstream, but much of that injected during the first quarter tidal day also returns and moves upstream. Some of the returning tracer travels up the Chechessee River as well as into other small channels filled on the flood tide.

The tendency during this initial period, and subsequently, for the main tracer plume to favor the right bank of the Chechessee River rather than to spread uniformly across the channel is of interest. This lack of lateral dispersion and mixing between streams below their confluence is typical of inland rivers.

From T = 0.50 to 0.75 tidal days (the third quarter) tracer again moves seaward with the ebb tide; Figure 9B shows the results at the end of this second low slack water. It is noteworthy that the leading edge of the tracer cloud has moved seaward only slightly as compared with its location at T = 0.25. The second ebb tide being weaker than the first probably accounts for this. Whereas much of the tracer that initially moved up the Colleton River has now moved downstream along with that injected during the two ebb tides, a large quantity remains upstream of the injection point due to dispersion. Some tracer also remains up the Chechessee River for the same reason.

The third low slack water (T = 1.25) is the first following cessation of all dye injection. The tracer cloud at this time is shown in Figure 9C. There has been further dispersion seaward, with the leading edge of the cloud beginning to enter the Broad River. A significant amount of tracer is now found in the upper Colleton and Chechessee Rivers. The mass center of the tracer cloud is still located at the point of injection, with maximum concentrations of

Figure 8A.—One of several automatic floating samplers utilized to sample dye-tracer cloud at night and under hazardous conditions; samplers were anchored at desired locations and set to sample every 45 minutes.

Figure 8B.—Helicopter utilized to sample over Port Royal Sound.

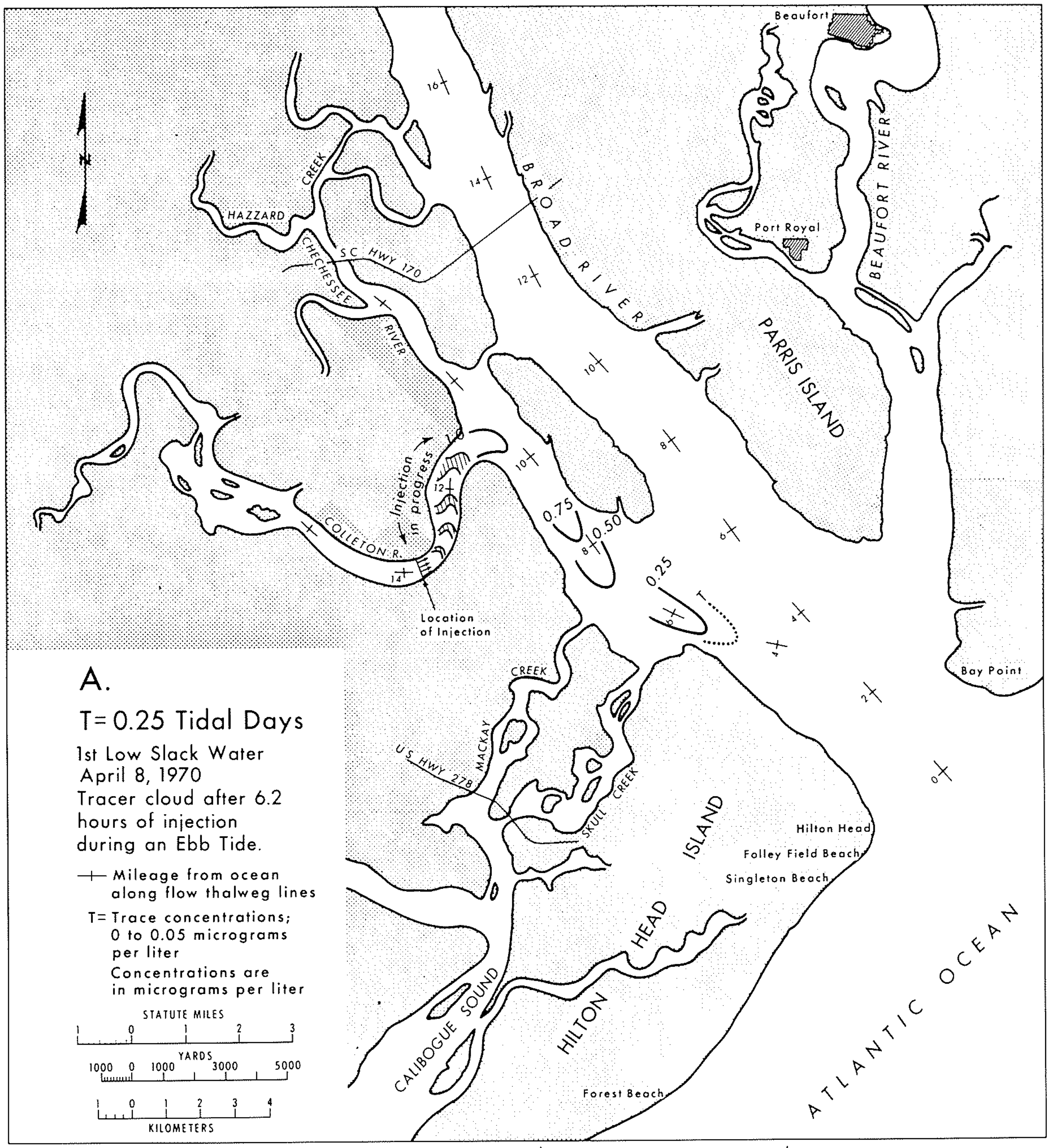

Figure 9A—Low-slack-tide isoconcentration map showing maximum seaward movement on the initial ebb tide.

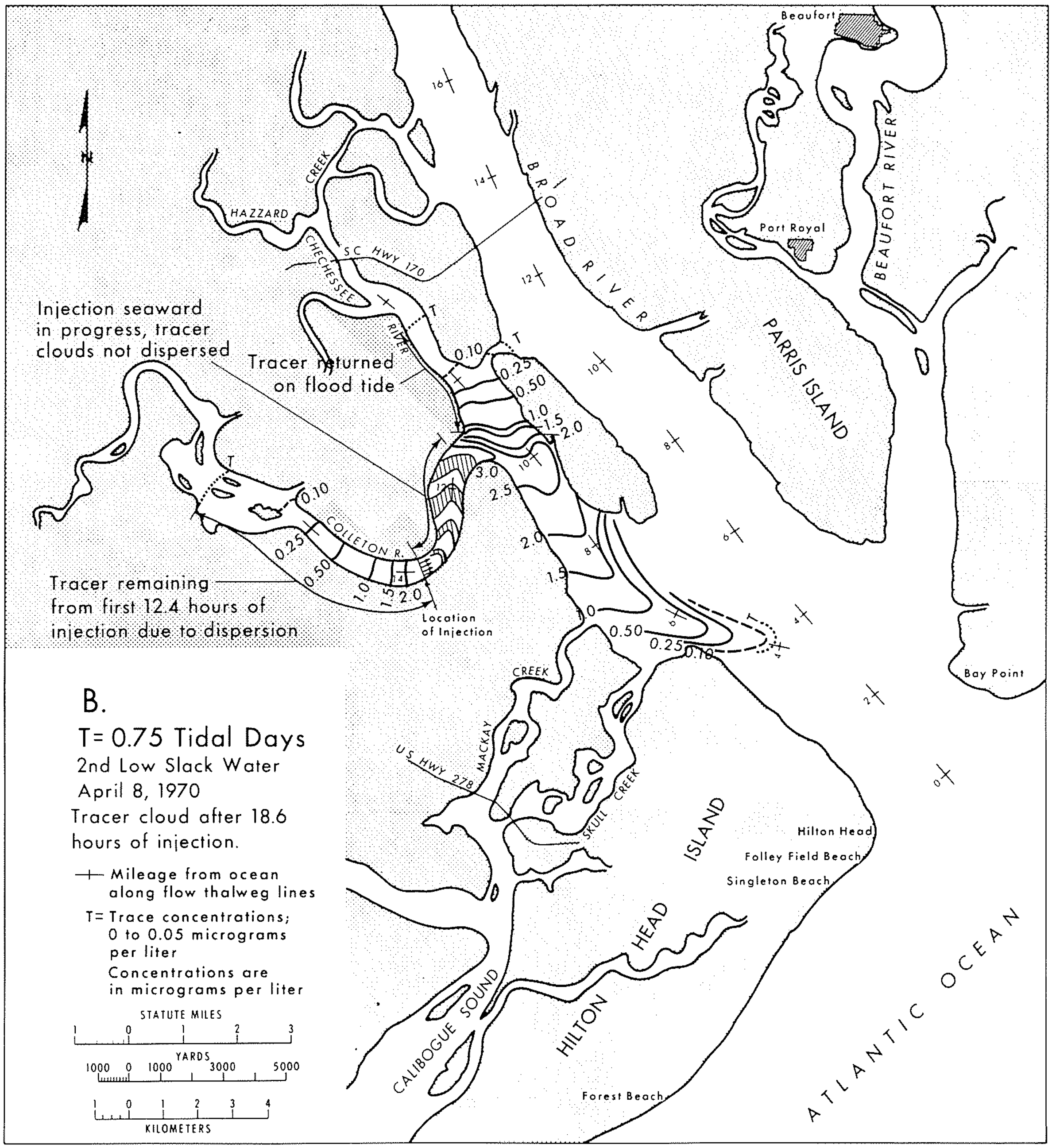

Figure 9B—Low-slack-tide isoconcentration map showing tracer remaining in upstream reaches due to dispersion effect.

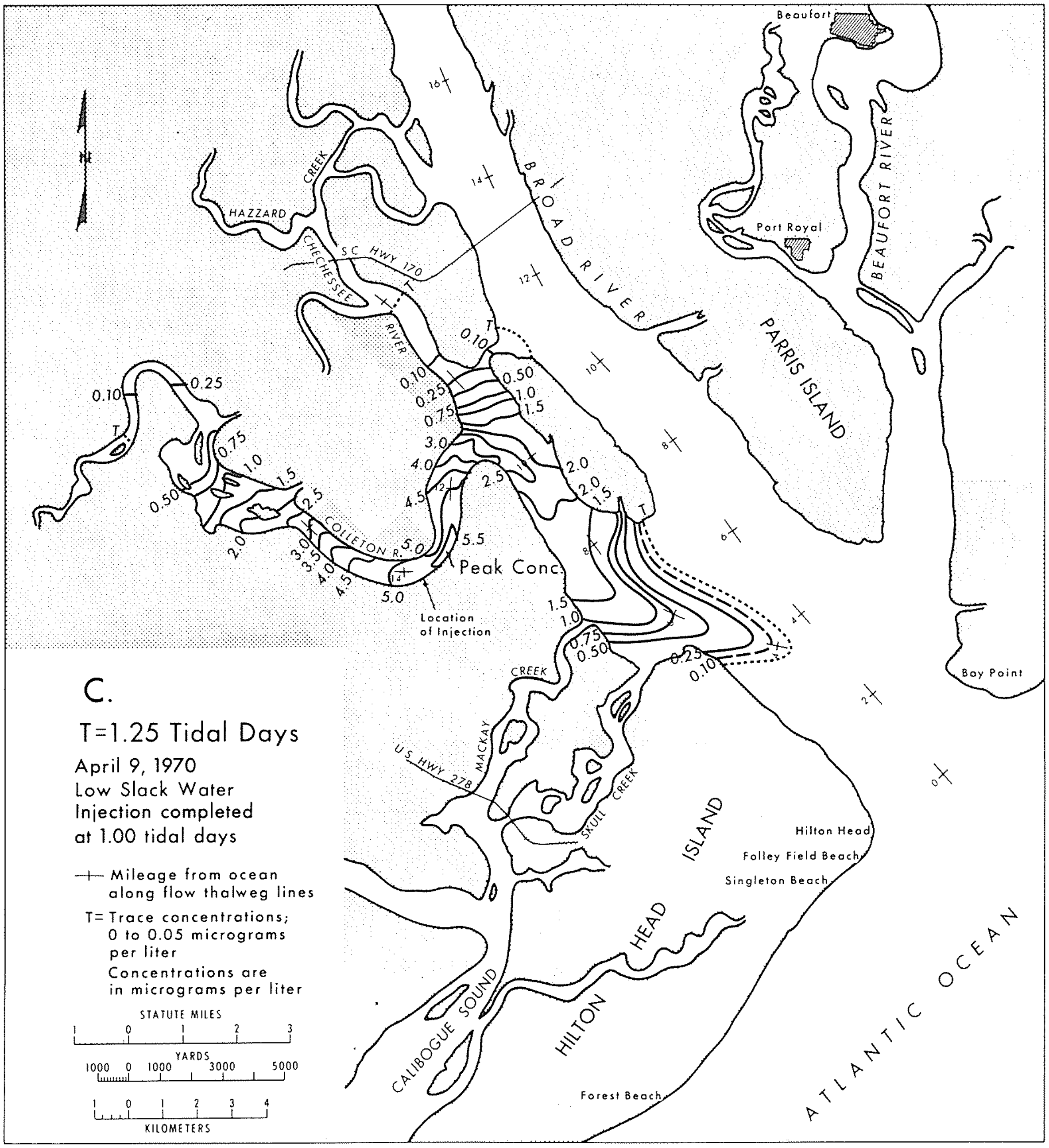

Figure 9C—Low-slack-tide isoconcentration map showing location and magnitude of dye cloud after injection had ceased.

about 5.5 μg/l existing just downstream from this point. Concentrations in the lower Chechessee River and at the confluence with the Broad River are low because of the large volumes of water available for dilution. Conversely, concentrations are relatively high in the upper Colleton River as a smaller volume of water is available for diluting the tracer which had been injected on the flood tides.

By T = 2.25 tidal days, the tracer cloud is shown in Figure 9D to have further dispersed, with significant amounts existing in the Broad River and in Skull and Mackay Creeks. The peak concentration is just over 4 μg/l and is just above the point of injection. Concentrations upstream in the Colleton River are relatively high as removal of this tracer by dispersion is a slow process, and there is insufficient fresh water inflow for dilution. Further dispersion of the tracer cloud up the Colleton and Chechessee Rivers is evident. Conversely, concentrations in the Broad River are very low owing to the large quantities of water available for dilution. As was the case below the confluence of the Colleton and Chechessee Rivers, the tracer cloud is favoring the right bank as it moves into the Broad River.

At T = 3.25 tidal days (see Figure 9E), the downstream edge of the tracer cloud has just reached the Atlantic Ocean, and hence, flushing begins at about this time. The tracer cloud has, in general, further dispersed, and the peak concentration has dropped to about 3.3 μg/l just above the injection point.

By 16.25 tidal days (Figure 9F), the tracer cloud has dispersed such that minor concentrations exist up the Beaufort River and up the Broad River above the South Carolina Highway 170 bridge. There is significant flushing into the Atlantic Ocean, with traces (less than 0.05 μg/l) of dye found along the beaches off Hilton Head Island. Since no traces of dye were observed in the Atlantic Ocean to the northeast, the ocean currents appear to be in a southeasterly direction at this time. The data indicate primarily a seaward movement of the tracer once it has passed the confluence with the ocean. The main channel of Port Royal Sound extends beyond the confluence, directly seaward, with shallow water existing off the beaches on both sides (see Figure 3). Most of the discharge past the confluence would therefore appear to move directly out into the ocean.

Only low tracer concentrations exist in Skull and Mackay Creeks at this time. The concentration in Mackay Creek is lower than in Skull Creek because at high slack water, tracer disperses into the more extensive marshland areas adjoining this waterway.

The maximum concentration is now reduced to just over 1 μg/l and is located over 2 miles upstream from the injection point. This inland migration of the peak continues, as may be seen in Figure 9G for T = 41.25 tidal days. The peak is now approximately 4.5 miles upstream from the injection point. This migration of the peak results from the fact that the upstream reach of the Colleton River is relatively short and presents a physical barrier to the dispersion and dilution of solutes.

As seen in Figure 9G, tracer concentrations are insignificant throughout the estuary after 41.25 tidal days. Traces of dye were also found in the Broad and Beaufort Rivers at this time, but at a level of detection that did not justify presentation in Figure 9G.

High Slack Water Isoconcentration Maps

Figures 9A through 9G show the tracer cloud at selected low slack water periods, or at maximum seaward positions. Water (or tracer) occupying a certain position at low slack water will move upstream with the flood tide. The position of the tracer cloud at high slack water after 16.00 tidal days is shown in Figure 10 for comparison with its next low slack water position in Figure 9F (T = 16.25 tidal days). The tidal excursion between high and low tide is about 4 miles.

Ultimate Pattern of Concentration with Continuous Injection

The ultimate concentration to be expected from continuous injection of a solute can be simulated by using the superposition principle, whereby the concentration at any location resulting from a slug injection of tracer is integrated with respect to time. The area under the observed concentration-time curve for any point in the estuary thus yields the ultimate concentration at that point for a solute which is injected continuously.

Figure 11A shows the observed concentration-time curves for 5 locations (refer to Figure 3) from the injection point to the confluence of the Broad River with the Atlantic Ocean. These locations are along a path taken initially by the main tracer plume. The results of numerically integrating the area under these curves to obtain the ultimate concentrations resulting from continuous injection at the same rate as used in this study are shown in Figure 11B. The ultimate concentrations for other locations in the estuary were obtained by determining the areas under the time-concentration curves plotted for those locations.

The data presented in Figures 9, 10, and 11 are based on the injection of 750 pounds of tracer during a 24.8-hour tidal day. The ultimate concentrations, as computed above, were adjusted, for ease of use, to reflect the response to continuous injection of a solute at the rate of 1000 lbs. per 24.0-hour day. These data were plotted on a base map, and the ultimate isoconcentration map for a nonconservative

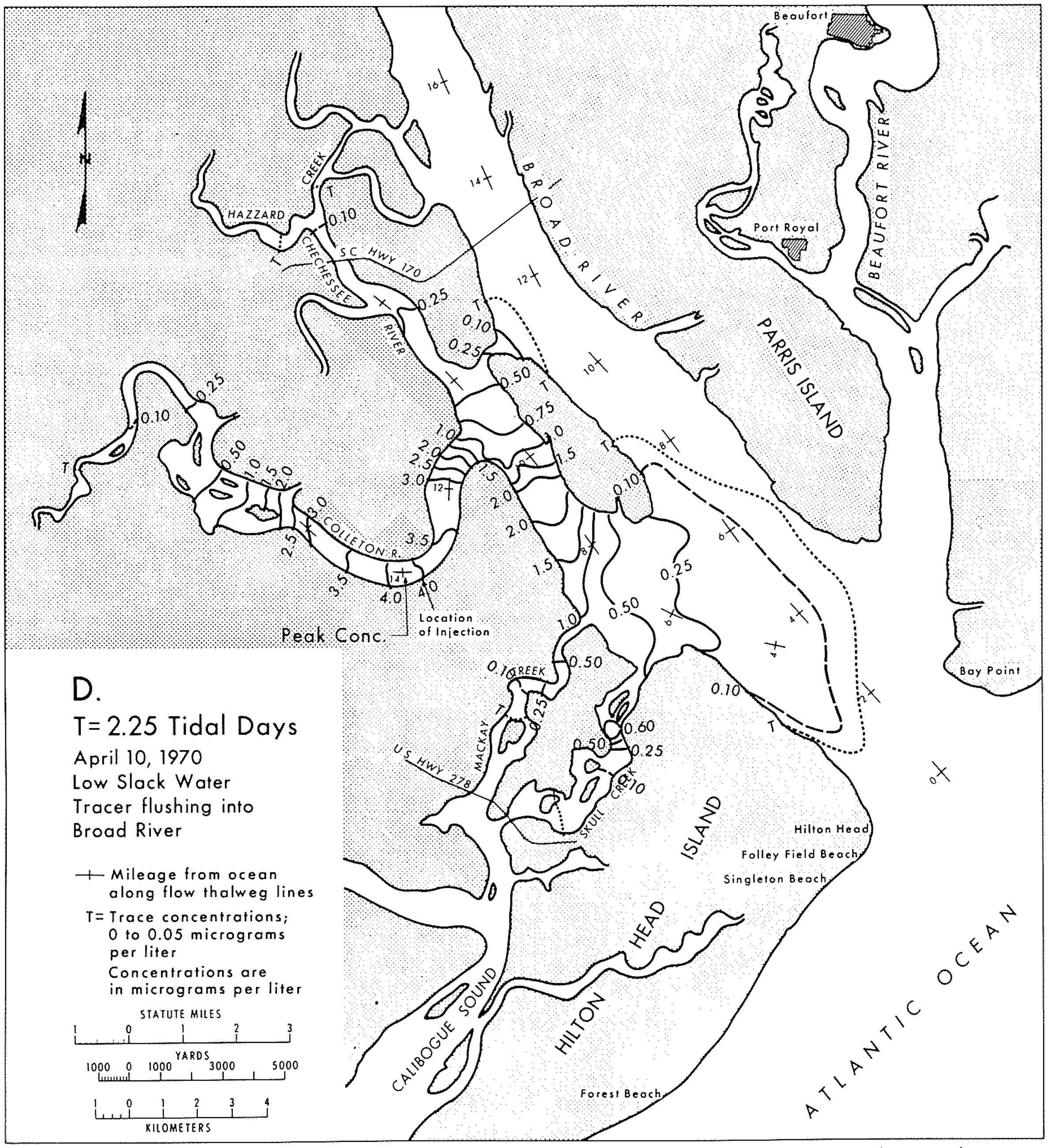

Figure 9D—Low-slack-tide isoconcentration map showing the first significant flushing into the Broad River.

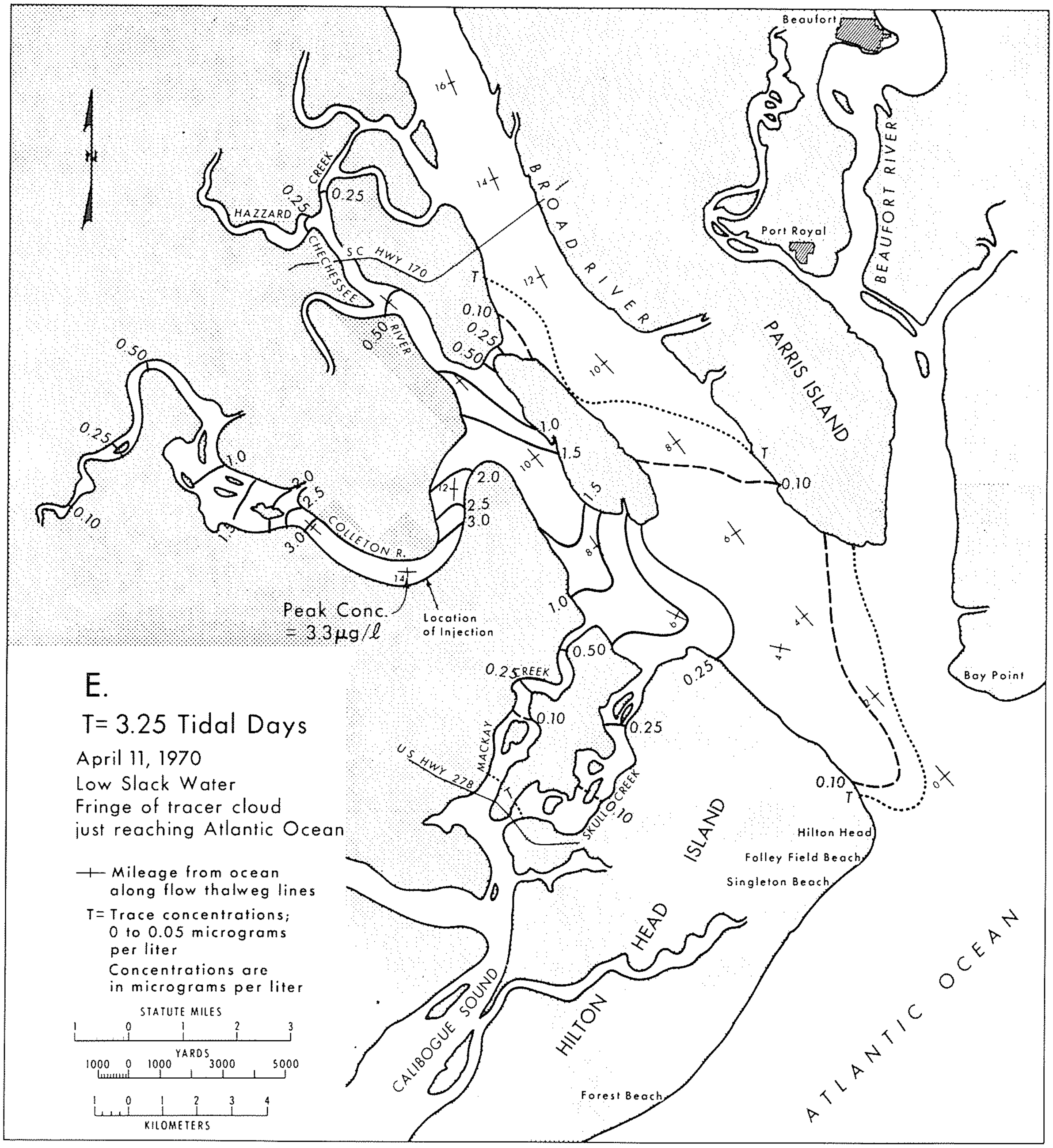

Figure 9E—Low-slack-tide isoconcentration map showing time and distribution of dye at first arrival with the Atlantic Ocean.

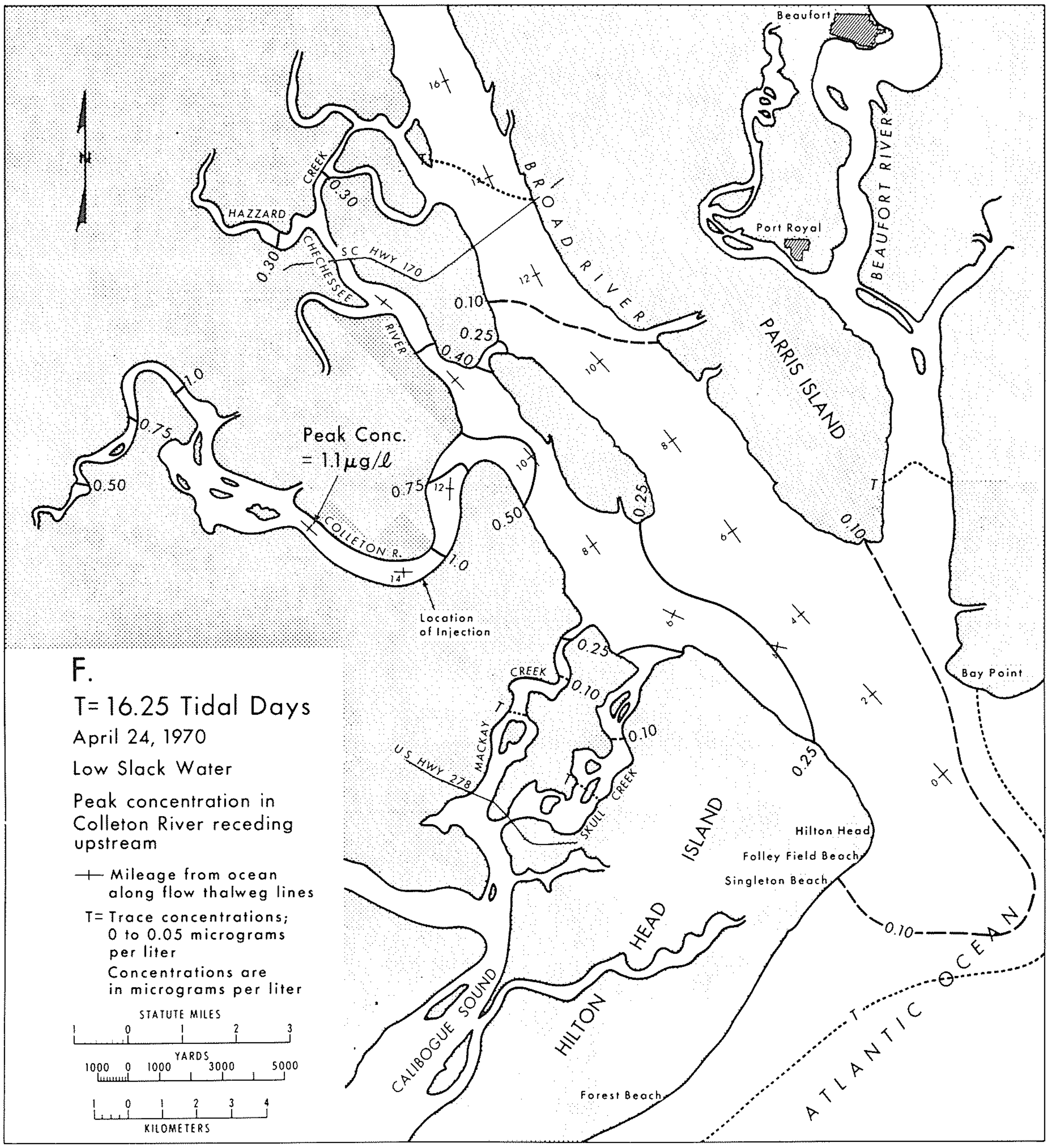

Figure 9F—Low-slack-tide isoconcentration map showing recession of peak up Colleton River.

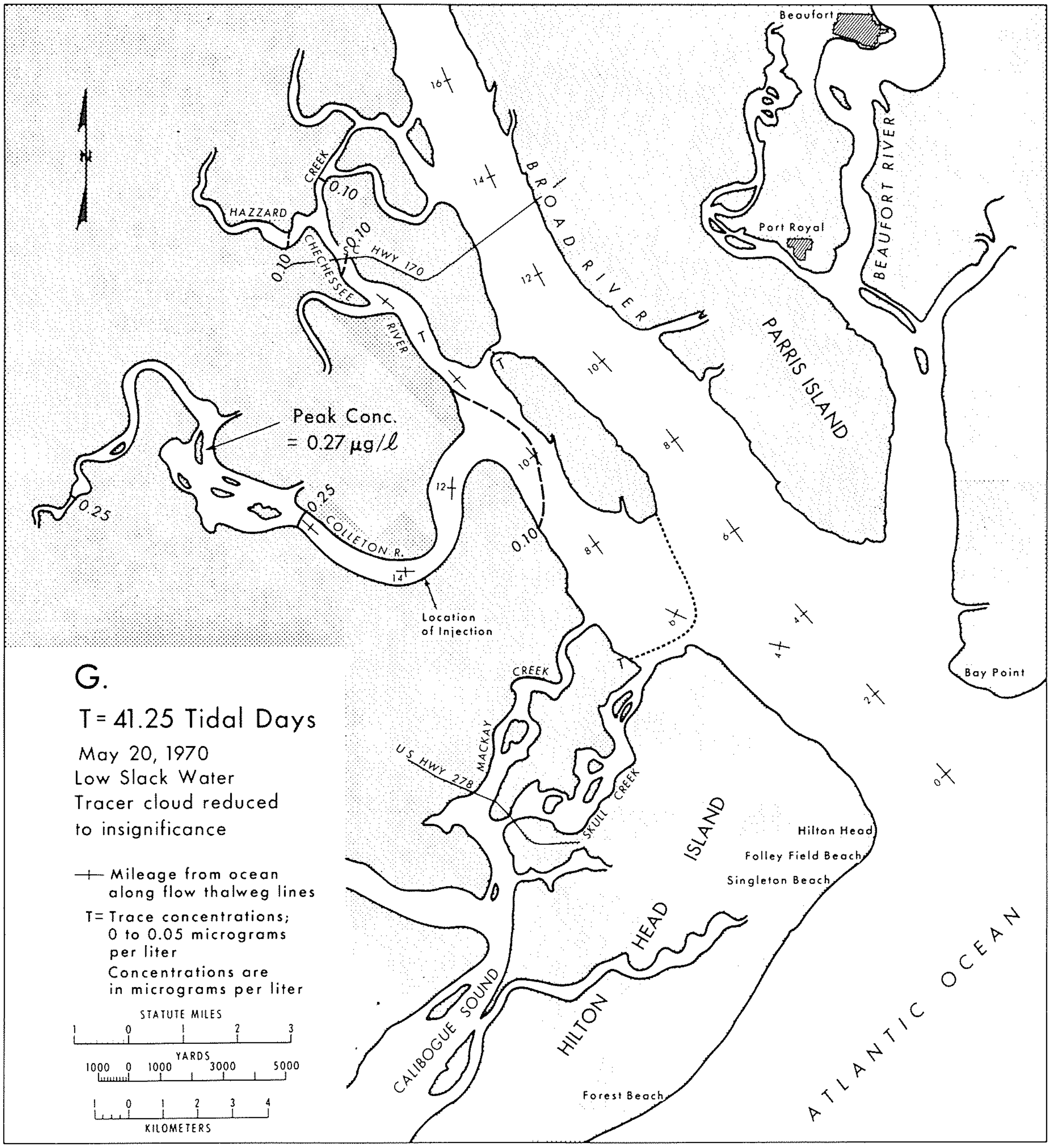

Figure 9G—Low-slack-tide isoconcentration map showing final observation of dye cloud.

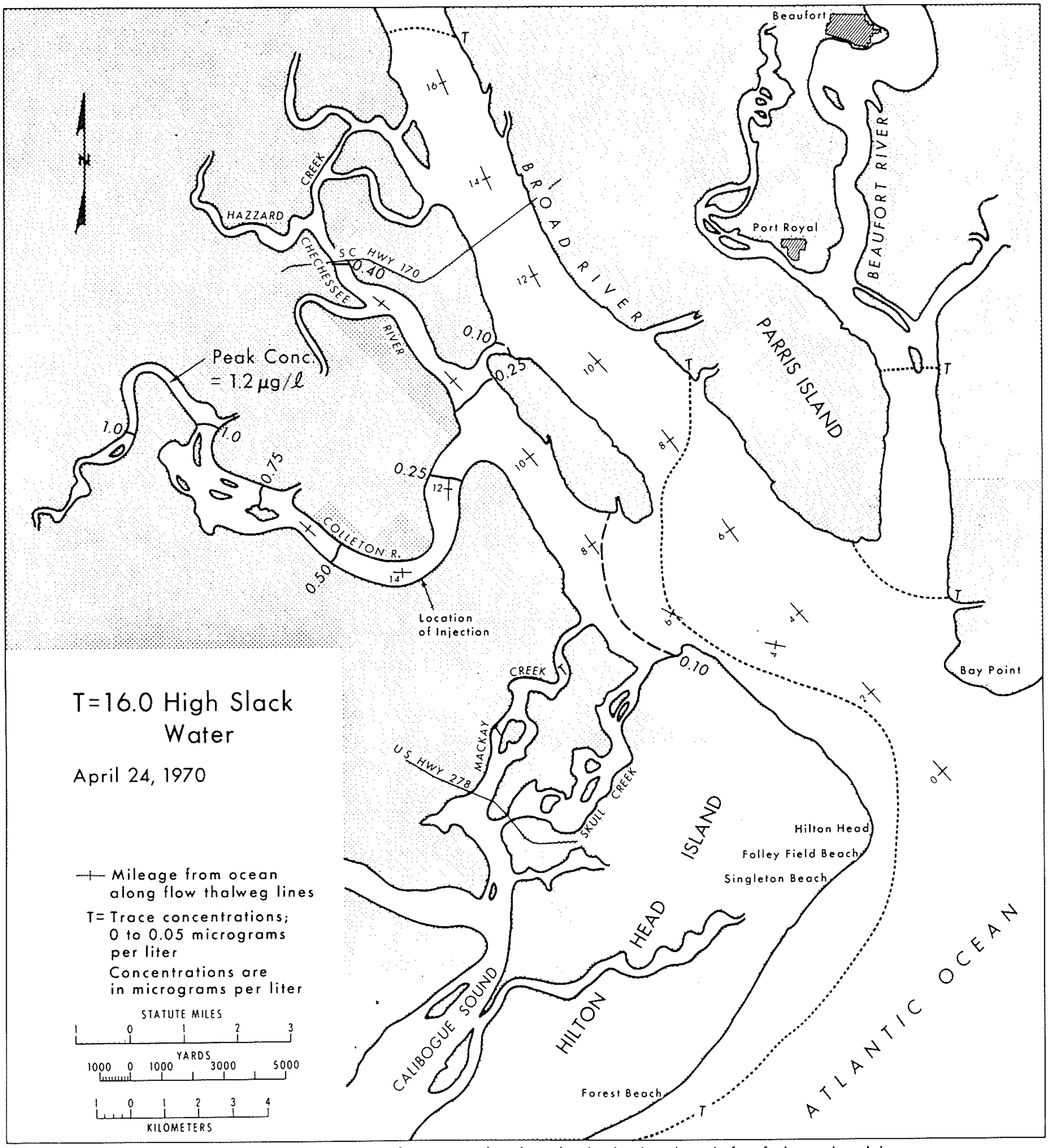

Figure 10—Isoconcentration map of tracer cloud at high-slack-tide; shift of dye cloud between low and high tide can be determined by comparing with Figure 9F.

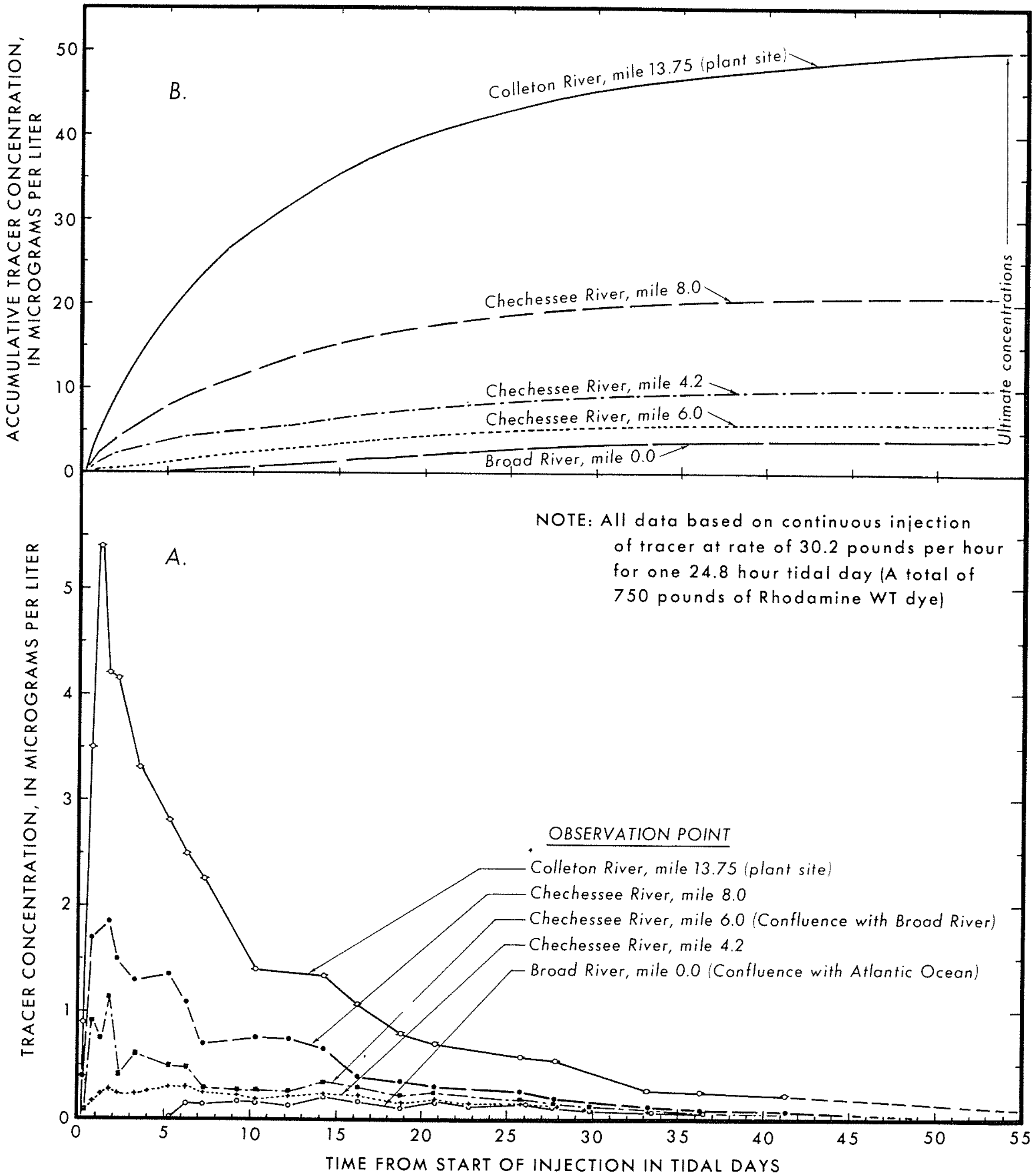

Figure 11. - (A) Graphs of time-concentration curves, and (B) computed ultimate concentration curves, for selected locations along the main tracer plume.

solute was constructed, as shown in Figure 12. If a solute were injected continuously into the Colleton River in the vicinity of Victoria Bluff, the resulting distribution and buildup in concentration is described both qualitatively and quantitatively in Figure 12. In effect, a buildup to the concentrations shown must be reached before dispersion flushes a solute out of the estuary at the same rate as it is injected into the Colleton River. Figure 11 indicates that about 50 days are required for this equilibrium flushing condition to be reached. The shapes of the curves of Figure 11A are momentarily affected at certain times and places by unusual tidal or wind conditions, but the area under any particular one, representing the ultimate concentration, is not significantly altered. Because the tide and weather conditions shown in Figure 7 were varied, but typical of the area during the test, the results of this study should be widely applicable.

Discussion and Conclusion

Figure 12 shows that maximum concentrations are near the injection point, as might be expected, and that relatively high values will exist upstream in the Colleton River. The Broad and Beaufort Rivers would experience low concentrations because of their tremendous dilution capacities. Only minor concentrations may be expected along the beaches of Hilton Head Island. It appears that the bulk of the solute would be transported directly seaward because the dominant path of tidal flow is the deep main channel. Because a solute originating in the Colleton River would favor the right bank after entering the Chechessee River, medium concentration would be experienced in this region and in the northeastern portions of Skull and Mackay Creeks. Under normal conditions no significant amount of solute should pass through Skull and Mackay Creeks into Calibogue Sound. Medium concentration would exist in the upper Chechessee River, caused by the back-flushing of solute from the lower Chechessee River at flood tides.

Application of Results

Figure 12 provides a means of evaluating the concentrations that may be expected at any point in Port Royal Sound from the continuous injection of any amount of solute into the lower reach of the Colleton River. For example, what concentrations would exist in Port Royal Sound from injecting continuously into the Colleton River at Victoria Bluff, 6 million gallons a day of a solute having a specific gravity of 1.3 and containing 20 percent substance Y. It is assumed that the actual solute Y has the same nonconservative characteristics as the tracer used in the study. Table 1 shows the computation and resulting concentrations at certain selected locations.

The maximum concentration of 846,000 $\mu g/l$ occurs in the Colleton River just upstream of the injection site; this is equivalent to approximately 846 ppm.

Conservative Concentrations

All data thus far presented in this report are observed except for the estimated discharge hydrographs in Figures 5 and 7. Bailey *et al.* (1966), Dyar (written communication), and Hetling and O'Connell (1966) have found that Rhodamine WT dye, the tracer used in this test, has a dye loss rate varying from 3.4 to 4.8 percent per day. No attempt was made to compute the dye loss rate by mass computations, as flushing occurred too early in the test to allow reliable evaluation. The dye lot supplied by the manufacturer was tested prior to acceptance and found to be above average. If it is assumed a rate of 3.0 percent per day would apply, the concentrations presented in Figure 12 should be multiplied by a factor of 1.8 to represent a conservative solute. Proper evaluation of the ultimate concentrations which may result thus requires not only a knowledge of the amount being injected, but information on the chemical, biochemical, and physical reactions that affect the decay rate. Certain substances such as chlorides, sulfates, sodium, and potassium are relatively conservative while cyanides, phenols, nitrates, and phosphates are non-conservative (McKee and Wolf, 1963). Most solutes, even those called conservative, generally are less conservative than the tracer used in this test. Figure 12 will therefore yield safe values, higher than would actually be the case.

Table 1.—Computation of Ultimate Concentrations for Selected locations in Port Royal Sound.

Location	Ultimate Conc. from Fig. 12 $\mu g/l$	Injection Rate in MGD	Specific Gravity of Solution*	Conc. of Solute	Computed** Conc. in $\mu g/l$
	(1)	(2)	(3)	(4)	(5)
Injection Site	65	6	1.3	0.2	846,000
Colleton R. Mile 21	32				417,000
Chechessee R. Hwy. 170	13				169,000
Broad R. Hwy. 170	2				26,000
Skull Cr. at mouth	9				117,000
Beaufort R. at mouth	3				39,000
Hilton Head	4	6	1.3	0.2	52,000

* If the substance is readily soluable, this high a specific gravity will not alter its dispersive characteristics due to the turbulent conditions existing.

** Note — Computed concentration (col. 5) = columns (1) x (2) x (3) x (4) x 8345 (factor to convert MGD to 1000's of lbs. of water per day).

Effect of Injection at Other Locations

The main advantage of a tracer simulation test is that it imitates exactly the movement of a solute

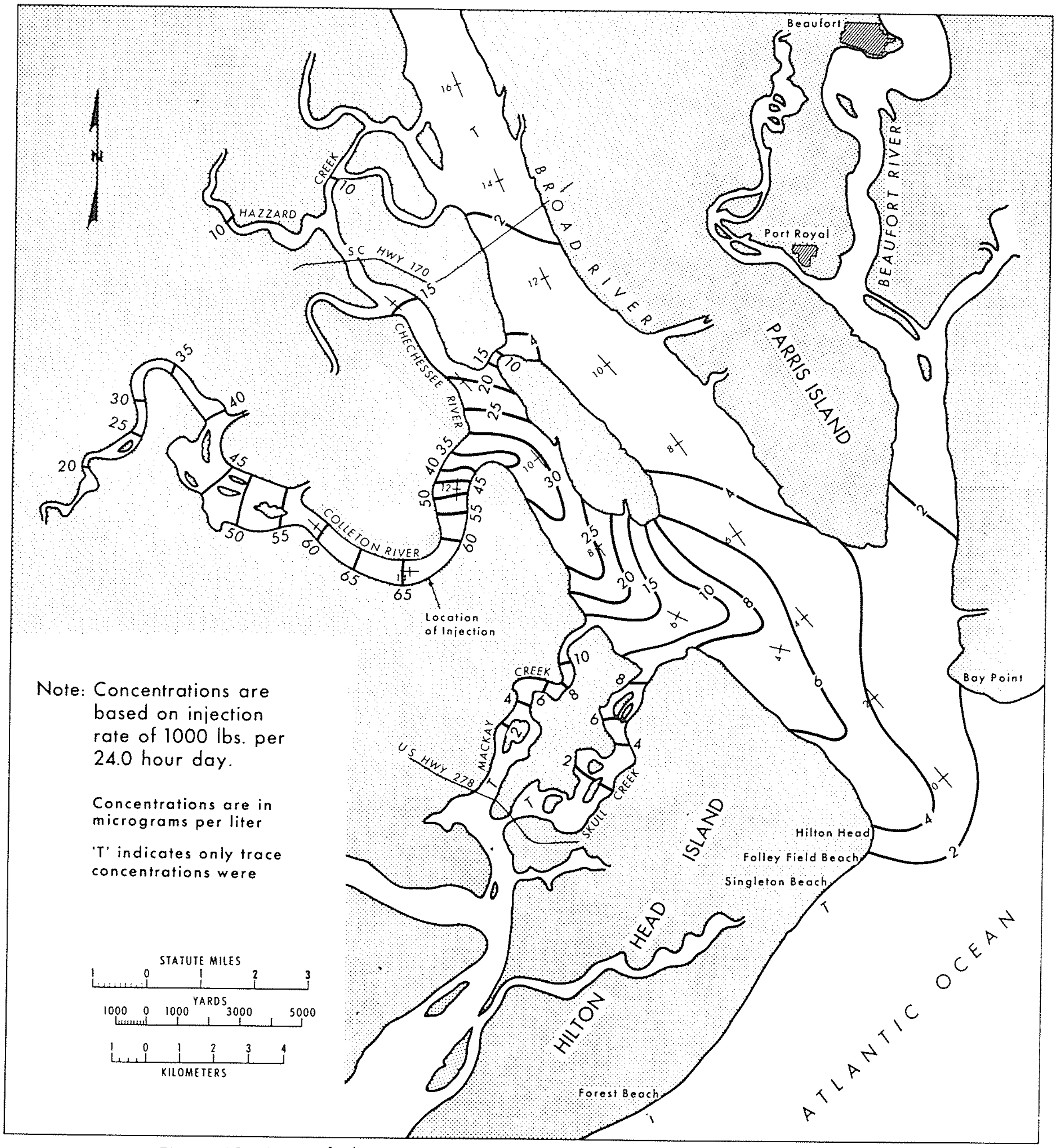

Figure 12— Map of ultimate concentrations for a nonconservative solute injected continuously at the rate of 1000 pounds per day.

injected at a given location. It responds to the hydraulics of the tidal system without the necessity of making extensive hydraulic measurements. Using the superposition principle and the dispersion properties of the tidal system it is possible to estimate the effect of a continuous injection at other locations. Such computations would use synthesized time-concentration curves as building blocks and would be estimates only, in lieu of actual test data. Nevertheless such estimates would be useful for planning purposes.

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Geology and Ground Water Hydrology

Donald J. Colquhoun
Geology Department,
University of South Carolina, Columbia, S. C.

Introduction

The Department of Geology of the University of South Carolina has investigated three facets of the geology portion of the Port Royal Sound Study. First, stratigraphy of the Port Royal Sound area; second, sedimentology of Port Royal Sound; and third, monitoring well implacement.

During the course of the investigation, the University's drilling capabilities were expanded to meet the needs of the project. The drilling rig, which previously had been used for undisplaced power augering was adapted for rotary drilling, using equipment available in the Department of Geology and through acquisition of necessary pumps, bits and packer. Laboratory facilities employed were in the Geology Department.

While much work has been done under this project, as the following report will summarize, much more remains to be studied using samples acquired.

Stratigraphy

Introduction

This report is based on analyses of 15 holes drilled for this investigation, other logs and comments of local water well drillers, as well as geophysical information obtained from logs run within the region.

The fifteen holes drilled for this project were used to supplement existing subsurface stratigraphic information and the locations of these holes were chosen specifically with respect to existing geologic information to provide better subsurface coverage. The method of drilling employed a highly modified B40 truck-mounted rig adapted for undisplaced auger drilling. This method of drilling involves screwing 4½″ auger rods directly into the ground without augering samples to the surface, for depths of up to 40 feet. The rods are then ripped directly out of the ground, the surface contamination on the auger land is peeled back, and the samples are collected from the uncontaminated material lying below this surface contamination. Normally the drilling was conducted from 0-40 feet after which the rods were pulled and sampled; the hole was re-entered and drilled from 40-60 feet, the rods were then pulled and sampled. The hole was then re-entered and drilled from 60-80 feet and so forth, until total depth had been penetrated. Generally, the drilling was conducted to such a depth that the cap rock lying on the top of the principle aquifer and a few feet of the principal aquifer itself were penetrated and sampled. Maximum depth of drilling was 190 feet.

During the course of drilling, observations with respect to rate of penetration and the position of changes in rate of penetration were noted. These observations were useful in lithologic comparison of material retained on the auger for sampling (See Appendix).

Sampling Method

Samples were collected along 5-foot intervals from the surface to total depth and also above and below significant changes in lithology. Approximately 200 to 300 grams of material were retained for analysis and transported to the Department of Geology of the University of South Carolina for processing.

Approximately 150 grams of sample were dried at temperatures of less than 80°C and a dry weight was recorded. The sample was then dispersed into distilled water and passed through a 230 mesh seive, the silt and clay portion of which was tagged, dried and retained for further analysis. The sand portion, or that material lying on the 230 mesh sieve was washed clean using tap water, dried and weighed. The dried sand sample was then split several times with a microsplitter to give an aliquot between 5 and 12 grams. This material was then subjected to rapid sediment analysis. The resulting strip charts from the recorder of this apparatus were then laid under a template. Various parameters, picked to characterize the size distribution of the sediment, then were noted (see Appendix). The parameters chosen were the 5, 16, 25, 50, 84 and 95th percentile. These values were selected because they are the common parameters used for calculations of Folk and Inman, for sediment statistical studies. Any other size values desired can be quickly picked by reference to the original strip charts. The size values quoted, which are theoretical diameters of spheres equivalent to the sediment response, are in phi units. This unit is the negative log of 10 to the base two of the theoretical diameter quoted in millimeters.

Splits of the dry sand sample were introduced into carbon tetrachloride, and the microfossil suites, which float upon the surface of this liquid, were poured off and sent to competent paleontologists for identification.

Stratigraphy

Stratigraphic units penetrated include a basal carbonate section of late Eocene age, an intermediate zone of slightly to moderately indurated marls, clays, sands and gravels of Early Miocene age, and a surficial layer of Pleistocene and Holocene muds, gravels and sands. Typically, the drilling near the ground surface was relatively easy and rapid during penetration of the Holocene and Pleistocene stratigraphic units. Penetration of the Hawthorne Formation was much more difficult, and ledgey and frequently bouncy drilling was characteristic as phosphatic nodule and shell zones were cut. Immediately above the principal aquifer a cherty and occasionally phosphatic cap was encountered up to two feet in thickness. The penetration of this cap was extremely difficult and slow. However, once the cap was breached, the penetration of the principal aquifer occurred relatively quickly and without difficulty.

Holocene-Pleistocene Surficial Units

In general, the Holocene and Pleistocene surficial units consisted of light to medium gray clays and fine sands with occasional coarse sandy layers. Often fine shell material was encountered and occasionally fossil wood and possible relic soils were discovered near the base. The relic soils were particularly characteristic of those sections thought to be Holocene in age. They are probably remnants of a drowned river system, inundated as the sea level rose to its present position thereby forming the estuary. None of the Pleistocene-Holocene material has been sent for further paleontological study. The reasons for this lie in the great abundance of this material that has been examined from other areas.

Hawthorne Formation

The Hawthorne Formation lithologies consist of 1) dark to light greenish, micaceous silty clays, often with chert and phosphate pebbles, 2) well-sorted, medium to coarse feldspathic, micaceous sandstones and 3) silty, clayey, bioclastic lime muds. The clays and the lime muds of the Hawthorne are usually quite compact, tight, and difficult to penetrate. The medium and coarse sands are porous and easily penetrated. With the exception of the top of the Hawthorne Formation, which is indicated by a change in drilling rate from easy to hard coupled with a lithologic break, and the base of the Hawthorne Formation which is indicated by the cap rock formed above the principal aquifer, correlation of any of the units within the Hawthorne Formation has proved impossible. Though the sands mark a secondary aquifer within the region, they are not widely occurring and appear irratically within the drilling logs.

W. K. Pooser (written communication), in examining floated microfossils suites from Beaufort 12, 14 and 15, notes characteristic brackish estuarine environments for deposition of these units, which probably explains their rapidly changing faces.

Santee Limestone

Below the cap rock previously described, a thick carbonate sequence is encountered which is porous and permeable at the top. This is the principal aquifer of the region. The carbonate unit, which consists of microgranular and micritic lime muds, contains in the upper beds, a Late Eocene faunal assemblage. Lithologic correlation to the Santee Limestone as developed in central South Carolina is reasonable. The upper portion of the Santee Limestone is slightly dolomatized and a loose, vuggy porosity has been developed by the leaching of calcium carbonate shell material. This porosity was probably developed after deposition of the shelf carbonate lime muds of the Santee and before a subsequent transgression of the seas in Early Miocene times to form the estuarine conditions of the Hawthorne Formation.

Several cross sections (Figure 1) of the stratigraphic relationships in the vicinity of Port Royal Sound, Dawes Island, Lemon Island, Port Royal Island and other areas of interest were constructed using drilling hole data and where appropriate, high resolution seismic data from Duncan (1971).

Structure

The structure indicated by the nature of the stratigraphy in the drilled holes surrounding Port Royal Sound together with the seismic records is depicted in Figures 2, 3 and 4. These cross-sections, the locations of which are indicated on Figure 1, confirm the presence of an arch area striking northeast from the vicinity of the Colleton River. Superimposed overall is a general southeasterly dip. The nature of the contacts between the Santee limestone and between the Hawthorne Formation and the overlying Holocene and Pleistocene beds is very irregular.

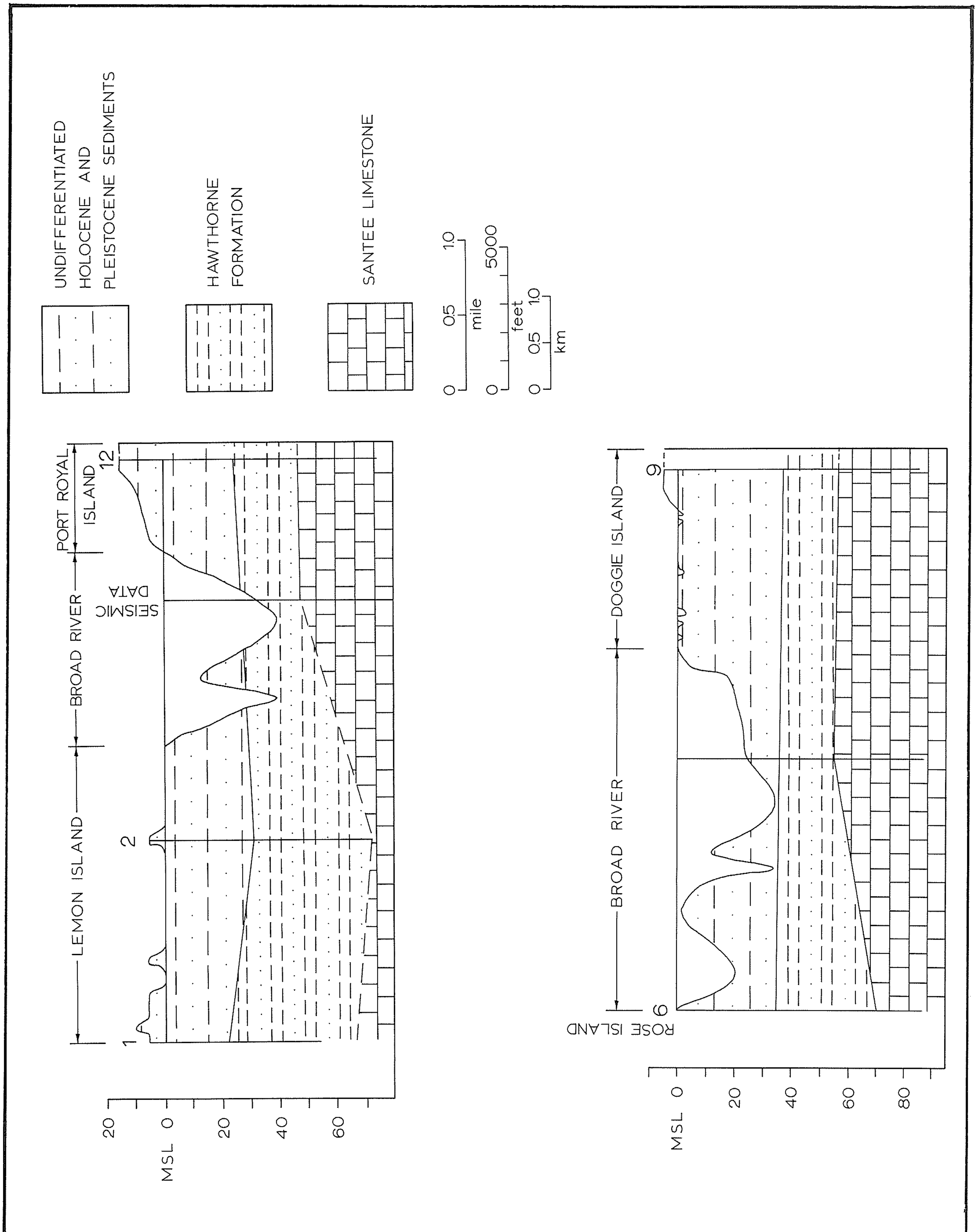
The Nature of Aquifer Cap Rocks

Principal Aquifer Cap Rock

The principal aquifer cap rock is a very dense, hard, cherty limesone which is occasionally phosphatic. It is, however, irratic in occurrence. Among the holes drilled, this cap rock was either absent or its presence was very questionable in Beaufort County holes 3, 5 and 11. In other holes, cap rock or cap rock-like material was encountered for thicknesses of up to 5 feet lying at the top of the principal aquifer. Therefore, aside from observations taken from the geophysical records which are reported in another section, there is ample evidence from the subsurface drilling that the principal aquifer within the Santee Limestone and the secondary aquifers of the overlying Hawthorne Formation are interconnected. Even though these aquifers have remarkably different pumping capabilities, they should not be regarded as separate units.

The Hawthorne Formation Cap

The surface of the Hawthorne Formation, which includes the secondary aquifers within coarse-grained, well-sorted, sand channel-like bodies, was determined on the basis of a sudden increase in pressures necessary for undisplaced augering, as well as coincident changes in lithologies. The surface so picked is highly irregular, having been eroded by both fluvial and estuarine processes during the deposition of overlying formations as well as by wave scour during subsequent advances and retreats of the sea. Where secondary aquifers lie at the contract of this eroded surface and where the overlying Pleistocene and Holocene facies are porous and permeable, these aquifers may be said to be interconnected as well.



UNDIFFERENTIATED HOLOCENE AND PLEISTOCENE SEDIMENTS
HAWTHORNE FORMATION
SANTEE LIMESTONE
0 0.5 1.0 mile
0 5000 feet
0 0.5 1.0 km
PORT ROYAL ISLAND
BROAD RIVER
LEMON ISLAND
SEISMIC DATA
MSL
20 0 20 40 60
DOGGIE ISLAND
BROAD RIVER
ROSE ISLAND
0 20 40 60 80

Figure 2.

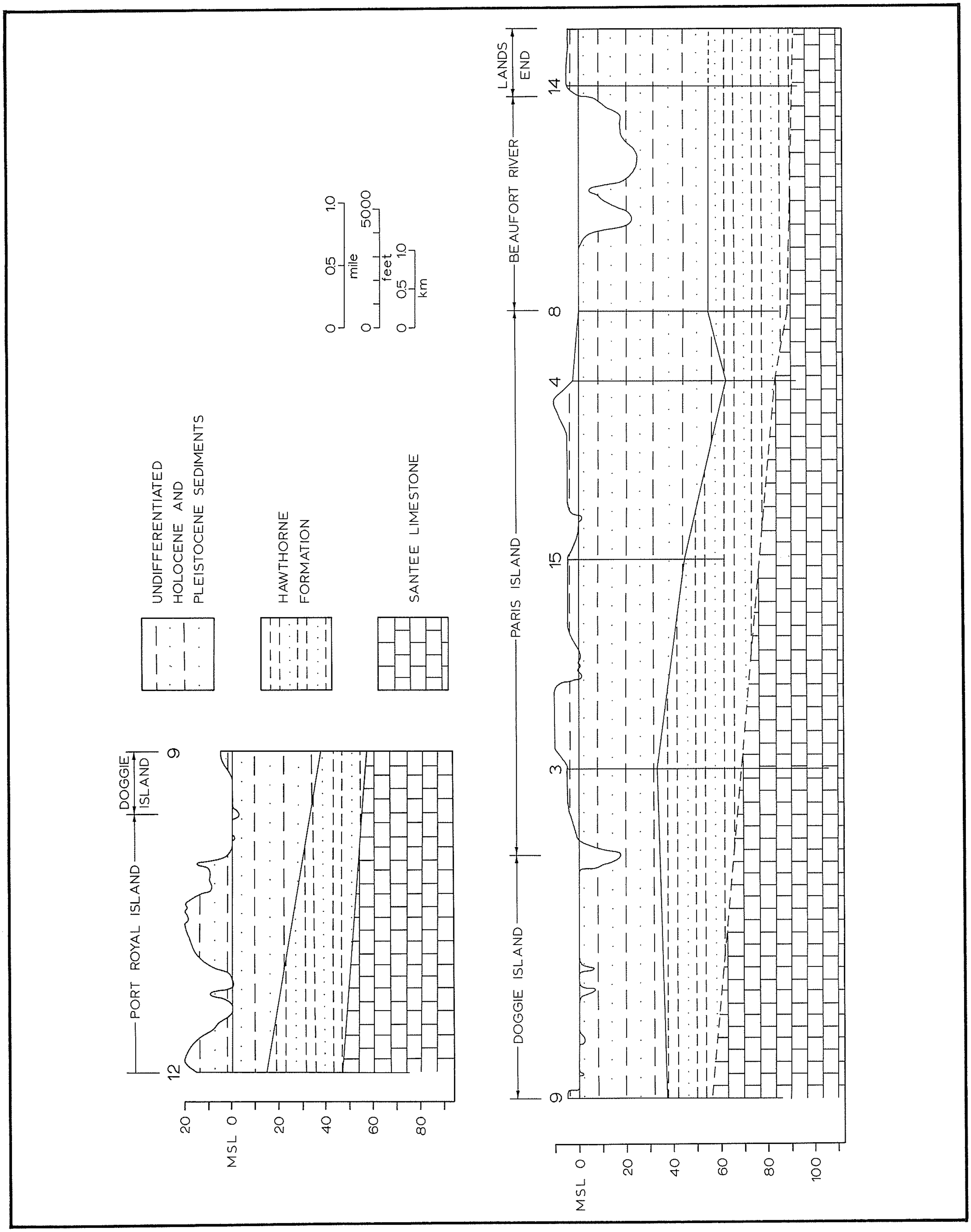

PORT ROYAL ISLAND
DOGGIE ISLAND
12
9
MSL 0
20
40
60
80
UNDIFFERENTIATED HOLOCENE AND PLEISTOCENE SEDIMENTS
HAWTHORNE FORMATION
SANTEE LIMESTONE
0 0.5 1.0 mile
0 5000 feet
0 0.5 1.0 km
DOGGIE ISLAND
PARIS ISLAND
BEAUFORT RIVER
LANDS END
9
3
15
4
8
14
MSL 0
20
40
60
80
100

Figure 3.

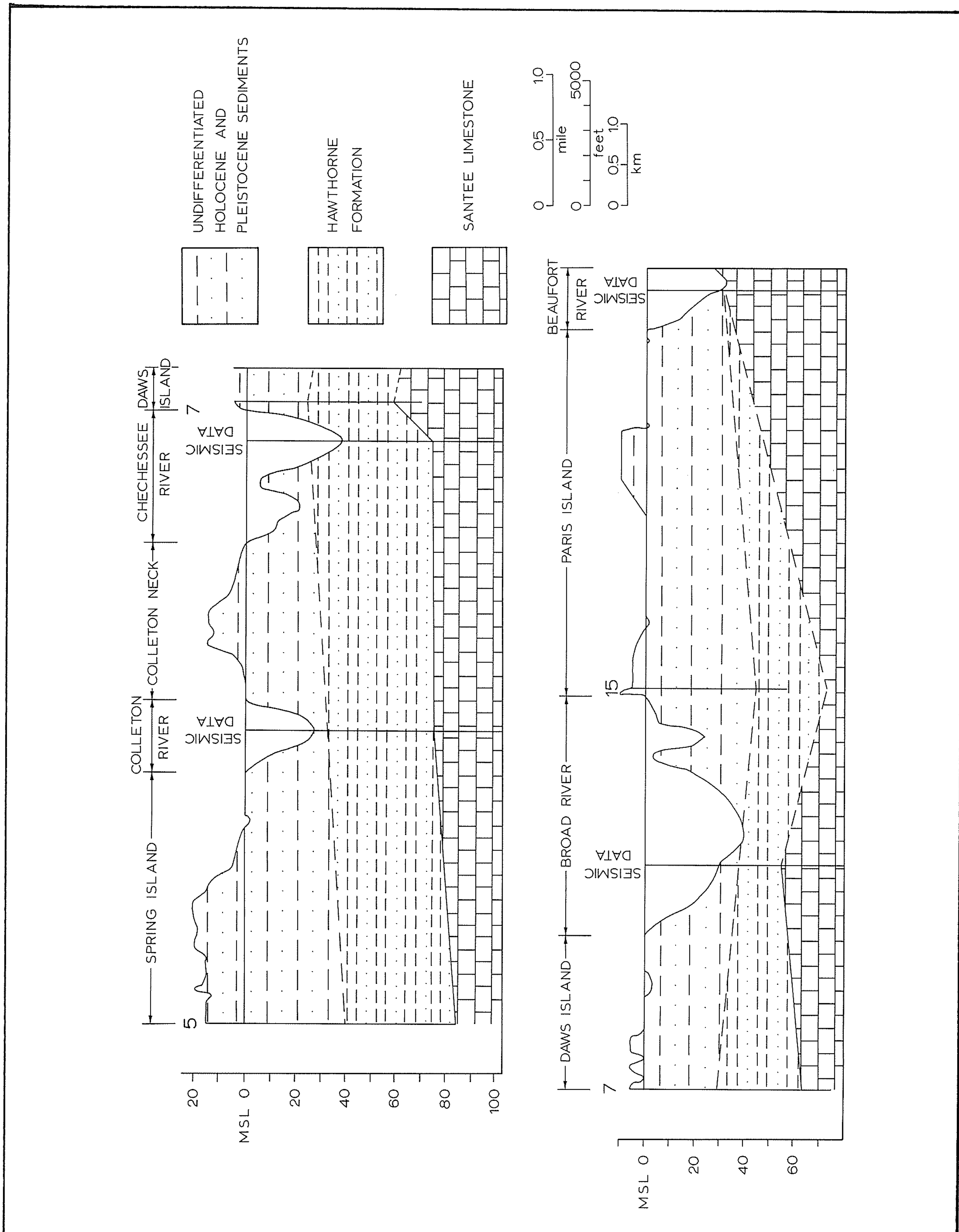

UNDIFFERENTIATED HOLOCENE AND PLEISTOCENE SEDIMENTS
HAWTHORNE FORMATION
SANTEE LIMESTONE
0 0.5 1.0 mile
0 5000 feet
0 0.5 1.0 km
SPRING ISLAND
COLLETON RIVER
COLLETON NECK
CHECHESSEE RIVER
DAWS ISLAND
SEISMIC DATA
MSL 0
20
40
60
80
100
5
7
DAWS ISLAND
BROAD RIVER
PARIS ISLAND
BEAUFORT RIVER
15

Figure 4.

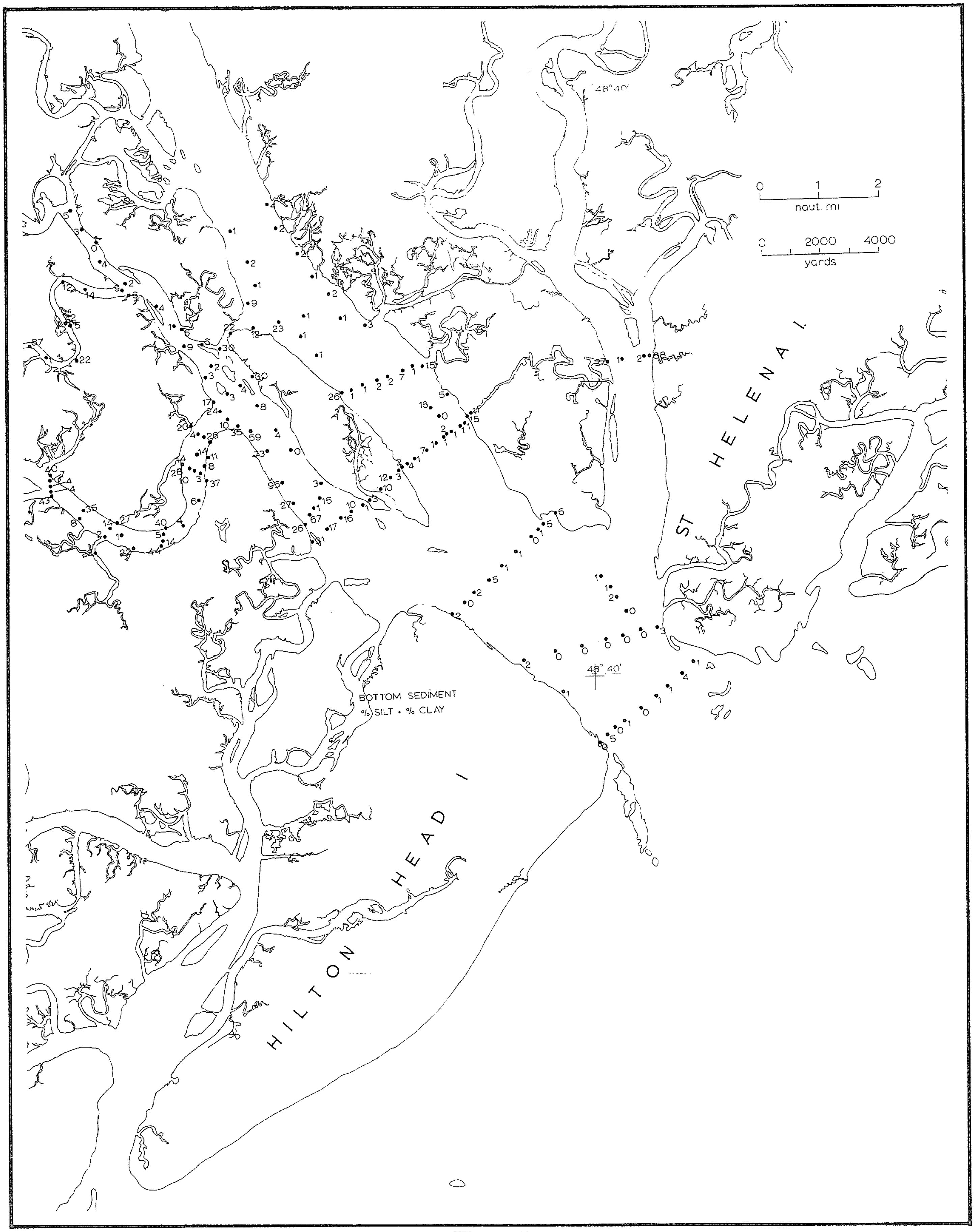

BOTTOM SEDIMENT
% SILT + % CLAY
naut. mi
yards
ST HELENA I.
HILTON HEAD I

Figure 5.

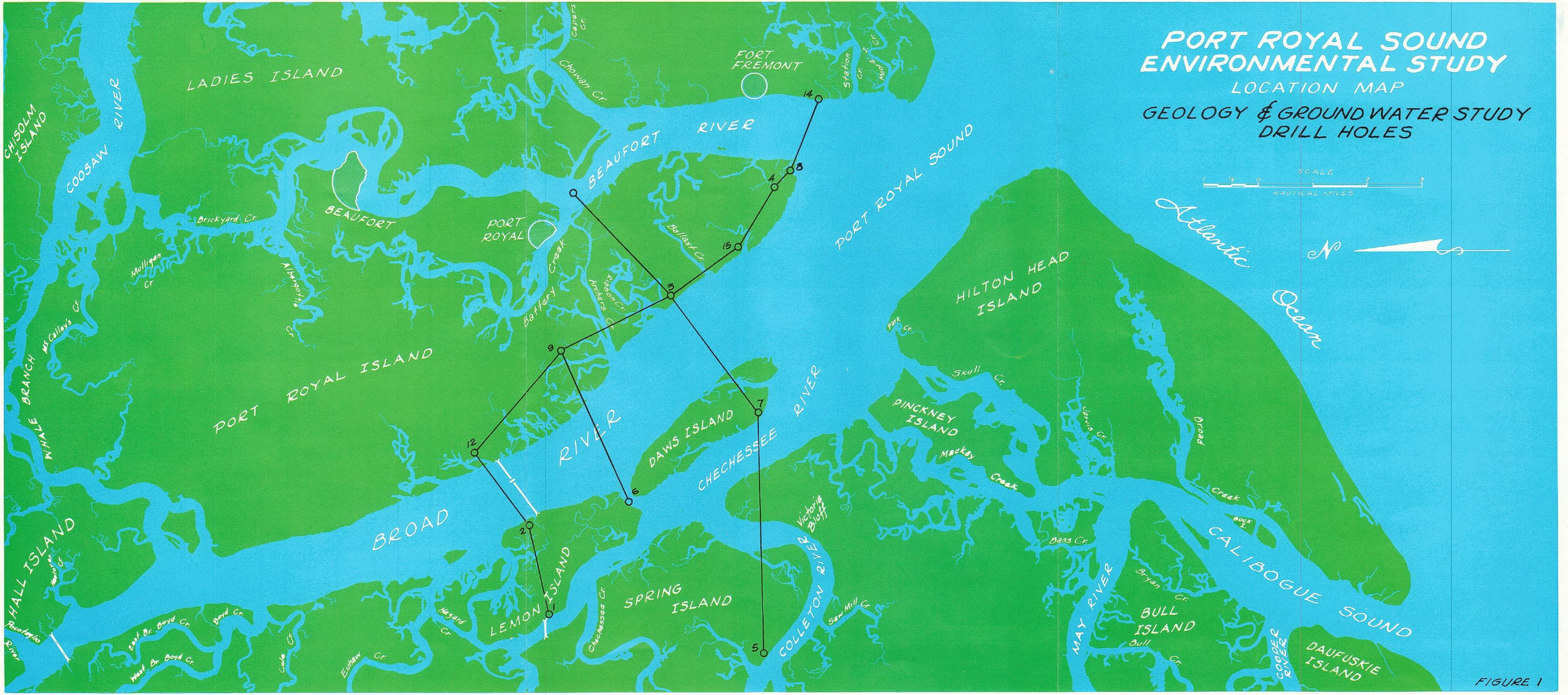

PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
GEOLOGY & GROUND WATER STUDY
DRILL HOLES
SCALE
NAUTICAL MILES
N
Atlantic Ocean
LADIES ISLAND
FORT FREMONT
BEAUFORT RIVER
BEAUFORT
PORT ROYAL
PORT ROYAL SOUND
CHISOLM ISLAND
COOSAW RIVER
Brickyard Cr.
Mulligan Cr.
Albergottie Cr.
McCalley's Cr.
WHALE BRANCH
PORT ROYAL ISLAND
Battery Creek
Archers Cr.
Ballast Cr.
Chowan Cr.
Capers Cr.
Station Cr.
HILTON HEAD ISLAND
Skull Cr.
PINCKNEY ISLAND
Mackay Creek
DAWS ISLAND
CHECHESSEE RIVER
BROAD RIVER
HALL ISLAND
LEMON ISLAND
SPRING ISLAND
Chechessee Cr.
COLLETON RIVER
Victoria Bluff
Sawmill Cr.
Bass Cr.
MAY RIVER
BULL ISLAND
Bryan Cr.
Bull Cr.
CALIBOGUE SOUND
COOPER RIVER
DAUFUSKIE ISLAND
Broad Creek
East Br. Boyd Cr.
West Br. Boyd Cr.
Boyd Cr.
Euhaw Cr.
Hazzard Cr.
Pocotaligo River
1
2
3
4
5
6
7
8
9
12
14
15

FIGURE 1

Sedimentology of Port Royal Sound

Introduction

Over 150 bottom samples were obtained from Port Royal Sound and subjected to physical size analyses. The samples were obtained using a modified small Peterson dredge. The sample locations were noted visually from known landmarks within the Sound.

Subsamples of approximately 70-100 grams of sample were dried and weighed. They were then disaggregated, washed and pressed through a 230-mesh seive. The portion remaining on the 230-mesh seive was then dried, weighed and split to approximately 7-12 gram aliquots and dropped through the rapid sediment analyzer for analysis. The results of the rapid sediment analysis are noted in the Appendix.

Sedimentology

Results of analyses are presented in Figures 5 and 6. Port Royal Sound is underlain in nearly all areas by fine-grained to coarse-grained, well-sorted sand (excluding bioclastic material). Generally, the percentage of silt and clay present is less than 5% in all open water areas. Silt and clay are the dominant sediments, however, around and in the marshes and headwaters of some of the minor tidal creeks, silt and clay increase abruptly with the appearance of *Spartina alterniflora.* In open waters, however, sand is the dominant lithology (Figure 5).

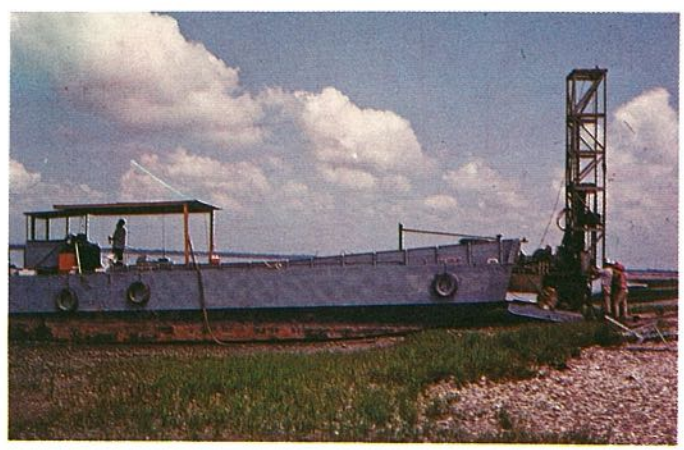
The median diameter of the sand is interpreted in Figure 6. A direct geographic correlation running parallel to the length of the estuary between the size of the sand particles and the intensity of tidal current distribution appears to exist.


MEDIAN DIAMETER
OF BOTTOM SEDIMENT
IN
PHI UNITS
ST HELENA I.
HILTON HEAD I.
0 1 2
naut. mi.
0 2000 4000
yards

Figure 6.

Although detailed mineralogical studies of the sand and clay samples are not as yet completed, in general the sands are ortho-quartzitic (greater than 95% quartz). Heavy minerals, such as ilminite and monazite comprise less than 1% of the lithology by weight. Minor phosphate (collaphane accumulations were noted rarely).

Observation well construction at Lands End; photo by D. Duncan, S. C. Water Resources Commission.



Exploration drilling on Daws Island; photo by D. Duncan, S. C. Water Resources Commission.

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High Resolution Seismic Study

Donald A. Duncan
South Carolina Water Resources Commission

Purpose and Scope of the Investigation

The South Carolina Water Resources Commission, as a part of its Port Royal Sound Environmental Study, made an analysis of the subsurface geology of the area. This analysis consisted of reconnaissance geologic mapping, exploration drilling, and geophysical surveys.

The objectives of the geological investigations within the study area related to determining the effect of proposed dredging and heavy pumping on the principal fresh-water aquifer which underlies the area. Ground water is widely used in this area for domestic, agricultural, public and industrial purposes. The availability, good quality, and the relatively low cost of ground water are the three primary reasons for its widespread use in the area.

However, over the years water levels have been continually lowered as a result of the heavy withdrawals in the Savannah area and in some areas in Beaufort County. The gradual lowering of water levels has caused a growing concern in the area that the water supply available from the principal aquifer might be seriously impaired or limited for future use. These limitations could result from overpumping or improper development causing saltwater contamination of the aquifer.

To provide a geologic framework for the ground-water investigation, it was necessary to make a detailed analysis of the effects of vertical and horizontal lithologic variations and geologic structures on the occurrence and movement of water in the principal aquifer.

The initial phase of the geologic investigation consisted of drilling fourteen exploration wells, four of which were constructed as permanent monitoring wells. Data collected consisted of: detailed rock samples, geophysical logs, water quality samples, water-level data and aquifer characteristics.

The test wells also provided control points necessary for the seismic survey.

The second phase of the geologic investigation consisted of high resolution seismic profiling in Port Royal Sound, and portions of Beaufort River, Broad River, Chechessee River, Colleton River, and Skull Creek.

The immediate objective of the seismic survey of these water areas was the delineation of the uppermost surface of the principal aquifer or its confining bed.

This determination was of immediate concern because of the fact that proposed dredging in these channels might penetrate the impervious "cap" rock on top of the aquifer and permit saltwater to enter and contaminate the fresh-water zones.

The seismic survey provided data sufficient to determine the subsurface geology of the water areas, configuration of the channel bottoms, type and thickness of the bottom sediments, and the top of the principal aquifer, and the configuration of the top of the principal aquifer.

The geologic study team consisted of the Water Resources Commission staff geologist, State geologist, staff and equipment of the University of South Carolina Geology Department, geologist and equipment of the United States Geological Survey's Water Resources Division, and a private consultant, Hydrosurveys, Incorporated of Fort Lauderdale, Florida.

The data obtained during the seismic survey of the Beaufort River revealed that the confining layer(s) overlying the principal aquifer and possibly the principal aquifer itself, are breached in the Beaufort River. This breach is primarily a result of naturally occurring geologic processes. However, dreding during construction of the existing navigation channels has aggravated a serious situation.

These findings, in the opinion of the study team, indicated that any additional dredging to deepen the existing navigation channel in the Port Royal and Cat Island Reaches of the Beaufort River would probably further aggravate and contribute to an accelerated deterioration of ground-water quality with salt-water encroachment into both the primary and secondary aquifers in the immediate area. These conditions, through time, along with the ever increasing ground-water withdrawals, would tend to spread gradually over a larger area of Beaufort County and vicinity.

At the request of the South Carolina State Ports Authority, the Water Resources Commission made additional geologic surveys in the critical section of the Port Royal navigation channel. These surveys were designed to determine the precise configuration and elevation of the geologic strata with emphasis on the principal aquifer system in this reach of the Port Royal Channel. The survey was designed also to determine if there was a possibility of locating a deeper navigation channel in the general vicinity of the Port Royal Channel without complicating or aggravating existing conditions.

The detailed geologic study of the Port Royal navigation channel was made in two phases. The first phase of the study was to thoroughly examine the area by making seismic traverses. The second phase consisted of drilling three exploratory drill holes for control points on Cat Island, Cane Island, and at Port Royal near the State docks.

Location of Study Area

The study area is located in central Beaufort County on the South Carolina coast. The investigation was limited to an area in and around Port Royal Sound within longitude 80° 36′ 34″ and 80° 51′ 33″ and by latitude 32° 06′ 03″ and 32° 32′ 30″ (Figure 1).

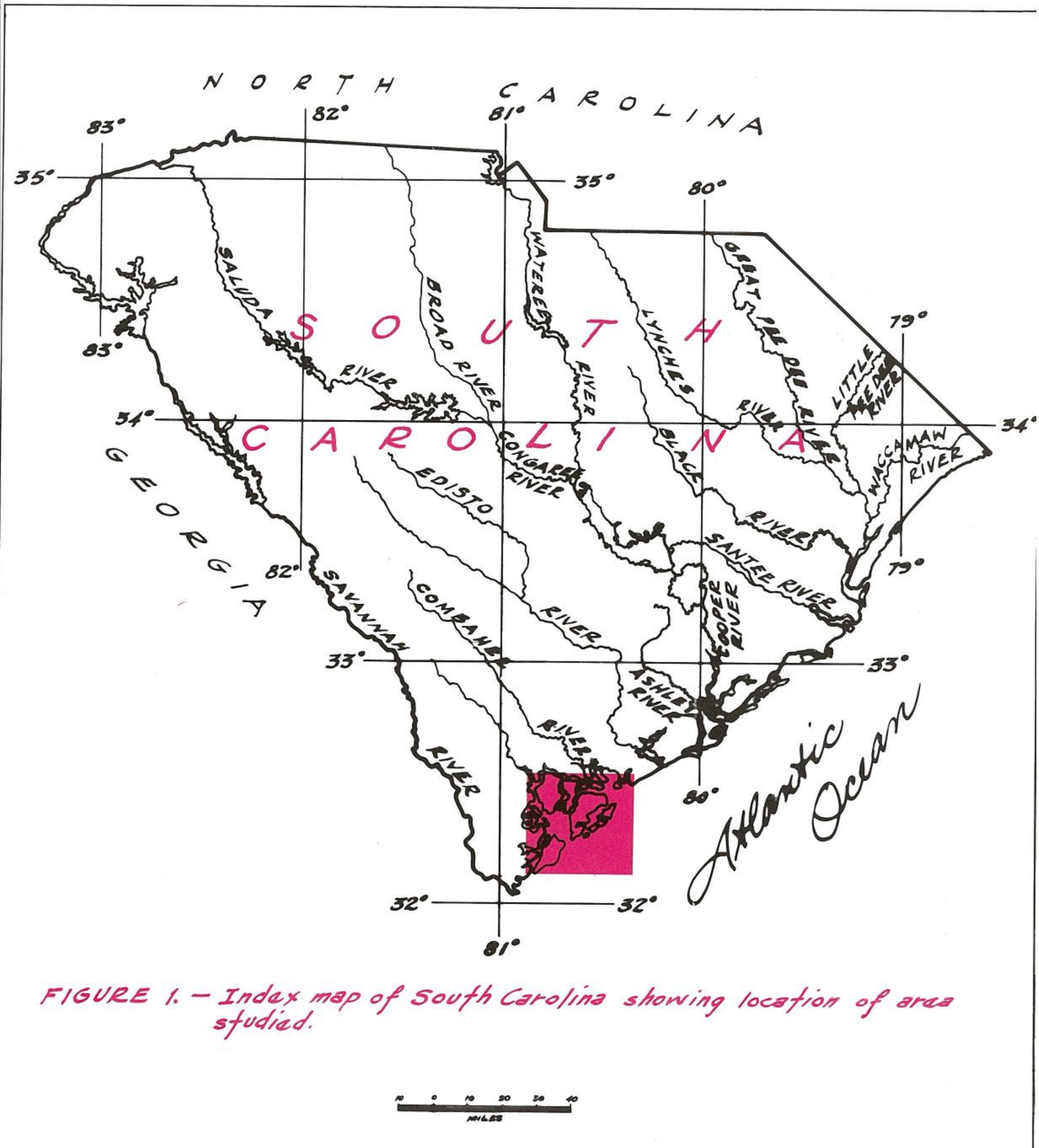


FIGURE 1. — Index map of South Carolina showing location of area studied.

Physiography

The study area lies within the Sea Island section of the Coastal Plain province, a part of the Atlantic Plain. The Atlantic Plain consists of the emerged plain, or Coastal Plain and the submerged continental shelf. Together the Coastal Plain and the continental shelf have a width of about 200 miles and a southeastward gradient of about 3.6 feet per mile.

The study area is drained principally by Port Royal Sound and its many tributaries. The principal tributaries include Broad River, Beaufort River, and Chechessee River. Secondary tributaries to the Beaufort River include Battery Creek, Archers Creek, and Chowan Creek. The Colleton River is a principal tributary to the Chechessee River. The drainage of these streams is principally to the southeast into the Atlantic Ocean.

Methods of Investigation

Equipment and Technique

The equipment utilized in the investigation of the subsurface geology of Port Royal Sound was well described by Welby and Leith in 1968. Their description is as follows: "The High Resolution Boomer is one of several continuous seismic profiling devices developed for use on water. A sound pulse is generated near the surface of the water. The pulse is strong enough and of sufficiently low frequency to insure penetration below the water-sediment interface but is not low enough in frequency to preclude resolutions of individual reflecting layers a foot or less apart. The various layers of sediment and rock reflect the energy back to the receivers at the water surface, the strength of the reflection being related to the elastic properties of the sediment. The reflected energy is amplified, filtered, and recorded on the strip chart, resulting in a profile of the sub-bottom conditions along the line transversed by the survey vessel.

"The High Resolution Boomer employs an electromechanical transducer to produce a clean, single pulse without secondary cavitation. The hydrophone is mounted separately, and both instruments are towed from the stern of the boat. Capacitor banks, generators, and the recorder are mounted on the boat."

Interpretation

The method for determining depths to a given geologic horizon involves the translation of the two-way time of travel of the acoustic signal through both water and sediment. Due to the horizontal separation of sound source and receiver, the formula

is utilized in translating the recorded two-way travel time to one-way travel time and vertical depth. In this formula

S = one-way vertical travel time
C = recorded travel time
t = the direct arrival travel time.

The two-way travel time for the acoustic signal is computed from the horizontal lines on the High Resolution Boomer record. The vertical distance between these horizontal lines represents a time of 10 milliseconds. The direct arrival time is the record of the signal received directly from the transducer as it passes through the water to the hydrophone. The zero time line represents the surface of the water body. The computation of the one-way travel time and subsequently the depth to a geologic horizon is accomplished by utilizing the two-way travel time and the direct arrival time in the formula above and as illustrated in Figure 2 which was modified from Welby and Leith (1968).

Critical to determining depths to a given geologic horizon from the High Resolution Boomer record is knowing the velocity of the acoustic signal as it travels through the sediment. This velocity was determined by comparing the High Resolution Boomer record with known depths for certain geologic horizons from drill hole data in the study area. The seismic survey was made to pass near the drill hole locations for correlation.

After comparing the High Resolution Boomer records with the well logs from the exploratory drill holes, it was determined that the average velocity of the acoustic signal traveling through the sediments was 5,600 feet per second.

The velocity by which the acoustic signal travels through sea water is approximately 4,900 feet per second. Therefore, to obtain accurate depths to given geologic horizons, two tables were utilized. (See Tables 1 and 2).

The first table, provided by the geophysical consultant, was utilized to determine depth of water during the July survey. The depth to river or channel bottoms was determined by measuring the record time from the zero time line to the river or channel bottom as shown on the High Resolution Boomer record and by going to the appropriate column based on direct arrival time at that location.

The second table constructed and utilized in interpretation, is based on a sediment velocity of 5,600 feet per second. This velocity was halved to account for the two-way travel time of the acoustic pulse. Thus, 10 milliseconds record time in the sediments is equivalent to 28 feet.

After computing the water depth from Table 1, the time in milliseconds was measured from the

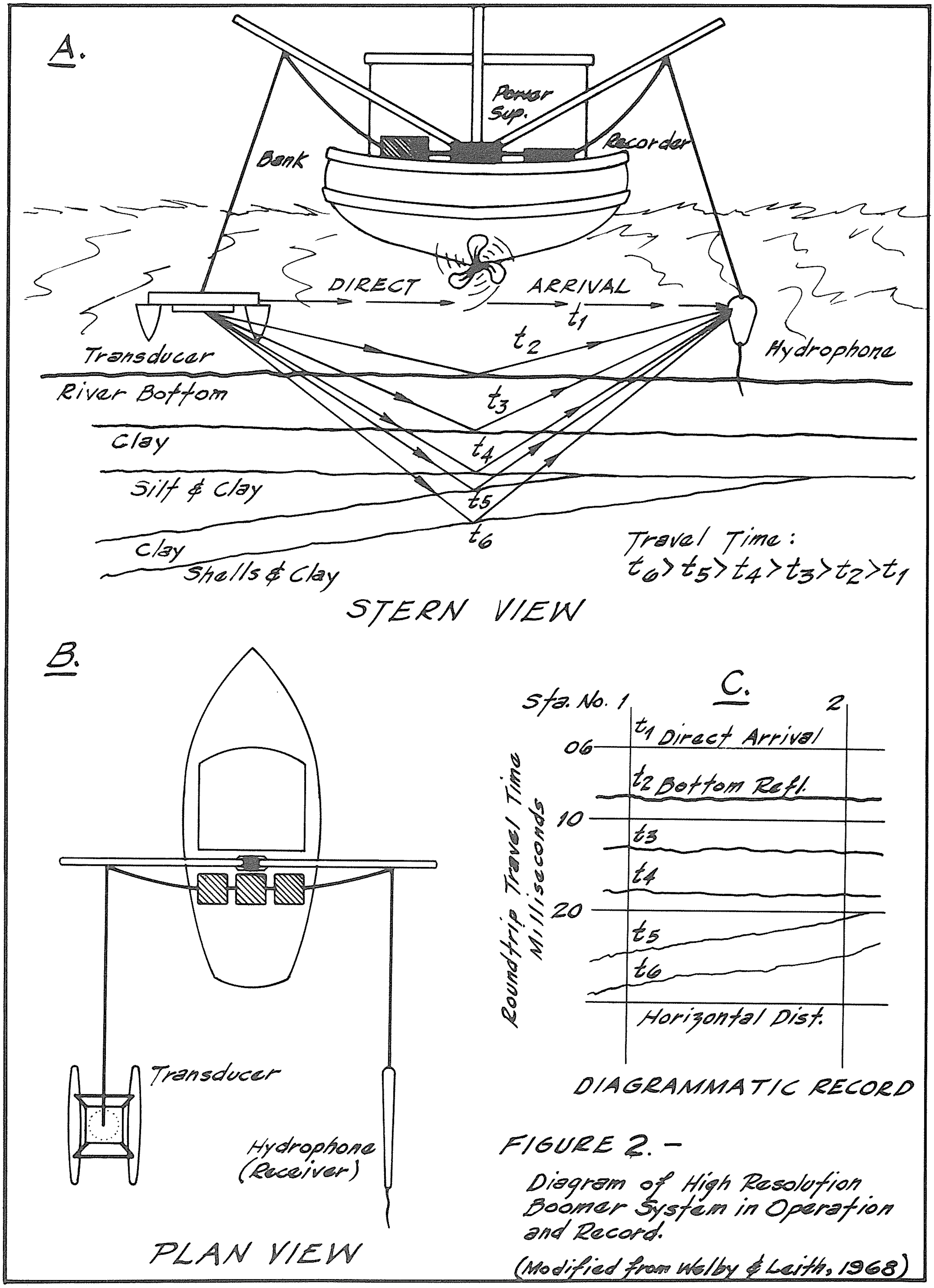


FIGURE 2.—
Diagram of High Resolution Boomer System in Operation and Record.
(Modified from Welby & Leith, 1968)

channel bottom to the geologic horizon and then converted to feet based on Table 2. Then the water depth and the depth from the channel bottom to the geologic horizon were added to determine total depth at that location to the geologic horizon.

In that a depth of one or two feet in the area could be critical, all depths were translated to mean sea level utilizing tide stage data for the time of the survey provided by the U. S. Geological Survey from digital recorders located in the area. (See Figures 3 and 4.) During the January survey of the Beaufort River, a recording echo sounder was used to determine water depths.

Table 1.—Water depth computation table.

Corrected Depths (Feet)					
Record Time (milliseconds)	DIRECT ARRIVAL TIME (milliseconds)				
	4	5	6	7	8
4					
6	11				
8	17	15	13		
10	22	21	20	17	15
12	28	27	25	24	22
14	33	32	31	30	34
16	38	37	36	35	34
18	43	42	42	41	39
20	48	48	47	46	45
22	53	52	52	51	50
24	58	58	57	56	55
26			62	61	61
28			67	66	66
30			72	71	70

Note: Corrections are based on Water Velocity of 4900 ft./sec.

Table 2.—Geologic Horizon(s) Computation Table.

Record Time (milli-seconds)	Depth in Feet	Record Time (milli-seconds)	Depth in Feet	Record Time (milli-seconds)	Depth in Feet
1	2.8	11	30.8	21	58.8
2	5.6	12	33.6	22	61.6
3	8.4	13	36.4	23	64.4
4	11.2	14	39.2	24	67.2
5	14.0	15	42.0	25	70.0
6	16.8	16	44.8	26	72.8
7	19.6	17	47.6	27	75.6
8	22.4	18	50.4	28	78.4
9	25.2	19	53.2	29	81.2
10	28.0	20	56.0	30	84.0

NOTE: Computed depths are based on a sediment velocity of 5600 feet per second.

INSIGNIFICANT CORRECTION

AGROUND

Regional Geology

The study area is in the lower Coastal Plain of South Carolina. Generally, the Coastal Plain rocks are unconsolidated to poorly consolidated alternating layers of sand, clay, and limestone ranging in geologic age from Cretaceous to Recent. These rocks comprise a wedge of sediments which ranges in thickness from a thin edge along the Fall Line in the central part of South Carolina to about 3,500 feet along the coast near Beaufort. The formations which comprise these rocks crop out at the surface in more or less parallel belts across the Coastal Plain in a northeasterly direction and dip gently toward the coast about 5 to 20 feet per mile.

Generally these sediments were deposited during transgressions and regressions of ancient seas. Along with the sediments that were deposited during the advance and retreats of the ocean are sediments which appear to represent deposition in near shore areas such as estuaries, lagoons, and bays. Also, some of the sediments appear to represent deposition on river flood plains and deltas near the coast lines of the ancient seas. These sediments overlie a variety of crystalline and metamorphic rocks which form the pre-Cretaceous basement.

In the Port Royal Sound area the near-surface section consists of an Upper Eocene limestone overlain unconformably by sediments of Oligocene age. The Oligocene sediments are in turn overlain unconformably by Miocene marine sediments. The post-Miocene sediments consist of marine sands, clays and marls of Pliocene, Pleistocene and Recent age.

The shallow geologic units underlying the study are described in the following table:

Table 3—Generalized lithologic description of shallow geologic units in Port Royal Sound Area.

SERIES	GENERAL LITHOLOGY
Recent to Pliocene	Fine to medium sands, silty-sandy clays and marl.
Miocene	Well bedded clayey sands and sandy clays, containing thin limestone beds. Base usually characterized by indurated phosphatic limestone.
Oligocene	Soft sandy limestone.
Eocene	Limestone; soft, granular, and fossiliferous.

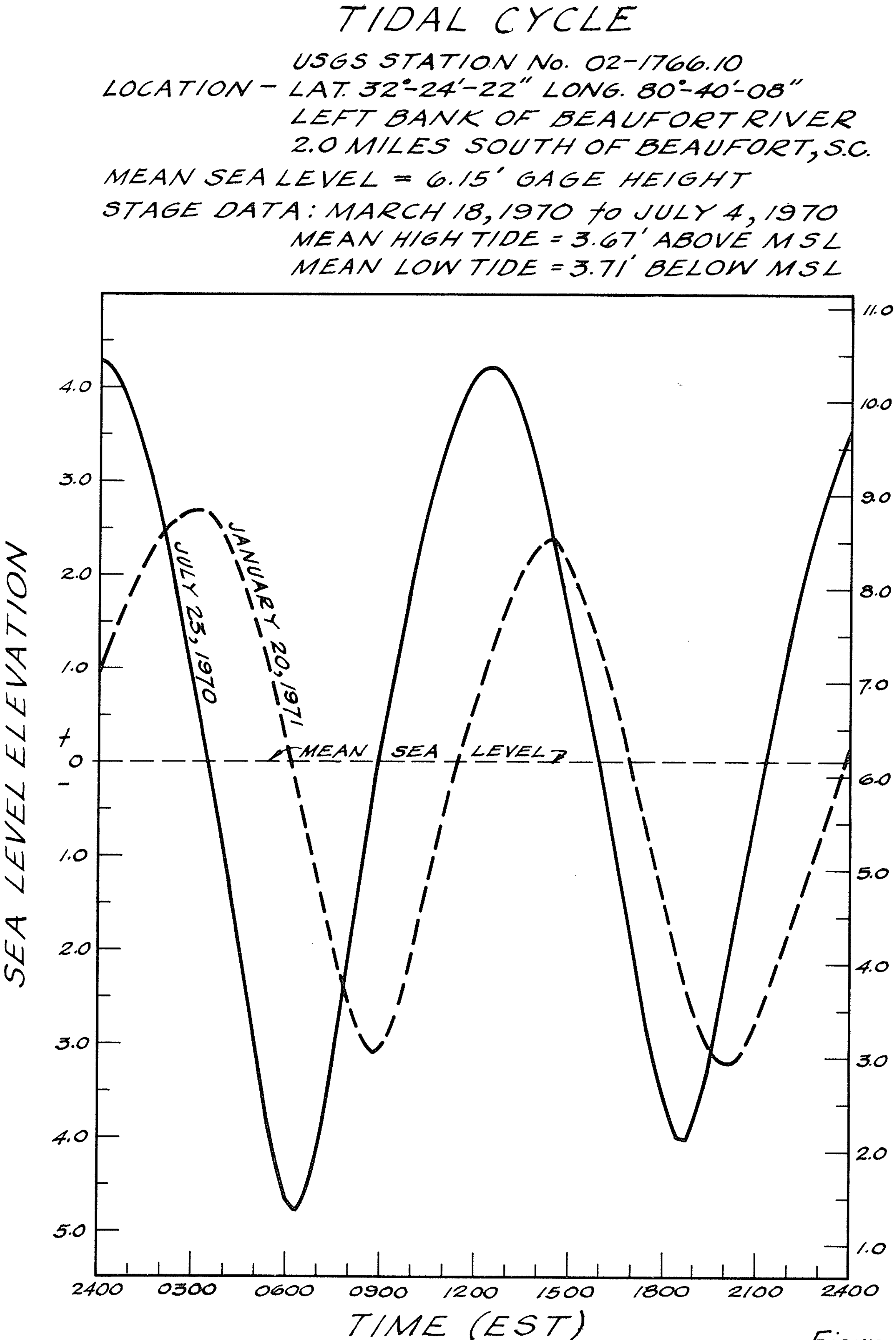

TIDAL CYCLE
USGS STATION No. 02-1766.10
LOCATION - LAT. 32°-24'-22" LONG. 80°-40'-08"
LEFT BANK OF BEAUFORT RIVER
2.0 MILES SOUTH OF BEAUFORT, S.C.
MEAN SEA LEVEL = 6.15' GAGE HEIGHT
STAGE DATA: MARCH 18, 1970 to JULY 4, 1970
MEAN HIGH TIDE = 3.67' ABOVE MSL
MEAN LOW TIDE = 3.71' BELOW MSL
SEA LEVEL ELEVATION
GAGE HEIGHT IN FEET
JULY 23, 1970
JANUARY 20, 1971
MEAN SEA LEVEL
4.0
3.0
2.0
1.0
+
0
-
1.0
2.0
3.0
4.0
5.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
2400
0300
0600
0900
1200
1500
1800
2100
2400
TIME (EST)

Figure 3.

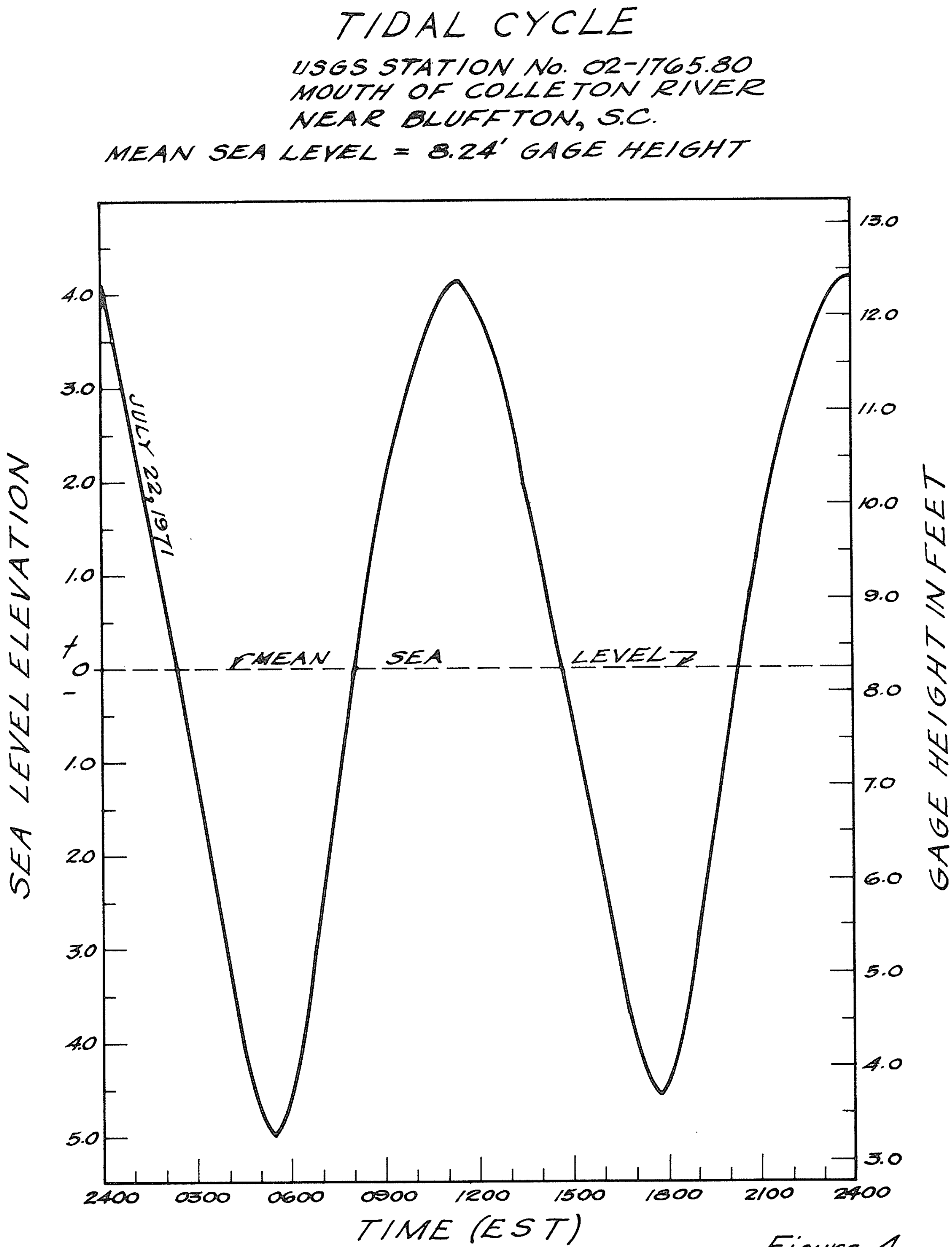

TIDAL CYCLE
USGS STATION No. 02-1765.80
MOUTH OF COLLETON RIVER
NEAR BLUFFTON, S.C.
MEAN SEA LEVEL = 8.24' GAGE HEIGHT
SEA LEVEL ELEVATION
GAGE HEIGHT IN FEET
JULY 22, 1971
MEAN SEA LEVEL
4.0
3.0
2.0
1.0
+
0
-
1.0
2.0
3.0
4.0
5.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2400
0300
0600
0900
1200
1500
1800
2100
2400
TIME (EST)

Figure 4.

While the entire geologic column is of continuing interest to the investigator, the development of data to provide a clear understanding of and relating to the shallow geologic units was the primary objective of the investigation. Particular objectives of the geological investigations related to determining effects of proposed dredging on the principal artesian aquifer. The shallow geologic units of chief concern are the uppermost portions of the principal artesian aquifer and the confining beds which overlie the aquifer.

Confining Beds

Typically, the confining beds consist of a gray to olive green silt and sand interbedded with thin discontinuous lenses of marl and limestone. These confining beds vary vertically and horizontally in both thickness and character. The base of the confining beds is usually characterized by the occurrence of a very hard but relatively thin layer which is generally referred to as the "cap" rock and is essentially composed of indurated limestone and phosphate. This layer, or cap rock, when present, in sufficient thickness, along with the overlying sediments, provides a very effective barrier to the vertical movement of water into and out of the underlying principal artesian aquifer.

Principal Artesian Aquifer

The uppermost part of the principal artesian aquifer generally consists of a blue gray to white poorly consolidated bioclastic limestone of middle Eocene to early Miocene age. Locally the limestone may contain lenses of silt and fine to medium grained sand.

Previous investigators have reported depths to the top of the principal aquifer in the study area. Siple (1960) indicated the top of the principal artesian aquifer to be 40 to 100 feet below the surface on Port Royal Island. Siple also cited evidence to indicate that a considerable amount of limestone had been dredged from the bottom of the Beaufort River near its confluence with Battery Creek. This indicates that the top of the aquifer occurs at an elevation of about 27 feet below msl (mean sea level) at this location.

Counts and Donsky (1963) published "old time residents report that during the years past submarine springs had been noted in the Beaufort River near Port Royal." These reports along with information reported by Siple lend strong evidence to the limestone subcropping in the Beaufort River near Port Royal.

Johnson and Geyer (1965) reported limestone occurring at 19 feet below mean sea level at Brickyard Point on the north end of Ladies Island 4.5 miles due north of the center of Beaufort and at 96 feet below msl at Lands End on St. Helena Island.

Seismic Survey Results

The objectives of the geological investigations included determining the effect of proposed dredging on the principal artesian aquifer and its confining beds in the Beaufort River and in the navigation channel designed to serve a proposed port facility at Victoria Bluff on the Colleton River. To adequately assess the potential effects of future dredging, determination of the elevation and configuration of the top of the principal artesian aquifer, configuration of channel bottoms, and the type and thickness of the bottom sediments were essential.

The top of the principal artesian aquifer as it is described in the following discussions is actually the lower-most unit of the confining beds, usually referred to as the "cap rock". This particular geologic horizon gave a strong reflection on the High Resolution Boomer record and was utilized to delineate the top of the principal artesian aquifer system to satisfy the needs and objectives of this study.

Figure 5 depicts the area covered by the July, 1970 seismic survey. The discussion of the results of the High Resolution Boomer profiling is broken down into the following segments:

1. Beaufort River
2. Broad River
3. Port Royal Sound-Chechessee River-Colleton River
4. Skull Creek-Calibogue Sound

Beaufort River Survey

The reconnaissance seismic survey of the Beaufort River made on July 23, 1970, provided data indicating that the confining beds and possibly the principal artesian aquifer are breached in the Beaufort River near Port Royal. As a result of these findings, the South Carolina State Ports Authority requested the Water Resources Commission to make an intensive seismic survey of the Beaufort River area. (Fig. 6)

The intensive seismic survey was made during the week of January 18, 1971, and included five traverses of the Port Royal Channel from the turning basin at the State docks downstream to Fort Freemont. These five traverses consisted of: (1) a center line traverse; (2) a traverse of the northeast side of the channel; (3) a traverse of the southwest side of the channel; (4) a traverse consisting of short runs at angles across the channel; and (5) a traverse of Chowan Creek and Cat Island Creek was made to evaluate the feasibility of developing

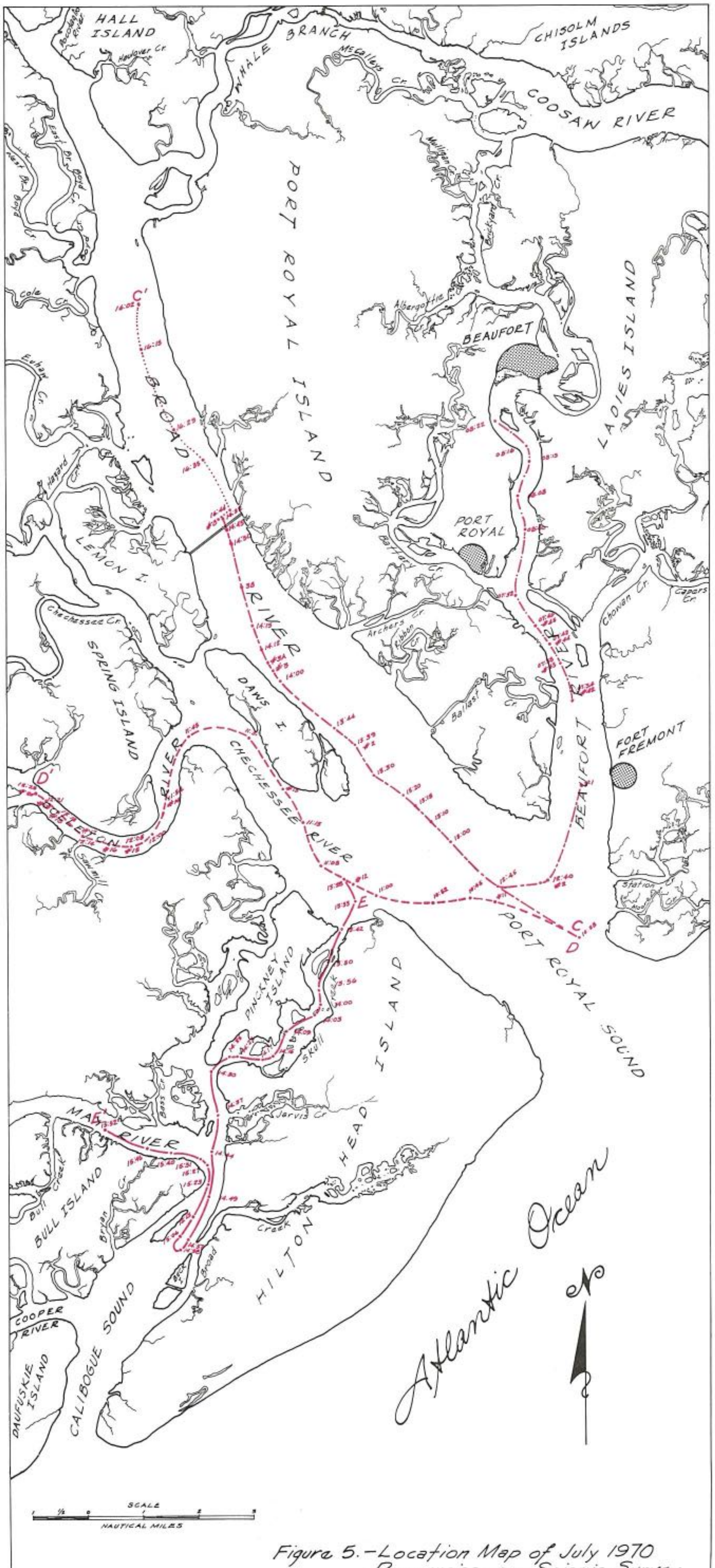


Figure 5.–Location Map of July 1970 Reconnaissance Seismic Survey

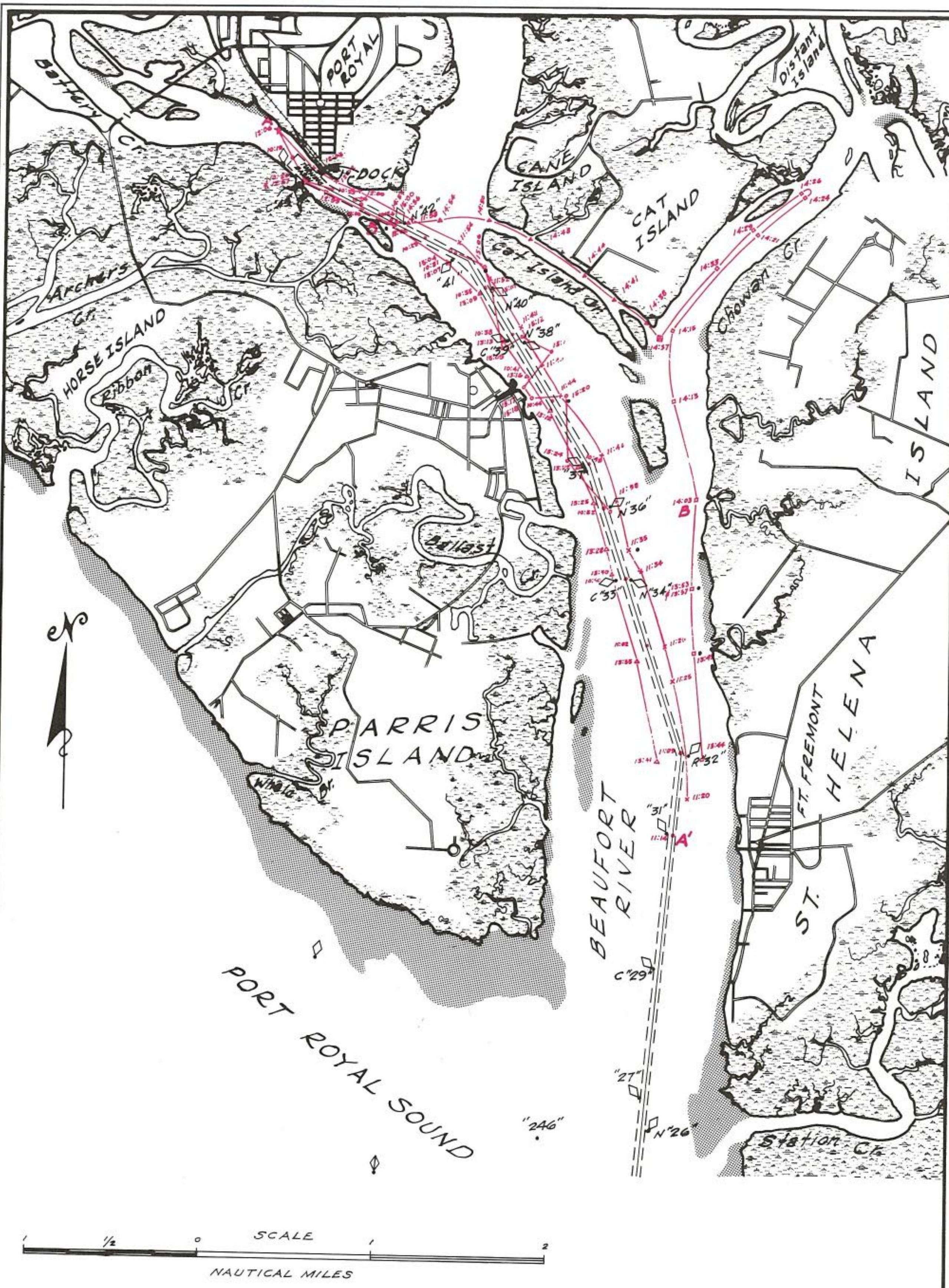


Figure 6.-Location of Beaufort River Intensive Seismic Survey

an alternative channel to the State docks at Port Royal.

In the Beaufort River, the High Resolution Boomer record shows the top of the principal artesian aquifer to range from an elevation of 95 feet below msl at the confluence of Beaufort River with Port Royal Sound up to 30 feet below msl near the confluence of Beaufort River and Battery Creek. Control points from existing wells or wells drilled during the investigation are shown in the following table.

Table 4.—Dept to Principal Aquifer from Control Points Along Beaufort River.

Well No.	*Location*	*Depth below msl (ft.)*
Beaufort #17	Ports Authority	30
Beaufort #18	Cane Island	31
Beaufort #16	Cat Island	41
Beaufort # 4	Ribault Monument	77
Beaufort #14	Lands End	91
Beaufort # 8	Bay Point	85+

The horizontal distance from the control point at the Ports Authority to the control point at Lands End is approximately 5.4 miles and the change in elevation to the top of the principal aquifer is from 30 feet below msl to 91 feet below msl or the slope on top of the principal aquifer is about 11.1 feet per mile in this section of the Beaufort River.

The critical area for any future dredging in the Beaufort River, either maintenance or deepening, lies in the area from the west end of the turning basin in Battery Creek downstream past the confluence with the Beaufort River approximately 2.6 miles to Channel Marker #37 (Fig. 7).

The High Resolution Boomer record shows the top of the principal aquifer at an elevation of 53 feet below msl in mid-channel at Channel Marker #37, at 40 feet below msl in mid-channel half-way between Channel Markers #37 and #38, and at 34 feet below msl in mid-channel at Channel Marker #38. In the navigation channel between Channel Markers #38 and #42 the top of the aquifer is exposed on the river bottom. Elevations to the top of the aquifer exposed on the bottom range from 28 feet below msl to 35 below msl in this reach of the channel.

Upstream in Battery Creek from Channel Marker #42 to the turning basin, the top of the aquifer occurs at 30 feet below msl on the south side of the channel and at 32 feet below msl on the north side. Opposite the Blue Channel Corporation Docks in Battery Creek upstream from the turning basin, the top of the aquifer occurs at 26 feet below msl.

The High Resolution Boomer record also shows fairly conclusive evidence that the confining beds and uppermost part of the principal artesian aquifer have been removed by dredging in the area of the turning basin and in the general area of Channel Markers #40 and #41. The High Resolution Boomer record also shows that the principal artesian aquifer sub-crops on the bottom of the Beaufort River upstream at the mouth of Battery Creek. All evidence indicates that this is a result of naturally occurring geologic processes and not dredging. In fact the aquifer may well have been naturally exposed on the river bottom where subsequent dredging has removed part of it. However, where dredging has occurred in this area, the dredging has surely aggravated a serious situation.

During the January survey, a profile was made of Chowan and Cat Island Creeks to evaluate the feasibility of locating an alternate route into the port. The results from this profile clearly eliminate any consideration of Cat Island Creek as an alternative. This is primarily due to the principal artesian aquifer being exposed on the bottom of the Beaufort River immediately northwest of the confluence of the Beaufort River and Cat Island Creek. Also, the top of the aquifer under Cat Island Creek occurs at 51 feet below msl at the confluence with Chowan Creek, at 42 feet below msl opposite the dock on Cat Island, and at 30 feet below msl at the confluence of Cat Island Creek with Beaufort River (Fig. 8).

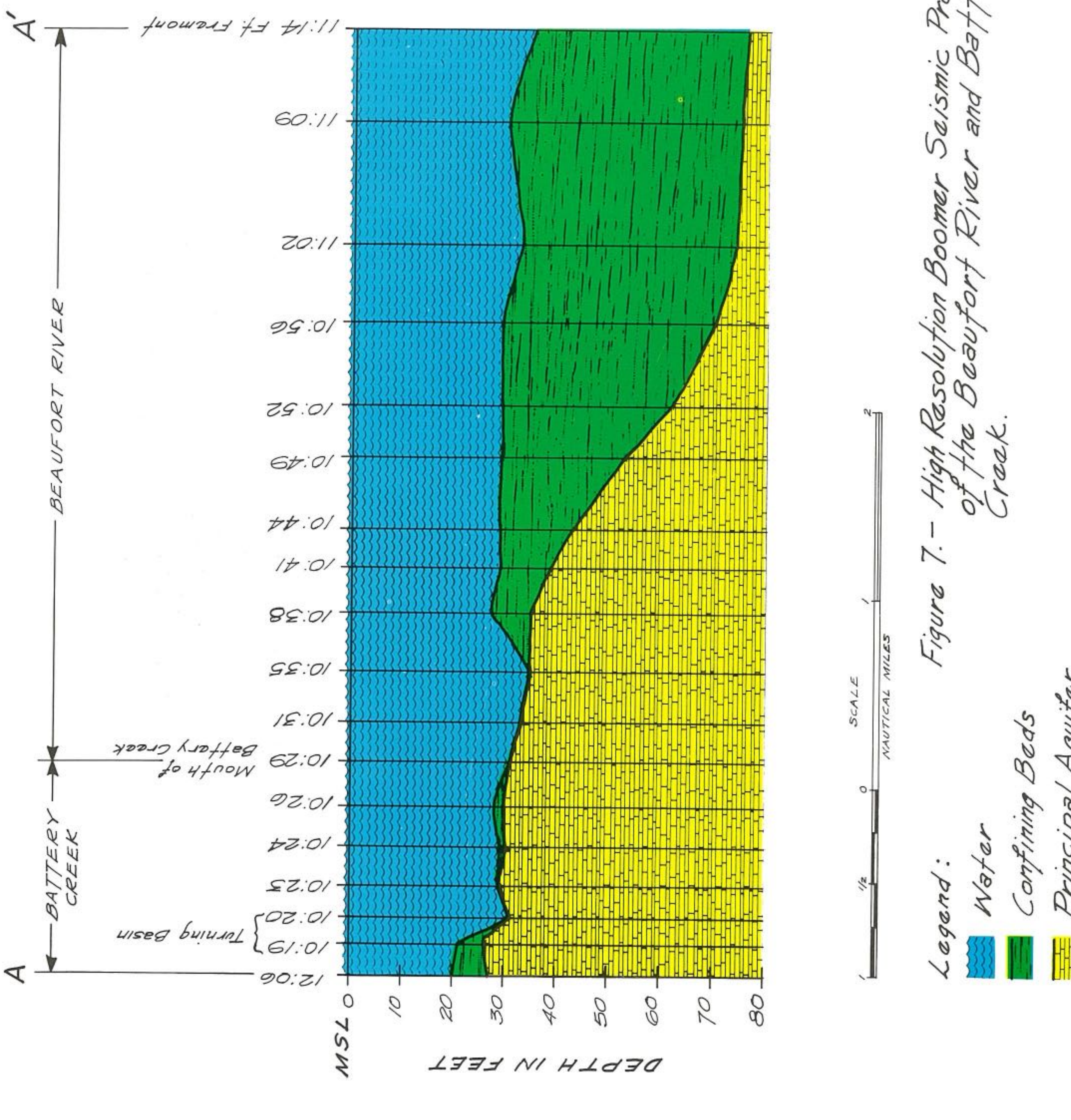


Figure 7.- High Resolution Boomer Seismic Profile of the Beaufort River and Battery Creek.

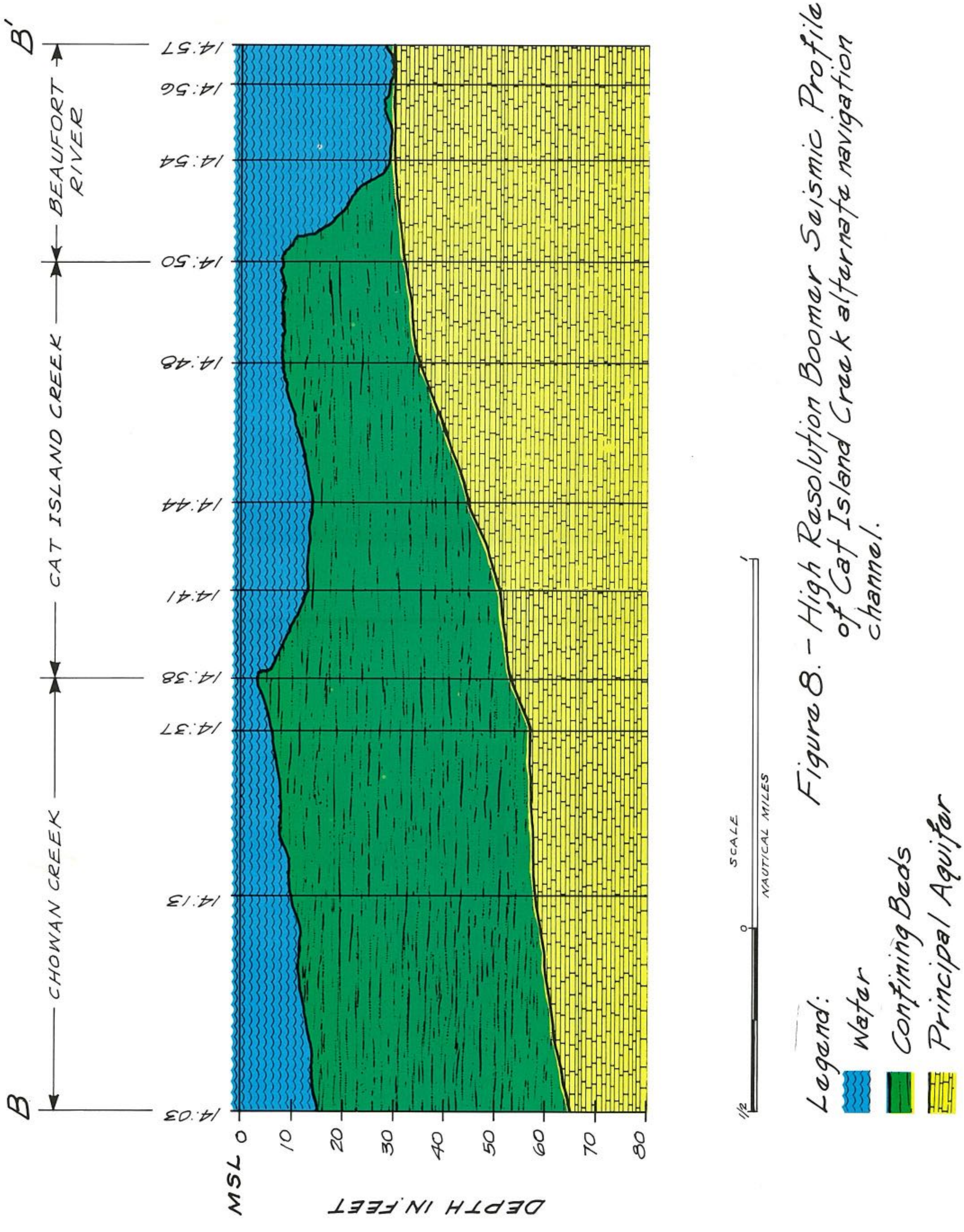


Figure 8. - High Resolution Boomer Seismic Profile of Cat Island Creek alternate navigation channel.

The results of the Beaufort River survey clearly indicate that any future dredging to deepen the navigation channel between Channel Marker #37 and the west end of the turning basin would have serious adverse effects. Saltwater is now present in the upper permeable zones of the principal artesian aquifer in this area of the Beaufort River. This saltwater is considered to be sea water which has entered into the aquifer through the breaks in the upper confining layer in the Beaufort River. These breaks in the upper confining layer are primarily the result of erosion during a lower stage of sea level during Pleistocene time. During the Pleistocene glacial stages, sea level was a minimum of 100 feet lower than present sea level. With this lowering of the level of the ocean, the erosion processes were accelerated resulting in the removal of the upper confining layers in some locations. The dredging of the navigation channel into Port Royal and dredging in the turning basin opposite the docks have increased the dimensions of the problem.

In summary, existing conditions alone are such that the principal artesian aquifer is exposed to the saltwater of the estuary and the continued heavy ground-water withdrawals from the aquifer will lead to a gradual acceleration of salt-water encroachment into the upper permeable zones of the principal artesian aquifer.

Broad River Survey

The Broad River High Resolution Boomer profile begins at the two channel markers off Bay Point and extends approximately 16 miles up Broad River to a point opposite a small dock at the Capehart Housing Project.

Control points for the Broad River survey included exploratory drill holes, geophysical logs (gamma ray) from existing wells, and well logs from previous investigations. These control points are listed in the following table.

Table 5.—Depth to Principal Artesian Aquifer from Control Points Along Broad River.

Well No.	*Location*	*Depth below msl (ft.)*
Beaufort # 4	Ribault Monument	77
Beaufort #15	General's Landing	72
Beaufort # 3	Small Arms Range	70
Beaufort # 9	Doggie Island	58
Beaufort #12	East End of Broad River Bridge	50
Beaufort # 2	Lemon Island	75
Beaufort # 6	Rose Island	75
Beaufort # 7	Daws Island	60
Beaufort PH-112	West End of Broad River Bridge	75
Beaufort # 3	Burton	44

The High Resolution Boomer record shows the top of the principal artesian aquifer at the channel markers off Bay Point at an elevation of 85 feet below msl. From this point to Channel Marker #30-B.W. the top of the aquifer decreases in elevation to 114 feet below msl. Proceeding upstream the top of the aquifer increases in elevation to 47 feet below msl at the S. C. Road 170 bridge across Broad River. Upstream from the bridge top of the aquifer gradually decreases in elevation to 65 feet below msl opposite the Capehart Housing Project where the Broad River survey ended (Fig. 9).

The results of the reconnaissance seismic survey of Broad River clearly indicate limits for development of a deep navigation channel above station 14:15 on the High Resolution Boomer Record. This station is located 1.85 miles downstream from the Broad River Bridge approximately parallel with the creek which separates Rose and Daws Islands. The top of the principal aquifer at this point is 52 feet below msl. From this point upstream the top of the aquifer is decreasing in elevation to 47 feet below msl downstream from the bridge. The potential for inadvertently breaching the aquifer by dredging a 35 to 40 foot channel is considered too great. It is recommended that no consideration be given to dredging in this reach of the Broad River. Dredging downstream from this location should present no problem.

Port Royal Sound-Chechesssee River-Colleton River Survey

This survey was made over a route to closely approximate the navigation channel proposed for the Victoria Bluff site.

The survey started at the two channel markers opposite Bay Point. From this point the survey was made in a northwesterly direction, across Port Royal Sound to a point opposite Skull Creek and Pinckney Island. The survey then proceeded up the Chechessee River on a more northerly course toward and parallel to Daws Island. At the mouth of the Colleton River the survey vessel turned southwestward into the Colleton River and proceeded upstream in mid-channel past Victoria Bluff and Spring Island to Callawassie Creek where the survey terminated.

This survey of the proposed navigation channel from the mouth of Port Royal Sound to Victoria Bluff for discussion purposes is divided in the following segments: Port Royal Sound, Chechessee River, and Colleton River.

The Port Royal Sound segment extends from the mouth of the Sound to the confluence of Skull Creek and the Sound. In this segment the top of the principal artesian aquifer occurs at 85 feet below msl at the two channel markers off Bay Point and rises to 73 feet below msl at the confluence with Skull Creek.

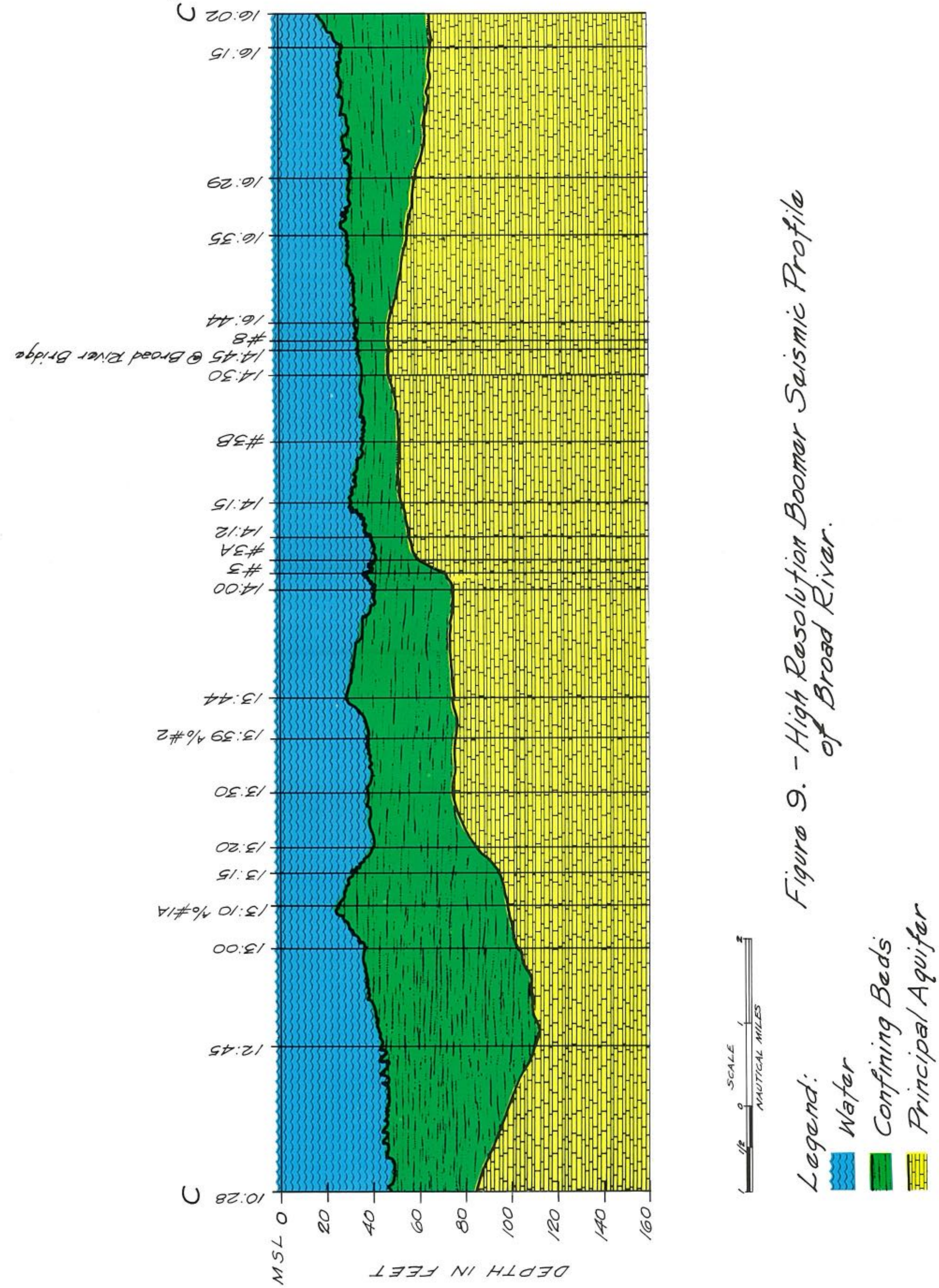


Figure 9. - High Resolution Boomer Seismic Profile of Broad River.

The Chechessee River segment extends from Skull Creek upstream to the mouth of the Colleton River. In this segment the top of the principal aquifer drops from 73 feet below msl at the mouth of Skull Creek to 77 feet below msl off Pinckney Island. From this point, upstream to the mouth of the Colleton River the top of the principal artesian aquifer remains at a fairly constant elevation, varying only 2 feet in elevation from the 77 feet below msl off Pinckney Island to 79 feet below msl at the mouth of the Colleton River (Fig. 10).

In the segment in the Colleton River, the High Resolution Boomer record shows the top of the principal artesian aquifer to vary somewhat more than the Chechessee segment. From the 75 feet below msl at the mouth of the Colleton, the top of the aquifer rises to 64 feet below msl opposite the Bluff and then drops sharply to 85 feet below msl opposite the old landing on Spring Island.

Control points used for this survey included exploratory drill holes, drill logs from previous investigations and geophysical logs from existing wells and are listed in the following table.

Table 6.—Depth to principal artesian aquifer from control points along Port Royal Sound—Chechessee River—Colleton River

Well No.	*Location*	*Depth below msl (ft.)*
Beaufort No. 8	Bay Point	85+
Beaufort 315 (USGS)	North End of Hilton Head Island	83
Beaufort No. 7	Daws Island	60
Beaufort No. 6	Rose Island	75
U.S.G.S. (Gamma Ray)	Victoria Bluff	64
Beaufort No. 5	Spring Island	
U.S.G.S. (Gamma Ray)	Spring Island	99

The results of the reconnaissance seismic survey of the route proposed for a navigation channel to Victoria Bluff indicate that a 35 to 40 foot navigation channel is feasible.

The most shallow points of the top of the principal aquifer occur at 64 feet below msl in the Chechessee River opposite the mouth of Skull Creek and in the Colleton River opposite Victoria Bluff.

Skull Creek-Calibogue Sound Survey

The Skull Creek-Calibogue Sound survey began at the confluence of Skull Creek with Port Royal Sound and extended into Calibogue Sound to Buck Island. Then a 180° turn was made and a short distance was resurveyed. This survey also included a short run upstream in the May River.

This survey was made generally following the center line of the Intracoastal Waterway channel with one or two minor deviations. Of particular interest during this survey was the deep hole, 65-70 feet deep, which occurs between Spanish Wells and Bram Point (Fig. 11).

This deep hole has received some attention from previous investigators in the area. It was generally considered that the aquifer could possibly be exposed on the bottom of the Sound at this location and was probably an area of natural fresh-water discharge. For these reasons two profiles were made of the deep hole.

The High Resolution Boomer record shows the top of the principal artesian aquifer to occur at an elevation of 75 feet below msl at the confluence of Skull Creek and Port Royal Sound; at 75 feet below msl at U. S. Highway 278 Bridge over Skull Creek; and at 71 feet below msl at the mouth of May River. The High Resolution Boomer profiles across the deep hole between Spanish Wells and Bram Point indicate that the lower most units of the confining beds and/or the top of the principal artesian aquifer system do in fact sub-crop at this location in Calibogue Sound.

Table 7.—Depth to principal artesian aquifer from control points along Skull Creek-Calibogue Sound Survey.

Well No.	*Location*	*Depth below msl (ft.)*
Beaufort 315	North End Hilton Head Island	70′
Ph 104	Pinckney Island at U. S. 278 Bridge	74
Ph 113	Brighton Beach	66
Ph 114	Spanish Wells	57
Beaufort 101	Central Hilton Head Island	92
Beaufort 317	Hilton Head Island Post Office	71
Beaufort 316	Bluffton	62
Beaufort 209	Sea Pines Plant-Hilton Head Island	79

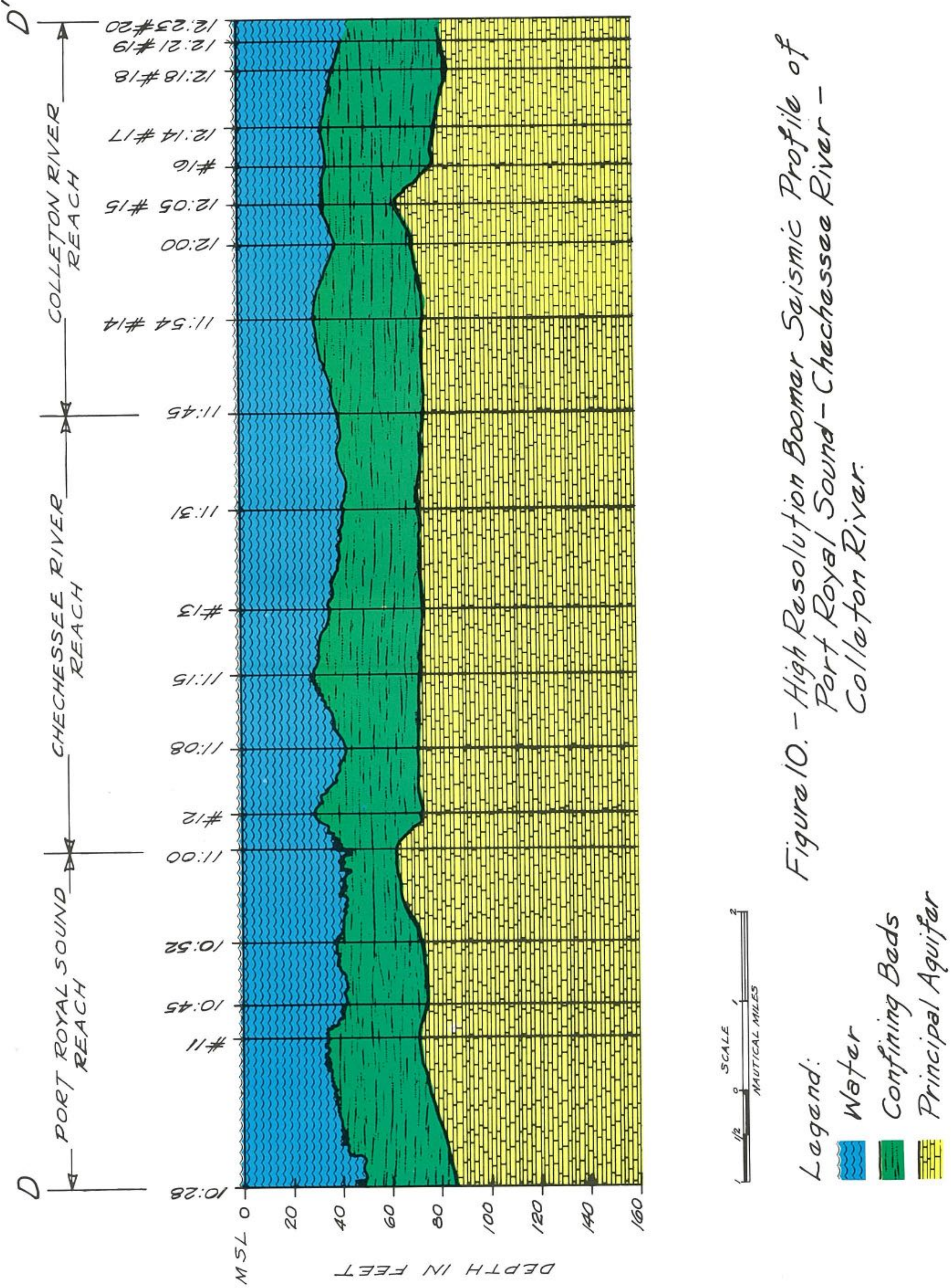


Figure 10.-High Resolution Boomer Seismic Profile of Port Royal Sound-Chechessee River-Colleton River.

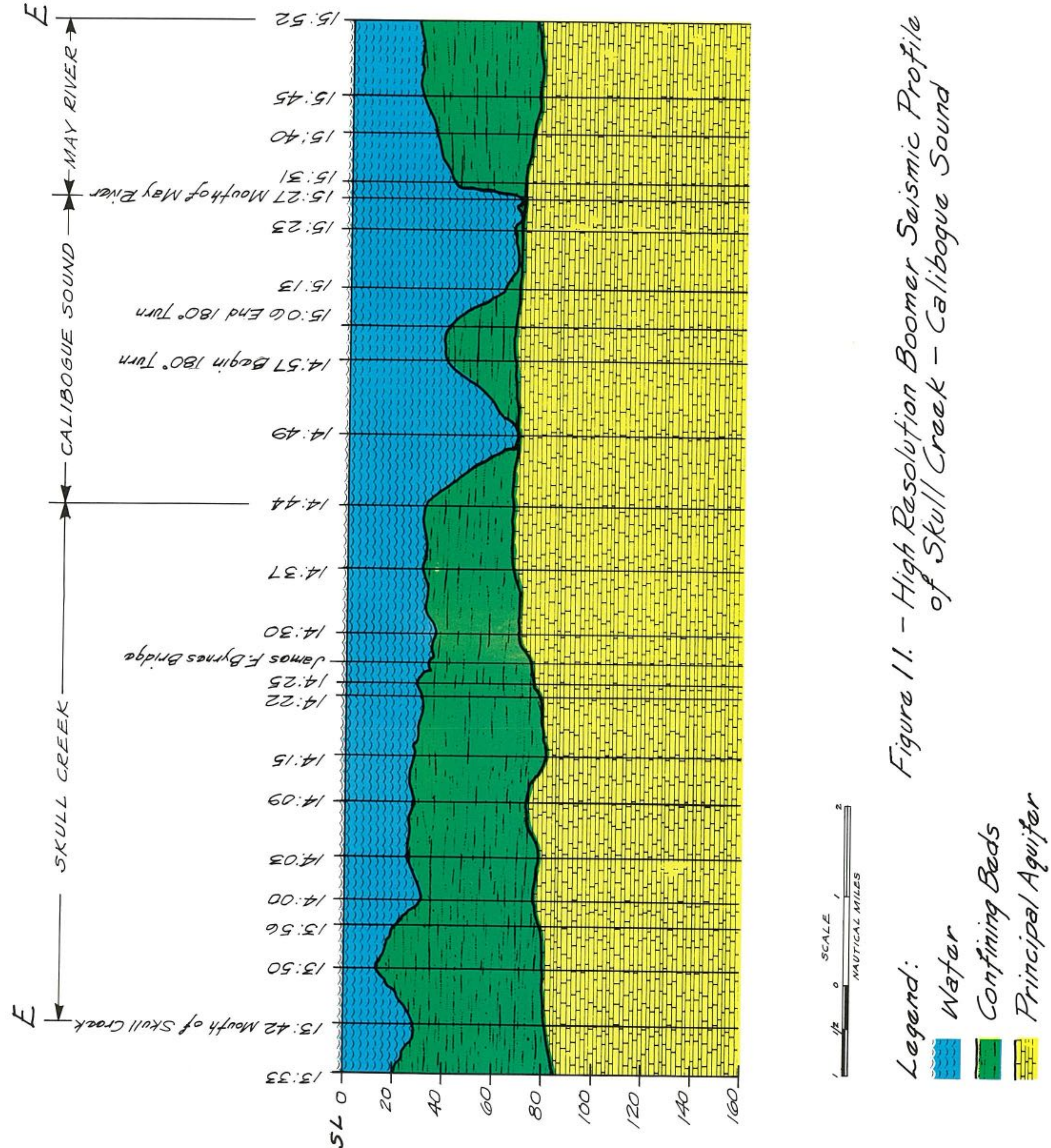


Figure 11. - High Resolution Boomer Seismic Profile of Skull Creek - Calibogue Sound

Bottom Sediments

The bottom sediments of the area of investigation are largely sand with some silt and clay. The High Resolution Boomer shows a relatively large number of sand waves present on the bottom of Port Royal Sound and a lesser concentration in the lower reaches of the Broad and Chechessee Rivers.

In the tributaries to the Sound surveyed, the High Resolution Boomer record shows an appreciable number of erosional and depositional structures in the post-Miocene sediments. Channel cutting and filling with pronounced bedding are common features in these sediments. Generally, these cut and fill structures are variable in width and are not deep, usually only 25 to 35 feet below the channel bottom. However some exceptions were noted, one being the deep cut (65 to 70 feet deep) in Calibogue Sound at the mouth of May River.

During the field investigations in the summer of 1970, approximately 200 bottom sediment samples were taken throughout the study area. A formal report resulting from an analysis of these samples is programmed for future publication.

Summary and Conclusions

The South Carolina Water Resources Commission as a part of its Estuarine Environment Study of Port Royal Sound made an analysis of the subsurface geology of the area. This analysis consisted of reconnaissance geologic mapping, exploration drilling, and seismic surveys.

The immediate objective of the seismic surveys of these water areas was the delineation of the uppermost surface of the principal aquifer or its confining bed.

This determination was of immediate concern because of the fact that proposed dredging in these channels might penetrate the impervious "cap" rock on top of the aquifer and permit saltwater to enter and contaminate the fresh-water zones.

The data obtained during the seismic survey of the Beaufort River revealed that the confining layer(s) overlying the principal aquifer and possibly the principal aquifer itself, are breached in the Beaufort River. This breach is primarily a result of naturally occurring geologic processes. However, dredging during construction of the existing navigation channels has aggravated a serious situation.

At the request of the South Carolina Ports Authority, the Water Resources Commission made additional investigations in the critical section of the Port Royal navigation channel to determine the precise configuration and elevation of the principal aquifer system. The possibility of locating a deeper navigation channel in the general vicinity of the Port Royal Channel without complicating or aggravating existing conditions was also evaluated.

The confining beds which overlie the aquifer consist of a gray to olive green silt and sand interbedded with thin discontinuous lenses of marl and limestone. These confining beds vary vertically and horizontally in both thickness and character. The base of the confining beds is usually characterized by the occurrence of a very hard but relatively thin layer which is generally referred to as the "cap" rock and is essentially composed of indurated limestone and phosphate.

The uppermost part of the principal artesian aquifer generally consists of a blue gray to white poorly consolidated bioclastic limestone which locally may contain lenses of silt and fine to medium grained sand.

Beaufort River

In the Beaufort River, the seismic survey indicates the top of the principal artesian aquifer to range from an elevation of 95 feet below msl at the confluence of Beaufort River with Port Royal Sound up to 30 feet below msl near the confluence of Beaufort River and Battery Creek.

The results of the Beaufort River survey clearly indicate that any future dredging to deepen the navigation channel between Channel Marker #37 and the west end of the turning basin would have serious adverse effects. Saltwater is now present in the upper permeable zones of the principal artesian aquifer in this area of the Beaufort River. The presence of this saltwater is considered to be sea water which has entered into the aquifer through the breaks in the upper confining layers in the Beaufort River.

The survey of Chowan and Cat Island Creeks to evaluate the feasibility of locating an alternate route into the port clearly eliminates any consideration of Cat Island Creek as an alternative route into Port Royal. This is primarily due to the principal artesian aquifer being exposed on the bottom of the Beaufort River immediately northwest of the confluence of the Beaufort River and Cat Island Creek. Also, the top of the aquifer under Cat Island Creek occurs at 51 feet below msl at the confluence with Chowan Creek, at 42 feet below msl opposite the dock on Cat Island, and at 30 feet below msl at the confluence of Cat Island Creek with Beaufort River.

Broad River

The results of the reconnaissance seismic survey of Broad River clearly indicate limits for development of a deep navigation channel above a point located 1.85 miles downstream from the Broad River Bridge approximately parallel with the creek which separates Rose and Daws Islands. The top of the principal aquifer at this point is 52 feet below msl.

It is recommended that no consideration be given to dredging in this reach of the Broad River.

Dredging downstream from this location should present no problem.

Port Royal Sound-Chechessee River-Colleton River

The survey of Port Royal Sound-Chechessee River-Colleton River was made over a route to closely approximate the navigation channel proposed for the Victoria Bluff Site.

The results of the reconnaissance seismic survey of the route proposed for a navigation channel to Victoria Bluff indicates that a 35 to 40 foot navigation channel is feasible.

The most shallow points of the top of the principal aquifer occur at 64 feet below msl in the Chechessee River opposite the mouth of Skull Creek and in the Colleton River opposite Victoria Bluff.

Skull Creek-Calibogue Sound

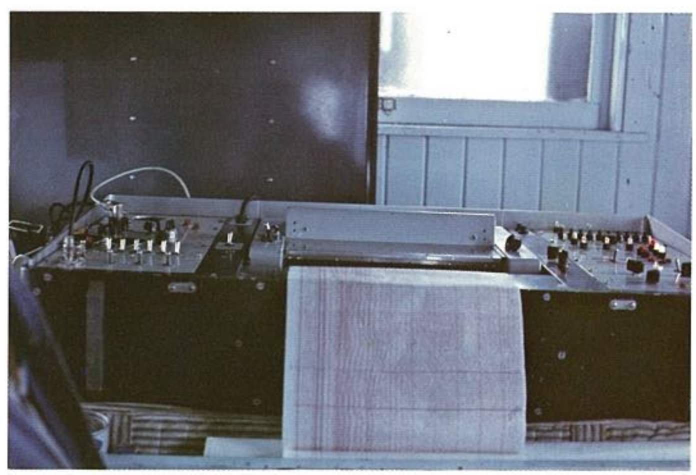
This survey was made generally following the center line of the intracoastal waterway channel with one or two minor deviations. Of particular interest during this survey was the deep hole, 65-70 feet deep, which occurs between Spanish Wells and Bram Point.

The High Resolution Boomer profiles across the deep hole between Spanish Wells and Bram Point indicate that the lower most units of the confining beds and/or top of the principal artesian aquifer system do in fact sub-crop at this location in Calibogue Sound.

Future Applications

The results obtained from the high resolution seismic profiling of the Port Royal Sound area indicate that limits exist for channel dredging in critical areas with respect to the principal aquifer and its confining beds. The results of the investigation also point out areas where the dredging of navigation channels would not affect the principal artesian aquifer.

High resolution seismic profiling during this investigation proved to be an efficient and economical method for assessing the impact of dredging on the geologic environment. Therefore, it is recommended that prior to the construction of future navigation projects in South Carolina detailed high resolution seismic profiling be made and evaluated in connection with potential routes for deep water channels.



Seismic Survey print-out; photo by D. Duncan, S. C. Water Resources Commission.

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Potential for Ground Water Development

by Richard A. Gardner*
Water Resources Division
U. S. Geological Survey
Columbia, South Carolina

*Publication authorized by the Director, U. S. Geological Survey.

The only potable fresh water naturally occurring in the area immediately surrounding Port Royal Sound is ground water. The principal water-bearing zone is the upper part of the Eocene limestone that supplies water for the City of Savannah, Georgia and other cities and industries in southeast Georgia and northeast Florida. The top of this limestone ranges from 50 to 100 feet in depth in the Port Royal Sound area.

A test well at the proposed industrial plant site at Victoria Bluff produced about 2900 gallons per minute for a period of 1 week, with a drawdown of about 20 feet. A vertical-vane velocity survey by the U. S. Geological Survey during the pumping of this well showed that nearly all of the water entered the well between 100 and 150 feet below sea level. This well, which had the largest yield of any well in South Carolina, demonstrates that the principal water-bearing zone in this area has a great potential for supplying water. Generally, this zone is overlain by a cap of lower permeability that prevents the direct entry of salt water into the water-bearing zone under the present conditions of small local withdrawals. However, since the top of the water-bearing zone is above the bottom of parts of Port Royal Sound, Calibogue Sound, and other bodies of salt water at places the potential exists for intrusion of salt water, if the fresh water head is lowered. If production of water from this zone were not properly managed, an extremely valuable resource might be destroyed. The potential for ground-water development and the problems which may arise as part of that development thus merit careful study.

No study of ground-water hydrology was included in the environmental analysis of the Port Royal Sound area because the original proposal for the industrial plant at Victoria Bluff did not include provisions for withdrawing water from the ground. Water was to be supplied by the Beaufort Water Authority's canal from the Savannah River. Ground water was subsequently considered as a potential supply, and one test production well and four observation wells were drilled. A pumping test was made on this system of wells. The U. S. Geological Survey assisted in the pumping test, and ran many geophysical logs of wells in the area. General ground-water information and some drillers logs were also collected. In addition, the Water Resources Commission and the U. S. Geological Survey cooperated in having a high resolution continuous seismic survey made in the arms of Port Royal Estuary. Information from this survey, coupled with the geophysical well logs, provided fairly detailed information on the geologic structure of the area. But no study of ground water commensurate with its importance and potential was made.

Some ground-water information for the area is included in general studies of the coastal region of South Carolina (South Carolina Water Resources Commission, 1970). Several studies of the effects of the large withdrawals of ground water in the City of Savannah, Georgia include information on the Port Royal Sound area (Warren, 1944; Counts and Donsky, 1963; McCollum and Counts, 1964; and McCollum, 1964). The potential for salt water encroachment was discussed in reports by Siple (1965) and Back *et. al.* (1970). In addition, some information on ground water had been collected at the Parris Island Marine Base and at the Naval Air Station. However, a much more comprehensive ground-water study is needed to provide information for the management of this resource before additional development takes place.

In addition to the principal water-bearing zone in the limestone, shallower zones (less than 100 feet in depth) provide small quantities of water in some areas. Some very deep sands (2700-2900 feet in depth) produce small quantities of fresh water, but its use is limited because of its relatively high mineral content (dissolved solids about 1140 mg/*l* (milligrams per liter) and fluoride about 5.0 mg/*l*.

The principal water-yielding zone has the form of a low gentle arch as do other parts of the geologic section. This arch trends northeast-southwest, about perpendicular to the Broad River and Port Royal Sound, with its axis passing near Victoria Bluff and Beaufort. The arch is colinear with an arch in the basement rocks determined by geophysical means (Woolard, 1957). Well yields on the west side of the arch are much greater than those on the east side.

It is along the crest of this arch, where the low permeability cap is thinest, that the greatest potential exists for salt water intrusion into the principal water-bearing zone. Water produced from some wells in this zone has a high chloride content. But information is lacking on whether the high chloride is actually due to sea-water contamination of the zone or to improper well construction methods that allow water to enter the well from other zones. Because of the occurrence of high chloride, some residents feel that ground water is not a potential source of fresh water and that all water must be imported from surface sources outside the area. Failure to conduct a comprehensive ground water study will, of course, reinforce this conclusion by default. The large yield of the test well, however, suggests a great potential for ground-water development in the area. Any such development and subsequent management of the ground water resource, requires a thorough study of the hydrology of the area.

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Water Quality Evaluation
Physical and Chemical

Richard K. Ballentine
Office of Water Programs
Environmental Protection Agency
Washington, D. C.

Field Studies Conducted By:
National Field Investigation Center
Environmental Protection Agency
Cincinnati, Ohio

Preface

This project was originated by the Department of the Interior, Federal Water Quality Administration. On December 2, 1970, that agency was incorporated into the Environmental Protection Agency. Also, when the study was undertaken, the National Field Investigations Center in Cincinnati, Ohio was under the direction of the Assistant Commissioner for Operations, FWQA. Presently, the National Field Investigations Center is in the Office of Enforcement and General Counsel.

Introduction

As part of the Port Royal Sound Environmental Study, the Environmental Protection Agency (then the Federal Water Quality Administration) through its Middle Atlantic Region, participated in physical, chemical, and other related investigations. To accomplish these studies, the National Field Investigations Center (NFIC), Cincinnati, Ohio, was requested by the Regional Office to participate and furnish the necessary laboratory services, equipment and manpower for the field investigations. NFIC was also asked to assist in the preparation of the report dealing with these findings.

Three intensive physical and chemical studies were performed on Port Royal Sound during the following periods: April 6 - May 3, 1970; July 13 - 26, 1970; and October 12 - 25, 1970. These studies were cooperatively performed by the Federal Water Quality Administration and the South Carolina Pollution Control Authority. These surveys were coordinated with other scientific investigations by the South Carolina Water Resources Commission.

Authority to participate in such technical assistance projects is contained in the Federal Water Pollution Control Act, as amended (33 U. S. C. 466 et sec), in Section 5 (b). This section authorized the Office of Water Programs, when requested, "... to make surveys concerning any specific problem of water pollution confronting any State, . . . with a view of recommending a solution for such a problem."

Summary and Conclusions

1. Port Royal Sound Water Quality surveys were made on three occasions: April 6-May 3, 1970; July 13-26, 1970; and October 12-25, 1970.
2. Port Royal Sound and its tributaries (excluding the Beaufort River and its tributaries which are classified as SB) have been classified by the South Carolina Pollution Control Authority as class SA, which denotes salt, "waters suitable for shellfishing for market purposes and any other usages."
3. Two principal sources of waste are discharged to the Beaufort River which is hydraulically connected to Port Royal Sound. These are the treated wastes from the U.S. Marine Corps facility on Parris Island (1 million gallons per day receiving secondary treatment) and the untreated municipal wastes from the city of Beaufort (population 10,350).
4. The chemical quality of the waters of Port Royal Sound was generally excellent and indicative of high quality water.
5. Dissolved oxygen concentrations in the Colleton River dropped below the 5.0 mg/ℓ South Carolina standard during July, 1970, without the influence of man-caused pollution. Additional oxygen demanding materials cannot be assimilated in the Colleton River during summer warm weather periods without further depleting the D.O. concentration and further contravening the established State water quality standards.
6. The primary source of oxygen-demanding material was from the peripheral marshes. Oxidation of organic materials in the bottom sediments also extracted large quantities of dissolved oxygen. These demands ranged up to 2 gm O_2/m^2 day.
7. Comparison of the nitrogen and phosphorus data indicates that concentrations of biologically available inorganic nitrogen (ammonia, nitrite and nitrate) are frequently undetectable while significant quantities of soluble phosphorous (0.02 mg/ℓ to 0.09 mg/ℓ) are present. Nitrogen is apparently the major nutrient limiting primary production.
8. Phytoplankton do not constitute a nuisance in Port Royal Sound. For example chlorophyll *a* and *c* concentrations were generally low. Average chlorophyll *a* concentrations never exceeded 10 μg/ℓ at any station while average chlorophyll *c* concentrations never exceeded 3 μg/ℓ.
9. To detect future discharges from potential industry sources, heavy metal concentrations were determined in the water column and in the sediments to establish background data.
10. Radioactive tritium was determined on samples collected during the April, 1970, survey. No effects from the distant Savannah River Plant of the Atomic Energy Commission were detected.
11. The FWQA Dynamic Estuary Mathematical Model was calibrated and verified for Port Royal Sound. The model, for example, calculated a decrease of 0.5 mg/ℓ in D.O. in the Colleton River if a simulated BOD loading of 60,000 pounds per day were discharged into the Colleton River adjacent to Victoria Bluff.


PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
WATER CHEMISTRY
SAMPLING STATIONS
SCALE
NAUTICAL MILES
N
Atlantic Ocean
LADIES ISLAND
CHISOLM ISLAND
COOSAW RIVER
FORT FREMONT
BEAUFORT RIVER
BEAUFORT
PORT ROYAL
PORT ROYAL SOUND
PORT ROYAL ISLAND
Brickyard Cr.
Mulligan Cr.
Albergottie Cr.
Battery Creek
Archers Cr.
Ballast Cr.
Chowan Cr.
Capers Cr.
Station Cr.
McCalley's Cr.
WHALE BRANCH
HILTON HEAD ISLAND
Park Cr.
Skull Cr.
PINCKNEY ISLAND
Mackay Creek
BROAD RIVER
DAWS ISLAND
CHECHESSEE RIVER
Victoria Bluff
COLLETON RIVER
Saw Mill Cr.
SPRING ISLAND
Chechessee Cr.
LEMON ISLAND
Hazard Cr.
Euhaw Cr.
Cole Cr.
HALL ISLAND
Pocotaligo River
East Br. Boyd Cr.
West Br. Boyd Cr.
Boyd Cr.
MAY RIVER
Bass Cr.
BULL ISLAND
Bryan Cr.
Bull Cr.
COOPER RIVER
DAUFUSKIE ISLAND
CALIBOGUE SOUND
Broad Creek
Buck I.
1
2
3
4
5
6
7
8
9
10
11
FIGURE 1

Water Uses

Water Quality Standards

Port Royal Sound, including the Chechessee River, the Broad River and its tributaries, and the Colleton River and its tributaries are classified by the State of South Carolina as Class SA waters. Class SA waters are defined in the South Carolina Pollution Control Authority's Classification—Standards System for Tidal Salt Waters as being ". . . suitable for shellfishing for market purposes and any other usages." Other uses include bathing, propagation of fish and commercial fishing. The applicable standards (Table 1) are in addition to requirements that waters be free from substances attributable to sewage, industrial wastes or other waste that: form sludge deposits; floating debris, oil, grease, scum, and other floating materials in nuisance amounts; produce taste, odor, color or other conditions creating a nuisance; and high-temperature, toxic corrosive or deleterious substances which interfere with water uses or are harmful to human, animal, plant or aquatic life.

Table 1

South Carolina Pollution Control Authority

CLASSES AND STANDARDS FOR TIDAL SALT WATERS

CLASS SA

Waters suitable for shellfishing for market purposes and any other usages. Suitable also for uses requiring water of lesser quality.

Quality Standards for Class SA Waters

Items	*Specifications*
1. Garbage, cinders, ashes, oils, sludge or other refuse.	None
2. Sewage or waste effluents.	None which are not effectivly disinfected.
3. Dissolved oxygen.	Not less than 5.0 mg/ℓ .
4. Toxic wastes, deleterious substances, colored or other wastes.	None alone or in combination with other substances or wastes in sufficient amounts as to be injurious to edible fish or shellfish or the culture or propagation thereof, or which in any manner shall adversely affect the flavor, color, odor, or sanitary condition thereof or impair the waters for any other best usage as determined for the specific waters which are assigned to this class.
5. Organisms of coliform group.	Shall meet U.S. Public Health Service Standards. (1965 Revision)
6. pH	Shall not vary more than 3/10 of a pH unit above or below that of effluent-free waters in the same geographical area having a similar total salinity, alkalinity and temperature.
7. Temperature (Applicable to all classes of tidal waters).	Fall, winter, spring, no more than 4° F. above natural. Summer, no more than 1.5° F. above natural.

The Beaufort River and its tributaries and Battery Creek are not of suitable quality for commercial shellfishing and are thusly classified as being Class SB (Table 2). Human sewage being discharged directly into these waters or seeping into them is primarily responsible for the lower quality and consequent classification of these streams.

Table 2

South Carolina Pollution Control Authority

CLASSES AND STANDARDS FOR TIDAL SALT WATERS

CLASS SB

Waters suitable for bathing and any other usages except shellfishing for market purposes. Suitable also for uses requiring water of lesser quality.

Quality Standards for Class SB Waters

Items	*Specifications*
1. Garbage, cinders, ashes, oils, sludge or other refuse.	None.
2. Sewage or waste effluents.	None which are not effectively disinfected.
3. Dissolved Oxygen	Not less than 5 mg/ℓ.
4. Toxic wastes, deleterious substances, colored or other wastes.	None alone or in combination with other substances or wastes in sufficient amounts as to be injurious to edible fish or the culture or propagation thereof, or which in any manner shall adversely affect the flavor, color, odor or sanitary condition thereof; to make the waters unsafe or unsuitable for bathing or impair the waters for any other best usage as determined for the specific waters which are assigned to this class.
5. Fecal coliform.	Not to exceed a geometric mean of 200/100 ml nor shall more than 10% of the samples in any 30 day period exceed 400/100 ml.
6. pH.	Shall not vary more than one-half of a pH unit above or below that of effluent-free waters in the same geographical area having a similar total salinity, alkalinity and temperature, but not lower than 6.75 or above 8.5.
7. Temperature (Applicable to all classes of tidal waters).	Fall, winter, spring, no more than 4°F. above natural. Summer, no more than 1.5°F. above natural.

Sources of Wastes

The Port Royal Sound system has two significant waste sources both of which discharge to the Beaufort River system. The city of Beaufort is a sewered community, but at the time of the survey, it provided no waste treatment. The system has a sewered population of 10,350 and discharged through 3 separate outfalls to the Beaufort River.

The U. S. Marine Corps training facilities at Parris Island had secondary treatment facilities for domestic type waste of about 1.0 million gallons per day but discharged industrial wastes of 40,000 gallons per day (vehicle repair shop wastes, vehicle washing wastes, heating and air conditioning wastes) without treatment. None of the wastes received chlorination for disinfection.

These wastes result in bacterial contamination of adjacent shellfish growing and harvesting areas. Collection of shellfish for market purposes is prohibited in the Beaufort River, Battery Creek, Albergottie Creek, Ballast Creek, Archers Creek and along the shoreline of Parris Island. With the tremendous dilution afforded by the waters of the Port Royal Sound System and the occurrence of strong tidal currents to rapidly mix wastes and dilution waters, the effects of the wastes upon other water quality parameters such as dissolved oxygen within the whole system are slight.

Description of Surveys Theory

The major forces affecting the ocean's tides are solar and lunar in origin. The oscillations of the tides show strong periodic components of both twenty-four hours and of twenty-eight days (lunar month). In the Atlantic Ocean in the vicinity of Port Royal Sound the net result is a semidiurnal tidal stage fluctuation approximately sinusoidal with an average period of twelve hours twenty-five minutes. Sampling a system as large as Port Royal Sound whether on an hourly basis or at the occurrence of slack current at each station was physically impossible. However, sampling a station at the same time each day for twenty-eight days theoretically approximates a daily survey where a sample is taken each fifty-two minutes. Although sampling at slack current is the preferred procedure, sampling a station at the same time each day was considered preferable to sampling at varying times. Chemical samples for the three surveys were collected at a given station at approximately the same time each day for each survey. Sample times at a station often varied between different surveys. The April 6-May 3, 1970, survey represented a complete tidal day; the July 13-26, 1970, survey and the October 12-25, 1970, survey each represented one tidal cycle.

Sampling Schedule

Two sample collection runs per day were scheduled: one beginning early in the morning, the other beginning early in the afternoon. The morning run performed all the field physical and chemical determinations and collected samples for laboratory physical and chemical determinations. FWQA personnel collected the morning samples while personnel from the S. C. Pollution Control Authority collected the afternoon samples.

Sample Collection Methods

Water samples were collected with a submersible pump. When the pump was inoperative, a 2-liter Kemmerer sampler was used. Chemical samples were collected one foot from the bottom, mid-depth and one foot from the water's surface. With the exception of dissolved oxygen analyses, chemical samples were composited in plastic buckets. Equal volumes of water were collected from each depth.

Field Determinations

Several determinations were made by field crews at the time of sample collection. If equipment failure prevented field determinations, then separate samples from each depth were collected and returned to the field laboratory for later determinations. Temperature, specific conductance, salinity, pH, Secchi Disc and dissolved oxygen were measured by field crews.

Sampling Stations

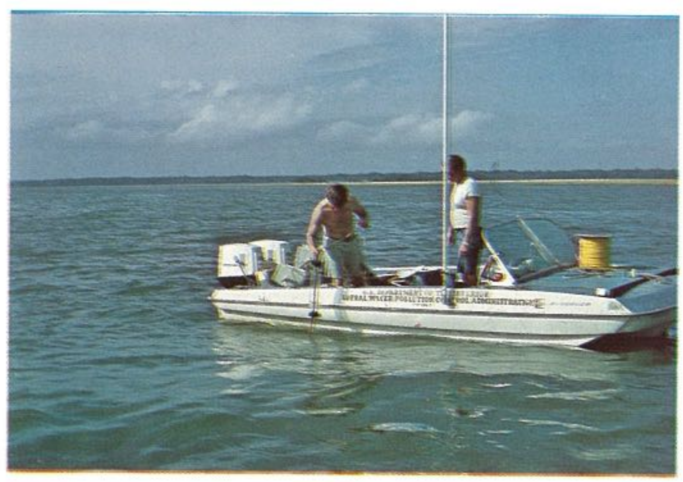
Establishing "base line" water quality requires the assessment of a host of chemical and physical conditions at various locations within the estuarine system. Sampling stations were established to assess the entire Port Royal Sound System (Figure 1). It was anticipated that selected chemical constituent concentrations at each station would be related to other stations by use of a mathematical model.

Laboratory Analyses and Analytical Methods

Chemical analyses were performed in the field, the field laboratory, the S. C. Pollution Control Authority Laboratory in Columbia, S. C., the S. C. Environmental Health Laboratory in Columbia, S. C., and in the Division of Field Investigations Laboratory, Cincinnati, Ohio. The analyses, laboratory location and the frequency of determination are given in Table 3. The analytical methods used, including any modification and a source reference, are given in Table 4.

Water Quality

Water quality assessment requires the determination of numerous chemical and physical parameters. Table 5 contains summaries of several of the important parameters for each separate survey and includes the maximum, minimum and average values and the number of determinations included in the average. Figures 2 to 4 show the daily concentrations of selected constituents during each survey. The variations in these parameters are evident from these graphs. Individual results for each constituent measured are included in the Appendix.



Field crew collecting water quality samples; photo by J. Darby, S. C. Water Resources Commission.

TABLE 3

PORT ROYAL SOUND ENVIRONMENTAL STUDY
FREQUENCY OF CHEMICAL
ANALYSES PER STATION

Determination Water Samples	Where * Determined	FREQUENCY OF DETERMINATION Apr-May	July	October
Temperature	F	2/day	2/day	2/day
Specific Conductance	F, FL	2/day	2/day	2/day
Salinity	F	2/day	—	2/day
Secchi Disc	F	2/day	2/day	2/day
pH	F, FL	2/day	2/day	2/day
Dissolved Oxygen	F, FL	2/day	2/day	2/day
Total Alkalinity	FL	1/day	1/day	1/day
Total Dissolved Solids	FL	1/day	3/Week	3/Week
Total Suspended Solids	FL	1/day	3/Week	3/Week
Turbidity	FL	1/day	1/day	1/day
Sulfates	FL	—	3/Week	3/Week
Biochemical Oxygen Dem.	FL	1/day	1/day	1/day
Total Phosphorus	BL	1/day	1/day	1/day
Soluble Phosphorus	BL	1/day	1/day	1/day
Organic Nitrogen	BL	1/day	1/day	1/day
Ammonia Nitrogen	BL	1/day	1/day	1/day
Nitrite & Nitrate Nitrogen	BL	1/day	1/day	1/day
Copper	BL	1/day	3/Survey	3/Survey
Zinc	BL	1/day	3/Survey	3/Survey
Chromium	BL	1/day	3/Survey	3/Survey
Manganese	BL	1/day	3/Survey	3/Survey
Barium	BL	1/day	3/Survey	3/Survey
Magnesium	BL	1/day	3/Survey	3/Survey
Calcium	BL	1/day	3/Survey	3/Survey
Sodium	BL	1/day	3/Survey	3/Survey
Potassium	BL	1/day	3/Survey	3/Survey
Silica	BL	1/day	3/Survey	3/Survey
Aluminum	BL	1/day	3/Survey	3/Survey
Mercury	BL	1/day	3/Survey	3/Survey
Color Spectrum	BL	1/day	3/Survey	3/Survey
Tritium	BL	1/Survey	—	—
Chlorophyll	BL	1/day	1/day	1/day
Chlorides	BL	1/day	3/Week	3/Week
Phenols	FL	—	1/Survey	1/Survey
Methylene Blue Active Substances	BL	—	3/Survey	3/Survey
Sediment Analyses (1 per survey)				
Pesticide Analysis	BL			
Copper	BL			
Zinc	BL			
Chromium	BL			
Manganese	BL			
Barium	BL			
Cadmium	BL			
Mercury	BL			
Nickel	BL			
Lead	BL			

*F = Field determination
FL = Field laboratory determination
BL = Base laboratory determination

Table 4

Port Royal Sound Environmental Study
Laboratory Analytical Procedure

Parameter Field	Survey Period*	Method Used	Test Modification	Method Reference
Temperature	1, 3	Thermistor	Beckman RS-5 (1)	Standard Methods, 12th Edition, 1965(2)
	2	Dial Type Thermometer	Weston	
Specific Conductance	1, 3	Salinometer	Beckman RS-5 (induction probe)	Standard Methods, 12th Edition, 1965
	2	Specific Conductance meter	Beckman RB-2	
Salinity	1, 3	Salinometer	Beckman RS-5 (induction probe)	Beckman Instrument Co.
pH	1, 2, 3	Field pH meter Laboratory pH meter	Instrumentation Lab. 175 Instrumentation Laboratories Digimatic 205	Standard Methods, 12th Edition, 1965
Dissolved Oxygen	1	Galvanic oxygen probe	Weston & Stack Model 300	FWPCA Methods for Chemical Analysis of Water and Wastes, 1969(3)
	1, 2, 3	Winkler	Azide modification with full bottle technique	
Secchi Disc	1, 2, 3	All White discs, 9" diameter		
Field Laboratory				
Total Alkalinity	1, 2, 3	Electrometric titration to pH 4.5		Standard Methods, 12th Edition, 1965
Total Dissolved Solids	1, 2, 3	Filtration, evaporation at 180°C, determination of weight gain of dish	Glass fiber filter discs	FWPCA Methods, 1969
Total Suspended Solids	1, 2, 3	Filtration, determination of weight gain of filter after drying at 103°C.	Glass fiber filter discs	FWPCA Methods, 1969
Turbidity	1, 2, 3	Nephelometric	Hach 2100	FWPCA Methods, 1969
Sulfates	1, 2, 3	Turbidimetric	Hach 2100	Standard Methods, 12th Edition, 1965
Biochemical Oxygen Demand	1, 2, 3	Winkler	Azide modified winkler, graduate cylinder dilution method	Standard Methods, 12th Edition, 1965
Phenolics	2, 3	4-aminoantipyrine		Standard Methods, 12th Edition, 1965
Base Laboratory				
Total phosphorus	1, 2, 3	Manual Persulfate Digestion, automated spectrophotometric determination (Potassium Antimonyl Tartrate)	Technicon Autoanalyzer	FWPCA Methods, 1969
Soluble Phosphorus	1, 2, 3	Filtration through 0.45 μ membrane filter, then same as total phosphorus	Technicon Autoanalyzer	FWPCA Methods, 1969
Organic Nitrogen	1, 2, 3	Total Kjeldahl digestion, distilation with ammonia correction	Micro glassware used	FWPCA Methods, 1969
Ammonia Nitrogen	1, 2, 3	Automated, sodium phenolate	Technicon Autoanalyzer	FWPCA Methods, 1969
Nitrite + Nitrate	1, 2, 3	Automated, cadmium reduction		FWPCA Methods, 1969
Copper	1, 2, 3	Atomic Absorption	Membrane Filtration, 0.45μ	FWPCA Methods, 1969
Zinc	1, 2, 3	Atomic Absorption	Membrane Filtration, 0.45μ	FWPCA Methods, 1969
Chromium	1, 2, 3	Atomic Absorption	Membrane Filtration, 0.45μ	FWPCA Methods, 1969
Manganese	1, 2, 3	Atomic Absorption	Membrane Filtration, 0.45μ	FWPCA Methods, 1969
Barium	1, 2, 3	Atomic Absorption	Membrane Filtration, 0.45μ	FWPCA Methods, 1969
Magnesium	1, 2, 3	Atomic Absorption	Membrane Filtration, 0.45μ	FWPCA Methods, 1969
Calcium	1, 2, 3	Atomic Absorption	Membrane Filtration, 0.45μ	FWPCA Methods, 1969
Sodium	1, 2, 3	Atomic Absorption	Membrane Filtration, 0.45μ	FWPCA Methods, 1969
Potassium	1, 2, 3	Atomic Absorption	Membrane Filtration, 0.45μ	FWPCA Methods, 1969
Silica	1, 2, 3	Molybdynum Blue Method	Membrane Filtration, 0.45μ	S. C. Pollution Control Authority
Aluminum	1, 2, 3	Atomic Absorption	Membrane Filtration, 0.45μ	FWPCA Methods, 1969
Mercury	1, 2, 3	Flameless Atomic Absorption	Membrane Filtration, 0.45μ	EPA Chemical Methods, 1971
Chlorides	1, 2, 3	Electrometric silver nitrate titration	Fisher Titralizes	Standard Methods, 12th Edition, 1965
Chlorophyll	1, 2, 3	Dissolved in acetone, spectrophotometric determination		A Practical Handbook of Seawater Analysis, Strickland & Parsons
Tritium	1	Liquid scintillation	Packard Tri-Carb Liquid Scintillation Counter	Jour. Assoc. of Off. Anal. Chem., Vol. 50, No. 1, 1969
Methylene Blue Active Substances	2, 3	Methylene Blue, spectrophotometric		Standard Methods, 1965
Color spectrum	1, 2, 3	Spectrophotometric	Beckman DB Spectrophotometer, 800mμ to 200mμ scan	S. C. Pollution Control Authority
Sediment Samples				
Copper		Acid digestion, atomic absorption		FWPCA Methods, 1969
Zinc		Acid digestion, atomic absorption		FWPCA Methods, 1969
Chromium		Acid digestion, atomic absorption		FWPCA Methods, 1969
Manganese		Acid digestion, atomic absorption		FWPCA Methods, 1969
Barium		Acid digestion, atomic absorption		FWPCA Methods, 1969
Cadmium	1, 2, 3	Acid digestion, atomic absorption		FWPCA Methods, 1965
Mercury	1, 2, 3	Acid digestion, atomic absorption		PWPCA Methods, 1965
Nickel	1, 2, 3	Acid digestion, atomic absorption		FWPCA Methods, 1965
Lead	1, 2, 3	Acid digestion, atomic absorption		FWPCA Methods, 1965
Pesticide Analysis	1, 2, 3	Extraction, Gas chromatography		S. C. State Health Department
Oil and grease	1, 2, 3	Hexane Soxhlet extraction		Standard Methods, 1965

Table 4—Continued

NOTES:
(1) The use of proprietary product names is for information purposes only and does not imply EPA endorsement of the product.
(2) Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, WPCF, 12th Edition, 1965.
(3) FWPCA Methods for Chemical Analysis of Water and Wastes, Dept. of Interior, Federal Water Pollution Control Administration, November, 1969. This manual has been superceded by:
Methods for Chemical Analysis of Water and Wastes, Environmental Protection Agency, 1971.

* 1 Indicates April-May Survey
2 Indicates July Survey
3 Indicates October Survey

The 28 day survey in April through May, 1970, was characterized by increasing temperatures. Initial water temperatures were approximately 16° C. These values gradually increased to approximately 28° C by the end of the survey. The July survey temperatures were more stable varying from 28° C to 31° C. The October survey temperatures were likewise stable but cooler than July levels. Water temperatures in October varied from 21° C to 26° C.

Secchi Disc

The Secchi disc used for the survey was an all white 9 inch flat plate. The disc was lowered by a calibrated rope below the waters surface until it first disappeared from sight. The disc was then retrieved until it just became visible. The depths of its disappearance and its subsequent reappearance were averaged (to the nearest 1 foot). Secchi disc values are affected by water color, opacity, and turbidity. They are relatable to the depth of light penetration into the water column. These values are frequently used to make estimates of the depth of the euphotic zone (from the surface to the depth at which one percent of the light penetrates). Photosynthesis takes place only within this zone. This depth was experimentally determined by comparison of Secchi disc values and values from a submersible photometer. A factor of 2.8 times the Secchi disc depth was equivalent to the lower limit of the euphotic zone.

The April survey had individual Secchi disc values ranging from a minimum of 2 feet to a maximum of 6 feet. In July, wind-induced mixing caused some extremely turbid waters. With Secchi disc readings as low as 1 foot. On calm days in July the water was clearer than during the other sruvey periods with individual Secchi disc values to a maximum of 12 feet. The October survey had individual Secchi disc values ranging from a minimum of 1 foot to a maximum of 8 feet.

Chemical Constituents

pH

The normal pH range within marine and estuarine systems is approximately 6.7 to 8.5. In Port Royal Sound, the morning sample run pH values varied from 7.8 to 8.0 units during the April-May survey. July survey values were only slightly higher varying from 7.9 to 8.2 units. October units were 7.9 to 8.1.

The pH values determined by the field crews are uncorrected in the Appendix Tables and are not as reliable as laboratory determined values. Field pH meters, although frequently checked and calibrated with a buffer, may occasionally, because of temperature changes and rough handling, yield erroneous results. Therefore, the maximum and minimum values listed in the tables may not reflect actual occurrences but rather meter aberrations. The merit of this summary is in the small pH differences shown between the top, middle and bottom samples. A significantly higher value for the top sample, for instance, might indicate abundant photosynthetic activity.

Alkalinity

Alkalinity values are generally higher in marine and estuarine waters than in fresh, surface waters of S. C. The average April - May survey values at the more inland and upstream stations (2, 5, 6, 7, 8 and 9) were 89-96 mg/ℓ expressed as $CaCO_3$. These values were less than those at stations nearer the ocean (1, 3, 4 and 10) were station average concentrations were from 101-103 mg/ℓ as $CaCO_3$.

The July survey average concentrations were greater than the April - May values. Average values were between 108-112 mg/ℓ $CaCO_3$ and were similar among all the stations except station 11. Station 11 averaged 100 mg/ℓ as $CaCO_3$, and is the only station affected appreciably by fresh water inflow to the system.

The October survey average values were slightly greater than in July, but again were similar among all stations except station 11. Average values were averaged 100 mg/ℓ as $CaCO_3$, and is the only station between 109-113 mg/ℓ as $CaCO_3$, at stations 1 to 10, and 100 mg/ℓ as $CaCO_3$, at station 11.

To estimate the amount of carbon available for primary production, conversion of alkalinity to available carbon was calculated for an assumed condition of: pH = 8.0; temperature = 24° C; salinity = 32 parts per thousand. This calculation yielded an available carbon value for photosynthesis of approximately 10.9 mg/ℓ when conversion of carbonate species to carbon dioxide was assumed.

TABLE 5

APRIL - MAY SUMMARIES		STATION 1 MAX	MIN	AVG	NO	STATION 2 MAX	MIN	AVG	NO	STATION 3 MAX	MIN	AVG	NO	STATION 4 MAX	MIN	AVG	NO
TOTAL DISSOLVED SOLIDS	MG/L	31000	27000	28663	27	28700	26800	27708	26	28700	24900	27240	25	30200	26400	27578	27
TOTAL SUSPENDED SOLIDS	MG/L	77	12	34	27	101	4	27	26	36	2	16	25	40	1	20	27
TOTAL ALKALINITY	MG/L CAL CARB	108	98	102	27	101	96	98	26	120	97	101	25	115	96	101	27
SULFATES	MG/L	2280	1950	2094	27	2300	1820	2047	26	2180	1560	1995	25	2280	1750	2040	27
SOLUBLE CALCIUM	MG/L	370	350	357	15	365	340	350	14	360	340	348	14	370	340	349	15
SOLUBLE MAGNESIUM	MG/L	1050	980	1002	15	1000	960	984	14	1015	960	983	14	1020	970	983	15
SOLUBLE SODIUM	MG/L	9000	8500	8633	15	8750	8400	8475	14	8500	8300	8429	14	8700	8300	8420	15
SOLUBLE POTASSIUM	MG/L	370	360	365	15	375	350	358	14	360	340	355	14	370	340	353	15
CHLORIDE	MG/L	19372	13950	16994	12	17988	12936	15316	12	19179	13516	15060	11	18005	13837	14957	12
CONDUCTIVITY, MORN-TOP	UMHOS/CM	39500	31850	35875	26	38540	32100	35331	25	39120	30760	35418	23	37780	30000	34829	25
CONDUCTIVITY, MORN-MIDDLE	UMHOS/CM	39480	32980	35932	26	38460	31680	35468	24	39000	31180	35357	23	37740	32500	34899	25
CONDUCTIVITY, MORN-BOTTOM	UMHOS/CM	39500	33170	36141	25	38980	31710	35544	24	38820	30520	35177	22	37800	30000	34836	25
CONDUCTIVITY, AFTR-TOP	UMHOS/CM	41320	34160	37196	20	40800	33500	36888	22	40090	32950	36923	22	40240	32930	36181	21
CONDUCTIVITY, AFTR-MIDDLE	UMHOS/CM	41220	34180	37191	20	40440	33340	36676	22	40090	32900	36890	22	40300	32990	36038	21
CONDUCTIVITY, AFTR-BOTTOM	UMHOS/CM	41180	33780	37183	20	40620	33350	36735	22	40100	32960	36857	22	40420	33140	36155	21
TURBIDITY	JTU	30.00	7.00	16.20	27	25.00	6.50	12.30	26	12.00	4.20	7.90	25	17.00	5.20	10.30	27
TOTAL PHOSPHORUS	MG/L	0.15	0.03	0.06	28	0.13	0.03	0.06	26	0.07	0.03	0.04	25	0.07	0.03	0.05	27
SOLUBLE PHOSPHORUS	MG/L	0.04	0.01	0.02	28	0.05	0.01	0.03	26	0.05	0.01	0.02	25	0.04	0.01	0.02	27
CHLOROPHYLL A	UG/L	6.54	0.76	3.51	24	5.74	1.65	3.32	23	4.84	1.16	2.70	22	5.66	1.57	3.04	24
CHLOROPHYLL C	UG/L	9.14		2.66	24	10.22		2.40	23	13.95	0.10	2.35	22	7.64	0.16	2.05	24
BOD, 2 DAY	MG/L	1.98	0.22	0.58	54	0.80	0.25	0.50	52	0.87	0.20	0.49	48	1.30	0.15	0.55	54
BOD, 5 DAY	MG/L	2.43	0.57	1.06	54	1.73	0.70	1.01	52	1.67	0.53	1.00	50	2.75	0.60	1.02	54
BOD, 7 DAY	MG/L	2.73	1.00	1.46	18	2.23	0.85	1.36	16	1.72	0.85	1.28	16	1.75	0.95	1.28	16
BOD, 10 DAY	MG/L	3.18	1.13	1.67	18	2.78	1.20	1.69	15	1.97	1.25	1.53	16	2.07	1.10	1.49	16
SALINITY, MORNING-TOP	PPT(G/L)	26.26	23.23	24.83	26	25.00	23.50	24.20	25	25.50	22.60	23.98	23	24.65	22.49	23.80	25
SALINITY, MORNING-MIDDLE	PPT(G/L)	26.30	23.72	25.08	26	25.50	23.60	24.30	24	25.76	22.68	23.97	23	24.82	22.80	24.01	25
SALINITY, MORNING-BOTTOM	PPT(G/L)	26.33	24.00	25.20	25	25.44	23.55	24.44	24	25.00	22.62	23.95	23	25.00	22.95	24.06	25
SALINITY, AFTERNOON-TOP	PPT(G/L)	27.66	25.50	26.61	20	26.90	25.14	25.87	22	26.58	24.79	25.66	22	26.45	24.26	25.38	21
SALINITY, AFTERNOON-MIDDLE	PPT(G/L)	27.68	25.86	26.66	20	26.90	25.28	25.90	22	26.58	24.76	25.65	22	26.72	24.71	25.59	21
SALINITY, AFTERNOON-BOTTOM	PPT(G/L)	27.90	23.30	26.63	20	27.54	23.78	26.07	22	26.58	24.79	25.51	22	26.50	24.60	25.58	21
TEMPERATURE, MORNING-TOP	C	25.00	16.20	21.00	27	26.60	16.20	21.60	26	27.00	16.50	22.10	25	26.60	16.00	21.50	27
TEMPERATURE, MORNING-MIDDLE	C	25.00	16.20	20.90	27	26.10	16.00	21.50	25	26.70	16.50	21.90	25	26.40	16.00	21.30	27
TEMPERATURE, MORNING-BOTTOM	C	24.70	16.20	20.90	26	25.90	16.00	21.90	19	26.70	16.50	21.60	24	26.20	16.80	21.30	26
TEMPERATURE, AFTERNOON-TOP	C	23.30	16.00	19.70	20	24.90	17.00	20.80	22	24.20	17.00	21.00	22	24.40	17.00	20.50	21
TEMPERATURE, AFTERNOON-MIDDLE	C	23.40	16.50	19.70	19	23.80	17.00	20.40	22	24.20	16.90	21.00	21	23.70	17.00	20.00	21
TEMPERATURE,AFTERNOON-BOTTOM	C	23.20	16.50	19.70	19	23.80	17.00	20.30	22	24.10	16.80	21.00	21	23.70	17.00	20.00	21
PH , MORNING TOP	UNITS	8.30	7.10	7.83	15	8.10	6.30	7.66	13	8.10	6.10	7.63	13	8.10	6.30	7.67	13
PH, MORNING-MIDDLE	UNITS	8.50	7.00	7.84	17	8.10	6.30	7.67	17	8.20	6.90	7.74	17	8.20	7.30	7.78	17
PH, MORNING-BOTTOM	UNITS	8.70	6.40	7.89	14	8.10	6.30	7.71	13	8.10	7.00	7.77	13	8.20	7.30	7.85	13
PH, MORNING-LABORATORY	UNITS	8.00	7.80	8.00	27	8.00	7.50	7.90	26	7.90	7.70	7.90	25	8.00	7.70	7.90	27
PH, AFTERNOON-TOP	UNITS	8.05	7.40	7.83	20	8.10	7.40	7.80	22	8.10	7.50	7.78	22	8.10	7.40	7.79	21
PH, AFTERNOON-MIDDLE	UNITS	8.05	7.40	7.83	20	8.00	7.40	7.79	22	8.10	7.40	7.78	22	8.05	7.40	7.78	21
PH, AFTERNOON-BOTTOM	UNITS	8.05	7.30	7.83	20	8.00	7.40	7.79	22	8.10	7.40	7.78	22	8.05	7.40	7.78	21
SECCHI DISC, MORNING	FT	5.00	2.00	3.00	24	5.00	2.00	4.00	22	5.00	3.00	4.00	19	6.00	2.00	4.00	22
SECCHI DISC, AFTERNOON	FT	6.00	3.00	4.00	20	5.00	3.00	4.00	22	6.00	3.00	4.00	21	6.00	3.00	4.00	19
DISSOLVED OXYGEN, MORN-TOP	MG/L	8.15	6.65	7.46	27	8.50	6.30	7.43	26	7.90	6.10	7.16	25	8.60	6.70	7.60	27
DISSOLVED OXYGEN, MORN-MID	MG/L	8.52	6.63	7.44	25	8.50	6.15	7.42	24	8.47	6.10	7.11	21	9.28	6.44	7.49	24
DISSOLVED OXYGEN, MORN-BOTT	MG/L	8.65	5.99	7.52	24	8.74	6.15	7.53	24	8.93	5.67	7.10	22	10.31	6.28	7.59	24
DISSOLVED OXYGEN, MORN-LAB	MG/L	8.15	6.65	7.47	27	8.50	6.30	7.43	26	7.90	6.10	7.14	25	8.60	6.70	7.60	27
DISSOLVED OXYGEN, AFTR-TOP	MG/L	8.20	0.69	7.32	20	10.30	7.00	7.87	21	8.90	6.40	7.58	22	8.65	7.10	7.86	21
DISSOLVED OXYGEN, AFTR-MID	MG/L	8.25	6.60	7.53	18	9.81	6.45	7.52	20	8.90	6.45	7.55	19	8.45	6.85	7.75	18
DISSOLVED OXYGEN, AFTR-BOTT	MG/L	8.25	6.80	7.48	15	8.60	6.45	7.21	13	8.94	6.15	7.51	19	8.40	6.80	7.53	13
DISSOLVED OXYGEN, AFTR-LAB	MG/L	8.20	6.80	7.63	19	10.30	7.00	7.87	21	8.90	6.40	7.58	22	8.65	7.10	7.86	21
ORGANIC NITROGEN	MG/L	0.9	0	0.4	27	1.7	0	0.4	26	1.0	0	0.4	25	2.5	0	0.4	25

TABLE 5 (Continued)

APRIL - MAY SUMMARIES		STATION 5				STATION 6				STATION 7				STATION 8			
		MAX	MIN	AVG	NO	MAX	MIN	AVG	NO	MAX	MIN	AVG	NO	MAX	MIN	AVG	NO
TOTAL DISSOLVED SOLIDS	MG/L	27700	25100	26611	27	26000	20600	24956	27	27800	22900	25189	28	27400	23900	26039	28
TOTAL SUSPENDED SOLIDS	MG/L	48	2	25	27	40	3	17	27	55	2	21	28	47	1	29	28
TOTAL ALKALINITY	MG/L CAL CARB	101	93	96	27	96	86	93	27	98	86	92	28	100	88	94	28
SULFATES	MG/L	2230	1640	1991	27	2140	1720	1881	27	2180	1610	1888	28	2210	1750	1975	28
SOLUBLE CALCIUM	MG/L	360	340	349	15	355	330	341	15	360	330	343	16	360	340	351	16
SOLUBLE MAGNESIUM	MG/L	995	970	981	15	1000	960	978	15	985	960	973	16	995	970	987	16
SOLUBLE SODIUM	MG/L	8700	8300	8427	15	8650	8300	8397	15	8550	8300	8409	16	8550	8300	8434	16
SOLUBLE POTASSIUM	MG/L	370	340	352	15	360	340	348	15	360	340	349	16	360	350	358	16
CHLORIDE	MG/L	15833	13210	14660	12	13850	12969	13618	12	15157	12679	13609	12	16814	12872	14260	11
CONDUCTIVITY, MORN-TOP	UMHOS/CM	37200	31130	34094	25	36500	29300	33146	25	37000	27940	32270	27	37700	28030	32590	27
CONDUCTIVITY, MORN-MIDDLE	UMHOS/CM	36900	31200	34093	25	36400	29300	33046	25	37100	28170	32413	27	37720	28450	33031	27
CONDUCTIVITY, MORN-BOTTOM	UMHOS/CM	37040	31300	34203	25	36420	29300	33046	25	37120	20050	32162	27	37700	29200	33360	27
CONDUCTIVITY, AFTR-TOP	UMHOS/CM	39240	30980	35279	23	38700	30320	34393	24	37300	30100	33428	24	38880	30980	34537	24
CONDUCTIVITY, AFTR-MIDDLE	UMHOS/CM	39380	31740	35362	23	38200	30430	34320	24	37300	30040	33455	24	38880	31580	34919	24
CONDUCTIVITY, AFTR-BOTTOM	UMHOS/CM	39500	31790	35430	23	38180	30430	34330	24	37300	30330	33492	24	38820	31820	35032	24
TURBIDITY	JTU	22.00	4.80	11.90	27	14.00	4.20	8.80	27	15.00	5.90	10.20	28	13.00	5.00	9.70	28
TOTAL PHOSPHORUS	MG/L	0.18	0.04	0.07	27	0.10	0.04	0.06	27	0.10	0.05	0.06	28	0.07	0.03	0.05	28
SOLUBLE PHOSPHORUS	MG/L	0.05	0.02	0.03	27	0.07	0.02	0.04	27	0.05	0.02	0.03	28	0.04	0.01	0.02	28
CHLOROPHYLL A	UG/L	5.64	1.59	3.19	24	4.83	1.20	3.02	23	5.66	1.26	2.81	24	4.92	1.25	2.63	25
CHLOROPHYLL C	UG/L	6.60		2.45	24	7.77	0.15	1.78	23	5.75	0.15	2.32	24	5.68	0.15	1.78	25
BOD, 2 DAY	MG/L	0.83	0.20	0.51	54	0.85	0.25	0.55	54	1.40	0.40	0.65	56	0.70	0.18	0.48	56
BOD, 5 DAY	MG/L	1.45	0.65	0.97	54	1.58	0.63	1.04	54	1.85	0.65	1.17	56	1.48	0.58	0.96	56
BOD, 7 DAY	MG/L	1.70	0.98	1.28	16	1.73	0.83	1.30	16	1.80	1.17	1.46	18	30.00	0.95	2.69	19
BOD, 10 DAY	MG/L	2.20	1.13	1.58	16	1.97	1.08	1.54	16	2.50	1.37	1.81	18	1.95	1.00	1.44	18
SALINITY, MORNING-TOP	PPT(G/L)	24.10	21.44	23.08	25	23.30	20.25	21.84	25	24.60	19.50	22.11	27	25.00	20.20	22.59	27
SALINITY, MORNING-MIDDLE	PPT(G/L)	24.32	21.81	23.25	25	23.30	20.88	21.95	25	24.20	20.00	22.23	27	24.60	20.45	23.02	27
SALINITY, MORNING-BOTTOM	PPT(G/L)	24.50	22.16	23.43	25	23.20	20.07	22.01	25	24.16	19.85	22.22	27	24.92	21.20	23.22	27
SALINITY, AFTERNOON-TOP	PPT(G/L)	25.76	23.20	24.65	23	25.58	22.59	23.75	24	24.50	21.14	22.98	24	25.44	21.94	23.94	24
SALINITY, AFTERNOON-MIDDLE	PPT(G/L)	26.18	23.68	24.75	23	24.66	22.55	23.60	24	24.72	21.54	23.16	24	25.56	22.22	24.26	24
SALINITY, AFTERNOON-BOTTOM	PPT(G/L)	26.76	23.78	24.98	23	25.58	22.57	23.89	24	24.75	20.86	23.13	24	25.56	20.88	23.88	24
TEMPERATURE, MORNING-TOP	C	26.30	16.00	21.80	27	28.50	16.50	22.90	27	25.70	16.00	21.30	28	24.80	15.70	20.60	28
TEMPERATURE, MORNING-MIDDLE	C	26.10	16.00	21.50	27	28.20	16.00	22.50	27	25.80	16.00	21.20	28	24.70	15.50	20.60	28
TEMPERATURE, MORNING-BOTTOM	C	25.90	17.00	21.50	26	27.80	17.50	22.50	26	25.80	16.00	21.40	27	24.50	15.50	20.60	28
TEMPERATURE, AFTERNOON-TOP	C	24.80	17.00	20.70	23	25.30	17.50	21.50	24	26.00	16.00	21.00	24	24.80	16.70	20.70	24
TEMPERATURE, AFTERNOON-MIDDLE	C	24.50	17.00	20.50	23	25.30	17.40	21.20	24	26.20	16.90	20.90	24	24.70	16.70	20.40	24
TEMPERATURE,AFTERNOON-BOTTOM	C	24.60	17.00	20.40	23	25.40	17.40	21.10	24	26.20	17.20	20.90	24	24.80	16.50	20.30	24
PH , MORNING TOP	UNITS	8.00	6.90	7.63	12	7.90	6.70	7.61	11	7.90	6.00	7.34	20	8.50	6.70	7.67	15
PH, MORNING-MIDDLE	UNITS	8.25	7.00	7.69	17	8.10	6.70	7.59	15	8.20	6.60	7.56	16	8.10	6.90	7.69	19
PH, MORNING-BOTTOM	UNITS	8.20	7.30	7.69	13	8.30	6.90	7.66	11	8.10	6.60	7.58	16	8.30	7.00	7.73	15
PH, MORNING-LABORATORY	UNITS	8.00	7.70	7.80	27	7.90	7.50	7.80	27	7.90	7.60	7.80	28	7.90	7.70	7.80	28
PH, AFTERNOON-TOP	UNITS	8.00	7.20	7.70	23	8.00	7.30	7.69	24	7.80	7.20	7.58	24	7.95	7.40	7.72	24
PH, AFTERNOON-MIDDLE	UNITS	8.00	7.40	7.75	23	8.10	7.30	7.70	24	7.80	7.20	7.61	24	7.95	7.40	7.73	24
PH, AFTERNOON-BOTTOM	UNITS	8.00	7.30	7.73	23	8.10	7.30	7.70	24	7.80	7.20	7.60	24	8.00	7.40	7.73	24
SECCHI DISC, MORNING	FT	5.00	2.00	4.00	23	6.00	3.00	4.00	21	5.00	3.00	3.00	27	5.00	3.00	3.00	27
SECCHI DISC, AFTERNOON	FT	6.00	3.00	4.00	23	6.00	3.00	4.00	24	5.00	2.00	4.00	25	5.00	2.00	4.00	25
DISSOLVED OXYGEN, MORN-TOP	MG/L	8.20	6.35	7.37	27	7.85	6.15	7.13	27	7.95	6.20	7.10	28	7.95	6.35	7.29	28
DISSOLVED OXYGEN, MORN-MID	MG/L	8.89	5.88	7.39	24	8.34	6.27	7.07	24	8.82	6.00	7.19	27	9.30	6.40	7.27	27
DISSOLVED OXYGEN, MORN-BOTT	MG/L	9.15	6.01	7.42	23	8.90	6.27	7.16	22	9.08	5.83	7.18	27	9.60	6.00	7.37	27
DISSOLVED OXYGEN, MORN-LAB	MG/L	8.20	6.35	7.37	27	7.85	6.15	7.13	27	7.95	6.20	7.10	28	7.95	6.35	7.29	28
DISSOLVED OXYGEN, AFTR-TOP	MG/L	8.25	6.60	7.50	24	10.85	6.20	7.50	23	8.30	6.25	7.27	25	10.15	6.60	7.71	25
DISSOLVED OXYGEN, AFTR-MID	MG/L	8.53	6.65	7.38	21	10.98	6.20	7.51	21	9.48	6.15	7.30	24	10.03	6.05	7.64	24
DISSOLVED OXYGEN, AFTR-BOTT	MG/L	8.65	6.40	7.26	16	10.98	6.20	7.47	14	8.75	6.00	7.28	23	9.80	5.76	7.64	23
DISSOLVED OXYGEN, AFTR-LAB	MG/L	8.25	6.60	7.47	23	10.85	6.35	7.53	24	7.85	6.25	7.15	22	10.15	6.60	7.71	24
ORGANIC NITROGEN	MG/L	0.9	0.1	0.6	27	0.7	0	0.3	23	0.9	0	0.4	28	0.8	0	0.40	28

TABLE 5 (Continued)

APRIL - MAY SUMMARIES

		STATION 9				STATION 10			
		MAX	MIN	AVG	NO	MAX	MIN	AVG	NO
TOTAL DISSOLVED SOLIDS	MG/L	27900	14400	24193	27	31700	27900	29312	26
TOTAL SUSPENDED SOLIDS	MG/L	32	5	14	27	48	2	19	26
TOTAL ALKALINITY	MG/L CAL CARB	97	79	89	27	105	100	103	26
SULFATES	MG/L	2090	1520	1854	27	3230	2020	2261	26
SOLUBLE CALCIUM	MG/L	345	310	328	15	370	350	358	14
SOLUBLE MAGNESIUM	MG/L	975	960	965	15	1020	1000	1005	14
SOLUBLE SODIUM	MG/L	8550	8000	8290	15	8800	8500	8643	14
SOLUBLE POTASSIUM	MG/L	355	320	340	15	380	360	370	14
CHLORIDE	MG/L	16508	13210	14469	11	18278	14449	16075	10
CONDUCTIVITY, MORN-TOP	UMHOS/CM	36220	24840	30845	26	40500	34250	36960	25
CONDUCTIVITY, MORN-MIDDLE	UMHOS/CM	36520	25300	31089	26	40520	34150	37007	25
CONDUCTIVITY, MORN-BOTTOM	UMHOS/CM	36700	26170	31390	26	40520	34400	37085	25
CONDUCTIVITY, AFTR-TOP	UMHOS/CM	36300	28600	31818	23	42320	34180	37946	17
CONDUCTIVITY, AFTR-MIDDLE	UMHOS/CM	36580	28740	32097	23	42280	35020	38009	17
CONDUCTIVITY, AFTR-BOTTOM	UMHOS/CM	36700	29180	32327	23	42300	35020	38154	17
TURBIDITY	JTU	8.80	4.20	6.60	27	21.00	3.90	8.70	26
TOTAL PHOSPHORUS	MG/L	0.07	0.03	0.04	27	0.14	0.04	0.06	26
SOLUBLE PHOSPHORUS	MG/L	0.04	0.01	0.02	27	0.06	0.02	0.03	26
CHLOROPHYLL A	UG/L	3.99	1.34	2.38	24	4.81	1.18	2.48	22
CHLOROPHYLL C	UG/L	7.72		1.59	24	7.62	0.18	1.46	22
BOD, 2 DAY	MG/L	0.75	0.15	0.47	54	1.25	0.15	0.51	52
BOD, 5 DAY	MG/L	1.35	0.40	0.85	54	2.45	0.50	0.94	52
BOD, 7 DAY	MG/L	1.55	0.72	1.10	18	9.00	0.65	1.81	16
BOD, 10 DAY	MG/L	1.65	0.87	1.30	18	3.30	0.90	1.59	16
SALINITY, MORNING-TOP	PPT(G/L)	23.80	17.44	21.40	26	27.20	24.10	25.73	25
SALINITY, MORNING-MIDDLE	PPT(G/L)	23.96	17.80	21.48	26	27.30	24.40	25.83	25
SALINITY, MORNING-BOTTOM	PPT(G/L)	24.16	18.50	21.70	26	27.42	24.60	26.01	25
SALINITY, AFTERNOON-TOP	PPT(G/L)	25.50	20.14	22.98	23	28.18	21.96	26.34	17
SALINITY, AFTERNOON-MIDDLE	PPT(G/L)	25.50	20.54	22.89	23	28.75	26.48	27.45	17
SALINITY, AFTERNOON-BOTTOM	PPT(G/L)	24.65	20.36	22.89	23	28.72	23.60	26.93	17
TEMPERATURE, MORNING-TOP	C	25.30	16.50	20.80	27	25.70	16.00	21.20	25
TEMPERATURE, MORNING-MIDDLE	C	24.90	16.50	20.70	27	25.50	16.00	21.10	25
TEMPERATURE, MORNING-BOTTOM	C	24.70	16.50	20.60	27	25.50	16.50	21.00	25
TEMPERATURE, AFTERNOON-TOP	C	23.80	16.00	19.90	23	23.80	16.00	19.70	17
TEMPERATURE, AFTERNOON-MIDDLE;	C	23.70	16.00	19.60	23	23.50	16.00	19.40	17
TEMPERATURE,AFTERNOON-BOTTOM	C	23.70	16.00	19.60	23	23.50	16.00	19.40	17
PH , MORNING TOP	UNITS	17.90	6.10	8.31	14	8.10	4.10	7.54	14
PH, MORNING-MIDDLE	UNITS	8.70	7.00	7.86	18	8.20	6.70	7.81	18
PH, MORNING-BOTTOM	UNITS	8.60	7.00	7.87	14	8.50	7.00	7.87	14
PH, MORNING-LABORATORY	UNITS	7.90	7.70	7.80	27	8.00	7.80	7.90	26
PH, AFTERNOON-TOP	UNITS	7.95	7.30	7.73	23	8.10	7.55	7.86	17
PH, AFTERNOON-MIDDLE	UNITS	7.95	7.30	7.72	23	8.10	7.60	7.86	17
PH, AFTERNOON-BOTTOM	UNITS	8.00	7.30	7.71	23	8.10	7.60	7.86	17
SECCHI DISC, MORNING	FT	5.00	3.00	4.00	26	6.00	3.00	4.00	24
SECCHI DISC, AFTERNOON	FT	6.00	3.00	5.00	23	6.00	3.00	5.00	17
DISSOLVED OXYGEN, MORN-TOP	MG/L	8.30	6.75	7.56	27	8.20	6.30	7.34	25
DISSOLVED OXYGEN, MORN-MID	MG/L	9.62	6.23	7.56	24	8.97	6.22	7.43	24
DISSOLVED OXYGEN, MORN-BOTT	MG/L	9.90	5.55	7.58	24	9.22	6.13	7.46	23
DISSOLVED OXYGEN, MORN-LAB	MG/L	8.30	6.75	7.55	26	8.20	6.30	7.30	23
DISSOLVED OXYGEN, AFTR-TOP	MG/L	8.30	6.95	7.69	24	8.30	6.85	7.59	17
DISSOLVED OXYGEN, AFTR-MID	MG/L	9.75	6.85	7.66	23	9.12	6.90	7.64	16
DISSOLVED OXYGEN, AFTR-BOTT	MG/L	9.93	6.80	7.62	17	9.49	6.95	7.62	12
DISSOLVED OXYGEN, AFTR-LAB	MG/L	8.30	6.95	7.70	23	8.30	6.85	7.57	16
ORGANIC NITROGEN	MG/L	0.7	0	0.3	27	1.0	0	0.2	26

TABLE 5 (Continued)

JULY SUMMARIES		STATION 1				STATION 2				STATION 4			
		MAX	MIN	AVG	NO	MAX	MIN	AVG	NO	MAX	MIN	AVG	NO
TOTAL SUSPENDED SOLIDS	MG/L	270	11	96	6	83	16	45	6	46	10	32	6
TOTAL ALKALINITY	MG/L CAL CARB	125	106	111	14	111	104	108	13	110	108	109	14
SULFATES	MG/L	2530	2200	2335	6	2370	2200	2293	6	2450	2250	2330	6
CHLORIDE	MG/L	19099	16943	17860	6	19533	16830	17611	8	18713	16235	17711	8
TEMPERATURE, MORNING-TOP	C	30	28	29	14	30	28	29	12	30	28	29	14
TEMPERATURE, MORNING-MIDDLE	C	30	28	29	14	30	28	29	13	30	28	29	14
TEMPERATURE,MORNING-BOTTOM	C	30	28	29	14	30	28	29	13	30	28	29	14
TEMPERATURE, AFTERNOON-TOP	C	31	29	29	12	31	29	30	12	31	29	30	13
TEMPERATURE, AFTERNOON-MID	C	39	29	30	12	31	29	30	12	31	29	30	13
TEMPERATURE,AFTERNOON-BOTTOM	C	31	29	30	12	31	29	30	12	31	29	30	13
TOTAL DISSOLVED SOLIDS	MG/L	32970	31690	32370	6	32700	30880	31712	6	32440	31330	31868	6
CONDUCTIVITY,MORNING-TOP	UMHO/CM	35200	18000	28600	13	34700	20600	29025	12	32200	23500	28215	13
CONDUCTIVITY, MORNING-MID	UMHO/CM	34500	18500	28785	13	34500	18000	29292	12	32700	23500	28569	13
CONDUCTIVITY, MORNING-BOTTOM	UMHO/CM	34600	18500	29062	13	35100	18000	29567	12	34160	23500	29566	13
CONDUCTIVITY,AFTERNOON-TOP	UMHO/CM	33900	23300	28925	12	33000	23300	28475	12	33700	24700	28925	12
CONDUCTIVITY,AFTERNOON-MID	UMHO/CM	32900	23500	29208	12	36400	25600	29592	12	32700	25600	29175	12
CONDUCTIVITY,AFTERNOON-BOTTOM	UMHO/CM	35300	25000	30317	12	34100	24700	29542	12	33900	25000	29725	12
TURBIDITY	JTU	*****	5.70	50.90	14	40.00	9.00	23.40	13	23.00	7.70	14.80	14
TOTAL PHOSPHORUS	MG/L	0.65	0.05	0.18	14	0.25	0.06	0.13	13	0.15	0.07	0.11	14
SOLUBLE PHOSPHORUS	MG/L	0.12	0.04	0.06	14	0.11	0.01	0.07	13	0.11	0.04	0.07	14
CHLOROPHYLL A	UG/L	29.50	3.90	9.60	13	12.00	4.50	8.00	12	10.10	3.40	6.40	14
CHLOROPHYLL C	UG/L	1.80	0.0	0.06	14	3.10	0.0	1.12	11	4.00	0.30	0.84	14
SALINITY, MORNING-TOP	PPT(G/L)	39.17	20.01	31.88	13	38.61	22.90	32.29	12	35.83	26.14	31.38	13
SALINITY, MORNING-MIDDLE	PPT(G/L)	38.39	20.57	32.02	13	38.39	20.01	32.59	12	36.38	25.24	31.68	13
SALINITY, MORNING-BOTTOM	PPT(G/L)	38.50	20.57	32.33	13	39.06	20.01	32.57	13	37.94	26.14	32.89	13
SALINITY, AFTERNOON-TOP	PPT(G/L)	37.72	25.91	32.18	12	36.72	25.91	31.71	12	37.50	27.47	32.18	12
SALINITY, AFTERNOON-MIDDLE	PPT(G/L)	36.61	26.14	32.49	12	40.51	28.48	32.92	12	36.38	28.48	32.46	12
SALINITY, AFTERNOON-BOTTOM	PPT(G/L)	39.28	27.81	33.73	12	37.94	27.47	32.96	12	37.72	27.81	33.07	12
PH, MORNING-TOP	UNITS	8.00	7.50	7.63	6	7.80	7.10	7.52	5	7.80	7.50	7.63	6
PH, MORNING-MIDDLE	UNITS	8.00	7.50	7.62	6	7.80	7.10	7.52	5	7.80	7.50	7.63	6
PH, MORNING-BOTTOM	UNITS	8.00	7.50	7.63	6	7.80	7.10	7.52	5	7.90	7.50	7.67	6
PH, MORNING-LABORATORY	UNITS	8.20	8.10	8.20	14	8.20	8.10	8.10	13	8.20	8.10	8.20	14
PH, AFTERNOON-TOP	UNITS	8.30	5.90	7.66	12	8.30	6.20	7.65	12	8.30	7.10	7.90	12
PH, AFTERNOON-MIDDLE	UNITS	8.30	6.20	7.70	12	8.30	6.50	7.64	12	8.30	7.10	7.89	12
PH, AFTERNOON-BOTTOM	UNITS	8.40	6.70	7.88	12	8.20	6.90	7.74	12	8.30	7.10	7.90	12
BOD, 2 DAY	MG/L	1.25	0.41	0.79	28	1.60	0.52	0.88	26	1.40	0.08	0.73	28
BOD, 5 DAY	MG/L	2.45	0.91	1.45	28	2.43	1.02	1.41	26	2.27	0.72	1.30	28
BOD, 7 DAY	MG/L	1.95	1.36	1.59	6	1.72	1.32	1.52	4	2.47	1.40	1.77	6
BOD, 10 DAY	MG/L	2.13	1.50	1.76	6	1.97	1.71	1.81	4	2.68	1.52	1.93	6
SECCHI DISC, MORNING	FT	6.00	1.00	3.00	13	3.00	1.00	2.00	12	4.00	1.00	2.00	13
SECCHI DISC, AFTERNOON	FT	6.00	2.00	4.00	12	5.00	2.00	4.00	12	8.00	2.00	4.00	13
DISSOLVED OXYGEN, MORN-TOP	MG/L	6.60	5.15	5.88	14	6.89	4.91	5.54	13	6.63	5.37	5.94	14
DISSOLVED OXYGEN, MORN-MID	MG/L	6.52	5.19	5.76	14	6.55	4.83	5.30	13	6.30	5.55	5.90	14
DISSOLVED OXYGEN, MORN-BOTT	MG/L	6.39	5.20	5.76	14	5.68	4.79	5.23	13	6.46	5.50	5.96	14
DISSOLVED OXYGEN, AFTR-TOP	MG/L	9.80	5.50	6.24	12	6.80	5.22	6.03	12	7.57	5.22	6.06	13
DISSOLVED OXYGEN, AFTR-MID	MG/L	9.92	5.30	6.17	12	6.41	4.59	5.68	12	7.21	5.34	6.03	13
DISSOLVED OXYGEN, AFTR-BOTT	MG/L	6.67	5.28	5.86	12	6.30	4.81	5.55	12	9.10	5.31	6.26	13
ORGANIC NITROGEN	MG/L	0.6	0	0.3	14	0.6	0	0.3	13	0.8	0	0.12	14

TABLE 5 (Continued)

JULY SUMMARIES

		STATION 5 MAX	MIN	AVG	NO	STATION 6 MAX	MIN	AVG	NO	STATION 7 MAX	MIN	AVG	NO	STATION 8 MAX	MIN	AVG	NO
TOTAL SUSPENDED SOLIDS	MG/L	130	18	62	6	92	18	44	6	79	24	44	6	93	11	41	6
TOTAL ALKALINITY	MG/L CAL CARB	111	108	110	14	111	107	109	14	111	107	109	14	111	107	109	14
SULFATES	MG/L	2370	2040	2233	6	2450	2080	2258	6	2330	2120	2232	6	2410	2080	2253	6
CHLORIDE	MG/L	19437	16331	17575	8	20837	15897	17678	8	18310	16106	17121	8	23041	16251	18124	8
TEMPERATURE, MORNING-TOP	C	30	28	29	14	30	28	29	14	30	27	28	14	29	28	28	14
TEMPERATURE, MORNING-MIDDLE	C	30	28	29	14	30	28	29	14	30	28	29	14	29	28	28	14
TEMPERATURE,MORNING-BOTTOM	C	30	28	29	14	30	28	29	14	29	26	28	14	29	28	28	14
TEMPERATURE, AFTERNOON-TOP	C	31	29	30	14	32	29	31	14	32	29	30	14	31	29	30	13
TEMPERATURE, AFTERNOON-MID	C	31	29	30	14	32	29	30	14	32	29	30	14	31	29	30	13
TEMPERATURE,AFTERNOON-BOTTOM	C	31	29	31	14	32	29	31	14	32	29	31	14	31	29	30	13
TOTAL DISSOLVED SOLIDS	MG/L	32200	31340	31733	6	31500	30140	31018	6	31940	30370	31307	6	32070	30830	31447	6
CONDUCTIVITY,MORNING-TOP	UMHO/CM	32200	24300	28462	13	34600	23200	28808	13	32500	22500	28754	13	33600	25800	29085	13
CONDUCTIVITY, MORNING-MID	UMHO/CM	33200	24300	28800	13	33300	22000	28608	13	33900	22500	29146	13	33600	23800	29246	13
CONDUCTIVITY, MORNING-BOTTOM	UMHO/CM	33400	24000	29262	13	34600	23800	29115	13	34400	22500	29585	13	34500	25400	30008	13
CONDUCTIVITY,AFTERNOON-TOP	UMHO/CM	34400	24900	29285	13	33100	24700	28354	13	30700	23500	27877	13	31300	24300	28431	13
CONDUCTIVITY,AFTERNOON-MID	UMHO/CM	33100	24700	28915	13	32400	24700	29069	13	35000	24200	29085	13	32500	24700	29015	13
CONDUCTIVITY,AFTERNOON-BOTTOM	UMHO/CM	33600	25000	29046	13	34600	25600	29781	13	33200	24700	29069	13	34000	24500	29646	13
TURBIDITY	JTU	52.00	9.80	27.10	14	40.00	12.00	22.40	14	30.00	12.00	19.60	14	42.00	7.10	19.90	14
TOTAL PHOSPHORUS	MG/L	0.30	0.07	0.15	14	0.23	0.06	0.14	14	0.25	0.07	0.13	14	0.25	0.06	0.13	14
SOLUBLE PHOSPHORUS	MG/L	0.12	0.04	0.07	14	0.20	0.04	0.09	14	0.13	0.04	0.08	14	0.13	0.04	0.07	14
CHLOROPHYLL A	UG/L	12.00	5.30	8.20	14	12.40	2.20	7.50	14	10.80	1.60	7.40	14	13.70	2.00	6.80	14
CHLOROPHYLL C	UG/L	4.30	0.10	1.00	14	11.10	0.20	1.45	14	4.30	0.10	1.46	14	2.40	0.10	0.51	14
SALINITY, MORNING-TOP	PPT(G/L)	35.83	27.03	31.66	13	37.16	25.80	31.50	13	36.16	25.02	31.99	13	36.38	28.70	31.80	13
SALINITY, MORNING-MIDDLE	PPT(G/L)	36.94	27.03	32.04	13	37.05	24.46	31.82	13	37.72	25.02	32.35	13	37.39	26.47	32.54	13
SALINITY, MORNING-BOTTOM	PPT(G/L)	37.16	26.69	32.55	13	38.50	26.47	32.39	13	38.28	25.02	32.91	13	38.39	28.25	33.38	13
SALINITY, AFTERNOON-TOP	PPT(G/L)	38.28	27.70	32.05	13	36.83	27.47	31.54	13	34.16	26.14	31.01	13	34.82	27.03	31.63	13
SALINITY, AFTERNOON-MIDDLE	PPT(G/L)	36.83	27.47	32.17	13	36.05	27.47	32.34	13	38.95	26.92	32.36	13	36.16	27.47	32.28	13
SALINITY, AFTERNOON-BOTTOM	PPT(G/L)	37.39	27.81	32.31	13	38.50	28.48	33.13	13	36.94	27.47	32.34	13	37.83	27.25	32.98	13
PH, MORNING-TOP	UNITS	7.70	6.60	7.42	6	7.70	7.40	7.55	6	8.30	7.40	7.70	6	7.90	7.00	7.67	6
PH, MORNING-MIDDLE	UNITS	7.70	6.40	7.40	6	7.70	7.40	7.55	6	8.30	7.30	7.68	6	7.90	6.70	7.62	6
PH, MORNING-BOTTOM	UNITS	7.70	6.70	7.45	6	7.70	7.40	7.57	6	8.30	7.40	7.68	6	7.90	7.30	7.70	6
PH, MORNING-LABORATORY	UNITS	8.20	8.00	8.10	14	8.00	7.90	8.00	14	8.10	8.00	8.00	14	8.20	8.00	8.10	14
PH, AFTERNOON-TOP	UNITS	8.20	7.10	7.89	13	8.10	6.90	7.72	13	9.20	7.00	7.93	12	8.20	7.00	7.88	13
PH, AFTERNOON-MIDDLE	UNITS	8.10	7.10	7.89	13	8.00	7.00	7.77	13	8.80	7.00	7.90	12	8.20	7.00	7.85	13
PH, AFTERNOON-BOTTOM	UNITS	8.20	7.10	7.89	13	8.00	7.00	7.79	13	8.90	7.00	7.92	12	8.20	7.00	7.88	13
BOD, 2 DAY	MG/L	0.99	0.48	0.73	28	1.23	0.52	0.81	28	3.86	0.52	1.14	28	1.10	0.54	0.81	28
BOD, 5 DAY	MG/L	1.73	0.97	1.33	28	2.00	0.93	1.40	28	5.51	1.17	1.88	28	1.78	0.90	1.37	28
BOD, 7 DAY	MG/L	2.05	1.41	1.70	6	2.33	1.34	1.85	6	3.01	1.28	2.07	6	1.58	1.22	1.43	6
BOD, 10 DAY	MG/L	2.18	1.49	1.76	6	2.60	1.61	2.05	6	3.41	1.45	2.30	6	1.81	1.44	1.65	6
SECCHI DISC, MORNING	FT	3.00	1.00	2.00	12	3.00	2.00	2.00	13	3.00	1.00	2.00	13	4.00	1.00	2.00	13
SECCHI DISC, AFTERNOON	FT	4.00	2.00	3.00	7	6.00	2.00	3.00	14	4.00	2.00	3.00	14	5.00	2.00	4.00	14
DISSOLVED OXYGEN, MORN-TOP	MG/L	6.40	4.86	5.40	14	6.17	4.41	5.32	14	6.19	4.80	5.70	7	6.18	4.75	5.58	14
DISSOLVED OXYGEN, MORN-MID	MG/L	5.99	4.81	5.37	14	6.10	4.57	5.20	14	6.39	4.96	5.57	14	6.30	4.87	5.61	14
DISSOLVED OXYGEN, MORN-BOTT	MG/L	6.21	4.80	5.35	14	6.10	4.59	5.26	14	6.42	4.59	5.38	21	6.29	4.50	5.53	14
DISSOLVED OXYGEN, AFTR-TOP	MG/L	13.03	4.69	6.12	14	7.42	4.41	5.42	14	5.84	4.79	5.39	13	6.90	5.03	5.99	14
DISSOLVED OXYGEN, AFTR-MID	MG/L	6.42	4.60	5.49	14	6.41	4.33	5.13	14	6.67	4.85	5.44	14	6.61	5.42	5.91	14
DISSOLVED OXYGEN, AFTR-BOTT	MG/L	6.72	4.75	5.45	14	6.00	4.41	5.00	14	6.60	4.80	5.41	14	6.73	5.10	5.78	14
ORGANIC NITROGEN	MG/L	0.7	0	0.3	14	0.9	0	0.4	14	0.7	0	0.2	14	0.4	0	0.1	14

TABLE 5 (Continued)

JULY SUMMARIES		STATION 9 MAX	MIN	AVG	NO	STATION 10 MAX	MIN	AVG	NO	STATION 11 MAX	MIN	AVG	NO
TOTAL SUSPENDED SOLIDS	MG/L	23	3	11	6	55	5	26	6	100	16	50	6
TOTAL ALKALINITY	MG/L CAL CARB	110	107	109	14	115	109	112	14	104	95	100	14
SULFATES	MG/L	2370	2080	2260	6	2450	2160	2327	6	2200	1930	2015	6
CHLORIDE	MG/L	18327	16154	17391	8	19987	17651	19030	8	17361	13081	15650	8
TEMPERATURE, MORNING-TOP	C	30	28	30	14	30	28	29	14	32	30	30	14
TEMPERATURE, MORNING-MIDDLE	C	31	29	30	14	30	28	29	14	32	28	30	14
TEMPERATURE,MORNING-BOTTOM	C	32	29	30	14	30	28	29	14	32	30	30	14
TEMPERATURE, AFTERNOON-TOP	C	30	29	29	9	31	29	30	6	31	29	30	6
TEMPERATURE, AFTERNOON-MID	C	30	28	29	9	31	29	30	6	31	29	30	4
TEMPERATURE,AFTERNOON-BOTTOM	C	31	28	30	9	31	29	30	6	31	29	30	6
TOTAL DISSOLVED SOLIDS	MG/L	32480	30820	31568	6	35520	32170	33730	6	29750	26330	28307	6
CONDUCTIVITY,MORNING-TOP	UMHO/CM	34100	21500	27500	13	34400	24300	29485	13	31200	18500	26800	13
CONDUCTIVITY, MORNING-MID	UMHO/CM	34500	22200	28300	13	35300	23900	29662	13	31300	21100	26808	13
CONDUCTIVITY, MORNING-BOTTOM	UMHO/CM	34700	22100	28615	13	35500	24300	30031	13	32000	22000	27369	13
CONDUCTIVITY,AFTERNOON-TOP	UMHO/CM	33400	23300	28250	8	34800	25000	27633	6	32900	22900	27183	6
CONDUCTIVITY,AFTERNOON-MID	UMHO/CM	35700	25700	29763	8	34600	25700	28150	6	32800	23100	27680	5
CONDUCTIVITY,AFTERNOON-BOTTOM	UMHO/CM	34700	25000	29775	8	34400	26500	28567	6	34600	24200	28133	6
TURBIDITY	JTU	9.20	1.60	5.60	14	20.00	3.50	11.60	14	45.00	9.10	23.20	14
TOTAL PHOSPHORUS	MG/L	0.14	0.05	0.09	14	0.13	0.05	0.09	14	0.25	0.09	0.15	13
SOLUBLE PHOSPHORUS	MG/L	0.11	0.04	0.07	14	0.09	0.03	0.05	14	0.13	0.04	0.08	13
CHLOROPHYLL A	UG/L	6.30	2.00	4.60	14	9.10	1.90	5.30	14	11.50	5.30	8.60	14
CHLOROPHYLL C	UG/L	2.00	0.20	0.55	14	3.00	0.80	1.11	14	5.50	0.20	1.27	14
SALINITY, MORNING-TOP	PPT(G/L)	37.94	23.91	30.59	13	38.28	27.03	32.80	13	34.71	20.57	29.89	13
SALINITY, MORNING-MIDDLE	PPT(G/L)	38.39	24.69	31.48	13	39.28	26.58	33.00	13	34.82	23.46	29.82	13
SALINITY, MORNING-BOTTOM	PPT(G/L)	38.61	24.58	31.83	13	39.50	27.03	33.41	13	35.60	24.46	30.44	13
SALINITY, AFTERNOON-TOP	PPT(G/L)	37.16	25.91	31.43	8	38.72	27.81	30.74	6	36.61	25.47	30.24	6
SALINITY, AFTERNOON-MIDDLE	PPT(G/L)	39.73	28.59	33.11	8	38.50	28.59	31.32	6	36.49	25.69	30.79	5
SALINITY, AFTERNOON-BOTTOM	PPT(G/L)	38.61	27.81	33.13	8	38.28	29.48	31.78	6	38.50	26.92	31.30	6
PH, MORNING-TOP	UNITS	8.00	7.30	7.55	6	8.00	7.50	7.63	6	7.80	6.90	7.35	6
PH, MORNING-MIDDLE	UNITS	8.00	7.30	7.55	6	7.90	7.50	7.62	6	7.80	6.90	7.35	6
PH, MORNING-BOTTOM	UNITS	8.00	7.40	7.57	6	7.90	7.50	7.62	6	7.80	6.90	7.35	6
PH, MORNING-LABORATORY	UNITS	8.20	8.10	8.20	14	8.40	8.10	8.20	14	8.00	7.80	7.90	14
PH, AFTERNOON-TOP	UNITS	8.20	5.80	7.48	8	8.40	6.50	7.55	6	7.80	6.50	7.23	4
PH, AFTERNOON-MIDDLE	UNITS	8.20	6.50	7.59	8	8.40	5.70	7.37	6	7.90	6.80	7.52	6
PH, AFTERNOON-BOTTOM	UNITS	8.20	6.30	7.60	8	8.40	7.00	7.93	6	8.10	6.70	7.53	6
BOD, 2 DAY	MG/L	0.90	0.40	0.63	28	1.00	0.44	0.69	28	1.09	0.57	0.84	27
BOD, 5 DAY	MG/L	1.46	0.78	1.13	28	1.63	0.95	1.22	28	1.86	0.95	1.52	28
BOD, 7 DAY	MG/L	1.62	1.08	1.32	6	1.65	1.34	1.49	6	2.28	1.67	1.94	6
BOD, 10 DAY	MG/L	2.04	1.22	1.56	6	1.74	1.50	1.67	6	2.93	2.25	2.57	6
SECCHI DISC, MORNING	FT	11.00	4.00	6.00	13	5.00	2.00	3.00	13	2.00	1.00	1.00	13
SECCHI DISC, AFTERNOON	FT	12.00	7.00	9.00	9	7.00	3.00	5.00	6	6.00	2.00	4.00	6
DISSOLVED OXYGEN, MORN-TOP	MG/L	6.80	6.07	6.41	14	6.55	5.47	5.98	14	6.20	4.61	5.15	14
DISSOLVED OXYGEN, MORN-MID	MG/L	6.79	5.94	6.33	14	6.50	5.25	5.82	14	9.70	4.70	5.43	14
DISSOLVED OXYGEN, MORN-BOTT	MG/L	6.62	6.00	6.25	13	6.34	5.50	5.79	14	6.11	4.70	5.09	14
DISSOLVED OXYGEN, AFTR-TOP	MG/L	6.80	6.22	6.47	9	6.85	5.19	6.20	6	6.74	4.77	5.71	6
DISSOLVED OXYGEN, AFTR-MID	MG/L	10.10	6.20	6.86	9	6.96	5.31	6.30	6	6.90	4.77	5.77	6
DISSOLVED OXYGEN, AFTR-BOTT	MG/L	6.78	6.19	6.50	8	9.03	5.92	6.77	6	6.90	4.46	5.62	6
ORGANIC NITROGEN	MG/L	0.9	0	0.2	14	1.7	0	0.3	14	0.6	0	0.3	14

TABLE 5 (Continued)

OCTOBER SUMMARIES		STATION 1				STATION 2				STATION 4			
		MAX	MIN	AVG	NO	MAX	MIN	AVG	NO	MAX	MIN	AVG	NO
TOTAL SUSPENDED SOLIDS	MG/L	103	32	75	6	61	18	42	6	63	18	31	6
TOTAL ALKALINITY	MG/L CAL CARB	116	110	113	14	131	109	113	14	131	108	112	14
SULFATES	MG/L	2640	2320	2487	6	24600	2440	13287	6	2580	2320	2450	6
CHLORIDE	MG/L	18701	17860	18131	6	18310	17458	17898	6	17989	16814	17451	5
TEMPERATURE, MORNING-TOP	C	26	22	24	14	26	22	23	14	26	22	24	14
TEMPERATURE, MORNING-MIDDLE	C	26	22	23	14	26	22	23	14	25	22	23	14
TEMPERATURE,MORNING-BOTTOM	C	26	22	23	14	26	22	23	14	25	22	23	14
TEMPERATURE, AFTERNOON-TOP	C	25	22	23	10	26	21	23	11	26	22	24	11
TEMPERATURE, AFTERNOON-MID	C	25	22	23	10	26	21	23	11	25	22	23	11
TEMPERATURE,AFTERNOON-BOTTOM	C	25	22	23	10	26	21	23	11	25	22	23	11
TOTAL DISSOLVED SOLIDS	MG/L	3382	3339	3361	6	3373	3260	3315	6	3396	3264	3320	6
CONDUCTIVITY,MORNING-TOP	UMHO/CM	48600	44300	46400	14	47900	43500	45200	14	48400	43000	45700	14
CONDUCTIVITY, MORNING-MID	UMHO/CM	48500	44300	46400	14	47900	43700	45300	14	48400	43100	45700	14
CONDUCTIVITY, MORNING-BOTTOM	UMHO/CM	48500	44500	46400	14	47900	43900	45300	14	48400	43400	45800	14
CONDUCTIVITY,AFTERNOON-TOP	UMHO/CM	48600	45800	47200	10	49300	44700	46500	11	48800	45400	46900	11
CONDUCTIVITY,AFTERNOON-MID	UMHO/CM	48600	45800	47100	10	48700	44700	46300	11	48600	45200	46800	11
CONDUCTIVITY,AFTERNOON-BOTTOM	UMHO/CM	48600	45800	47100	10	48700	44700	46300	11	48600	41800	46000	15
TURBIDITY	JTU	5.00	1.10	3.00	14	2.90	0.80	1.90	14	3.20	0.80	1.70	14
TOTAL PHOSPHORUS	MG/L	0.23	0.08	0.14	14	0.20	0.08	0.12	14	0.15	0.08	0.10	14
SOLUBLE PHOSPHORUS	MG/L	0.15	0.04	0.07	14	0.09	0.04	0.07	14	0.10	0.04	0.07	14
CHLOROPHYLL A	UG/L	15.13	4.72	9.26	12	10.09	2.59	5.12	12	13.61	2.31	5.70	12
CHLOROPHYLL C	UG/L	3.90	0.0	1.34	12	4.71	0.0	1.02	12	3.62	0.0	1.38	12
SALINITY, MORNING-TOP	PPT(G/L)	32.63	30.96	31.59	14	31.57	30.32	30.94	14	32.07	30.17	31.20	14
SALINITY, MORNING-MIDDLE	PPT(G/L)	32.67	30.97	31.66	14	31.55	30.41	31.01	14	32.04	30.25	31.24	14
SALINITY, MORNING-BOTTOM	PPT(G/L)	32.64	31.03	31.62	14	31.59	30.61	31.11	14	32.08	30.29	31.29	14
SALINITY, AFTERNOON-TOP	PPT(G/L)	32.49	31.55	31.93	10	31.75	30.68	31.28	11	32.38	30.80	31.59	11
SALINITY, AFTERNOON-MIDDLE	PPT(G/L)	33.56	31.62	32.09	10	31.75	31.23	31.44	11	32.36	31.00	31.63	11
SALINITY, AFTERNOON-BOTTOM	PPT(G/L)	32.15	30.74	31.74	10	32.22	31.32	31.60	11	31.86	30.12	31.27	11
PH, MORNING-TOP	UNITS	9.80	7.00	8.60	13	9.40	7.00	8.40	13	10.20	7.60	8.60	13
PH, MORNING-MIDDLE	UNITS	9.50	6.80	8.40	13	9.40	6.40	8.30	13	9.60	7.40	8.40	13
PH, MORNING-BOTTOM	UNITS	9.90	7.50	8.60	13	10.10	7.40	8.50	13	10.20	7.90	8.70	13
PH, MORNING-LABORATORY	UNITS	8.30	8.00	8.10	14	8.10	7.80	8.00	14	8.20	7.90	8.00	14
PH, AFTERNOON-TOP	UNITS	8.10	7.40	7.80	9	8.30	6.80	7.70	11	8.50	7.50	7.90	11
PH, AFTERNOON-MIDDLE	UNITS	8.20	7.40	7.80	9	8.40	6.80	7.60	11	8.40	7.40	7.90	11
PH, AFTERNOON-BOTTOM	UNITS	8.10	7.40	7.80	9	8.20	6.90	7.70	11	8.40	7.40	7.90	11
BOD, 2 DAY	MG/L	0.70	0.20	0.50	28	0.85	0.15	0.47	28	0.80	0.35	0.48	26
BOD, 5 DAY	MG/L	1.30	0.60	0.99	28	1.25	0.55	0.83	28	1.15	0.50	0.83	28
BOD, 7 DAY	MG/L	1.60	0.70	1.26	14	1.80	0.60	1.09	14	1.15	0.20	0.88	14
BOD, 10 DAY	MG/L	2.35	1.10	1.65	14	1.60	1.05	1.34	14	1.45	0.90	1.21	14
SECCHI DISC, MORNING	FT	5.00	1.00	3.00	14	5.00	2.00	3.00	14	6.00	1.00	4.00	14
SECCHI DISC, AFTERNOON	FT	4.00	1.00	2.00	10	4.00	2.00	3.00	11	4.00	2.00	3.00	11
DISSOLVED OXYGEN, MORN-TOP	MG/L	6.85	6.10	6.43	14	6.90	5.40	6.21	14	7.00	5.80	6.52	14
DISSOLVED OXYGEN, MORN-MID	MG/L	7.00	5.70	6.41	14	6.90	5.40	6.21	14	6.90	6.15	6.48	14
DISSOLVED OXYGEN, MORN-BOTT	MG/L	6.80	5.90	6.39	14	6.85	5.45	6.20	14	7.00	6.00	6.51	14
DISSOLVED OXYGEN, AFTR-TOP	MG/L	6.80	5.80	6.41	10	6.80	5.40	6.43	11	7.50	5.90	6.61	11
DISSOLVED OXYGEN, AFTR-MID	MG/L	6.75	5.80	6.34	9	6.65	5.50	6.32	11	7.35	5.90	6.52	11
DISSOLVED OXYGEN, AFTR-BOTT	MG/L	6.80	5.70	6.30	10	7.05	5.40	6.33	11	6.85	5.95	6.40	11
ORGANIC NITROGEN	MG/L	1.0	0	0.4	14	1.1	0	0.4	14	1.3	0	0.3	14

TABLE 5 (Continued)

OCTOBER SUMMARIES		STATION 5 MAX	MIN	AVG	NO	STATION 6 MAX	MIN	AVG	NO	STATION 7 MAX	MIN	AVG	NO	STATION 8 MAX	MIN	AVG	NO
TOTAL SUSPENDED SOLIDS	MG/L	103	20	63	6	74	18	40	6	70	20	41	6	45	22	37	6
TOTAL ALKALINITY	MG/L CAL CARB	136	106	112	14	114	104	109	14	118	104	110	14	113	108	110	14
SULFATES	MG/L	2620	2240	2445	6	2460	2140	2310	6	2420	2240	2337	6	2520	2280	2377	6
CHLORIDE	MG/L	17844	16589	17384	6	18841	16042	17283	6	18729	16026	17305	6	18906	15570	17436	6
TEMPERATURE, MORNING-TOP	C	26	22	23	14	26	21	23	14	26	21	23	14	26	21	23	14
TEMPERATURE, MORNING-MIDDLE	C	26	22	23	14	26	21	23	14	26	21	23	14	26	21	23	14
TEMPERATURE,MORNING-BOTTOM	C	25	22	23	14	26	21	23	14	26	21	23	14	26	21	23	14
TEMPERATURE, AFTERNOON-TOP	C	25	22	23	11	26	22	24	11	25	22	23	11	25	22	24	11
TEMPERATURE, AFTERNOON-MID	C	25	22	23	11	26	22	24	11	25	22	23	11	25	22	23	11
TEMPERATURE,AFTERNOON-BOTTOM	C	25	22	23	11	26	22	24	11	25	22	23	11	25	22	23	11
TOTAL DISSOLVED SOLIDS]	MG/L	3345	3164	3262	6	3233	3045	3152	6	3319	3008	3175	6	3328	3207	3261	6
CONDUCTIVITY,MORNING-TOP	UMHO/CM	47900	41400	44900	14	46600	39500	43300	14	47000	39600	43500	14	47300	42100	44500	14
CONDUCTIVITY, MORNING-MID	UMHO/CM	47900	42100	45100	14	46600	40100	43400	14	47100	39700	43600	14	47400	42200	44600	14
CONDUCTIVITY, MORNING-BOTTOM	UMHO/CM	47900	42400	45000	14	46600	40400	43400	14	47200	39800	43600	14	47500	42200	44700	14
CONDUCTIVITY,AFTERNOON-TOP	UMHO/CM	47600	44500	45900	11	46800	42100	44700	11	47600	41900	45100	11	48300	41600	45600	11
CONDUCTIVITY,AFTERNOON-MID	UMHO/CM	47700	44200	45800	11	46800	41900	44600	11	47700	41600	44600	11	48300	41700	45700	11
CONDUCTIVITY,AFTERNOON-BOTTOM	UMHO/CM	47800	44300	45900	11	46800	41900	44700	11	47800	41600	45100	11	48300	45400	47000	7
TURBIDITY	JTU	3.60	1.10	2.20	14	3.20	0.80	1.70	14	2.60	0.80	1.50	14	3.30	0.80	1.90	14
TOTAL PHOSPHORUS	MG/L	0.35	0.08	0.15	14	0.15	0.08	0.12	14	0.15	0.09	0.11	14	0.25	0.08	0.13	14
SOLUBLE PHOSPHORUS	MG/L	0.21	0.05	0.09	14	0.11	0.05	0.08	14	0.09	0.03	0.07	14	0.10	0.05	0.07	14
CHLOROPHYLL A	UG/L	9.56	3.02	5.66	12	7.80	2.22	5.17	11	7.82	1.65	4.96	12	10.67	1.73	5.67	12
CHLOROPHYLL C	UG/L	6.61	0.0	1.17	12	3.85	0.0	1.06	11	1.67	0.0	0.49	12	5.11	0.0	0.90	12
SALINITY, MORNING-TOP	PPT(G/L)	31.70	29.18	30.63	14	30.72	27.76	29.63	14	31.44	28.12	29.93	14	31.51	29.50	30.58	14
SALINITY, MORNING-MIDDLE	PPT(G/L)	31.73	29.74	30.73	14	30.83	28.55	29.77	14	31.23	28.14	29.94	14	31.50	29.86	30.65	14
SALINITY, MORNING-BOTTOM	PPT(G/L)	31.72	29.80	30.75	14	31.40	28.47	29.85	14	31.50	28.22	30.02	14	31.51	30.13	30.74	14
SALINITY, AFTERNOON-TOP	PPT(G/L)	31.84	30.14	30.89	11	31.02	28.38	29.97	11	31.50	25.24	29.69	11	31.72	30.20	30.92	11
SALINITY, AFTERNOON-MIDDLE	PPT(G/L)	31.85	30.30	31.00	11	31.09	29.00	30.05	11	31.04	28.66	29.46	4	31.63	30.20	31.03	11
SALINITY, AFTERNOON-BOTTOM	PPT(G/L)	31.90	28.84	30.63	11	31.86	29.11	30.45	11	32.21	28.96	30.69	18	31.72	28.80	30.70	11
PH, MORNING-TOP	UNITS	10.40	7.90	8.70	14	10.20	7.90	8.40	14	10.80	7.80	8.40	14	9.60	7.90	8.40	14
PH, MORNING-MIDDLE	UNITS	10.10	7.80	8.60	14	9.40	7.80	8.30	14	10.80	7.20	8.30	14	9.10	7.60	8.20	14
PH, MORNING-BOTTOM	UNITS	10.40	7.90	8.70	14	10.20	7.90	8.50	14	10.80	7.80	8.40	14	9.60	7.90	8.40	14
PH, MORNING-LABORATORY	UNITS	8.10	7.80	8.00	14	8.00	7.80	7.90	14	8.10	7.80	8.00	14	8.20	8.00	8.10	14
PH, AFTERNOON-TOP	UNITS	8.30	7.10	7.70	11	8.40	6.50	7.60	11	8.00	6.60	7.60	11	8.50	6.80	7.70	11
PH, AFTERNOON-MIDDLE	UNITS	8.60	7.40	7.80	11	8.50	7.30	7.70	11	8.20	7.10	7.70	11	8.40	6.70	7.70	11
PH, AFTERNOON-BOTTOM	UNITS	8.60	7.40	7.80	11	8.30	7.40	7.80	11	8.40	7.20	7.60	11	8.30	6.30	7.70	11
BOD, 2 DAY	MG/L	0.65	0.10	0.42	28	0.85	0.20	0.52	28	0.80	0.25	0.55	28	0.80	0.15	0.46	28
BOD, 5 DAY	MG/L	1.15	0.50	0.80	28	1.10	0.60	0.90	28	1.45	0.85	1.04	28	1.20	0.45	0.86	28
BOD, 7 DAY	MG/L	1.70	0.80	1.18	14	1.70	0.60	1.13	14	1.60	0.90	1.31	14	1.30	0.45	0.94	14
BOD, 10 DAY	MG/L	2.00	1.00	1.43	14	1.55	0.95	1.29	14	1.95	0.85	1.51	14	1.50	0.80	1.25	14
SECCHI DISC, MORNING	FT	5.00	1.00	3.00	14	4.00	2.00	3.00	14	4.00	1.00	3.00	14	5.00	2.00	3.00	14
SECCHI DISC, AFTERNOON	FT	5.00	1.00	2.00	11	4.00	1.00	2.00	11	4.00	1.00	2.00	11	4.00	2.00	3.00	11
DISSOLVED OXYGEN, MORN-TOP	MG/L	6.80	5.70	6.34	14	6.60	5.40	6.07	14	6.80	5.50	6.26	14	6.90	5.80	6.36	14
DISSOLVED OXYGEN, MORN-MID	MG/L	6.65	5.60	6.28	14	6.50	5.40	6.05	13	7.10	5.40	6.29	14	6.85	5.60	6.36	14
DISSOLVED OXYGEN, MORN-BOTT	MG/L	7.00	5.50	6.31	14	6.60	5.30	6.02	14	7.20	5.50	6.30	14	6.90	5.80	6.44	14
DISSOLVED OXYGEN, AFTR-TOP	MG/L	6.90	5.35	6.20	11	6.75	5.20	5.97	11	6.80	5.45	6.13	11	6.80	5.75	6.34	11
DISSOLVED OXYGEN, AFTR-MID	MG/L	6.60	5.30	6.09	11	6.40	4.95	5.77	11	6.70	5.50	6.13	11	6.80	5.75	6.33	11
DISSOLVED OXYGEN, AFTR-BOTT	MG/L	6.65	5.30	6.09	11	6.85	5.05	5.87	11	6.60	5.30	6.07	11	6.70	5.80	6.35	11
ORGANIC NITROGEN	MG/L	1.3	0	0.5	14	1.0	0	0.4	14	0.9	0	0.3	14	2.7	0	0.5	14

TABLE 5 (Continued)

OCTOBER SUMMARIES		STATION 9 MAX	MIN	AVG	NO	STATION 10 MAX	MIN	AVG	NO	STATION 11 MAX	MIN	AVG	NO
TOTAL SUSPENDED SOLIDS	MG/L	30	11	20	6	208	20	91	6	67	22	44	6
TOTAL ALKALINITY	MG/L CAL CARB	113	106	110	13	116	111	113	13	106	90	100	13
SULFATES	MG/L	2440	2200	2360	6	2620	2320	2470	6	2020	1840	1930	6
CHLORIDE	MG/L	18733	16959	17783	6	18584	17860	18139	6	18101	14433	15589	6
TEMPERATURE, MORNING-TOP	C	25	22	24	13	26	21	23	13	26	22	24	13
TEMPERATURE, MORNING-MIDDLE	C	25	23	24	13	26	21	23	13	26	22	24	13
TEMPERATURE,MORNING-BOTTOM	C	25	23	24	13	26	21	23	13	26	22	24	13
TEMPERATURE, AFTERNOON-TOP	C	25	22	24	12	26	21	23	12	26	22	23	11
TEMPERATURE, AFTERNOON-MID	C	25	22	24	12	26	21	23	8	26	22	23	11
TEMPERATURE,AFTERNOON-BOTTOM	C	25	22	24	12	26	21	23	8	26	22	23	11
TOTAL DISSOLVED SOLIDS 1	MG/L	3365	3189	3294	6	3450	3388	3428	6	2961	2613	2793	6
CONDUCTIVITY,MORNING-TOP	UMHO/CM	47800	42400	45300	13	49600	44700	46700	13	42600	33300	38700	13
CONDUCTIVITY, MORNING-MID	UMHO/CM	47900	42500	45300	13	49600	44600	46600	13	42600	33300	38700	13
CONDUCTIVITY, MORNING-BOTTOM	UMHO/CM	48000	42500	45300	13	49600	44600	46600	13	42600	33200	38700	13
CONDUCTIVITY,AFTERNOON-TOP	UMHO/CM	47400	44600	45800	12	49500	45600	47100	8	40100	38400	39300	11
CONDUCTIVITY,AFTERNOON-MID	UMHO/CM	47400	44600	45800	12	49500	45600	47200	8	40100	38400	39200	11
CONDUCTIVITY,AFTERNOON-BOTTOM	UMHO/CM	147400	44500	45900	12	0	*****	0	0	40100	38400	39300	11
TURBIDITY	JTU	1.10	0.40	0.80	13	6.20	0.80	3.10	13	2.20	0.80	1.60	13
TOTAL PHOSPHORUS	MG/L	0.11	0.05	0.09	13	0.60	0.08	0.18	13	0.15	0.10	0.12	13
SOLUBLE PHOSPHORUS	MG/L	0.09	0.05	0.07	13	0.11	0.03	0.06	13	0.12	0.05	0.09	13
CHLOROPHYLL A	UG/L	6.70	1.49	3.84	11	17.47	3.19	7.83	11	6.83	2.77	4.97	11
CHLOROPHYLL C	UG/L	3.35	0.0	0.51	11	18.31	0.0	3.54	11	1.83	0.0	0.60	11
SALINITY, MORNING-TOP	PPT(G/L)	31.87	29.17	30.60	13	33.25	31.17	32.02	13	28.54	22.13	25.90	13
SALINITY, MORNING-MIDDLE	PPT(G/L)	31.91	29.21	30.63	13	33.07	31.20	32.03	13	28.57	22.13	25.96	13
SALINITY, MORNING-BOTTOM	PPT(G/L)	32.17	29.31	30.89	13	33.25	31.24	32.02	13	28.72	22.70	25.97	13
SALINITY, AFTERNOON-TOP	PPT(G/L)	31.51	29.92	30.77	12	32.82	31.64	32.29	8	27.79	24.64	26.26	11
SALINITY, AFTERNOON-MIDDLE	PPT(G/L)	32.00	30.02	30.90	12	32.90	31.68	32.48	8	31.00	24.60	26.60	11
SALINITY, AFTERNOON-BOTTOM	PPT(G/L)	34.50	30.00	31.37	12	32.84	31.90	32.45	8	32.16	25.05	29.21	11
PH, MORNING-TOP	UNITS	9.70	7.60	8.50	12	10.40	7.90	8.80	12	9.10	7.50	8.10	12
PH, MORNING-MIDDLE	UNITS	9.30	7.60	8.40	12	9.30	7.80	8.50	12	9.10	7.40	8.00	12
PH, MORNING-BOTTOM	UNITS	9.90	7.60	8.60	12	10.40	7.90	8.80	12	9.10	7.40	8.10	12
PH, MORNING-LABORATORY	UNITS	8.20	8.00	8.10	13	8.20	8.00	8.10	13	8.00	7.60	7.90	13
PH, AFTERNOON-TOP	UNITS	8.10	5.50	7.70	10	8.00	7.70	7.90	7	8.00	7.30	7.70	9
PH, AFTERNOON-MIDDLE	UNITS	8.00	6.00	7.70	10	8.00	7.80	7.90	7	8.00	7.30	7.70	9
PH, AFTERNOON-BOTTOM	UNITS	8.20	5.10	7.60	10	8.00	7.60	7.90	7	8.00	7.40	7.70	9
BOD, 2 DAY	MG/L	0.85	0.20	0.45	26	0.90	0.15	0.50	26	1.00	0.30	0.56	26
BOD, 5 DAY	MG/L	1.30	0.50	0.78	24	1.65	0.60	1.01	26	1.45	0.65	1.04	26
BOD, 7 DAY	MG/L	1.50	0.65	1.01	14	1.90	0.70	1.37	14	1.95	1.00	1.28	14
BOD, 10 DAY	MG/L	1.55	0.90	1.14	14	2.85	1.15	1.75	14	2.00	1.15	1.51	14
SECCHI DISC, MORNING	FT	8.00	4.00	6.00	13	6.00	1.00	3.00	13	5.00	2.00	3.00	13
SECCHI DISC, AFTERNOON	FT	8.00	3.00	4.00	12	4.00	1.00	3.00	8	4.00	2.00	3.00	11
DISSOLVED OXYGEN, MORN-TOP	MG/L	7.00	6.30	6.68	13	7.00	5.55	6.43	13	6.50	5.05	5.74	13
DISSOLVED OXYGEN, MORN-MID	MG/L	7.00	6.30	6.69	13	7.10	5.60	6.37	13	6.40	4.95	5.77	13
DISSOLVED OXYGEN, MORN-BOTT	MG/L	6.85	1.05	6.23	13	7.20	5.50	6.32	13	6.30	5.10	5.81	13
DISSOLVED OXYGEN, AFTR-TOP	MG/L	7.00	6.20	6.64	12	7.30	5.20	6.29	8	7.00	5.00	6.00	11
DISSOLVED OXYGEN, AFTR-MID	MG/L	6.90	6.30	6.59	12	7.00	5.20	6.37	8	6.75	4.90	5.90	11
DISSOLVED OXYGEN, AFTR-BOTT	MG/L	7.80	6.20	6.71	12	7.15	4.80	6.29	8	6.80	4.90	5.92	11
ORGANIC NITROGEN	MG/L	1.8	0	0.4	13	2.9	0	0.7	12	0.9	0	0.4	13

Figure 2

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
APRIL 6,-MAY 3, 1970
STATION 1

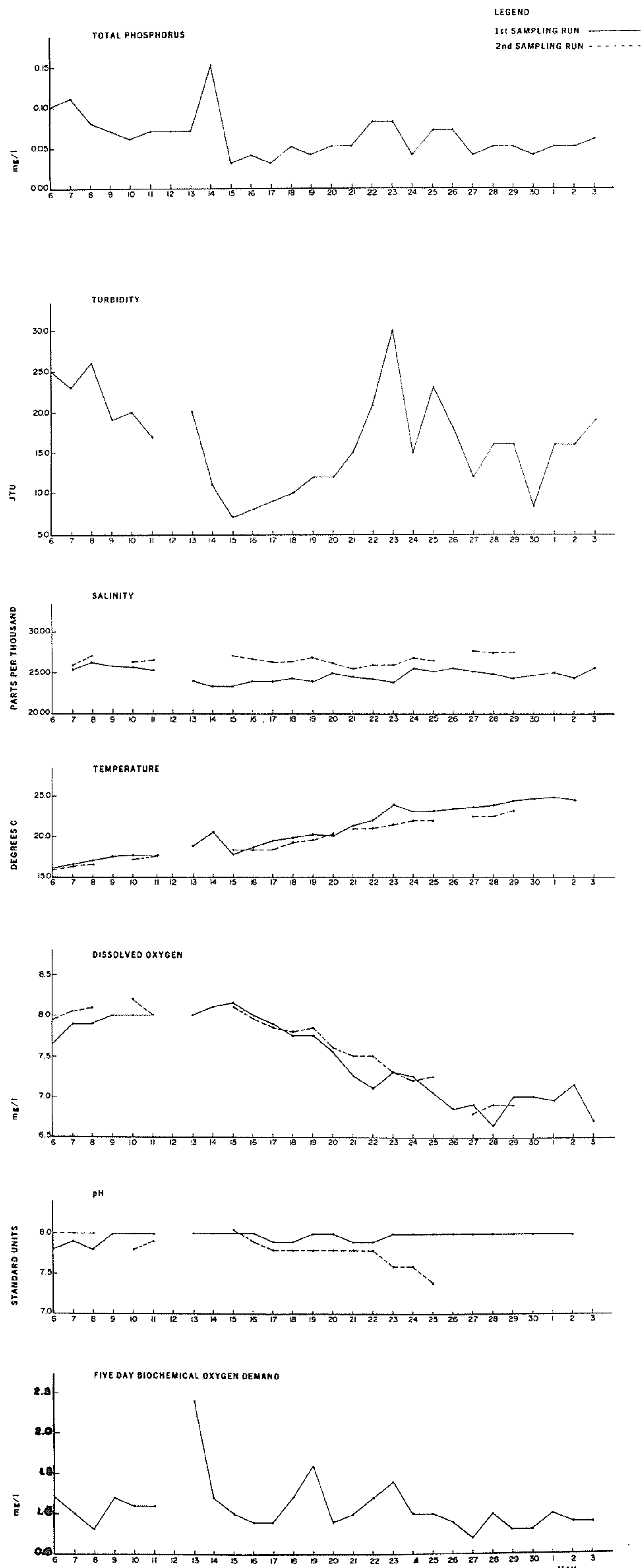


Figure 2

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
APRIL 6,-MAY 3, 1970

STATION 2

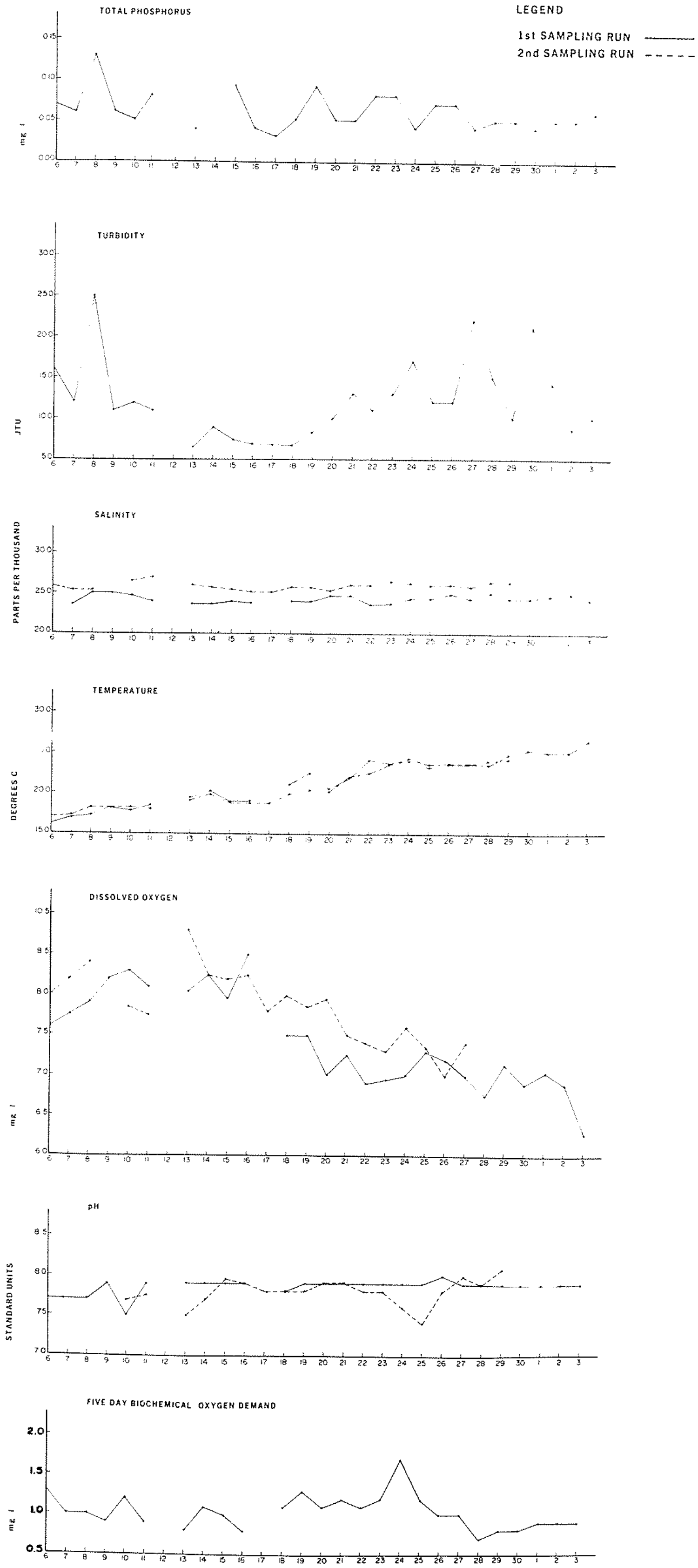


Figure 2

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
APRIL 6,-MAY 3, 1970

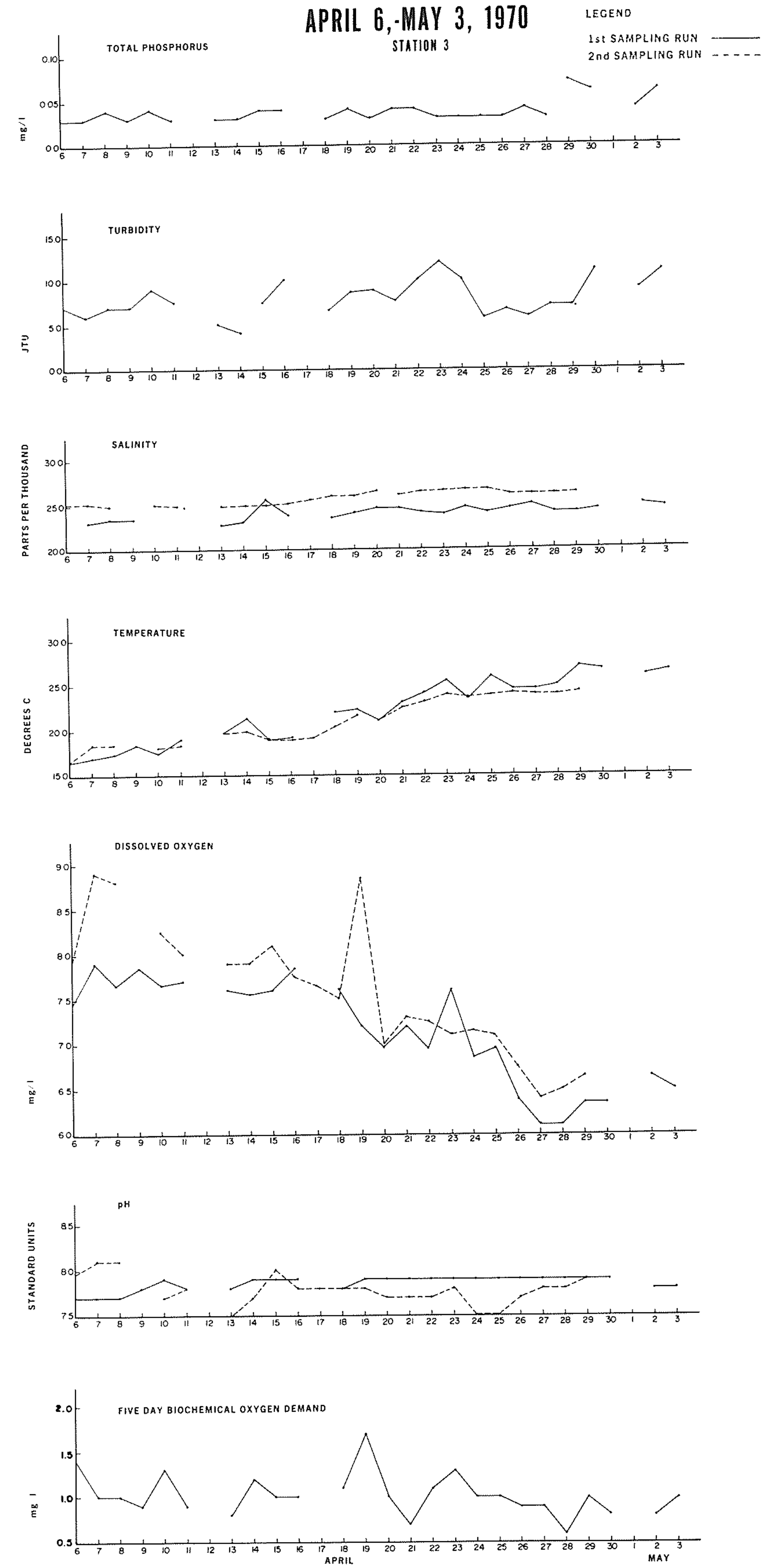


Figure 2

PORT ROYAL SOUND ENVIRONMENTAL STUDY SELECTED CHEMICAL CONSTITUENTS APRIL 6,-MAY 3, 1970

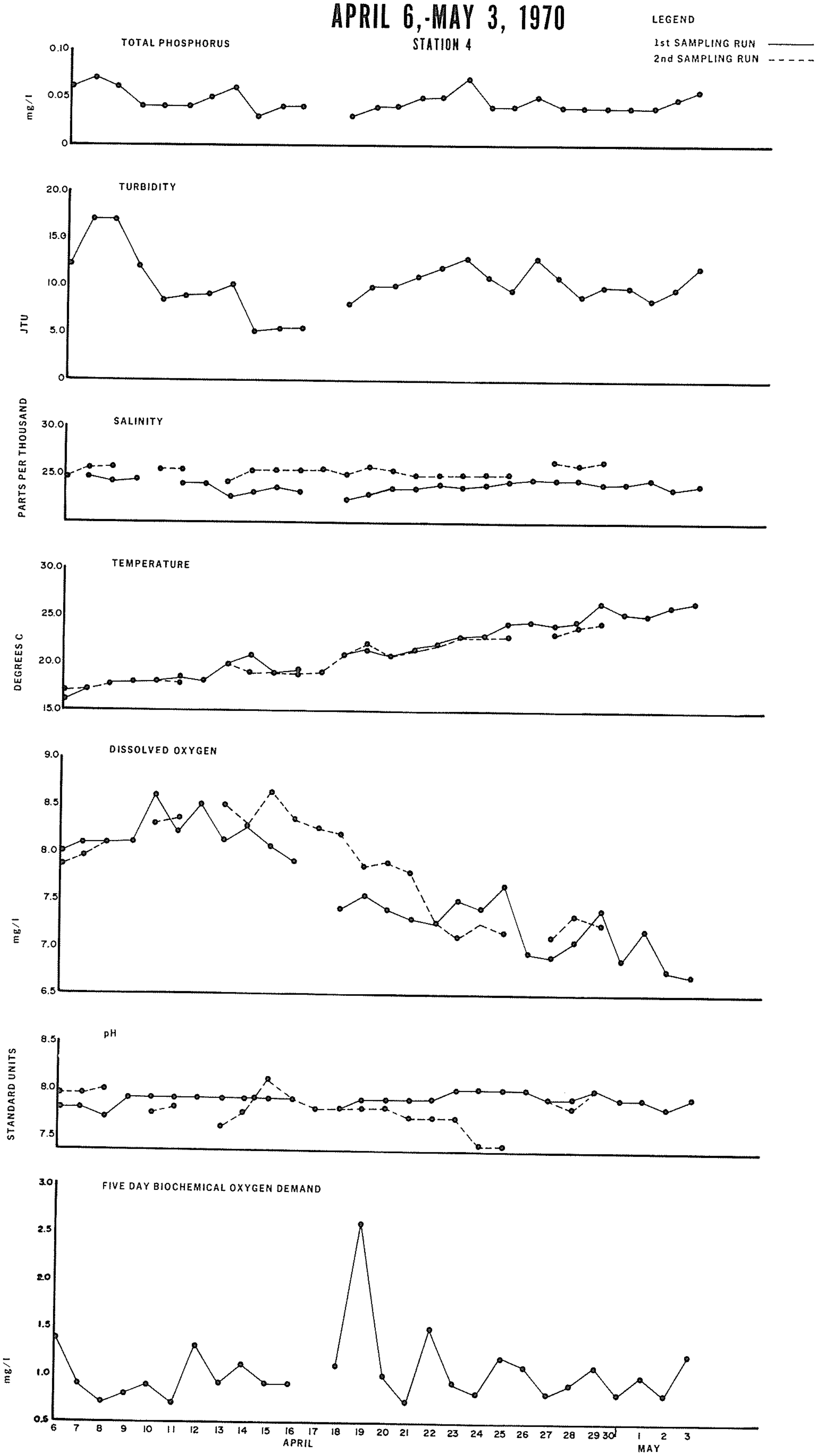


Figure 2

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
APRIL 6,- MAY 3, 1970

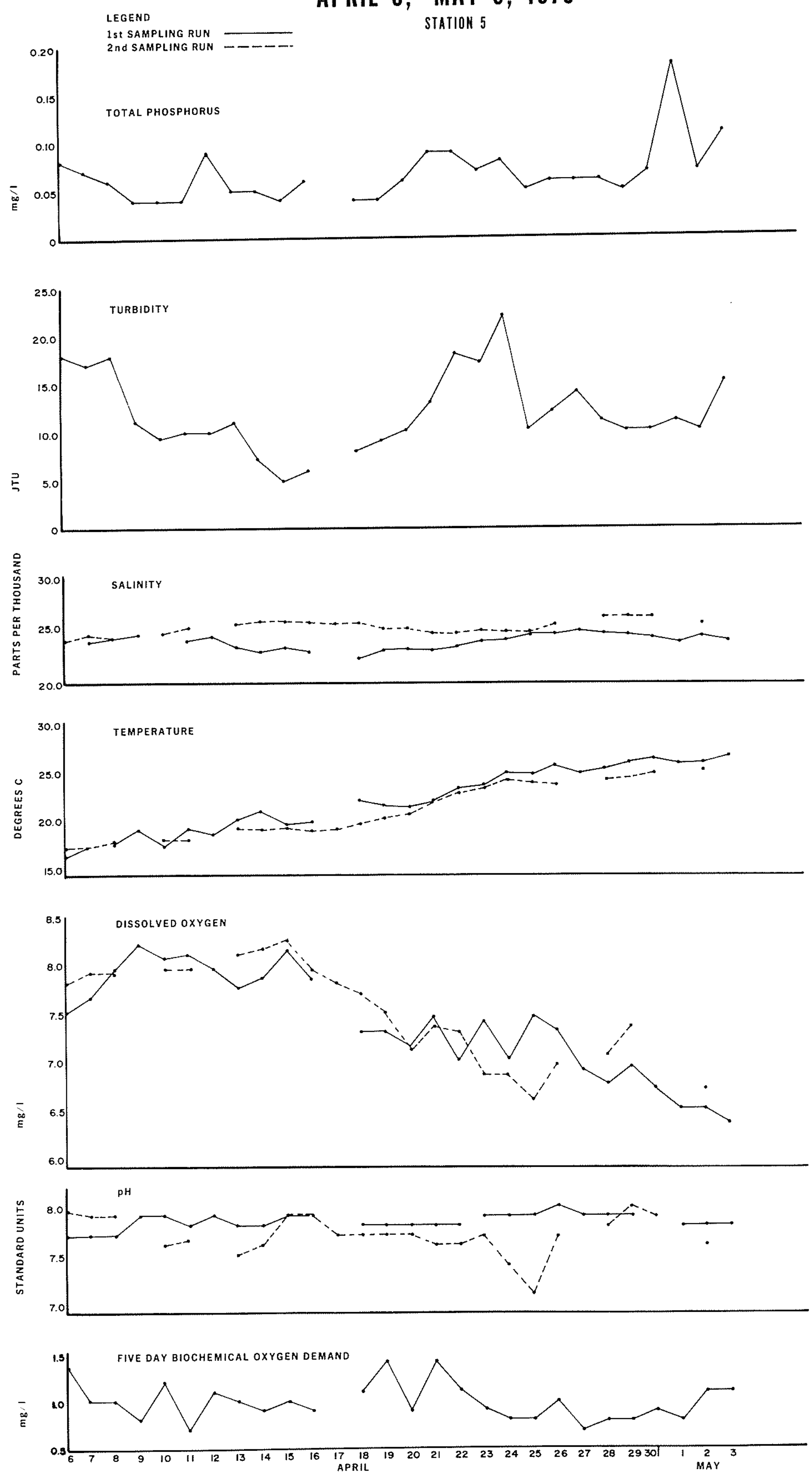


Figure 2

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
APRIL 6,- MAY 3, 1970
STATION 6

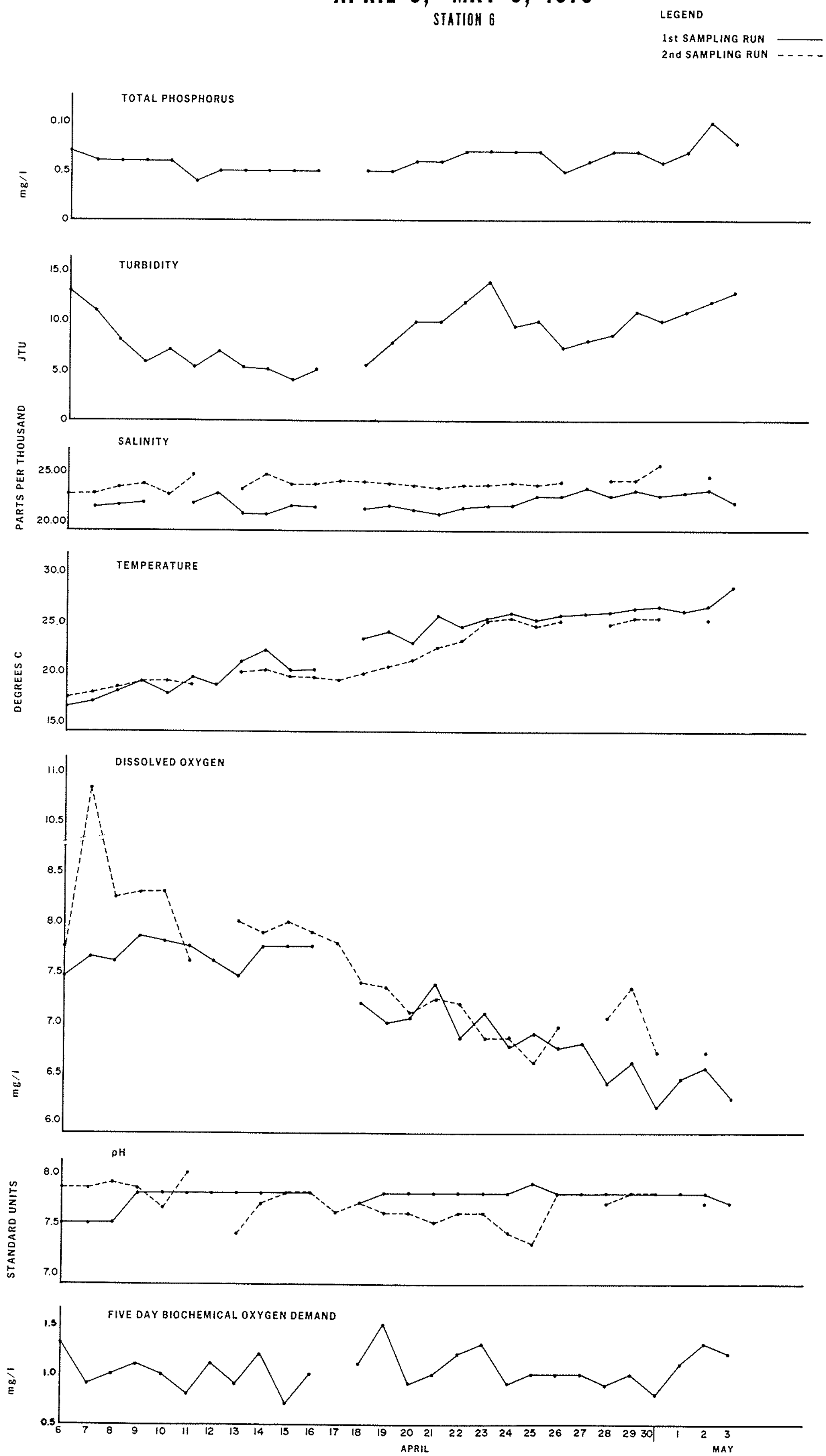


Figure 2

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
APRIL 6,-MAY 3, 1970

STATION 7

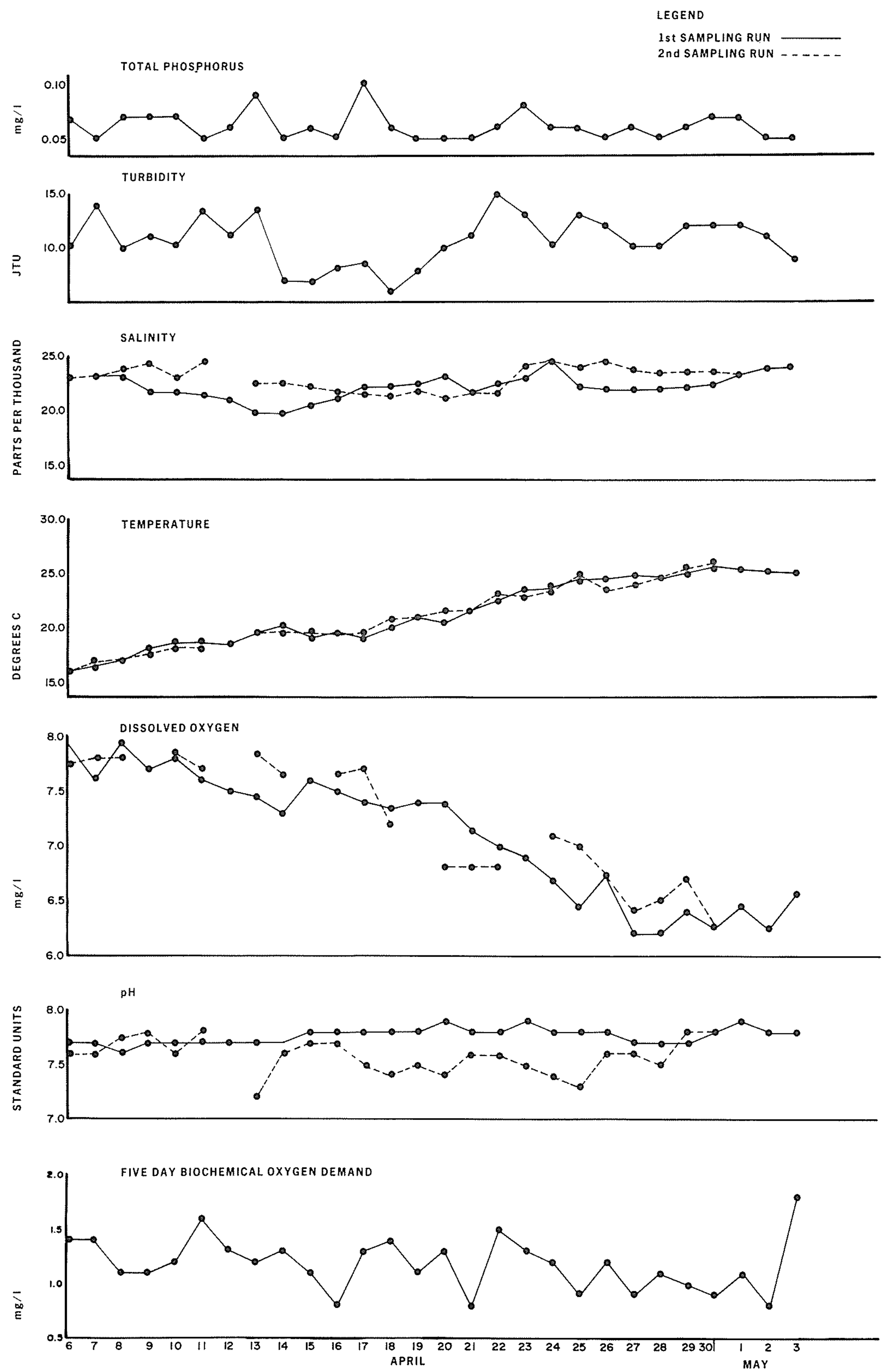


Figure 2

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
APRIL 6,-MAY 3, 1970

STATION 8

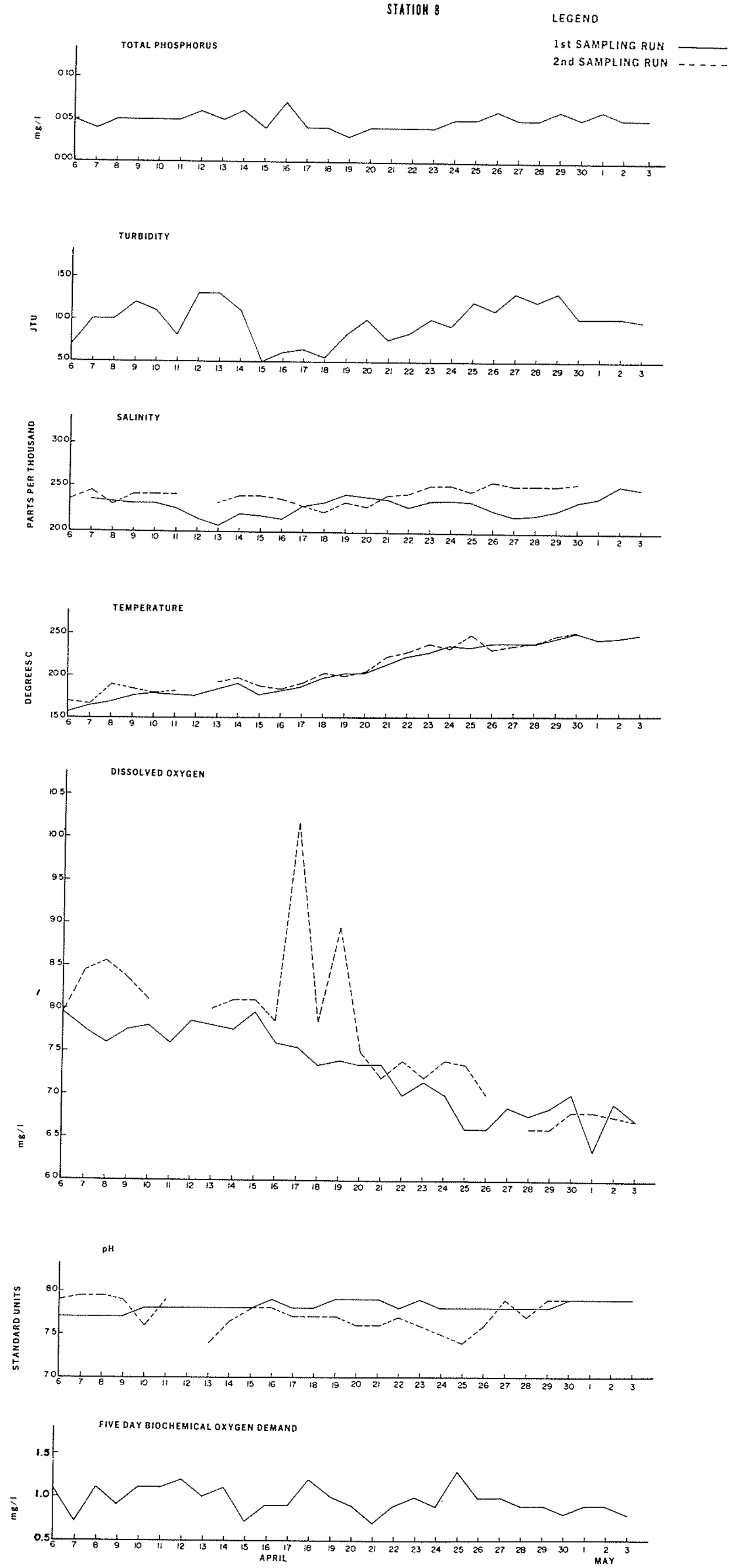


Figure 2

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
APRIL 3,- MAY 3, 1970
STATION 9

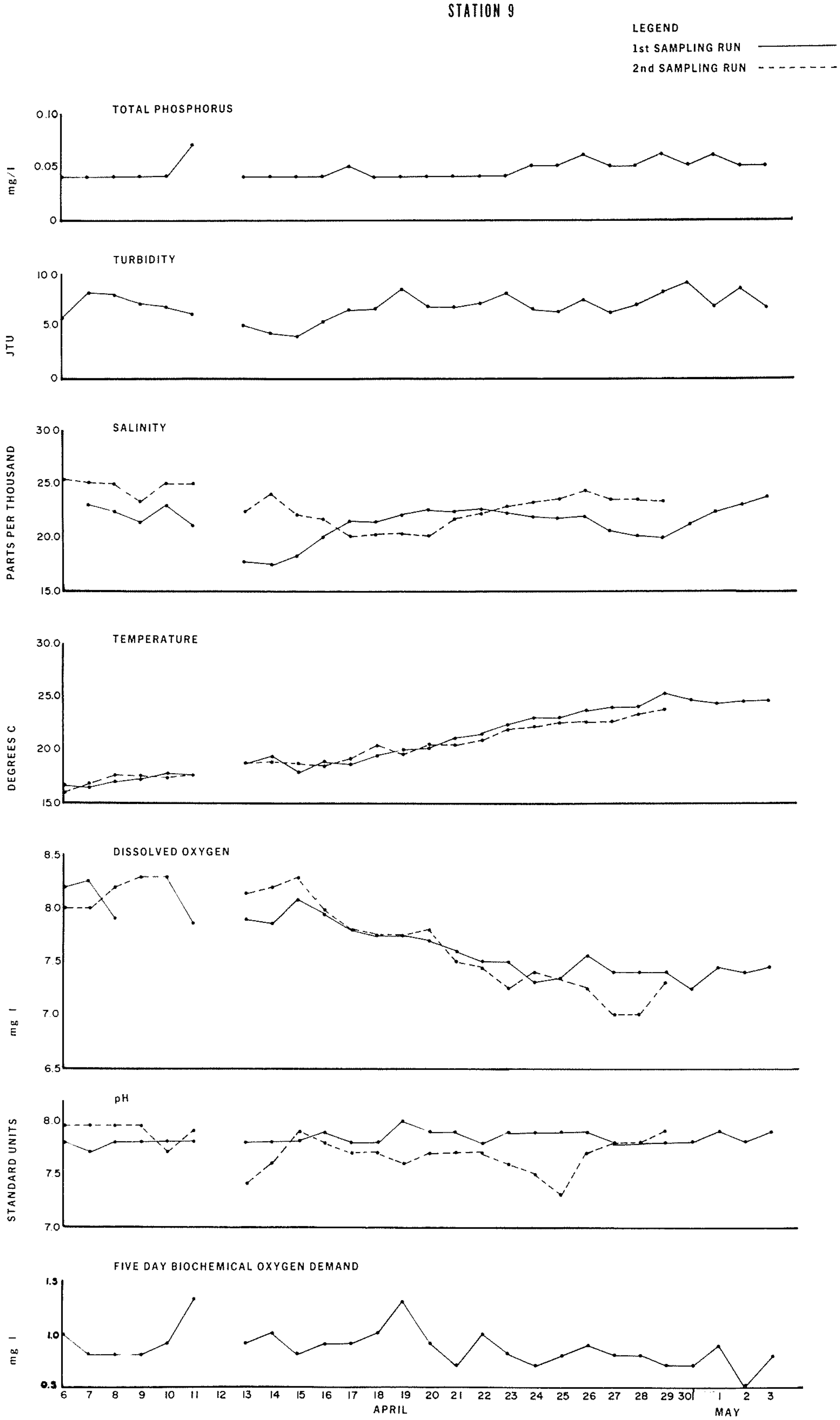


Figure 2

PORT ROYAL SOUND ENVIRONMENTAL STUDY SELECTED CHEMICAL CONSTITUENTS APRIL 6- MAY 3, 1970

STATION 10

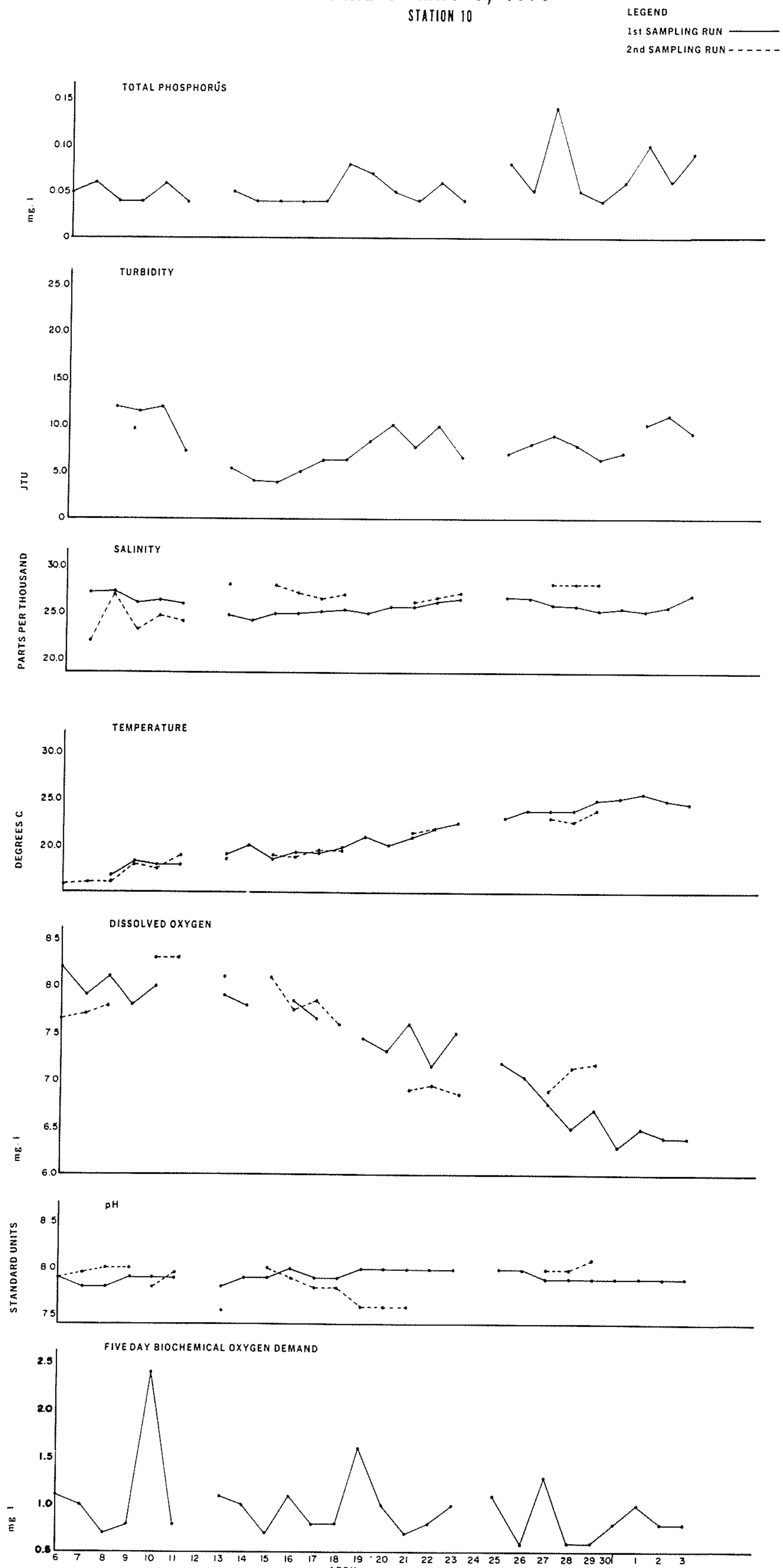


Figure 3

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
JULY 1970

STATION 1

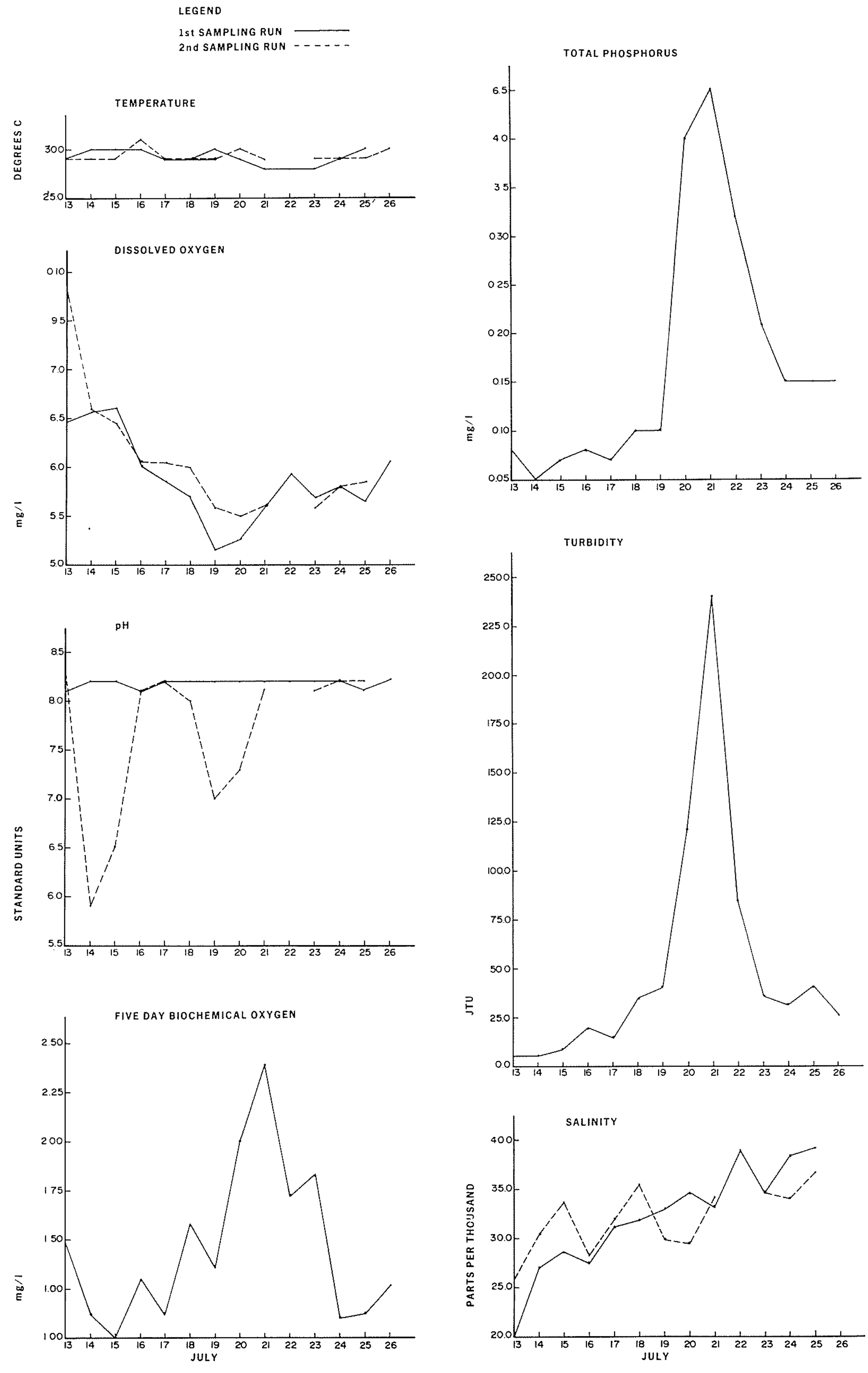


Figure 3

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
JULY 1970

STATION 2

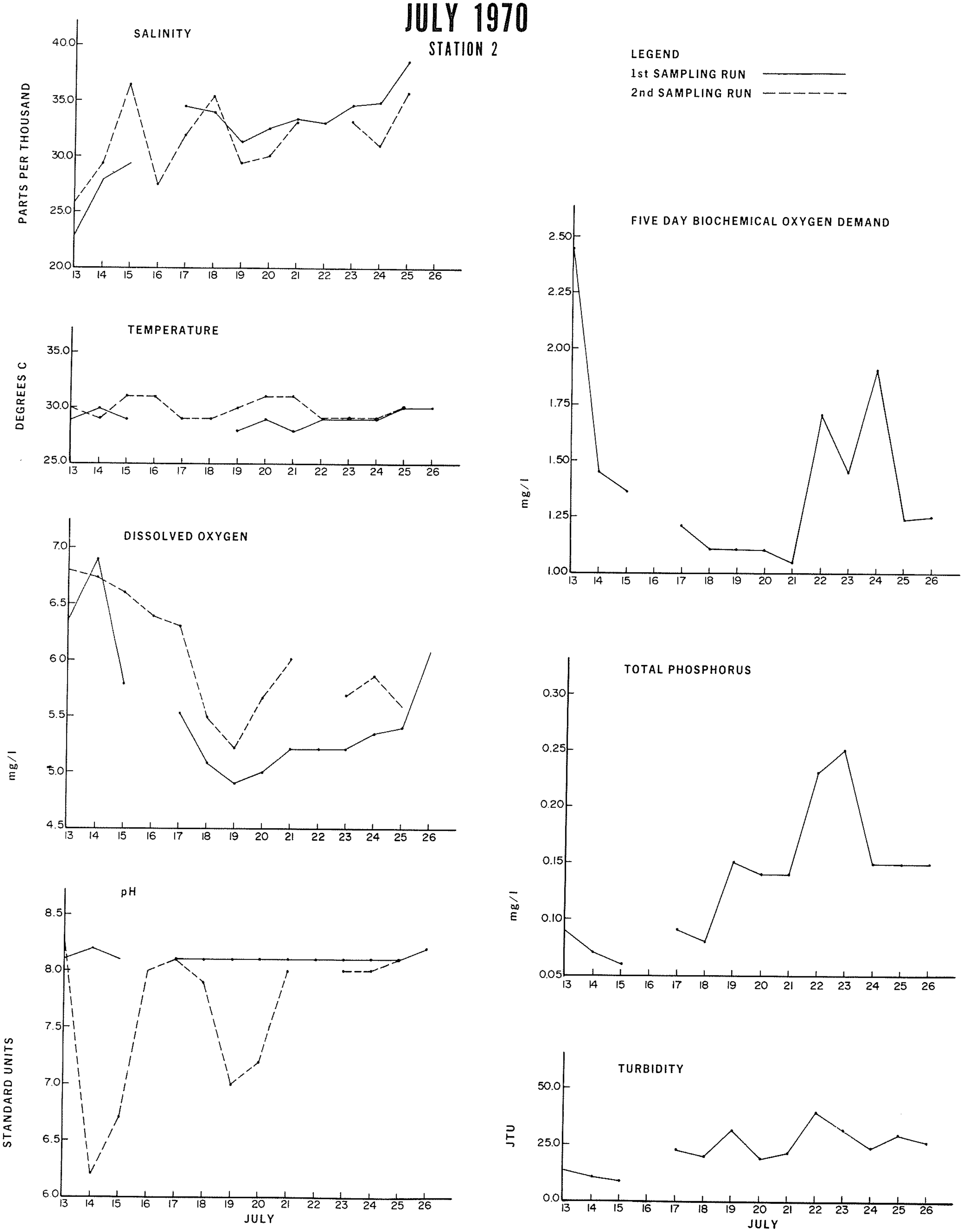


Figure 3

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
JULY 1970
STATION 4

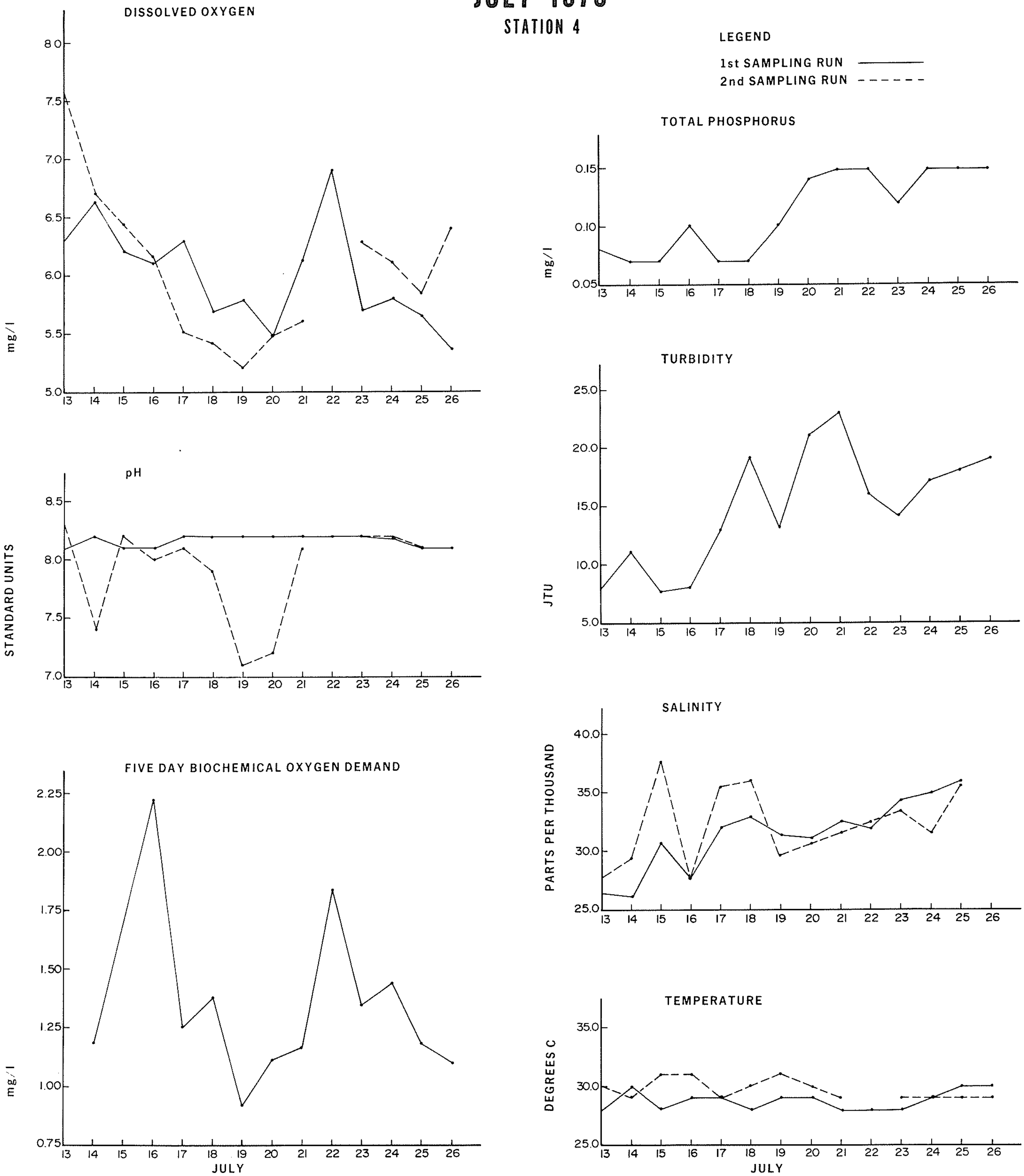


Figure 3

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
JULY 1970
STATION 5

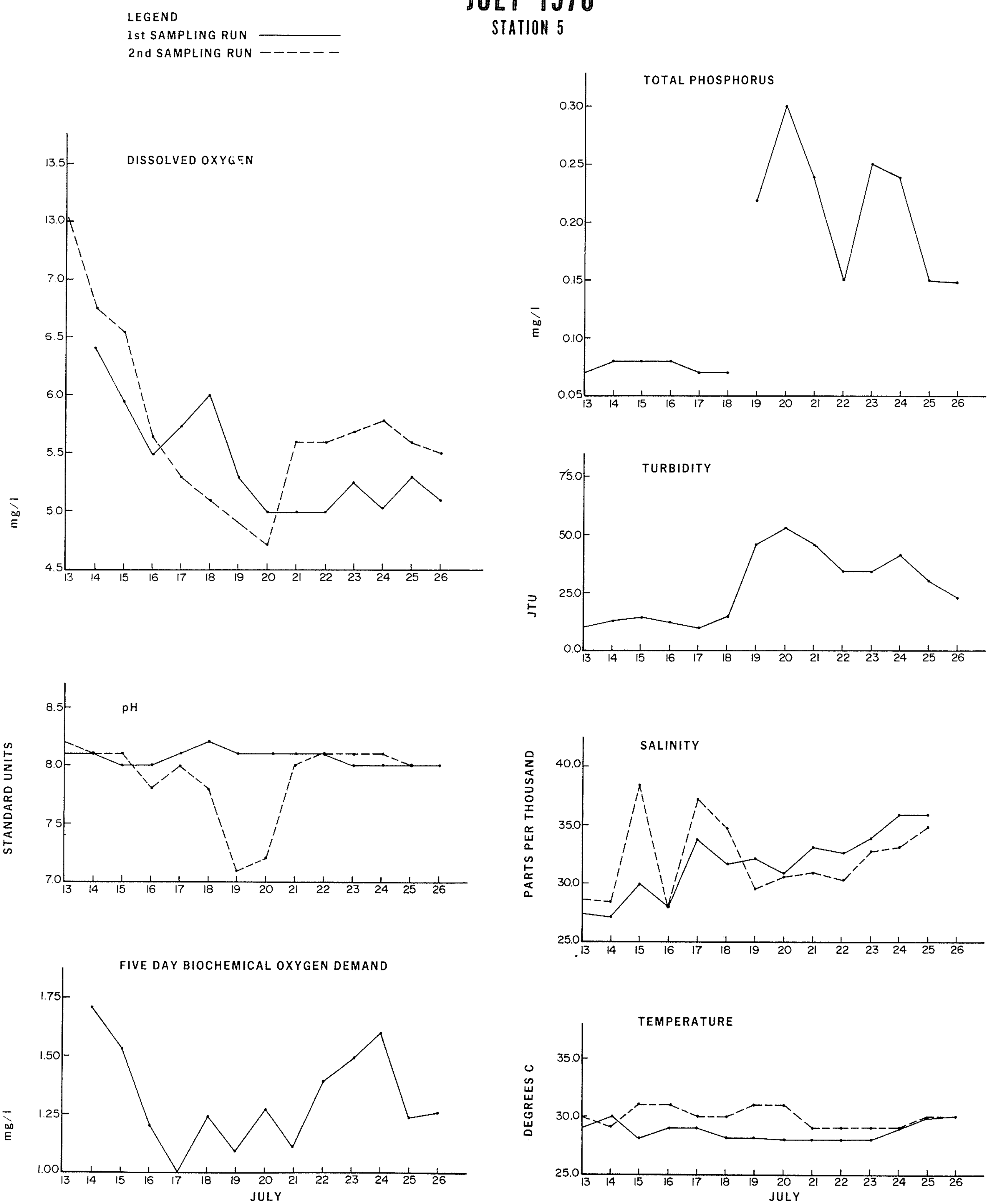


Figure 3

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
JULY 1970

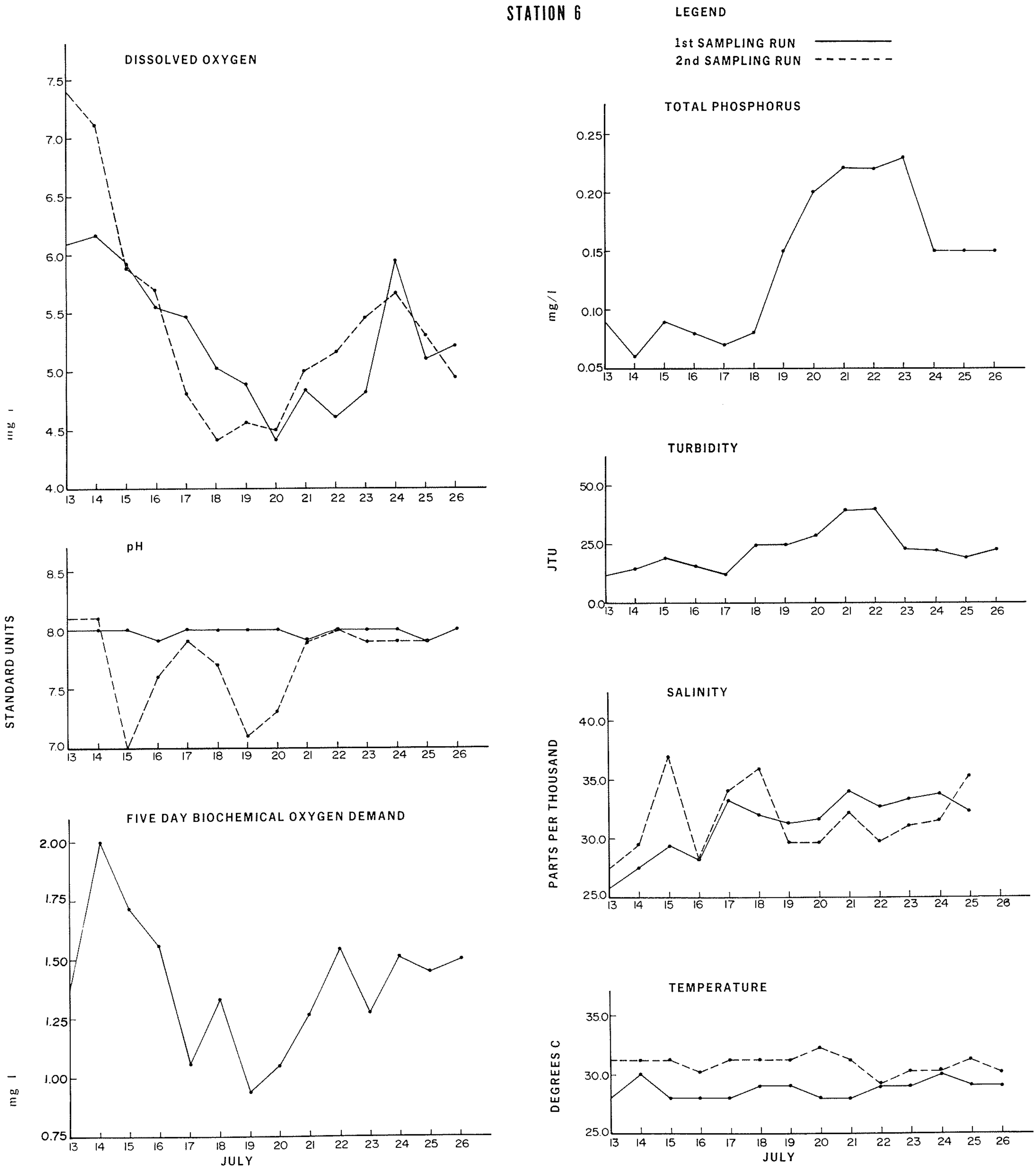


Figure 3

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
JULY 1971

STATION 7

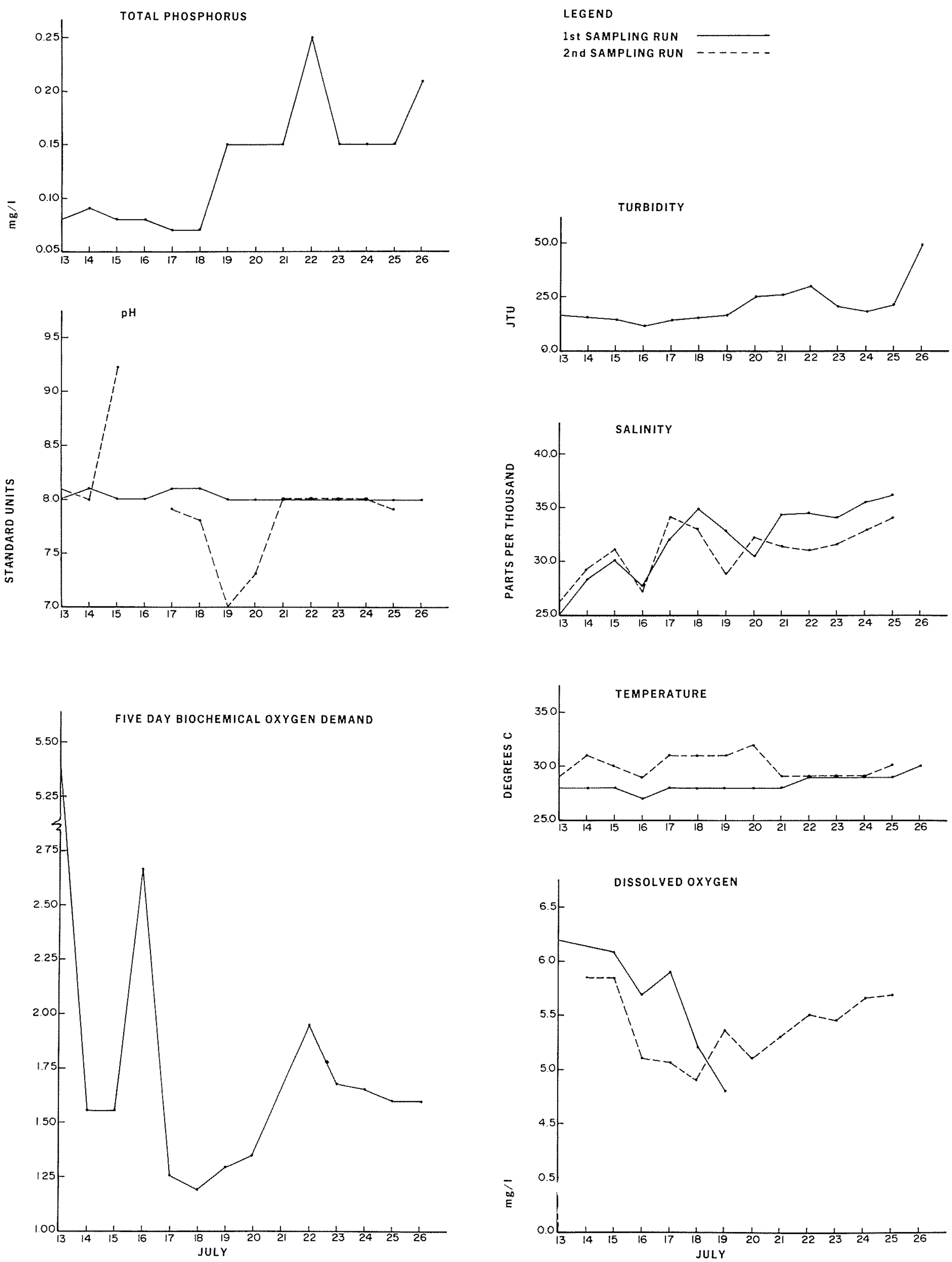


Figure 3

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
JULY 1970
STATION 8

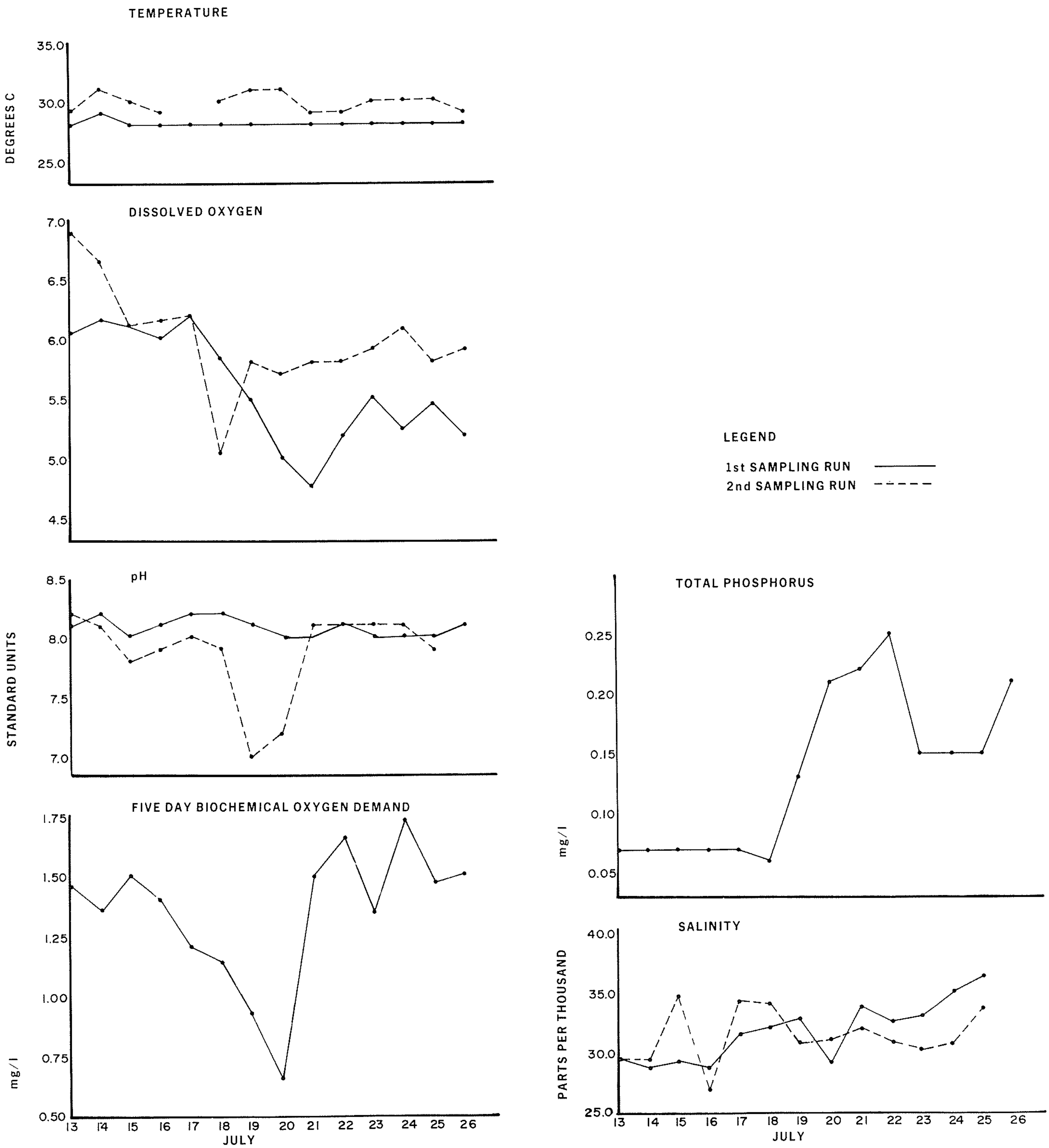


Figure 3

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
JULY 1970

STATION 9

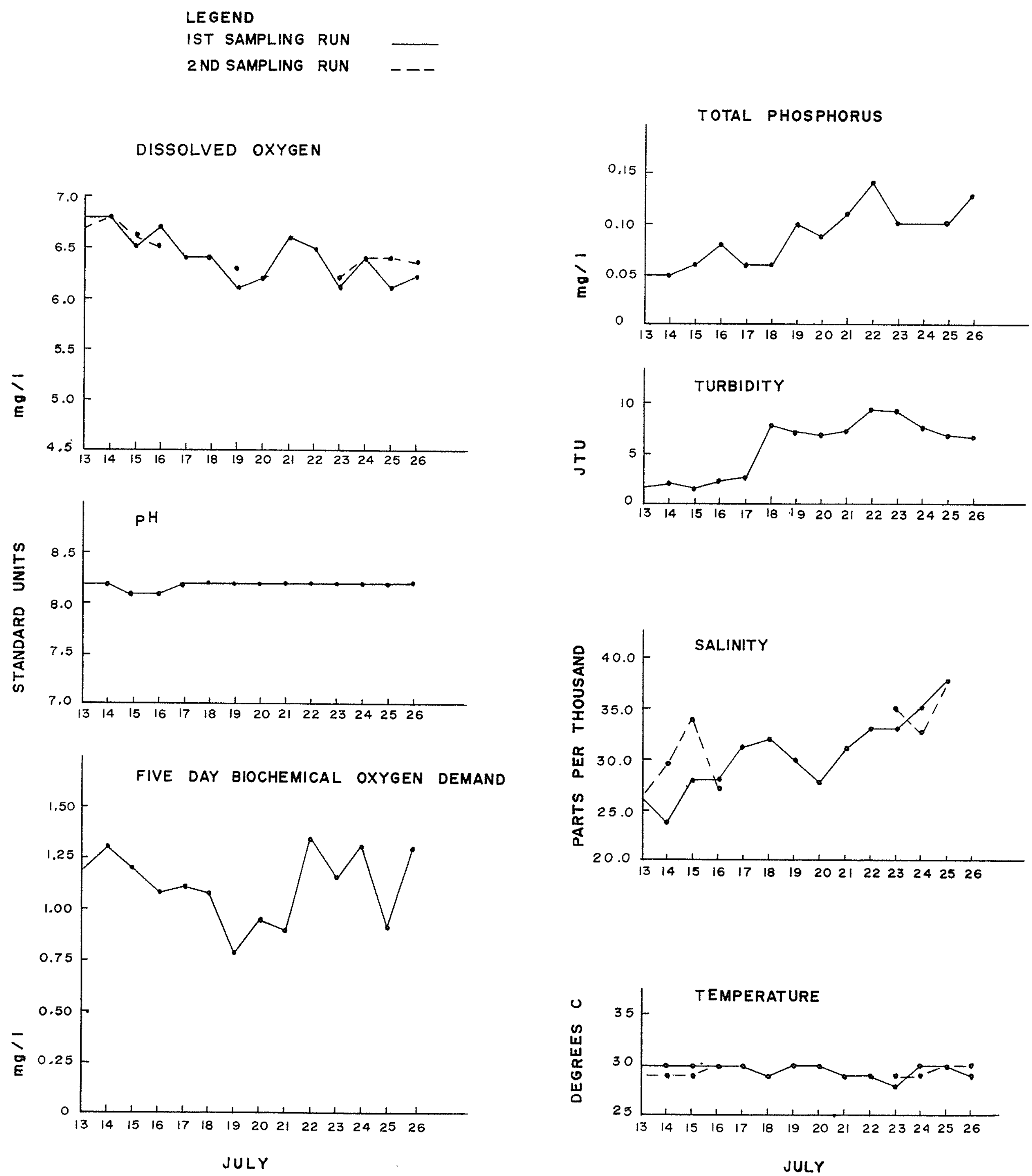


Figure 3
PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
JULY 1970
STATION 10

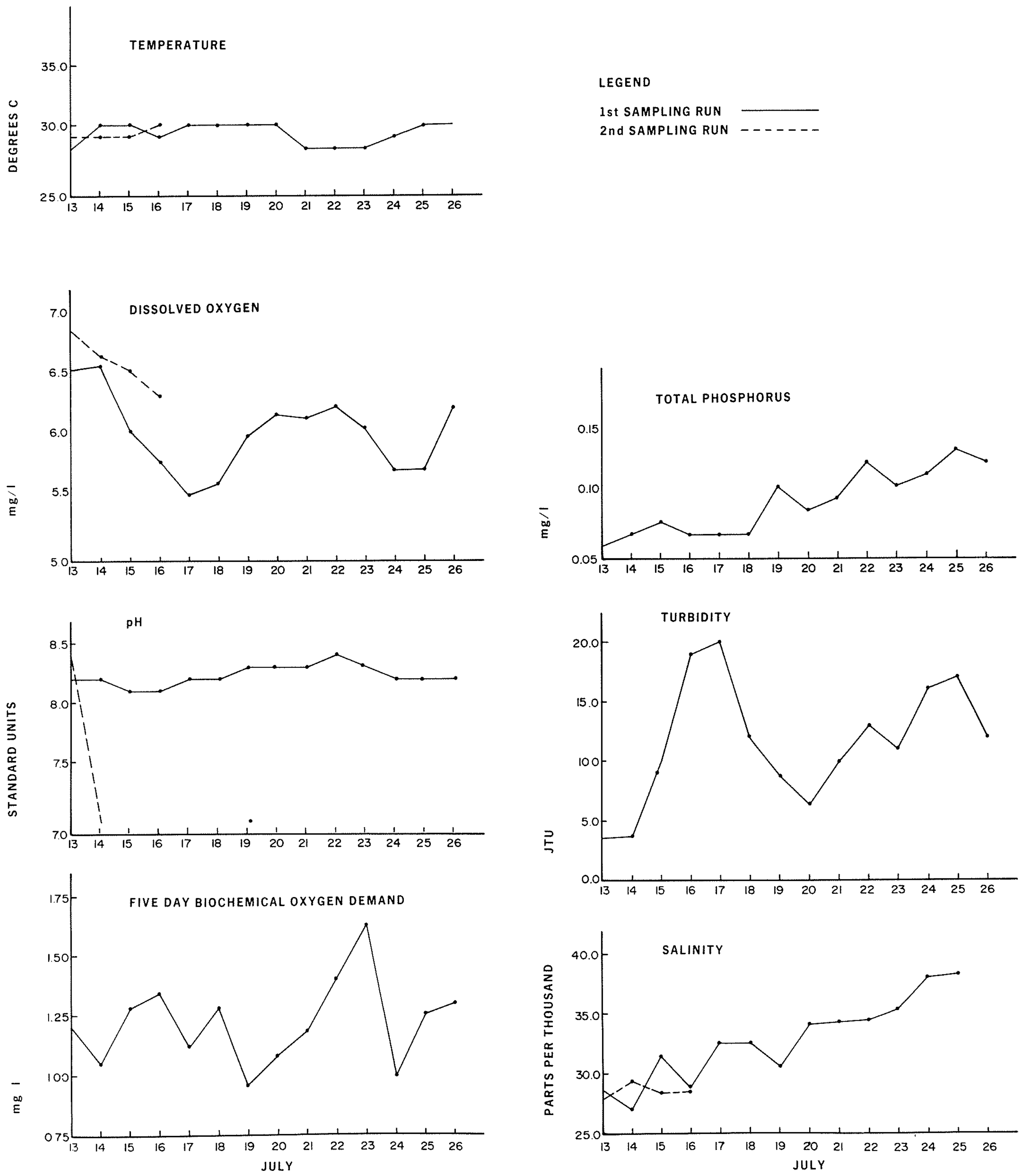


Figure 3

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
JULY 1970

STATION 11

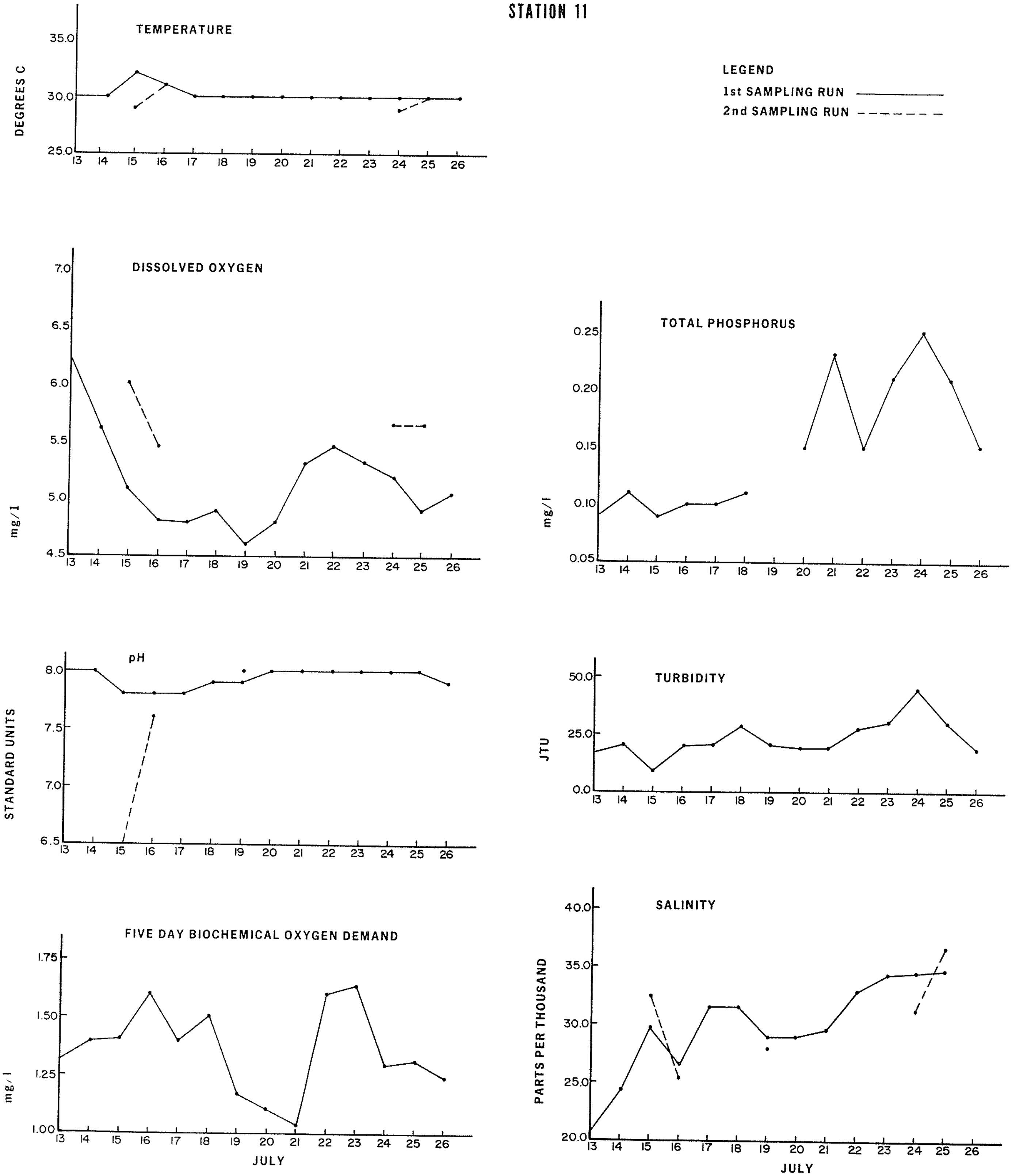


Figure 4

PORT ROYAL SOUND ENVIRONMENTAL STUDY SELECTED CHEMICAL CONSTITUENTS OCTOBER 1970

STATION 1

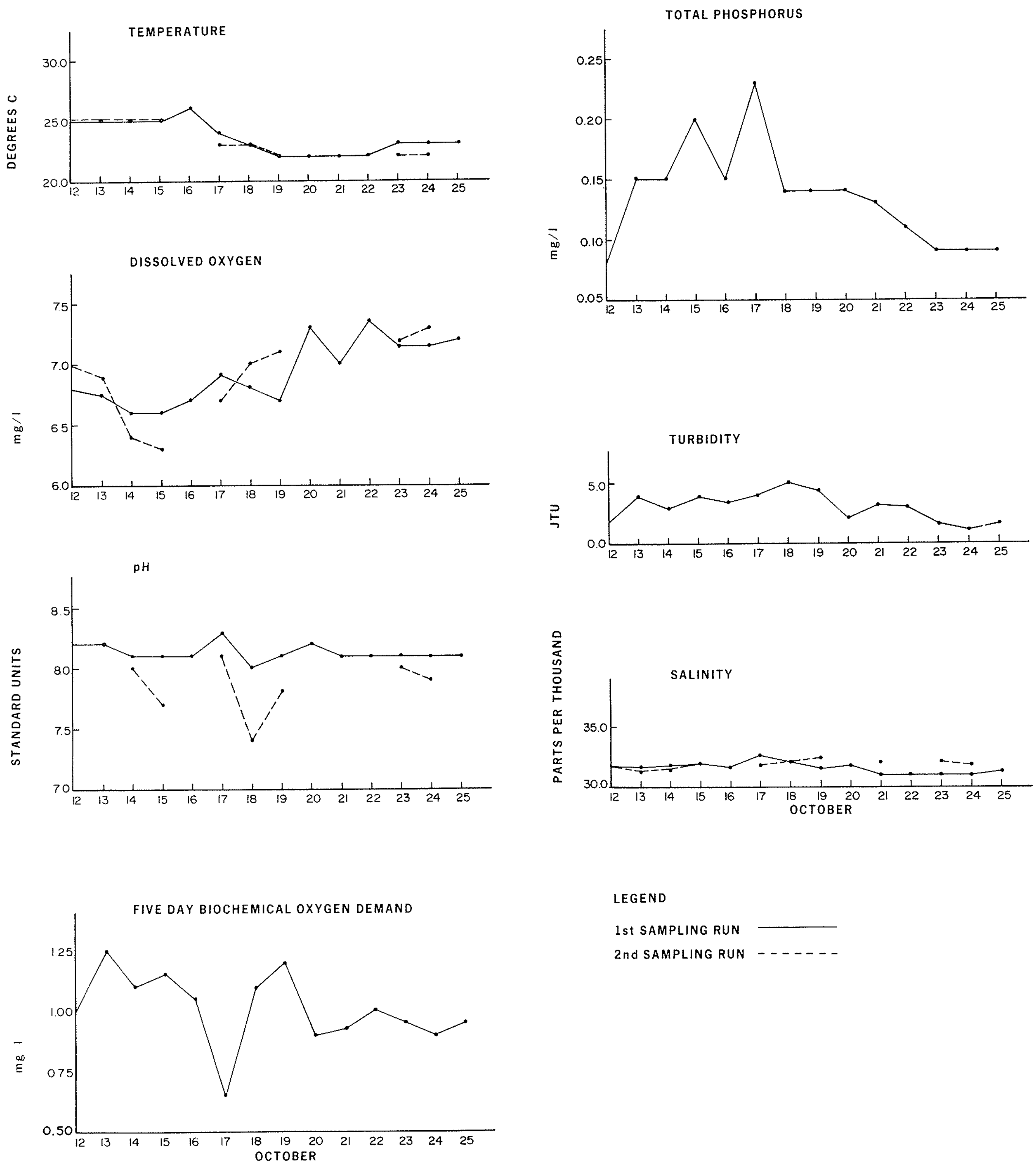


Figure 4

PORT ROYAL SOUND ENVIRONMENTAL STUDY SELECTED CHEMICAL CONSTITUENTS OCTOBER 1970

STATION 2

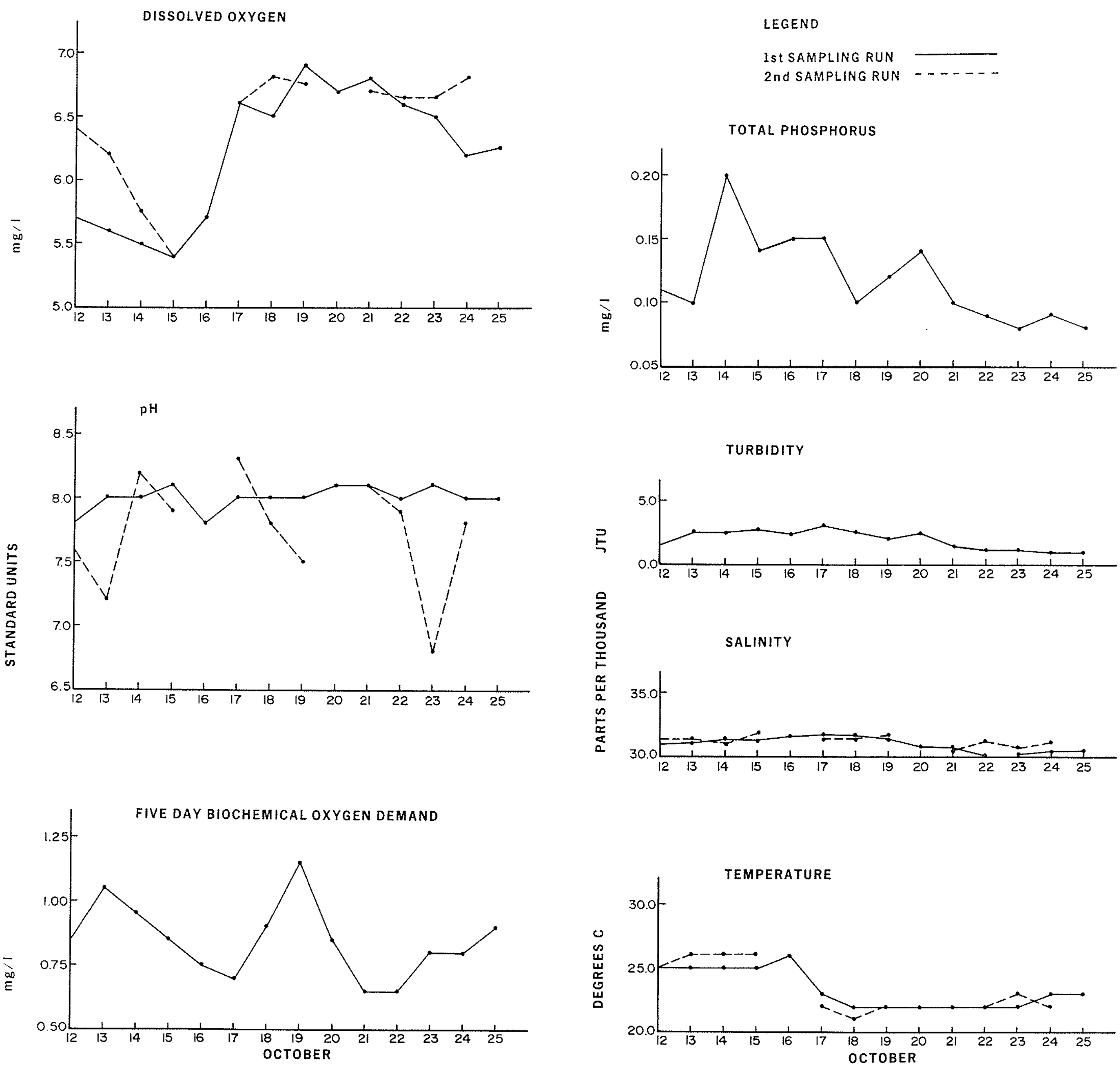


Figure 4

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
OCTOBER 1970

STATION 4

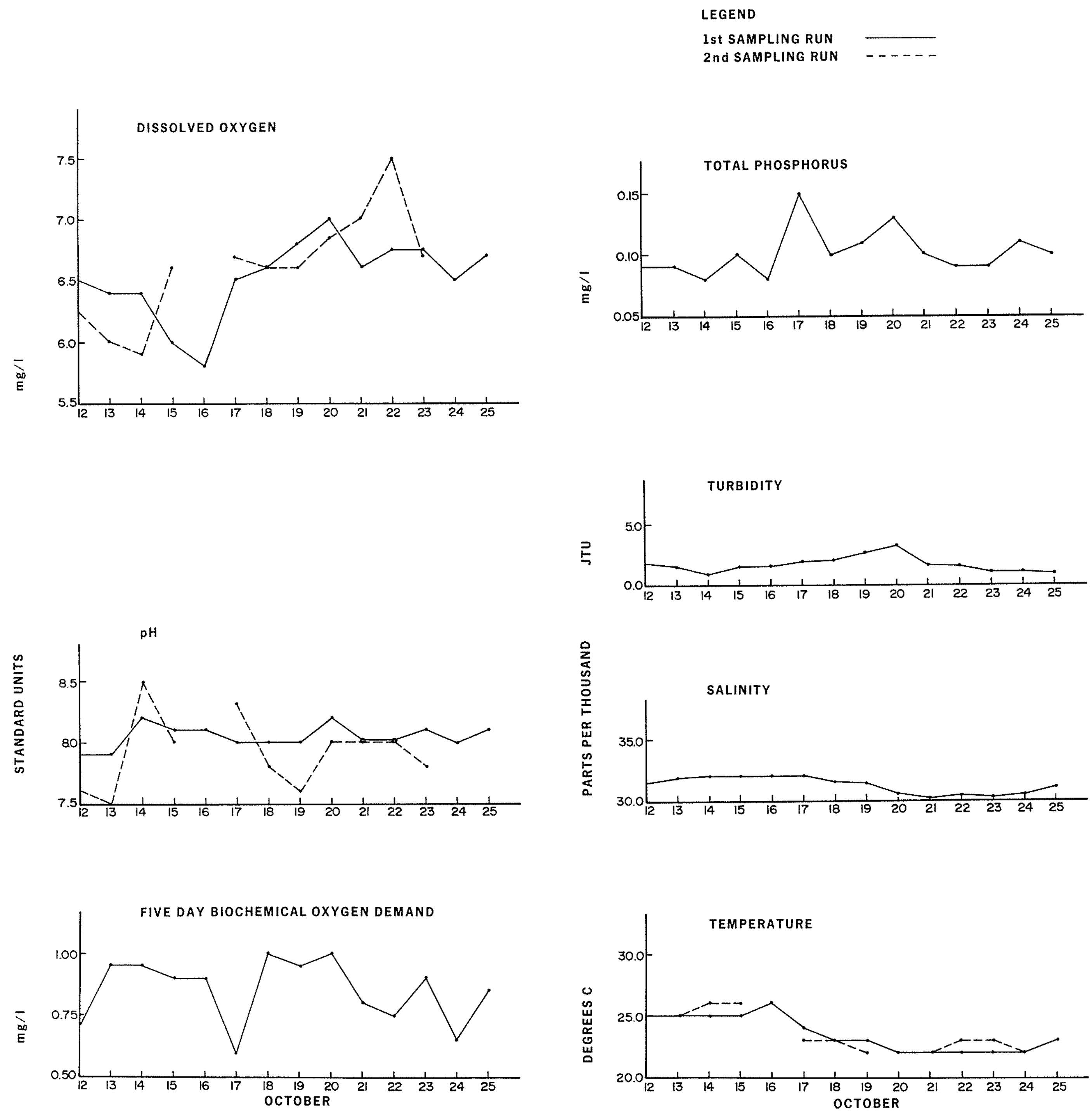


Figure 4

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
OCTOBER 1970
STATION 5

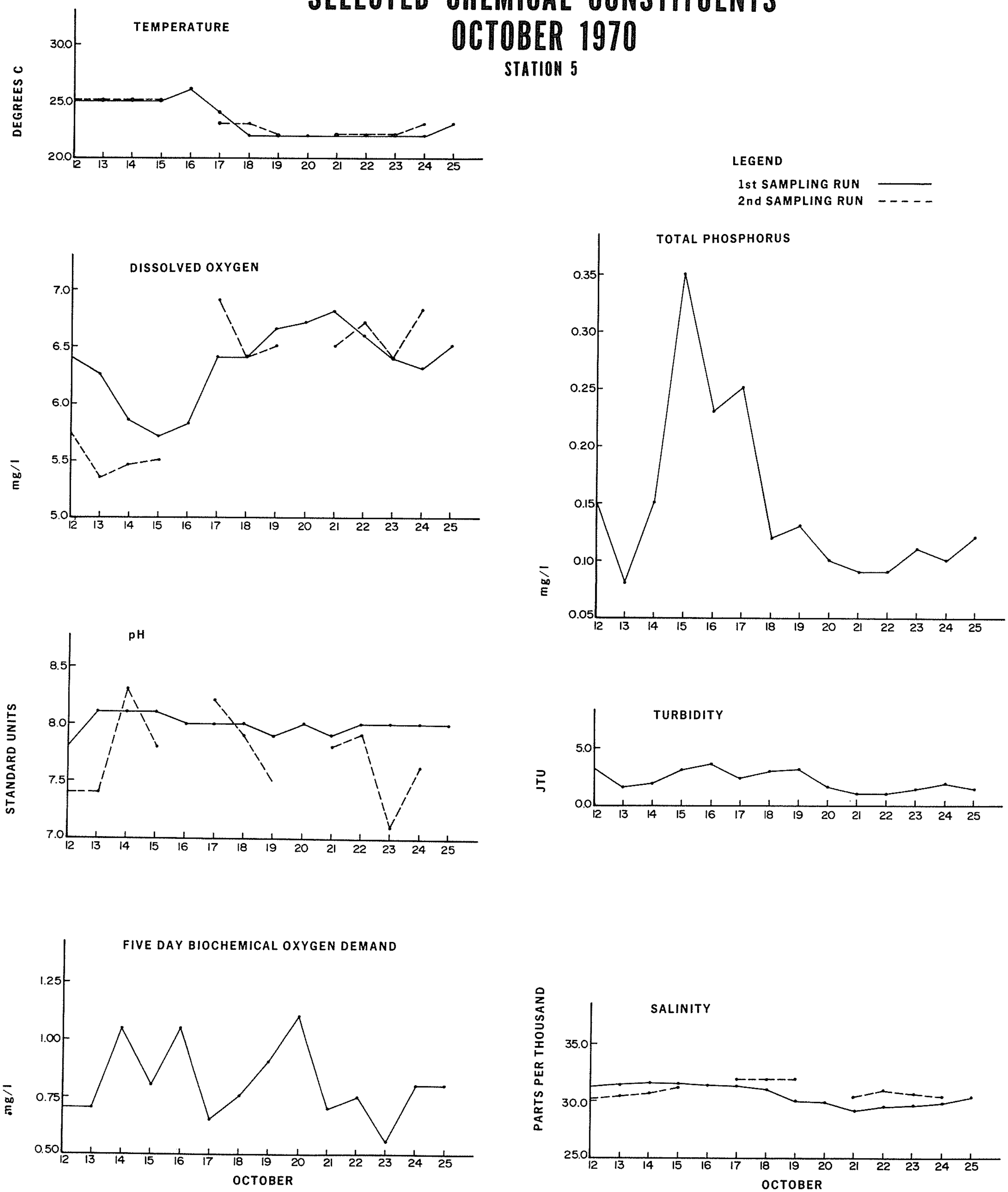


Figure 4

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
OCTOBER 1970
STATION 6

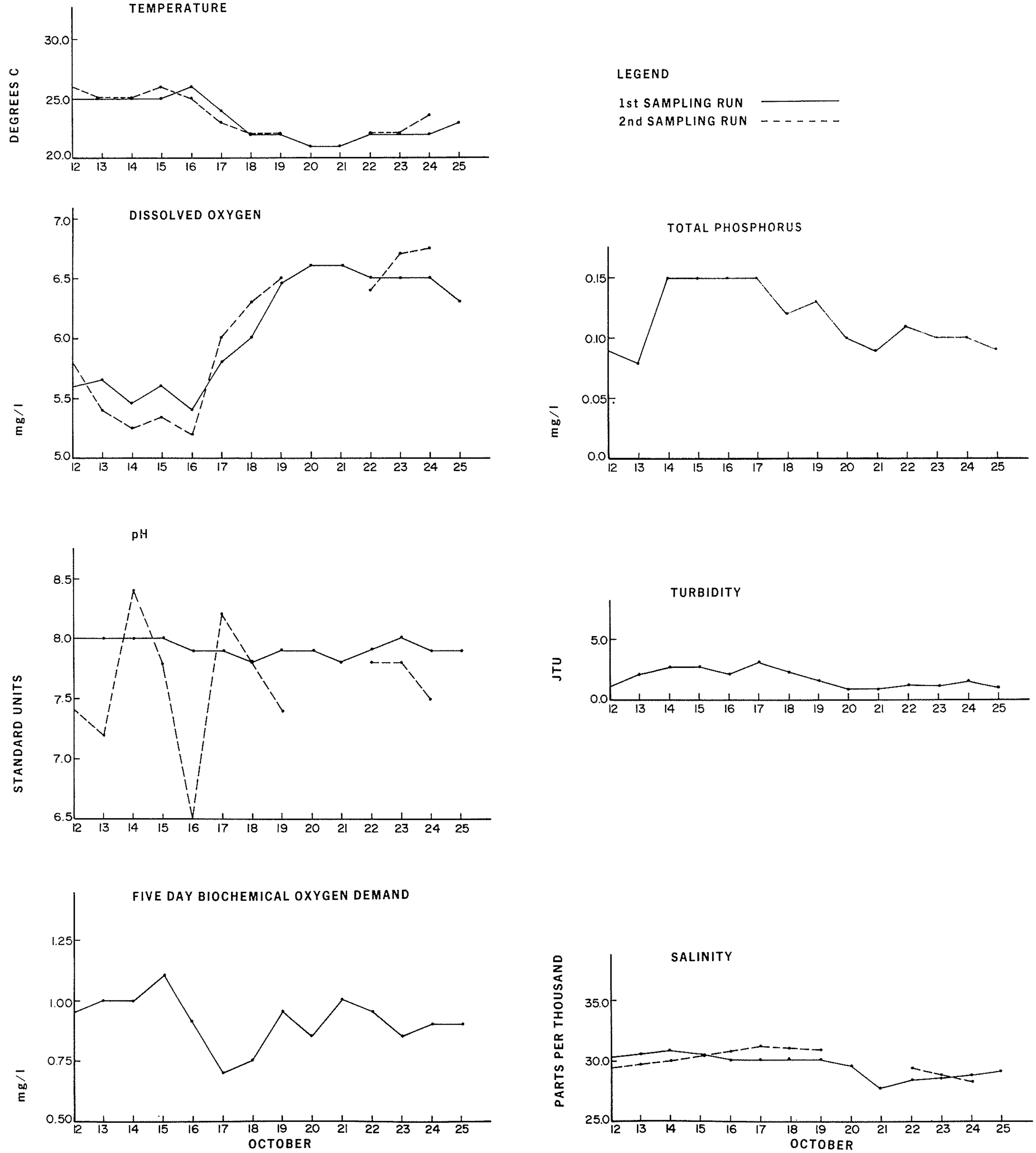


Figure 4

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
OCTOBER 1970
STATION 7

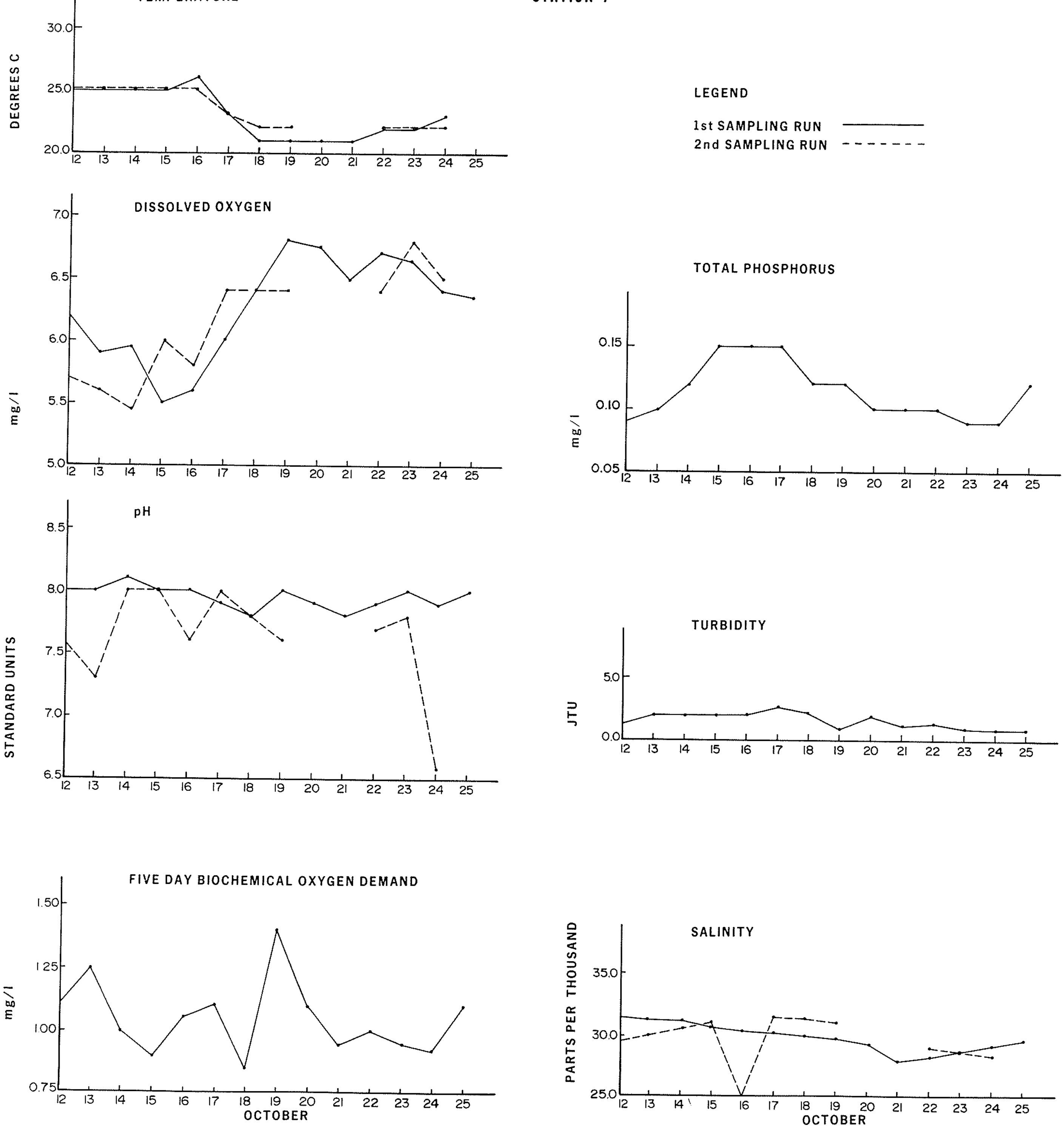


Figure 4

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
OCTOBER 1970

STATION 8

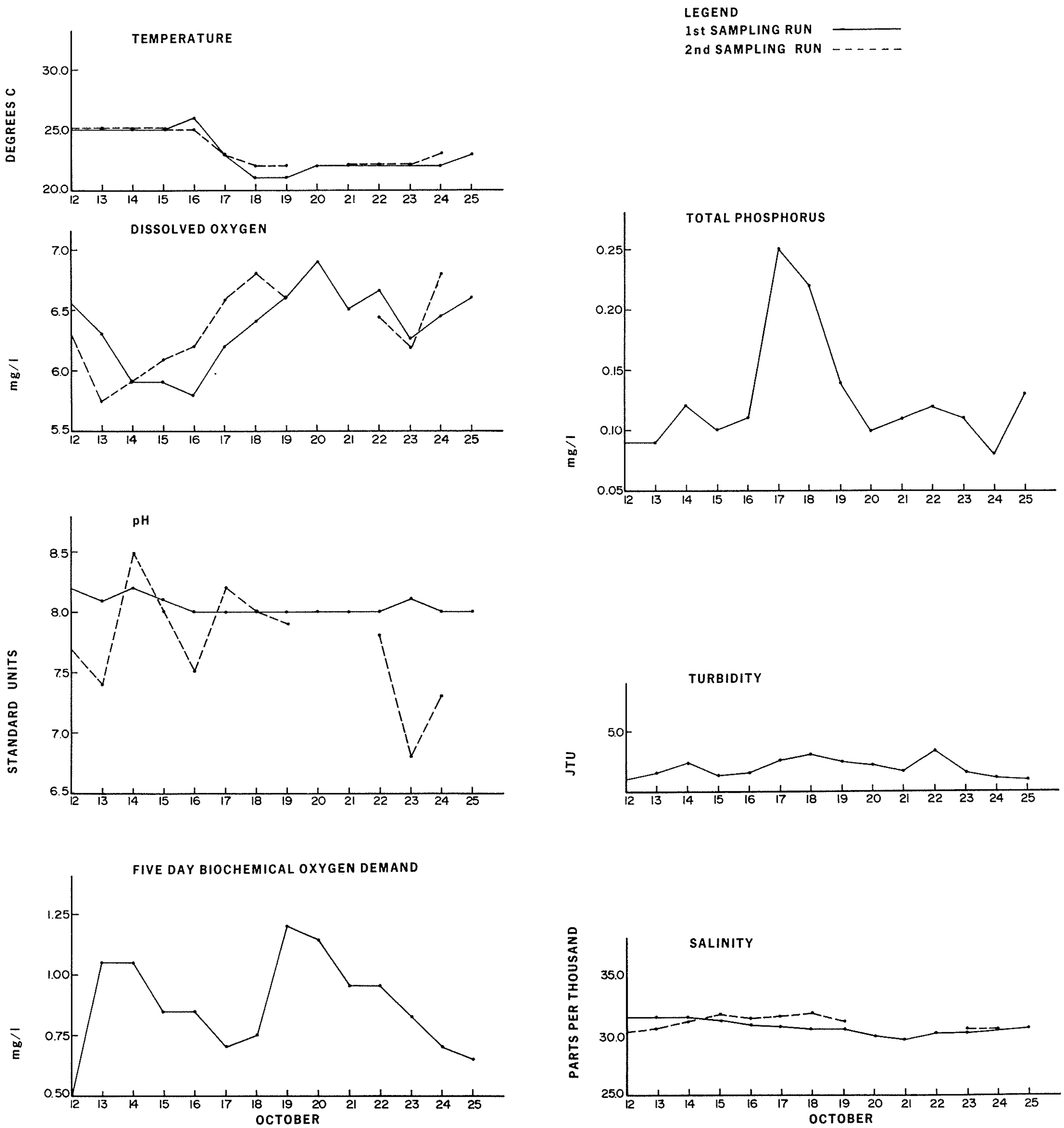


Figure 4

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
OCTOBER 1970

STATION 9

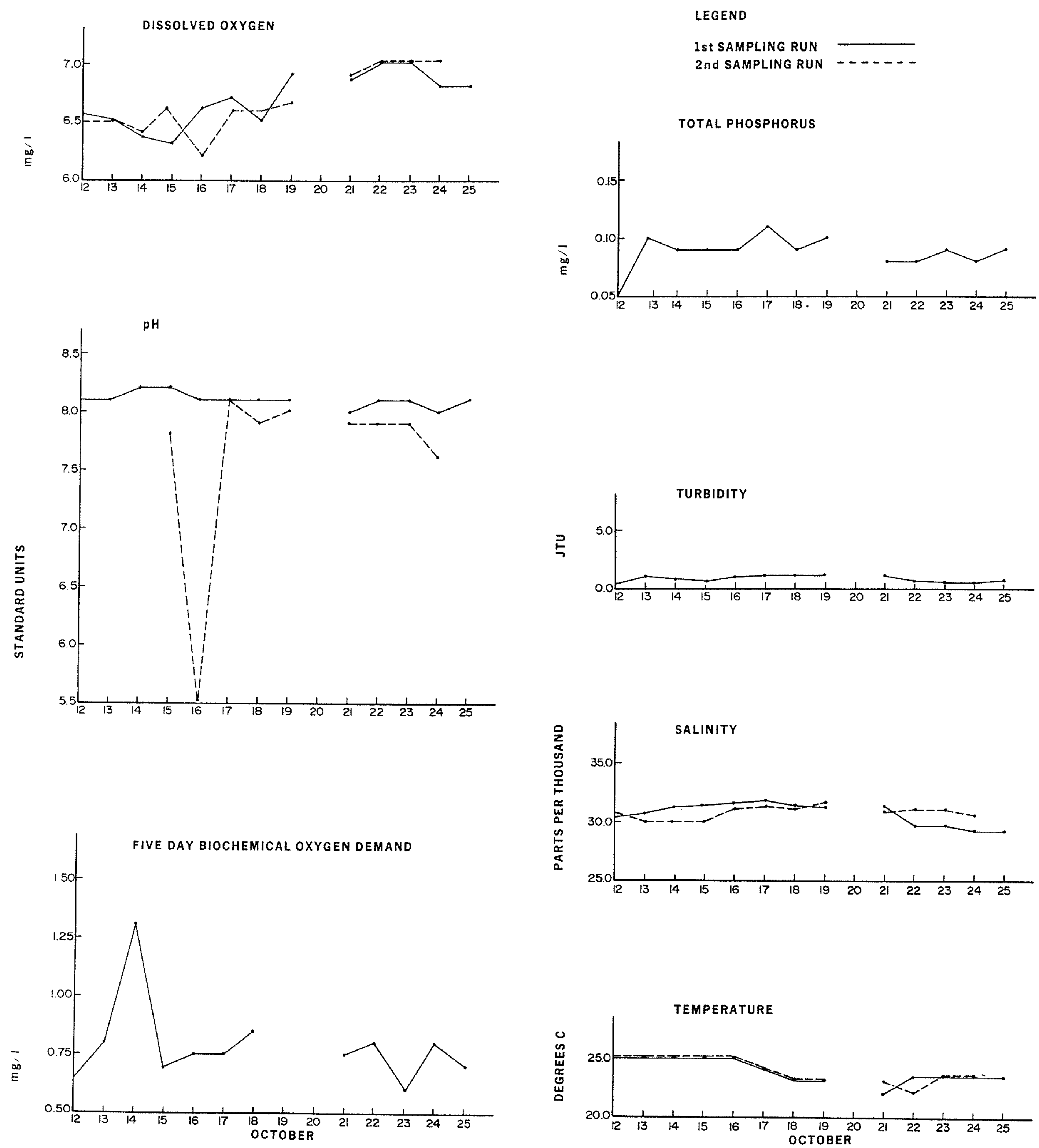


Figure 4

PORT ROYAL SOUND ENVIRONMENTAL STUDY SELECTED CHEMICAL CONSTITUENTS OCTOBER 1970

STATION 10

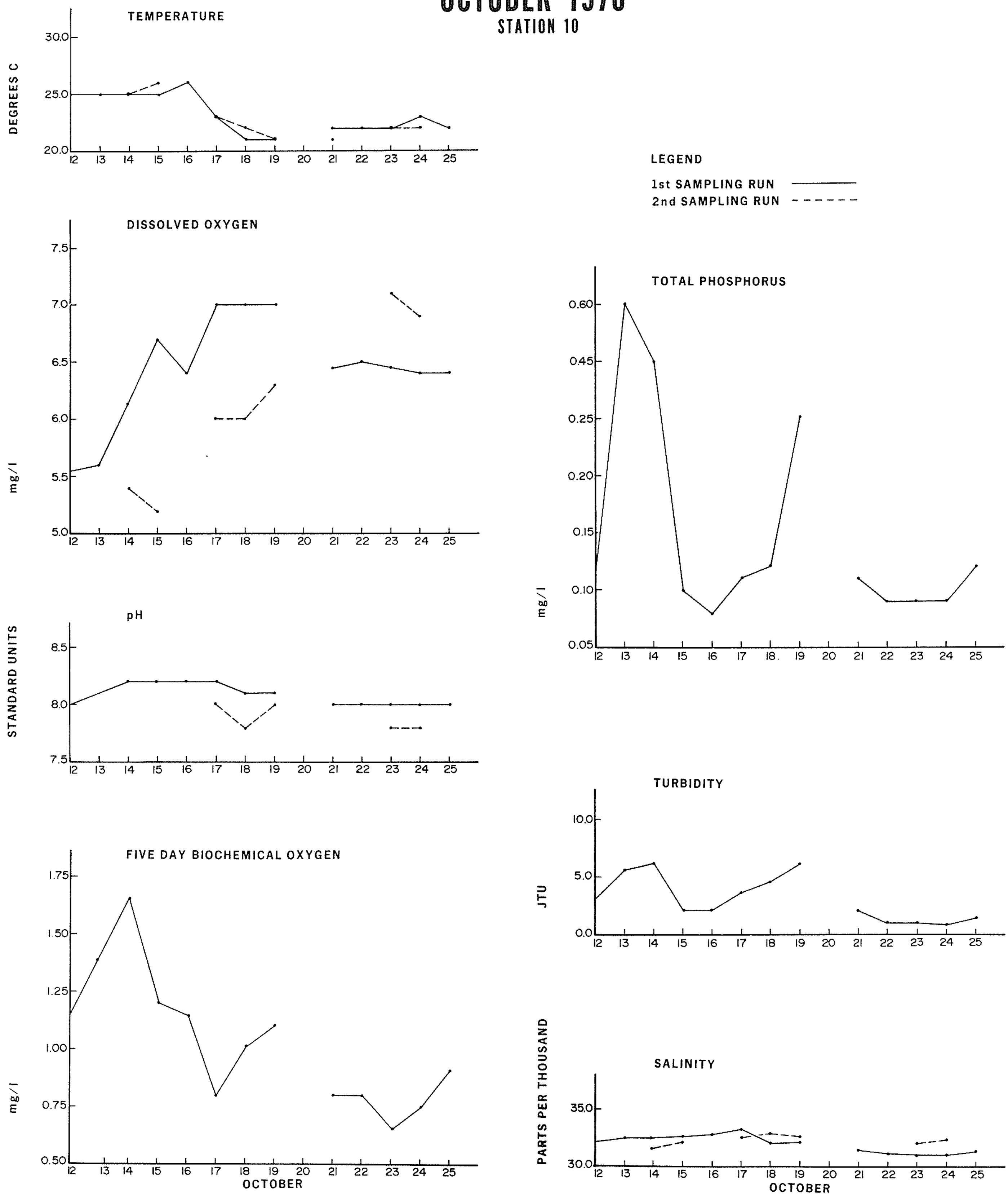
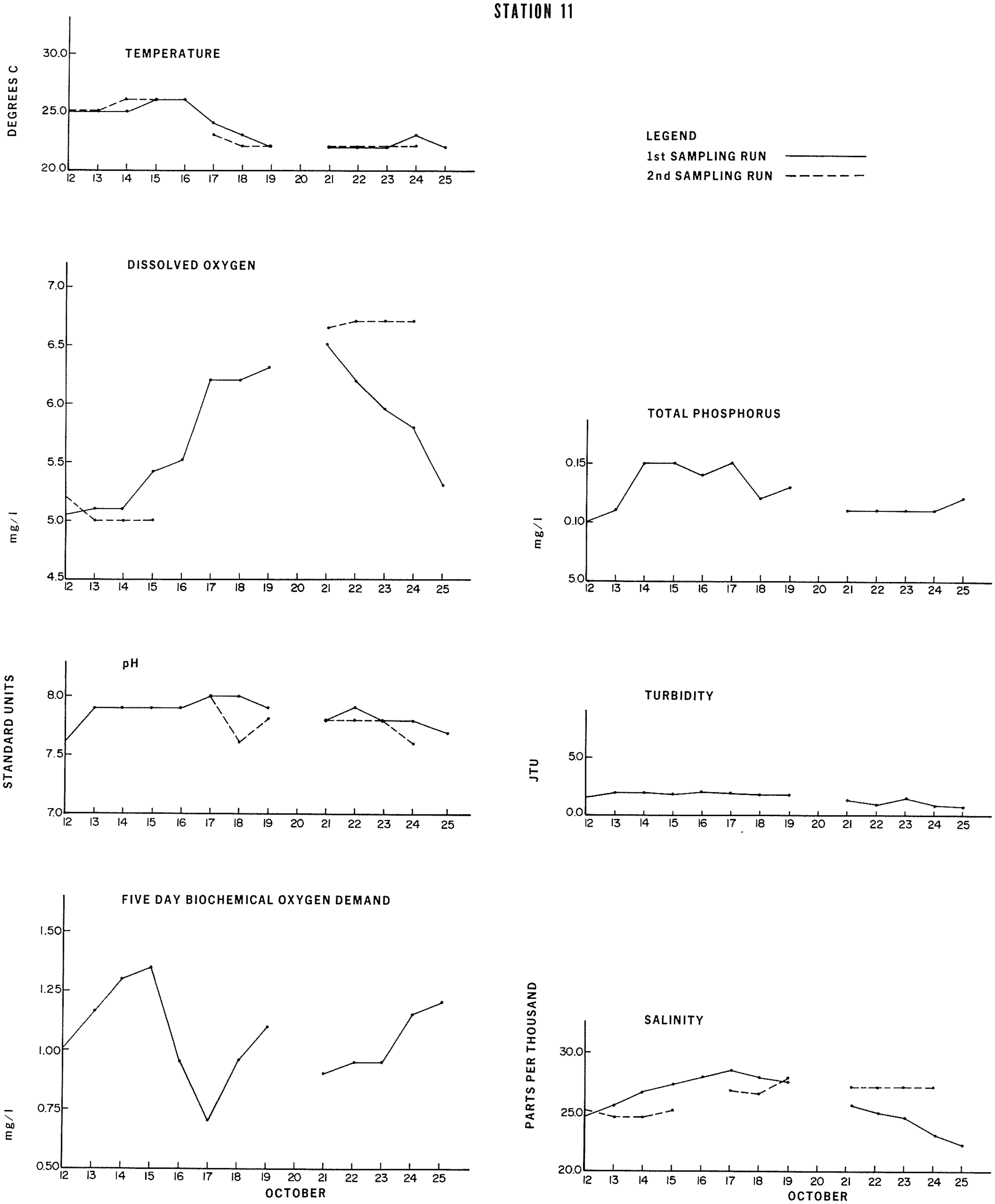


Figure 4

PORT ROYAL SOUND ENVIRONMENTAL STUDY
SELECTED CHEMICAL CONSTITUENTS
OCTOBER 1970

STATION 11



Salinity

The salt content of the ocean is commonly expressed in several different units. One such unit is salinity which is defined by Strickland and Parsons (1968) as approximately the weight of dissolved salts in one kilogram of sea water when dried to a constant weight at 480° C. In practice, the salinity is defined in terms of chlorinity by the equation: S (ppt) = 0.030 + 1.805 Cl (ppt). Chlorinity is defined to be the weight of halogens in one kilogram of sea water. Chlorosity is another common unit and is the weight of halogens in one liter of sea water.

Salinity is usually determined either directly by electrical conductivity or by calculation from a chlorinity value determined by a silver nitrate titration. It can also be estimated closely by determining the total dissolved solids in the sea water. In fresh water systems, the more common measurements for dissolved inorganic materials are total dissolved solids and specific conductance. Both fresh and marine classes of water measurement were included because of the anticipated salinity gradient from fresh to brackish to marine in passing through the estuarine Port Royal Sound system.

Stations 1 and 10 are physically closest to the ocean and most nearly reflect oceanic water quality. Salinity concentrations at the other stations generally average less than these two stations, and reflect the varying additions of fresh water. Average salinities during the April - May survey at all stations were significantly less than ocean values. They ranged from a maximum of 26 parts per thousand (ppt) at station 10 to 22 ppt at station 6 near the head of the Colleton River. July, 1970 salinity values were appreciably higher than April - May, 1970 values with average values ranging from 33 ppt at station 10 to 30 ppt at station 11, located at the head of the Broad River. These elevated levels reflect the small amounts of fresh water flow into the system. October, 1970 survey salinities averaged from 32.5 ppt at station 1 to 26 ppt at station 11.

Biochemical Oxygen Demand (BOD)

The BOD in Port Royal Sound is primarily derived from natural sources. Owing to the volume of the system, waste discharges do not exert a significant demand. The major BOD contributors in the system are the extensive marshes which provide not only vegetative debris but waste from aquatic and aquatic-related fauna. With each flood and ebb tide these organic materials are flushed from the marshes into the open waters. In the open waters and in the waters covering the marshes during flood tide, the microbial decomposition of organic matter, derived from both plants and animals, requires some of the available dissolved oxygen.

BOD's in Port Royal Sound were performed in duplicate. Two-and 5-day BOD's were routinely performed. Additionally, 7- and 10- day BOD's were determined 3 days per week for the first 3 weeks during the April - May survey and for the first week during the July and October surveys.

A graph which represents the BOD expressed in mg/ℓ as the ordinate versus incubation time as the abscissa permits the evaluation of kinetic rates of BOD exertion. Such a graph also allows a qualitative description of the oxidation process. Examination of a typical graph (Figure 5) indicates that two reactions occur, the second beginning on approximately day 6 of incubation. Classical theory states that the first section of the curve (day 0 to 5 or 6) is due to the oxidation of carbonaceous materials in the sample. The second part of the curve reportedly is due to the oxidation of nitrogenous materials present. Five-, 7-, and 10-day BOD tests were conducted, however the 5-day BOD period is generally regarded as the standard, and for this discussion only these values will be presented.

The 5-day BOD concentrations were quite low throughout the system for all three surveys. Average concentrations ranged from 0.85 mg/ℓ to 1.17 mg/ℓ during the April-May, 1970 survey; from 1.13 mg/ℓ to 1.88 mg/ℓ during the July survey; and from 0.78 mg/ℓ to 1.04 mg/ℓ during the October survey. These concentrations were insufficient to account for the low dissolved oxygen concentrations observed at several stations during the survey.

Sediment Oxygen Demand

Oxygen demands of the bottom sediments can have a significant effect on the dissolved oxygen concentrations of the overlying waters. The causes of such demands in the Port Royal Sound system are the decaying vegetation present and respiration of the associated bottom animal community.

In-situ measurements of the sediment oxygen demands were performed using the methods and apparatus of Lucas and Thomas (1971). The methods involve covering an area of the bottom sediments with an enclosed plexiglass chamber. The chamber seals itself at the mud-water interface thereby enclosing a known volume of water and area of substratum. Water inside the chamber is circulated by a pump past a dissolved oxygen probe. As respiration and decomposition utilize dissolved oxygen in the chamber, the subsequent reduction is detected by the probe. Knowing the volume and areal coverage of the chamber allows the calculation of the sediment oxygen demand.

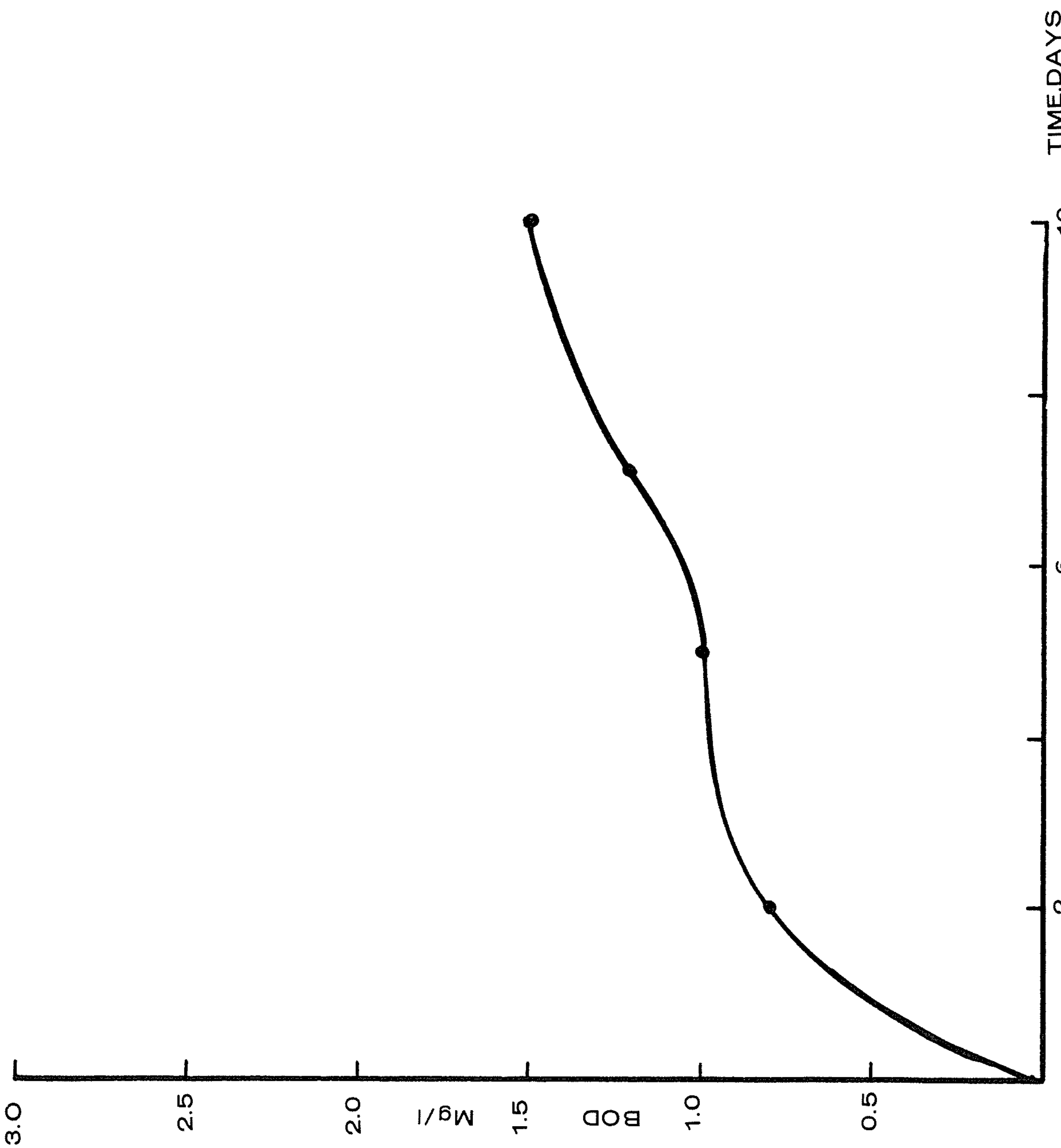
With the exception of station 4, sediment oxygen uptake rates were significantly higher during the July survey as compared with the April survey (Table 6). A seasonal increase in temperatures, which accelerates the rate of biochemical reactions, partially accounts for the differences between the April oxygen uptake rates when the water tempera-

FIG.5. PORT ROYAL SOUND ENVIRONMENTAL STUDY

TYPICAL BIOCHEMICAL OXYGEN DEMAND

STATION 5

APRIL 15,1970



tures were approximately 22-25° C and the July rates when the water temperatures exceeded 30° C.

Table 6

Date	Location	Oxygen Uptake Rate Gm $0_2/m^2/day$
4/26/70	Sta 4	0.744
4/26/70	Victoria Bluff	0.744
4/25/70	Sta 5	0.413
4/25/70	Sta 6	0.372
7/20/70	Sta 4	0.338
7/17/70	Sta 6	1.052
7/14/70	Sta 7	2.190
7/15/70	Sta 8	1.860
7/24/70	Chechessee Ck. near bridge	1.860

Representative values from the April survey ranged from 0.372 gm $0_2/m^2/day$ at station 6, to 0.744 gm $0_2/m^2/day$ at both station 4 and near Victoria Bluff on the Colleton River. July survey values ranged from 0.372 gm $0_2/m^2/day$ at station 6, to 2.19 gm $0_2/m^2/day$ at station 7. Four of the five values determined in July exceeded 1.0 gm $0_2/m^2/day$.

Attempts were made to measure the uptake rates at other locations. However, the existence of either a sandy or hard bottom kept the chamber from properly sealing and prevented a rate determination. A similar situation existed in the flooded marsh areas where the marsh grass prevented a proper seal.

Considering the large areal extent of marsh in the Port Royal Sound system, it is probable that demands of the sediments in these areas, as well as in the channels, presently exert the major oxygen demand in the system.

Dissolved Oxygen (D.O.)

As was discussed earlier, most of the Port Royal Sound system is classified by the South Carolina Pollution Control Authority as being Class SA waters. This classification requires that dissolved oxygen concentrations not drop below 5 mg/ℓ (See Table 1)

Open water stations such as those on Port Royal Sound (Station 1), the Chechessee River downstream from Lemon Island (Station 4), and the Broad River downstream from the Highway 170 bridge (Station 9) consistently had D.O. concentrations greater than 6.3 mg/ℓ during the April-May survey (approximately 90% of oxygen saturation); greater than 5.3 mg/ℓ during the July survey (approximately 87% of oxygen saturation); and greater than 6.2 mg/ℓ during the October survey (approximately 90% of oxygen saturation). Stations adjacent to marsh areas had lower D.O. concentrations. The Colleton River Stations (Stations 5 and 6) and the Chechessee River near Highway 170 bridge had D.O. concentrations as low as 6.0 mg/ℓ during the April-May survey (approximately 80% of saturation), as low as 4.5 mg/ℓ during the July survey (approximately 70% of saturation) and as low as 5.1 mg/ℓ during the October survey (approximately 75% of saturation).

The lower D.O. concentrations observed in the confined waters must result from biological processes occurring within the marsh areas and shellfish beds adjoining the marsh. During flood tide, dissolved oxygen in the waters covering these areas is utilized by respiring benthic and neretic organisms and by bacteria decomposing the naturally occurring organic matter. During ebb tide, these deoxygenated waters flow and mix with the waters in the open parts of the system. Biochemical oxygen demand tests (BOD), which give an indication of the amount of organic material present in a body of water, did not detect a significant difference between the amounts of organic compounds present in the open and confined waters. Obviously, therefore, the D.O. disparity between open and confined waters is a combination of several factors. In open waters the effects of tidal water turbulence, wind, and the decreased numbers of benthic organisms all combine to either maintain or increase the D.O. In confined waters, however, the lack of turbulence, and the abundance of benthos, and the high detrital concentrations decrease the D.O. concentrations.

During July, 1970 survey conditions, D.O. concentrations in the Colleton River were reduced to concentrations less than the 5.0 mg/ℓ State standard. This condition occurred without any source of man-made pollution and was caused by the normal processes of the marsh. The introduction into the Colleton River of oxygen demanding wastes during the warm summer months would reduce D.O. levels further. Such reduction in D.O. could interrupt the delicate biological balances within this area and cause deterioration of the fishery in the whole Port Royal Sound system.

Continuous Dissolved Oxygen Measurements

At several of the stations which were somewhat protected from wave action, dissolved oxygen was continuously measured over a 24 hour period during the April-May and July, 1970 surveys. The purpose of the measurements was to demonstrate the presence or absence of significant amounts of photosynthetically produced dissolved oxygen; and to measure the variation of dissolved oxygen in the waters that moved past a station as a result of tidal fluctuations.

Calculations were made for oxygen produced per unit of carbon fixed using a stoichiometric relationship for photosynthesis. The values used for carbon fixed during the surveys were those derived from the primary production study (this volume). Based on Secchi disc depths, it was assumed that the euphotic zone occupied one-third the volume of the estuary. These calculations yielded a photosynthetic oxygen production of approximately 0.2 mg/ℓ for each 500 mg C/m^2/day fixed during primary production. Primary production values at stations 5, 6, 7 and 8 were equal to or less than this rate (500 mg C/m^2/day) of primary production during both the April-May and July, 1970 surveys. Phytoplankton photosynthetic oxygen production did not, therefore, significantly affect dissolved oxygen concentrations at these stations. The dissolved oxygen fluctuations noted were primarily caused by the tidal advection of waters of varying dissolved oxygen concentrations past a station. Photosynthetic oxygen production by rooted aquatic plants in the marshes probably did occur adding oxygen to the water. This production would account for the 24 hour cyclical variation observed at these stations (Figures 6 and 7).

The dissolved oxygen fluctuations observed were greater during the April-May survey than during the July survey (Figures 6 and 7). This occurrence is partially accounted for by different tidal conditions. Tidal ranges during the April 22-26, 1970, measurement period averaged 7.5 ft. with a range of 6.3 ft. to 8.6 ft. Tidal ranges for the July 13-18 period averaged 7.2 ft. with a range of 5.3 ft. to 9.3 ft. A major difference between the April and July, 1970, continuous D.O. surveys was that the April period occurred as tidal ranges were decreasing following an earlier maximum while the July perior occurred as tidal ranges were increasing following an earlier minimum. Thus during the April period relatively deoxygenated waters were being flushed from the peripheral marshes possibly accounting for the greater dissolved oxygen fluctuations than observed during the July period.

Nitrogen

Nitrogen is one of the major nutrients essential for primary production. In the environment, biologically available inorganic nitrogen usually exists as atmospheric nitrogen, ammonia, nitrate, and occasionally as nitrite. Organic nitrogen, that nitrogen which is a chemical constituent of amino acids (and, therefore, proteins) is indicative of the microscopic biomass of the system.

During all three surveys, inorganic nitrogen concentrations, (ammonia, nitrite and nitrate) rarely exceeded the detectable limit of the test. Ammonia was not detected during the April-May survey, only infrequently during the July survey and only on 3 occasions during the October survey. The highest concentration during July was 0.3 mg/ℓ but all stations averaged less than 0.1 mg/ℓ.

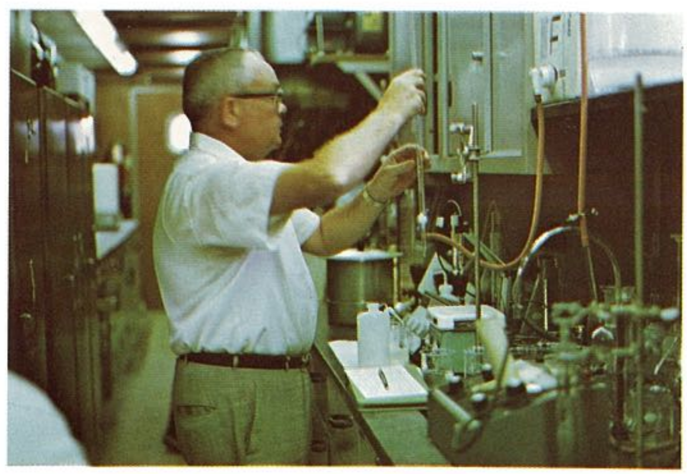
Phosphorus

Phosphorus is a major nutrient essential for primary production. It can be assimilated at seemingly low concentrations of only a few hundredths of a mg/ℓ and support substantial quantities of plant biomass. The April-May survey average total phosphorus concentrations ranged from 0.04 mg/ℓ to 0.07 mg/ℓ. Soluble phosphorus ranged from 0.02 mg/ℓ to 0.04 mg/ℓ and was 33% to 60% of the total at individual stations.

In July, phosphorus concentrations in the water were higher than the April-May values. Average total phosphorus concentrations at the different stations were between 0.09 mg/ℓ to 0.18 mg/ℓ. Average soluble phosphorus values were between 0.06 mg/ℓ to 0.09 mg/ℓ and were 33% to 78% of the total phosphorus present at individual stations.

In October, phosphorus concentrations were remarkably similar to the July values. Average total phosphorus concentrations were between 0.09 mg/ℓ to 0.18 mg/ℓ. Average soluble phosphrous concentrations were between 0.06 mg/ℓ to 0.09 mg/ℓ and these values were 33% to 78% of the total phosphorus present at individual stations.

The important point to be made from these data is that at least 33% of the phosphorus was soluble and available for biological use. Phosphorus therefore was not one of the nutrients limiting the primary production of the Port Royal Sound system.



Chemist analyzing water samples; photo by J. Darby, S. C. Water Resources Commission.

Chlorophyll

Chlorophyll is a pigment contained in green plants which acts as a light-trapping catalyst during the process of photosynthesis. There are several varieties of chlorophylls and other closely related carotenoids, but the most common form is chlorophyll *a*. Chlorophyll *c* rarely occurs in fresh water phytoplankton but is characteristic of marine forms.

Average chlorophyll concentrations were relatively low for all three surveys. The concentrations

PORT ROYAL SOUND EVIRONMENTAL STUDY

24 HOUR CONTINUOUS DISSOLVED OXYGEN RECORDS

TO ASCERTAIN DIURNAL AND TIDAL EFFECTS

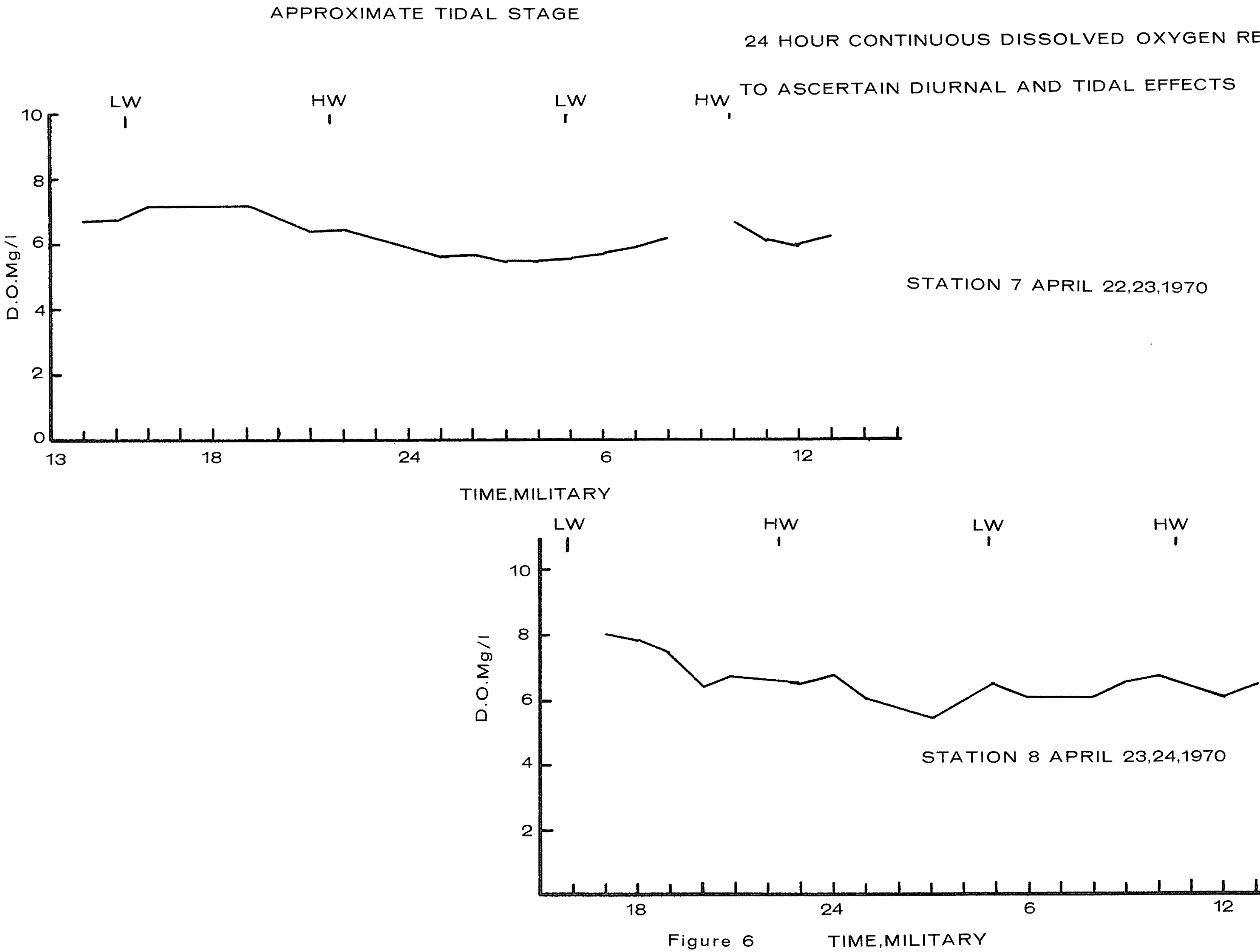


Figure 6

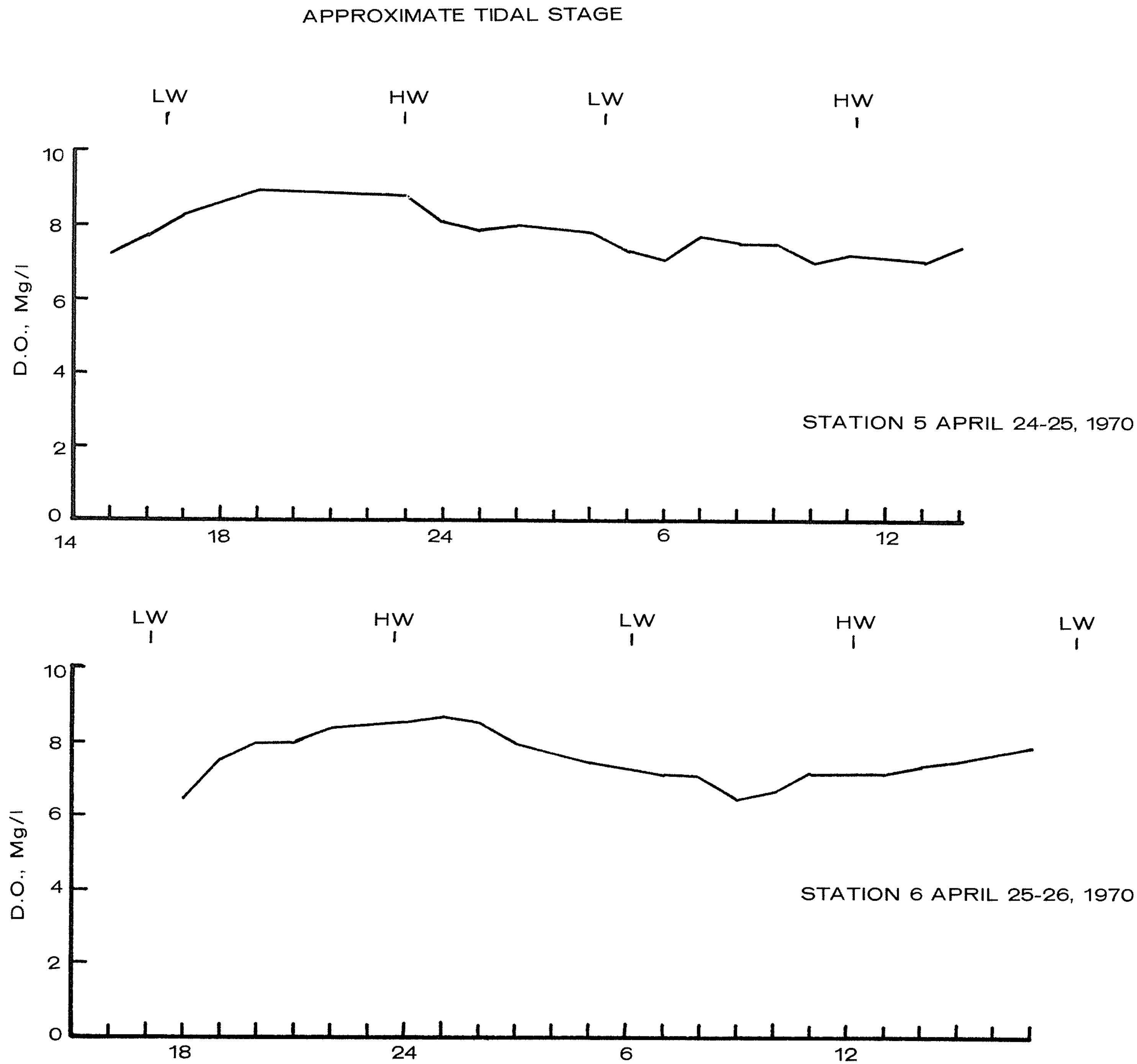


Figure 6 Continued

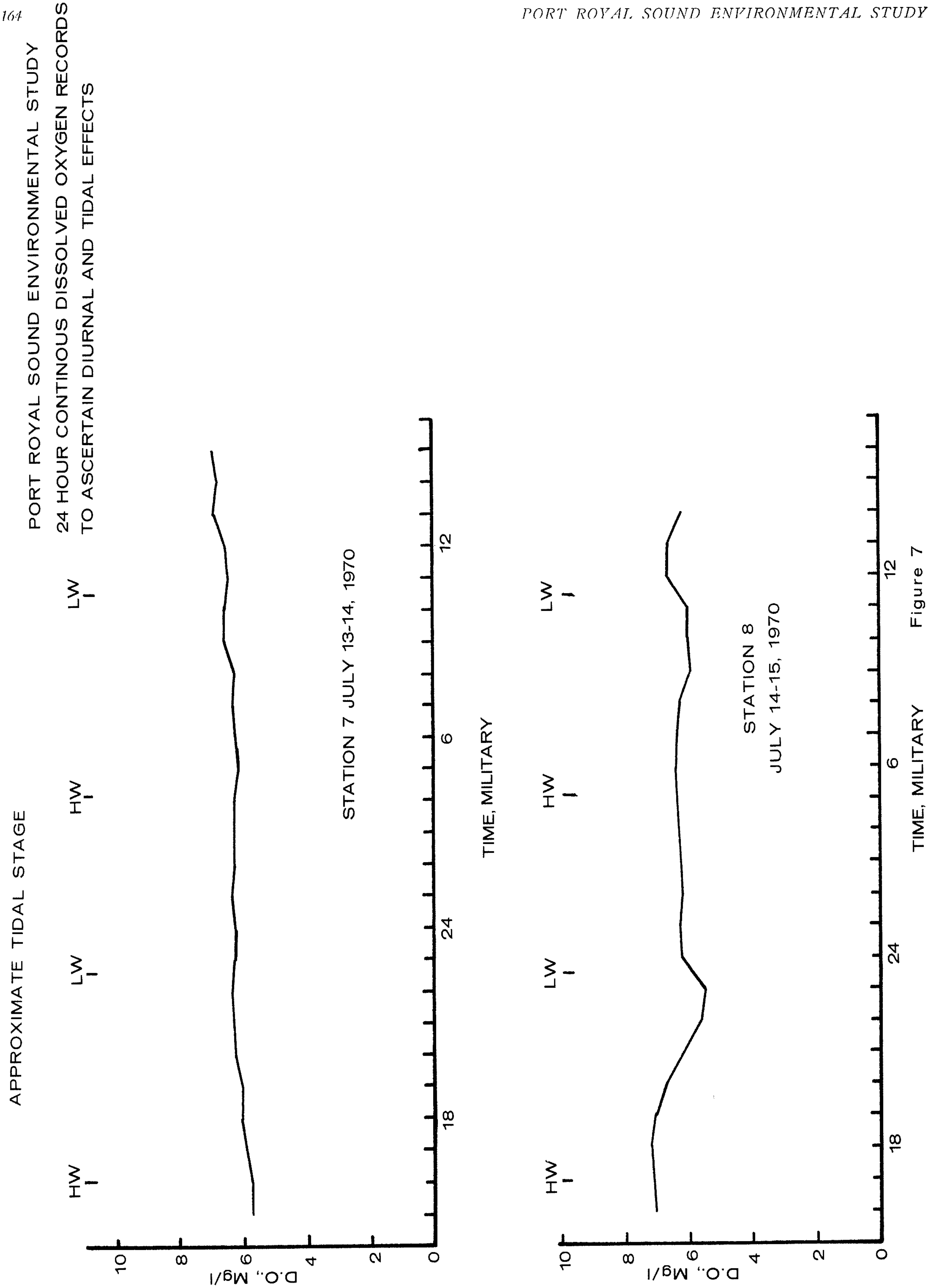

PORT ROYAL SOUND ENVIRONMENTAL STUDY
24 HOUR CONTINOUS DISSOLVED OXYGEN RECORDS
TO ASCERTAIN DIURNAL AND TIDAL EFFECTS
APPROXIMATE TIDAL STAGE
HW
LW
HW
LW
STATION 7 JULY 13-14, 1970
D.O., Mg/l
0
2
4
6
8
10
18
24
6
12
TIME, MILITARY
HW
LW
HW
LW
STATION 8
JULY 14-15, 1970
D.O., Mg/l
0
2
4
6
8
10
18
24
6
12
TIME, MILITARY

Figure 7

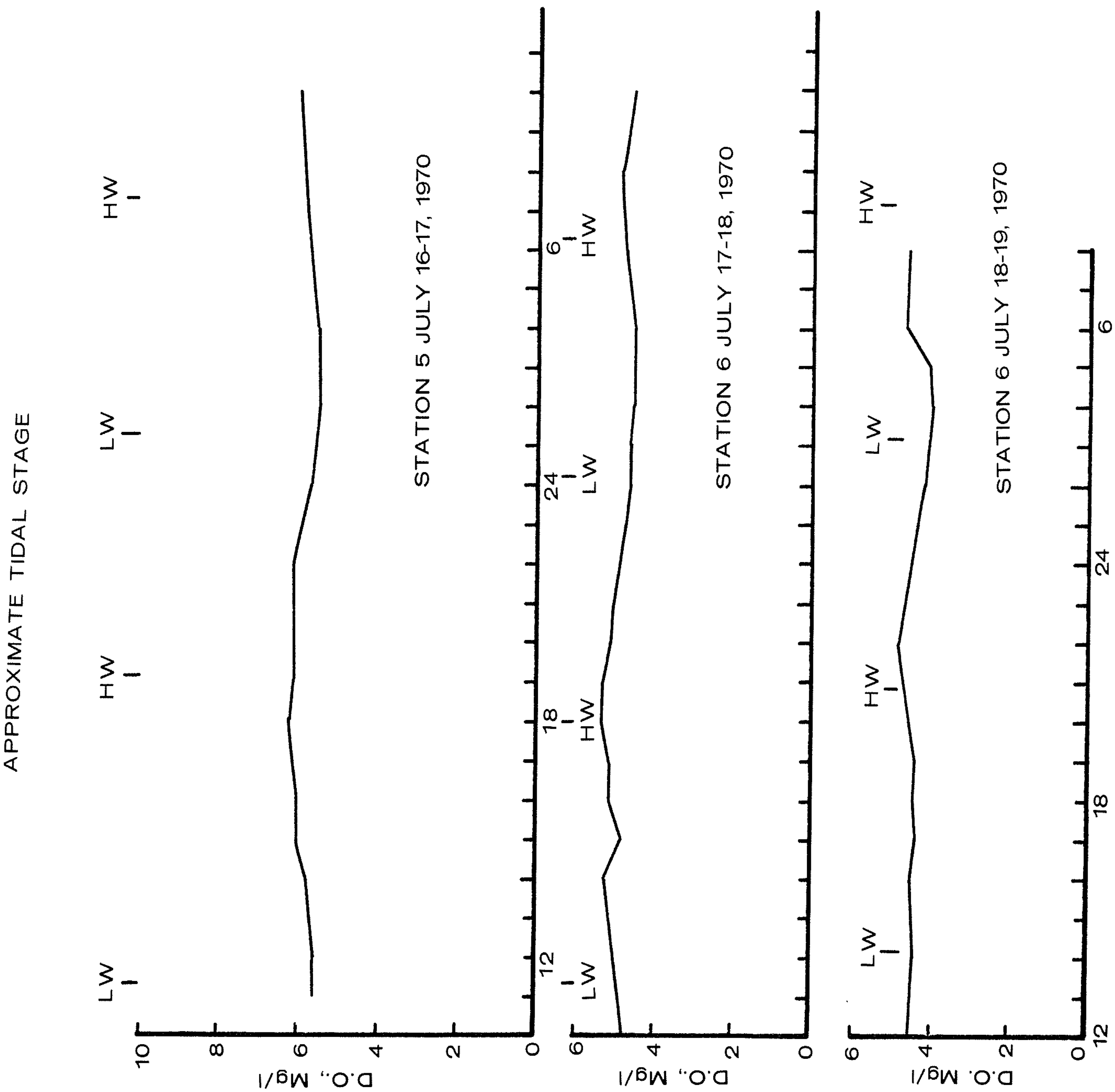


Figure 7 Continued

of chlorophyll *a* from the April-May survey were approximately one-third the concentrations of either July or October. Conversely, the chlorophyll *c* concentrations were generally greater during the April-May survey when compared with the other two surveys, being more than double the concentration at several stations (except station 10).

Average concentrations during the April-May survey for chlorophyll *a* and *c* were approximately 2.4 - 3.5 μg/ℓ and 1.7 - 2.7 μg/ℓ respectively. July survey concentrations for chlorophyll *a* and *c* averaged 4.6 to 9.6 μg/ℓ and 0.51 to 1.46 μg/ℓ respectively. October survey concentrations for chlorophyll *a* and *c* averaged 3.84 to 9.26 μg/ℓ and 0.49 to 3.54 μg/ℓ respectively.

Heavy Metals

The concentrations of several different heavy metals were determined in both the water column and in the sediments of Port Royal Sound. The metals determined were barium, cadmium, chromium, copper, mercury, manganese, nickel, lead and zinc. Most of these metals are normal constituents of sea water in trace amounts. Appendix D presents the data for the sediments while the concentrations in the water column are in Appendix B.

Tritium Results

Samples were collected and analyzed for radioactive tritium, H^3 during the April, 1970 survey. The data do not indicate any effect from the distant (approximately 150 miles by water) Savannah River Plant of the Atomic Energy Commission which discharges tritium to the Savannah River. The Savannah River is hydraulically interconnected with Calibogue Sound which in turn is hydraulically interconnected with Port Royal Sound.

The 4ml samples were counted for 200 minutes. Seven of the ten stations were less than the 261 pCi/ℓ sensitivity of the liquid scintillation counter. Station 3 which was connected to the Calibogue Sound System had the highest activity of 615 pCi/ℓ. Stations 5 and 7 had activities of 294 pCi/ℓ and 372 pCi/ℓ respectively (Table 7).

Mathematical Model

The FWQA Dynamic Estuary Model (1970) was applied to the Port Royal Sound System. The model represents the two-dimensional areal flow and dispersion of an estuary and is applicable to any estuary such as Port Royal Sound where vertical stratification is not prevalent. The model can accommodate either conservative or non-conservative constituents including the D.O. sag caused by the introduction of biochemical oxygen demand.

The version of the model applied to Port Royal Sound consisted of a nodal grid of 97 nodes and 112 interconnecting channels. Tidal inputs from 3 sources were incorporated: Calibogue Sound, Port Royal Sound and St. Helena Sound. All three sounds are hydraulically interconnected.

Model Verification

The model consists of two major sections: hydraulic and water quality. The hydraulic section was verified by using the stage data and water current data furnished by the U. S. Geological Survey for Port Royal Sound and Calibogue Sound. During the April dye study period when the U.S.G.S. gage at the mouth of Port Royal Sound was inoperative, data from the Savannah River Entrance Gage (Ft. Pulaski) were used to calculate the tides in St. Helena Sound and at the mouth of Port Royal Sound. Correction factors from the U. S. Coast and Geodetic Surveys *Tide Tables* were applied to these data.

The initial step in applying the model was to describe the physical system with a grid pattern consisting of nodes and connecting channels. The final result of this procedure is shown in the Appendix. The area represented by each node was assigned and planimetered from the navigation chart. Each channel was then scaled for length and assigned hydraulic values for roughness (Manning's *n*) and depth.

The next step involved the selection of a tide to operate the model. Since the April dye data from the U.S.G.S. dye study were used for the verification of the quality section of the model, the April 10, 1970, tide was constructed for the hydraulic verification. The tide used for the entrance to Port Royal Sound had a range of 7.2 feet and a time interval of 25.0 hours, which encompasses two diurnal tidal cycles. Two tidal cycles were used to account for the occurrence of a higher high tide and lower low tide rather than sinusoidal cycles with equal high and low tides.

A typical verification is shown in Figure 8 for node 17 which corresponds to the U.S.G.S. gage at the mouth of the Colleton River (02 - 1765.80). The solid line in the figure represents a smoothed plot from the tide gage and the circle plot represent the calculated stage. Similar comparisons were made

TABLE 7

Port Royal Sound Environmental Study
Tritium

Date	Station	Tritium pCi/ℓ
April, 1970	1	<261
	2	<261
	3	615 ± 108
	4	<261
	5	294 ± 106
	6	<261
	7	372 ± 106
	8	<261
	9	<261
	10	<261

Note: Error term is for 1 standard deviation.

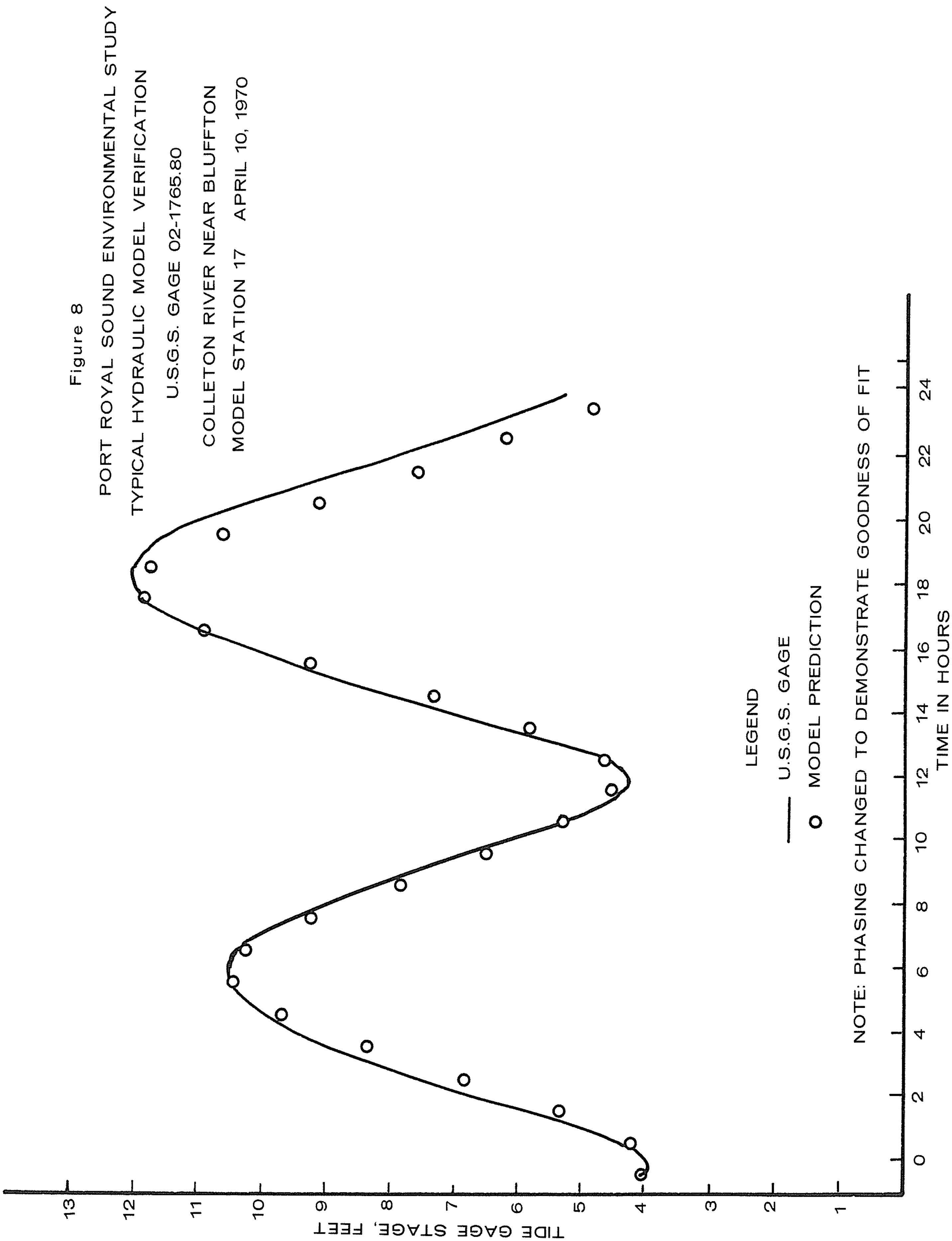


Figure 8
PORT ROYAL SOUND ENVIRONMENTAL STUDY
TYPICAL HYDRAULIC MODEL VERIFICATION
U.S.G.S. GAGE 02-1765.80
COLLETON RIVER NEAR BLUFFTON
MODEL STATION 17 APRIL 10, 1970
LEGEND
U.S.G.S. GAGE
MODEL PREDICTION
NOTE: PHASING CHANGED TO DEMONSTRATE GOODNESS OF FIT
TIME IN HOURS
0 2 4 6 8 10 12 14 16 18 20 22 24
TIDE GAGE STAGE, FEET
1 2 3 4 5 6 7 8 9 10 11 12 13

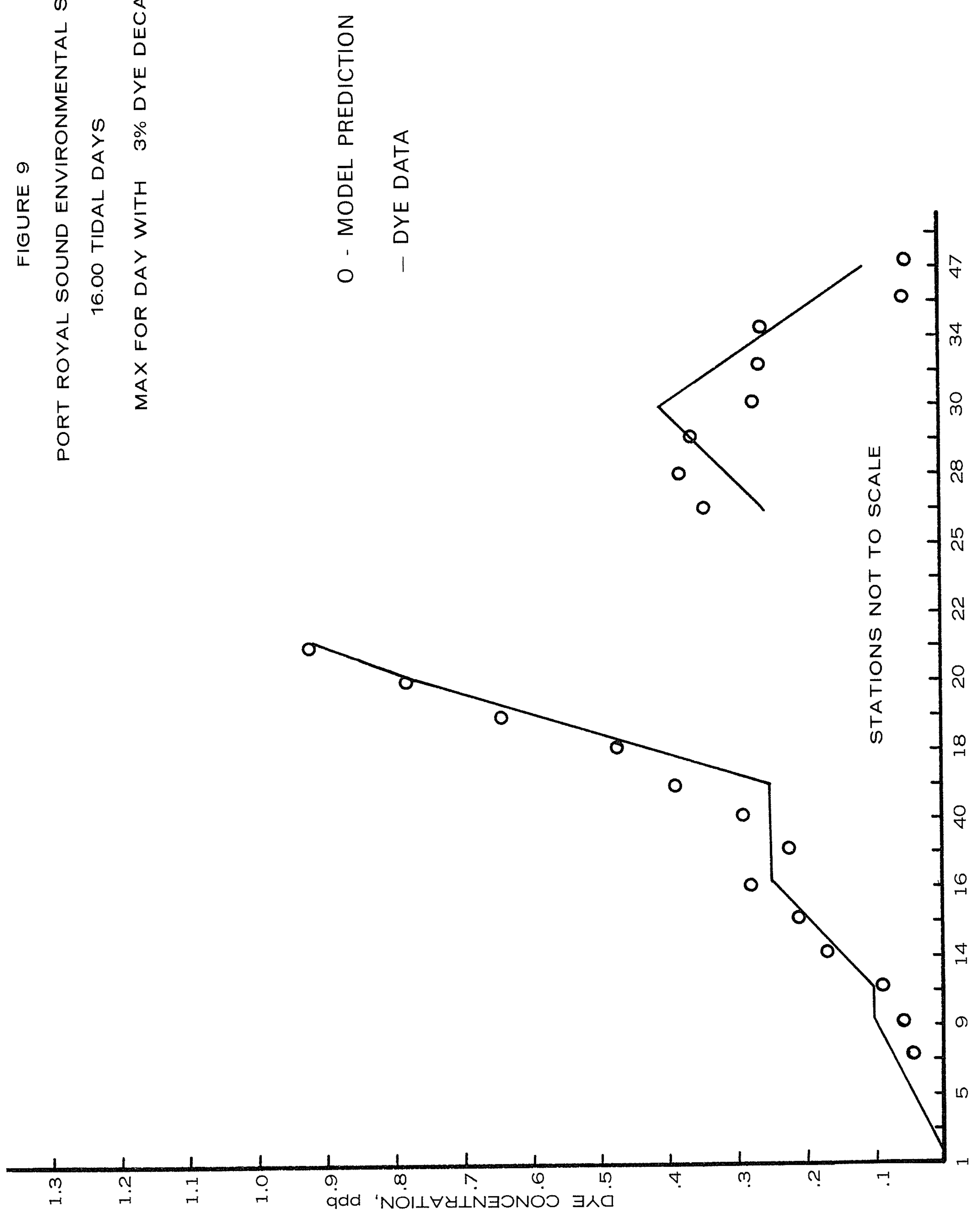


FIGURE 9
PORT ROYAL SOUND ENVIRONMENTAL STUDY
16.00 TIDAL DAYS
MAX FOR DAY WITH 3% DYE DECAY

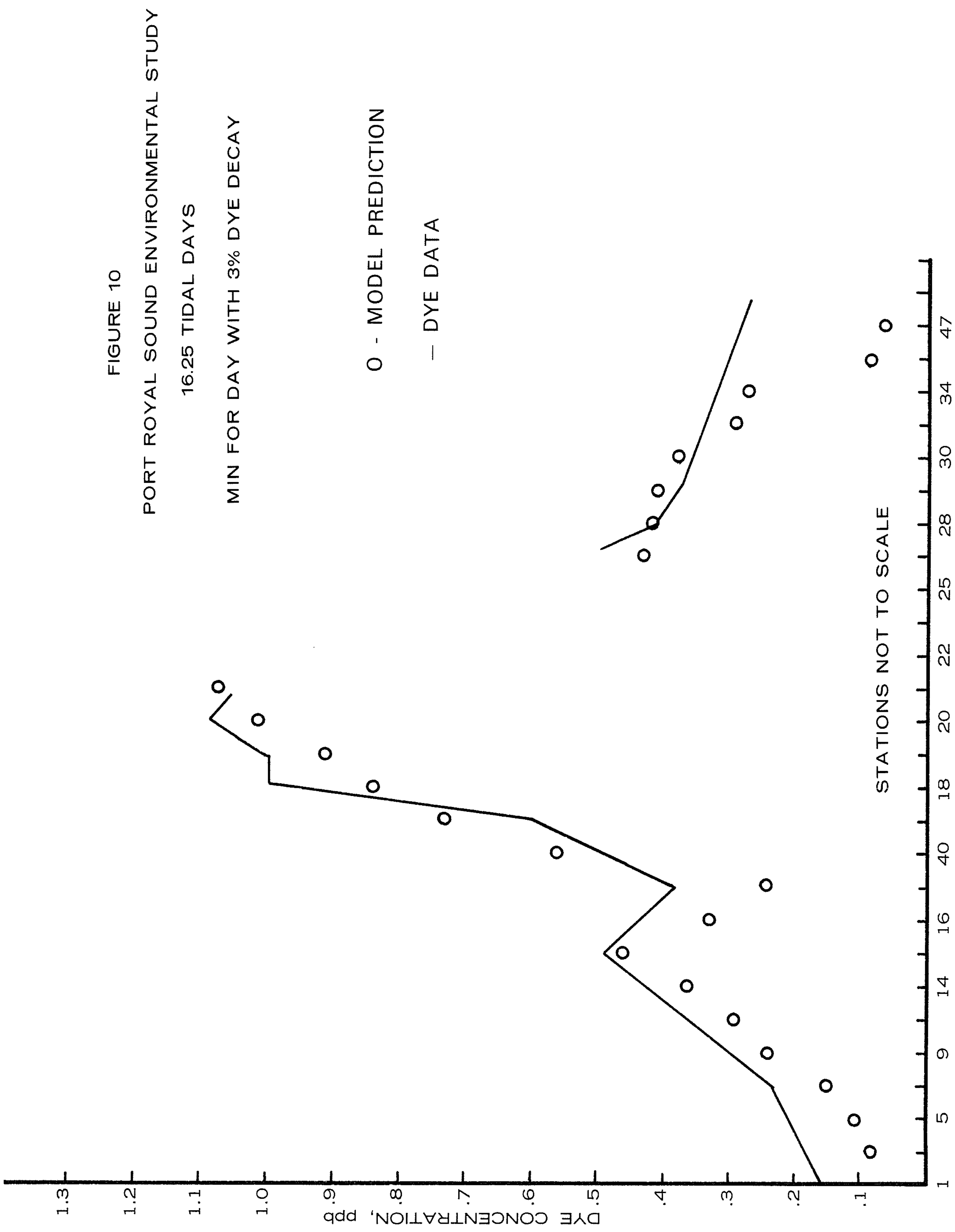
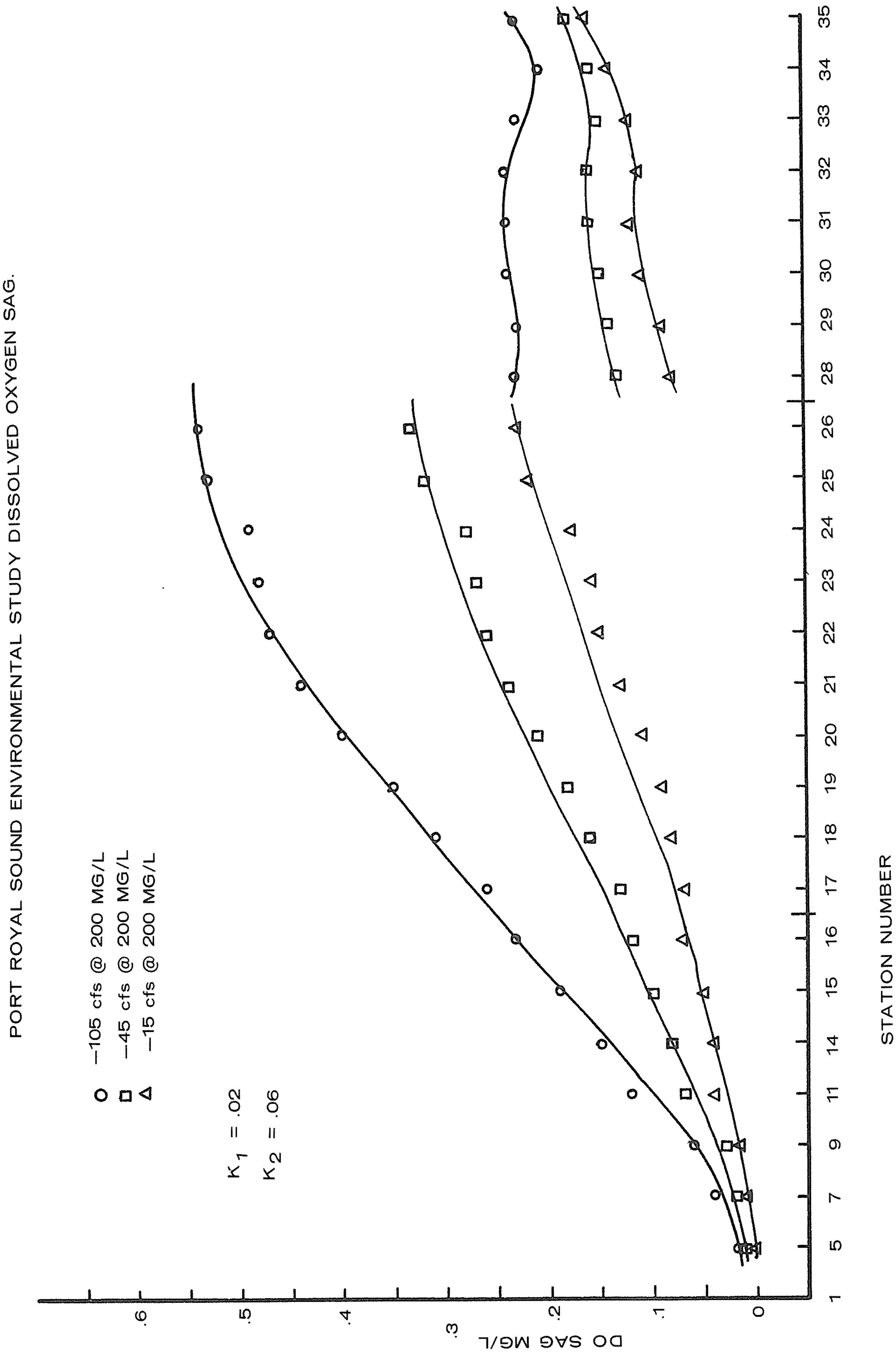


FIGURE 10

PORT ROYAL SOUND ENVIRONMENTAL STUDY

16.25 TIDAL DAYS

MIN FOR DAY WITH 3% DYE DECAY


PORT ROYAL SOUND ENVIRONMENTAL STUDY DISSOLVED OXYGEN SAG.
○ –105 cfs @ 200 MG/L
□ –45 cfs @ 200 MG/L
△ –15 cfs @ 200 MG/L
K1 = .02
K2 = .06
DO SAG MG/L
0
.1
.2
.3
.4
.5
.6
STATION NUMBER
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7
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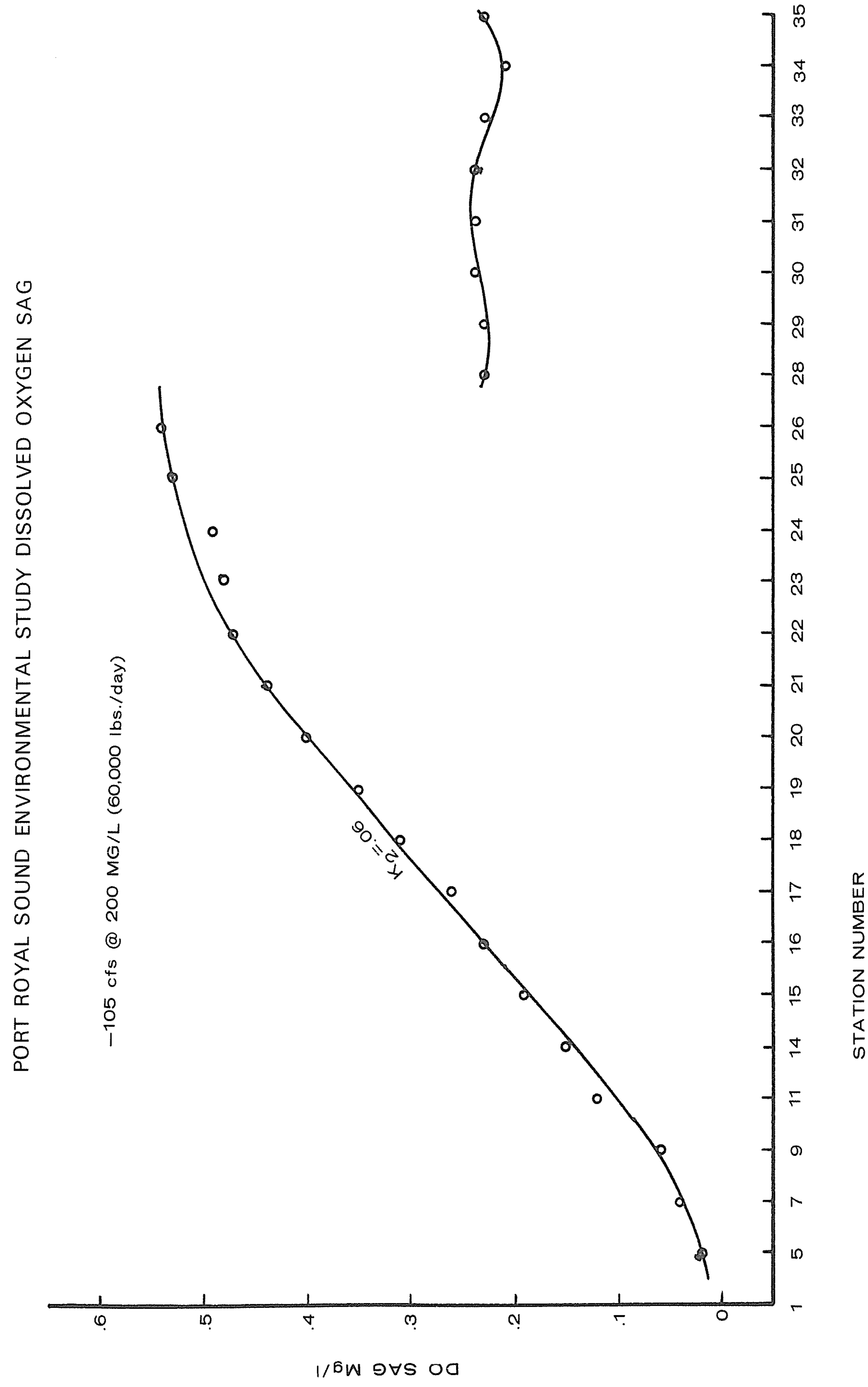
Figure 11


PORT ROYAL SOUND ENVIRONMENTAL STUDY DISSOLVED OXYGEN SAG
−105 cfs @ 200 MG/L (60,000 lbs./day)
K2=.06
DO SAG Mg/l
.6
.5
.4
.3
.2
.1
0
1
5
7
9
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STATION NUMBER

Figure 12

for the other U.S.G.S. gages located throughout the estuarine system. The final "system assumed conditions" are presented in the Appendix. The water quality model section was calibrated from the April, 1970, flourescent dye data furnished by the U. S. Geological Survey.

The actual dye concentrations were interpolated from charts in the U.S.G.S. dye tracer report (this volume) which depicted isoconcentration waves. The dye study consisted of injecting a total dose of 750 pounds of Rhodamine WT dye spaced over a 24.8 hour period along a transect across the Colleton River at Victoria Bluff. The dye study began on April 7, 1970, and continued through May 20, 1970.

Determining dye concentrations from such graphs does not yield exact numbers for comparison with those calculated by the model. However, the model predictions do adequately represent the curve shape and dye concentrations. The goodness of fit can be qualitatively ascertained from Figures 9 and 10 which show the dye concentrations from tidal day 16.0 (high water slack) and for 16.25 tidal days (low water slack) versus the model predictions for similar conditions. The similarity was considered adequate to justify subsequent calculations of waste assimilative capacity.

Model Predictions

Following verification of the model, several runs were made to predict the effects on the D.O. of the system with the input of additional BOD from a waste source. The conditions assumed were those of the July, 1970 period which included high water temperatures and essentially zero fresh water flow. Reaeration was calculated by the O'Connor - Dobbins formula. The condition of the analysis assumed that July, 1970 physical conditions of bottom oxygen demands, photosynthetic production of D.O. and tidal conditions would prevail. The model was then used to calculate the change caused by a projected waste load. These runs have assumed a discharge from the Victoria Bluff area along the Colleton River.

These runs indicate that a soluble BOD input of 60,000 lbs./day with a decay rate of 0.1 day (base 10) discharged into the Colleton River off Victoria Bluff would cause a maximum additional D.O. sag of 0.54 mg/ℓ and would cause a D.O. profile as shown in Figures 11 and 12. Since the D.O. concentration in the Colleton River dropped below 5.0 mg/ℓ, additional waste loads cannot be assimilated during the warm summer months. However, the model can be used to predict the effects of other projected waste loads at different locations or the effects on water quality of physical modifications such as channel deepening or port construction.

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A Discussion of Selected Water Quality Parameters

Temperature

Temperature plays an important role in regulating biological functions within the aquatic environment. Such natural processes as feeding, growth, respiration, reproduction, and physical activity are directly influenced by temperature. Responses in these processes probably reflect temperature induced physiological changes such as altered chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes. Consequently, temperature is one of the most important physical parameters pertaining to life and life processes.

The general range of naturally occuring marine temperatures is from about 30° C in tropical waters to around —1.5° C in polar seas. The temperatures of extremely shallow bays and estuaries commonly exceed 30° C. The extent of the thermal fluctuations in a given area is a vital factor in determining the ability of an organism to inhabit that area. If intolerable temperatures occur, mobile organisms can usually escape while attached and planktonic forms expire as their thermal ranges are exceeded (high or low).

One general rule of thumb concerning the effects of temperature is that chemical reaction rates are approximately doubled for every 10° C increase. In an aquatic environment, biochemical reactions are thus accelerated by increasing and decelerated by decreasing temperatures.

Increasing temperatures not only accelerate chemical reactions but they also inversely affect the solubility of gases in water. Adequate dissolved oxygen is essential to aquatic fauna. In sea water (salinity approximately 36 parts per thousand) the solubility of atmospheric oxygen is decreased by about 46 percent (11.3 to 6.1 ppm) as the temperature rises from 0° to 30°C under 1 atmosphere of pressure (760 mm Hg). With increasing temperatures, aquatic animals are faced with the dilemma of having increased metabolic rates which require more oxygen, decreased solubility of oxygen in the water, and increased bacterial decomposition of organic material which place further demands upon the available dissolved oxygen. Therefore, in some shallow estuaries, hot summer weather can produce critical if not lethal conditions.

pH

To a chemist, the pH of a system is defined by the following expressions:

$$pH = Log \frac{1}{(H^+)}$$

Interpreted respectively, these expressions mean that the pH of a system is the logarithm of the reciprocal of the hydrogen ion concentration expressed in moles per liter, or in slightly different terms, that pH is the negative log of the hydrogen ion concentration, again expressed in moles per liter.

A pH of 7 (that of pure water) is considered to be neutral. A solution that has an excess of H^+ ions in relation to OH^- ions will possess a pH value below 7, and it is referred to as being acidic. Conversely, a solution that has an abundance of OH^- ions in relation to H^+ ions will have a pH higher than 7, and is referred to as being basic. The pH scale extends from O to 14, with solutions becoming more acidic or basic towards the extremes of this range respectively.

The pH of most living matter is generally around 7. The pH of human blood, for example, is approximately 7.3. Most aquatic organisms can tolerate pH values ranging from about 5 to 9. Lower and higher pH values can be tolerated by some resistant organisms, but such values would generally not be suitable to the maintenance of a viable aquatic community. As Lloyd (1968) stated:

> "There is no definite pH range within which a fishery is unharmed and outside which it is damaged, but rather there is a gradual deterioration as the pH values are further removed from the normal range."

Alkalinity

According to *Standard Methods for the Examination of Water and Wastewater* (1971) the alkalinity of a water is the capacity of that water to accept protons (H^+). Alkalinity, which is usually imparted by the bicarbonate (HCO_3^-) carbonate ($CO_3^{=}$), and hydroxide (OH^-) components of a natural or treated water supply, is a quantitative measure of the ability of a given sample to neutralize strong acids to an arbitrarily designated pH or indicator end point. The results are expressed as mg/ℓ $CaCO_3$, implying an alkalinity which is equivalent to this amount of $CaCO_3$. Inorganic carbon in the forms of carbonate, bicarbonate, and carbon dioxide is used by phytoplankton during photosynthesis (primary production).

Biochemical Oxygen Demand

The following discussion of BOD was taken directly from *Methods for Chemical Analysis of Water and Wastes* (1971):

The biochemical oxygen demand test (BOD) is used for determining the relative oxygen requirements of municipal and industrial wastewaters. Application of the test to organic waste discharges allows calculation of the effect of the discharges on the oxygen resources of the receiving water. Data from BOD tests are used for the development of engineering criteria for the design of wastewater treatment plants.

The BOD test is an empirical bioassay-type procedure which measures the dissolved oxygen consumed by microbial life while assimilating and oxidizing the organic matter present. The standard test conditions include dark incubation at 20°C for a specified time period (often 5 days). The actual environmental conditions of temperature, biological population, water movement, sunlight, and oxygen concentration cannot be accurately reproduced in the laboratory. Results obtained must take into account the above factors when relating BOD results to stream oxygen demands.

The sample of waste, or an appropriate dilution, is incubated for 5 days at 20°C in the dark. The reduction in dissolved oxygen concentration during the incubation period yields a measure of the biochemical oxygen demand.

Dissolved Oxygen

Adequate dissolved oxygen (D.O.) is necessary for the existence of aquatic fauna. The amount of D.O. in the water is interrelated with such parameters as temperature, light, living organisms, naturally occurring decomposable organic matter, and pollution.

Oxygen has two principle paths by which it may enter a body of water. It may be absorbed from the atmosphere, or it may be released into the water by photosynthesizing plants. Via the first path, the atmospheric oxygen may become dissolved oxygen by direct diffusion or by surface-water agitation caused by winds, waves and currents. Under conditions of supersaturation of the water, oxygen may be released back to the atmosphere.

During photosynthesis, aquatic plants utilize carbon dioxide and release oxygen to the water. This process, however, is limited to that upper layer or zone of water where sufficient radiant energy is present to permit photosynthesis to occur.

Increasing temperatures, decomposing organic matter, respiring organisms, and salinity all have an adverse affect on the amount of D.O. present. The inverse relationship of temperature and salinity to D.O. are illustrated in Table 1.

TABLE 1
SATURATION OF OXYGEN IN WATER OF DIFFERENT SALINITIES*

Temperature in °C	Salinity in parts per thousand (ppt) 0	9	18	27	36
	Dissolved Oxygen—mg/l				
0	14.6	13.8	13.0	12.1	11.3
1	14.2	13.4	12.6	11.8	11.0
2	13.8	13.1	12.3	11.5	10.8
3	13.5	12.7	12.0	11.2	10.5
4	13.1	12.4	11.7	11.0	10.3
5	12.8	12.1	11.4	10.7	10.0
6	12.5	11.8	11.1	10.5	9.8
7	12.2	11.5	10.9	10.2	9.6
8	11.9	11.2	10.6	10.0	9.4
9	11.6	11.0	10.4	9.8	9.2
10	11.3	10.7	10.1	9.6	9.0
11	11.1	10.5	9.9	9.4	8.8
12	10.8	10.3	9.7	9.2	8.6
13	10.6	10.1	9.5	9.0	8.5
14	10.4	9.9	9.3	8.8	8.3
15	10.2	9.7	9.1	8.6	8.1
16	10.0	9.5	9.0	8.5	8.0
17	9.7	9.3	8.8	8.3	7.8
18	9.5	9.1	8.6	8.2	7.7
19	9.4	8.9	8.5	8.0	7.6
20	9.2	8.7	8.3	7.9	7.4
21	9.0	8.6	8.1	7.7	7.3
22	8.8	8.4	8.0	7.6	7.1
23	8.7	8.3	7.9	7.4	7.0
24	8.5	8.1	7.7	7.3	6.9
25	8.4	8.0	7.6	7.2	6.7
26	8.2	7.8	7.4	7.0	6.6
27	8.1	7.7	7.3	6.9	6.5
28	7.9	7.5	7.1	6.8	6.4
29	7.8	7.4	7.0	6.6	6.3
30	7.6	7.3	6.9	6.5	6.1

*Adapted from *Standard Methods for The Examination of Water and Wastewater*, 1971, American Public Health Association, Washington, D. C., pp. 480-481.

Phosphorus and Nitrogen

The elements phosphorus and nitrogen are both essential nutrients. Either can be the limiting factor in the plant growth that a body of water can support. Nitrogen, however, frequently appears to be the more critical factor limiting primary production in waters.

Phosphorus that occurs in natural waters and in wastewaters is almost exclusively found in the form of phosphate. These phosphates are commonly grouped into three categories—orthophosphates, condensed phosphates, and organically bound phosphates, Each may occur in soluble form, in particles of detritus, or in the bodies of aquatic organisms. When phosphorus is a growth-limiting nutrient, the discharge of raw or treated sewage, agricultural drainage or certain types of industrial wastes to a body of water may stimulate nuisance growths of photosynthetic aquatic organisms.

Nitrogen, like phosphorus, can assume several forms in the aquatic environment. The following forms and the methods for their detection are discussed in *Standard Methods for the Examination of Water and Wastewater* (1971):

1. Albuminoid Nitrogen—This test gives an approximate level of the proteinaceous nitrogen available in water. This form is largely derived from indigenous aquatic plant and animal life.
2. Ammonia Nitrogen (NH_3)—This form of nitrogen results primarily from the microbial decay of the organic nitrogen compounds present in animal byproducts and in the remains of dead plants and animals. The presence of ammonia nitrogen is often an indication of sanitary pollution when it is encountered in raw surface water supplies.
3. Nitrite Nitrogen (NO_2^-)—Certain nitrifying bacteria can convert ammonia nitrogen into nitrite nitrogen. Nitrite nitrogen, when detected in water with other forms of nitrogen, can in trace amounts indicate organic pollution. Most drinking water supplies have less than a 0.1 mg/ℓ nitrite concentration.
4. Nitrate Nitrogen (No_3^-)—Just as certain nitrifying bacteria convert ammonia to nitrite ions, other types converte nitrite ions to nitrate ions. This is an important step in the nitrogen cycle for nitrate nitrogen is a major source of nitrogen for plants. Nitrate nitrogen generally occurs in trace amounts in surface waters, rarely exceeding 10 mg/ℓ in drinking water supplies.
5. Organic Nitrogen—Organically bound nitrogen is determined by the kjeldahl method. This detects nitrogen in the tri-negative state which includes nitrogen that occurs in amino acids, polypeptides and proteins. Nitrogen compounds occurring in these forms all result from biological processes. Albuminoid nitrogen would also be detected by this test. The occurrence of organic nitrogen in a body of water may result from the discharge of sewage or certain types of industrial wastes.

   "Total kjeldahl nitrogen" refers to the determination of organic nitrogen plus the ammonia nitrogen present. "Organic nitrogen" refers only to the organic portion present and does not include the ammonia nitrogen.

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Biological Evaluations

Standing Crops of Aquatic Organisms in Five South Carolina Tidal Streams

by WILLIAM R. TURNER and GEORGE N. JOHNSON
National Marine Fisheries Service
Beaufort, North Carolina

Introduction

Surveys were undertaken by the National Marine Fisheries Service, Beaufort, North Carolina, to determine the extent that aquatic macroorganisms utilized the tidal streams of Port Royal Sound, South Carolina. Five saltmarsh creeks were selected within the system and estimates of the standing crops of fishes and macroinvertebrates were obtained by blocking each creek with a net at high slack tide, effectively trapping organisms upstream when the waters receded. The five sites were located on tributaries to Chechessee Creek, Colleton River (2 sites), Mackay Creek and Skull Creek (Figure 1). Surveys were conducted in mid-April, mid-July and mid-October of 1970, to provide seasonal data at each of the five sites.

The Port Royal Sound Estuarine System is a complex of anastomosing streams bordered by vast expanses of salt marsh. Tidal amplitude at Hilton Head Island during these three study periods ranged from 5.8 to 6.0 ft. in April, 6.0 to 8.1 ft. in July, and 8.6 to 9.4 ft. in October. The saltmarsh creeks lose their identity at high tide as waters inundate the surrounding marshlands and many streams become interconnected. If a compensating exchange of organisms is assumed, however, a measure of the organisms leaving a particular drainage on a falling tide would provide an estimate of productivity.

Methods

The block net was 150 x 11 ft. and was made of 0.25-inch mesh (bar measure) knotted multifilament nylon. The central 20 ft. of net consisted of a trawl body tapering 22 ft. to the cod end. Four-inch diameter floats were spaced on 18-inch centers along the head-line; the foot line was made of braided leadcore nylon, 0.14 lb. to the running foot. A 3-ft. staff was tied to the head line and foot line at the end of each wing. A bridle was attached to each staff and received an anchor line for securing the net.

Block net used in sampling; photo by J. Darby, S. C. Water Resources Commission.

At high slack tide the net was stretched across a stream at the desired location, and anchored to two stakes (2 x 4 inches, 10 ft. long) driven deeply into the adjoining marsh along each bank. When the tide began to ebb, the force of the current set the net. After the waters drained from the marshlands and fell within the stream banks, rotenone was applied at the head of each rivulet to herd the gill-breathing organisms into the net. Since most of the streams did not drain completely, treatment of the waters with rotenone was necessary for a successful study. Rotenone was applied while the current was strong enough to sweep the distressed organisms into the net before they were trapped within intertidal pockets formed by the prominent oyster reefs. The net containing the catch was removed from the stream while enough water remained to operate the work boat, a sixteen-foot aluminum skiff powered by a 40 hp. outboard motor; the mucky substrate precluded working afoot. To free the net, the anchor lines were severed near the bridle leaving the stakes in position for subsequent sampling.

Larger organisms in the catch were counted, measured and weighed in the field. Specimens of uncertain identity were preserved in formalin for later identification. To avoid the arduous task of processing numerous small fishes and invertebrates in the field, a subsample of the smaller organisms was preserved for laboratory examination. These three to five pound subsamples were used to estimate the abundance of small organisms in the catches.

Net in place during ebb tide; photo by J. Darby, S. C. Water Resources Commission.

All estimates of productivity (standing crop) were based upon the surface acreage of waters within the creek banks upstream from the block net; flooded marshlands were not considered. Surface areas were computed from aerial photographs and U. S. Geological Survey topographic maps. The size of the survey sites ranged from 0.50 to 2.75 surface acres in April. In July the block net was repositioned at the smallest site, Chechessee Creek, to include 1.00 acre and this was retained during the October study. The surface area of the other sites remained the same throughout the study. On the high tide, salinity and temperature were measured with a portable salinometer at the water surface near each block-net site (Table 1).

Table 1. Temperature and Salinity of five South Carolina tidal streams in April, July and October, 1970.

Survey Site	*Study date*	*Salinity Parts per thousand*	*Water temperature °F*
	April		
Chechessee Creek	18	21.6	68.0
Colleton River No. 1	19	24.2	68.2
Colleton River No. 2	22	24.1	71.8
Mackay Creek	21	25.2	69.4
Skull Creek	20	26.1	68.4
	July		
Chechessee Creek	16	28.6	84.6
Colleton River No. 1	17	29.9	84.7
Colleton River No. 2	18	30.1	85.1
Mackay Creek	20	30.2	84.9
Skull Creek	19	30.1	84.6
	October		
Chechessee Creek	14	29.6	77.7
Colleton River No. 1	16	31.2	78.1
Colleton River No. 2	15	30.7	78.1
Mackay Creek	18	31.5	72.5
Skull Creek	19	31.5	69.4

Species Composition

Fifty-nine species of fishes and eight species of macroinvertebrates, representing 40 different families, were collected in the combined samples from the five tidal streams. The number of species that inhabited the tidal streams correlated with the surface area of the sampling sites; the largest site, Colleton River No. 1, supported the greatest diversity of macroorganisms (46), while the smallest sites, Chechessee Creek and Skull Creek, supported the least (31 and 33 species, respectively). The greatest variety of fishes was taken in Mackay Creek (39) and Colleton River No. 1 (38); fewer than 30 species were taken in each of the other three streams (Table 2). The relation between stream size and number of species may reflect the greater diversity and stability of habitat in the larger streams. Although water levels fluctuated considerably at all survey sites, more water remained in the larger streams at low tide than in the smaller streams.

Table 2. Number of species collected from five tidal streams in Port Royal Sound, South Carolina, during 1970.

Survey site	*Surface acres*	*Number of species* Fishes	Macro-invertebrates	Total
Chechessee Creek	[1]1.00	25	6	31
Skull Creek	1.00	26	6	32
Colleton River No. 2	1.40	29	6	35
Mackay Creek	1.40	39	4	43
Colleton River No. 1	2.75	38	8	46

1. Only 0.50 acre was included in the April survey on Chechessee Creek.

A greater number of species was collected during the summer (44) than during fall (40) and spring (36), (Table 3). Correspondingly, a high (though non-significant) correlation existed between numbers of species collected and mean water temperatures (r=0.98). Mean water temperatures were 84.8°F in July, 75.2°F in October and 69.2°F in April.

Table 3. Seasonal distribution of organisms in five tidal streams in Port Royal Sound, South Carolina, during 1970.

Survey month	*Mean surface temperature (°F)*	*Number of species* Fishes	Macro-invertebrates	Total
April	69.2	32	4	36
July	84.8	40	4	44
October	75.2	36	4	40

Net and catch being retrieved; photo by J. Darby, S. C. Water Resources Commission.

Standing Crop

Fishes — A mean standing crop of 8,132 fish per acre was taken in the three surveys combined. Although the greatest diversity of fishes occurred in saltmarsh creeks during the summer, greater numbers were taken during the spring and fall (Table 4).

Of the 59 species of fishes collected during the surveys, 10 species constituted approximately 98% of the total catch. Four of these species accounted for more than 95% of the total catch. Bay anchovy (a three survey average of 6,428) dominated the fish population within the tidal creeks, and was followed in order of decreasing abundance by Atlantic silverside (508 per acre), striped mullet (463 per acre), and silver perch (371 per acre). Mummichog, Atlantic thread herring, spot, striped anchovy, Atlantic menhaden, and Atlantic needlefish rounded out the 10 most abundant species, in that order. The abundance of these latter six species ranged from 20 to 61 individuals per acre, while the remaining 59 species were each represented by fewer than 20 individuals per acre.

Biomass (fresh weight) for the three surveys averaged 53.8 pounds per acre. The four most numerous species in the samples constituted over 80% of the biomass. Striped mullet (22.7 pounds per acre) accounted for 42% of the total biomass, and was followed by bay anchovy (13.0 pounds per acre), silver perch (4.0 pounds per acre) and Atlantic silverside (3.7 pounds per acre). Atlantic menhaden, spot, summer flounder and spotted seatrout each made up from 1.0 to 2.0 pounds per acre of the total crop. In aggregate, these eight species composed about 90% of the total sample weight. Biomass of the remaining 51 species was less than 1.0 pound per acre each. Fish biomass was greatest in the spring and summer surveys, 71.5 and 51.1 pounds per acre, respectively, and in the fall decreased to 39.0 pounds per acre.

Invertebrates — A mean standing crop of 453 invertebrates weighing an average of 6.8 pounds was taken per surface acre in all surveys combined. Grass shrimps, taken only during the spring survey, represented about 40% of the total number and 4% of the total weight of the invertebrates; for the three surveys, their mean standing crop was estimated at 180 per acre and their average biomass at 0.3 pounds per acre.

Blue crab made up most of the invertebrate biomass (70%), and was the third most important species in terms of weight. The average weight of blue crabs in the combined samples was 4.8 pounds per acre, and was exceeded only by striped mullet and bay anchovy. Numerically, blue crabs were represented in the combined samples by an average of 26 per acre.

Catch on beach; photo by J. Darby, S. C. Water Resources Commission.

White shrimp occurred in the saltmarsh creeks only during the summer but ranked second in importance in terms of total invertebrate biomass. This species made up 10% of the invertebrate biomass in the combined surveys, or about 0.7 pound per acre. The mean standing crop was estimated at 257 per acre in July. Brown spotted shrimp replaced white shrimp in the tidal streams in the fall, but were far less abundant. No penaeid shrimp were taken in the April surveys.

Squid was the second most abundant invertebrate and, like the blue crab, occurred at all sampling sites throughout the surveys. A mean of 146 squid weighing 0.7 pound per acre was estimated for the three surveys.

Species Diversity

Diversity indices were computed for the 1970 collections of fishes and macroinvertebrates in Port Royal Sound saltmarsh creeks to establish the relation between species and numbers in an environment little disturbed by human activity. Indices summarizing the saltmarsh creek community structure should provide a base for evaluating subsequent habitat alteration.

Three indices of diversity were used to describe seasonal collections from the five tidal streams. The Shannon-Wiener function takes into account both the number of species and individuals of each species and reduces them to a common scale. This function, expressed as $\bar{H} = -\sum_{i=1}^{s} p_i \log_e p_i$ where s is the total number of species and pi is the proportion of individuals belonging to the i-th species, generally increases with s but is also influenced by the evenness of distribution or equitability of individuals among the various species. A minimum hypothetical value is obtained if all individuals are of the same species, and a maximum value if each individual is of a different species.

Since the two components of the Shannon-Wiener function may react differently under certain environmental stresses, it is often desirable to consider them separately (Dahlberg and Odum, 1970). The number of species, or "species richness," component was measured by $D = (S-1)/\log_e N$

where N is the total number of individuals (Margalef, 1968). A measure of the distribution of individuals among species was obtained by the "evenness" index of Pielou (1966), $J = \bar{H}/\log_e S$

where H is the diversity measured by the Shannon-Wiener formula. Log S is a maximum of H for a fixed number of species.

Seasonal values of H for total organisms were lowest in spring, highest in summer, and decreased in fall reflecting changes in both the number of species and their relative abundance (Figure 4). Seasonal values for fishes paralleled the total values of all organisms for each index computed. Species richness (D) exerted a greater influence upon H than did relative abundance (J). The Shannon-Wiener index for invertebrates apparently was influenced more by the distribution of individuals than by the number of species.

Indices describing the associations or populations of aquatic organisms provide a more sensitive and reliable measure of environmental health than does the occurrence of individual indicator species (Dahlberg and Odum, 1970). Wilhm (1967) showed that streams receiving organic wastes supported a wealth of individuals but only a small number of species of benthic macroinvertebrates in enriched areas. Hopefully, the indices established for the saltmarsh creek populations will provide a basis for the detection and evaluation of pollution.

Utilization of Saltmarsh Creeks

Despite the large tidal amplitude, a wide variety of organisms utilized the saltmarsh creeks and surrounding marshes of Port Royal Sound during periods of tidal inundation. Sixty-seven different species of fishes and macroinvertebrates were disclosed by the 1970 tidal stream surveys. The saltmarsh creeks supported an average of 8,585 macroorganisms per acre and a biomass of 60.7 pounds per acre. Fishes made up 94.7% of the total number and 88.7% of the total weight of all organisms in the samples. The values for biomass are estimates only of the free swimming organisms large enough to be captured by the net and are thus in no way an estimate of the total biomass of animal life supported by these marshes. The biomass and numerical abundance of small organisms and benthic organisms undoubtedly far exceeded that of the large free swimming forms captured by our net.

Of the 67 different organisms recorded in the saltmarsh creeks, five species were represented by more than 100 individuals per acre and made up 92.2% of the numerical composition of the total catch. Bay anchovy was the dominant species in the catches and was followed by Atlantic silverside, striped mullet, silver perch and squid. Nine of the 67 species in the surveys had mean weights exceeding 1.0 pound per acre and accounted for 87.3% of the biomass. Ranked in order of decreasing importance, they were: striped mullet, bay anchovy, blue crab, silver perch, Atlantic silverside, Atlantic menhaden, spot, summer flounder and spotted seatrout.

Small forage species were the chief components of the tidal stream populations, however, the young of many sport and commercial species also utilized the habitat. Young Atlantic thread herring, American eel, gray snapper, bluefish, crevalle jack, silver perch, spotted seatrout, weakfish, spot, Atlantic

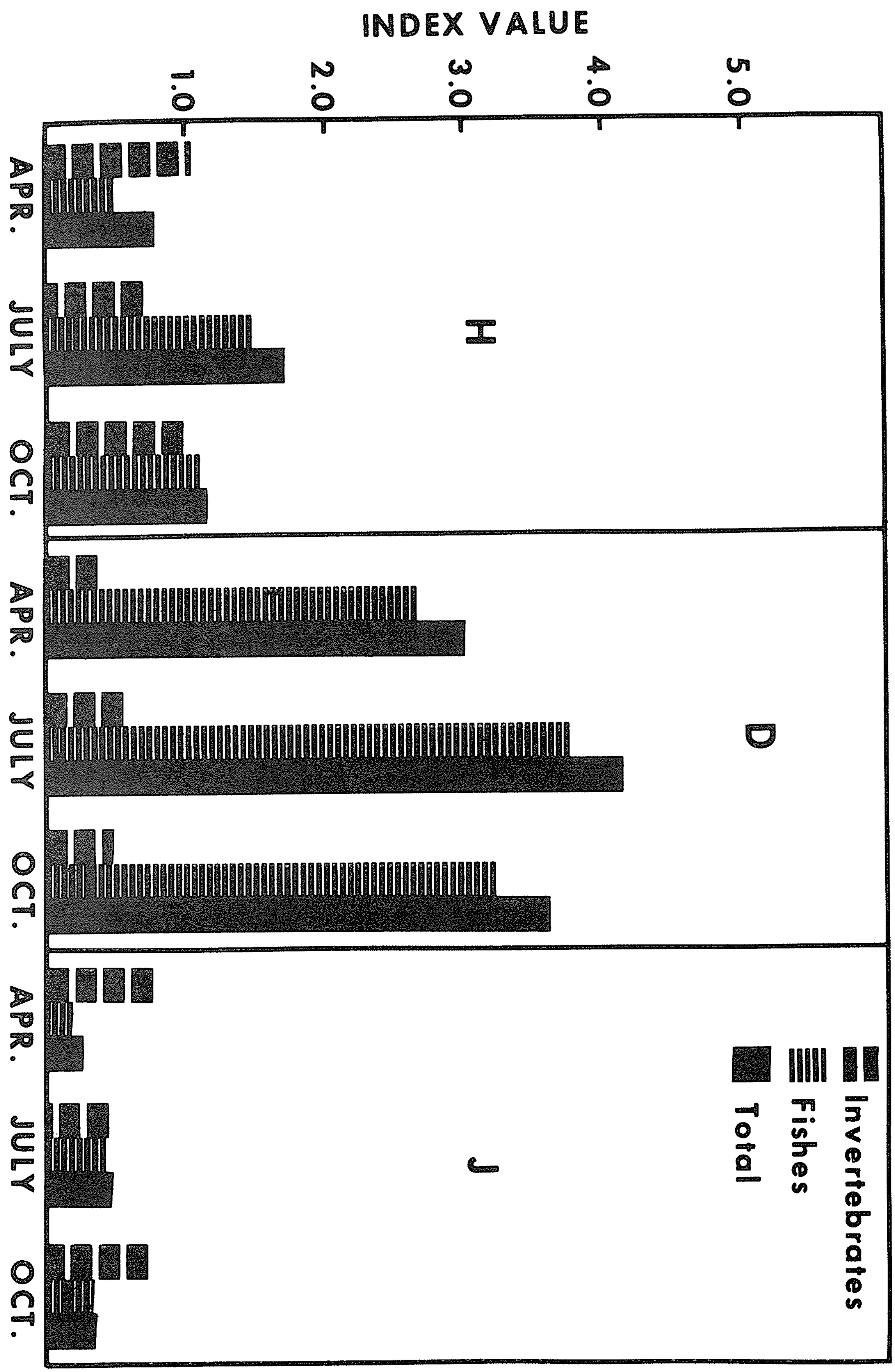

Figure 4. Seasonal cycles of species diversity in saltmarsh creeks of Port Royal Sound, 1970.


PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
TIDAL STREAM SAMPLING STATIONS
SCALE
NAUTICAL MILES
Atlantic Ocean
N
LADIES ISLAND
FORT FREMONT
CHISOLM ISLAND
COOSAW RIVER
BEAUFORT RIVER
Chowan Cr.
Station Cr.
PORT ROYAL SOUND
BEAUFORT
Brickyard Cr.
Mulligan Cr.
Albergottie Cr.
Ballast Cr.
Archers Cr.
Battery Creek
McCalley's Cr.
WHALE BRANCH
PORT ROYAL ISLAND
HILTON HEAD ISLAND
Skull Cr.
PINCKNEY ISLAND
Mackay Creek
DAWS ISLAND
CHECHESSEE RIVER
BROAD RIVER
HALL ISLAND
SPRING ISLAND
Chechessee Cr.
Victoria Bluff
COLLETON RIVER
Saw Mill Cr.
Bass Cr.
MAY RIVER
BULL ISLAND
Bryan Cr.
Bull Cr.
CALIBOGUE SOUND
COOPER RIVER
DAUFUSKIE ISLAND
Broad Creek
East Br. Boyd Cr.
West Br. Boyd Cr.
Boyd Cr.
Cole Cr.
Euhaw Cr.
Hazard Cr.
LEMON ISLAND

FIGURE 1

croaker, black drum, sheepshead, Atlantic spadefish, Spanish mackerel, great barracuda, striped mullet, paralichthid flounders, penaeid shrimps, and blue crab apparently used the saltmarsh creeks as nursery areas.

Adults of many predatory species also frequented the survey areas, thereby enhancing the sport fishing quality of the saltmarsh creeks. Among the larger of the predatory species were lemon shark, southern stingray, ladyfish, sea catfish, pigfish, silver perch, spotted seatrout, red drum, pinfish, Gulf flounder, southern flounder, summer flounder, and blue crab.

The most important adult non-predatory species frequenting the saltmarsh creeks was striped mullet. This important commercial fish abounded in all of the survey streams. Yearling Atlantic menhaden were also taken throughout the study area, but no young-of-the-year were found in the population samples. In past years large numbers of young-of-the-year of this valuable commercial species were taken in Sawmill Creek, which is adjacent to the Colleton River No. 1 survey site, during routine trawling surveys for estimating juvenile menhaden year-class strength (Pacheco, 1966). The absence of young-of-the-year menhaden in the present studies, presumably due to a weak year class, undoubtedly reduced the standing crops of fishes in the saltmarsh creeks.

Gravid fishes taken during the studies include bay anchovy (April and July—throughout area), Atlantic silverside (July—throughout area) and chain pipefish (July—Colleton River No. 1). Southern stingray bearing live young were taken from the Chechessee Creek site in July. Eggs of the sea catfish in advanced stages of development were taken in July from Mackay Creek. Although these fishes may not have spawned in the saltmarsh area, they were spawning within the confines of the study area.

Examples of organisms collected; photo by J. Darby, S. C. Water Resources Commission.

Summary

Based upon these surveys, saltmarsh creeks of Port Royal Sound supported a highly diversified macrofauna. Notwithstanding the large tidal amplitude, many species utilized the streams and the adjoining marshlands in some capacity. Conceivably, annual variations in spawning success of one or any number of species could influence the standing crops of organisms within saltmarsh creeks, and in interpreting results from a single year of sampling it must be assumed that the data are representative of a "typical" or average year. Continuation of the saltmarsh creek surveys for an additional year or two would therefore provide much more substantial data.

Identifying and enumerating macroorganisms; photo by J. Darby, S. C. Water Resources Commission.

Table 4.--Standing crops (catch per surface acre) of fishes and macroinvertebrates in 5 South Carolina tidal streams in April, July, and October 1970

[Numbers of organisms are subtended by total weights (pounds) in parentheses]

Organisms	Sampling site																	
	Chechessee Creek			Colleton River No. 1			Colleton River No. 2			Mackay Creek			Skull Creek			Totals		
	April	July	October	April	July	October	April	July	October	April	July	October	April	July	October	April	July	October
Fishes																		
Carcharhinidae - requiem sharks Negaprion brevirostris, lemon shark											1 (5.67)						<1 (0.99)	
Dasyatidae - stingrays Dasyatis americana, southern stingray	6 (10.52)	10 (7.93)				<1 (0.95)				<1 (1.03)						<1 (0.95)	1 (1.05)	<1 (0.35)
Elopidae - tarpons Elops saurus, ladyfish.											2 (1.74)						<1 (0.32)	
Clupeidae - herrings Brevoortia tyrannus, Atlantic menhaden	102 (2.62)	24 (1.85)	3 (0.37)	22 (1.14)	6 (0.32)			9 (0.85)			16 (1.79)	49 (6.87)	149 (6.56)	35 (3.00)		37 (1.56)	15 (1.25)	9 (1.32)
Dorosoma cepedianum, gizzard shad.													1 (0.37)			<1 (0.05)		
Opisthonema oglinum, Atlantic thread herring.		42 (0.32)	12 (0.19)			87 (1.83)		9 (0.08)	102 (1.97)		191 (1.45)	18 (0.36)	1 (0.03)	24 (0.17)	6 (0.15)	<1 (<0.01)	46 (0.35)	56 (1.14)
Engraulidae - anchovies Anchoa hepsetus, striped anchovy		7 (0.17)	2 (0.03)		43 (0.34)	48 (0.92)		5 (0.04)	4 (0.06)		74 (0.54)	6 (0.09)	1 (0.02)	7 (0.07)	60 (1.06)	<1 (<0.01)	32 (0.26)	27 (0.51)
Anchoa mitchilli, bay anchovy	114 (0.50)	168 (0.25)	2,109 (5.17)	25,111 (49.76)	80 (0.24)	870 (2.30)	82 (0.21)	914 (0.74)	5,913 (8.73)	15,804 (40.69)	264 (0.20)	8,500 (22.46)	5,340 (17.34)	9,836 (2.91)	5,495 (7.63)	13,715 (30.03)	1,573 (0.68)	3,997 (8.32)
Synodontidae - lizardfishes Synodus foetans, inshore lizardfish.											2 (0.14)						<1 (0.03)	
Ariidae - sea catfishes Galeichthys felis, sea catfish										7 (2.51)	21 (8.57)					1 (0.50)	4 (1.59)	
Anguillidae - freshwater eels Anguilla rostrata, American eel.	28 (0.50)			<1 (0.01)		1 (0.25)	27 (0.30)			1 (0.10)			12 (0.76)	1 (0.40)		10 (0.23)	<1 (0.05)	<1 (0.09)
Belonidae - needlefishes Strongylura marina, Atlantic needlefish	2 (0.62)	35 (0.56)	2 (0.16)		16 (0.18)	6 (0.43)	3 (0.66)	40 (0.71)	24 (2.06)	5 (0.85)	81 (1.48)	54 (5.72)		36 (0.71)	26 (2.45)	2 (0.34)	38 (0.64)	20 (1.95)

Table 4.--Continued

Organisms	Sampling site																	
	Chechessee Creek			Colleton River No. 1			Colleton River No. 2			Mackay Creek			Skull Creek			Totals		
	April	July	October	April	July	October	April	July	October	April	July	October	April	July	October	April	July	October
Fishes																		
Hemiramphidae - halfbeaks																		
Hyporhamphus unifasciatus, halfbeak.				<1 (0.01)		<1 (0.01)				3 (0.09)						<1 (0.02)		<1 (<0.01)
Cyprinodontidae - killifishes																		
Fundulus heteroclitus, mummichog	162 (0.56)	91 (0.31)		161 (0.68)	5 (0.04)	<1 (<0.01)	271 (1.64)	1 (0.01)		52 (0.14)			163 (1.44)	60 (0.43)		162 (0.86)	22 (0.11)	<1 (<0.01)
Fundulus majalis, striped killifish				28 (0.06)		<1 (<0.01)							242 (0.53)			45 (0.10)		<1 (<0.01)
Gadidae - codfishes and hakes																		
Urophycis tenuis, white hake.										<1 (0.06)						<1 (0.01)		
Syngnathidae - pipefishes and seahorses																		
Syngnathus louisianae, chain pipefish.			1 (0.02)		<1 (<0.01)										1 (<0.01)		<1 (<0.01)	<1 (<0.01)
Lutjanidae - snappers																		
Lutjanus grisseus, gray snapper.						<1 (<0.01)						4 (0.03)						<1 (<0.01)
Pomatomidae - bluefishes																		
Pomatomus saltatrix, bluefish.		1 (0.06)								1 (0.02)		6 (0.01)		4 (0.36)	19 (0.21)	<1 (<0.01)	<1 (0.06)	4 (0.03)
Carangidae - jacks, scads, and pompanos																		
Caranx hippos, crevalle jack			1 (0.01)			<1 (0.01)			7 (0.01)		<1 (0.07)						<1 (0.01)	2 (<0.01)
Chloroscombrus chrysurus, bumper.		7 (0.02)	8 (0.05)		<1 (<0.01)	53 (0.15)		6 (<0.01)	8 (0.01)		7 (0.03)	104 (0.39)		6 (0.01)	8 (0.07)		4 (0.01)	42 (0.15)
Oligoplites saurus, leatherjacket		21 (0.09)															3 (0.01)	
Selene vomer, lookdown.			3 (0.02)			1 (0.01)			<1 (0.01)									1 (<0.01)
Pomadasyidae - grunts																		
Orthopristis chrysopterus, pigfish					1 (0.03)			14 (0.40)			6 (0.06)						4 (0.10)	
Gerridae - mojarras																		
Eucinostomus gula, silver jenny.						9 (0.11)						61 (1.12)						15 (0.25)
Sciaenidae - drums																		
Bairdiella chrysura, silver perch.		1,092 (3.21)	24 (0.90)	1 (0.32)	470 (3.12)	105 (3.81)	19 (2.67)	156 (0.98)	155 (6.64)	38 (3.66)	1,205 (7.12)	2,058 (8.16)	67 (10.21)	404 (3.26)	141 (10.25)	21 (2.83)	622 (3.49)	470 (5.61)
Cynoscion nebulosus, spotted seatrout.					32 (1.76)	44 (3.81)		4 (0.09)	4 (0.10)	<1 (0.13)	19 (0.72)	7 (0.23)	3 (1.13)	2 (1.19)	19 (3.31)	<1 (0.19)	16 (0.95)	21 (1.89)
Cynoscion regalis, weakfish.								3 (0.06)									<1 (0.01)	
Leiostomus xanthurus, spot.	92 (0.16)	16 (0.80)		28 (0.06)	101 (2.62)	12 (1.31)	6 (0.01)	<1 (0.03)	1 (0.17)		36 (3.85)	31 (3.31)	46 (2.33)	49 (2.38)	13 (1.85)	25 (0.37)	52 (2.10)	12 (1.37)
Micropogon undulatus, Atlantic croaker.				119 (0.55)	<1 (0.18)								13 (0.03)	1 (0.34)		48 (0.22)	<1 (0.11)	
Pogonias cromis, black drum.					<1	1 (0.55)						6 (1.81)			1 (0.23)		<1 (0.07)	2 (0.57)

Table 4.--Continued

Organisms	Sampling site: Chechessee Creek			Colleton River No. 1			Colleton River No. 2			Mackay Creek			Skull Creek			Totals		
	April	July	October	April	July	October	April	July	October	April	July	October	April	July	October	April	July	October
Fishes																		
Sparidae - porgies																		
Archosargus probatocephalus, sheepshead					<1 (<0.01)						3 (0.03)	1 (0.11)					<1 (<0.01)	<1 (0.02)
Lagodon rhomboides, pinfish												1 (0.26)						<1 (0.05)
Ephippidae - spadefishes																		
Chaetodipterus faber, Atlantic spadefish					<1 (<0.01)						<1 (<0.01)						<1 (<0.01)	
Trichiuridae - cutlassfishes																		
Trichiurus lepturus, Atlantic cutlassfish													2 (0.03)			<1 (<0.01)		
Scombridae - mackerels and tunas																		
Scomberomorus maculatus, Spanish mackerel		3 (0.10)	7 (0.63)		<1 (<0.01)			<1 (<0.01)	<1 (0.01)		25 (0.84)			4 (0.24)			6 (0.20)	1 (0.08)
Gobiidae - gobies																		
Gobiosoma bosci, naked goby	24 (0.08)						6 (0.01)									3 (0.01)		
Microgobius gulosus, clown goby										1 (<0.01)		<1 (<0.01)				<1 (<0.01)		<1 (<0.01)
Microgobius thalassinus, green goby	16 (0.02)															1 (<0.01)		
Triglidae - searobins																		
Prionotus scitulus, leopard searobin								<1 (<0.01)									<1 (<0.01)	
Blenniidae - combtooth blennies																		
Hypsoblennius hentzi, feather blenny									<1 (0.01)									<1 (<0.01)
Stromateidae - butterfishes																		
Peprilus alepidotus, southern harvestfish					<1 (<0.01)	8 (0.24)		3 (<0.01)									<1 (<0.01)	3 (0.09)
Poronotus triacanthus, butterfish			2 (0.02)										1 (0.03)		6 (0.39)	<1 (<0.01)		1 (0.05)
Sphyraenidae - barracudas																		
Sphyraena barracuda, great barracuda						4 (0.03)												1 (0.01)
Mugilidae - mullets																		
Mugil cephalus, Striped mullet	6 (1.26)	736 (23.31)	20 (1.46)	5 (0.59)	1,147 (23.31)	343 (20.82)	1,012 (95.71)	2 (0.06)	10 (0.52)	159 (22.50)	2,011 (118.18)	55 (2.36)	475 (15.16)	449 (2.56)	6 (0.80)	302 (25.95)	948 (33.84)	140 (8.42)
Atherinidae - silversides																		
Membras martinica, rough silverside				42 (0.37)			4 (0.01)									17 (0.15)		
Menidia menidia, Atlantic silverside	522 (3.72)	28 (0.05)	425 (2.21)	172 (1.61)		1,241 (8.20)	94 (1.09)	46 (0.08)	1,265 (9.20)	873 (7.30)	516 (0.85)	1,056 (6.98)	902 (13.28)	180 (0.24)	220 (1.21)	424 (4.44)	132 (0.21)	968 (6.44)

Table 4.--Continued

Organisms	Sampling site																	
	Chechessee Creek			Colleton River No. 1			Colleton River No. 2			Mackay Creek			Skull Creek			Totals		
	April	July	October	April	July	October	April	July	October	April	July	October	April	July	October	April	July	October
Bothidae - lefteye flounders																		
Ancylopsetta quadrocellata, ocellated flounder. . . .										2 (0.03)						<1 (0.01)		
Citharichthys spilopterus, bay whiff					<1 (0.01)						<1 (0.03)	6 (0.08)					<1 (0.01)	1 (0.01)
Etropus crossotus, fringed flounder.					<1 (<0.01)	3 (0.02)					7 (0.01)						2 (<0.01)	1 (<0.01)
Paralichthys albigutta, Gulf flounder				<1 (0.27)	1 (0.15)	<1 (0.07)	6 (2.14)					6 (0.54)	2 (0.55)			2 (0.61)	<1 (0.06)	1 (0.12)
Paralichthys dentatus, summer flounder					3 (1.87)		6 (2.15)			7 (5.81)	8 (5.14)			1 (0.15)		3 (1.58)	3 (1.65)	
Paralichthys lethostigma, southern flounder			1 (0.31)			1 (0.28)					6 (4.54)				1 (0.36)		1 (0.84)	1 (0.19)
Paralichthys spp., unidentified young. . . .	18 (0.04)			533 (0.74)						23 (0.05)			112 (0.12)			230 (0.32)		
Cynoglossidae - tonguefishes																		
Symphurus plagiusa, blackcheek tonguefish . .	30 (0.06)			56 (0.22)	<1 (<0.01)		13 (0.01)						13 (0.03)			27 (0.10)	<1 (<0.01)	
Balistidae - triggerfishes and filefishes																		
Alutera schoepfi, orange filefish								<1 (<0.01)									<1 (<0.01)	
Monacanthus setifer, pygmy filefish.								1 (<0.01)									<1 (<0.01)	
Diodontidae - porcupinefishes																		
Chilomycterus schoepfi, striped burrfish.								<1 (<0.01)	<1 (0.01)								<1 (<0.01)	<1 (<0.01)
Batrachoididae - toadfishes																		
Opsanus tau, oyster toadfish.										<1 (0.08)						<1 (0.02)		
Total fishes (59 species)	1,122 (20.66)	2,281 (39.03)	2,620 (11.55)	26,278 (56.39)	1,905 (34.36)	2,837 (46.11)	1,549 (106.60)	1,213 (4.13)	7,493 (29.51)	16,976 (85.05)	4,501 (163.05)	12,029 (60.89)	7,545 (69.95)	11,099 (18.42)	6,022 (29.97)	15,075 (71.45)	3,524 (51.05)	5,796 (39.03)

Table 4.--Continued

Organisms	Sampling site: Chechessee Creek			Colleton River No. 1			Colleton River No. 2			Mackay Creek			Skull Creek			Totals		
	April	July	October	April	July	October	April	July	October	April	July	October	April	July	October	April	July	October
Invertebrates																		
Penaeidae - penaeid shrimps																		
Penaeus setiferus, white shrimp		1,232 (2.07)			166 (4.14)			4 (0.05)			144 (1.21)			49 (0.56)			257 (2.09)	
Penaeus duorarum, brown spotted shrimp . . .			57 (1.00)			47 (0.91)			66 (2.33)			4 (0.26)			60 (1.26)			46 (1.11)
Palaemonidae - grass shrimps *Palaemonetes* spp., (2 species)	14 (0.02)			126 (0.22)			2,438 (4.05)						39 (0.06)			540 (0.90)		
Callianassidae *Upogebia affinis*					<1 (<0.01)												<1 (<0.01)	
Portunidae - swimming crabs *Callinectes sapidus*, blue crab.	78 (10.52)	24 (6.06)	34 (3.81)	2 (0.18)	<1 (0.16)	7 (3.01)	64 (25.18)	9 (2.50)	16 (3.78)	42 (3.72)	26 (5.62)	13 (2.87)	155 (8.59)	30 (8.50)	9 (2.51)	50 (7.77)	14 (3.49)	14 (3.17)
Callinectes ornatus						4 (0.04)												1 (0.02)
Loliginidae - squids *Lolliguncula brevis*	50 (0.44)	63 (0.28)	15 (0.11)	708 (3.21)	64 (0.33)	70 (0.19)	11 (0.06)	79 (0.31)	69 (0.26)	33 (0.21)	80 (0.71)	61 (0.23)	107 (0.53)	24 (0.10)	135 (0.28)	304 (1.41)	64 (0.36)	69 (0.21)
Total invertebrates (8 species).	142 (10.98)	1,319 (8.41)	106 (4.92)	836 (3.61)	230 (4.63)	128 (4.15)	2,513 (29.29)	92 (2.86)	151 (6.37)	75 (3.93)	250 (7.54)	78 (3.36)	301 (9.18)	103 (9.16)	204 (4.05)	894 (10.08)	335 (5.94)	130 (4.51)
Total organisms (67 species)	1,264 (31.64)	3,600 (47.44)	2,726 (16.47)	27,114 (60.00)	2,135 (38.99)	2,965 (50.26)	4,062 (135.89)	1,305 (6.99)	7,644 (35.88)	17,051 (88.98)	4,751 (170.59)	12,107 (64.25)	7,846 (79.13)	11,202 (27.58)	6,226 (34.02)	15,969 (81.53)	3,859 (56.99)	5,926 (43.54)

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Seasonal Distribution and Relative Abundance of Fishes in the Channel Reaches and Shore Areas

Delbert B. Hicks
Environmental Protection Agency
Division of Field Investigations
Cincinnati Center, Cincinnati, Ohio

Introduction

The purpose of this study was to determine the species composition, relative abundance and distribution of marine fishes in Port Royal Sound and adjoining waters during April, July and October, 1970.

Materials and Methods

Fish were sampled in Port Royal Sound and adjoining waters by use of experimental type gill nets, constructed of monofilament mesh grading from ¾ inch to 2½ inches (bar measure). Each net was 125 feet long and 6 feet deep. Sampling stations were identical with the sites established for studying water chemistry, bottom animals and zooplankton (Figure 1). Numerical designations were retained accordingly. Two distinct types of aquatic habitat characterized the sampling stations, deep channels and shallow near-shore areas. The deep channels were characterized by deep waters, sandy to clayey bottoms, and swift currents. Mud flats with oyster shoals and adjoining marshlands typified the nearshore habitat, except at the most seaward stations where marshlands were replaced by sandy beaches. The fish fauna of the near-shore areas was surveyed only in October.

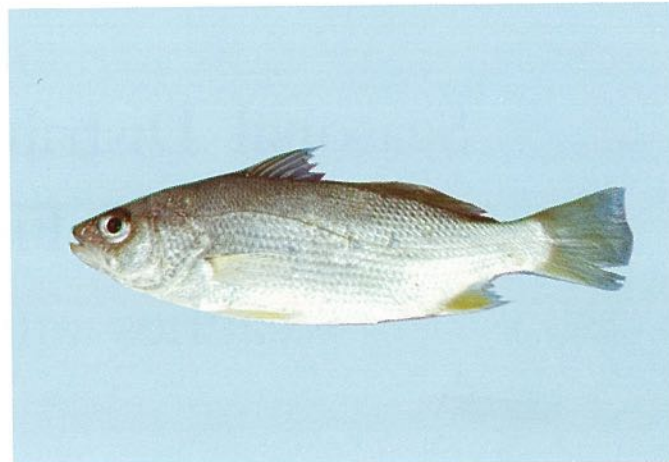
Fish collections from the channel area were obtained by anchored gill nets and by gill nets drifted with the current. Only the stationary nets were used during the April survey and drift nets and anchored nets were fished during July. In October, drift nets were used exclusively. All nets were fished horizontally for nearly equal periods at depths of 1-2 feet and 3-4 feet above the bottom.

Anchored nets were fished for 24 hour periods. During this time, the nets were raised frequently for fish removal, inspection and repairs. The twenty-four hour period constituted one net day of fishing effort.

For drift fishing, one end of the net was secured to a work boat by a light line, and a small sea anchor was attached to the opposite end of the net. The boat drifted freely with the current for two 1-hr. periods on both incoming and outgoing tides. Drift fishing was limited to daylight hours.

Near-shore sites selected for sampling were usually adjacent to the mouths of small tidal streams where oyster shoals were prominent. Approximately one hour prior to high tide, two nets were set across a shoal, each secured by anchors. Nets were fished until one hour after slack high tide upon which they were raised and cleaned of fish. Catches from the two sets at each site were composited. Catches in drift nets and shallow water sets were reported as numbers of fish per net hour.

The fish of each species were counted and total lengths of individuals were measured to the nearest 0.1 inch. Specimens of questionable identity were preserved in formalin and returned to the laboratory for examination. Fish nomenclature is in accordance with current usage adopted by the American Fisheries Society (1960).



Silver Perch (*Bairdella chrysura*); photo by National Marine Fisheries Service.

Results And Discussion

In the absence of closely regulated sport and commercial fisheries, experimental fishing serves as the principal means of determining species composition, distribution and relative abundance of a fish communinty. However, experimental sampling has inherent biases which require consideration before the catch information can be evaluated. Basic to this problem is the choice of sampling gear. All fishing gears are selective to species, size and age of fish they will capture. However, a given piece of gear will usually yield sufficient catch data for measuring changes in relative abundance and distribution of various fish species. The gear, when fished in the same manner, will usually catch the same proportion of the fish population exposed to it. Thus, catch per unit effort provides a fair measure of a species relative abundance.

To compare the relative abundance of one species to another is difficult because all species are not equally subject to capture by the same gear. If continuous sampling is impossible, as was the case in the present study, sampling should be conducted during periods when yields are greatest to help ensure that differences in catches are significant. Greater confidence can be placed in larger catches than in smaller numbers.

In the present study, surveys with gill nets coincided with maximum tidal exchange periods for the year. Associated with these peak tidal fluctuations would be an expected increase in the fish activities brought about by the seasonal flushing of nutrients and food material from the marshlands adjoining Port Royal Sound.

Fish Fauna of the Channel Areas

Because two dissimilar sampling techniques were employed in the surveys of the channel reaches, the order of the data presentation will be respective to the techniques used to gather the information and the survey period in which it was obtained.

Anchored Net Sets, April and July, 1970

Fish collected during April and July by the anchored sets totaled 1,588 individuals, representing 32 species. Catches in April (Table 1) accounted for 24 species and exceeded by 7 the number of species recorded in July. However, nearly 50% more fish were caught during the summer than during the spring. Correspondingly, the average catch from April compared to July increased from 12.2 to 19.8 fish per net day.

Flounder *(Paralichthys lethostigma)*; photo by National Marine Fisheries Service.

Table 1. Summary of Catch Data from Anchored Net Sets in Channel Reaches, Port Royal Sound, South Carolina, April and July Surveys, 1970

	April Survey			*July Survey*		
Species of Fish	*No. of Station Species Occurred*	*No. Caught*	*Ave. Catch per Net Day*	*No. of Station Species Occurred*	*No. Caught*	*Ave. Catch per Net Day*
Finetooth shark	4	8	0.1	8	119	2.4
Scalloped hammerhead	3	11	0.2	8	68	1.4
Bonnethead shark	5	6	0.1			
Atlantic guitarfish	3	13	0.2			
Atlantic stingray	5	7	0.1			
Atlantic sturgeon	1	2	<0.1			
Longnose gar	8	77	1.4	2	2	<0.1
Atlantic menhaden	10	314	5.7	9	630	12.9
Atlantic thread herring				4	25	0.5
Gafftopsail catfish				2	4	0.1
Sea catfish	4	10	0.2	7	29	0.6
Spotted hake	5	26	0.5			
Black seabass	2	3	<0.1			
Bluefish	6	24	0.4	2	4	0.1
Bumper				1	1	<0.1
Silver perch	4	42	0.8	3	15	0.3
Spotted seatrout				1	1	<0.1
Weakfish	1	1	<0.1			
Spot				4	19	0.4
Northern kingfish	8	33	0.6	6	21	0.4
Atlantic croaker				4	4	0.1
Atlantic cutlassfish	1	1	<0.1	1	1	<0.1
Spanish mackerel				1	3	<0.1
Northern searobin	1	2	<0.1			
Butterfish	2	3	<0.1			
Fringed flounder	1	2	<0.1			
Summer flounder	3	6	0.1			
Southern flounder	3	6	0.1			
Hogchoker	1	1	<0.1			
Blackcheek tonguefish	7	42	0.8			
Sharksucker				1	1	<0.1
Striped burrfish	1	1	<0.1			
Total Catch		641	12.2		947	19.8

Atlantic menhaden comprised nearly 56% of the total number of fishes caught and was widely distributed throughout the study area. This species was comparatively more abundant in July than in April, and average catch per net day during the two sampling periods increased from 5.7 to 12.9 fish. The modal length of menhaden in the collections increased from 143 mm (5.6 in.) in April to 173 mm. (6.9 in.) in July which is a modest growth rate for yearling fish, (Figure 2). Other species indicating discernible trends in seasonal abundance were the longnose gar, finetooth shark, scalloped hammerhead and blackcheek tonguefish.

The longnose gar is a euryhaline species often found foraging in South Carolina tidal waters (Bearden, 1961). This species numbered 77 individuals in the catches during April and occurred in collections from all stations except the two most seaward sites (stations 1 and 10). A lack of nearby marshland probably accounted for the lack of gar at these stations. Average catch of gar decreased from 1.4 to less than 0.1 fish per net day from April to July when only two fish were caught. Only adult fish were taken in the April population and probably represent the population structure of this species in the estuarine environment. No juvenile gar were taken in any of the catches, nor were any reported present in the tidal streams. Several of the larger individuals were gravid females. Ovaries inspected were well developed as evidenced by their size and the greenish color of the eggs which were loosely held by the ovarian tissues. Gar probably use Port Royal Sound as a foraging area until spring spawning behavior directs them to regions of fresher water. Emigration of gar from the area also coincided with increasing water temperature and maximum salinity which increased on the average from 66.4° F and 26.2‰ (parts per thousand) in April to 86.2° F and 37.9‰ in July.

The finetooth shark was the most numerous shark in catches from the channel areas, during April and July. This species increased in abundance from April to July with average catches of 0.1 and 2.4 fish per net day, respectively. Finetooth sharks are known to be common in South Carolina waters. The principal distribution of the species is in the Gulf, but occasional stragglers do appear in the south Atlantic as far north as North Carolina (Breder, 1948). The finetooth shark is a relatively small shark and its physical features are very similar to those of the Atlantic sharpnose shark which is commonly reported along the Atlantic coast. The definitive features used to separate the two species are the placement of the second dorsal fin and the dentition (Casey, 1964).

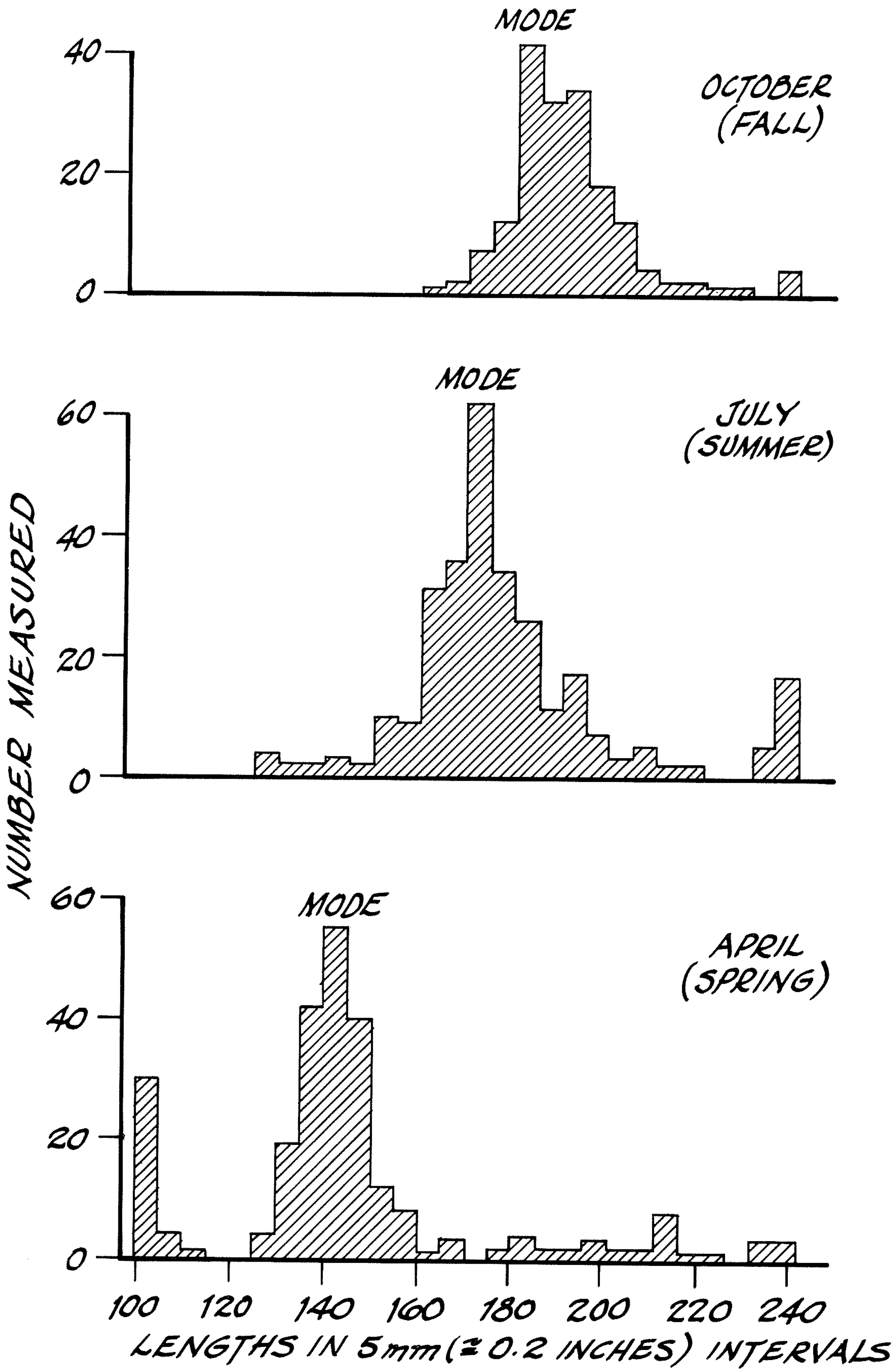
A second shark species that increased in relative abundance from April to July was the scalloped hammerhead. The average catch per net day advanced from 0.1 fish in April to 1.4 fish in July. The increase was due to an influx of young-of-the-year fish into the study area. Bohlke and Chaplin (1968) have reported unborn specimens of the species to measure nearly 18 inches. A majority of the scalloped hammerhead taken in July measured from 16 to 24 inches.

Blackcheek tonguefish numbered 42 individuals in the collection from April but were absent from the samples in July. This species has been shown in other studies from other waters to be least abundant during the summer (Copeland and Fruh, 1970).

Prior to this study, the northern kingfish was regarded as the least common of the three kingfish species found in South Carolina waters (Bearden, 1961). Catches in the channel during April and July yielded a total of 54 northern kingfish, ranging in length from 5.9 to 13.0 inches. No other species of kingfish was taken during this study. Other species included in the catches exhibited either no apparent trend in seasonal distribution and relative abundance or were represented by only a few individuals and hence considered incidental in catches taken by the anchored net sets.

To obtain credible data from anchored sets in the channel required an inordinate demand of manpower to maintain the nets in sampling condition. Blue

Black Sea Bass *(Centropristis striata)*; photo by National Marine Fisheries Service.



LENGTH-FRENQUENCY OF ATLANTIC MENHADEN IN PORT ROYAL SOUND, SOUTH CAROLINA, 1970

Figure 2.

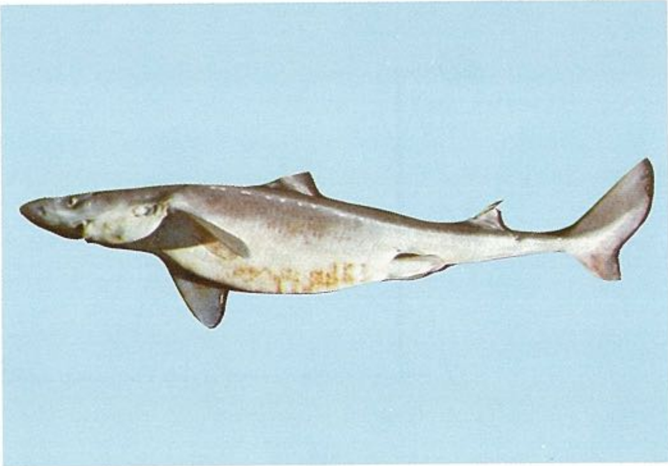
crabs were a constant menance to the gill nets; their entanglement in and removal from the webbing often caused extensive damage. In general, drift nets were spared this aggravation.

Drift Nets, July and October, 1971

Drift nets were employed in July to establish base line data that could be used to judge changes in relative abundance and distribution of channel species taken by the same method in October. Species diversity of the catches by drift nets in July was similar to that reported for the anchored sets in July (Tables 1 and 2); although, the catches are not readily comparable on a quantitative basis because of spacial and temporal differences in fishing effort. The qualitative similarities indicated that gear selectivity was not affected by the method employed.

Combined catches from drift nets in July and October yielded a total of 1,038 fishes representing 23 species (Table 2). Average catch per net hour increased from 12.2 in July to 17.8 in October. This substantial increase was partially due to a greater number of Atlantic menhaden in catches during the fall.

Average catch of menhaden increased from 5.7 to 13.6 fish per net hour from July to October. The modal length of the October population was 183 mm (7.3 in.) which represented a 10 mm increase from July. Increased catches of menhaden in October indicated that the population had moved into the lower reaches of the estuary beginning their fall migration to offshore waters. Few menhaden were taken by gill net sets at the four of the most inland stations sampled (Stations 5, 6, 7 and 9). Other species that were more abundant in the fall than during the summer included spot, northern kingfish, and bluefish. During July, catches for these species were 1.1, 0.3 and less than 0.1 fish per net hour, respectively. The same unit effort in October yielded 1.5, 0.8 and 0.4 fish, respectively. These species also were more widely distributed in the fall. The presence of six blackcheek tonguefish in the collections from October marks the first appearance of this species since April.



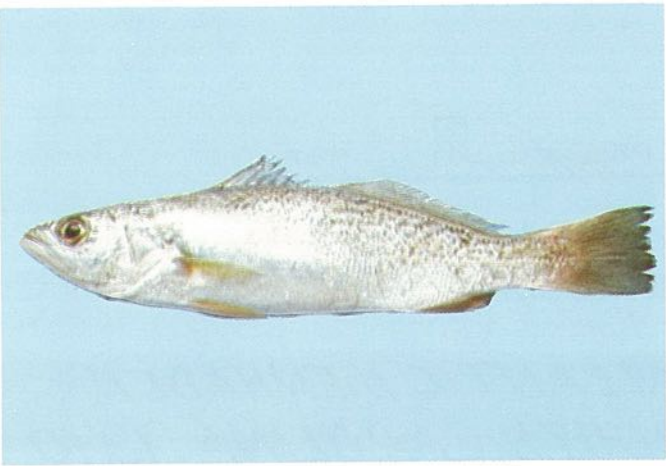
Spiny Dogfish *(Squalus acanthias)*; photo by National Marine Fisheries Service.

Species less abundant in October were the finetooth shark, scalloped hammerhead shark, silver perch and sea catfish. The brief appearance of finetooth sharks during the summer is probably the principal reason for its lack of notoriety in South Carolina waters. As mentioned previously, the majority of scalloped hammerhead sharks taken in July were juveniles, thus Port Royal Sound must serve as a summer nursery grounds for this species. The average catch of silver perch per net hour decreased from 0.5 fish to less than 0.1 fish from July to October. Other species common to catches by drift nets in July and October indicated little change in relative abundance based on catch per unit effort.

Fish Fauna of the Near-Shore Habitat

Catches from shallow sets in near-shore areas yielded the greatest seasonal variety taken during the entire study. Twenty-eight species were recorded of which 14 kinds were of noted commercial and sport value (Table 3). Also included were 11 species new to the catches.

The drum family (Scianidae) was represented by seven species which included spot, the most numerous fish in the combined collections from near-shore. (Spot was also the second most numerous species in the channel sets during October). The longnose gar ranked second in total numbers, and was taken at all stations; a distribution pattern similar to that reported in the spring.

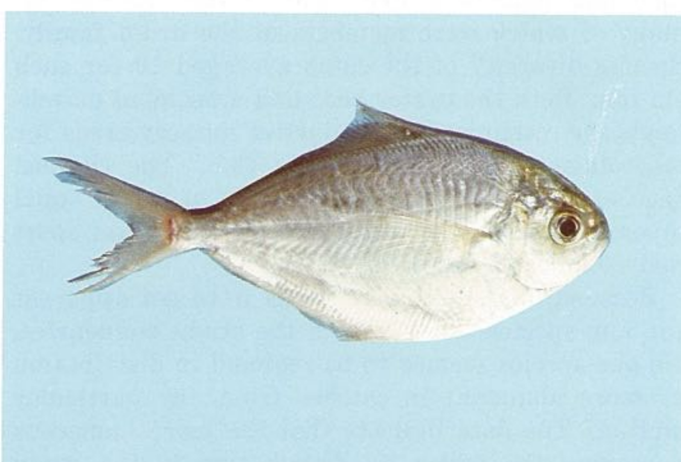


Sea Trout (*Cynoscion nebulosus*); photo by National Marine Fisheries Service.

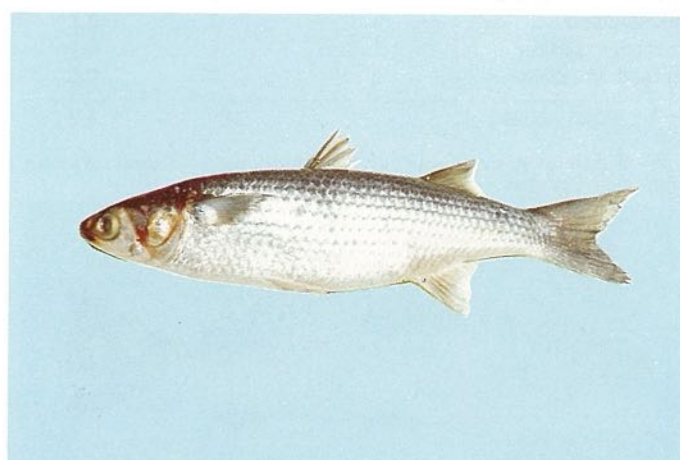
Table 2. Summary of Catch Data from Drift Nets in Channel Reaches, Port Royal Sound, July and October Surveys, 1970, South Carolina

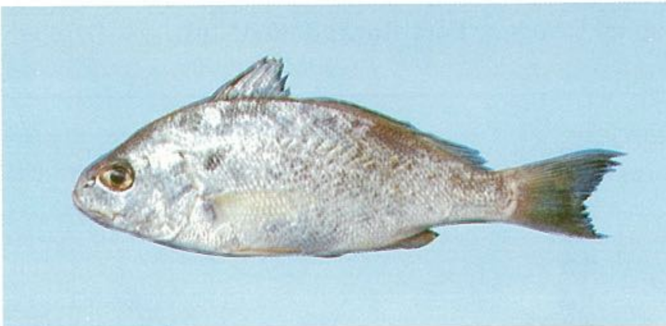
	July Survey			October Survey		
Species of Fish	No. of Station Species Occurred	No. Caught	Ave. Catch per Net Day	No. of Station Species Occurred	No. Caught	Ave. Catch per Net Hour
Finetooth shark	8	49	1.4			
Scalloped hammerhead	6	34	0.9			
Bonnethead shark	1	1	<0.1	1	1	<0.1
Atlantic stingray	1	1	<0.1			
Longnose gar				2	4	0.1
Atlantic menhaden	8	206	5.7	9	491	13.6
Atlantic thread herring	3	7	0.2	2	9	0.3
Gafftopsail catfish	1	1	<0.1	1	1	<0.1
Sea catfish	5	20	0.6			
Bluefish	1	1	<0.1	3	15	0.4
Bumper	2	4	0.1	1	2	<0.1
Silver perch	3	19	0.5	3	3	<0.1
Spotted seatrout				1	2	<0.1
Spot	5	38	1.1	7	54	1.5
Northern kingfish	5	10	0.3	7	29	0.8
Atlantic croaker	4	9	0.3			
Atlantic cutlassfish	1	1	<0.1			
Spanish mackeral	1	2	<0.1	1	1	<0.1
Leopard searobin	1	6	0.2	1	1	<0.1
Butterfish	3	6	0.2			
Fringed flounder	1	1	<0.1	1	1	<0.1
Blackcheek tonguefish				2	6	0.2
Sharksucker				2	2	<0.1
Total Catch		416	12.2		622	17.8

Butterfish *(Pronotus triacabthus)*; photo by National Marine Fisheries Service.



Striped mullet *(Mugil cephalus)*; photo by National Marine Fisheries Service.





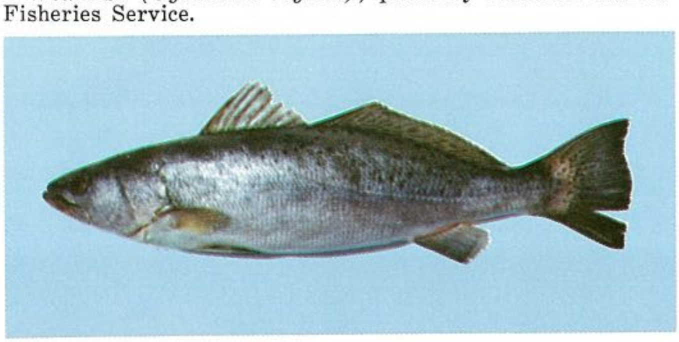
Spot *(Leiostomus xanthurus)*; photo by National Marine Fisheries Service.

Table 3

Summary of Catch Data from Near-Shore Gill Net Sets, Port Royal Sound, South Carolina October 1970

Species of Fish	*No. of Stations Species Occurred*	*No. Caught*	*Avg. Catch per Net Hour*
Lemon shark	2	4	0.1
Atlantic stingray	3	3	0.1
Longnose gar	6	24	0.6
Ladyfish	2	5	0.5
Atlantic menhaden	2	2	0.1
Gafftopsail catfish	1	1	<0.1
Sea catfish	3	18	0.6
Bluefish	3	3	0.1
Pigfish	5	8	0.3
Silver perch	3	6	0.2
Spotted seatrout	5	15	0.5
Weakfish	1	1	<0.1
Spot	4	43	1.5
Northern kingfish	4	11	0.4
Black drum	4	11	0.4
Red drum	2	4	0.1
Sheepshead	2	4	0.1
Pinfish	3	3	0.1
Spadefish	1	1	<0.1
Spanish mackerel	1	1	<0.1
Leopard searobin	2	3	0.1
Butterfish	1	1	<0.1
Striped mullet	3	7	0.1
Gulf flounder	2	2	0.1
Southern flounder	2	3	0.1
Sharksucker	1	1	0.1
Northern puffer	1	1	0.1
Striped burrfish	2	3	0.1
Total catch		189	6.9

Weakfish *(Cynoscion regalis)*; photo by National Marine Fisheries Service.



The appearance of substantial numbers of longnose gar in catches from October indicates a fall return of the gar population to the study area. October water temperatures averaged nearly 5 degrees lower than in July. Average high salinity decreased from 37.9% in July to 31.5% in October. Because salinity tolerance of most euryhaline species increases with reduced temperatures, environmental conditions in October were probably more suited for the return of gar species from freshwater. As in the spring, the fall population was one of adult individuals. Following the longnose gar in descending order of abundance were the sea catfish, spotted trout and black drum. All other species numbered 10 or fewer individuals for the total catch in near-shore waters which was representative of 28 net hours of effort.

The occurrence of sea catfish only in the near-shore sets indicted that the population moved from the deepwater environment of the channel reaches to the shallower zones near shore following summer spawning. Several specimens taken during the summer survey had evidence of recent spawning.

Summary

A total of 47 species of fish were caught during the study. A check list of fish species for Port Royal Sound has yet to be reported, but Bearden (1961) lists over 100 kinds of marine fishes common to South Carolina waters. The lack of any previous collections by gill nets from the study area, however, precludes judging the representativeness of the present data.

Two types of habitat generally characterized the sampling stations, channel reaches and adjoining mud flats with prominent near-shore oyster beds and adjacent marshlands. These two distinct habitat types supported, at least in the fall, fish communities markedly different in species composition. The near-shore fish fauna comprised a wide variety including numerous sport and commercial species, many of which were members of the drum family. Species diversity of the catch averaged 10 for each station. Both the oyster beds and associated marshlands are recognized as productive nursery areas for macroinvertebrates and forage fish. The channel reaches supported a fish community of nearly equal diversity, which also included some important sport and commercial species.

Seasonal distribution patterns were not apparent for any species taken within the study boundaries. No one species seemed to be regional in distribution or more abundant in catches from any particular station. The data indicate that the more numerous a species, the wider its distribution in the study area.


PORT ROYAL SOUND ENVIRONMENTAL STUDY
LOCATION MAP
FISHERY SAMPLING STATIONS
SCALE
NAUTICAL MILES
N
Atlantic Ocean
LADIES ISLAND
FORT FREMONT
BEAUFORT RIVER
PORT ROYAL SOUND
CHISOLM ISLAND
COOSAW RIVER
BEAUFORT
Brickyard Cr.
PORT ROYAL
Ballast Cr.
HILTON HEAD ISLAND
PORT ROYAL ISLAND
WHALE BRANCH
BROAD RIVER
DAWS ISLAND
CHECHESSEE RIVER
PINCKNEY ISLAND
Skull Cr.
Mackay Creek
HALL ISLAND
SPRING ISLAND
COLLETON RIVER
Victoria Bluff
Saw Mill Cr.
MAY RIVER
BULL ISLAND
Bull Cr.
Bryan Cr.
Bass Cr.
CALIBOGUE SOUND
COOPER RIVER
DAUFUSKIE ISLAND
Broad Creek
Chowan Cr.
Capers Cr.
Station Cr.
Mulligan Cr.
Albergottie Cr.
Archers Cr.
East Br. Boyd Cr.
West Br. Boyd Cr.
Boyd Cr.
Cole Cr.
Euhaw Cr.
Hazzard Cr.
Chechessee Cr.
Pocotaligo River
1
2
3
4
5
6
7
8
10
11
FIGURE 1

Several species occurring in the catches from the channel reaches exhibited apparent seasonal changes in abundance. Most notable among this group was the Atlantic menhaden which was the most frequently caught species. Port Royal Sound and tributaries have been recognized as productive nursery areas for this commercially important clupeid. Size distribution of individuals sampled indicated the menhaden population was comprised principally of yearling fish. The absence of young-of-the-year fish in the catches may have been due to size selectivity of the nets although juveniles were also absent from the tidal stream fish community. Atlantic menhaden were most abundant in the lower reaches of the estuary in October reflecting their fall migration to offshore waters. In view of the increasing demand on the Atlantic menhaden fishery and the increasing threat of pollution to other nursery areas, menhaden could become one of the most important species to Port Royal Sound and adjacent waters. Other species demonstrating seasonal changes in relative abundance are listed in Table 4.

Conclusions

1. Port Royal Sound and adjoining waters supported a wide variety of marine fish which included several species of sport and commercial value. A total of 47 species was recorded in the collections.

2. Port Royal Sound and adjoining waters serve as a nursery area for several species including the commercially important Atlantic menhaden.

3. The channel and near-shore habitats of the study area differed markedly in species composition. A greater variety of sport and commercial species was associated with the near-shore environment. This reflects a probable dependence on the marshland and tidal creeks which are productive areas for food organisms essential to the fish community.

4. Twelve species of the channel reaches exhibited seasonal trends in relative abundance. The bonnethead shark, Atlantic stingray, longnose gar, spotted hake, bluefish, and blackcheek tonguefish were most numerous during the spring, finetooth shark, scalloped hammerhead, sea catfish, and Atlantic croaker during the summer, and Atlantic menhaden and spot during the fall.

5. Regional distribution patterns within the boundaries of the study area were not apparent for any of the recorded species except Atlantic menhaden. This species increased in numbers throughout the lower reaches of the estuary prior to its fall migration to offshore waters.

Table 4. Seasonal Peaks* in Relative Abundance of Species Taken in Channel Reaches Port Royal Sound, 1970

Species of Fish	*Spring (April)*	*Summer (July)*	*Fall (October)*
Finetooth shark		x	
Scalloped hammerhead		x	
Bonnethead shark	x		
Atlantic stingray	x		
Longnose gar	x		
Atlantic menhaden			x
Sea catfish		x	
Spotted hake	x		
Bluefish	x		
Spot			x
Atlantic croaker		x	
Blackcheek tonguefish	x		

* Seasonal peaks based on catch per unit effort and distribution of species from Tables 1, 2, 3.

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Fishery Resources of Port Royal Sound Estuary

Charles M. Bearden and C. H. Farmer, III
Marine Resources Division
South Carolina Wildlife and Marine Resources
Department
Charleston, S. C.

Introduction

Participation by the South Carolina Wildlife and Marine Resources Department, Marine Resources Division, in the Port Royal Sound Environmental Study was initiated in February of 1970. This participation consisted of otter trawl, seine and macro-zooplankton sampling throughout one annual cycle at selected stations in the estuary as well as a survey of the commercial fishery resources of the Colleton River system. The primary objectives of this work were to establish base line information pertaining to species diversity, abundance and seasonality of fishes and to provide data concerning the significance of this area to marine fishery resources.

Information related to the significance of the Port Royal estuary to fishery resources and utilization was felt to be of value in assessing future environmental and economic changes in the area. Primary considerations in this phase of the study were: the status of the existing fishery resources within the estuary itself; and the significance of the estuary as a nursery ground for fish and shellfish of value to sport and commercial fisheries. Although only a brief summarization of the magnitude and value of the fishery resources of the Port Royal estuarine area is presented herein, a voluminous amount of such information, both current and historical, is available, in the reports and records of the National Marine Fisheries Service and the Marine Resources Division.

Methods

Biological sampling by the Marine Resources Division in the Port Royal estuarine area was conducted during the period of February 1, 1970, through January 31, 1971. Regular monthly collections were made during this time on board the Division's 55 foot research vessel and by smaller outboard boats. The following is a summary of the station locations and gear used in this part of the study:

A. *Twenty Foot trawl (0.5 inch square mesh), twenty minute tows.*
Colleton River, Victoria Bluff
Port Royal Sound, Hilton Head
Calibogue Sound, Marsh Island
Whale Bridge, Hwy. 21 Bridge

B. *Eight and fifteen foot trawl (0.5 in. square mesh), ten minute tows.*
Colleton River, Sawmill Creek
Colleton River, Spring Island
Whale Branch, Camble Creek
Whale Branch, Small Creek by Brown Island

C. *One-half meter plankton net, (#00 mesh)*
Colleton River, Victoria Bluff
Port Royal Sound, Hilton Head
Calibogue Sound, Marsh Island
Beaufort River near mouth
Whale Branch, Hwy. 21 Bridge

D. *Sixty-five foot seine, (0.25 inch mesh)*
Whale Branch, Gray's Hill Landing
Fripp Island Beach
Hilton Head Island

The above stations were sampled once monthly to provide data on species composition, seasonality and relative abundance of fishes and commercially significant invertebrates. Specimens collected were normally identified, counted and measured in the field, although on occasions specimens were preserved in formalin and returned to the laboratory for analysis. Physical environmental data, including water temperature, salinity, turbidity, tidal stage, and weather conditions were recorded at each station for each collection period.

The sampling stations and gear used were selected to include as diversified a range of habitats and sizes of specimens as possible within the scope of study participation. Figure 1 shows the general locations of trawl and seine stations within the Port Royal estuarine area.

Field survey of the fisheries resources in the Port Royal estuary was confined primarily to the Colleton River system and consisted of an inventory of shellfish grounds as well as an estimation of blue crab production in the area. Other data used in this report were from the publication "S. C. Landings" of the National Marine Fisheries Service and records of the Marine Resources Division.

A shellfish survey of the Colleton River system was conducted in the Spring of 1970. This was a comparison with an earlier survey conducted in 1967. Data collected included the locations of intertidal oyster beds, as well as details on their dimensions and the average volume of oysters per square yard sample. A cursory survey of hard clam *(Mercenaria mercenaria)* resources in the Colleton River system was also conducted along with the oyster inventory.

Hog Croaker (*Trinectes maculatus*); *photo by National* Marine Fisheries Service.

Results and Discussion

A total number of 48 trawl samples, using a 20 foot net, were made during February 1970-January 1971 at Port Royal estuary stations. These collections resulted in a total of 30,344 fish specimens, comprising 53 species and 32 families with an average catch-per-unit-of effort of 632.16 individuals. The monthly occurrence and relative abundance of the various fish species taken is prensented in Table 1.

Limits of time and personnel did not allow for detailed analyses of invertebrates collected by otter trawl. Table 2 lists the seasonal occurrence and numbers of commercially significant invertebrates collected in the aforementioned trawl sampling. Other invertebrates commonly taken in trawl samples in the Port Royal estuary included various species of crabs *(Cancer irroratus, Menippe mercenaria, Callinectes ornatus, Libinia dubia, Limulus polyphemus, Pagurus sp.)* squid (*Loligo sp.*); mantis shrimp *(Squilla sp.)*; shrimp *(Paleomonetes spp., Trachypenaeus constrictus)*; and starfish *(Asterias forbesi, Luidia sp.)*.

Table 1. Monthly Occurrence of Fish Species at Port Royal Trawling Station, 1970. (S.O.=Seasonal Occurrence).

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL	S.O.
Squalidae														
Squalus acanthias (Dogfish)		1											1	C
Rajidae														
Raja eglanteria (Skate)										1			1	Y
Dasyatidae														
Dasyatis sabina (Sting Ray)	1								3				4	Y
Dasyatis sayi (Southern Sting Ray)							1						1	
Gymnura micura (Sting Ray)									1				1	U
Anguillidae														
Anguilla rostrata (American Eel)										1	1		2	Y
Ophichthidae														
Ophichthus gomesi (Sea Serpent)						1	2						3	U
Clupeidae														
Alosa aestivalis (Summer Herring)			1										1	U
Brevoortia tyrannus (Menhaden)	3	352	28		1	3	5						392	Y
Opisthonema oglinum (Thread Herring)					7		8	72	3	3			93	Y
Engraulidae														
Anchoa hepsetus (Anchovy)					145			83	33	12			273	Y
Anchoa mitchilli (Bay Anchovy)	242	465	329	316	508	156	50	3	76	47	63	630	2,885	Y
Synodontidae														
Synodus foetans (Lizard fish)							1	1		1	3		6	Y
Ariidae														
Bagre marinus (Sea Catfish)								1	2	1			4	W
Galeichthys felis (Sea Catfish)				1		48	18	16	31	9			123	W
Batrachoididae														
Opsanus tau (Toadfish)				1	1	1	1						4	Y
Gobiesocidae														
Gobiesox strumosus (Cling-fish)			1							1			2	U
Gadidae														
Urophycis regius (Codling)	2	16	45	22									85	C
Ophidiidae														
Rissola marginata (Cusk Eel)			1			5		4			1		11	Y
Atherinidae														
Menidia menidia (Silverside)	7	58											65	Y
Serranidae														
Centropristis striata (Black Sea Bass)	1												1	Y
Carangidae														
Chloroscombrus chrysurus (Pampano) (Bumper)								1	18	132			151	W
Vomer setapinnus (Pampano) (Horsefish)					1								1	U

Table 1—Continued

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	TOTAL	S.O.
Gerreidae														
Eucinostomus argenteus (Mojarras)											1		1	U
Pomadasyidae														
Orthopristis chrysopterus (Sailor's Choice) (Pigfish)									5				5	W
Sparidae														
Lagodon rhomboides (Sailor's Choice) (Pinfish)								8					8	Y
Sciaenidae														
Bairdiella chrysura (Yellow-tail)	1		1		2		9	246	474	22	3	11	769	Y
Cynoscion nebulosus (Spottted Weakfish)		1		1			1					1	4	Y
Cynoscion regalis (Weakfish, Common)	2			5	4	835	456	325	382				2,009	Y
Larimus fasciatus (Weakfish)											43	3	46	Y
Leiostomus xanthurus (Spot)		1			99	212	78	6	6	1		1	404	Y
Menticirrhus americanus (Sand Whiting)	6					8	15	21	17	3	7		77	Y
Micropogon undulatus (Croaker)				9	17	485	125	74	13	2			725	Y
Stellifer lanceolatus (Croaker)	1						2	2,613	13,629	2,695	12	2,695	21,597	Y
Ephippidae														
Chaetodipterus faber (Angel-fish)							1	74	30	9			114	W
Labridae														
Halichoeres bivittatus (Wrasse-fish)									1				1	U
Mugilidae														
Mugil cephalus (Common Mullet)											1		1	Y
Blenniidae														
Hypsoblennius hentzie (Blennie)	1												1	U
Trichiuridae														
Trichiurus lepturus (Silverfish) (Cutlass Fish)				14	6	1	1						22	W
Stromateidae														
Peprilus alepidotus (Butter-fish)					6			4					10	W
Peprilus triacanthus (Butter-fish)					4				1				5	W
Triglidae (Gurnards)														
Prionotus carolinus (Sea Robin)				1	1	24	7	1				1	35	Y
Prionotus scitulus (Sea Robin)							1						1	Y
Prionotus tribulus (Sea Robin)				3		8							11	Y
Bothidae														
Ancylopsetta quadrocellata (Flounder)	2			6	2								10	Y
Citharichthys spilopterus (Flounder)											12	11	23	Y
Etropus crossotus (Flounder)	4		1										5	Y
Paralichthys dentatus (Summer Flounder)					1	14	4	3	10	2		1	35	Y
Paralichthys lethostigma (Southern Flounder)	3					5		2		2			12	Y
Scophthalmus aquosus (Flounder)			4	1		2					1		8	Y
Soleidae														
Trinectes maculatus (American Sole)						12	5	1	5	2	1	2	28	Y
Cynoglossidae														
Symphurus plagiusa (Tongue-fish)	29	1	4	44	1	8	2	9	33	97	26	10	264	Y
Balistidae														
Stephanolepis hispidus (Trigger-fish)										2			2	U
Diodontidae														
Chilomycterus schoepfi (Burr-fish)											1		1	U
Total Fish Collected													30,344	

Y = Occurs year long
C = Present only during colder months
W = Present only during warmer months
U = Uncommon

The most productive of the 20 foot trawl sampling stations in the Port Royal estuary in terms of overall numbers and biomass was the Colleton River location near Victoria Bluff. Comparison of Colleton River sampling data with that from other estuarine areas throughout South Carolina indicates that this river system is of considerable significance to marine fishery resources. The Port Royal estuary, as indicated by the results of this survey (as well as by previous trawl surveys conducted by the Marine Resources Division and Bears Bluff Laboratories since 1953), is of prime importance as a habitat for white shrimp, blue crab and commercially important fin-fish species.

Pinfish *(Lagodon rhomboides)*; photo by the National Marine Fisheries Service.

Small trawl sampling at tidal creek stations in the Port Royal estuary resulted in the collection of 1,512 individual fish specimens comprising 17 species and 14 families. All of the species taken by small trawl were also taken in twenty foot trawl sampling. Dominant fish species included anchovy *(Anchoa mitchilli)*, yellow-tail *(Bairdiella chrysura)* and tongue sole *(Symphurus plagiusa)*. Invertebrate species of commercial significence included Penaeid shrimp and blue crab.

Beach seine sampling at three regular stations (Figure 1) produced 46 species of fishes, representing 23 different families. A total of 2, 921 individual fish specimens was collected by seine during the study period (Table 3). A number of species collected by seine were not represented in trawl sampling, indicating differences in habitat preferences.

Macro-zooplankton sampling during 1970 indicated that the recruitment patterns, species and relative abundance of larval and postlarval fishes and invertebrates were quite similar throughout the Port Royal estuary. The dominant forms at all five plankton sampling stations were anchovy, goby larvae, Sciaenid larvae and postlarvae, blue crab larvae and postlarval Penaeid shrimp. Twenty-five species of larval and postlarval fishes were collected in plankton sampling during 1970. Table 4 summarizes the species and seasonal occurrence of fish and commercially important invertebrate larvae and postlarvae collected.

Table 2. Occurrence of Commercially Important Invertebrate Species at Trawl Stations, Port Royal Estuary, 1970.

	Immature	*Mature*	*Total*	*Occurrence*
A. *Port Royal Sound*				
Callinectes sapidus (Blue Crab)	10	26	36	Year round
Penaeus aztecus (Brown Shrimp)	3	1	4	June
Penaeus setiferus (White Shrimp)	56	90	146	Aug.-Jan.
Penaeus duorarum (Pink Shrimp)	1	—	1	September
B. *Colleton River, Victoria Bluff*				
Callinectes sapidus (Blue Crab)	385	125	510	Year round
Penaeus aztecus (Brown Shrimp)	4	—	4	June
Penaeus setiferus (White Shrimp)	115	260	375	Aug-Dec.
Penaeus duorarum (Pink Shrimp)	6	—	6	Aug.-Nov.
C. *Calibogue Sound, Marsh Island*				
Callinectes sapidus (Blue Crab)	46	53	109	Year round
Penaeus aztecus (Brown Shrimp)	52	6	58	June-July
Penaeus setiferus (White Shrimp)	548	404	952	Aug.-Dec.
Penaeus duorarum (Pink Shrimp)	1	—	1	October
D. *Whale Branch*				
Callinectes sapidus (Blue Crab)	123	24	147	Year round
Penaeus aztecus (Brown Shrimp)	90	131	221	May-Aug.
Penaeus setiferus (White Shrimp)	594	186	780	Aug.-Nov.
Penaeus duorarum (Pink Shrimp)	34	9	43	Aug.-Nov.

Table 3. Seasonal Occurrence of Fish Species at Beach Seine Stations in the Port Royal Estuary, 1970.

	Jan.-Mar.	*Apr.-June*	*Jul.-Sept.*	*Oct.-Dec.*	*Total*
Brevoortia tyrannus (Menhaden)	320	—	—	—	320
Anchoa hepsetus (Anchovy)	—	—	39	—	39
Anchoa mitchilli (Bay Anchovy)	1	201	602	106	910
Synodus foetans (Lizard Fish)	—	1	16	2	19
Galeichthys felis (Sea Catfish)	—	—	1	—	1
Fundulus heteroclitus (Common Killifish)	—	6	6	12	24
Fundulus majalis (Killifish)	2	36	12	5	55
Poecilia latipinna (Killifish)	—	—	—	2	2
Cyprinodon variagatus (Sheephead Minnow)	—	—	—	31	31
Urophycis regius (Codling)	4	—	—	—	4
Syngnathus fuscus (Common Pipefish)	1	—	1	1	3
Syngnathus louisianae (Pipefish)	—	—	1	—	1
Pomatomus saltatrix (Bluefish) (Skipjack)	—	6	—	—	6
Chloroscombrus chrysurus (Pampano) (Bumper)	—	—	5	—	5
Selene vomer (Moonfish)	—	—	—	1	1
Caranx latus (Horse-Eye Jack)	—	—	3	—	3
Trachinotus carolinus (Common Pampano)	—	297	7	—	304
Trachinotus falcatus (Round Pampano)	—	5	2	—	7
Trachinotus goodei (Great Pampano)	—	—	1	—	1
Bairdiella chrysura (Yellow-tail)	—	1	—	—	1
Cynoscion nebulosus (Spotted Weakfish)	1	—	6	4	11
Sciaenops ocellata (Channel Bass)	4	—	—	6	10
Larimus fasciatus (Weakfish)	—	—	1	—	1
Menticirrhus littoralis (Surf Whiting)	—	4	52	10	66
Menticirrhus americanus (Sand Whiting)	—	13	10	2	25
Gobiosoma bosci (Naked Goby)	—	1	—	—	1
Prionotus scitulus (Sea-Robin)	—	1	1	—	2
Prionotus tribulus (Sea-Robin)	—	1	15	10	26
Astroscopus y-graecum (Electric Star Gazer)	1	2	—	1	4
Mugil curema (White Mullet)	—	—	—	—	—
Mugil cephalus (Common Mullet)	—	8	2	2	12
Membras martinica (Silverside)	—	—	3	12	15
Menidia menidia (Silverside)	287	178	52	320	837
Scomberomorus maculatus (Spanish Mackerel)	—	—	1	—	1
Eucinostomus gula (Mojarras) (Silver Jenny)	—	—	5	—	5
Eucinostomus argentus (Mojarras)	—	—	2	—	2
Strongylura marina (Atlantic Needlefish)	—	3	2	—	5
Ancylopsetta quadrocellata (Flounder)	1	—	—	—	1
Citharichthys spilopterus (Flounder)	—	—	1	—	1
Etropus crossotus (Flounder)	—	17	44	23	84
Paralichthys dentatus (Summer Flounder)	—	33	2	—	35
Paralichthys squamilentus (Southern Flounder)	—	5	—	—	5
Paralichthys dentatus (Summer Flounder)	—	9	16	6	31
Monocanthus hispidus (File Fish) (Fool Fish)	—	1	—	—	1
Sphaeroides maculatus (Puffer) (Swell-toad)	—	1	2	—	3
Chilomycterus schoepfi (Burr-fish)	—	—	2	—	2

Total Sample Periods—36 Total Number — 2,921


PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
OTTER TRAWL (T) & SEINE (S)
COLLECTING STATIONS
SCALE
NAUTICAL MILES
N
Atlantic Ocean
LADIES ISLAND
FORT FREMONT
BEAUFORT RIVER
BEAUFORT
PORT ROYAL
PORT ROYAL SOUND
COOSAW RIVER
CHISOLM ISLAND
Brickyard Cr.
Battery Creek
Ballast Cr.
Chowan Cr.
PORT ROYAL ISLAND
HILTON HEAD ISLAND
WHALE BRANCH
BROAD RIVER
DAWS ISLAND
CHECHESSEE RIVER
PINCKNEY ISLAND
Skull Cr.
Mackay Creek
HALL ISLAND
LEMON ISLAND
SPRING ISLAND
COLLETON RIVER
Victoria Bluff
Saw Mill Cr.
Bass Cr.
MAY RIVER
BULL ISLAND
CALIBOGUE SOUND
COOPER RIVER
DAUFUSKIE ISLAND
East Br. Boyd Cr.
West Br. Boyd Cr.
Boyd Cr.
Euhaw Cr.
Chechessee Cr.
Hazzard Cr.
Broad Creek

FIGURE 1

Table 4. Species and Seasonal Occurrence of Fish and Invertebrate Larvae and Postlarvae, Port Royal Estuary, 1970.

Fishes	*Jan-March*	*April-June*	*July-Sept*	*Oct-Dec*
Eel larvae (Eel)	x	—	—	—
Brevoortia tyrannus (Menhaden)	xx	—	—	—
Anchoa, spp. (Anchovy)	—	xxx	xx	—
Syngnathus sp. (Pipefish)	x	xx	xx	—
Bairdiella chrysura (Yellow-tail)	—	xx	—	—
Cynoscion nothus (Bastard Weakfish)	—	—	x	x
Stellifer lanceolatus (Croaker)	—	xx	—	x
Cynoscion regalis (Common Weakfish)	—	xx	x	—
Leiostomus xanthurus (Spot)	xx	—	—	—
Micropogon undulatus (Croaker)	xx	—	—	—
Menticirrhus spp. (Croaker)	—	x	xx	—
Gobiidae (Gobies)	—	xxx	xxx	—
Prionotus spp. (Gurnards)	x	—	x	—
Mugil cephalus (Common Mullet)	xx	—	—	—
Menidia sp. (Silverside)	—	xx	—	—
Scopthalmus aquosus (Flounder)	x	—	—	—
Paralichthys dentatus (Summer Flounder)	xx	—	—	—
Paralichthys lethostigma (Southern Flounder)	xx	—	—	—
Paralichthys albigutta (Gulf Flounder)	xx	—	—	—
Trinectes maculatus (American Sole)	—	—	x	—
Symphurus plagiusa (Tongue-fish)	—	—	x	—
Hippocampus erectus (Sea-Horse)	—	x	—	—
Lagodon rhomboides (Sailor's Choice)	xx	—	—	—
Hypsoblennius hentzi (Blennie)	—	—	x	—
Invertebrates				
Callinectes larvae (Blue Crab)	—	xxx	x	—
Penaeus setiferus p.l. (White Shrimp)	—	xx	x	—
P. aztecus p.l. (Brown Shrimp)	xx	—	—	—
P. duorarum p.l. (Pink Shrimp)	—	xx	x	—

xxx=Abundant xx=Common x=Rare —=Absent p.l. =Post larvae

The above sampling during 1970-71 produced useful information concerning species, relative abundance and seasonal occurrence of fishes and invertebrates in the Port Royal estuary. This information, along with trawl and plankton sampling data from Port Royal estuarine stations on hand for the years 1953-1969, should prove quite valuable in developing indices for species diversity which can be used to evaluate man-induced changes in the estuary. Species numbers-diversity is felt to be a reliable tool as an indicator of biological health in estuaries, especially as related to water pollution.

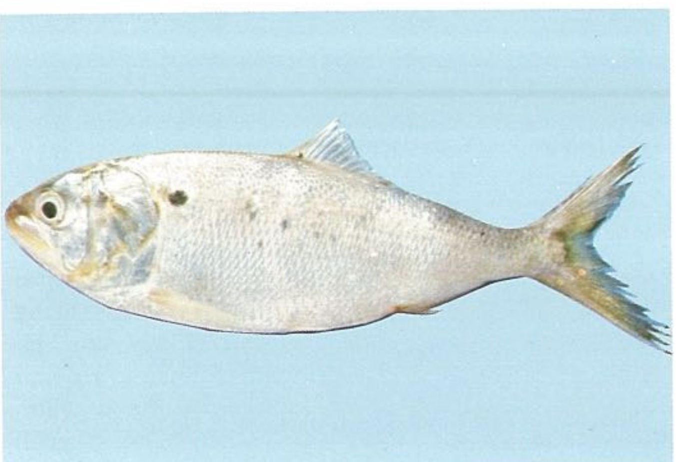
Shrimping in Port Royal Sound; photo by J. Darby, S. C. Water Resources Commission.

Commercial Fisheries

The major commercial fisheries of the Port Royal estuary are for blue crab, oyster and Penaeid shrimp. The oyster and blue crab fisheries are confined almost entirely within the inner estuarine area of the sounds and tidal streams. Shrimping is primarily carried out in the major sounds and in the open ocean from near shore to five miles offshore. Table 5 summarizes commercial fisheries landings in the Southern District of the State which includes the Port Royal estuary.

The Southern District of South Carolina produces the major portion of the State's blue crab landings. In the Colleton River system alone, an estimated 307,000 pounds of blue crabs were harvested in 1970 by commercial fishermen.

The oyster fishery of the Port Royal estuary is also of considerable magnitude. The vast majority of oyster grounds in this area are intertidal, and most of these grounds, totalling approximately 2,150 acres, are currently under lease by commercial operators. Details concerning these leases, including acreages, management practices and annual production, are on hand at the Marine Resources Division. Table 6 presents the commercial production for oysters and other important shellfish species within the Port Royal estuaries for 1970.



Menhaden *(Brevoortia tyrannus)*; photo by National Marine Fisheries Service.

Spider Crab *(Libinia eninartita)*; photo by National Marine Fisheries Service.

Table 6. Commercial Shellfish Landings, Port Royal Sound, 1970

Shellfish	*Pounds*	*Dollar Value*	*Percent of Total S. C. Landings*
Clams[1]	1,415	574	1.6
Hard Crabs	1,883,238	123,893	27.1
Oysters[1]	215,652	126,139	22.4
Shrimp[2]	106,057	65,837	2.1
Total	2,181,362	316,445	16.9

1. Data collected as U. S. Standard Bushels and converted to pounds of meats.
2. Data collected as heads-off and converted to heads-on.

Oyster Bed in Port Royal Sound.

Table 5. Commercial Fisheries Production, Southern District*

Year	*Blue Crab*	*Shrimp*	*Oyster*	*Clams*	*Finfish*	*Total*
1967	4,573,233	1,371,268	1,272,835	1,479	62,202	7,281,017
1968	3,278,586	2,517,311	1,326,806	——	75,673	7,199,376
1969	7,029,117	2,533,278	816,009	52	18,663	10,397.119
1970	6,007,379	1,895,694	554,646	11,462	19,888	8,489,069

(Landings listed in pounds and pounds of meat)
*Includes both Port Royal and St. Helena Estuaries.

In 1970, the intertidal oyster resources of the Colleton River system were re-surveyed as a comparison with an earlier 1967 inventory. The results of the 1970 survey indicated that the locations and characteristics of these beds in the Colleton River had changed insignificantly. The volume of oysters on the intertidal beds in the Colleton River ranged from as little as 1/20 bushel per square yard sample to as high as 1 bushel per square yard sample. The total volume of marketable oysters in the Colleton River system was estimated to be approximately 31,000 U. S. Standard bushels.

At sampling stations in the Colleton River, the volume of oysters averaged about 1/4 bushel per square yard. The number of oysters per square yard sample averaged 200.4, with the following percentage for various size groups; 0-1 in.—41.9% ; 1-2 in. —18.9% ; 2-3 in.—24.0% ; 3+ in.—15.2%.

In July of 1970, a brief study of hard clam *(Mercenaria mercenaria)* resources in the Colleton River was conducted by Division biologists. This survey indicated that the hard clam population of this river system is not extensive in comparison with other estuarine areas of the State. Large clam beds are known to exist, however, in Port Royal Sound, Calibogue Sound and in other adjacent areas. At this time, only a very small commercial clam fishery exists, but the potential for development of this resource appears promising.

Blue Crab *(Callinectes sapidus);* photo by the National Marine Fisheries Service.

Sport Fisheries

At present, very little information concerning the harvest and economic aspects of the sport fishery of the Port Royal estuary is available. A survey of sport fishing in South Carolina was conducted in 1968-69 by the Marine Resources Division, however, and the resulting report contains general information on the sport fishing of the Port Royal estuarine area.

Aerial surveys conducted in 1968-69 indicate that the Port Royal area is not utilized as intensively for sport fishing as are the central and northern coastal sections of South Carolina. The total number of sport fishermen utilizing the Port Royal area in 1968-69 was estimated to be less than 40% of the total for the greater Charleston area and only 12% of the number in the Little River—Pawley's Island area. Major sport fishing activity is confined to the Broad River, Fripp Island, Hilton Head Island and Trenchards inlet areas. 83% of sport fishermen observed by aerial survey in the Port Royal area were small boat anglers, 12% were bridge fishermen and 5% were surf or shore fishermen.

The major fish species of the Port Royal estuary are spotted sea trout *(Cynoscion nebulosis)*; channel bass *(Sciaenops ocellatus)*; flounder *(Paralichthys lethostigma)*; black drum *(Pogonias cromis)*; king whiting *(Menticirrhus spp.)*; spot *(Leiostomus xanthurus)*; croaker *(Micropogon undulatus)*; sheepshead *(Archosargus probato cepahlus)*; cobia *(Rachycentron canadum)*; bluefish *(Pomatomus saltatrix)*; and mackerels *(Scomberomerus maculatus* and *S. cavalia)*.

Summary

The value of the Port Royal estuary to fishery resources, both as a nursery area and in the production of fish and shellfish, is of considerable magnitude. This area is the largest estuary in the coastal zone of South Carolina still relatively unaltered by man. Commercial fisheries in the estuary are primarily limited to Penaeid shrimp, blue crab and oysters, although potentials exist for hard clam, finfish and mariculture activities. The overall economic value of commercial fisheries in the area could be increased significantly through the development of processing facilities and improved marketing techniques. Sport fishery resources of the Port Royal estuary are generally underdeveloped at present, and considerable potential for future utilization exists.

Currently, major values associated with the marine resources of the Port Royal estuary are related to recreation, aesthetics and fisheries. Potentials for other types of use and development exist, but adequate consideration must be made during all stages of planning to insure that such utilization is compatible with the conservation of the marine resources of the estuary.

Hydrographic Data

STATION: Victoria Bluff; GEAR: 20′ x ½″ sq. mesh Otter Trawl; BOTTOM TYPE: Mud-sand; DEPTH: 24-30 feet

Month	*Tidal St.*	*B.T.°C.*	*B.S.°/oo*	*Air.T.°C.*	*Turbidity*
Jan. 71	2/3 Fld.	11.2	32.0	6.5	48″
Feb.	3/4 Fld.	12.2	28.5	9.2	Mod.
Mar.	1/3 Fld.	14.2	26.9	24.0	Mod.
Apr.	1/6 Fld.	19.0	22.6	21.0	4′
May	1st. Fld.	24.3	23.7	23.5	3½′
Jun.	1/3 Ebb	26.7	26.9	26.1	3′
July	1/3 Ebb	28.9	29.1	31.2	4′
Aug.	1/3 Fld.	29.2	26.9	24.2	1′6″
Sept.	1st Fld.	29.3	28.7	30.8	3′6″
Oct.	1/3 Fld.	23.8	30.0	23.5	30″
Nov.	1/3 Ebb	14.0	35.0	3.5	24″
Dec.	1/3 Ebb	12.8	34.0	17.4	33″

Hydrographic Data

STATION: Port Royal Sound; GEAR: 20′ x ½″ sq. Otter Trawl; BOTTOM TYPE: Mud and sand; DEPTH: 12-20 feet

Month	*Tidal St.*	*B.T.°C.*	*B.S.°/oo*	*Air.T.°C.*	*Turbidity*
Jan. 71	½ Ebb	10.7	32.0	7.0	19″
Feb. 70	Full Fld.	11.9	30.4	9.0	Clear
Mar. 70	2/3 Fld.	13.5	28.0	20.7	Mod.
Apr. 70	5/12 Fld.	18.6	25.3	19.9	2′½″
May 70	1/3 Fld.	24.2	26.9	25.1	4′
Jun. 70	1/2 Ebb	26.8	28.0	28.0	1′2/3″
July 70	5/6 Ebb	28.7	28.5	29.2	3½′
Aug. 70	1/3 Fld.	28.9	30.7	25.5	2′7″
Sept. 70	1st. Fld.	28.6	31.0	29.3	4′
Oct. 70	1st. Fld.	23.6	32.1	21.8	3′10″
Nov. 70	1st Fld.	13.0	35.0	2.0	18″
Dec. 70	1/3 Ebb	13.1	34.0	13.9	3′

Brown Shrimp *(Penaeus aztecus)*; photo by the National Marine Fisheries Service.

Hydrographic Data

STATION: Whale Branch; GEAR: 20′ x ½″ sq. mesh Otter Trawl; BOTTOM TYPE: Mud and Organic Matter; DEPTH: 16-20 feet

Month	*Tidal St.*	*B.T.°C.*	*B.S.°/oo*	*Air.T.°C.*	*Turbidity*
Jan.	½ Flood	12.0	29.0	9.4	54″
Feb.	5/6 Ebb	13.5	18.0	9.3	Mod.
Mar.	½ Ebb	13.1	17.2	18.3	Mod.
Apr.	1/3 Ebb	19.4	11.8	17.6	2½′
May	1/3	25.7	16.2	27.5	2½′
Jun.	Full Flood	27.4	21.5	27.6	2′5″
July	2/3 Flood	28.8	24.8	29.4	2′5″
Aug.	½ Flood	30.8	26.9	30.0	2′6″
Sept.	Full Flood	28.7	26.0	26.2	3′5″
Oct.	1/3 Ebb	23.3	28.5	23.5	2′5″
Nov.	2/3 Ebb	14.5	30.0	6.4	2′
Dec.	1/3 Flood	12.3	31.0	21.9	5′

Hydrographic Data

STATION: Marsh Island; GEAR: 20′ x ½″ sq. mesh Otter Trawl; BOTTOM TYPE: Mud, shell, some live bottom; DEPTH: 12-24 feet

Month	*Tidal St.*	*B.T.°C.*	*B.S.°/oo*	*Air.T.°C.*	*Turbidity*
Jan. 71	Full Ebb	11.3	32.0	8.5	44″
Feb. 70	1/6 Ebb	12.0°C	29.2°/oo	8.9°C	Mod.
Mar. 70	5/6 Fld.	13.7°C	26.9°/oo	21.0°C	Mod.
Apr. 70	2/3 Fld.	18.8°C	25.8°/oo	20.1°C	4′
May 70	½ Flood	24.5°C	25.8°/oo	27.8°C	4′
Jun. 70	5/6 Fld.	28.0°C	26.9°/oo	30.6°C	1½′
Jul. 70	Full Ebb	28.6°C	26.9°/oo	28.2°C	3½′
Aug. 70	½ Flood	28.8°C	29.6°/oo	26.3°C	2′
Sept. 70	½ Flood	28.9°C	30.0°/oo	30.7°C	4½′
Oct. 70	3/4 Fld.	23.8°C	30.1°/oo	21.0°C	4′2″
Nov. 70	2/3 Ebb	13.2°C	35.0°/oo	2.0°C	4′
Dec. 70	2/3 Ebb	13.0°C	33.0°/oo	19.9°C	3′4″

A Study of the Primary Productivity of Port Royal Sound

Nelson A. Thomas

ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI CENTER, CINCINNATI, OHIO

Introduction

In an estuary the primary sources of food are detrital material from the marshes and free-floating plankton. Primary production by phytoplankton in the marine environment is greatest along the inshore areas where nutrient concentrations are high. Many higher organisms rely on phytoplankton and zooplankton for food during their early life stages and some organisms continue to feed upon them throughout their life span.

Through seasonal measurements of primary production with radioactive tracers, the portion of the total production of a body of water contributed by the phytoplankton can be determined. Estimates of primary production were made during the spring, summer and fall seasons of 1970 to obtain information on the activity in Port Royal Sound.

Methods

It is a common practice to estimate primary production in the aquatic environment by the uptake of radioactive carbon (C^{14}) by the algae and phytoplankton. The technique used in the Port Royal Sound Study, as outlined in the 13th edition of Standard Methods for the Examination of Water and Wastewaters (1971), is a slight modification of Steemann Nielsen's (1952) method. Estimates of primary production by phytoplankton were made in duplicate at four depths at each of 11 stations (Figure 1). The interval between the depths was determined by subdividing the euphotic zone. The euphotic zone is that column of water between the surface and the depth at which one percent of the incident light remains. The depth of the euphotic zone was determined with a submarine photometer. Light energy received during incubation periods and daily photoperiods was determined with a pyroheliometer. The light energy values are reported in gram calories per cm^2 per day (Appendix, Table 1).

Water samples were collected at four depths with a Kemmerer Sampler. The water sample was used to fill three 300 ml bottles. Two of these bottles were unaltered and considered light bottles. All light penetration was eliminated from the third bottle. Five microcuries of carbon-14 as sodium carbonate in solution were added to each bottle. The bottles were then suspended in the water at the depth from which the sample was obtained. Samples were incubated in location for four to six hours during a time period of high photoenergy. After incubation the bottles were iced in a dark container until filtration. This period did not exceed 3 hours. Fifty milliliter aliquots of the sample were filtered through HA .45 μ membrane filters which were then dried and stored in the dark. The following procedure was used to determine the amount of C^{14} assimilated by the algal cells.

1. Fume millipore filter and algae for 20 minutes over hydrochloric acid.
2. Dissolve filters with 2 ml of dimethylforamide in a liquid scintillation counting vial.
3. Fill vial with Cab-O-Sil.
4. Dissolve Cab-O-Sil with 15 ml of liquid scintillation counting medium (Permafluor).
5. Samples counted for 20 minutes by a Packard liquid scintillation counter Model 3320.
6. Counter efficiency was determined by measurement of standard solution of C^{14}.
7. Carbon assimilation was determined from the following:

$$\text{mg Carbon fixed/m}^3\text{/day} = \frac{\text{Counts of filtered sample}}{\text{Total activity added}} \times \text{eff} \times \frac{300 \text{ ml}}{\text{Volume filtered ml}}$$
$$\times \text{ mg/linitial inorganic Carbon (22 mg/l)*} \times \frac{1000 \text{ L}}{\text{m}^3}$$
$$\times \ 1.064^{**} \times \frac{\text{Daily Gm Cal}}{\text{Gm Cal during incubation}}$$

$$\text{Mg Carbon/m}^3\text{/day} \times \text{Euphotic Zone depth (m)} = \text{mg C/m}^2\text{/day}$$

Primary production can be expressed as the amount of carbon incorporated into algal cells in a volume of water per unit time. Commonly, primary production is expressed as milligrams of carbon fixed per cubic meter of water per day. Primary production can also be expressed as the quantity of carbon fixed by algae for an entire water column (mg carbon fixed per square meter per day). This expression provides for the comparison of primary production of different bodies of water on an areal basis.

In order to compare primary productivity from different locations and different months as well as from the same stations on concurrent days, primary productivity estimates are presented (Appendix Tables 2, 3 and 4) corrected for light variation. This was accomplished by multiplying the observed primary productivity by the following factor:

$$\frac{\text{maximum intensity measured at Port Royal Sound}}{\text{intensity on sample day}}$$

These values are presented in Appendix, Table 1. The maximum intensity used was 666 gm cal/cm^2/day.

Results

Primary production expressed on a volume basis indicates algal growth and can reflect nutrient enrichment. On a volume basis primary production of Port Royal Sound Estuary was low during April, less than 150 mg C/m^3/day with estimates corrected to a clear day (Appendix, Table 2). This low productivity indicates that there was a relatively low algal growth in Port Royal Sound. The data presented in the phytoplankton population studies (Lear and Smith, this volume) indicate that the population density was low. When primary production is expressed on the basis of a square meter water column through the euphotic zone, the productivity of a water mass can be obtained. In April, the clarity of the water of Port Royal Sound permitted phytoplankton productivity in the euphotic zone for a maximum depth of 12 feet. Even a sparse phytoplankton population can have a significant total production when growth is possible at such depths. In the seaward areas of the estuary (station 1), where the euphotic zone extended to 12 feet, the corrected primary production values for the water column averaged 414 mg C/m^2/day for three days in April.

In the Beaufort River (station 10) primary production on a volume basis corrected for light variation averaged 111 mg C/m^3/day. Other levels of productivity were observed in the Broad River, station 9, (97 mg C/m^3/day); Mackay Creek, station 3, (124 mg C/m^3/day); Upper Chechessee River, station 7, (110 mg C/m^3/day); Colleton River, station 6, (109 mg C/m^3/day); lower Chechessee River, station 4, (79 mg C/m^3/day); and Skull Creek, station 2, (134 mg C/m^3/day). The water temperatures range from 16° to 26°C during April.

Measurements of primary productivity during the July survey indicated a much higher rate of algal growth than was observed in April. Average primary production, on a volume basis, increased from 131 to 937 mg C/m^3/day from April to July at station 1. This increase probably resulted from increased water temperatures (average temperature 30°, an increase of 11°C) and the increase in nutrients released from the warmer marsh. The largest increase in primary productivity occurred in the Colleton River where primary production increased from 109 to 1155 mg C/m^3/day from April to July. The smallest increase was at Daws Island cut where primary production increased from 89 to 262 mg C/m^3/day.

In July, the abundance of plankton and detritus in the waters reduced the depth of the euphotic zone at most of the stations. Even though the average depth of the euphotic zone decreased more than 4 feet at station 1 from April to July, primary production for the water column increased 4.2 times from 414 to 1743 mg C/m^2/day. Productivity on an areal basis during July ranged from 1324 to 1743 mg C/m^2/day in the main portion of the estuary (stations 1, 2, and 4). The only area that had a production rate of less than 1,000 mg C/m^2/day was Daws Island cut (station 8). The Beaufort River had the highest production (2502 mg C/m^2/day) measured during the entire survey. The magnitude of the primary production measured during the summer survey indicates that Port Royal Sound is a very productive body of water. The rate of primary production measured during July indicates that PRS supports almost double the algal production as compared to other estuaries (Ragotzkie, 1959).

The variation in the measurements made at a single station over a three-day period indicates that there is either wide fluctuations in the plankton density or sudden changes in the turbidity. Turbidity in shallow estuaries is greatly affected by wave action. At station 9 from July 16-July 20, there was a 40 percent decrease in the euphotic zone and a 400 precent increase in primary production. At the other stations there was no relationship between the changes in primary production and turbidity. The daily variations in primary production probably resulted from the movement of the water masses up and down the estuary in relation to the tides, thus changing the concentration of phytoplankton in an area.

During the fall survey, the seaward area (station 1) and the Broad River (station 9) were the only areas that supported primary production in excess of 1,000 mg C/m^2/day. The open water of Port Royal Sound (stations 2 and 4) supported primary production ranging from 520 to 744 mg C/m^2/day. The Colleton and Upper Broad Rivers had low primary production—less than 500 mg C/m^2/day.

In summary, primary productivity for an average cubic meter of water in the Port Royal Sound area when corrected to strong sunlight (666 gm cal/cm^2/day), showed a seasonal trend which averaged 110 mg C/m^3/day in April, 770 mg C/m^3/day in July and 540 mg C/m^3/day in October. Considering the primary productivity in the entire depth of the euphotic zone, the averages become 330 mg C/m^2/day in April, 1598 mg C/m^2/day in July and 838 mg C/m^2/day in October.

Summary and Conclusions

1. During April, primary production on a volume basis, was very low; however, the deep euphotic zone permitted significant production for the entire water mass. In the seaward areas primary production during April averaged 414 mg C/m^2/day, which is typical of a non-turbid, unpolluted estuary.
2. Primary production increased considerably from April to July in Port Royal Sound. Primary production in the water column in Beaufort River exceeded 2500 mg C/m^2/day which was the highest rate observed during the entire survey.
3. During October primary production was reduced; however, in the open estuary, primary production still exceeded 1000 mg C/m^2/day in the euphotic zone.
4. The level of primary production in the entire water column as observed during April, July, and October indicates that Port Royal Sound is a productive estuary capable of contributing to the growth of aquatic organisms.

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Analysis of Phytoplankton Standing Crop

D. W. Lear and S. K. Smith
Environmental Protection Agency
Annapolis, Maryland

INTRODUCTION

The primary trophic level, i.e. the plants, is the key to a healthy ecosystem. As one component of the estuarine system, EPA Annapolis Field Office undertook to describe the basic phytoplankton community as one segment of a comprehensive environmental survey of the Port Royal Sound area.

Methods

Sampling was conducted during the spring, summer and fall, 1970, to note population type, change in relative abundance and variation in the standing crop. During the spring survey, samples were collected at stations 1 through 10 (see Figure 1). During the summer and fall surveys, however, station 11 was added and station 3 was deleted from the other locations.

Fresh samples were taken, iced aboard the sampling vessels and returned to a temporary shore facility for direct microscopic enumeration on the same day. Counting was done at 200X magnification in standard Sedgwick-Rafter counting cells. Phytoplankton organisms were diagnosed to genus, except where easily discernible species were a major portion of the community. Counts were of morphological units, i.e. clump counts, rather than individual cells.

Chlorophyll *a* was determined on preserved samples by 90% acetone extraction and spectrophotometric analysis by EPA, Cincinnati, Ohio.

Results and Discussion

Several approaches were made in analyzing the phytoplanktonic populations in Port Royal Sound. The first was basic community structure. This was done using the Simpson index, which is a relatively simple comparison of the number of taxa common to the stations. The number of common taxa are compared to the station with the least number of taxa, and the figure is expressed as a simple percentage, $\left(\frac{C}{N} \times 100\right)$ (Table 2.)

As can be seen in the spring, summer and fall results, the communities at all ten stations were fairly similar with a slightly greater standing crop and slightly greater diversity showing at all stations during the fall sampling. In examining the raw data, Port Royal Sound was found to be primarily a coastal diatom community throughout, and there were no remarkable differences going up the estuary or from station to station when considering spring, summer and fall data together.

The standing crop of phytoplankton at the various sampling stations as expressed by the phytoplankton counts was examined using a "t" test of the logarithm of phytoplankton counts (Table 3). There were insufficient data from the spring survey to compare with the July and October surveys.

There seems to be a pattern of difference in standing crop, Station 1 being significantly higher than other stations. This is not completely consistent, but seems to be more consistent than relationships between other stations. Most stations did not have significantly different levels than neighboring stations.

Another index of standing crop was chlorophyll *a* as estimated by acetone extraction and by reading in the spectrophotometer (Table 4). A "t" test of the estimation of chlorophyll *a*, indicated a tendency for Station 1 to be more different than other stations in the study area compared to each other (Table 5). Indeed the chlorophyll *a* levels at Station 1 were consistently higher than any other station in spring, summer and fall, although not always statistically signficantly different.

Since we have two estimators of standing crop, phytoplankton counts and chlorophyll *a*, examination was made for a relationship between chlorophyll *a* and total counts. This is shown as a plot (Figure 2) and as can be seen, no relationship is evident whatsoever between these two indices. This has been found to be true in certain Chesapeake Bay populations also.

This would indicate, at least in the estuarine systems examined, phytoplankton counts and chlorophyll *a* levels are apparently independent estimators of standing crop levels. This does not necessarily imply one is more useful than the other. Phytoplankton counts in this case are probably low because they are clump counts; for example, when cells occur in chains, the chain is counted as one unit and not individual cells. Also there is great variability in size of various phytoplankters. Only relatively immobile forms were identified. The dinoflagellates were only occasionally identifiable and countable because of their extreme mobility. Consequently, the counts were lower than actually exist, but are a reasonable approximation of the community and standing crop.

TABLE 2

SIMPSON INDEX
PORT ROYAL SOUND

$$\frac{C}{Ni} \times 100$$

	Station No. 1	2	4	5	6	7	8	9	10	11
Spring										
Station No. 1	—									
2	78	—								
4	81	81	—							
5	66	66	72	—						
6	78	64	81	83	—					
7	85	78	72	66	71	—				
8	91	75	54	66	75	91	—			
9	70	60	60	80	80	70	60	—		
10	83	75	72	58	83	75	66	50	—	
Summer										
1	—									
2	81	—								
4	72	87	—							
5	55	66	75	—						
6	83	83	100	75	—					
7	72	62	83	66	91	—				
8	72	75	88	66	83	66	—			
9	85	71	100	71	57	85	71	—		
10	88	93	90	75	100	88	83	85	—	
11	92	76	84	69	66	91	76	85	92	—
Fall										
1	—									
2	93	—								
4	84	93	—							
5	81	81	93	—						
6	81	87	93	81	—					
7	84	87	85	87	87	—				
8	78	93	89	81	87	78	—			
9	66	68	83	75	68	69	72	—		
10	93	93	100	87	87	93	93	75	—	
11	68	81	84	81	81	73	73	66	87	—

C = number of taxa common to stations.
Ni = number of taxa at station with lesser number.

Chlorophyll *a* extractions, on the other hand, unless specially analyzed, sometimes include the "fossil" chlorophylls, the phaeophytin and phaeophorides and tend in some cases to overestimate the standing crop. The fact that both of these indices, although apparently unrelated, reflect the apparent difference between Station 1 and the other stations, indicates the usefulness of both of these techniques.

Conclusion

The following points can be inferred from this study: (1) at all stations Port Royal Sound is apparently an unstressed ecosystem at the moment, (2) the community structures at all the stations were quite similar, and if stress were introduced at any point in the system sufficient to change the population characteristics, it could be reflected by comparison to other stations remote from it, and (3) except for Station 1, standing crops were generally quite similar and if an introduced stress affected a given station, this study gives some indication of the level of field measurement necessary to find statistically significant differences.

TABLE 3

ANALYSIS OF PHYTOPLANKTON COUNTS

"t" Test

Station No.

		1	2	4	5	6	7	8	9	10	11
	Summer										
Station No.	1	–									
	2	2.25**	–								
	4	1.39	0.49	–							
	5	1.54	0.63	0.06	–						
	6	2.33**	1.38	1.56	1.65	–					
	7	0.25	2.08	1.22	1.35	2.24**	–				
	8	2.05	0.13	0.37	0.49	1.43	1.88	–			
	9	3.90**	1.70	1.92	2.27**	0.64	3.79**	1.77	–		
	10	0.05	2.15**	1.36	1.49	2.31**	0.28	1.97	3.70**	–	
	11	3.02**	0.48	0.91	1.17	1.23	2.87**	0.60	1.44	2.82**	—
	Fall										
	1	–									
	2	2.63**	–								
	4	0.82	1.81	–							
	5	1.56	1.26	0.65	–						
	6	2.67**	1.09	1.32	0.50	–					
	7	1.19	1.74	0.24	0.48	1.23	–				
	8	2.00	1.19	0.93	0.21	0.32	0.78	–			
	9	3.44**	0.69	1.90	1.07	0.95	1.94	1.01	–		
	10	1.44	0.61	0.84	0.38	0.11	0.71	0.26	0.22	–	
	11	2.27**	0.27	1.49	0.94	0.71	1.40	0.84	0.31	0.37	—

**Significantly different $P < 0.05$

TABLE 4

CHLOROPHYLL *a* VALUES

(μg/l)

Station	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
4/18	2.46	2.35	2.13	3.17	2.08	2.00	1.69	1.48	1.42	2.7
4/19	2.93	2.94	1.99	2.16	2.97	2.67	2.24	1.82	1.95	1.2
4/21	1.88	2.83	2.17	2.27	3.36	4.51	2.42	2.83	1.74	3.0

Station	*1*	*2*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
7/19	12.83	6.60	3.43	7.58	4.55	4.20	3.88	3.75	4.03	7.0
7/20	29.53	6.59	5.03	9.48	6.93	7.11	6.61	5.45	5.39	6.6
7/21	52.24	9.68	10.06	9.83	7.28	8.32	6.70	6.28	4.48	5.2
7/22	3.88	12.01	7.44	6.31	8.06	7.38	9.95	6.00	5.08	8.7
7/23	12.93	7.97	7.98	9.49	8.12	10.09	7.34	6.29	6.15	11.4
7/24	8.50	8.33	8.53	11.95	9.25	8.59	6.18	3.51	6.95	11.1
10/14	–	–	–	–	–	–	–	–	–	–
10/15	–	–	–	–	–	–	–	–	–	–
10/16	5.32	3.85	3.93	5.19	4.38	4.79	2.18	2.87	4.79	5.4
10/17	5.24	2.59	2.36	3.07	–	3.23	2.17	1.49	3.19	2.7
10/18	11.23	5.34	3.85	3.02	2.59	2.93	5.00	3.10	5.14	4.5

TABLE 5

ANALYSIS OF CHLOROPHYLL *a* AS AN INDICATOR OF STANDING CROP

"t" Test

Station No.

Spring *Station No.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1	–										
2	0.45	–									
3	1.92	1.92	–								
4	1.11	.83	.98	–							
5	0.72	.36	1.39	.43	–						
6	1.14	.88	.96	.058	.48	–					
7	1.64	1.51	.34	.64	1.05	.57	–				
8	2.15**	2.16**	.15	1.18	1.63	1.11	.50	–			
9	2.85**	3.16**	1.07	2.94**	2.47**	1.99	1.38	.95	–		
10	2.54**	2.75**	.81	1.76	2.14**	1.68	1.12	.69	.68	–	
11	2.37**	2.96**	1.53	2.11**	2.33**	2.05**	1.66	1.48	1.00	.94	—

**Significantly different P >0.05

TABLE 5—*Continued*

"t" test

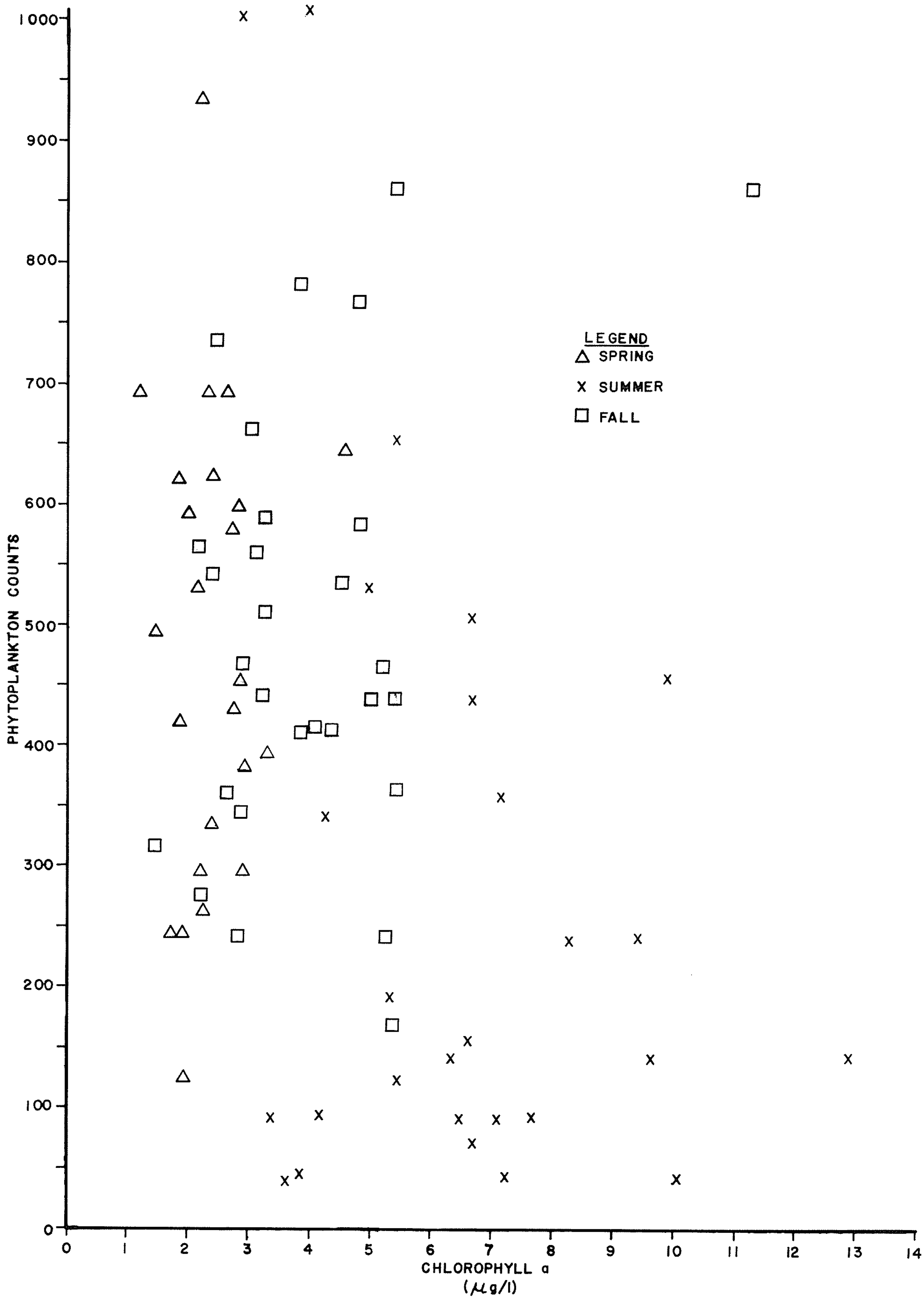
Station No.

Station No.	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Summer											
1	–										
2	.93	–									
3	–	–	—								
4	1.78	2.17**	—	–							
5	1.15	.26	—	2.83**	–						
6	1.30	.78	—	1.92	.78	–					
7	1.40	1.05	—	1.44	1.13	.39	–				
8	1.71	1.71	—	.117	1.95	1.33	0.99	–			
9	2.43**	4.18**	—	2.99**	6.01**	4.84**	4.20**	2.06**	–		
10	2.13**	3.17**	—	1.49	4.32	3.33**	2.80**	1.20	1.39	–	
11	.96	.20	—	3.57**	.68	1.42	1.77	2.47**	6.89**	5.09**	—
Fall											
1	–										
2	3.79**	–									
3	–	–	—								
4	2.83**	0.58	—	–							
5	3.34**	0.70	—	0.04	–						
6	3.74**	0.06	—	0.53	1.48	–					
7	3.60**	0.45	—	0.33	3.48	.41	–				
8	2.86**	0.55	—	0.025	0.007	.52	.22	–			
9	4.96**	1.60	—	1.79	2.43**	1.77	2.25**	1.76**	–		
10	0.89	1.95	—	.72	1.57	1.88	1.74	1.40	2.78**		
11	4.11**	0.22	—	1.29	1.05	.31	.78	.75	1.73	2.08**	—

**Significant at P >0.05

FIGURE 2

CHLOROPHYLL a PHYTOPLANKTON COUNTS



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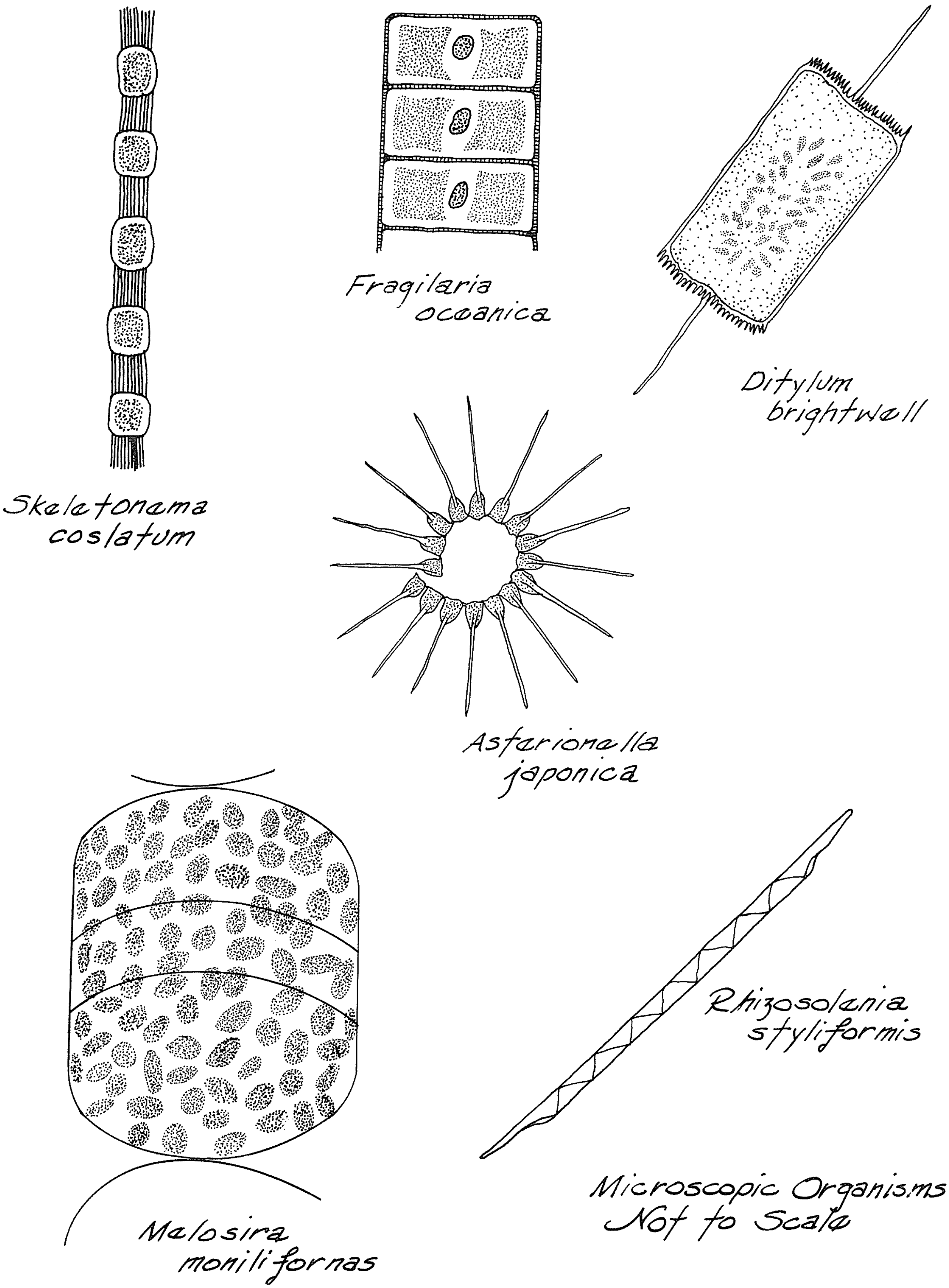
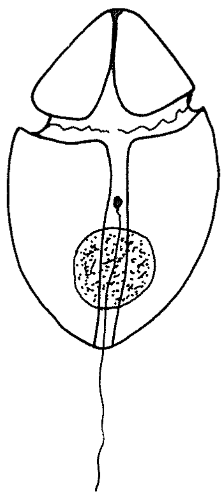
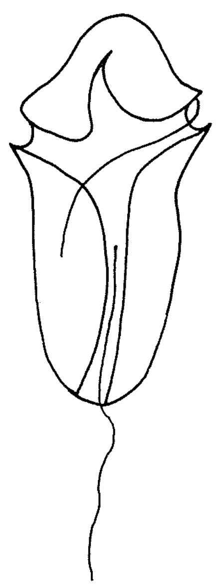

Skeletonema costatum
Fragilaria oceanica
Ditylum brightwell
Asterionella japonica
Melosira monilifornas
Rhizosolenia styliformis
Microscopic Organisms Not to Scale


PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
PHYTOPLANKTON
SAMPLING STATIONS
SCALE
NAUTICAL MILES
N
Atlantic Ocean
LADIES ISLAND
FORT FREMONT
BEAUFORT RIVER
BEAUFORT
PORT ROYAL
PORT ROYAL SOUND
HILTON HEAD ISLAND
PINCKNEY ISLAND
DAWS ISLAND
CHECHESSEE RIVER
BROAD RIVER
PORT ROYAL ISLAND
COOSAW RIVER
CHISOLM ISLAND
WHALE BRANCH
HALL ISLAND
LEMON ISLAND
SPRING ISLAND
COLLETON RIVER
Victoria Bluff
MAY RIVER
BULL ISLAND
COOPER RIVER
DAUFUSKIE ISLAND
CALIBOGUE SOUND
Brickyard Cr.
Mulligan Cr.
Albergottie Cr.
McCalley's Cr.
Chowan Cr.
Capers Cr.
Station Cr.
Battery Creek
Archers Cr.
Ballast Cr.
Skull Cr.
Mackay Creek
Jarvis Cr.
Broad Creek
Buck I.
Bass Cr.
Bryan Cr.
Bull Cr.
Saw Mill Cr.
Chechessee Cr.
Hazard Cr.
Euhaw Cr.
Cole Cr.
Boyd Cr.
East Br. Boyd Cr.
West Br. Boyd Cr.
Pocotaligo River
1
2
3
4
5
6
7
8
9
10
11

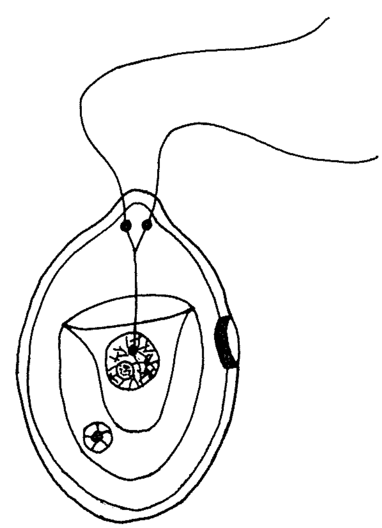
FIGURE 1



Amphidinium crassum



Gymnodinium lunula



Chlamydomonas

Microscopic Organisms
Not to Scale

Port Royal Sound Periphyton Studies

RICHARD W. WARNER
Environmental Protection Agency
Denver, Colorado

Introduction

The term periphyton, as used throughout this study, refers to microscopic organisms which become attached to solid substrates in the water. Periphyton include both plants, such as algae, as well as animals, such as protozoa, sponges and coelenterates. Similar organisms, when floating free in the water (not attached to a solid substrate), are referred to as plankton. Periphyton constitute an important source of food for many grazing or browsing aquatic animals.

The abundance and composition of periphyton are influenced by a number of factors, including nutrient levels, currents, light penetration, temperatures, salinity and overall water quality. To assess the periphyton development in various areas of Port Royal Sound, attached organisms were collected from artificial substrates during April, July and October, 1970.

Methods

Anchored polypropylene lines were tied to floats at all sampling stations (Figure 1). Clean glass microscope slides were attached vertically to these lines and suspended approximately one foot beneath the water surface to serve as artificial substrates for the attachment of periphyton. The slides remained in place during the study periods of April 15 to 25, July 14 to 27 and October 13 to 25, 1970. Upon retrieval, some of the slides from each station were preserved in five percent formalin solution, and returned to the EPA laboratory in Cincinnati for identification and enumeration of organisms. Periphyton were counted in a calibrated Sedgwick-Rafter counting chamber at a magnification of 200 times, using procedures outlined in *Standard Methods* (APHA, 1965). The results of these analyses were expressed as numbers of organisms per square inch of substrate (Table 1).

The remainder of the artificial substrates retrieved at each station were placed in 90 percent acetone solution and returned to the EPA laboratory for chlorophyll analyses. Analyses were performed and results were calculated by the methods of Strickland and Parsons (1960). Results of these analyses were expressed as micrograms of chlorophyll per square inch of artificial substrate (Table 2). An insufficient number of slides were recovered for chlorophyll determinations at all stations studied.

Results

Periphyton colonization of artificial substrates was sparse at all of the stations measured during April 1970 (Table 1). Only at the inshore stations, which were located in the Chechessee River, Mackay Creek and the Colleton River did periphyton growth of any significance (>50,000 organisms/inch^2) occur (Figure 2). In these collections, as in those of July and October, the majority of the periphyton were diatoms. However, a variety of other organisms also colonized the artificial substrates, with no particular group of organisms predominant to the exclusion of others. Such well-balanced periphyton communities exist in non-polluted estuaries. For those stations that were so measured, Chlorophyll *a* concentrations were very low ($<2\mu$g/inch^2) in April. The only significant concentration in the periphyton was collected from the Chechessee River (Table 2).

Artificial substrates exposed during the July survey were colonized by much higher numbers of periphyton (Table 1), consisting of much greater masses of algae (as indicated by higher chlorophyll *a* concentrations—Table 2) than the April collections. This would be expected since the month of July falls within the peak of the growing season. As in April, the in-shore areas produced the greatest number of periphyton. The Chechessee River, Colleton River and Skull Creek all supported more than 10,000,000 organisms per square inch (Figure 3). Chlorophyll *a* concentrations were also high (>20 μg/inch^2) in the Chechessee River and Skull Creek (Table 2). The Beaufort River, which is fairly open at Station 10, also supported more than 10,000,000 organisms per square inch. The high production rate at this location is probably due to nutrient enrichment. Periphyton colonized the substrates in moderate numbers in the Broad River; the chlorophyll *a* concentration of 11.2 μg/inch^2 at Station 11 in the upper Broad River was also considered relatively high, and resulted from the growth of a considerable amount of green algae. The numbers of periphyton at the other (open-water) stations (Stations 1 and 4), were relatively lower ($<$2,000,000/inch^2). In general, the quantity of periphyton grown on artificial substrates during the summer survey indicates that Port Royal Sound is a highly productive estuary, and the variety of organisms constituting the periphyton indicates that the estuary is not being severely affected by pollution.

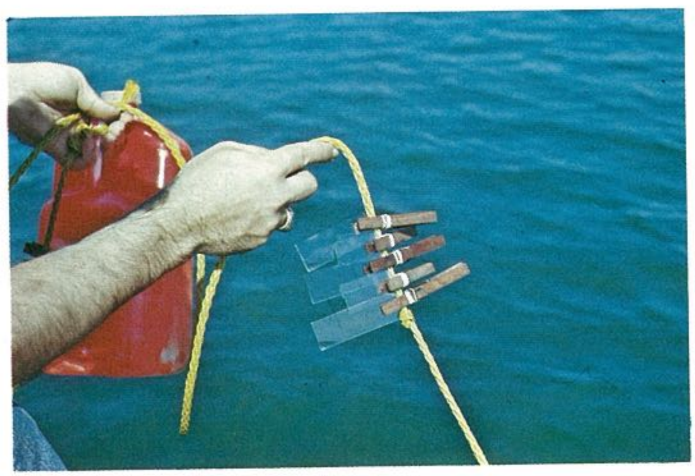
During the fall survey, periphyton populations and chlorophyll *a* concentrations were somewhat lower than were those of July, but still much greater than those of April (Tables 1 and 2). Skull Creek supported over 12 million organisms per square inch, and had chlorophyll concentrations of over 10 micrograms per square inch. Both the Chechessee River and the Beaufort River also supported the high numbers of over 1,000,000 periphyton organisms per square inch (Figure 4). Again the open-water areas of Port Royal Sound supported the fewest periphyton, with the lowest chlorophyll concentrations.

Table 1. Periphyton, Port Royal Sound, South Carolina (Numbers/Inch²)

Date	Station	Greens	Bluegreens	Diatoms	Flagellates	Other (protozoa coelenterata etc.)	Total	No. Kinds	No. Slides Counted
4/15-25/70	1	636	1,271	10,169	5,720	0	17,796	10	1
	2	—	—	—	—	—	—	—	—
	3	12,446	4,356	275,047	1,245	8,712	301,806	10	1
	4	—	—	—	—	—	—	—	—
	5	3,575	0	22,044	3,575	2,979	32,173	7	1
	6	0	636	34,320	4,449	50,842	90,247	10	1
	7	287	0	598,620	23,355	1,668	623,921	11	2
	8	0	4,687	961,264	1,562	2,343	969,856	11	1
	9	675	1,350	4,727	8,103	0	14,855	6	1
	10	—	—	—	—	—	—	—	—
	11	—	—	—	—	—	—	—	—
7/14-27/70	1	69,563	0	543,127	26,755	42,808	682,253	17	1
	2	251,008	0	14,655,000	405,474	57,925	15,369,407	15	2
	3	—	—	—	—	—	—	—	—
	4	80,322	0	903,609	57,372	54,504	1,095,807	17	1
	5	222,321	17,102	8,567,902	153,914	153,915	9,115,154	18	2
	6	209,633	0	16,728,715	337,339	167,706	17,483,393	21	1
	7	102,609	0	10,432,007	273,626	205,220	11,013,462	17	1
	8	407,130	0	3,483,219	452,366	90,473	4,433,188	12	1
	9	202,572	0	3,056,454	125,118	47,664	3,431,808	14	1
	10	109,230	0	13,599,135	54,615	81,922	13,844,902	18	1
	11	487,672	75,027	7,727,739	150,053	187,566	8,628,057	18	1
10/13-25/70	1	557	0	103,621	3,899	6,685	114,762	12	1
	2	0	0	12,155,975	215,150	107,575	12,487,700	20	1
	3	—	—	—	—	—	—	—	—
	4	—	—	—	—	—	—	—	—
	5	1,180	0	353,628	3,541	52,528	410,877	14	1
	6	—	—	—	—	—	—	—	—
	7	106,096	33,765	4,330,404	75,972	126,620	4,672,857	20	1
	8	0	0	2,724,992	89,344	178,688	2,993,024	16	1
	9	60,028	0	530,247	40,019	60,028	690,322	15	1
	10	49,325	0	2,799,213	36,994	36,994	2,922,526	12	1
	11	101,035	0	1,403,271	134,714	56,131	1,695,151	16	1

Table 2. Chlorophyll in Periphyton — Port Royal Sound, South Carolina
(Micrograms/Inch²)

Station	April 1970 Chlorophyll a	April 1970 Chlorophyll b	April 1970 Chlorophyll c	July 1970 Chlorophyll a	July 1970 Chlorophyll b	July 1970 Chlorophyll c	October 1970 Chlorophyll a	October 1970 Chlorophyll b	October 1970 Chlorophyll c
1	0.122	0.065	0.017	0.264	0.230	—	—	—	—
2	—	—	—	20.041	2.032	5.450	10.241	2.146	3.989
3	—	—	—	—	—	—	—	—	—
4	—	—	—	2.698	0.422	1.335	—	—	—
5	—	—	—	7.897	1.469	3.479	2.099	0.005	0.239
6	—	—	—	9.592	0.708	6.570	—	—	—
7	1.613	0.043	0.232	20.559	2.914	3.968	5.501	0.307	1.292
8	1.497	0.302	0.380	7.591	0.853	1.541	3.285	0.830	0.613
9	0.061	0.028	—	0.982	—	0.440	1.260	—	0.174
10	—	—	—	2.442	0.347	0.998	2.416	—	0.713
11	—	—	—	11.233	0.454	5.046	3.321	—	0.499



Examining slides for periphyton growth; photo by J. Darby, S. C. Water Resources Commission.

Summary

1. Periphyton production in Port Royal Sound was low in April, very high in July and moderately high in October. The high numbers of organisms involved as well as the variety of organisms involved, indicate that the estuary is a highly productive, but not polluted, body of water.

2. The in-shore areas of the Chechessee River, Mackay Creek, Skull Creek, and the Broad River supported the most abundant periphyton growths. The open-water areas of Port Royal Sound were the least productive of periphyton.

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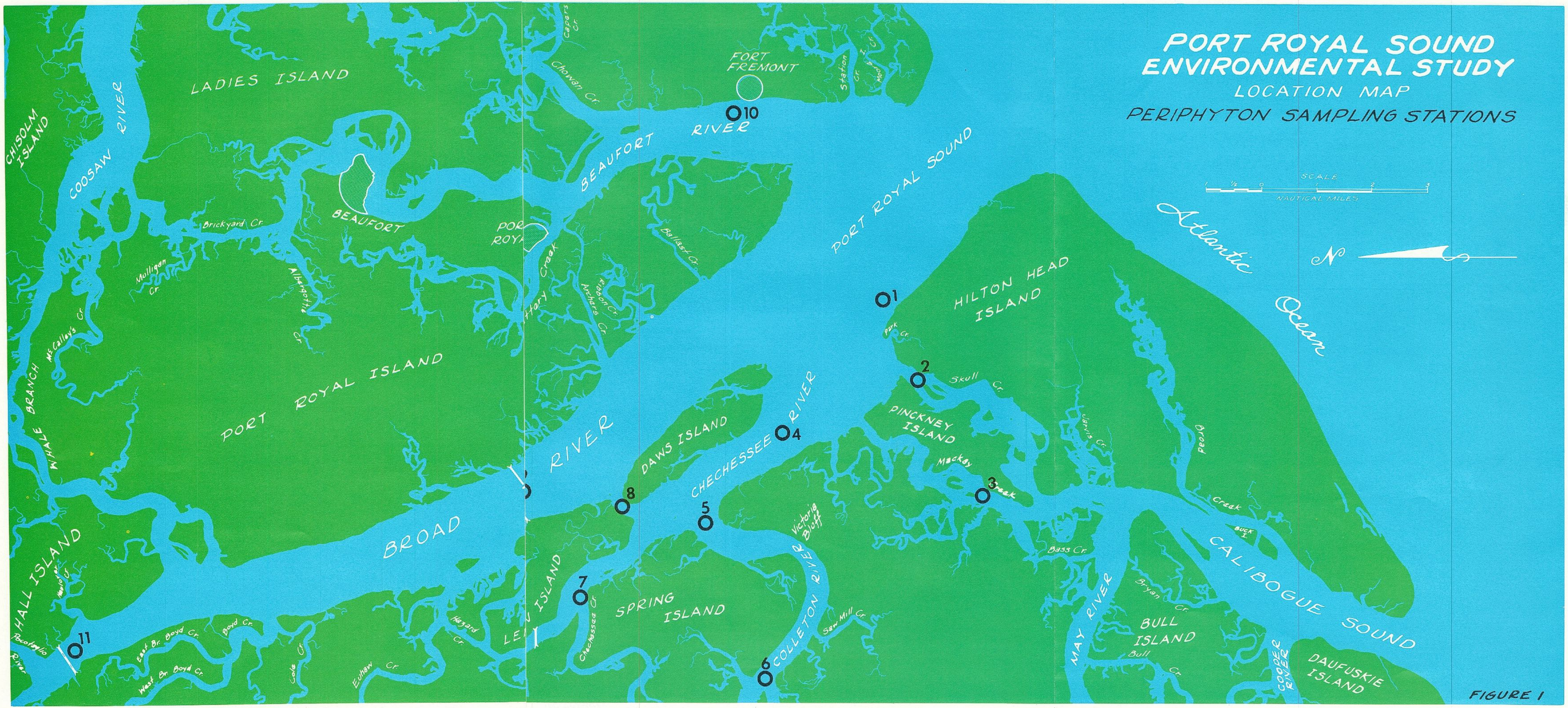
Strickland, J. D. H. and T. R. Parsons. 1960.
A Manual of Sea Water Analysis. Bull. Fish. Res. Bd. Canada. 125:107-112.


PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
PERIPHYTON SAMPLING STATIONS
SCALE
NAUTICAL MILES
Atlantic Ocean
PORT ROYAL SOUND
HILTON HEAD ISLAND
LADIES ISLAND
FORT FREMONT
BEAUFORT RIVER
BEAUFORT
PORT ROYAL ISLAND
BROAD RIVER
CHECHESSEE RIVER
DAWS ISLAND
PINCKNEY ISLAND
SPRING ISLAND
COLLETON RIVER
MAY RIVER
BULL ISLAND
CALIBOGUE SOUND
DAUFUSKIE ISLAND
COOPER RIVER
CHISOLM ISLAND
COOSAW RIVER
WHALE BRANCH
HALL ISLAND
LEMON ISLAND
Skull Cr.
Mackay Creek
Broad Creek
Bass Cr.
Victoria Bluff
Chechessee Cr.
Brickyard Cr.
Ballast Cr.
Chowan Cr.
Station Cr.
Euhaw Cr.
East Br. Boyd Cr.
West Br. Boyd Cr.
Boyd Cr.
Pocotaligo River
Sawmill Cr.
Bryan Cr.
Hazard Cr.
1
2
3
4
5
6
7
8
10
11
FIGURE 1


PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
DISTRIBUTION OF PERIPHYTON
APRIL, 1970
SCALE
NAUTICAL MILES
Legend:
>50,000/□"
50,000–300,000
>300,000
Atlantic Ocean
LADIES ISLAND
CHISOLM ISLAND
COOSAW RIVER
BEAUFORT
FORT FREMONT
BEAUFORT RIVER
PORT ROYAL SOUND
PORT ROYAL ISLAND
BROAD RIVER
DAWS ISLAND
CHECHESSEE RIVER
PINCKNEY ISLAND
HILTON HEAD ISLAND
SPRING ISLAND
BULL ISLAND
DAUFUSKIE ISLAND
CALIBOGUE SOUND
MAY RIVER
COOPER RIVER
HALL ISLAND
WHALE BRANCH
Mackay Creek
Skull Cr.
Brickyard Cr.
Chowan Cr.
Ballast Cr.
Archers Cr.
Sawmill Cr.
Victoria Bluff
Bass Cr.
Bryan Cr.
Euhaw Cr.
East Br. Boyd Cr.
West Br. Boyd Cr.
Boyd Cr.
Chechessee Cr.
COLLETON RIVER
FIGURE 2


PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
DISTRIBUTION OF PERIPHYTON
JULY, 1970
SCALE
NAUTICAL MILES
N
Atlantic Ocean
Legend:
< 2,000,000/□"
2,000,000 to 10,000,000
> 10,000,000
LADIES ISLAND
CHISOLM ISLAND
COOSAW RIVER
FORT FREMONT
BEAUFORT RIVER
BEAUFORT
PORT ROYAL
Brickyard Cr.
Mulligan Cr.
Albergottie Cr.
Chowan Cr.
Capers Cr.
Station Cr.
Battery Creek
Ballast Cr.
Archers Cr.
PORT ROYAL SOUND
PORT ROYAL ISLAND
McCalleys Cr.
WHALE BRANCH
HALL ISLAND
Pocotaligo River
BROAD RIVER
DAWS ISLAND
CHECHESSEE RIVER
HILTON HEAD ISLAND
Park Cr.
Skull Cr.
PINCKNEY ISLAND
Mackay Creek
Jarvis Cr.
Broad Creek
Buck I.
CALIBOGUE SOUND
Victoria Bluff
Bass Cr.
MAY RIVER
Bryan Cr.
BULL ISLAND
Bull Cr.
COOPER RIVER
DAUFUSKIE ISLAND
SPRING ISLAND
Chechessee Cr.
LEMON ISLAND
Hazard Cr.
Euhaw Cr.
Cole Cr.
Boyd Cr.
East Br. Boyd Cr.
West Br. Boyd Cr.
Saw Mill Cr.

FIGURE 3


PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
DISTRIBUTION OF PERIPHYTON
OCTOBER, 1970
SCALE
NAUTICAL MILES
Atlantic Ocean
N
Legend:
< 1,000,000/□"
1,000,000 to 5,000,000
> 5,000,000
LADIES ISLAND
FORT FREMONT
CHISOLM ISLAND
COOSAW RIVER
BEAUFORT RIVER
BEAUFORT
PORT ROYAL
Brickyard Cr.
Mulligan Cr.
Albergottie Cr.
Chowan Cr.
Capers Cr.
Station Cr.
Ballast Cr.
Archers Cr.
PORT ROYAL SOUND
PORT ROYAL ISLAND
McCalley's Cr.
WHALE BRANCH
HILTON HEAD ISLAND
Park Cr.
Skull Cr.
PINCKNEY ISLAND
Mackay Creak
DAWS ISLAND
CHECHESSEE RIVER
BROAD RIVER
HALL ISLAND
Pocotaligo River
East Br. Boyd Cr.
West Br. Boyd Cr.
Boyd Cr.
Cole Cr.
Euhaw Cr.
Hazard Cr.
LEMON ISLAND
Chechessee Cr.
SPRING ISLAND
Victoria Bluff
COLLETON RIVER
Saw Mill Cr.
Bass Cr.
MAY RIVER
BULL ISLAND
Bryan Cr.
Bull Cr.
Broad Creek
Buck I.
CALIBOGUE SOUND
COOPER RIVER
DAUFUSKIE ISLAND

FIGURE 4

Fish Eggs and Larvae from Port Royal Sound and Adjacent Waters

by THOMAS W. MCKENNEY
National Marine Fisheries Service
Beaufort, North Carolina

Introduction

As part of the environmental analysis of Port Royal Sound, biologists of the South Carolina Pollution Control Authority collected plankton samples seasonally in the Sound and adjacent waters during 1970. These samples were sent to the National Marine Fisheries Service, Mid-Atlantic Coastal Fisheries Research Center where the fish eggs and larvae were removed and examined. This report summarizes the observations on those eggs and larvae.

Materials and Methods

The basic materials for this study were 261 plankton samples composing three series: a series of 83 samples taken from 15 to 24 April, a series of 93 samples taken from 14 to 24 July, and a series of 85 samples taken from 13 to 25 October. The samples were taken during daylight at 11 stations (Figure 1). Station 11 was not occupied in April and Station 3 was not occupied in July or October. Inclement weather and difficulties with equipment sometimes interfered with the sampling, so some stations were not occupied as often as others in a sampling period.

The sampling devices were Clarke-Bumpus plankton samplers with number 2, 10 or 20 nets and bucket screens. The numbers refer to mesh sizes of 0.015 inches (0.366mm), 0.006 inches (0.158mm), and 0.003 inches (0.076mm) respectively. The samplers were towed for 10 minutes at each station, and collectors estimated the tow depths were from about 3 to 10 feet. The samples were preserved in 5% formalin.

The samples were examined microscopically at 9X magnification, and fish eggs and larvae were removed, counted and, as far as was possible, identified. The range of total lengths of each species of larvae in each sample was measured with an eyepiece micrometer. The eggs and larvae and copies of the field data were stored at the Mid-Atlantic Coastal Fisheries Research Center.

Results and Discussion

Table 1 gives the numbers of eggs and larvae by species, by month and by station. The data accompanying the samples reported frequent malfunctions of the flometers on the samplers, therefore, the flowmeter readings in treatment of the data were not used, but instead, the average number of eggs and larvae per 10 minute tow (Table 2) was calculated. The samples showed two main features; a paucity of eggs and larvae in October and preponderance of the bay anchovy in April and July (Figure 2).

Samples taken in July contained 74.7% of the eggs and larvae collected while those in April contained 25.2%. The October samples only contained 0.1% of the eggs and larvae collected. The same order, July-April-October, held when the average number of eggs and larvae per tow was considered. Eggs outnumbered larvae at all stations every month, except for station 5 in October and Station 6 in April. Overall there were about 6 eggs to every larva, (Figure 2).

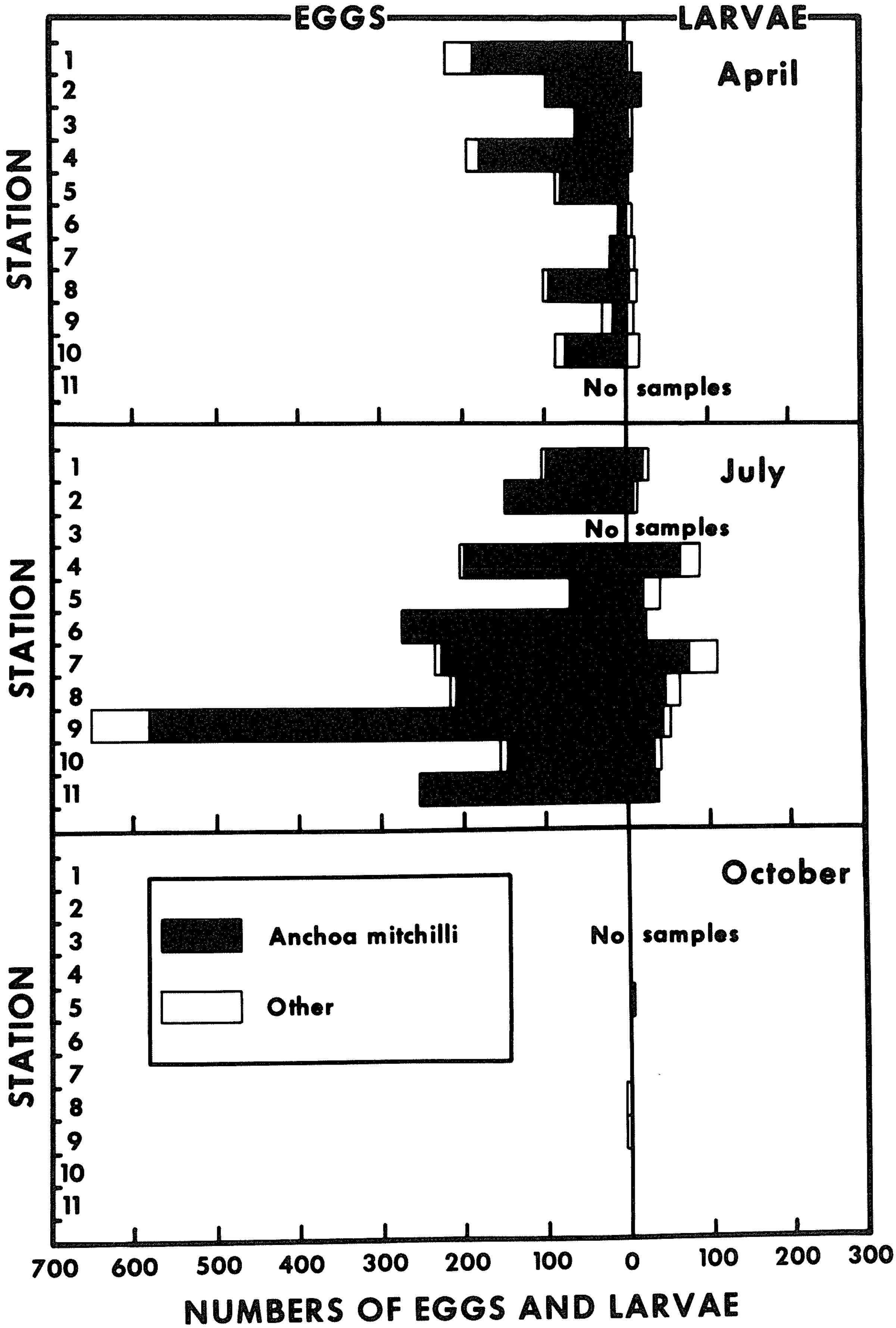
The bay anchovy, *Anchoa mitchilli,* was the most numerous species in these samples. It represented 81% of the eggs and larvae together, 95% of the eggs and 68% of the larvae. Bay anchovy eggs were taken at every station in April and July, and its larvae were taken at every station in July and at all but three stations in April. Samples from October contained no bay anchovy eggs or larvae.

Next to bay anchovy, the most numerous larvae in the samples were those of a goby *(Gobiosoma sp.)* Larvae of this species made up 16% of all larvae taken. The species occurred at six of ten stations in April and at every station in July. The only larvae in the October samples were of this species.

Other identified larvae in these samples in order of decreasing numbers were as follows: the feather blenny, *Hypsoblennius hentzi*; the hog choker, *Trinectes maculatus;* the Atlantic silverside, *Menidia menidia;* and the leatherjacket *Oligoplites saurus.* These four species made up only about 5% of the larvae collected.

About 5% of the eggs and about 11% of the larvae were unidentified. At least two-thirds of the unidentified eggs were those of one species, but there were larvae of at least three unidentified species.

The samples did not include a complete developmental series of the bay anchovy. About 18% of the bay anchovy eggs collected in April were in early cleavage stages (Mansueti and Hardy, 1967), but the rest of the eggs from April and all but seven of the eggs from July were in tail-bud and tail-free stages. The samples contained no eggs at later developmental stages. About 25% of the bay anchovy larvae taken in April and about 15% of the bay anchovy larvae taken in July retained some yolk and had unpigmented eyes. The range of total lengths for the larvae found in these collections is summarized in Table 3. Two juvenile bay anchovies (total lengths 0.9 and 1.4 inches or 23.8 and 36.0 millimeters) and a dusky pipefish, *Syngnathus floridae,* (total length 5.2 inches or 133 millimeters) collected in July were considered adventitious and were not included in the numerical treatment of data.


EGGS
LARVAE
April
July
October
STATION
1
2
3
4
5
6
7
8
9
10
11
No samples
Anchoa mitchilli
Other
700
600
500
400
300
200
100
0
100
200
300
NUMBERS OF EGGS AND LARVAE

The bay anchovy material in these samples revealed that its early life history in Port Royal Sound and the adjacent waters was similar to its life history in Virginia and North Carolina waters (Mansueti and Hardy, 1967). Hildebrand and Cable (1930) reported that the species spawned in the evening from 6:00 to 9:00 p.m. Kuntz (1914) reported that the eggs hatched in about 24 hours at about 80°F (27°C). The collections in Port Royal Sound were made between 9:00 a.m. and 5:00 p.m., so the fact that the eggs were nearly all in the tail-bud and tail-free stages was consistent with their having been spawned the previous evening. The eggs were at least 12 hours old but less than 24 hours old when collected.

Fishes identified in these samples are common in estuaries, although some workers regard most of these species as marine inhabitants, (McHugh, 1967). Most can spend their lives within an estuarine system and its adjacent waters as Dovel *et al.* (1969) found to be the case for the hogchoker in the Patuxent River Estuary. The bay anchovy may move offshore in the winter in parts of its range (Hildebrand, 1963) and several of these species, including bay anchovy, hogchoker and Atlantic silverside, occasionally are found also in fresh water (Massmann, 1954; Tagatz, 1968).

A second feature of the larvae in these collections was their small size (Table #3). Aside from the two juvenile bay anchovies and the dusky pipefish, the largest larva was a leatherjacket 0.6 inch (14 mm) long. The rest of the larvae were all less than 0.5 inch (12.7 mm) and most were less than 0.25 inch (6.4 mm) long. Larger larvae probably avoided the samplers.

A third characteristic of the identified species is that none were of direct economic or recreational importance even though these waters support populations of such species. (See Turner and Johnson in this volume). Striped mullet, *Mugil cephalus;* Atlantic menhaden, *Brevoortia tyrannus;* spot, *Leiostomus xanthurus;* and Atlantic croaker, *Micropogon undulatus* are examples of species that use southern estuaries for at least part of their lives. These species, however, spawn mainly offshore and the young enter the estuaries as postlarvae which are generally larger and more agile than the larvae found in these plankton samples. Furthermore, larvae of these species enter Carolina estuaries mainly from late fall through early spring, so their size and time of entry help explain their absence in these samples. Accounts of the life histories are given by Anderson (1958) for the striped mullet; by Hildebrand (1963) for the Atlantic menhaden; by Dawson (1958) for the spot; and by Haven (1957) for the Atlantic croaker. Gunter (1967) gives a general account of larval entry into estuaries.

Display of necessary equipment: Clarke-Bumpus sampler, formaldehyde, and map; photo by J. Darby, S. C. Water Resources Commission.

Recommendations

The following changes in future sampling for fish eggs and larvae should be observed: First, the samples should be taken at least every two months to insure coverage in the late fall, winter and early spring. Several economically important species enter the estuary during this period.

Second, the Clarke-Bumpus should be supplemented by tows with a larger net, such as that described by Lewis *et al.* (1970). This net will catch the larger larvae, particularly the larvae of those species spawning elsewhere and entering the estuary relatively late in their development.

Particular attention should also be given to the general biology, population dynamics and distribution of the bay anchovy. Although this species is not of direct economic importance, it is likely an important one in the ecology of this estuary. Turner and Johnson (this volume) report that the bay anchovy was the most numerous fish taken in their survey of the Sound. McHugh (1967) believes this species to be the most numerous fish on our Atlantic coast and Gunter (1967) believes that the bay anchovy is present in greater numbers and constitutes the greatest biomass of any fish in the shallow waters of the northern Gulf of Mexico. The bay anchovy occupies an intermediate trophic level, feeds on zooplankton and is forage for larger fishes, several of which are of economic importance (Hildebrand, 1943; Hildebrand, 1963; and McHugh, 1967). This intermediate position probably makes bay anchovy populations sensitive to changes at higher or lower trophic levels. Another feature of this animal is that all of its life stages are relatively easy to capture in the numbers usually required for experimental studies. Detwyler and Houde (1970) and Houde and Palko (1970) described rearing bay anchovy from the egg. Finally, the bay anchovy has an extensive range. Hildebrand (1963) and Daly (1970) give its range as Cape Cod to Yucatan. Spawning has been reported as far north as Narragansett Bay (Herman, 1963) and as far south as Biscayne Bay (Detwyler and Houde, 1970), as well as in the Gulf of Mexico (Gunter, 1945). The bay anchovy probably lives in most of the estuaries within its range and offers an opportunity to study a single species in a great variety of estuarine conditions.

Table 1.—The numbers of fish eggs and larvae from stations in Port Royal Sound, South Carolina and adjacent waters by station, by month and by species.

		Eggs			Larvae								Eggs and larvae
Station	Month	*Anchoa mitchilli* (bay anchovy)	Unidentified	Total	*Anchoa mitchilli* (bay anchovy)	*Gobiosoma* sp. (goby)	*Hypsoblennius hentzi* (feather blenny)	*Menidia menidia* (Atlantic silverside)	*Trinectes maculatus* (hogchoker)	*Oligoplites saurus* (leatherjack)	Unidentified	Total	
1	April	189	31	220	1	1	1	0	0	0	1	4	224
	July	100	2	102	23	1	0	0	0	0	5	29	131
	October	0	0	0	0	0	0	0	0	0	0	0	0
	Total	289	33	322	24	2	1	0	0	0	6	33	355
2	April	96	1	97	17	0	0	0	0	0	0	17	114
	July	150	0	150	7	6	0	0	1	0	2	16	166
	October	0	0	0	0	0	0	0	0	0	0	0	0
	Total	246	1	247	24	6	0	0	1	0	2	33	280
3	April	58	1	59	1	1	1	1	0	0	0	4	63
	July (sta. deleted)	—	—	—	—	—	—	—	—	—	—	—	—
	October (sta. deleted)	—	—	—	—	—	—	—	—	—	—	—	—
	Total	58	1	59	1	1	1	1	0	0	0	4	63
4	April	180	13	193	2	0	1	0	0	0	1	4	197
	July	202	2	204	67	5	1	0	1	0	16	90	294
	October	0	0	0	0	0	0	0	0	0	0	0	0
	Total	382	15	397	69	5	2	0	1	0	17	94	491
5	April	82	3	85	1	0	0	0	0	0	0	1	86
	July	66	0	66	21	16	1	0	0	0	2	40	106
	October	0	0	0	0	1	0	0	0	0	0	1	1
	Total	148	3	151	22	17	1	0	0	0	2	42	193
6	April	2	0	2	0	2	0	1	0	0	1	4	6
	July	275	0	275	20	3	0	0	0	0	1	24	299
	October	0	0	0	0	0	0	0	0	0	0	0	0
	Total	277	0	277	20	5	0	1	0	0	2	28	305
7	April	15	1	16	1	0	1	3	0	0	1	6	22
	July	230	4	234	76	25	0	0	2	0	9	112	339
	October	0	0	0	0	0	0	0	0	0	0	0	0
	Total	245	5	250	77	25	1	3	2	0	10	118	361
8	April	95	4	99	1	4	1	0	0	0	2	8	107
	July	209	4	213	48	6	0	0	2	0	12	68	281
	October	0	1	1	0	0	0	0	0	0	0	0	1
	Total	304	9	313	49	10	1	0	2	0	14	76	389
9	April	17	11	28	0	3	1	1	0	0	0	5	33
	July	585	65	650	43	1	1	0	0	1	10	56	706
	October	0	1	1	0	0	0	0	0	0	0	0	1
	Total	602	77	679	43	4	2	1	0	1	10	61	740
10	April	76	8	84	0	9	1	0	0	0	0	10	94
	July	146	5	151	28	5	1	0	1	0	1	36	187
	October	0	0	0	0	0	0	0	0	0	0	0	0
	Total	222	13	235	28	14	2	0	1	0	1	46	281
11	April (sta. deleted)	—	—	—	—	—	—	—	—	—	—	—	—
	July	252	1	253	31	2	1	0	0	0	1	35	288
	October	0	0	0	0	0	0	0	0	0	0	0	0
	Total	252	1	253	31	2	1	0	0	0	1	35	288
Totals	April	810	83	883	24	20	7	6	0	0	6	63	946
	July	2,215	73	2,298	364	70	5	0	7	1	59	507	2,805
	October	0	2	2	0	1	0	0	0	0	0	1	3
	Grand Totals	3,025	158	3,183	388	91	12	6	7	1	65	571	3,754

Table 2.—The average number of fish eggs and larvae per 10 minute tow from stations in Port Royal Sound, South Carolina and adjacent waters by station, by month, and by species. The figures are to the nearest whole number.

			Eggs			Larvae								Eggs and larvae
Station	Month	Number of Samples	*Anchoa mitchilli* (bay anchovy)	Unidentified	Total	*Anchoa mitchilli* (bay anchovy)	*Gobiosoma* sp. (goby)	*Hypsoblennius hentzi* (feather blenny)	*Menidia menidia* (Atlantic silverside)	*Trinectes maculatus* (hogchoker)	*Oligoplites saurus* (leatherjacket)	Unidentified	Total	
	April	7	27	4	31	<1	<1	<1	0	0	0	<1	<1	31
1	July	8	13	<1	13	3	<1	0	0	0	0	1	4	17
	October	7	0	0	0	0	0	0	0	0	0	0	0	0
	Total	22	13	2	15	1	<1	<1	0	0	0	<1	1	16
	April	9	11	<1	11	2	0	0	0	0	0	0	2	13
2	July	10	15	0	15	1	1	0	0	<1	0	<1	2	17
	October	7	0	0	0	0	0	0	0	0	0	0	0	0
	Total	26	10	<1	10	1	<1	0	0	<1	0	<1	1	11
	April	9	6	<1	6	<1	<1	<1	<1	0	0	0	<1	6
3	July (sta. deleted)	0	—	—	—	—	—	—	—	—	—	—	—	—
	October (sta. deleted)	0	—	—	—	—	—	—	—	—	—	—	—	—
	Total	9	6	<1	6	<1	<1	<1	<1	0	0	0	<1	6
	April	9	20	1	21	<1	0	<1	0	0	0	<1	<1	21
4	July	10	20	<1	20	7	1	<1	0	<1	0	2	10	30
	October	9	0	0	0	0	0	0	0	0	0	0	0	0
	Total	28	14	1	15	3	<1	<1	0	<1	0	1	4	19
	April	9	9	<1	9	<1	0	0	0	0	0	0	<1	9
5	July	10	7	0	7	2	2	<1	0	0	0	<1	4	11
	October	11	0	0	0	0	<1	0	0	0	0	0	<1	<1
	Total	30	5	<1	5	1	1	<1	0	0	0	<1	2	7
	April	9	<1	0	<1	0	<1	0	<1	0	0	<1	<1	<1
6	July	10	28	0	28	2	<1	0	0	0	0	<1	2	30
	October	11	0	0	0	0	0	0	0	0	0	0	0	0
	Total	30	9	0	9	1	<1	0	<1	0	0	<1	1	10
	April	9	2	<1	2	<1	0	<1	<1	0	0	<1	<1	2
7	July	9	26	<1	26	9	3	0	0	<1	0	1	13	39
	October	10	0	0	0	0	0	0	0	0	0	0	0	0
	Total	28	9	<1	9	3	1	<1	<1	<1	0	<1	4	13
	April	10	10	<1	10	<1	<1	<1	0	0	0	<1	<1	10
8	July	9	23	<1	23	5	1	0	0	0	0	1	7	30
	October	10	0	<1	<1	0	0	0	0	0	0	0	0	<1
	Total	29	10	<1	10	2	<1	<1	0	0	0	1	3	13
	April	9	2	1	3	0	<1	<1	<1	0	0	0	<1	3
9	July	10	59	7	66	4	<1	<1	0	0	<1	1	5	71
	October	9	0	<1	<1	0	0	0	0	0	0	0	0	<1
	Total	28	22	3	25	2	<1	<1	<1	0	<1	<1	2	27
	April	3	25	3	28	0	3	<1	0	0	0	0	3	31
10	July	9	16	1	17	3	1	<1	0	<1	0	<1	4	21
	October	5	0	0	0	0	0	0	0	0	0	0	0	0
	Total	17	13	1	14	2	1	<1	0	<1	0	<1	3	17
	April (sta. deleted)	0	—	—	—	—	—	—	—	—	—	—	—	—
11	July	8	32	<1	32	4	<1	<1	0	0	0	<1	4	36
	October	6	0	0	0	0	0	0	0	0	0	0	0	0
	Total	14	18	<1	18	2	<1	<1	0	0	0	<1	2	20
	April	83	10	1	11	<1	<1	<1	<1	0	0	<1	1	12
Totals	July	93	24	1	25	4	1	<1	0	<1	<1	1	6	31
	October	85	0	<1	<1	0	<1	0	0	0	0	<1	<1	<1
	Grand Totals	261	12	1	13	2	<1	<1	<1	<1	<1	<1	2	15

Table 3.—Size ranges (total lengths) of larval fishes from collections made in Port Royal Sound, South Carolina and adjacent waters. The species are arranged in order of their decreasing abundance in the samples.

Species	*Size range*	
	Inches	*Millimeters*
Anchoa mitchilli (bay anchovy)	0.09-0.28	2.2- 7.2
Gobiosoma sp. (goby)	0.08-0.21	2.1- 5.4
Unidentified	0.06-0.24	1.6- 6.0
Hypsoblennius hentzi (feather blenny)	0.10-0.40	2.4-10.2
Trinectes maculatus (hogchoker)	0.13-0.16	3.4- 4.0
Menidia menidia (Atlantic silverside)	0.19-0.22	4.8- 5.6
Oligoplites saurus (leatherjacket)	0.55	14.0

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PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
FISH EGGS & LARVAE
SAMPLING STATIONS
SCALE
NAUTICAL MILES
N
Atlantic Ocean
LADIES ISLAND
FORT FREMONT
BEAUFORT RIVER
PORT ROYAL SOUND
CHISOLM ISLAND
COOSAW RIVER
BEAUFORT
PORT ROYAL
Brickyard Cr.
Mulligan Cr.
McCalleys Cr.
Battery Creek
Archers Cr.
Ballast Cr.
Chowan Cr.
HILTON HEAD ISLAND
Park Cr.
Skull Cr.
PORT ROYAL ISLAND
WHALE BRANCH
BROAD RIVER
DAWS ISLAND
CHECHESSEE RIVER
PINCKNEY ISLAND
Mackay Creek
Jarvis Cr.
Broad Creek
Buck I.
CALIBOGUE SOUND
Bass Cr.
Victoria Bluff
COLLETON RIVER
HALL ISLAND
Pocotaligo River
East Br. Boyd Cr.
West Br. Boyd Cr.
Boyd Cr.
Euhaw Cr.
Hazzard Cr.
LEMON ISLAND
Chechessee Cr.
SPRING ISLAND
Sawmill Cr.
MAY RIVER
BULL ISLAND
Bryan Cr.
Bull Cr.
COOPER RIVER
DAUFUSKIE ISLAND
1
2
3
4
5
6
7
8
9
10
11

FIGURE 1

Seasonal Abundance and Distributions of the Benthic Invertebrates Community

LOYS P. PARRISH
Environmental Protection Agency
Cincinnati, Ohio

Introduction

Samples of the benthic (bottom) invertebrate community were collected from the vicinity of Port Royal Sound, South Carolina, in order to assess the base line water quality and to document the invertebrate community of this relatively undisturbed estuarine area. The estuary was sampled during the months of April, July and October, 1970. Each survey was initiated during the full moon phase to minimize population changes that could occur with different phases of the moon and thus different magnitudes of tidal cycle.

Port Royal Sound is formed by the confluences of the Beaufort, Broad, Chechessee and Colleton Rivers with the Atlantic Ocean (Figure 1). The shoreline between the estuarine waters and the dry ground is covered by extensive growths of marsh grasses. Such salt water marsh areas provide major amounts of nutrients to the estuary through the decay and resultant release of nutrients and through the consumption and utilization of nutrients in the grasses by organisms present in the estuary (Teal, 1962). Decaying marsh grasses and the nutrients resulting from this decay are an important source of food for the bottom invertebrate community. Consequently many of the invertebrates present are detrital feeders, dependent upon organic material in the bottom muds. These organisms represent a major portion of the base of the food web for the sport, commercial and forage fishes in the estuary and near shore areas.

Since the life span of most bottom organisms extends from three months to several years, such organisms reflect both past and present water quality.

Methods

Samples of the benthic invertebrate community were collected at selected stations in the estuary (Figure 1). Each station was transected and samples of the bottom organisms were taken at selected locations along each transect. Since the water chemistry of Stations 2 and 3 was similar, Station 3 was dropped after the April survey and Station 11 was added. A Peterson dredge was used to collect the bottom samples. Material from the dredge was sieved through a U. S. No. 30 standard sieve, and all material remaining on the sieve was preserved in 5% formalin and returned to Cincinnati, Ohio for processing. All preserved samples were examined and the benthic invertebrates were identified. Keys used in the identification are listed at the end of this report.

RESULTS AND DISCUSSION

The benthic invertebrate community of Port Royal Sound is typical of a non-polluted estuary bounded by salt marshes. A predominance of the organisms present are detrital feeders dependent on organic material in the substrate for their major food source.

The species and numbers of bottom organisms collected at each sampling location on the transects are reported in the Appendix. A summary of total species of organisms and average numbers of bottom organisms per square foot is presented in Table 1. For purposes of thids study, the term species represents an anatomically distinct form and not necessarily a genetic species.

In estuaries, invertebrates are influenced by four main factors: salinity, temperature, depth, and substrate type. Because of differences in salinity and temperature, many animals migrate up or down an estuary either with the tide or seasonally. Some short-lived forms may colonize areas at one season that they cannot inhabit during other seasons (Moore, 1962). In the estuarine area of Port Royal Sound, both temperature and salinity were fairly constant during each survey (Figures 2 and 3). However, temperature and salinity differed from survey to survey with the lowest salinities and temperatures recorded in April and the highest in July. Approximately 70 percent of the stations sampled supported the greatest number of organisms per square foot in April, indicating a probable preference of the organisms for lower temperatures and salinities. Stations 1 and 6 differed in that Station 1 supported the greatest number of organisms in October and Station 6 supported the greatest number in July. Station 1 exhibited an increase in Echinoderms (brittle stars) in October and Station 6 had an increase in Amphipods (scuds) in July.

The general trend of high organism numbers in April has also been noted by Dr. Gordon Thayer who is studying the benthic invertebrate populations of eel grass beds in North Carolina.[1] Dr. Thayer has noted a spring maximum in both numbers and species diversity, with young of the year predominant in the samples.

The lower portion of the estuary (Stations 1, 2, 4, and 10) supported the smallest numbers of invertebrates in July and the upper portion of the estuary (Stations 5, 6, 7, 8 and 9) supported the smallest numbers in October. Station 11 can be compared only for the months of July and October, with July supporting the smallest number of organisms.

In general, there was a greater number of organisms per square foot collected at stations on the Chechessee River side of the estuary compared to the number collected from the Broad River side of the estuary. This would indicate that the Broad River system had a lower productivity in the areas sampled.

A comparison of number of species of benthic organisms collected at the stations during each month indicates only small changes in numbers oc-

1. Personal communication with Dr. Gordon Thayer, National Marine Fisheries Service, Center for Estuarine and Menhaden Research, Beaufort, North Carolina, 1971.

curring at most stations. Six of the eleven stations sampled had the fewest species present in July.

Stations 2, 4 and 5 had significant changes in the numbers of species collected during each month. At Station 2 the number of species collected decreased from 30 in April to 19 in July and then increased to 31 in October. Changes occurred mainly in the *Gastropoda, Amphipoda* and *Polychaeta* (Appendix). At Station 4 the major increase in number of species occurred in October with *Gastropoda* and *Amphipoda* reflecting greater numbers. During one July survey, Station 5 exhibited an increase in most of the species of organisms, as compared to the April survey, with no significant increases in any one group.

The effect of depth on the organisms was minimized by sampling at various depths along each transect and averaging the number of organisms per square foot for each sampling station (Table 1). Bottom type had a definite effect on the distribution of organisms as reported by Moore (1962), Green (1968), and Teal (1962). Bottom types sampled during the survey have been compared to the number of species of organisms found in each bottom type (Table 2). The greatest numbers of spe-

Table 1.
Number of species and average number of bottom organisms collected at each station during the April, July and October 1970 surveys.

	April		*July*		*October*	
Station Number	*No. of Species*	*Avg. No. per ft.²*	*No. of Species*	*Avg. No. per ft.²*	*No. of Species*	*Avg. No. per ft.²*
1	11	21	11	19	16	36
2	29	405	19	86	31	99
4	26	488	20	55	36	95
5	17	386	30	98	15	29
6	27	202	23	328	13	27
7	34	394	28	87	22	70
8	21	250	20	132	21	50
9	25	220	18	47	19	29
10	19	183	23	40	17	86
11			17	66	14	260

Table 2. Number of species of benthic invertebrates collected from observed bottom types.

	Silt, Clay Sand	*Coarse Sand*	*Medium to Fine Sand*	*Sand and Shell*	*Sand, Shell and Silt or Clay*	*Clay with Silt, Sand and Detritus*	*Clay and Shell*	*Silt and Sand*
Organisms	*No. of Species*	*No. of Species*	*No. of Species*	*No. of Species*	*No. of Species*	*No. of Species*	*No. of Species*	*No. of Species*
P. MOLLUSCA								
Pelecypoda	12	5	3	5	5	3	5	8
Gastropoda	10	5	2	5	6	5	8	12
P. ARTHROPODA								
Amphipoda	7	6	4	7	5	5	4	7
Caprellidea	1	1	—	1	1	1	—	1
Stomatopoda	1	—	—	—	—	—	—	—
Mysidacea	—	—	1	—	—	—	—	—
Cumacea	2	1	—	1	1	1	—	1
Thoracica	—	—	—	1	—	—	—	—
Decapoda	5	6	1	4	6	1	3	10
Isopoda	2	1	—	3	1	1	2	1
Pycnogonida	1	—	—	—	—	—	—	—
P. COELENTERATA								
Anthozoa	2	1	1	1	1	1	—	2
P. ECHINODERMATA								
Ophiuroidea	4	2	—	2	2	2	1	2
P. PLATYHELMINTHES			—	—	—	—	1	—
P. NEMERTEA	1	1	—	1	1	1	1	1
P. ANNELIDA								
Polychaeta	1	1	1	1	1	1	1	1
Sipunculoidea	—	—	—	—	1	—	—	1
Total	49	30	13	32	31	22	26	47

NOTE: For the phyla Nemertea and Annelida the entire phylum is considered as one species.

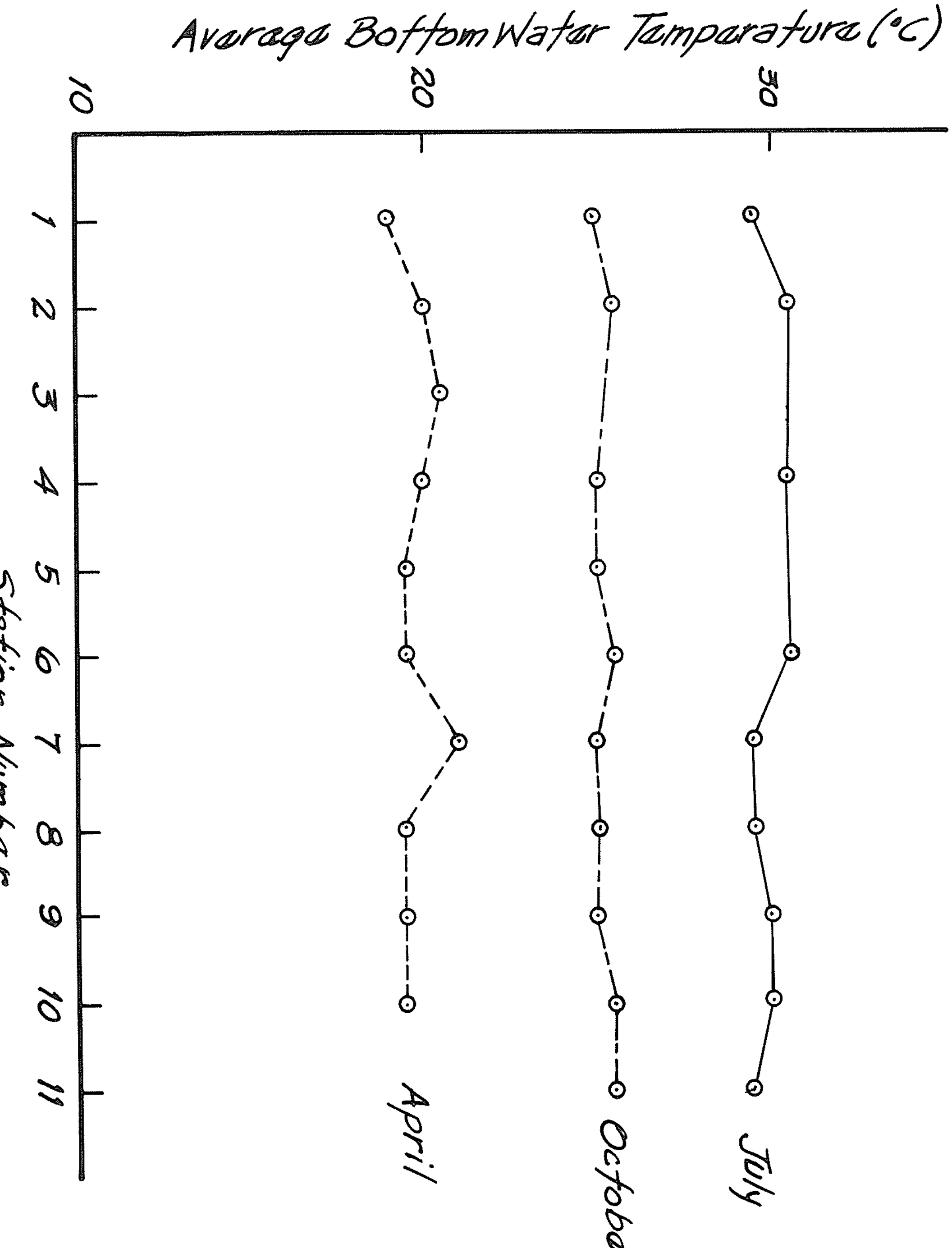


Figure 2. Average bottom water temperatures at each station on Port Royal Sound - April, July, & October, 1970.

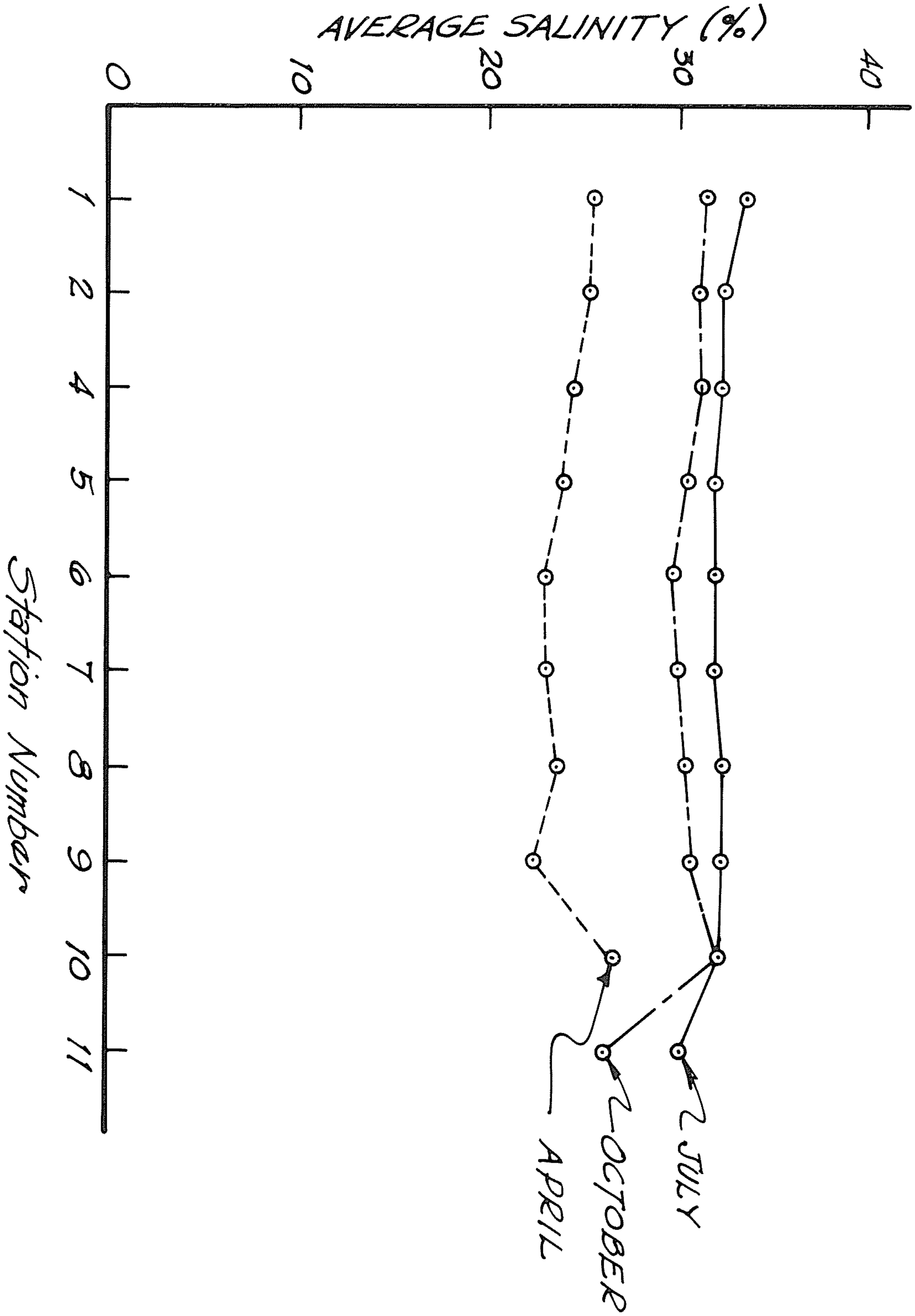


Figure 3. Average salinity at each station on Port Royal Sound - April, July, & October, 1970.

cies (48 to 56) were collected from bottom materials consisting of mixtures of silt and sand; or silt, clay and sand. The smallest number of species of organisms (13) was collected in medium to fine sand. Clay with silt or fine sand and detritus also supported a small number of species (17 to 22).

Exceptions to the above distributions are: the Pelecypoda which had the smallest number of species in a maxture of clay and silt; Stomatapoda and Pycnogonida which were collected only in a medium to fine sand; Platyhelminthes which were collected only in clay and shell; and Sipunculoidea which were collected in a mixture of sand, shell and silt or clay. Thus bottom material preference has a definite influence on organism distributions in the estuary but such influences were minimized by sampling the same areas during all surveys.

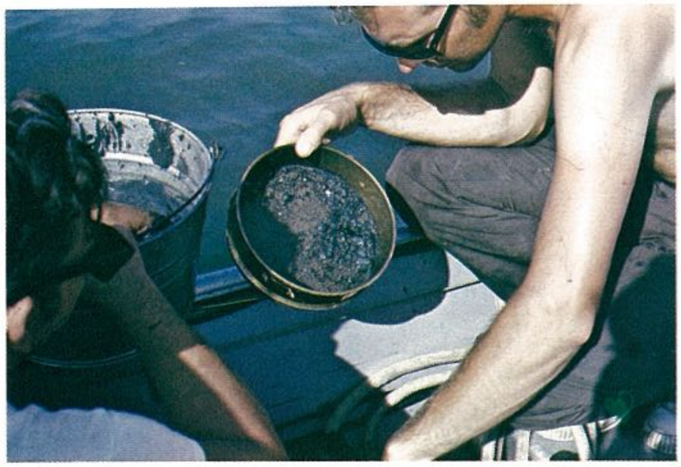
The unpolluted conditions of Port Royal Sound can be shown by comparing the benthic community in the Sound with a similar community affected by pollution. In September of 1965 a survey of Charleston Harbor, South Carolina, which was affected by domestic and industrial pollution, revealed a benthic invertebrate community with a small variety of organisms (Anon. 1966). Numbers of species ranged from 0 to 8 per square foot. Most of the stations (60%) sampled supported only polychaete worms.

In comparison, the numbers of species of benthic organisms collected from Port Royal Sound in October 1970 ranged from 12 to 36, a two- to five-fold difference between the two locations. Most of the stations sampled in the Sound supported a wide variety of benthic invertebrates. The total number of organisms per square foot was consistently larger at each station sampled in the Sound as compared to the stations sampled in Charleston Harbor.

Summary

The benthic invertebrate community of Port Royal Sound is typical of the type found in unpolluted estuaries bounded by extensive salt marshes. Populations in the estuary are mainly affected by environmental factors such as temperature, salinity, and bottom type. The Chechessee River area supported a larger number of organisms than the Broad River section.

Numbers of species of organisms, with the exception of Stations 2, 4, and 5, did not change greatly during the months of April, July, and October. Total numbers of organisms tended to be greatest in April when salinities and temperatures were low.



Field examination of sample; photo by J. Darby, S. C. Water Resources Commission.

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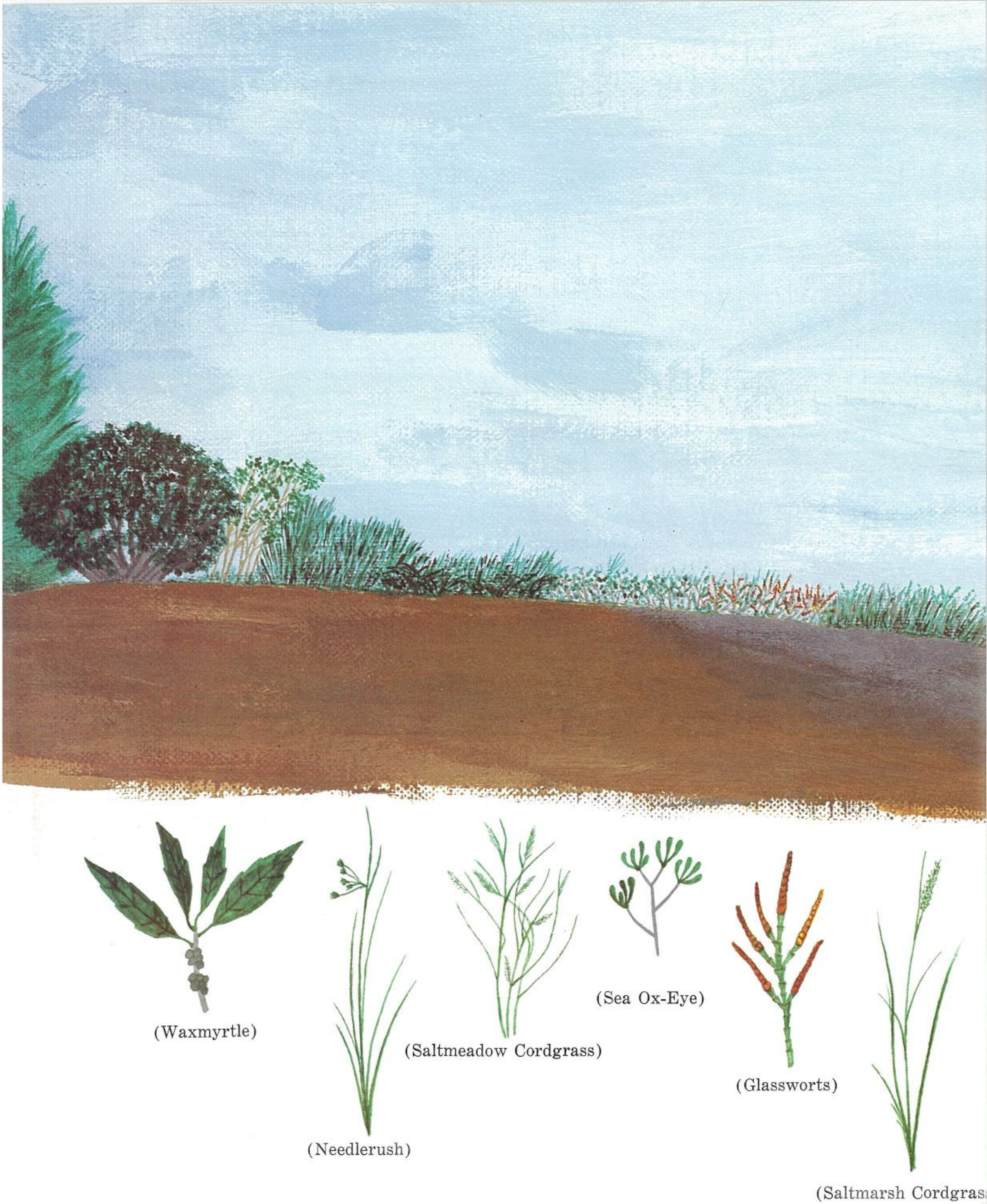
(Waxmyrtle)
(Needlerush)
(Saltmeadow Cordgrass)
(Sea Ox-Eye)
(Glassworts)
(Saltmarsh Cordgras

Types and General Distribution of

Typical Salt Marsh Vegetation

Key
(From Left to Right)

1. *Juniperus virginiana* (Eastern Redcedar)
2. *Myrica cerifera* (Waxmyrtle)
3. *Baccharis halimifolia* (Sea-myrtle)
4. *Juncus roemerianus* (Needlerush)
5. *Spartina patens* (Saltmeadow Cordgrass)
6. *Borrichia frutescens* (Sea Ox-Eye)
7. *Sailcornia spp.* (Glassworts)
8. *Spartina alterniflora* (Saltmarsh Cordgrass)


PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
BENTHIC INVERTEBRATE
SAMPLING TRANSECTS
SCALE
NAUTICAL MILES
Atlantic Ocean
LADIES ISLAND
FORT FREMONT
BEAUFORT RIVER
PORT ROYAL SOUND
BEAUFORT
PORT ROYAL
CHISOLM ISLAND
COOSAW RIVER
Brickyard Cr.
Mulligan Cr.
Albergottie Cr.
McCalley's Cr.
WHALE BRANCH
PORT ROYAL ISLAND
Ballast Cr.
Archers Cr.
Chowan Cr.
HILTON HEAD ISLAND
Skull Cr.
PINCKNEY ISLAND
Mackay Creek
Jarvis Cr.
DAWS ISLAND
CHECHESSEE RIVER
BROAD RIVER
Victoria Bluff
SPRING ISLAND
COLLETON RIVER
Saw Mill Cr.
Chechessee Cr.
LEMON ISLAND
HALL ISLAND
Pocotaligo River
East Br. Boyd Cr.
West Br. Boyd Cr.
Boyd Cr.
Cole Cr.
Euhaw Cr.
Hazzard Cr.
Bass Cr.
MAY RIVER
BULL ISLAND
Bryan Cr.
Bull Cr.
CALIBOGUE SOUND
COOPER RIVER
DAUFUSKIE ISLAND
Creek
Buck I.
1
2
3
4
5
6
7
8
9
10
11

FIGURE 1

Vascular Plant Inventory of Selected Marsh Transects in Port Royal Sound

Dorothy Shriner
University of South Carolina
Columbia, South Carolina

Introduction

A vascular plant inventory of seven marsh areas in the Port Royal Sound vicinity was conducted during the period of June 1 through August 25, 1970. The purpose of this study was to identify and determine the condition and quantity of the vascular plant species present in this environment.

Method

Seven representative transects were located in the study area (Figure 1). Quadrat locations along these transects were selected depending upon variations in elevation, vegetation, soil and/ or the density of a species. Generally, a uniform stretch was sampled every 15 meters to determine slight variations in densities and evaluations.

Average heights and densities were determined for July; average heights and volumes were determined for August. Plant heights were measured in inches while quadrats were measured in square meter areas (in transect number 1, these measurements could only be approximated due to the presence of pluff mud; however, with the assistance of high tide and a small boat, random samples were taken from several areas along this transect.) Volume measurements were obtained for *Spartina alterniflora* by computing the amount of water displaced by the cordgrass in a 1000 ml graduated cylinder. All plants used to make volumetric determinations were measured for height, and these measurements were averaged for each quadrat.

Tables expressing the information gathered during this study were prepared. Table 1 depicts the plants found above mean high water at each transect. This table also notes the abundance of each vascular species present. Table 2 gives the average heights of *Spartina alterniflora* at each quadrat in each transect during the investigation. Tables 3 and 4 depict the densities and volumes respectively of *Spartina alterniflora* again at each quadrat in each transect at the noted dates. Table 5 depicts the species in quadrats of the high marsh.

Transect Locations

Transect 1 is located on Chechessee Creek about one-half mile NNE of the small bridge that crosses the Creek from the mainland to Callawassie Island. This transect was bounded landward by the steep Callawassie bluff estimated to be four meters high, and waterward by the first small inlet from land. A compass reading of 208° from north, reading from the yellow post on the creek bank to a dead pine stump on the bluff was taken.

Transect 2 is located on the north bank of the Colleton River near its confluence with Chechessee River. It is immediately west of the first creek on the north side which empties into the Colleton River. Two reference points were used here. One was a channel marker in the Colleton River near the mouth of the small creek and the other was the third small group of palmetto trees (counting from the western tip) on a small island located in the middle of this marsh area. Using the palmetto trees as a base a transect line was established through the marsh on line with the channel marker in the Colleton River. This was on a compass heading of 135°SE. Sighted from the channel marker the heading would be 315°N. This transect was approximately 53 meters long and crossed a 30 foot wide tidal creek. Near the low tide area the transect crossed a sandy mud flat and ended at the Colleton River.

Transect 3 is located on the west side of Sawmill Creek, ¼ mile from its confluence with the Colleton River. Near this area the remains of an oyster factory and large mounds of bleached oyster shells are evident. A transect line was established into the marsh using a cedar tree located at the forest's edge on a point of land 100 yards north of the oyster shell mounds. The transect line was sighted along a compass heading of 315°N into the marsh and ended at the first tidal creek. Total length of the transect was approximately 20 meters.

Transect 4 is located on the North side of Mackay Creek near its confluence with Port Royal Sound. The transect through this marsh runs parallel to Mackay Creek between the east side of Corn Island and the first small tidal creek that empties into Mackay Creek. A palmetto tree at the edge of the forest on Corn Island about 50 yards from Mackay Creek and with a "no trespassing" sign attached to it was used as a reference point to establish a transect line into the marsh along a compass heading of 125°E. The total length of the transect from the palmetto tree to the small creek was approximately 34 meters.

Transect 5 is located on the northern tip of Hilton Head Island near Elliot Creek (Park Creek) which drains into Skull Creek near its confluence with Port Royal Sound. A transect line was established on a compass heading of 160°S using as a base a solitary palmetto tree which stands about 100 yards Northeast of Elliot Creek at the northern edge of the marsh. It can easily be seen from Skull Creek and Elliot Creek. The transect line was approximately 40 meters long and extended to a small drainage creek in the marsh about 3 meters from the east bank of Elliott Creek.

Transect 6 is located on the south bank of the Colleton River approximately 4,500 yards from the confluence of the Colleton and Chechessee Rivers. The transect is located on a large, low-lying area that appears to be the remains of a large fresh water pond that now is being slowly inundated by the encroaching tides. This depression separates the high bank of Victoria Bluff. Transect 6 runs parallel to the river through this low area from the upper bluff to the lower bluff.

Table 1
VASCULAR SPECIES FOUND ABOVE HIGH WATER

Transect Length in meters	1 18	2 53	3 20	4 34	5 40	6 15	7 20
Distichlis spicata (Salt Grass)	—	—	—	—	—	pres	pres
Andropogon virginicus (Broom Sedge)	—	—	—	3 cl	abd	25 cl	abd
Chenchrus longispurus (Chenchrus)	—	—	—	—	11	—	—
Chloris petraea (Finger Grass)	—	—	—	6 cl	—	—	—
Gymnopogon ambiguus (Beard Grass)	—	—	—	4 cl	—	—	—
Spartina patens (Saltmeadow Cordgrass)	—	10 ft bd	6 ft	1 cl	—	—	—
Cynodon dactylon (Bermuda Grass)	—	—	—	—	—	6 ft bd	—
Panicum virgatum (Tall Smooth Panicum)	7 cl	—	1 cl	—	—	—	—
Paspalum sectaceum (Slender Paspalum)	—	—	2 cl	2 cl	—	—	—
Pharlaris caroliniana (Canary Grass)	—	—	—	—	—	34 cl	—
Sporbolus poiretii (Smut Grass)	—	—	—	1 cl	—	—	—
Sphenopholis spp. (Wedge Grass)	—	—	—	—	—	6 cl	15 ft bd
Uniola paniculata (Sea Oats)	—	—	—	—	169 pl	—	—
Uniola sessiliflora (Uniola)	—	—	—	1 cl	—	1 cl	—
Yucca spp. (Yucca)	—	6	—	—	25	—	—
Juncus roemerianus (Needlerush)	—	—	—	1 cl	—	—	—
Fimbristylis spadacea (Stiff Fimbristylis)	—	—	—	—	abd	10 cl	—
Cyperus spp. (Sedge)	—	—	—	—	1 cl	—	—
Digitaria sanguinalis (Crab Grass)	—	—	—	—	—	15 pl	—
Juniperus virginiana (Eastern Redcedar)	—	13	4	—	—	2	6
Pinus taeda (Loblolly Pine)	11	—	6	—	1	—	—
Liquidambar styraciflua (Sweetgum)	3	—	—	—	—	—	—
Magnolia grandiflora (Southern Magnolia)	1	—	—	—	—	—	—
Nyssa sylvatica (Black Gum)	7	—	—	—	—	—	—
Persea borbonia (Red Bay)	—	—	—	1	—	—	—
Prunus serotina (Black Cherry)	2	—	—	—	—	—	—
Quercus nigra (Water Oak)	5	—	—	—	2 (sm)	—	—
Quercus virginiana (Live Oak)	7	13	9	12	4 (sm)	5	2
Sabal palmetto (Cabbage Palmetto)	11	34 (81g)	2	8	3	2	20 (61g)
Myrica cerifera (Wax Myrtle)	3	—	2	—	—	—	1
Ilex vomitoria Yaupon (Cassino Berry)	18	30	6	13	—	16	6
Baccharis halimifolia (Sea-Myrtle)	4	—	4	—	1	—	7
Iva frutescens (Marsh Elder)	—	1	1	—	3	20 ft bd	48
Serenoa repens (Saw Palmetto)	—	41	—	25	—	—	—

Table 1, continued

Transect Length in meters	1	2	3	4	5	6	7
Hypericum hypericoides (St. Andrew's Cross)	—	5	—	—	—	—	—
Agalinis maritima (Gerardia)	—	—	—	—	—	—	20 ft bd
Erythrina herbacea (Erythrina)	—	3	—	—	—	—	—
Phytolacca americana (Pokeweed)	—	—	—	1	—	1	—
Lespedeza cuneata (Lespedeza)	—	—	—	—	—	—	142
Oenothera speciosa (Evening Primrose)	—	—	—	—	10	—	—
Heterotheca subaxillaris (Heterotheca)	—	—	—	—	48	—	—
Solidago sempervirens (Goldenrod)	26	—	—	—	241	—	—
Robinia elliottii (Robinia)	—	—	—	—	79	—	—
Sabatia stellaris (Sabatia)	—	—	—	—	14	—	—
Limonium carolinianum (Sea Lavender)	—	—	—	—	79	—	—
Chenopodium album (Pigweed)	—	—	—	—	—	21	—
Erigeron canadensis (Horseweed)	—	—	—	—	13	—	—
Tragia urens (Eastern Tragia)	—	—	—	—	—	39	—
Croton punctatus (Croton)	—	—	—	—	—	12	—
Peasum spp. (Peasum)	—	—	2	—	58	—	—
Apios americana (Apios)	1	—	—	1	—	—	—
Portulaca pilosa (Hairy Portulaca)	—	—	—	—	37	160	—
Sesuvium portulascastrum (Sea Purslane)	—	—	—	—	abd	3	—
Cynanchum palustre (Milkweed)	—	—	—	—	38	—	—
Smilax spp. (Greenbriar)	3	—	—	2	42	2	5
Ipomoea sp. (Morning-Glory)	6	—	2	—	27	—	—
Cuscuta spp. (Love-Vine)	—	—	—	—	abd	—	—

Abbreviations: abd — abundant
bd — bed
cl — clump
ft — foot, feet
lg — large
med — medium
pl — plant, plants
pres — present
sm — small

Transect 7, which is located on the Chechessee River side of Rose Island, is adjacent to the small creek which creates the island. Sighting from the island near the first *Sabal palmetto* tree next to the creek towards a red sign on the edge of the Chechessee River, this transect is 227° from north.

Results and Discussion

At transect 1 the soil on the shore, which was solid, had a high sand content. This area supported a good mussel population. The solid ground of the transect graded gently into a region of soft mud and oysters, and then finally, into pluff mud that was cut by many uniform islets and interlaced with waterways. In July, the small islets supported stands of *Spartina alterniflora* with an average density of 53 culms/meter^2 and an average height of 56 inches. On these islets in August, the average height of the *Spartina alterniflora* was 78 inches and the average volume was 170 ml. The presence of the high bluff was reflected in the land species found at this transect (Table 1). In July, the *Spartina alterniflora*, throughout the transect, had an average height of 31.71 inches and an average density of 79.3 culms/meter^2 (Tables 2 & 3); in August, the average height was 45.6 inches while the average volume was 61.5 milliliters.

Transect 2 changed little through the months except for an obvious increase in plant size. The individual *Spartina alterniflora* blades increased in length from about four inches in June to approximately 10 inches in August. The average *Spartina alterniflora* density was 102.93 culms/meter^2 and the average height was 35.15 inches in July. In August the average height was 46.3 inches and the average volume was 75.1 milliliters (Tables 2, 3 and 4). The species found on the hammock, located on the transect, were typical of those found on low elevations bordering salt marshes with the exception of *Osmanthus americana* encountered in the central region of the hammock (Table 1). This transect is protected behind the oyster shell barriers near its shore and the soil was generally very soft. The creek that cuts the marsh closest to the hammock had a swift current and a fairly stable bottom. The consociation here of *Spartina alterniflora* had a surprisingly high average volume in spite of the dwarf species sampled near the hammock. The cordgrass was quite chlorotic near and on the oyster shell barriers, but the plants in the rest of the transect did not appear to be so affected. This marsh transect was representative of a typical marsh area in that the elevation changed little resulting in many drainage areas and a soft bottom (Chapman, 1960).

In Transect 3, the average density for *Spartina alterniflora* in July was 87.75 culms/meter^2, and the average height was 31.75 inches. The height averaged 40.5 inches and the volume averaged 54.7 milliliters in August (Tables 2, 3, and 4). The cordgrass showed no chlorosis as was evident in Transect 2. The land species were typical low elevation salt marsh boundary species (Table 1). Only the height of the *Spartina alterniflora* changed significantly during the period of study. The soil was primarily sandy and graded gently into soft mud at the edge of a small tidal creek bounding this site. This transect had a very robust stand of *Borrichia frutescens*. The species present on the high marsh area of this transect were unusually dense and robust (Table 5).

Transect 4 was unusual in that the soil along the edge of the high land was composed of a clay or marl overlain with sand. Few plants grew along this stretch of shore (Table 1). The land gently sloped down about 10 or 20 feet from a deciduous

Spartina alterniflora (cordgrass); photo by M. Thompson, S. C. Water Resources Commission.

TABLE 2

AVERAGE HEIGHTS OF *SPARTINA ALTERNIFLORA* IN SAMPLE AREAS
(in inches)

QUADRAT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Transect 1																
July 13, 1970	11	14	37	25	39	45	51									
August 15	28	23	44	35	48	64	77									
Transect 2																
June 30	8¼	10½	20	27½	58	45	62	41	44	41	38	32	38	30	37	41
August 16	16	13	26	32	66	67	70	56	56	56	62	37	42	35	39	68
Transect 3																
June 28	—	27	15	37	48											
August 8	—	32	23	46	61											
Transect 4																
June 29	21	26	42½	52	64	42	61	42	46	48	59	73	21	20	62	63
August 15	31	33	57	65	71	66	71	63	64	71	63	81	31	30	71	70
Transect 5																
July 11	—	8	9	43	40	31	15	12	20	28	42	56				
August 15	—	16	18	46	48	37	24	24	48	48	60	84				
Transect 6																
August 8	—	—	6	10	6	10	44									
Transect 7																
August 8	—	16	25	36	36	61										

TABLE 3

DENSITY OF *S. ALTERNIFLORA*
(culms/meter^2 quadrat)

QUADRAT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Transect 1																
July 3	41	99	86	136	101	43	49									
Transect 2																
June 30	179	241	108	85	76	27	33	67	41	93	87	128	119	129	51	73
						(21)	(59)	SHOOTS								
Transect 3																
June 28	—	85	141	76	49											
Transect 4																
June 29	12	61	45	78	92	43	72	37	91	68	47	69	64	55	65	15
						(16)	(10)	(48)	SHOOTS							
Transect 5																
July 11	—	19	172	107	48	95	98	123	24	46	41	35				

forest to the marshland. *Morus rubra, M. alba, Persea borbonia, Carya spp.,* and *Serenoa repens* were abundant in the central regions of the small island. *Quercus virginiana* and *Q. nigra* were abundant along the edge of this island (Table 1). This transect had the tallest *Spartina alterniflora* stand of all the transects sampled in July (Table 2). The average height for *Spartina alterniflora* in July was 45.3 inches, its average density was 79.93 culms/meter^2; in August, the average height was 58.6 inches and the average volume was 100.56 ml (Tables 2, 3 and 4). The greatest average volumes and heights of all the transects sampled were found in this transect.

At Transect 5, the southernmost transect, the salinities were high due to the close proximity of the Atlantic Ocean. The soil was generally firm and the area supported more mussel colonies than any other location studied. *Salicornia bigeloveii* and *S. virginica* were abundant. Several pannish regions nearby were bounded by *Juncus roemerianus* near the higher land of the nearby hammock. The vegetation was more varied in this transect than at any of the other transects (Table 1). For July *Spartina alterniflora* averaged 25.33 inches in height with an average density of 67.33 culms/meter^2; in August, the average height was 37.8 inches with an average volume of 57.00 ml (Tables 2, 3, and 4). During August the *Limonium caroliniana* and *Sesuvium portulascastrum* had reached maximum growth and were in bloom. *Portulaca pilosa,* which appeared after the July study, was also in bloom. This area was quite interesting due to the large stands of *Robinia elliotii, Yucca* and *Uniola paniculata* near the area (Tables 1, 5).

Juncus roemerianus (Needlerush); photo by M. Thompson, S. C. Water Resources Commission.

Salicornia virginica (glasswort); photo by H. Thompson, S. C. Water Resources Commission.

At Transect 6, *Suaeda* was very dense and shrublike. It grew in the very sandy soil, crowding out practically every other species. *Salicornia virginica* and *S. bigloveii* were both found here. *S. bigeloveii,* which was very robust and succulent, was mixed with dwarf *Spartina alterniflora* (Tables 2, 5). August values for *Spartina alterniflora* were very small with the average height being 14.8 inches and the average volume 11.6 milliliters (Tables 2, 4).

Transect 7 had a red clay substratum beneath the upper layer of sand and shells. A rather dense stand of *Agalinis maritima* was present just above the high water mark. The average height of *Spartina alterniflora* taken at this transect was 34.8 inches and the average volume was 30.6 milliliters (Tables 2, 4). The quadrats in this transect were taken until the first drainage area was reached and no more quadrats were recorded except for the quadrat at the river's edge.

Each transect had some variable which made it unique, but likewise, each followed the typical pattern of high marsh species followed by a homogeneous stand of *Spartina alterniflora* as one approached the water's edge. The high marsh species

TABLE 4

VOLUMES OF *S. ALTERNIFLORA* (in ml.)

QUADRAT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Transect 1 August 16	35	20	35	30	40	90	170									
Transect 2 August 16	3	3	20	22	90	140	170	120	125	120	130	33	50	40	45	90
Transect 3 August 8	—	40	21	58	100											
Transect 4 August 15	23	20	60	80	85	145	130	110	115	120	105	240	45	46	150	140
Transect 5 August 15	—	2.5	3	70	65	48	20	22	70	75	90	230				
Transect 6 August 8	—	—	1.3	5	2	6	38									
Transect 7 August 8	—	11	20	30	34	58										

TABLE 5

SPECIES IN QUADRATS OF THE HIGH MARSH

Quadrat	1	2	3	4
Transect 3	*B. frutescens*			
	109 plants, 22″			
Transect 5	*B. frutescens*			
	83 plants, 18″			
	D. spicata (Saltgrass)			
	201 culms, 18″			
	S. bigeloveii			
	32 plants, 12″	131 plants, 7″		
	S. patens (Saltmeadow cordgrass)			
	25 plants, 18″			
		Salicornia spp. (Glassworts)		
		37 plants, 6″	23 plants, 10″	
Transect 6	*D. spicata*			
	very dense	63 culms, 6″		83 plants, 8″
	S. virginica, S. bigeloveii			
	1 plant, 8″	2 plants, 10″	26 plants, 11″	98 plants, 6″
Transect 7	*D. spicata*			
	49 culms, 7″			
	S. virginica			
	12 plants, 10″			


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BULL ISLAND
CALIBOGUE SOUND
DAUFUSKIE ISLAND
COOPER RIVER
Brickyard Cr.
Battery Creek
Ballast Cr.
Chowan Cr.
Station Cr.
Skull Cr.
Mackay Creek
Broad Creek
Bass Cr.
Bryan Cr.
Bull Cr.
Sawmill Cr.
Victoria Bluff
Chechessee Cr.
Hazard Cr.
Euhaw Cr.
Boyd Cr.
East Br. Boyd Cr.
West Br. Boyd Cr.
1
2
3
4
5
6
7

FIGURE 2

varied somewhat and the height of the *Spartina alterniflora* was not uniform due to such variables as soil texture, presence or absence of vegetative debris, animals, and swift currents. Some transects were protected more from wind and wave action than were others. Nevertheless, *Spartina alterniflora* was the dominant vascular plant species.

Although pluff mud was very abundant in Transect 1, the softest soil was found in Transect 2 behind the oyster shell barriers and in the lower elevations. Transects 3, 4, 5 and 6 had firm soil. The high sand content in shore regions seemed to be the dominant factor in the firmness of these areas, especially in Transects 5 and 6.

Spartina alterniflora heights, densities and volumes varied from transect to transect. Transect 4 had the tallest sample in July at 73 inches and Transect 5 had the tallest sample in August. In July, the density of *S. alterniflora* at Transect 4 was 69 culms/meter^2 whereas the density in August for Transect 5 was 35 culms/meter^2. The blades of *Spartina alterniflora* at both transects averages 34 inches long and three-fourths of an inch wide. Frequently, the shortest samples of *Spartina alterniflora* were found mixed with *Salicornia* as in Transect 2.

In July, the most robust high marsh plants were found in Transect 3. Here *B. frutescens* was the most robust during the study period. In some transects *B. frutescens* was very sparse or absent. In August, Transect 6 revealed a very robust stand of *Suaeda*, about 48 inches tall, and *Iva frutescens* near the shore.

Drift was present in great abundance in transects 2, 3 and 7; however, it was sparse in Transects 1, 4 and 6. There was no drift present in Transect 5. This drift may have resulted in the absence of high-marsh species such as *Limonium, Distichlis spicata* and possibly *Aster tenuifolius* by keeping the seedlings from light and by having a crushing effect upon them.

Borrichia frutescens (sea ox-eye); photo by M. Thompson, S. C. Water Resources Commission.

Spartina patens (salt meadow cordgrass); photo by M. Thompson, S. C. Water Resources.

Volumetric determinations were performed as late as possible during the study period in order that maximum volume measurements would be obtained. The salt marsh cordgrass does not reach maximum growth until it blooms in the early fall. Only a few plants were in bloom in August, and they were a foot taller than the nonblooming plants. None of the plants in bloom were used in this report. A relationship between plant height and volume did not exist. Also, the volumetric determinations were affected by the number of shoots attached at the base of the plant. Usually one or two of the shoots, which ranged from 3 to 8 milliliters in volume, were attached to each plant. The greatest volume for a sample area was 240 milliliters in Transect 4. The least volume recorded was in quadrat 12 of Transect 6, 1.3 ml for 6 inch plants (Table 4).

Yucca sp. photo by M. Thompson, S. C. Water Resources Commission.

Baccharis halimifolia (Sea-Myrtle); photo by M. Thompson, S. C. Water Resources Commission.

Magnolia grandiflora (Southern Magnolia); photo by M. Thompson, S. C. Water Resources Commission.

The land bounding these marshes was very unspoiled. The dominant land species varied from transect to transect, but all exhibited plants usually found in the coastal plains area. Transect 1 had 26 *Solidago sempervirens* and 18 *Ilex vomitoria* as the most numerous species, but further investigations revealed the community to be *Quercus-Pinus*. Transect 2 had 41 *Serenoa repens,* 34 *S. palmetto,* 30 *Ilex vomitoria,* and a 10-foot bed of *S. patens.* This was a *Sabel-Quercus-Juniperus* community. Transect 3 had nine *Q. virginiana,* 6 *Pinus taeda,* and 6 *Ilex vomitoria,* but was a *Quercus-Pinus* formation. Transect 4 had 25 *Serenoa,* 13 *Ilex vomitoria,* 12 *Quercus virginiana,* and was a *Quercus-Carya-Sabal* formation. Transect 5 had 160 *Uniola paniculata,* 79 *Robinia elliotii,* 241 *Solidago sempervirens,* 79 *Limonium caroliniana,* and 48 *Peasum,* but the actual community was *Uniola-Andropogon-Quercus.*

Saw Palmetto *(Serenoa repens);* photo by M. Thompson, S. C. Water Resources Commission.

Juniperus virginiana (Eastern Redcedar); photo by M. Thompson, S. C. Water Resources Commission.

Conclusion

1. *Spartina alterniflora* was the dominant plant species in the marshes of Port Royal Sound during this survey.

2. Each transect had some variable which made it unique, and also, each displayed the typical pattern of high marsh species followed by a homogeneous stand of *Spartina alterniflora* near the waters edge.

3. The heights, densities and volumes of the plants, particularly the *S. alterniflora*, varied at the different transects, but the overall indication was that the marshes of Port Royal Sound were generally unspoiled and in excellent condition.

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Algae

Algae are generally thought of as being plants. They are chiefly aquatic, unicellular and green. The green color that one normally associates with algae is due to the presence of the green pigment, chlorophyll. Often, however, other pigments are predominant over the everpresent chlorophyll and algal lines of different colors are produced. In addition, therefore, to the green line of algae, which in itself contains several major groups or phyla, a brown line exists which includes three phyla and a red line exists which includes one phyla. Another group of so-called "algae," the blue-greens, exists, but because of several structural differences, they are often not considered true algae, but rather organisms related to the bacteria.

In addition, some recent classification schemes, have revised the strict plant-animal concept and replaced it with perhaps a more realistic system in which the algae are grouped with the fungi, slime molds and protozoa and not with the multicellular plants.

Since algae contain the essential pigments, they are capable of photosynthesis, the process whereby radiant energy is converted into chemical energy in the form of carbohydrates. Not only do the carbohydrates represent an extremely important source of food for aquatic organisms, but the oxygen that is released by the algae as an end-product of photosynthesis is important in maintaining adequate amounts of dissolved (aquatic) and atmospheric oxygen.

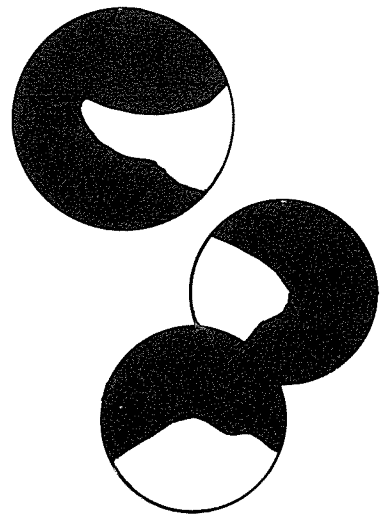
Most algae are microscopic. Without the aid of magnification, their presence is usually disclosed only when they appear in sufficient numbers to add coloration to the water. Others, however, like the brown kelps, the most structurally complex of all the algae, often attain lengths of several hundred feet.

Biologists do not always agree on a classification scheme for algae, but even with this in mind, the following one is offered. It will divide the algae into 6 different major divisions or phyla which attempt to include the organisms that are most closely related (by having common characteristics). The blue-greens are described although we do not classify them with the rest of the algae.

CHLOROPHYTA (GREEN ALGAE)

Obviously, the algae included in this phylum are green. Representatives are also unicellular, colonial or multicellular. Most of the Chlorophyta are filamentous.

Green algae are widely distributed, growing in such diverse places as salt and fresh water (chiefly fresh water), on wet soil, moist stones, tree bark and wet posts. Greens are important sources of food for fish and other aquatic organisms; they are valuable oxygenators; and they can also be utilized as a source of human food.

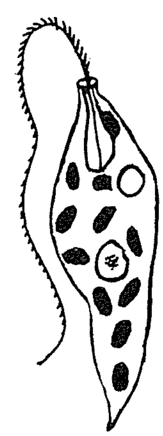


Chlorella

EUGLENOPHYTA (EUGLENOIDS)

The members of this phylum are almost exclusively one-celled organisms that swim by means of flagella. They may be green, brownish, reddish, or yellowish-green in color. Because of their mobility and green pigmentation, they possess both animal and plant characteristics.

The euglenoids are found in practically all bodies of water—oceans, lakes, ponds, streams, pools and so forth. They are a widely dispersed group of organisms, and thus they constitute an important source of food for fish and other aquatic organisms. Unfortunately, they can create a bad taste and odor problem in water supplies, rendering the water very unpalatable.



Euglena

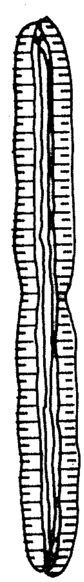
CHRYSOPHYTA (GOLDEN-BROWN ALGAE)

Structurally speaking, this group of algae contains more different types than any other algal group. Most are unicellular and colonial, however, multicellular types do exist. Flagella may be present or absent.

Probably the most widely known members of this phyla are the diatoms. Almost all are unicellular organisms that possess cell walls which are impregnated with silica. The walls consist of two halves that fit together as if they were a lid and a box.

Diatoms form an important food source for fish. In addition to this, great deposits of diatom shells, called diatomaceous earth, are mined in order that the shells can be used, for example, as abrasives in polishes and toothpastes, as filters in industry, and as insulators for pipes, furnaces and refrigerators. Perhaps the most important product, or in this case, by-product, of diatom shells is petroleum. Much of today's petroleum is felt to be derived from ancient diatom deposits.

Again, like most algae, the Chrysophyta are widely distributed. They can be found in damp soil and in fresh and salt water. In salt water, particularly, they can occur in enormous numbers.

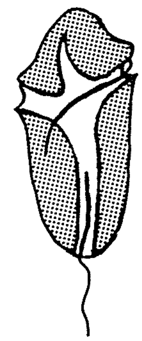


Nitzschia, diatom

PYRROPHYTA (FIRE ALGAE)

The most important members of this phylum, the dinoflagellates, are generally microscopic, unicellular, flagellate organisms. They are primarily marine and they enjoy worldwide distribution.

The importance of these organisms lies in their role as primary producers. They constitute an important supply of food for other aquatic inhabitants. Occasionally, however, dinoflagellate blooms in localized areas create conditions that may prove to be toxic to marine life. The reddish colored *Gymnodinium*, for example, may occur in such excessive numbers that the water is actually tinted red, resulting in the so called red tide, which can produce massive fish kills.



Gymnodinium

PHAEOPHYTA (BROWN ALGAE)

The brown algae, which are the most complex of all algal types, are multicellular and sessile. Except for a few rare fresh water species, they are entirely marine, growing attached to the substratum, in cool, shallow waters.

Members of the Phaeophyta include *Fucus*, the common rockweed found along many shores, and most of the seaweeds, which include the kelps. Many of these representatives possess leaflike, rootlike and stemlike parts, and some of the giant kelps grow to lengths of several hundred feet.

Like most other algae, the brown algae are important food sources for aquatic animals. In addition to this function, however, they have become very useful to man. They are, for example, a source of iodine, algin, mineral salts, food and medicinal ingredients.

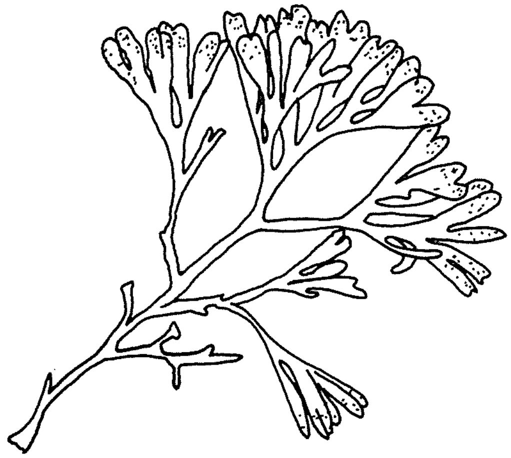
RHODOPHYTA (RED ALGAE)

Red algae are entirely sessile, primarily multicellular, and exclusively marine. They tend to grow at depths somewhat greater than the brown algae. Structurally, they assume feathery, branched-filamentous or ribbon-like shapes, and rarely do they exceed lengths of three to four feet.

The Rhodophyta provide food for both sea animals and man. Additionally, they have attained commercial success as the source of agar-agar, a culture medium, and as the source of additives in glue, shoe polishes, cosmetics and jellies.

CYANOPHYTA (*Blue-Green Algae*)

Although many members of this phylum do appear blue-green in color, others assume hues of yellow, green, gray-green, black, blue, purple, red, tan, brown, or shades somewhere in between these. This wide variety of colors is due to the numerous pigments that occur within this phylum.



Fucus

While most of the blue-green are unicellular, colonial and filamentous forms are present. According to Weisz (1967), blue-greens can be found in practically every location where water is present, whether it be fresh, salt, hot (85°C or more) or cold (the Polar regions). Even areas that are only wetted intermittently, such as tidal flats frequently support growths of blue-greens.

Blue-greens can in excessive numbers contaminate water supplies and render the water poisonous to fish and some domesticated animals. From a positive standpoint, however, they do provide food for aquatic animals and some, as nitrogen fixing organisms, increase the fertility of the soil.

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Algae of the Marshlands

Brenda C. Blackwelder
University of South Carolina

Introduction

During June, July and August of 1970, an investigation in the salt marshes of the Port Royal Sound area was made to determine the species and distribution of algae. Five major transects were established along the Colleton and Chechessee Rivers and in the Hilton Head area.

Transect Locations

Transect #1 was located on Chechessee Creek in the marsh bordering Callawassee Island approximately one quarter mile east of the wooden bridge leading to the island (Figure 1). The transect was marked on the landward side by a *Liquidambar* (the only sweetgum tree observed in the area bordering the marsh) and ran a length of 130 feet NNE to a large, shallow creek. The creek end of the transect was marked with a stake.

Transect #2 was located near the mouth of the Colleton River in the marsh bordering a hammock off Spring Island (Figure 1). The transect ran from the large pilings near the mouth of the small creek to the center palmetto tree in the small cluster of five trees due west from the pilings. This transect was 706 feet long from the palmetto tree to the edge of the marsh. It extended over 100 feet beyond the marsh to the low water line. The transect was marked along the length with bamboo poles.

Transect #3 was located on Sawmill Creek which branched from the Colleton River (Figure 1). It was located near palmetto pilings which marked the site of several large oyster shell mounds. This transect ran NNW from the land to the first large creek—a distance of 197 feet. It ran parallel with Sawmill Creek. The site was marked on each end with wooden stakes.

Transect #4 was located near the mouth of Mackay Creek (Figure 1). It ran NE from the marked palmetto tree to the first large creek, a total of 800 feet. The transect paralleled Mackay Creek.

Transect #5 was located in the Hilton Head area at the most northern tip (Figure 1). It was in a marsh located at the mouth of Park Creek (Elliott Creek) between Bobb Island and Dolphin Head. The transect was accessible by boat from the Port Royal Sound or by Park Creek. This transect ran SSE from a marked, lone palmetto tree on the hammock to the right of Park Creek to a small branch of Park Creek approximately 600 feet from the palmetto.

Purpose

The object of this investigation was to determine what algal species occurred in the marshes during the summer months, where they were found, the abundance of these species, and the possible changes occurring during the summer months.

Methods of Investigation

Each transect was initially explored and marked with wooden stakes or bamboo poles. Compass readings were taken, and each transect was measured with a measuring line.

Initially, samples were taken at random along the transect where a visible difference in flora or change in physical conditions occurred. This preliminary scan indicated where the algae were most likely to occur, and gave a general idea of what would be found.

Subsequently, permanent sampling stations were established throughout the length of the transect. These stations were marked with bamboo poles. Samples at each station along the transect were taken within a quarter meter square, not more than a meter on either side of the transect line. *Spartina alterniflora* was collected within the quarter meter since the grass provided the major surface area for the attachment of algae in the marshes. Living grass and dead stalks of grass were collected from each station. Shells were collected when present in the quarter meter sample, and mud samples were taken for the identification of algae growing on the surface. Notes were made at each station within a transect on the characteristics of the station.

In one transect (#4—Mackay Creek), elevations were measured at each station with a surveying transit. This provided data for correlations of vertical distribution of algae with elevation and water level. Time limitations did not permit other stations to be measured with regard to elevation.

Spartina collected from each station was labelled with the transect number, station number and date, and allowed to air dry. It was then taken to the laboratory where it was examined for presence of algae. Starting at the base of the stem, the grass was marked and cut into two-inch sections and soaked in water to rehydrate the algae. Each section was then examined under a dissecting scope with a calibrated disc. Slides were then made of the algae found, and each one was identified under a compound microscope. Records were kept of each species found, the abundance and the distribution on the stem.

Abundance was determined by an arbitrary standard, as follows:

Very abundant (VA): 10 strands or more per square millimeter (small filamentous forms)
10 plants or more per square inch (forms larger than 1 centimeter)

Abundant (A): 5 strands or more per square millimeter (small forms)
5 plants or more per square inch (larger forms)

Scarce (S): less than 5 strands or more per square millimeter (small)
less than 5 plants per square inch (larger forms)

Very Scarce (VS): found only a few in scattered places (less than one strand per square inch or millimeter)

Shells collected from the sampling stations were examined superficially under the dissecting scope for location of surface growth of algae. These were then examined under the compound scope for identification. The shells were broken into smaller pieces and decalcified with hydrochloric acid to dislodge algae growing within the shells. These algae were then identified.

Algae growing on the surface of the mud were collected and examined under the dissecting scope. The algae were then transferred to the compound scope for identification. Francis Drouet's revised classification system was used for determining species of the blue green algae, while W.R. Taylor was the primary source for identification of the other forms.

Results

Species distribution data are as follows:

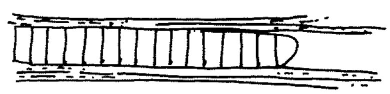
Transect #1: Chechessee Creek
- July 3, 1970—8 species found
  - Cyanophyta—5 species
  - Rhodophyta—2 species
  - Chlorophyta—1 species
- August 20, 1970—8 species found
  - Cyanophyta—6 species
  - Rhodophyta—1 species
  - Chlorophyta—1 species

Transect #2: Colleton River
- June 30, 1970—13 species found
  - Cyanophyta—7 species
  - Rhodophyta—4 species
  - Chlorophyta—2 species

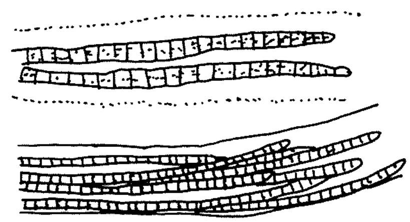
Transect #3: Sawmill Creek
- June 18, 1970—8 species found
  - Cyanophyta—5 species
  - Rhodophyta—2 species
  - Chlorophyta—1 species
- July 14, 1970—7 species found
  - Cyanophyta—4 species
  - Rhodophyta—2 species
  - Chlorophyta—1 species
- August 21, 1970—4 species found
  - Cyanophyta—1 species
  - Rhodophyta—2 species
  - Chlorophyta—1 species

Transect #4: Mackay Creek
- July 1, 1970—19 species found
  - Cyanophyta—14 species
  - Rhodophyta—3 species
  - Chlorophyta—2 species
- July 29, 1970—10 species found
  - Cyanophyta—6 species
  - Rhodophyta—2 species
  - Chlorophyta—2 species

Transect #5: Hilton Head
- June 17, 1970—5 species found
  - Cyanophyta—3 species
  - Rhodophyta—1 species
  - Chlorophyta—1 species
- July 15, 1970—9 species found
  - Cyanophyta—6 species
  - Rhodophyta—2 species
  - Chlorophyta—1 species
- August 22, 1970—8 species found
  - Cyanophyta—5 species
  - Rhodophyta—2 species
  - Chlorophyta—1 species



Porphyrosiphon



Microcoleus

Discussion

In the high area of the marsh, where the *Spartina* was short and the ground was usually firm and sandy, very little algal growth was found. This was related to infrequent inundation. Most algae found in this area were on the shells of *Littorina irrorata* (the marsh periwinkle). Since these animals were not fixed in the habitat, it was unlikely that a particular snail could be considered a permanent part of a particular station. Careful examination of the *Spartina* in the upper reaches of the marsh, where the plants averaged about 2 to 3 inches in height, revealed no algal attachment. In the higher ground, toward the slightly wetter areas of the marsh, a few scattered blue-greens were found, such as *Porphyrosiphon, Microcoleus* and *Schizothrix*. These blue-greens were sparsely distributed and found within the basal four inches of the plant, often beneath the outer sheath and between the "ribs" of the *Spartina*.

Most of the algal growth was found bordering the creeks which wound through the marshes. In these areas, the mud was soft and deep, and the *Spartina* attained heights of seven feet during the late summer. Attached to this grass, up to a height of about 10 inches, an abundant growth of two red algae—*Bostrychia* and *Calloglossa* was found. Scattered between these two algae were filaments of the small green alga, *Chaetomorphia.* Above the area where these were found, the algae which were more resistent to drying, the blue-greens, were located. *Entophysalis* and *Schizothrix* were commonly found in the upper reaches of the algal growth, with *Microcoleus* being found slightly lower on the plants.

Bostrychia and *Calloglossa* were the most obvious plants noticed on the *Spartina* in the wetter areas and along the creek banks. Reproductive structures were observed on *Bostrychia* during July and August. Other red algae were more prevalent around and below the low water line of the large creeks bordering the marshes. *Gracilaria* was the most common form, with *Polysiphonia* sometimes found growing epiphytically upon it.

The green algae were found only in wetter areas of the marsh and in the large creeks bordering the marsh. *Chaetomorpha* was the most frequently found of the green algae. It grew among the *Bostrychia* on the lower portions of the stem of the *Spartina* found along the creek banks. *Ulva* was the second most common green algae—sometimes found on *Spartina* along the creek banks but most often found below the low water line of the large creeks.

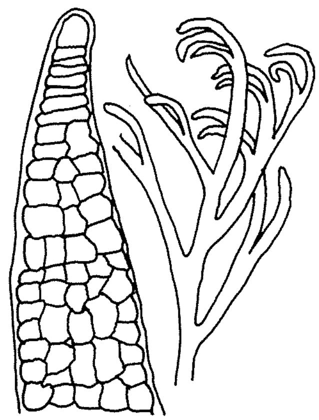
The blue-greens were the most abundant of the species found. They were perhaps the best suited for this habitat since they are most resistant to conditions such as drying and change in salinity. They were found in the dryest regions of the marshes, and were located in the highest area of the *Spartina* where the other algae did not grow. *Schizothrix* appeared to be the most common form in the dryer zones.

The most common alga found on the surface of the mud was a blue-green, *Arthrospira.* It formed large, green patches on the surface of the mud throughout the wet areas of the marsh.

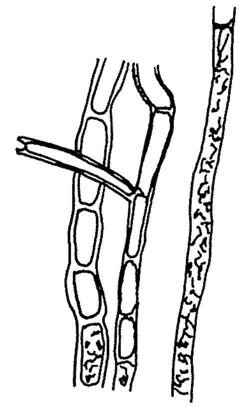
The algae found in the shells were as abundant as expected. The major algae found were *Entophysalis, Schizothrix* and *Anacystis.* Several species, common in other areas along the coast were not found. Among these were *Gomotia, Rhizoclonium* and *Mastigocoleus.*

In early summer, there was little algal growth observed on the live *Spartina.* In later summer, the growth had increased and while the algae found on the live *Spartina* was still not as abundant as that on the dead stalk, it occurred more frequently than in early summer.

Schizothrix

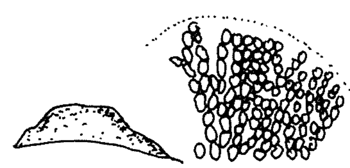


Bostrychia



Rhizoclonium

Arthrosplra



Entophysalia

Conclusions

Twenty-eight species of algae were found in the marshlands during June, July and August of 1970. Six species were of the phylum Rhodophyta, four species of the phylum Chlorophyta, and eighteen species of the phylum Cyanophyta.

Most of the algal growth occurs in the wetter areas of the marsh and along the creek banks—on dead *Spartina* stems, with lesser amount on the mud surfaces and on shells.

On the *Spartina* stalks, the algal growth occurs mostly within the basal twelve inches.

In early summer, very little algae were found on the live *Spartina* with occurrences increasing during the late summer.

SPECIES LIST

CYANOPHYTA (on *Spartina*)

Microcoleus lyngbyaceus
M. chthonoplastis
Schizothrix arenaria
S. mexicana
S. calicola
Oscillatoria lutea
O. princeps
O. submembranacea
Porphyrosiphon Notarisii
P. Kurzii
P. miniatus
Entophysalis conferta
Arthrospira brevis

(on shells)

Entophysalis deusta
Schizothrix calicola
Anacystis sp.
Calothrix sp.

(on mud)

Arthrospira brevis

RHODOPHYTA (on *Spartina*)

Bostrychia rivularis
Calloglossa leprieurii
Erythrotrichia carnea

(on shells)

none

(on mud)

Gracilaria verrucosa
Polysiphonia denudata
P. fibrillosa

CHLOROPHYTA (on *Spartina*)

Chaetomorpha minima
Ulva lactuca
Cladophora frascatii
Enteromorpha sp.

(on shells)

none

(on mud)

Ulva lactuca

Studies on Salt Marsh Invertebrates of Port Royal Sound

F. John Vernberg and Chester Sansbury
Belle W. Baruch Coastal Research Institute
University of South Carolina
Columbia, South Carolina

Objectives and Study Plan

During the spring of 1970 a study of the dominant salt marsh invertebrates of the Port Royal Sound region of South Carolina was initiated. The main purpose of this study was to assess for a period of approximately one year the ecology of common marsh invertebrates that might be affected by any future industrial developments of this region. In addition to monitoring animal densities on a seasonal basis, the gonadal index and size-weight relationship of fiddler crabs (*Uca pugnax*) were considered as these data give a basis for future comparison of possible lethal and sublethal effects.

Invertebrates considered in the density studies were the mud fiddler crab (*Uca pugnax*), the sand fiddler crab (*Uca pugilator*), the common marsh periwinkle (*Littorina irrorata*), the eastern mud nassa (*Nassarius obsoleta*), the Atlantic ribbed mussel (*Modiolus demissue*) and several species of polychaete worms that inhabit the marsh mud. In addition, the following limited observations were made: a sample for insects was taken from one marsh and individuals identified to family; and the density of the hard shell clam (*Mercenaria mercenaria*) on the southeastern tip of Parris Island was estimated.

Location of Sites

Five marsh sites located along the south side of Port Royal Sound were selected for study. The general location of each marsh site is depicted on the appended location map of the area (Figure 1). for a more detailed view of these areas refer to the United States Geological Survey maps entitled "The Spring Island Quadrangle" and "The Parris Island Quadrangle".

Site #1 is located on the upper region of Chechessee Creek between the creek and Callawassie Island. A road crosses a wooden bridge over Chechessee Creek near this site and leads on to Callawassie Island. A tall sweet gum tree (*Liquidambar styraciflua*) located approximately 200 yards east of this road immediately above the high tide mark at the edge of the forest was used as a reference point for establishing a transect line into the marsh. Using this tree as a base, the transect was established along a compass heading of 40° North out into the marsh until the first tidal creek was encountered. Total length of the transect from the reference point to the outer sample point was approximately 130 feet.

Site #2 is located on the north bank of the Colleton River near its confluence with Chechessee River. It is immediately west of the first creek on the north side which empties into the Colleton River. Two reference points were used here. One was a channel marker in the Colleton River near the mouth of the small creek and the other was the third small group of palmetto trees (counting from the western tip) on a small island located in the middle of this marsh area. Using the palmetto trees as a base, a transect line was established through the marsh on line with the channel marker in the Colleton River. This was on a compass heading of 135°SE. Sighted from the channel marker, the heading would be 315°N. This transect was approximately 1000 feet long and crossed a 30 foot wide tidal creek. Near the low tide area the transect crossed a sandy mud flat and ended at the Colleton River.

Site #3 is located on the west side of Sawmill Creek, ¼ mile from its confluence with the Colleton River. Near this area the remains of an oyster factory and large mounds of bleached oyster shells are evident. A transect line was established into the marsh using a cedar tree located at the forest's edge on a point of land 100 yards north of the oyster shell mounds. The transect line was sighted along a compass heading of 315°N into the marsh and ended at the first tidal creek. Total length of the transect was approximately 210 feet.

Site #4 is located on the North side of Mackay Creek near its confluence with Port Royal Sound. The transect through this marsh runs parallel to Mackay Creek between the east side of Corn Island and the first small tidal creek that empties into Mackay Creek. A palmetto tree at the edge of the forest on Corn Island about 50 yards from Mackay Creek and with a "no trespassing" sign attached to it was used as a reference point to establish a transect line into the marsh along a compass heading of 125°E. The total length of the transect from the palmetto tree to the small creek was approximately 800 feet.

Site #5 is located on the northern tip of Hilton Head Island near Elliot Creek which drains into Skull Creek near its confluence with Port Royal Sound. A transect line was established on a compass heading of 160°S using as a base a solitary palmetto tree which stands about 100 yards northeast of Elliot Creek at the northern edge of the marsh. It can easily be seen from Skull Creek and Elliot Creek. The transect line was approximately 600 feet long and extended to a small drainage creek in the marsh about 10 yards from the east bank of Elliot Creek.

All the marsh sites were similar in substrate composition. They were very sandy near the high tide mark and extremely muddy near the low tide mark. The highest marsh was on Hilton Head and the lowest was on Mackay Creek. The marsh on the Colleton River was the most variable; it had large oyster shell mounds near the low tide area and a 30 foot wide tidal creek, which had less than a foot of water at low tide, crossed the transect line.


PORT ROYAL SOUND ENVIRONMENTAL STUDY
LOCATION MAP
ALGAL INVENTORY TRANSECTS
SCALE
NAUTICAL MILES
Atlantic Ocean
LADIES ISLAND
FORT FREMONT
BEAUFORT RIVER
BEAUFORT
PORT ROYAL
PORT ROYAL SOUND
CHISOLM ISLAND
COOSAW RIVER
Brickyard Cr.
Mulligan Cr.
McCalleys Cr.
WHALE BRANCH
PORT ROYAL ISLAND
Battery Creek
Ballast Cr.
Archers Cr.
Chowan Cr.
Station Cr.
HILTON HEAD ISLAND
Skull Cr.
PINCKNEY ISLAND
Mackay Creek
DAWS ISLAND
CHECHESSEE RIVER
BROAD RIVER
HALL ISLAND
LEMON ISLAND
Hazzard Cr.
Euhaw Cr.
Cole Cr.
Boyd Cr.
East Br. Boyd Cr.
West Br. Boyd Cr.
Pocotaligo River
Chechessee Cr.
SPRING ISLAND
COLLETON RIVER
Victoria Bluff
Saw Mill Cr.
MAY RIVER
Bass Cr.
BULL ISLAND
Bryan Cr.
Bull Cr.
COOPER RIVER
DAUFUSKIE ISLAND
CALIBOGUE SOUND
Broad Creek
Buck I.
1
2
3
4
5
6
7

FIGURE 2


PORT ROYAL SOUND
ENVIRONMENTAL STUDY
LOCATION MAP
INVERTEBRATE
INVENTORY TRANSECTS
SCALE
NAUTICAL MILES
N
Atlantic Ocean
LADIES ISLAND
FORT FREMONT
BEAUFORT RIVER
BEAUFORT
PORT ROYAL
COOSAW RIVER
CHISOLM ISLAND
PORT ROYAL ISLAND
PORT ROYAL SOUND
HILTON HEAD ISLAND
BROAD RIVER
DAWS ISLAND
CHECHESSEE RIVER
PINCKNEY ISLAND
Skull Cr.
Mackay Creek
WHALE BRANCH
HALL ISLAND
LEMON ISLAND
SPRING ISLAND
COLLETON RIVER
Victoria Bluff
Sawmill Cr.
MAY RIVER
BULL ISLAND
CALIBOGUE SOUND
COOPER RIVER
DAUFUSKIE ISLAND
Brickyard Cr.
Mulligan Cr.
Battery Creek
Ballast Cr.
Chowan Cr.
Capers Cr.
Station Cr.
Bass Cr.
Bryan Cr.
Bull Cr.
Broad Creek
Jarvis Cr.
Chechessee Cr.
Hazzard Cr.
Euhaw Cr.
Cole Cr.
East Br. Boyd Cr.
Boyd Cr.
Head Br. Boyd Cr.
Pocotaligo River
1
2
3
4
5
6
7
FIGURE 2

Methods

Random samples for density determinations were taken at low tide along the transects at 50 foot intervals or in different habitats. A wooden 0.25 square meter frame was used for counting macroinvertebrates on or near the surface. This frame was thrown randomly into the marsh at selected sampling points along the transect. All the snails, mussels and fiddler crabs inside the frame were then counted. Usually, a 10 minute wait was necessary before fiddler crabs returned to their normal activity at the surface and could be counted.

The density of polychaete worms was determined by pressing a metal cylinder 13.5 cm deep and with a surface area of 78.5 cm^2 into the mud at each sample site. The cylinder of mud was then removed, transferred to a labelled plastic bag, and returned to the laboratory where the sample was sieved through wire screens to separate the worms. The smallest screen used had mesh openings of 0.710 mm.

Other animals not included in the density determinations were collected and brought back to the laboratory for identification. Clumps of oysters were also collected and their associated macrofauna identified.

In addition to determining population densities, studies on the average size and weight of *Uca pugnax* were conducted. These crabs were collected using a large aluminum cylinder 12 inches deep and 0.25 m^2 in surface area. This cylinder was pressed at random into the mud enclosing all of the crabs that were inside this particular area. All the mud fiddler crabs (*Uca pugnax*) over 5mm in carapace width were then collected by digging them from their burrows or picking them from the surface. This procedure was repeated until a sample size of 100 or more was obtained. The crabs were then transported alive to the laboratory where each crab was measured and weighed. Crabs for these measurements were always collected from the high portion of the Colleton River marsh site.

The gonadal index of male and female *Uca pugnax* was also monitored over a period of several months. Large size male and female *Uca pugnax* were collected by hand and returned to the laboratory where whole body and gonadal weights were determined. Gonads were dissected from live crabs, rinsed in sea water, blotted on a paper towel and weighed immediately.

A sample for insects was taken at the Mackay Creek marsh site using a 15 inch sweep net. The net was swept over the top of the *Spartina* in a four foot arc (approximate) with a return stroke over the same area. A single step forward was then taken and the double stroke repeated. One hundred steps were taken in this fashion and then 100 more steps back through the same area.

An estimate of the hard shell clam density on the tip of Parris Island was made by counting the clams recovered from a 0.25 square meter area. This was repeated three times over a small area and the counts averaged.

Results/Discussion

Table 1 lists all species collected at each of the five marsh sites. This list does not necessarily reflect all the invertebrates inhabiting the salt marshes, but only those collected along the transect lines in each marsh. A total of 27 different species of macroinvertebrates were collected and identified. Twelve of these were crustaceans, three were bivalves, three were gastropods, and nine were polychaete worms. Of the twelve crustaceans, eight were decapod crabs.

The most widespread species in terms of habitat range in all the marsh sites was the mud fiddler crab (*Uca pugnax*). Other crabs of the order Decapoda were also abundant. The sand fiddler crab (*Uca pugilator*) was common at all of the marsh sites in sandy substrate near the high tide line. During the summer months, at low tide, these crabs could be seen in large herds. The mud crab (*Panopeus herbstii*) was common at all of the sites and was most prevalent around areas of heavy oyster growth and where oyster shells had accumulated. A similar species (*Eurypanopeus depressus*) was also common in the same habitat areas. Two species of square back crabs, *Sesarma reticulatum* and *S. cinereum,* were common at all of the marsh sites. The wharf crab, *S. cinereum,* was restricted mostly to near the high tide mark while *S. reticulatum* was found in lower regions of the marsh in muddier substrate and around oyster shells. The blue crab (*Callinectes sapidus*) was common during the summer at all of the marsh sites actively seeking food in tidal pools and creek beds. The hermit crab (*Clibanarius vittatus*) was common on a sandy mud beach at the lowest portion of the Colleton River site, but was

Sand Fiddler Crabs *(Uca pugilator)*; photo by M. Thompson, S. C. Water Resources Commission.

TABLE 1

Common marsh invertebrates of the Port Royal Sound region and their occurrence at selected marsh sites

	Chechessee Creek	Colleton River	Sawmill Creek	Mackay Creek	Hilton Head
Class Crustacea					
Uca pugnax	x	x	x	x	x
Uca pugilator	x	x	x	x	x
Panopeus herbstii	x	x	x	x	x
Eurypanopeus depressus	x	x	x	x	x
Callinectes sapidus	x	x	x	x	x
Sesarma reticulatum	x	x	x	x	x
Sesarma cinereum	x	x	x	x	x
Clibanarius vittatus		x			
Cyathura carinata	x			x	
Squilla empusa		x		x	x
Chthamalus fragilis		x		x	x
Talorchestia longicornis	x	x	x	x	x
Class Pelecypoda					
Crassostrea virginica	x	x	x	x	x
Modiolus demissus	x	x	x	x	x
Mercenaria mercenaria		x	x		
Class Gastropoda					
Littorina irrorata	x	x	x	x	x
Nassarius obsoleta	x	x	x	x	x
Melampus lineatus	x	x	x	x	x
Class Polychaeta					
Nereis succinea	x	x	x	x	x
Laeonereis culveri	x	x	x		
Phyllodoce fragilis	x	x	x	x	x
Scoloplos fragilis	x	x	x	x	
Lumbrinereis tenuis		x		x	
Glycera dibranchiata		x		x	
Diopatra cuprea		x	x	x	x
Maldanidae (family)	x	x	x	x	x
Goniada maculata		x			

Table 2

Common families of insect collected at the Mackay Creek marsh site during the month of August

Order Homoptera

- Family Ceropidae
- Family Cicadellidae

Order Hemiptera

- Family Reduviidae
- Family Nabidae
- Family Lugaeidae

Table 3

Average number/m^2 of selected invertebrates along a transect at the Chechessee Creek (Station I) marsh site during sampling periods

Species	*15 July*	*21 August*
Uca pugnax	3.0	3.4
Uca pugilator	6.0	6.7
Modiolus demissus	0.3	2.0
Littorina irrorata	9.7	9.4
Nassarius obsoleta	108.5	80.0
Nereis succinea	63.7	127.4
Laeonereis culveri	127.4	148.6
Scoloplos fragilis	211.5	0
Maldanidae (family)	0	21.2

never encountered in the *Spartina* marsh itself. An amphipod, *Talorchestia longicornis,* was very common at all the sites under debris near the high tide mark where moist sandy substrate was prevalent. A small barnacle, *Chthamalus fragilis,* was extremely abundant on the lower portion of *Spartina* stems near creek beds and low runoff areas during June, July, and August, but was no longer present in late September. Two other crustaceans encountered less frequently were an isopod, *Cyathura carinata,* and a mantis shrimp, *Squilla empusa.*

The most common pelecypod mollusk was the Atlantic oyster, *Crassostrea virginica.* It occurred in large numbers at all the marsh sites, either in clumps or in large beds in small creeks and provided habitats for many other invertebrates, such as crabs and polychaete worms. The Atlantic ribbed mussel (*Modiolus demissus*) was common as solitary individuals in sandy mud or attached to oyster shells in clumps or single individuals. The hard shell clam (*Mercenaria mercenaria*) was encountered at two of the marsh sites but was most common in a creek bed at the Colleton River site. Even here, however, they were not concentrated in large numbers, but occurred as scattered individuals.

Three gastropods that were abundant in all of the marshes were the common marsh periwinkle, *Littorina irrorata,* the eastern mud snail, *Nassarius obsoleta,* and a smaller less noticeable snail, *Melampus lineatus.* The periwinkle was commonly found on *Spartina* in high regions of the marsh near sandy substrate while the mud snail was only found in very low areas where the substrate was always wet and muddy. They were extremely abundant on sandy mud flats near the Colleton River marsh site. The third snail, *Melampus lineatus,* was found living under washed up plant debris near the high tide mark in the same area as the amphipod, *Talorchestia longicornis.*

Polychaete worms were very dense at all the marsh sites. One polychaete, *Nereis succinea,* was more widespread than the others. It could be found in sandy or muddy substrate wherever *Spartina* was present. A closely related species, *Laeonereis culveri,* was less abundant and did not have as wide a habitat range. Usually, this species was found in intermediate areas of the marsh. A slender, green polychaete, *Phyllodoce fragilis,* was found living among oyster shells but nowhere else. Small polychaete worms belonging to the family Maldanidae were extremely abundant at all the marsh sites and seemed to reach peak numbers in mid-summer. *Scoloplos fragilis* was prevalent in lower portions of the marsh well below the high tide mark. The tube worm, *Diopatra cuprea,* was found only near the low tide mark in soft, muddy substrate where *Spartina* was not present. Three other less abundant species encountered occasionally were *Lumbrinereis tenuis, Glycera dibranchiata* and *Goniada maculata.*

Table 2 lists insects by order and family that were collected at the Mackay Creek marsh site. In addition to these, flying insects belonging to the orders Diptera, Odonata and Lepidoptera were observed in the marshes. No density estimations were made for insects. However, based on general observations, the population density appeared to be the greatest during the month of August. Mosquitos were abundant from the beginning of this study until December.

The tip of Parris Island was chosen as an area to determine clam density, as this region is known to be a favorable habitat for clams. In the less dense areas of the beds an average density of 84 clams per square meter was observed based on three samples. This area is covered extensively by oyster beds and access is difficult.

Tables 3-7 show the average density of the selected invertebrates for several samples taken along a transect line in each marsh site during monthly sampling periods. Fluctuations in density of crabs, snails and mussels may be attributed to sampling methods and variable weather conditions between sampling periods. However, in the case of polychaete worms it appears that they reached their greatest density during July and August with a decrease in density as temperature began to drop in the fall. Further sampling during the winter should show an even lower density.

Table 8 represents a summation of the minimum and maximum number of animals that occurred in samples collected along the transects. These figures show that there was also an area of the marsh in which a particular species could not be found. This patchiness in distribution can be attributed to variations in elevation above mean low water and to substrate composition at the sample sites.

Table 9 shows the average size and weight of *Uca pugnax* during successive sampling periods. All of the samples were taken from the same habitat to permit a common basis for comparison of data. The sample area was on the high portion of the Colleton River marsh site and on the land side of a small creek that cuts across the transect. If one ignores those samples of less than 40 individuals, the average size and weight of individuals in the population appeared to be consistent, except for females in the early spring. During this time a reduction in weight may have occurred as a result of egg masses being released in the late spring.

Table 10 reflects figures on the gonadal index of male and female fiddler crabs from three of the marsh sites, but mostly from the Colleton River site. The gonadal weight of females decreased sharply during late August and early September. In the sample taken August 29 only 3 out of 12 crabs had

Table 4

Average number/m^2 of selected invertebrates along a transect at the Colleton River (Station 2) marsh site during successive sampling periods

Species	*30 June*	*28 July*	*29 August*	*27 September*
Uca pugnax	21.3	34.0	30.0	17.2
Uca pugilator	0	2.4	0	0
Modiolus demissus	0.4	0	0.8	0
Littorina irrorata	21.8	9.2	14.4	5.6
Nassarius obsoleta	No sample	139.6	109.3	176.0
Nereis succinea	212.0	70.7	52.2	63.7
Laeonereis culveri	0	0	0	0
Scoloplos fragilis	14.0	84.9	63.6	12.7
Maldanidae (family)	56.0	353.8	279.0	114.6

Table 5

Average number/m^2 of selected invertebrates along a transect at the Sawmill Creek (Station 3) marsh site during successive sampling periods

Species	*18 June*	*14 July*	*21 August*	*28 Sept.*	*14 Nov.*
Uca pugnax	30.7	17.0	18.5	22.9	1.0*
Uca pugilator	4.7	2.0	4.6	3.4	2.5
Modiolus demissus	0.7	1.0	0.5	2.3	2.0
Littorina irrorata	7.3	20.0	17.0	10.3	23.5
Nassarius obsoleta	0	56.5	125.0	74.3	46.5
Nereis succinea	78.0	191.1	47.8	36.4	114.0
Laeonereis culveri	0	31.8	19.8	0	79.6
Scoloplos fragilis	0	79.6	0	0	0
Maldanidae (family)	0	31.8	47.8	0	15.9

*Weather was rainy and overcast; crabs were inactive.

Table 6

Average number/m^2 of selected invertebrates along a transect at the Mackay Creek (Station 4) marsh site during successive sampling periods

Species	*1 July*	*29 July*	*29 August*
Uca pugnax	12.6	22.9	26.5
Uca pugilator	No sample	3.4	3.1
Modiolus demissus	0.6	0.6	0
Littorina irrorata	0.6	0.5	0.6
Nassarius obsoleta	112.0	160.0	88.4
Nereis succinea	249.0	257.3	63.6
Laeonereis culveri	0	0	0
Scoloplos fragilis	14.0	72.8	143.3
Maldanidae (family)	567.0	1528.7	445.7

Table 7

Average number/m^2 of selected invertebrates along a transect at the Hilton Head (Station 5) marsh site during successive sampling periods

Species	*17 June*	*15 July*	*20 August*
Uca pugnax	33.3	27.2	40.0
Uca pugilator	8.3	8.8	4.4
Modiolus demissus	0.6	0.8	2.4
Littorina irrorata	18.6	20.8	16.4
Nassarius obsoleta	No sample	44.4	10.2
Nereis succinea	32.0	114.7	76.4
Laeonereis culveri	0	0	0
Scoloplos fragilis	0	0	0
Maldanidae (family)	0	127.4	63.8

Table 8

Summation of maximum and minimum number of animals/m²
that occurred in individual samples collected along each transect at each marsh site

Species	Marsh Site				
	Chechessee Creek	Colleton River	Sawmill Creek	Mackay Creek	Hilton Head
Uca pugnax	0-16	0-84	0-60	0-80	0-96
Uca pugilator	0-28	0-12	0-16	0-20	0-48
Modiolus demissus	0-4	0-8	0-12	0-4	0-8
Littorina irrorata	0-28	0-120	0-84	0-4	0-108
Nassarius obsoleta	0-868	0-1344	0-1000	0-476	0-256
Nereis succinea	0-255	0-1146	0-764	0-1146	0-509
Laeonereis culveri	0-382	0-129	0-509	0-129	0-0
Scoloplos fragilis	0-1146	0-510	0-636	0-510	0-0
Maldanidae (family)	0-129	0-2675	0-382	0-2675	0-1146

Table 9

Average size (mm) and weight (gm) of *Uca pugnax* from the Colleton River marsh site during successive sampling periods (June 1970 - Feb. 1971)

Date	Male			Female		
	Size	Wt.	No.	Size	Wt.	No.
2 June	10.99	0.55	41	11.24	0.48	41
6 Aug.	10.78	0.54	45	12.04	0.64	59
29 Aug.	10.82	0.54	45	12.20	0.62	42
27 Sept.	10.24	0.55	42	11.27	0.62	20
21 Feb.	11.42	0.78	39	12.84	0.44	22

Table 10

Gonadal index of *Uca pugnax* from the Colleton River marsh site during successive sampling periods (June 1970 - Feb. 1971)

Date	Male	No. Crabs	Female	No. Crabs
3 June	0.0014	16	0.0196	4
16 July	0.0019	10	0.0385	10
6 Aug.	0.0020	10	0.0219	10
29 Aug.	0.0018	10	0.0081	12
27 Sept.	0.0020	10	0.0015	10
21 Feb.	0.0251	10	0.0015	10

eggs. In the September sample none of the crabs had eggs. This condition should continue until the spring when reproduction will resume.

Conclusions

One year is not a sufficient length of time to accurately determine population density fluctuations and a sampling period of several years would be necessary to establish definite trends. However, the data from this study do provide a basis for future comparison of the faunal make-up of the marshes studied.

Generally speaking, the salt marshes of the Port Royal Sound region are in a well developed, unspoiled state and support a dense, diverse community of invertebrates.

Common marsh periwinkle *(Littorina irrorata)*; photo by M. Thompson, S. C. Water Resources Commission.

A Report on Upland Habitat and Wildlife Conditions

Jerry J. Blackard
Warren T. Parker
Ferd Sumrell
U. S. Department of the Interior
Fish & Wildlife Service
Atlanta, Georgia

Introduction

The Bureau of Sport Fisheries and Wildlife, Division of Federal Aid, Atlanta, was assigned the responsibility of providing "base line data" on wildlife species in the Port Royal Sound area of Beaufort County, South Carolina. The Division accepted this assignment and outlined a study plan in March, 1970. Field work was initiated in June on a limited basis; most work was conducted from July through October.

In-depth studies of wildlife, such as population dynamics and food habits, were not possible within the time allocated for establishing base line data. Thus, considering available time and rather limited investigational methods, the activities were confined to determining major types of wildlife present, estimating their relative abundance, and estimating production of colonial nesting waterbirds.

Wildlife populations are products of their habitat, thus it was determined that some type of analysis should be made of the upland habitat. Standard forestry type mapping appeared to be the best procedure to use in "characterizing" the wildlife habitat. About 90 one-fifth acre plots randomly located in the various cover types were sampled.

Methods employed and results of the habitat and wildlife studies are given in the following sections.

Upland Habitat Analysis

Objective

The primary objective was to determine as precisely as possible the various habitat types present and land use patterns within the study area.

Study Area

The study area chosen was based on careful analysis of recent aerial photographs and topographic maps. One factor was established as a premise: the proposed industrial plant and its resulting operation would influence a defined area so far as upland wildlife populations were concerned. This area was delineated so that it would generally follow natural boundaries. The only exception to this was State Highway 278 which formed the southern-most boundary. The salt marsh along the Chechessee River was established as the eastern-most boundary. The Colleton River was used as the northern boundary and Sawmill Creek formed the western boundary. The unit thus defined totaled slightly over 4,000 acres (Figure 1).

Methods

Timber: Aerial photographs (scale: 8″ = 1 mile, 1965) were utilized to define major timber types. To accurately determine actual timber composition and to better define the intergradation from one type to another, about ninety sample plots of one-fifth acres each were established on an aerial photo overlay. For location of these plots, see Figure 2.

An on-the-ground inspection was made of each plot site. Using a steel tape, a one-fifth acre sample was made. All trees within this circular plot were counted and tallied as to species, percent stocking, and average diameter at breast height. This information was used to determine type changes as well as specific composition within types. A type-map was developed from these data (Figure 1).

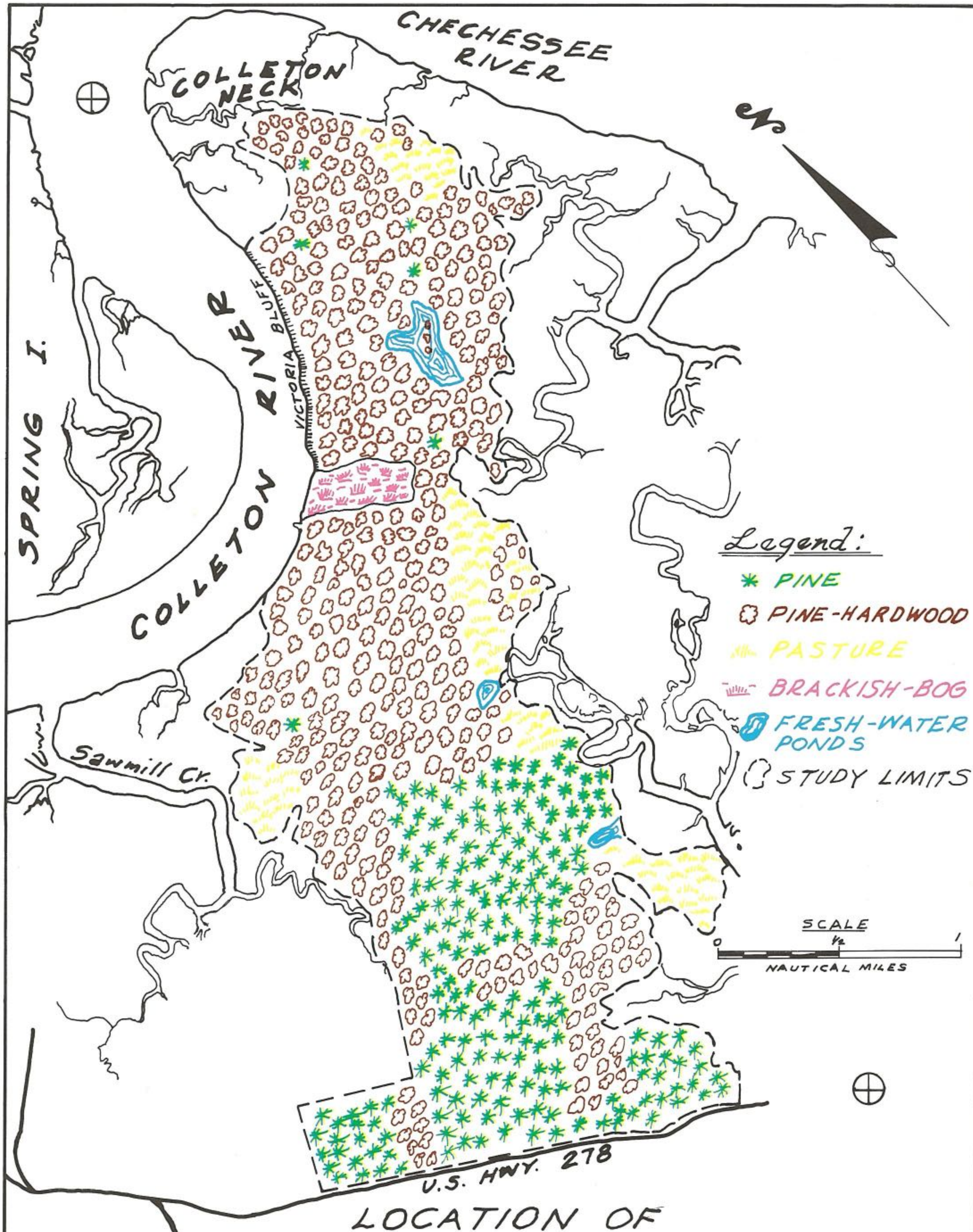
Understory: At each of the above mentioned plots, special reference was made to understory composition, size, etc. This information was compiled in much the same manner as overstory data and used primarily as a basis to determine predominant deer browse on the area.

Land Use: Discussions with landowners and other individuals who have lived in the project area for many years indicated traditional land use on the area. Direct observation of habitat, as well as maps and reference books, provided clues to past land use.

Results

Timber: The type map produced from aerial photo interpretation and the one-fifth acre plots indicate that there were two predominant overstory types present on the study area. The first was an essentially pine type composed of loblolly (*Pinus taeda*), longleaf (*P. palustris*), and slash pine (*P. caribaea*). Pond pine (*Pinus serotina*) occured in lowland areas near Highway 278. This overstory was typical of the southern one-third of the study area, within which were found scattered stands of hardwoods. These hardwood "islands in a sea of pine" were typically composed of laurel oak (*Quercus laurifolia*), willow oak (*Q. phellos*), and sweetgum (*Liquidambar styraciflua*). These hardwood stands were confined to wet sites, stream courses, natural swales, etc.

Various size classes were found in the pine type, and evidence of past logging operations and burning was readily observed throughout much of the type. The survey indicated that about 1,140 acres of pine were found on the project study area. The 2nd major type found was various pine and hardwood species, generally with the pine making up no more than 25 percent of the stand. This pine-hardwood type covered an estimated 1,930 acres and was typical of the northern-most two-thirds of the study area. The most commonly encountered hardwood species were mature laurel oak, live oak (*Quercus virginiana*), willow oak and sweetgum on the drier sites, with red maple (*Acer rubrum*), blackgum (*Nyssa sylvatica*), and Carolina ash (*Fraxinus caroliniana*), found along stream courses and other wet sites. One of the most valuable areas from a wildlife standpoint was found along the Victoria Bluff area. There were almost solid stands of mature hickory (*Carya spp.*), laurel oak, live oak, and water oak (*Q. nigra*) in this

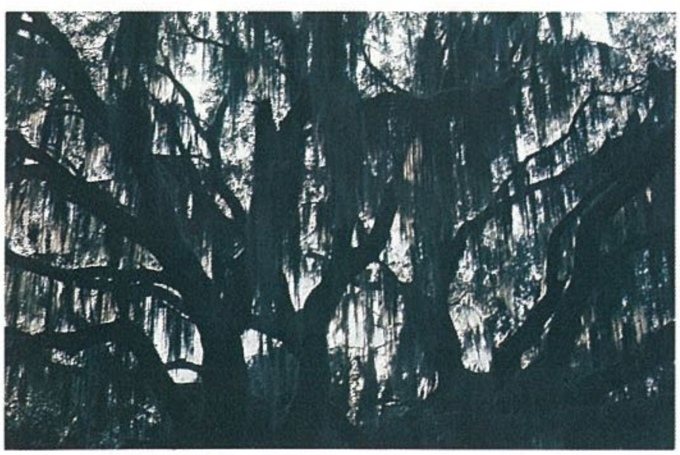


LOCATION OF TIMBER TYPES

FIGURE 1

UPLAND HABITAT ANALYSIS
(APPROX. SAMPLE PLOT LOCATIONS) FIGURE 2

Cabbage Palmetto *(Sabal palmetto)*; photo by M. Thompson, S. C. Water Resources Commission.



Live Oak *(Quercus virginiana)*; photo by M. Thompson, S. C. Water Resources Commission.

area. Occasional hardwoods found throughout the study area were sweetbay (*Magnolia virginiana*), American elm *(Ulmus americana)*, and southern red oak (*Quercus falcata*).

Understory: As could be expected, understory composition varied with the overstory type. On the more open pine sites almost impenetrable stands of gallberry (*Ilex coriacea*), *catbrier* (*Smilax spp.*), and sweet pepperbush (*Clethra alnifolia*) were found, especially where past fire or logging operations were evident. Under a more closed canopy of pine, the understory tended to open up more with such species as gallberry, wax-myrtle (*Myrica cerifera*), french mulberry (*Callicarpa americana*), palmetto (*Sabal sp.*), blueberry (*Vaccinium spp.*), and sweet pepperbush predominating. Small pine and hardwood reproduction was also common among the understory.

On the typical hardwood-pine sites the understory changed dramatically. Here such species as American holly (*Ilex opaca*), sassafras (*Sassafras albidum*), palmetto, blueberry, and hardwood reproduc-

Longleaf Pine *(Pinus palustris)*; photo by M. Thompson, S. C. Water Resources Commission.

Bald Cypress *(Taxodium distichum)*; photo by U. S. Forestry Service.

tion predominated. Grape vines (*Vitis spp.*) were common throughout the hardwood-pine type.

Land Use: A history of cattle grazing within the hardwood-pine type has left a substantial acreage of this timber in a park-like condition with very little understory. Fire has generally been confined to the pine type, and has probably been responsible for retarding hardwood competition. Most of the logging operations seemed to have been confined to the pine type. Cutting of mature overstory pine timber has served to open up the canopy with resulting thick understory vegetation. About 500 acres of open fields are found on the area, most of which are typically Coastal Bermuda and broomsedge pasture. The entire area is hunted, mostly by landowners and their guests, but some illegal hunting does occur. Exploratory drilling operations for oil have been conducted on the area.

About 73 acres of natural freshwater ponds were scattered throughout the study area. The largest of these was a 36-acre pond located within the northern one-third of the area. All of these ponds were shallow. Some probably dry up during drought periods. Bald cypress (*Taxodium distichum*), and buttonbush (*Cephalanthus occidentalis*), typify the vegetation found around these pools. A small acreage of freshwater marsh, mostly cattail (*Typha sp.*), and brackish-bog was also found on the area. Much of the study area was surrounded by essentially pure stands of saltwater cordgrass (*Spartina alterniflora*), especially along the eastern boundary and portions of the western boundary. Road access to the area is confined to a short reach of State Highway 278. Boat access is readily available from the Colleton River, Sawmill Creek, and numerous smaller tidal streams and guts.

Conclusions

The study area is typical of much of the southeastern South Carolina low country. Stands of pine and various hardwoods typify the area, generally with a thick understory. This condition prevails as a result of burning and logging.

Wildlife Species

Objective

The primary objectives were to determine principal kinds of resident wildlife species present; to estimate abundance of principal wildlife species; and to estimate the annual production of egrets, herons, and ospreys.

Study Area

Investigations on the status of resident wildlife species were conducted primarily on the 4,000-acre upland area from State Highway 278 north to the Colleton River and its juncture with the Chechessee River, and from Sawmill Creek east to the marshes on the west side of the Chechessee River. The upland areas on Spring Island and Daws Island were also checked for relative abundance of principal wildlife species. The marshes and open water areas of Port Royal Sound from State Highway 170 south to Highway 278 were surveyed to determine abundance and distribution of migratory waterfowl. The field work on most resident wildlife species was conducted from May through October, 1970. Aerial surveys to determine distribution and abundance of migratory waterfowl were made monthly from November, 1970, through February, 1971.

Methods

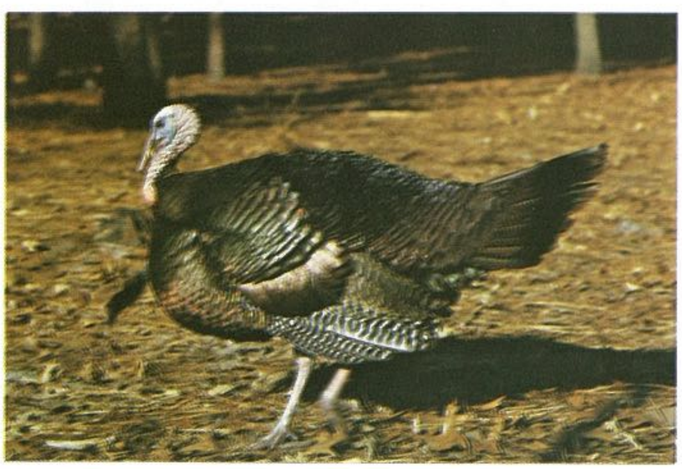
Herons, Egrets, and Other Waterbirds: Observers flew over the study area in a small plane at an altitude of about 300 feet to locate heron and egret rookeries in May, 1970. These rookeries were checked from the ground during the first week in June when nesting activity appeared to be at a peak. Nests were counted and an average clutch size was obtained for each species.

Green Heron; photo by T. Yaw, Bureau of Sport Fisheries & Wildlife.

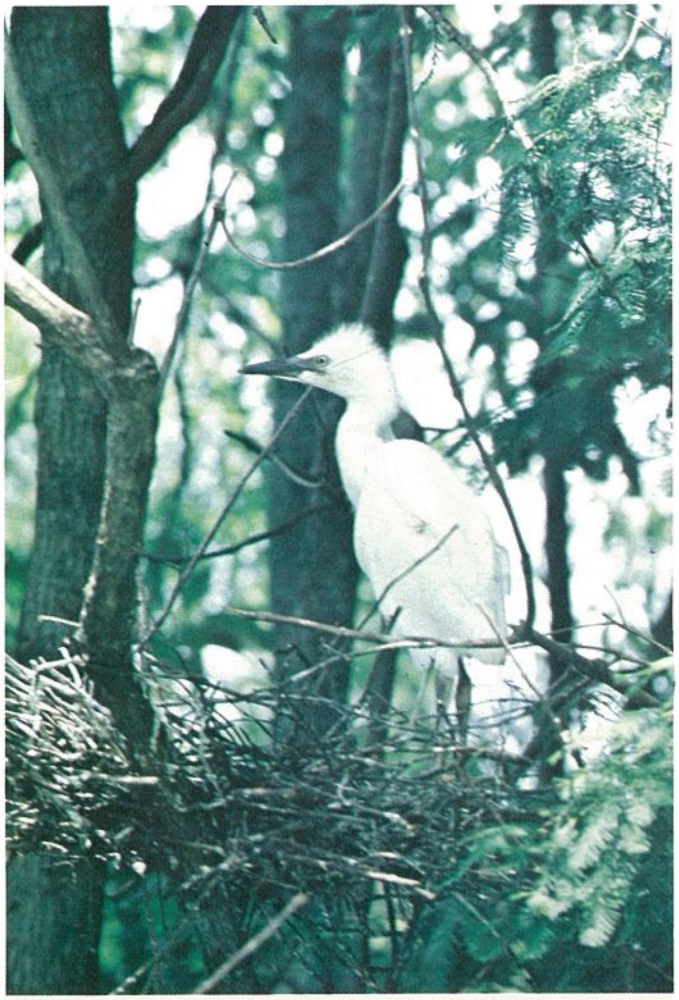
Osprey; photo by S. C. Wildlife Dept.

Black-crowned Nnight Heron; W. D. Pfitzer, Bureau of Sport Fisheries & Wildlife.

Louisiana Heron; photo by W. D. Pfitzer, Bureau of Sport Fisheries & Wildlife.



Turkey; photo by T. Borg, S. C. Wildlife Resources Dept.



Cattle Egret; photo by G. Moore, S. C. Wildlife Resources Dept.

Ospreys and Hawks: The location of Osprey nests was recorded during a flight in a small plane in May. These nest locations were also verified from the ground. No special effort was made to census hawks, however, notes were made on number and species when encountered during other field activities.

Clapper Rail: The saltwater cordgrass marshes along the Colleton River were checked by boat to determine presence of rails (Marsh Hens). Nesting density was not determined because most rail nesting had been completed prior to initiation of the field work. It has been established, however, that Marsh Hens make use of these *Spartina* marshes for nesting purposes (Blandin, 1965).

Turkeys: An estimate of turkeys was based on the number of birds seen in various areas and the number of turkey roosts encountered during field work on habitat investigations.

Waterfowl: Monthly aerial surveys were made over all water areas from Highway 278 north to Highway 170, including the Broad River, from November, 1970, through February, 1971. These surveys were flown at an altitude of about 150 feet in a small airplane. All four flights were made over the same route each time. The location, species, and number of waterfowl were recorded during each flight.

Small Birds: An estimate of relative density of small birds in various habitat types was obtained by counting the number of birds seen or heard during three minutes on one-fifth acre plots. These counts were made during September at various intervals during the daylight hours.

White-tailed Deer: An estimate of the deer population was based on the frequency of deer tracks observed and the number and location of deer seen during the habitat analysis work. The fields in the study area were also checked at night with a spotlight to obtain an estimate of the number of deer. The number of deer seen at night on the study area roads was also used in estimating the deer population.

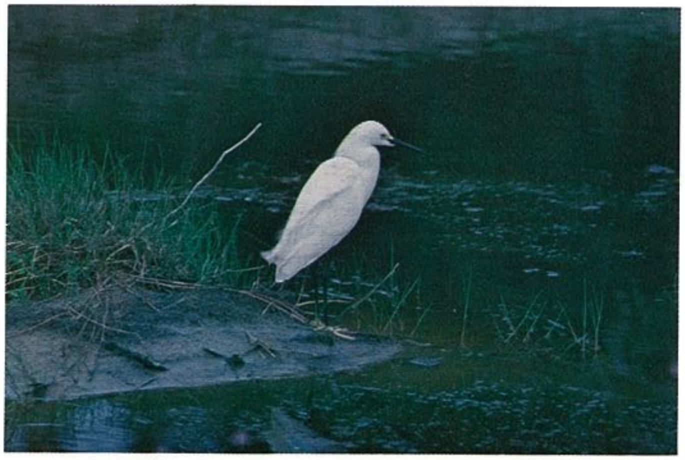
Squirrels: Time-area counts were made in hardwood areas on the study site. This method consisted of counting the number of squirrels seen or heard during a thirty-minute period and estimating the distance from observer to the furtherest squirrel. The estimated distance is used as the "effective radius" of a circular plot censused.

Rodents: Mouse traps, rat traps, and small metal box traps were placed in various habitat types over the study area to determine species of rodents present and relative abundance. Traps were baited with peanut butter and placed in trails and runways in pine stands, hardwood areas, around old house sites, brush piles, and field edges. All traps were checked daily.

Endangered Wildlife Species: Freshwater ponds were checked during the regular field work to determine presence of Alligators. Several ponds were also checked at night with a spotlight. No special survey was made to determine number of Bald Eagles, however, records were kept of birds seen during field work and aerial surveys over the Port Royal Sound Area. The number and location of Brown Pelicans were also recorded during aerial surveys and boat trips.

Results

Herons, Egrets, and Other Waterbirds: Three heron and egret rookeries were found on the study area. The largest rookery was in the 36-acre freshwater pond on the H. S. Cram land and contained about 450 heron and egret nests. A small pond located about 100 yards northwest of this large rookery had three Black-crowned Night Heron nests. A rookery of about 55 Yellow-crowned Night Heron nests was found in the small pond 500 yards south of Victoria Bluff. Table 1 shows the estimated minimum production of herons and egrets on the study area during 1970.



Snowy Egret; photo by W. D. Pfitzer, Bureau of Sport Fisheries & Wildlife.

Other waterbirds were seen on the study area, but no nests were found. On June 3, 108 White Ibis (*Eudocimus albus*) and six Anhinga (*Anhinga anhinga*) were observed on the Cram property. On September 24, 100 Wood Ibis (*Mycteria americana*) and 125 Common Gallinules (*Gallinula Chloropus*) were seen on the large freshwater pond on Cram's property. Freshwater and saltwater marshes are used extensively by all waterbirds for loafing and feeding purposes.

Ospreys and Hawks. Four active Osprey *(Pandion haliaetus)* nests were found on the study area in late May and early June. These nests were located as follows: One nest half a mile east of Frank Hodge residence; two nests northwest edge of the large freshwater pond on H. S. Cram land; and one nest on edge of Colleton River, one and one-third miles northeast of Victoria Bluff. All nests were built in the top of large loblolly pine trees. No other Osprey nest, active or otherwise, was found on the study area. The hawk population appeared to be low during the time of field work. One Red-shouldered (*Buteo lineatus*) and two Red-tailed Hawks (*Buteo jamaicensis*) were observed east of Victoria Bluff.

Clapper Rail: Clapper Rails *(Rallus longirostris)* were found in all saltwater marshes along the Colleton and Chechessee Rivers. No attempt to census these birds was made, but it was confirmed that rails use these marshes extensively for nesting, feeding, and loafing purposes. Blandin (1965) conducted a study on Clapper Rails from 1960 to 1965 in Beaufort County near Beaufort. He found up to two rail nests per acre in some areas with extensive stands of black rush (*Juncus roemerianus*) and patches of saltwater cord-grass. The marshes around Victoria Bluff are predominantly saltwater cord-grass bordered by patches of black rush. Blandin classified these "Colleton, Chechessee, and Port Royal Areas" as low productivity areas with an average 0.1 to 0.3 nests per acre. He pointed out, however, that only one visit was made to each sample plot and some nests undoubtedly were started after his one visit. Thus, production based on the above nesting data would represent minimum figures.

Red-Shouldered Hawk; photo by W. D. Pfitzer, Bureau of Sport Fisheries & Wildlife.

Turkeys: Seven turkeys *(Meleagris gallopava)* were seen and two active turkey roosts were located on the study area. Based on these observations, the turkey population on the study area was estimated to be about 15 birds or one bird per 265 acres.

Waterfowl: Wood Ducks (*Aix sponsa*) are permanent residents in the Port Royal Sound area. Woodies were seen on the freshwater ponds all summer and fall. Migratory waterfowl had arrived on the study area by the last week in September when Blue-winged Teal (*Anas discors*) and Shovelers (*Spatula clypeata*) were seen. A summary of the monthly aerial waterfowl surveys is presented in Table 2.

These surveys reveal that the majority of waterfowl species wintering in the Port Royal Sound area are Common Merganser and Lesser Scaup. It should be noted that Wood Ducks are more abundant than the surveys indicate since these birds inhabit areas which are extremely difficult to census from an airplane. The distribution of waterfowl recorded during the surveys is shown in Table 3.

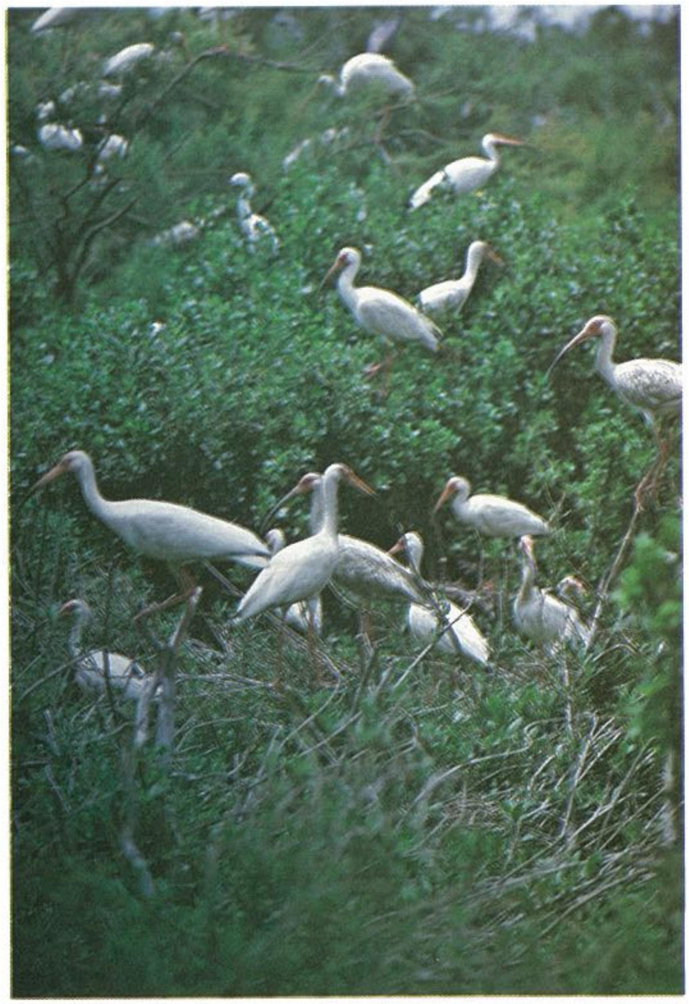
Table 1

Heron and Egret Production; Port Royal Sound Study Area; June, 1970

Species	Nests Found	Avg. No. of Eggs or Yg.	Minimum Production
Louisiana Heron (*Hydranassa tricolor*)	190	4	750
Green Heron (*Butorides virescens*)	12	3	35
Yellow-crowned Night Heron (*Nyctanassa violacea*)	110	3	330
Black-crowned Night Heron (*Nycticorax nycticorax*)	3	3	10
Cattle Egret (*Bubulcus ibis*)	173	2	345
Snowy Egret (*Leusophoyx thula*)	29	4	115

Wood Ibis; photo by W. D. Pfitzer, Bureau of Sport Fisheries & Wildlife.

Common Gallinule; photo by L. C. Goldman, Bureau of Sport Fisheries & Wildlife.



White Ibis; photo by S. C. Wildlife Dept.

Most waterfowl were on the Broad River just off shore from the northeast end of Hilton Head Island. Lesser Scaup, Common Merganser, and Ring-necks were the predominant species in this area. Most of the ducks on freshwater ponds on the study area consisted of dabblers such as Mallards, Blacks, Widgeon, Pintail, and Wood Ducks.

Waterfowl surveys were scheduled through March, 1971, however, due to the relatively few birds seen on the February survey, it was evident that another survey would not be worthwhile.

Table 2

Waterfowl Species Present; Port Royal Sound Area; 11/70 - 2/71

Species	Survey Date 11-18-70	12-18-70	1-20-71	2-24-71
Mallard (*Anas platyrhynchos*)	———	161 (15%)	109 (7%)	12 (3%)
Black Duck (*Anas rubripes*)	11 (2%)	53 (5%)	130 (9%)	15 (4%)
American Widgeon (*Mareca americana*)	———	———	70 (5%)	54 (15%)
Pintail (*Anas acuta*)	———	20 (2%)	———	———
Wood Duck (*Aix sponsa*)	———	53 (5%)	———	5 (1%)
Green-winged Teal (*Anas carolinensis*)	90 (19%)	25 (2%)	———	———
Com. Goldeneye (*Bucephala clangula*)	———	3 (T)	5 (T)	———
Bufflehead (*Bucephala albeola*)	65 (14%)	103 (10%)	159 (10%)	63 (17%)
Common Merganser (*Mergus merganser*)	139 (29%)	171 (16%)	167 (11%)	101 (27%)
Hooded Merganser (*Lophodytes cucullatus*)	1	52 (5%)	8 (T)	5 (1%)
Lesser Scaup (*Aythya affinis*)	100 (21%)	285 (27%)	606 (41%)	84 (23%)
Ring-necked Duck (*Aythya collaris*)	15 (3%)	105 (10%)	201 (14%)	8 (2%)
Unidentified spp.	52 (11%)	10 (1%)	5 (T)	25 (5%)
TOTAL	473	1,040	1,460	372

Wood Duck; photo by B. Julian, Bureau of Sport Fisheries & Wildlife.

Mallard; photo by T. Borg, S. C. Wildlife Dept.

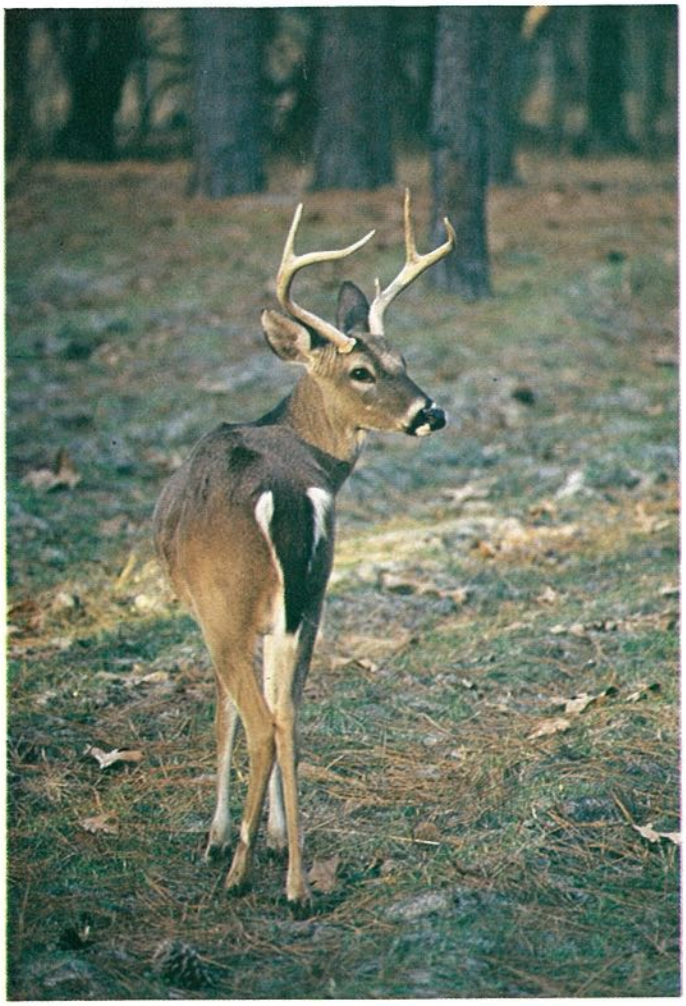
Pintail; photo by Bureau of Sport Fisheries & Wildlife

Bufflehead; photo by Bureau of Sport Fisheries & Wildlife.

Small Birds: An estimate of small bird densities on the study area was obtained by making three-minute counts on one-fifth acre plots. About 70 samples were taken in various habitat types. These counts indicated 5 to 35 birds per acre in pine stands with an average of 13 birds per acre. Pine-hardwood types held 5 to 45 birds per acre with an average of 19 birds per acre. Bird densities in hardwood stands ranged from 10 to 50 per acre with an average of 29 birds per acre. These counts were made during the third week in September, thus the figures reflect resident population densities. The type, amount, and distribution of understory vegetation also influenced the density of small birds and small mammals on the study area. Birds and mammals were particularly scarce in relatively open pine stands which had a low, dense understory of gallberry and sweet pepperbush. The large Pileated Woodpecker (*Dryocopus pileatus*) was common on the study area; over 30 of these birds were seen or heard during the field work. No attempt was made to census marsh wrens (*Telmatodytes palustris*), but this species was fairly common in the salt marshes adjacent to the study area.

Gray squirrel; photo by J. Duke, S. C. Water Resources Comm.

White-tailed Deer: During field investigations, from June 4 through October, 18 deer (*Odocoileus virginianus*) were observed. Most of these were seen in fields at night on the study area. Deer tracks were observed over the entire study area. Based on these observations, the pure pine type was estimated to support one deer per 50 acres and the pine-hardwood type, one deer per 20 acres. Weighing these figures according to amount of habitat in the various types, the study area supported about 140 deer or one deer per 28 acres. Deer browse appeared sufficient to support this relatively high population. The carrying capacity will undoubtedly be increased as cattle grazing is further reduced and prescribed burning is resumed. Deer tracks were seen also on Daws Island, Callawassie Island, and Spring Island, however, these observations were deemed too few for population estimation purposes.



White-tail deer; photo by T. Borg, S. C. Wildlife Resources Dept.

Cotton rat; photo by B. Mahan, S. C. Wildlife Resources Dept.

Squirrels: Time-area counts were made at 21 sample sites in the hardwood type on the study area. The number of Gray Squirrels *(Sciurus carolinensis)* heard or seen varied from 0.31 to 8.63 squirrels per acre. The average value was 2.85 squirrels per acre.

A few Fox Squirrels *(Scurius niger)* were seen, however, the population of this species on the study area was very low.

Rodents: During a total of 296 trap-nights (one trap set for one night is a trap-night), two Cotton Mice *(Peromyscus gossypinus)* and an Eastern Wood Rat *(Neotoma floridana)* were caught. Apparently, the rodent population on the study area was quite low during the period of field investigations.

Endangered Wildlife Species:

Bald Eagle: One Bald Eagle (*Haliaeetus leucocephalus*) was observed about a mile east of Victoria Bluff in May. This was the only eagle observed during the period of investigation.

Bald Eagle; photo by W. D. Pfitzer, Bureau of Sport Fisheries & Wildlife.

Brown Pelican; photo by T. Borg, S. C. Wildlife Resources Dept.

Brown Pelican: Twelve Brown Pelicans (*Pelecanus occidentalis*) were observed on October 29, on the Chechessee River about three and one-half miles northeast of Victoria Bluff. Twelve birds assumed to be the same birds) were observed at the mouth of Port Royal Sound during an aerial waterfowl survey on December 18, 1970. No pelican nests or nest sites in the Port Royal Sound area were found.

Alligator: The Alligator *(Alligator mississipiensis)* population on the study area and in the Port Royal Sound area appeared to be low. Two 'gators were seen on the study area; one in a pond about a mile northeast of Victoria Bluff and one in a small freshwater impoundment about two and one-half miles south of Victoria Bluff.

Alligator; photo by T. Borg, S. C. Wildlife Resources Dept.

Conclusions

Realizing that habitat conditions have changed little since the field surveys in 1970, it is reasonable to assume that the upland study area from Highway 278 north to the Colleton River still supports a substantial population of various wildlife species. Herons and egrets make extensive use of several freshwater ponds for nesting, feeding, and loafing purposes Over 1,500 of these birds are estimated to be produced each year on the study area. Other waterbirds such as White Ibis, Anhingas, Wood Ibis, and Gallinules use the freshwater ponds for feeding and loafing purposes. Ospreys nest in the Port Royal Sound area. The "sanctuary" effect of plantations and "restricted access" lands may be a factor in nest site selections by Ospreys. Clapper Rails are permanent residents of the saltwater marshes in the Port Royal Sound area. Rail production probably is not high in the marshes along the Colleton and Chechessee Rivers. The study area supports a fair turkey population. Restricted access and limited legal hunting probably contribute to what appears to be a fairly stable turkey population. Wood Ducks are permanent residents of the Port Royal Sound area. Migratory waterfowl winter in this area, with common mergansers and lesser scaup being the most abundant species. Waterfowl seem to prefer the Broad River near Hilton Head Island as a loafing and feeding site during winter months. Small song birds are abundant, particularly in the hardwood stands. Pileated Woodpeckers are common perm-

Table 3

Waterfowl Distribution; Port Royal Sound Area; 11/70 - 2/71

Area	Survey Date 11-18-70	12-18-70	1-20-71	2-18-71
Colleton River and Adjacent Marshes (Highway 278 to Chechessee River)	192 (40%)	154 (15%)	125 (8%)	18 (6%)
Sawmill Creek Area	5 (1%)	18 (1%)	14 (1%)	2 (1%)
Chechessee River (Foot Point to one mile north Highway 270)	36 (8%)	17 (1%)	97 (6%)	20 (6%)
Broad River (One mile above Highway 170, south to Atlantic Ocean)	192 (40%)	496 (48%)	970 (66%)	178 (47%)
Skull Creek (Port Royal Sound to Highway 278)	4 (1%)	80 (8%)	62 (5%)	25 (7%)
Mackay Creek (Port Royal Sound to Highway 278)	4 (1%)	35 (3%)	55 (4%)	35 (9%)
Freshwater Ponds on Study Area	49 (9%)	240 (23%)	137 (10%)	94 (24%)
TOTAL	473	1,040	1,460	372

Black Duck; photo by A. Pursley, Bureau of Sport Fisheries & Wildlife.

Ring-necked Duck; photo by A. Pursley, Bureau of Sport Fisheries & Wildlife.

Pileated Woodpecker photo by Bureua of Sport Fisheries & Wildlife.

anent residents. There is a moderate to high deer population in this area due to favorable habitat and limited hunting pressure. The study area supports a high squirrel population, particularly in the more mature hardwood stands. The rodent population appears to be low. Three species of endangered wildlife species—Bald Eagle, Brown Pelican, and Alligator—are found on the area, but none of these species is abundant.

Summary of Habitat and Wildlife Species in the Port Royal Sound Area

The Port Royal Sound area contains a variety of medium to high quality areas of wildlife habitat. Upland pine-hardwood stands, particularly on the south edge of the Colleton River, support high populations of deer and Gray Squirrels. Freshwater ponds are used extensively by several species of waterbirds for nesting, feeding, and loafing purposes. Waterfowl, particularly Wood Ducks, and deer, turkey, and squirrels are also attracted to these ponds. The open water areas of the Colleton, Chechessee, and Broad Rivers and adjacent marshes are used in the winter by migratory waterfowl as feeding and loafing areas. Clapper Rails utilize the salt marshes extensively for feeding purposes and, to a certain extent, for nesting. Ospreys nest throughout the Sound area, however, the population appears to be low. Timbered uplands, especially hardwoods, harbor high populations of small song birds and a substantial population of Pileated Woodpeckers. Numerous species of resident and migrant song birds also winter in the Port Royal Sound area. The upland habitat does not appear to be conducive to high rodent populations. Three species of endangered wildlife occur in the Sound area. Cattle grazing in some places has reduced the carrying capacity for deer, however, burning and timber cutting have enhanced deer habitat in other areas.

Thus, the Port Royal Sound region, particularly the study area from Highway 278 to the Colleton River, contains diverse but excellent wildlife habitat and substantial populations of wildlife species. Current land use practices on burning, limited timber harvest, and restricted public access, tend to favor wildlife.

Table 4

Habitat Analysis Sample Plots, Port Royal Sound Study Area

Table 4: Habitat Analysis Sample Plots, Port Royal Sound Study Area, Beaufort County, South Carolina

Plot No.	Terrain	Predominant Timber (In descending order)	Timber Stocking Rate*	Avg. DBH	Understory & Density**	Recent Land Use
1	Flat	Loblolly, Pond Pine	Medium	5-8 ″	Gallberry-Heavy	Burned & Cut
2	Flat	Pond Pine	Light	5-8 ″	Sweetbay-Medium	Burned & Cut
3	Flat	Longleaf Pine	Medium	9-12″	Bay-Heavy	Burned
4	Stream Bottom	Blackgum, Sweetgum, Maple	Heavy	13-15″	0	Cut
5	Flat	Pond Pine	Heavy	9-12″	Sweetbay-Heavy	Burned
6	Flat	Pond Pine	Medium	9-12″	Gallberry-Heavy	Burned
7	Flat	Longleaf Pine	Medium	9-12″	Vaccinium-Heavy	Burned & Cut
8	Flat	Longleaf, Hickory, Red Oak	Medium	9-12″	Yaupon-Medium	Burned & Cut
9	Flat	Longleaf, Slash Pine	Medium	9-12″	Palmetto-Medium	Burned
10	Flat	Longleaf Pine	Medium	9-12″	Palmetto-Medium	Burned
11	Stream Bottom	Sweetgum, Laurel Oak, Water Oak	Medium	9-12″	Waxmyrtle-Medium	Cut
12	Flat	Longleaf Pine	Heavy	9-12″	Gallberry-Medium	Burned & Cut
13	Flat	Loblolly, Slash Pine	Heavy	1-4 ″	Vaccinium, Wax-myrtle-Medium	Cut
14	Flat	Laurel Oak, Water Oak, Loblolly	Medium	9-12″	Waxmyrtle-Light	0
15	Stream Bottom	Sweetgum, Laurel Oak, Blackgum	Heavy	5-8 ″	Waxmyrtle-Light	0
16	Stream Bottom	Sweetgum, Cow Oak, Live Oak	Light	9-12″	Palmetto-Medium	0
17	Flat	Loblolly Pine	Medium	9-12″	Gallberry-Light	Burned
18	Flat	Loblolly Pine	Medium	9-12″	Bay-Medium	Burned & Cut
19	Flat	Loblolly, Slash Pine	Heavy	9-12″	Gallberry-Light	Burned
20	Flat	Loblolly Pine	Medium	9-12″	Bay-Medium	0
21	Flat	Water Oak, Laurel Oak	Heavy	9-12″	Palmetto-Light	Cut
22	Flat	Longleaf Pine	Light	5-8 ″	Laurel Oak-Heavy	Burned & Cut
23	Flat	Laurel Oak, Water Oak, Ash	Light	5-8 ″	Waxmyrtle-Light	Cut
24	Flat	Sweetgum, Water Oak, Loblolly	Heavy	9-12″	Waxmyrtle-Light	Burned & Cut
25	Flat	Loblolly, Longleaf	Medium	13-15″	Smilax-Heavy	Burned
26	Flat	Slash Pine, Loblolly	Medium	5-8 ″	Bay, Gallberry-Medium	Burned & Cut
27	Stream Bottom	Sweetgum, Bay, Blackgum	Medium	1-4 ″	Waxmyrtle-Medium	0
28	Stream Bottom	Slash Pine, Water Oak	Medium	13-15″	Sweetgum-Medium	Burned
29	Stream Bottom	Sweetgum, Laurel Oak, Water Oak	Medium	9-12″	Waxmyrtle-Medium	Cut
30	Flat	Laurel Oak, Water Oak, Sweetgum	Heavy	5-8 ″	Waxmyrtle-Light	Burned & Cut
31	Flat	Slash Pine	Medium	9-12″	Waxmyrtle-Heavy	Burned & Cut
32	Flat	Loblolly Pine	Medium	9-12″	Bay-Waxmyrtle-Heavy	Burned & Cut
33	Flat	Slash Pine	Light	9-12″	Waxmyrtle-Medium	Burned & Cut
34	Flat	Slash Pine	Heavy	1-4 ″	Waxmyrtle-Gall-berry-Medium	Burned & Cut
35	Flat	Loblolly, Slash Pine	Heavy	1-4 ″	Smilax-Medium	Burned & Cut
36	Flat	Pond, Slash Pine	Medium	5-8 ″	Waxmyrtle-Heavy	Burned & Cut
37	Flat	Slash Pine	Heavy	13-15″	Bay-Magnolia-Medium	Burned & Cut
38	Flat	Laurel Oak	Medium	9-12″	Sassafras-Light	Cut
39	Flat	Loblolly Pine, Water Oak	Medium	9-12″	Palmetto, Vacci-nium-Medium	Burned & Cut
40	Stream Bottom	Blackgum, Water Oak	Medium	13-15″	Bay-Light	Cut
41	Flat	Loblolly Pine	Heavy	1-4 ″	Sweet Pepper-bush-Heavy	Burned
42	Flat	Loblolly Pine	Heavy	9-12″	Bay-Sweet Pepper-bush-Heavy	Burned & Cut
43	Flat	Laurel, Water Oak	Medium	5-8 ″	Waxmyrtle-Bay-Medium	Burned & Cut

* Stocking Rate: Light = 0-33% stocked; Medium = 34-66% stocked; and Heavy = 67-100% stocked.

** Understory Density: Light = 0-33% of area covered; Medium = 34-66% of area covered; and Heavy = 67-100% of area covered.

Table 4 (Continued)

Habitat Analysis Sample Plots, Port Royal Sound Study Area

Plot No.	Terrain	Predominant Timber (In descending order)	Timber Stocking Rate*	DBH Avg.	Understory & Density**	Recent Land Use
44	Flat	Laurel, Water Oak	Medium	9-12″	Waxmyrtle-Smilax-Medium	Cut
45	Flat	Loblolly Pine, Laurel Oak	Medium	13-15″	Waxmyrtle-Bay-Light	Cut
46	Flat	Laurel Oak	Medium	5-8 ″	Palmetto-Light	Cut
47	Flat	Sweetgum, Red Oak, Water Oak	Heavy	9-12″	Smilax-Light	0
48	Flat	Sweetgum, Loblolly Pine	Heavy	13-15″	0 0	0
49	Flat	Sweetgum, Water Oak	Medium	9-12″	0 0	0
50	Flat	Laurel, Water Oak, Loblolly Pine	Medium	9-12″	0 0	0
51	Flat	Laurel, Water Oak, Loblolly Pine	Heavy	5-8 ″	Palmetto-Light	Burned & Cut
52	Flat	Laurel Oak	Light	9-12″	0 0	Cut
53	Flat	Loblolly Pine, Sweetgum	Medium	9-12″	Sweetgum-Light	Cut
54	Flat	Water Oak, Laurel Oak	Heavy	5-8 ″	Palmetto-Medium	Cut
55	Flat	Water Oak, Laurel Oak	Heavy	5-8″	Oak reprod.-Light	Cut
56	Flat	Loblolly Pine, Sweetgum	Heavy	9-12″	0 0	Cut
57	Flat	Laurel, Water Oak	Medium	9-12″	Waxmyrtle-Medium	Cut
58	Flat	Water Oak, Laurel Oak	Heavy	5-8 ″	0 0	0
59	Flat	Hickory, Live Oak	Heavy	16″	0 0	Burned
60	Flat	Laurel Oak, Live Oak	Heavy	9-12″	Hardwood reprod.-Light	0
61	Flat	Laurel Oak, Water Oak, Sweetgum	Heavy	5-8 ″	Palmetto-Medium	Cut
62	Flat	Loblolly Pine, Laurel Oak	Medium	9-12″	Palmetto-Light	Cut
63	Flat	S. Red, Laurel Oak	Medium	9-12″	Palmetto-Light	Burned & Cut
64	Flat	Laurel Oak, Loblolly Pine	Heavy	9-12″	Palmetto-Medium	Burned & Cut
65	Flat	Laurel Oak, Loblolly Pine	Medium	13-15″	Hardwood reprod.-Light	Burned & Cut
66	Flat	Laurel Oak, Loblolly Pine	Medium	9-12″	Waxmyrtle-Light	Burned & Cut
67	Flat	Laurel Oak, Loblolly Pine	Medium	9-12″	0 0	Cut
68	Flat	Blackgum, Laurel-Water Oak	Medium	9-12″	Bay-Heavy	Grazed & Burned
69	Flat	Loblolly Pine, Willow Oak	Medium	13-15″	0 0	Grazed
70	Flat	Hickory, Willow Oak	Medium	9-12″	0 0	Grazed
71	Flat	Laurel Oak, Loblolly-Slash Pine	Heavy	9-12″	Holly-Light	Cut
72	Flat	Laurel Oak, Loblolly Pine	Heavy	9-12″	Holly-Yaupon-Light	Cut & Grazed
73	Flat	Laurel-Water Oak, Loblolly Pine	Heavy	9-12″	Palmetto-Light	Cut & Grazed
74	Flat	Blackgum, Laurel-Water Oak	Medium	9-12″	Holly-Light	0
75	Flat	Laurel Oak, Loblolly Pine	Heavy	9-12″	Palmetto-Light	Cut & Grazed
76	Flat	Laurel-Water Oak	Heavy	9-12″	Fedderbush-Medium	Cut & Grazed
77	Flat	Laurel-Water Oak	Heavy	9-12″	Waxmyrtle-Ilex-Light	Grazed
78	Flat	Laurel-Water Oak	Heavy	9-12″	Waxmyrtle-graze Light	Cut & Grazed
79	Flat	Laurel Oak, Loblolly Pine	Heavy	5-8 ″	Waxmyrtle-Palmetto-Light	Cut
80	Flat	Live Oak	Heavy	16″	Palmetto-Light	Grazed
81	Flat	Laurel-Water Oak, Loblolly Pine	Heavy	13-15″	Waxmyrtle-Light	Cut & Grazed
82	Flat	Laurel-Water Oak	Heavy	5-8 ″	Palmetto-Light	Cut
83	Flat	Loblolly Pine	Heavy	5-8 ″	Palmetto-Light	Cut
84	Flat	Laurel-Water Oak	Heavy	9-12″	Waxmyrtle-Light	Grazed
85	Flat	Laurel-Water Oak	Heavy	5-8 ″	Waxmyrtle-Medium	Cut
86	Flat	Laurel-Water Oak, Loblolly Pine	Heavy	9-12″	Palmetto-Light	Cut & Grazed
87	Flat	Sweetgum, Laurel-Water Oak	Heavy	9-12″	Palmetto-Light	Cut & G
88	Flat	Laurel Oak, Loblolly Pine	Medium	5-8 ″	Palmetto-Light	Cut & G

* Stocking Rate: Light = 0-33% stocked; Medium = 34-66% stocked; and Heavy = 67-100% stocked.
** Understory Density: Light = 0-33% of area covered; Medium = 34-66% of area covered; and Heavy = 67-100% covered.

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Air Quality Evaluation

The South Carolina Pollution Control Authority
Columbia, South Carolina

Introduction

Basically, the purpose of the air quality portion of the Port Royal Sound Study was to evaluate the existing levels of common air pollutants in the vicinity. These levels represented the baseline air quality conditions upon which future changes can be assessed. The air quality investigations consisted of a three-phase analysis that included: the evaluation of background air pollution in the area, the meteorological prediction of air pollution potential from any source in the area, and thirdly, an evaluation of interstate air pollution potential. This last phase was performed by the Air Pollution Control Office of the Environmental Protection Agency, which also studied (and subsequently rejected) the feasibility of devising a dispersion model for the area.

Method

To make background determinations for each of the possible specific pollutants which could be injected into the atmosphere as a result of future industrial growth in the area would have been impractical. Consequently, known bad-actors, as well as classes of pollutants, were selected to be used as air pollution indicators. These included suspended particulates, settleable particulates, sulfation rates (an approximate measure of sulfur dioxide) and corrosion rates on mild steel (Table 1 Appendix).

During three separate periods of seven days each, 24 hours a day, intensive sampling and analyses for additional gases were made. These periods were conducted during the weeks of April 20th, August 3rd, and October 19th, 1970. The gases monitored include sulfur dioxide, nitrogen, carbon dioxide, total oxidants, aldehydes, ammonia and hydrogen sulfide (Table 2, Appendix).

Air quality sampling station; photo by J. Darby, S. C. Water Resources Commission.

Additional analyses were also performed. For example: dust fall buckets for settleable particulates were exposed and a gravimetric analysis was performed at the end of each month. Lead peroxide cylinders for sulfation rates were exposed for a one month period and analyzed at the end of the period. Also, steel panels were exposed for a period of ninety (90) days for corrosion rates (Tables 3 and 4, Appendix).

On April 2, 1970, the background air quality study which was conducted by the South Carolina Pollution Control Authority, Division of Air Pollution, began. Air sampling stations were operated at the following locations: (1) Beaufort County Health Department, (2) Mr. Pinckney's (near Oakatie Monkey Farm), (3) Bluffton Health Center, (4) Victoria Bluff and (5) Palmetto Bay Marina.

Since the prevailing winds in the study area were oriented in approximately a NE-SW direction, three of the five sampling points were located along this general line; the one in Beaufort atop the County Health Department Building, another on Victoria Bluff and the third atop the Health Center Building in Bluffton, South Carolina. This last site would have been more ideally located nearer to Savannah, Georgia, but no suitable facilities were found within practical reach. The two additional sites were selected along a line rotated approximately ninety degrees from the first line; the one on the Pinckney place near Oakatie Monkey Farm, and the other at the Palmetto Marina on Hilton Head Island.

All of the sampling was done from the five permanently situated sites. These sites were selected with Victoria Bluff as the focal point. Actually, ideal sites were difficult to find and pragmatism played a part in the site selection. High volume air samplers, which were located at the five stations, were operated on a random basis, averaging two days per week over the entire period of study, to determine concentrations of suspended particulate matter. Filters from these measurements were subjected to the following analyses: gravimetric analyses for total suspended particulates; metal analyses for chromium, manganese, iron, lead, copper, cadmium, zinc, magnesium and calcium; non-metal analyses for phosphates, sulfates, nitrates, chlorides and total benzene soluble organics (Tables 5, 6, 7 and 8, Appendix).

Results

The data obtained in this study substantiate the speculation that air in this general vicinity is very pure. One item which does bear a closer look is that of suspended particulates. This is one of the main indicators of general air pollution, and is what the public recognizes as "air pollution." These values were quite low during the period of this study, but they would probably show a slightly higher value during the cold weather months, due to the increased use of fuel and to adverse meteorological conditions which are prevalent during the winter period. (Table 5, Appendix).

It is interesting to note that the Bluffton and Beaufort areas show slightly higher suspended particulate values than the surrounding open land. Against any other background this difference would not be detectable for even the Beaufort and Bluffton values were extremely low. As a matter of fact, the data from the Beaufort station, which has been in operation for some two years, have been used as an example to illustrate how clean city air can be.

Because of these low levels of pollutants being found, any unusual occurrence, such as a forest fire or extremely dry weather and consequent dust clouds could dramatically affect any samples taken during these periods. As an illustration, the suspended particulate values were generally so low that the presence of pine pollen during April made a significant impression upon the weight of samples, as did a wild fire in the vicinity, and unusually heavy traffic in Bluffton. Furthermore, a significant proportion of the particulates near the coast are probably due to evaporated salt spray.

Only one surprise was encountered in this air quality study, and it consists of an anomaly, the explanation for which is quite elusive. One of the several parameters measured was that of airborne metal concentrations. All values were at or below expected levels except for a rather high copper content in Beaufort, South Carolina (Table 6, Appendix). This is by far the highest long-term value ever found in South Carolina, even in heavily industrial areas, and is well above the national averages. No explanations for this high copper level can be offered and the health significance of this value is not known. The average copper concentrations in samples collected at the Beaufort County Health Department ($3.7 \mu g/m^3$) were approximately eight times the average of values found at the other four main sampling locations. This value is based upon sixty-four samples and every aspect of the analytical process was investigated thoroughly to be sure that it was accurate.

In addition to all of the previously mentioned descriptions, a continuously operating weather data tower, which was utilized at Victoria Bluff, was dismantled on August 2, 1971 after operating for over a year. Information gathered at the Victoria Bluff site includes wind speed and direction data. A preliminary analysis of wind data collected at this site indicates that meteorological data being collected at the Beaufort Marine Corp Air Station and at the Savannah, Georgia, National Weather Service Office were sufficiently representative of the wind flow in the Port Royal Sound area. Therefore, operation of the automatic meteorological station at Victoria Bluff was discontinued.

Originally, these meteorological data along with data from the Weather Bureau at Savannah, Georgia, and Charleston, South Carolina, were to be utilized in the calibration of a diffusion model that was to be prepared by the Air Quality Office of the Environmental Protection Agency.

Conclusions

1. The overall air quality in the study vicinity was excellent.

2. The high concentration of atmospheric copper incurred at the Beaufort sampling station indicates the need for additional investigative sampling of this parameter in the vicinity.

3. Some of the meteorological data being collected at the Beaufort Marine Corps Air Station and at the Savannah, Georgia, National Weather Service Office, such as wind speed and direction, are fairly representative of similar conditions in the Victoria Bluff vicinity.

4. A year-round sampling program would be beneficial and informative,particularly from the standpoint of determining the concentrations of suspended particles during the cold-weather months.

Solid Waste Disposal Practices in Beaufort and Jasper Counties

INTRODUCTION

A survey was conducted in January, 1972, to re-evaluate solid waste management in Beaufort and Jasper Counties, South Carolina.

In 1967 and 1968, a survey of community solid waste practices in this area was conducted by the Solid Waste Section, Environmental Sanitation, South Carolina State Board of Health. This survey indicated that Beaufort County had nine disposal sites and Jasper County had three sites. In June of 1970, another survey was instigated by the Environmental Health Service, DHEW, Region IV, Atlanta, Georgia, as part of the Port Royal Sound Environmental Study. During this 1970 study, four of these major county sites were resurveyed in Beaufort County and two, in Jasper County. These sites were not being operated in a manner which would meet minimum standards for a sanitary landfill operation. They were more appropriately classified as open or open burning dumps.

Beaufort County open dump; photo by S. C. Water Resources Commission.

In January, 1972, an inventory of the six disposal sites that were studied in 1970 was conducted by the South Carolina Water Resources Commission. In this survey, it was noted that while little had changed at the Jasper County sites, Beaufort County had taken definite steps to combat the problem of inadequate solid waste disposal. Beaufort County had reduced the number of disposal sites and had instigated a rural solid waste collection system. Recent communications, however, with personnel of the Solid Waste Division of the S. C. State Board of Health indicate that significant progress has been made as of this writing (May, 1972) in Jasper as well as Beaufort County towards the proper disposal of solid waste.

DISCUSSION

In the 1970 study, the disposal sites at Ridgeland and Hardeeville were found to be in deplorable condition. Open burning was evident, and salvaging and scavenging were not prohibited. The sites were overloaded with waste and at infrequent intervals the waste was obviously pushed farther into the swamps surrounding these sites. No compaction or covering was practiced, and these sites were best classified as open burning dumps.

Upon reappraising these sites in 1972, there was little evidence of changes in conditions. Open burning was observed at both sites and no fences had been erected. There was no equipment present at the Hardeeville site, and although there was a dozer present at Ridgeland, it was readily apparent that it was used infrequently.

The 1970 study investigated four main sites in Beaufort County: Bluffton, Hilton Head Island, Lady's Island, and the site at the City of Beaufort. These sites, although labeled as "Sanitary Landfills," were found to be open or open burning dumps. They were only minimally adequate. However, by January, 1972, Beaufort County had taken definite steps to alleviate its problems of solid waste disposal. The county had only one main site in operation during the 1972 survey, a 60 acre tract off S.C. Secondary Road 86 near Burton. This operation is a sanitary landfill.

To combat indiscriminate dumping by private individuals, as of January, 1972, Beaufort County had placed 70 metal containers along roads in the county for collection purposes. These containers, which have a capacity of between four cubic yards and forty cubic yards, have contributed greatly to the county's fight against promiscuous dumping. The containers were being emptied at least twice a week and their contents, trucked to the landfill site at Burton.

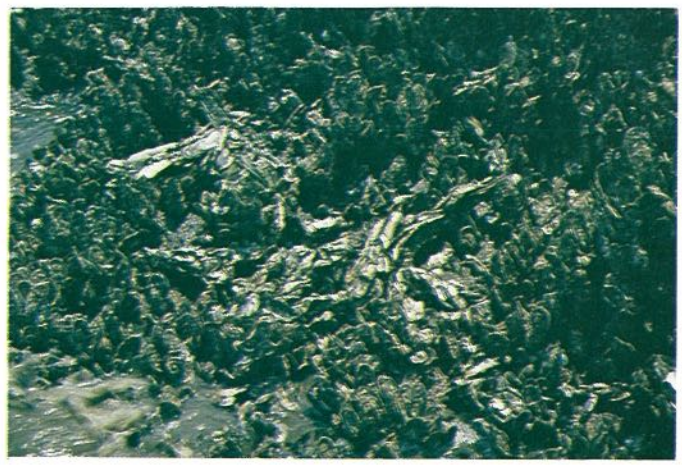
As of January, 1972, the sites at the city of Beaufort, Hilton Head Island and Lady's Island, which were studied during the 1970 survey, had all been closed, and all except the Lady's Island site, had been covered. County officials reported that the site at Lady's Island would be covered in the near future. The Bluffton site had been changed by the county from an open dump to a collection point for the Burton landfill site, by installing a 40 cubic yard container. The old dump, however, had not been covered and this led to some indicriminate dumping at the site. This situation could possibly be eliminated by covering the old waste, landscaping the area and encouraging the use of the metal container.

SUMMARY

The South Carolina State Board of Health has adopted minimum standards for sanitary landfill design, construction and operation. As of this writing (May, 1972), Beginning on July 1, 1972, all systems for land disposal of domestic solid waste must be approvide sanitary landfills. Industries wishing to utilize established municipal and county landfills must also comply with the regulations promulgated by the State Board of Health. Apparently, Beaufort County will be in compliance with the Solid Waste Division's regulations.

Communications with State Board of Health personnel in May, 1972, indicate that Jasper County will contract with private collectors to gather that county's solid waste. The collectors will, in turn, deposit this material probably at the new Hampton sanitary landfill (being constructed and scheduled for completion by July, 1972) or perhaps at the Beaufort site.

Realizing that Colleton County also has an operating sanitary landfill and that all industries within the above mentioned counties utilize these county or municipal sites, one can only conclude that significant progress has been made in the State's Low country region concerning the urgent need for adequate solid waste disposal practices. In view of the deplorable conditions cited in the earlier surveys, particularly in the 1970 survey, the leaders and people of these Lowcountry counties can only be complimented; firstly for recognizing the solid waste problems that did exist, and secondly for taking the decisive steps necessary to alleviate them.



Beaufort County Sanitary Land Fill; photo by M. Thompson, S. C. Water Resources Commission.

The Port Royal Sound Ecosystem - A Review

James O'Hara
South Carolina Water Resources Commission
Columbia, S. C.

An estuary is an ecosystem. An ecosystem is that ecological unit within which the biotic community and abiotic components exhibit a functioning relationship. Examination of a complete ecosystem, even by components, is difficult. The purpose of this section of the Port Royal Sound Environmental Study is to draw from the information gathered by the separate agencies that conducted research on Port Royal Sound and from other reference sources to attempt to demonstrate the overall complexity of this estuarine ecosystem.

Few professional scientists would consider a study predicated largely on April, July and October samples as being an adequate representation of a system as complex as Port Royal Sound. Yet, from these samples, we can make some general conclusions and comparisons with the published literature on estuaries.

The ecology of the estuary is dependent upon both the phytoplankton and the plants of the marsh. The general discussion about estuaries (Thompson, this volume) pointed out that the plants basic to a food chain must be extremely numerous and highly productive in order to support the entire biomass of consumer organisms that depend upon them. In the estuary, there are two major pathways of energy transfer through the food chain; the detritus pathway and the phytoplankton pathway. The first, the detritus food chain, has the major portion of its energy supply coming from the marshland. As shown by Shriner (this volume) the principle marsh plant of this area is *Spartina alterniflora.* She found the *Spartina* population to range between 12 and 241 plants per square meter (average 77/sq. m.) in the Port Royal Sound study areas. Shriner gives no usable data on productivity of the *Spartina,* but Teal (1962) showed about 6500 calories net production per square meter per year when *Spartina* production was averaged for the whole marsh. Net production is that energy available over and above the energy needs of the plant.

The eventual death and decay of the *Spartina* makes its energy available to the myriad of organisms which feed primarily on organic detritus. Teal (1962) estimated 45% of the net energy produced by the *Spartina* is lost to the estuarine waters. Odum and de la Cruz (1969) found 90% of the detritus in the estuary waters was of *Spartina* origin while only a small percentage of the *Spartina* plant was used for food while the plant was living. This abundant organic material that washes out of the marshes is available to help feed the oysters, clams and filter-feeding fish such as anchovy and menhaden which are extremely common in the Port Royal Sound Estuary. Vernberg and Sansbury (this volume) identified 27 common species of invertebrates in the Port Royal Sound marshes. Most of these derive their basic nutrition from plant detritus. Since the salt marsh is intertidal, many of these organisms are daily exposed to the extreme fluctuations of temperature, salinity and dryness of the intertidal zone. These variations are often stressful and slight changes in the ecology of the area may combine with the natural stress to the detriment of species (O'Hara, 1972; Vernberg and Vernberg, 1972). The ramifications of changes in the marsh would be felt by the strictly aquatic animals as well as those of the intertidal zone.

Parrish (this volume) examined the benthic invertebrate community during April, June and October, 1970. He noted that most of the benthic organisms were detritus feeders and indicated that the invertebrate community of Port Royal Sound was typical of a non-polluted estuary bounded by salt marshes. He found that the invertebrate populations were highest in April when salinities and temperatures were low. Whether the low populations during July were the direct result of high bottom temperatures (30°C) and salinity (33 o/oo) affecting the reproduction of the abundant amphipods has not been established, but it is known that many larval stages of crustaceans survive best around 25°C and 30 o/oo salinity (Costlow *et al.* 1960; Costlow, 1967).

In September, 1965, a Federal Water Pollution Control Administration (FWPCA, 1966) survey was made of bottom organisms of Charleston Harbor. This body of water is about 60 miles north of Port Royal Sound and is heavily polluted by domestic and industrial wastes. The number of benthic species collected ranged from 0 to 8 per square foot in different parts of the harbor. Sixty percent of the stations contained only polychaete worms. By comparison, Port Royal Sound samples from October, 1970, ranged from 12 to 30 species per square foot. Patrick *et al.* (1954) showed that the number of diatom species present in a body of water could be related to the degree of pollution with the greater species diversity associated with a non-polluted habitat. Wilhm and Dorris (1968) elaborated this concept for many organisms and Bechtel and Copeland (1970) brought supportive data for this concept from marine and estuarine fish species.

In addition to the organic material of the marsh, many animals derive some of their energy needs from the other major energy pathway. Plankton are microscopic plants and animals which drift with water currents. The phytoplankton of the estuary are important for the survival of the biotic community and their energy supply to the Port Royal Sound food chain is exceeded only by that of the detritus of the estuary.

The radiant energy of the sun is converted to plant tissue wherever there is enough light for the phytoplankton cells to thrive. The combined turbidity of the inorganic suspended material, the suspended organics and the plankton themselves limit the penetration of light for photosynthesis. Thomas (this volume) and Ballentine (this volume) got vastly different estimates of the photosynthetic (euphotic) zone. Thomas estimated the depth of the euphotic zone to range between 7 and 12 feet at the different stations sampled in April, 1970. This zone was found to be 5 to 25 feet deep in July and 4 to 15 feet deep in October, 1970. The average depths of the euphotic zone were 10 feet in April, 8 feet in July and 7.4 feet in October.

Thomas' data indicate that photosynthesis was possible over the entire area of Port Royal Sound down to the average euphotic depth given and that increased amounts of light and phytoplankton would produce a corresponding increase in organic carbon content of the estuary. His determinations, corrected to a maximum light intensity, show an average production of 330 milligrams of carbon per square meter of surface per day during April. This, of course, takes into account the average depth of 10 feet. This value also represents an assimilation rate of approximately 110 mg C/m^3/day for Port Royal Sound. The corresponding values for July were 1,598 mg C/day in the 8 foot water column or an average of 706 mg C/day in each cubic meter of the euphotic zone. October averages were still quite high with 838 mg C/day in the 7.4 foot euphotic zone which is about 540 mg C/day for each cubic meter of this zone.

While Thomas omits too much information on methods and calculations from his report to allow for clear interpretation, a few comparisons might be made with published information:

The productivity of Port Royal Sound is similar to that of North Carolina estuaries. Thomas only compared his work to Ragotzkie (1959) to justify the claim of high productivity for Port Royal Sound.

These measures of photosynthesis or primary productivity do show good algal growth in Port Royal Sound. This is necessary to help support the base of the energy pyramid described by Thompson (this volume). Lear and Smith (this volume) suggest that the phytoplankton diversity is the key to a healthy ecosystem. On the basis of samples taken in April, July, and October, they state that the phytoplankton species were fairly uniform throughout Port Royal Sound with the exception of station 1. Should an additional stress factor be added somewhere in the study area, its effect on the phytoplankton can be assessed by comparing the affected area with other areas in Port Royal Sound. Again, the relationship between species diversity and pollution may give meaningful data. The standing crop of algal cells is low compared to Williams and Murdoch's (1966) data on Beaufort Channel in North Carolina. These authors found counts to be seasonally irregular with standing crops ranging from .13 to 5.4 x 10^6 cells/liter (average 2 x 10^6 cells/liter). Port Royal Sound populations are reported to be .27 to .70 x 10^6 cells/liter in spring, .49 to 1.28 x 10^6 cells/liter in summer, and .15 to 1.13 x 10^6 cells/liter in October. In Charleston Harbor, phytoplankton concentrations ranged from .2 x 10^6 to 3.0 x 10^6 cells/liter in September 1965 (FWPCA, 1966). This puts the average standing crop much lower in Port Royal Sound, but Lear and Smith's technique of counting algal units rather than cells makes comparison difficult.

The fishes of Port Royal Sound were sampled by anchored gill nets, drift gill nets, otter trawls, seines, macro-zooplankton drag nets and by blocking off selected tidal streams with nets. Samples were taken between April and October.

			Measured Productivity	
Author	*Location*	*Time*	*Average mg C/m²/day*	*Average mg C/m³/day*
Williams and Murdoch (1966)	North Carolina estuaries	Dec. to May	318	182
		June to Oct.	1196	553
Thayer (1969)	North Carolina estuaries	Dec. to May		137
		June to Oct.		420
Ragotzkie (1959)	Georgia estuaries	April to May	980	
		July	577 > 567*	360 > 300*
		October	577	240
Thomas ** (this volume)	Port Royal Sound	April	266	90
		July	1225 > 901*	576 > 425*
		October	578	275

* Average
** Values uncorrected for light intensity

Hicks (this volume), using various gill nets, found the greatest species diversity in the spring samples, but greater numbers of individuals in the summer. Over 50% of the fish taken in all seasons were Atlantic menhaden. Menhaden breed offshore and the young-of-the-year move into the shallow waters and estuaries for protection and to feed on the plankton and detritus. This species would represent an intermediate between the plankton and the carnivores.

Another important species that feeds on plankton and is preyed upon heavily by the carnivores on the top of the food chain is the Bay anchovy. McKenney (this volume) showed that 81% of the fish eggs and larvae taken in 261 plankton samples in spring, summer, and fall, 1970, were of this species. The size of the fishes precluded their occurrence in the gill nets.

Hicks found a total of 47 species of fishes in Port Royal Sound. Although his collecting technique might have been selective, he noted different populations of fishes in the channel reaches and in the near shore areas. Since the water quality is quite uniform throughout Port Royal Sound, this distribution probably reflects habitat preferences or feeding differences.

Turner and Johnson (this volume) blocked off 5 tidal creeks with a 0.25-inch mesh net during the April, July, and October sampling period. Their catches included macroinvertebrates as well as fishes and are expressed in terms of species and density. They found 59 species of fish and 8 species of macroinvertebrates. The size of the creek correlated with the diversity of species and an average of 8,132 fish per acre was taken from the tidal creeks. 95% of the fish collected were of four species with Bay anchovy dominating the fish populations. Silversides, mullet, and silver perch constituted the other three species that dominated the catch. These fish comprised over 80% of the biomass of the fishes taken. It should be noted that these species are plankton and detritus feeders and obviously the tidal creeks produce large numbers of fishes to be preyed upon by higher carnivores. Young of 17 commercial and/or sport species were also taken. We can safely conclude that the tidal creeks represent an important productive habitat for Port Royal Sound fishes.

Bearden's (this volume) monthly otter trawls produced 53 species from Port Royal Sound. Again, the largest group was the plankton feeding clupeid fishes, Bay anchovy, and Atlantic menhaden. The dominant predator species were members of the Sciaenidae, which included croakers, whiting, spot, weakfish and yellowtail.

The sample techniques used in these studies are not appropriate for capturing the larger predators that make up most of the sport fisheries. While it is recognized that these fish would only be accidentals or juveniles in the estuarine area, their large numbers off the coast of South Carolina attest to the high productivity of these waters. Much of this productivity comes from the estuaries. Bearden (1961) reports the presence of about 100 common species of fish in South Carolina waters. The identification of 47, 59, and 53 species from Port Royal Sound by authors in this volume shows a fairly good representation of fishes in their collections. A total species list compiled from these reports has 107 species from Port Royal Sound (see Appendix). A similar study by Dahlberg (1972) lists 151 species from Georgia waters.

The macroinvertebrates collected by Turner and Johnson were primarily grass shrimp, blue crabs, and penaeid shrimp. The penaeid shrimp showed marked seasonality in their occurrence. They were present in the summer and fall collections only. Summer collections were of juveniles with the 257 shrimp per acre comprising only 0.7 pounds. These shrimp breed offshore and the larval stages drift into the estuaries where they develop and grow. As they become larger, they move offshore. 1.9 million pounds of shrimp were commercially harvested in the southern district of South Carolina in 1970. (In 1971, the shrimp harvest was more than double the 1970 crop). Grass shrimp were taken only in the spring. Blue crabs averaged 26 individuals per acre and the total harvest of blue crabs in Port Royal Sound was approximately 1.9 million pounds in 1970. Over 215,000 pounds of oyster meat was taken from Port Royal Sound in the same year.

South Carolina landings data for 1970 show 27% of the total state catch of blue crabs and 22% of the state's oysters came from Port Royal Sound. These figures clearly show the importance of this region to the commercial shellfish industry.

The South Carolina landing for shrimp taken in Port Royal Sound was given as 106,000 pounds in 1970. This is about 5% of the southern district total harvest of 1.9 million pounds—indicating a high shrimp population. C. M. Bearden (personal communication) of the South Carolina Marine Resources Division indicated that this estuary is important to the juvenile shrimp population and the offshore catch of adult shrimp is high. It is reasonable to assume that the Port Royal Sound landings of 106,000 pounds in 1970 reflect the limited time the shrimpers are allowed to harvest the Sound area and are not reflective of the availability of the shrimp nor the contribution of the Port Royal Sound estuary to the offshore population.

It is clear that Port Royal Sound is a clean, healthy and productive area that is dependent upon the salt marsh detritus and the phytoplankton. The water quality of Port Royal Sound was judged to be excellent by Ballentine (this volume). He found no mercury or cadmium pollution and only traces of copper, lead, and zinc in the water. The sediments of Port Royal Sound had a minor accumulation of these metals, but since there is no major industrialization in the area, this probably reflects the natural levels of metals in the sediments (See Mullin and Riley, 1956).

Temperature and salinity data indicate that seasonal fluctuations are present, but are not harsh. Dissolved oxygen is generally adequate and the acidity changes are minimal.

Ballentine also reports an extremely low nitrogen value for the water of Port Royal Sound and suggests that this could be limiting to the phytoplankton. Low nitrogen concentrations are common in this type of estuary and the rapid recycling of nitrogen during warm weather has been frequently cited as the cause of increased productivity during the summer months, (Ryther, 1963; Williams and Murdoch, 1966). Thus, primary productivity could be enhanced by fertilization of the estuary. The proportionately high phosphorous content of the water suggests that this element is in excess of the needs of the phytoplankton.

There appears to be ample ground water of good quality available in the Victoria Bluff area (Gardner, this volume) to support economic development. If commercial development takes place, careful consideration of the type of development should be exerted to protect the ecosystem. The dye tracer study (Kilpatrick, this volume) clearly shows that certain types of pollutants (conservative) released at Victoria Bluff would concentrate in the Colleton River—although Kilpatrick's hypothetical effluent of six million gallons a day resulting in 846 ppm of solute must be considered illustrative rather than potential. Toxic effluents should be kept from this area because the low flushing rate will allow them to accummulate in the water and sediments resulting in potential long-range deterimental effects.

Practically any business or industry locating at Victoria Bluff would produce an effluent that would be discharged to the estuary. Perhaps a degree of cleanliness can be maintained if this imaginary effluent is released only on ebb tide into an area of the system that exhibits greater flushing characteristics. The United States Geological Survey's mathematical model of the entire Port Royal Sound system should be able to predict, among other things, the movement and ultimate concentrations of an effluent discharged into any portion of the estuary. If this model can demonstrate that an effluent released at a certain point during specific tidal conditions will not result in a deterioration of the quality of the system, then such a discharge can be considered. For industries or businesses, such careful management would probably necessitate the construction of holding ponds and lengthy effluent pipe lines. Consideration should be given to offshore outfalls for the treated effluent if this is more practical than holding ponds. Under any situation, an effluent must be treated to the highest level of known technology rather than to minimum standards in order to assure the maintenance of this relatively unpolluted ecosystem. Continuous discharge of an effluent into the Colleton River does not appear to be a viable alternative.

Industries, such as seafood processing plants, have an effluent with a high BOD, and, if allowed to discharge into the Colleton River, would lower the dissolved oxygen levels in the River. If Ballentine's mathematical model (this volume) is appropriate, an input of 60,000 pounds per day would only decrease the oxygen content by 0.5 ppm. While this might bring the oxygen level slightly below the state minimum of 5.0 ppm during the warm months, there is no evidence that this level of oxygen would be detrimental to the existing ecosystem. The low nitrogen : phosphorus ratio of Port Royal Sound would be enhanced by this organic addition, and the resulting increase in primary productivity in other areas of the estuary may well offset any decrease in productivity in the Colleton (see Caperon *et al.* 1971).

While it would be highly desirable to describe the ecosystem by a mathematical model, the interreactions are too complex for this treatment except in a few selected instances. The United States Geological Survey's report of flow dynamics (this volume) in Port Royal Sound states for its model:

> The specific purpose of the modeling effort is to permit simulation of the movement and dispersal of one or more conservative or nonconservative solute constituents injected concurrently into the Sound at one or more geographical locations. Within the context of this report, excess heat may be considered as a possible constituent. The Port Royal Sound simulation model should prove useful, however, for a variety of other purposes. It could be used to study the probable effects of potential, man-made modifications to the embayment configurations or to the bathymetry of the Sound. Such modifications might result from navigational dredging and the construction of spoil islands, from the diking and/or filling of marshlands, or from the construction of road causeways. The model might be used to assist with an areal investigation of the productivity of the tidal marshes or to investigate the movement and dispersal of a potential waste-heat loading. It could be used to delineate existing as well as hypothetical currents throughout a navigation channel, and to aid with the safe and economical design of an improved navigation channel. With some modification it could be used to determine the region that would be adversely affected by the dispersal and deposition of fine materials placed in suspension by a proposed dredging operation. The model could also be em-

ployed to determine the effects of extreme events such as the occurrence of unusual flooding (or dewatering) in the Sound caused by the proximity of a tropical-storm depression.

The USGS model is a tool which can help immensely in the management of Port Royal Sound, but it does not pretend to be an all-purpose panacea that can be programmed to consider the entire ecosystem.

Port Royal Sound appears to be a typical salt marsh estuary of the southeast coast. The air quality (S. C. Pollution Control Authority, this volume) has been examined and is considered to be of highest quality. The wildlife of the area is apparently abundant and diverse (Blackard *et al.*, this volume). The present industrialization apparently causes only localized effects. In summary, the area is most notable for its cleanliness and lack of development. This makes its status somewhat precarious and necessitates establishment of a clear program to protect the almost pristine conditions of the estuary and still allow for, and promote, economic expansion of the area. This is a difficult balance to achieve, but it is worth the effort. This region should neither be spoiled nor wasted.

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CHAPTER FOUR

SOCIAL ECONOMIC AND GOVERNMENTAL EVALUATIONS

Social Use and Governmental Management of Environmental Resources in Beaufort County, S. C.

Hardy Wickwar*
Bureau of Governmental Research and Service,
University of South Carolina, Columbia, S. C.

*Currently: Director of Planning,
Richland Memorial Hospital, Columbia, S. C.

Preface

1. *Purpose of this inquiry*
   a. In general,
   To cooperate with the State Water Resources Commission in a comprehensive study of environmental conditions in the Lowcountry and in developing proposals to meet the special problems raised by the potential introduction of water-using industry into Beaufort county, including consideration of the requirements and problems of urban and rural areas;
   b. In particular,
   To consider social and governmental means by which this development of water and related land resources can contribute to the development and wellbeing of all the people of the Lowcountry planning area and especially of Beaufort County.
2. *Methods used in this inquiry*
   a. Consultation and cooperation with state and local governmental agencies and non-governmental organizations concerning the management of environmental resources;
   b. Incorporation and integration to the maximum extent feasible of the plans, programs, reports, research and studies of federal, state, regional and local units, agencies and departments of government relating to the development of the environment (see Appendix).
3. *Scope*
   a. In the *social* development of an area, what matters is the use of environmental resources to provide benefits that can be enjoyed by all residents of the area. It leaves to a companion inquiry the *economic* development of the area, in the sense of using environmental resources to produce increasing quantities of goods and services that can be sold to the people of other areas.
   b. *Government* provides important means for managing environmental resources for purposes of social and economic development. It furnishes a public infrastructure of laws, facilities and services that can be used for the purpose not only of economic development at the hands of private business but also of social development at the hands of families and other groups. It reminds us that we have to think in terms of managing our environmental resources, rather than exploiting them away or conserving them unchanged; of balancing the general interest of state, nation and humanity against any combination of particular interests; and of weighing future need against present gain.

The role of government in man's management of his environment has begun to be studied only of recent years. The relationship between social progress and the environment is only now beginning to be studied. In social and governmental as in many other respects the present study of the Port Royal Sound area breaks new ground.

RELATIONSHIPS BETWEEN POPULATION GROUPS AND THE ENVIRONMENT

Changes in social structure

The social structure of Beaufort county has evolved in such a way that different segments of its population differ markedly in their dependence on natural resources.

A new Beaufort county has been created during the thirty years since the outbreak of World War II. Whereas the population declined from more than 30,000 in 1900 to 20,000 in the 1920s, it has since risen to 51,000 in 1970. It has also changed in color: the ratio of black to white fell from almost 10 to 1 in 1900 to 4 to 1 in 1920, 2 to 1 in 1940, 1 to 1 about 1955, and 1 to 2 in 1970. An outmigration of blacks has been more than balanced by an inmigration of whites, with the two counter-movements reaching their peaks with a massive exodus of blacks during World War I and an even more massive influx of whites since World War II.

These changes were of course related to exogenous factors. Where it had once helped supply a world market with such staples as cotton and rice, the county reverted largely to forest to help supply a national market with hunting plantations for the few and wood pulp for the many. Above all, however, it cashed in on the expanding demand of United States armed services for such facilities as the Marine Corps Depot on Parris Island, the Marine Corps Air Station on the mainland side of Beaufort city, and a naval hospital. This demand was to some extent only the latest recognition of the military advantages of the natural site—the same recognition as had been given by the 200-year struggle of Spain to prevent French, Scots or English occupation, and by the Union selection of Port Royal Sound as the base from which to blockade the Confederate States. It was also partly, however, the result of the play of national and international political forces, the future of which is so unpredictable that there is no sure base for any valid projections concerning the future growth of the county or region. Remembering the defense cutbacks of 1945-50 as well as the steadily increasing defense outlays of 1950-68, the elected representatives of the county have sought some more secure, more capital-intensive, more civilian and less governmental underpinning for the recent growth in land values and tax effort. They have therefore welcomed non-governmental exogenous interests which would use the site and the natural resources for the heavy capital investment that would augur well for their permanence. Two such have presented themselves: first a resort industry on the Sea Islands and, more recently, the possibility of a water-using heavy industry.

The demographic changes provide some measure of the general, although insecure, change that has transformed Beaufort county and made it appear to be the only expanding part of the Lowcountry. In 1900 it was a small rural county, most of whose inhabitants extracted a living from the natural resources of their soil and water by means of agriculture and fishing. Today, only about one-sixth of the civilian labor force gets its living directly from agriculture and fishing. Instead, one civilian wage-earner in three works in federal, state and local government, and another one in three in other service occupations, while only one-sixth has moved into construction, manufacturing industry, and transportation, utilities and communications. To this civilian labor force (about 12,000) has been added a variable number of military personnel (11,000 at 1960 census; 20,000 in late 1968, of whom 11,000 were marine recruits; 12,000 in early 1970, of whom 5,000 were marine recruits), creating the illusion of a labor force composed of half or more of the population—an unusually high ratio.

Sources of income and earnings also reflect the distinctive characteristics of the county's population structure. Total personal income, both civil and military, doubled in the 1950's (in round figures, from $30 to $60 million) and trebled in the 1960's (from $60 to $180 million), with the proportion consisting of federal wages and salaries rising from more than 55 to more than 60 percent, while the proportion consisting of farm wages, proprietors' income and property income remained constant at about 18 percent.

Degrees of dependence on natural resources

One implication of this transformation is that the population falls into two unequal parts according to the manner in which they relate to natural resources: (i) A minority who use the natural resources to produce goods and services for sale; and (ii) the majority who use them.

i. Transformers of natural resources

A minority of the population of Beaufort County, including about one-fourth of its civilian workers, derive all or most of their living from natural resources, primarily by farming or gathering them, secondly by processing them, or tertiarily by using them in related services, in order that the resulting products or services may be sold on the national market. The numbers engaged vary from week to week, so that "covered" unemployment fluctuates between 1.4 and 4 percent. Employment in primary and perhaps in these secondary occupations has declined with mechanization and the impact on wages of a national labor market including competition from U.S. Defense employment and extention of U.S. minimum wage legislation.

a) Agriculture producers:

There are about 1050 year-round fulltime farm workers covered by federal legislation. Day-haul hoe hands and harvest hands are also brought in from neighboring counties in large numbers: those arranged for by the South Carolina State Employment Service on behalf of about 40 employers reached their 1970 spring peak at about 40 per day, but are reputed to have been two or three times as numerous about a decade or two earlier; those brought in directly by farmers are believed to be more numerous, bringing the seasonal peak to over 1000. Interstate migrant crews coming north from Florida and engaged locally by about 20 farm managers through the Employment Service reached their 1970 peak in June at about 1400 (down from 2100 in 1968 and perhaps twice as many ten years earlier). In Beaufort county there is no migrant housing conforming with U. S. Department of Labor standards. A few large landowners lease land to out-of-state farm corporations; and an unknown number of small part-time farmers contract with Florida brokers to send in migrant crews to harvest the tomatoes they have planted. A by-product of truck farming is the custom of allowing local inhabitants to glean the produce left behind by the pickers—which has militated against their keeping vegetable gardens.

b) Fishermen:

Oyster-farmers, crabbers and shrimp fishers are mainly regarded as self-employed. Their exact numbers are therefore not regularly known to any administrative agency; but they are estimated by informed persons at up to perhaps 1000 fulltime and as many again part-time. Some shellfish-catching is seasonal here, with shrimp in the warmer and oyster in the cooler months; but many shrimpers are said to operate year-round by fishing also to the south as far as the Gulf and Guyana. Many shrimpers are said to own their homes: The great "common" of the sea supplements the exiguity of their family holdings. Paid or unpaid family labor can also help with oyster shucking and shrimp heading. No other sizeable segment of the population is so concerned with the accessibility and water quality of the Sound and its branches. In particular, shrimp boats are said to shelter in the Chechessee river when the high seas are rough, while Bluffton men gather oysters up the Colleton river. Port Royal and St. Helena sounds are the only two large inlets remaining in the SA class (fit for oyster gathering) in South Carolina. Scientific studies in South Carolina have shown how susceptible crabs are to agricultural arthropod-killing poisons, so that restrictions have had to be placed on the use of insecticides near coastal fisheries. The ability of shellfish to concentrate harmful substances is also a matter of common scientific knowledge.

c) Food processors:

Beaufort and Port Royal have eight fish canneries with about 350 workers—more than any other South Carolina county—of whom more than one-half work in one crab plant in Port Royal. Although many work year-round, their pay may fluctuate with the seasons; "partial claims" for unemployment insurance benefits are submitted when they work only part time. Employment in some canneries is reputed to have declined with substitution of machines for labor. The closing of the Daufuskie Island oyster cannery is attributed to pollution from the Savannah River.

d) Resort service workers:

About 800 persons are regularly employed in hotels, restaurants and maintenance on Hilton Head, besides domestics and yardmen unknown to administration agencies and construction workers from many counties (about 250 from Beaufort County). Hilton Head interests estimate 1800 jobs on the Island with payroll $10 million, including construction workers; about 1000 are estimated to be resident and 800 commuting; and it is possible that these numbers will increase greatly. Another 500 persons are regularly employed in motels, restaurants and marinas at and around Beaufort city, of whom many depend on the Marine Corps Recruit Depot's 100,000 visitors a year. It is understood that employment connected with commercial seaport facilities such as marinas and charter boats for offshore fishing is increasing. An unknown number of resort service workers are family members of military personnel.

e) Port and dock workers:

About 25 persons are regularly and about 50 irregularly employed for loading ships and otherwise operating the dock facilities at Port Royal.

ii. Consumers of natural resources

While only a minority of the population relate directly to natural resources as producers of goods and services, nearly all may be presumed to have a domestic and leisuretime interest in enjoying natural resources and outdoor amenities, both rural and urban. These may be presumed to include people at all income levels, from the members of private garden, golf, hunt, pony, saddle and bridle, and yacht and sailing clubs, and owners of private swimming pools, to the users of public boat ramps, fishing piers, hunting grounds, oyster grounds, playing fields and beaches.

Game licenses purchased in Beaufort County indicate that a slightly higher ratio of population than in the State at large engage in hunting. This may be related to conditions more favorable to wildlife survival than in most parts of the state, including a physical configuration conducive to formation of natural wildlife reserves, and land-use patterns which have not destroyed the wildlife food chain. In the absence of salt-water fishing licenses, no administrative evidence is available concerning the popularity of seaport fishing. It is believed that marine sport fishermen may outnumber commercial ones and that their catch may be as great. Insofar as the nutrients of shellfish and finfish are provided, the beneficial management of tidelands, as well as of estuarine and coastal waters, would seem to be basic to the continuance of sport and commercial fisheries alike.

Many consumers of natural resources are permanently resident here. They may be found among the locally recruited employees at military installations (more than 1000 with payroll $8 million, 1968), as well as local residents engaged in other lines of work or receiving social security benefits.

Many live here, however, during only a phase of their lives. Some grow up here. Some retire here. Many come to work for outside concerns, including defense installations (9000 with payroll $26 million, 1968; 7000 in 1970). The decision to remain would probably be influenced by the degree of satisfaction found in living in the area.

Poverty as an ecological constant?

A sharp contrast has developed between the exogenously developed prosperity of Beaufort county and the low income level of much of its native population. This contrast is illustrated by the widening gap between average and median disposable household income, with the average estimated at $8000 ($5000 in 1960), compared with a median just above $5000 ($3500 in 1960).

In the aggregate, many criteria illustrate the comparative prosperity of Beaufort county. Thus the U. S. Department of Commerce has held that it and its Lowcountry neighbors have not had a low enough average income or a high enough net out-migration to justify grants from the U. S. Economic Development Administration (except for a short while in Jasper County). So many new housing units have been built that the fraction of units that were sound and had plumbing reached 60 percent in Beaufort county (70 in Beaufort city), compared with 55 in the State and 47 in the four-county Low-country district (1960 census). So many children have been able to stay at school that the proportion graduating from high school has reached two-thirds, compared with one-half for the State (but many of the graduates may be white transients and many of the dropouts may be black out-migrants). A little more than half the estimated civilian labor force is covered by unemployment insurance (about 4700 in the private and over 1800 in the public sector). The proportion of the population receiving public assistance is 5.6 percent in Beaufort county (6.5 if the marine recruits are omitted), compared with 8.0 in the four-county Lowcountry district (though it is only 4.0 percent for the State). These differences in ratio, however, may reflect administrative as well as other variables, as indicated by the doubling of the public assistance ratio in Beaufort during the 1960s while it tended to remain stable or to decline in the rest of the Lowcountry.

Far more seasonal labor is hauled in from other Lowcountry counties, than is recruited in Beaufort county. There is also no current evidence of an unemployed labor reserve in Beaufort county, although there may be employed persons who could improve their earnings if there were employers competing for their labor, and there may be outmigrants who would stay or return if they saw more chance of well-paying employment.

When one turns from aggregates, however, to a study of specific segments of the population, it becomes evident that these indicators of generally superior levels of living are accompanied by indicators of low levels of living among the bottom half of the population. Some 3000 or so households (4000 in 1960) are estimated to have less than $3000 income, while more than 2000 may have between $3000 and $5000. The proportion of families falling below the poverty cut-off of the United States Social Security Administration has remained about the same as for the State and twice as high as for the nation, although it fell from four to three in ten (1960-66), and although it remained lower than in the Lowcountry mainland, where it fell from six to four in ten during the same years. It is estimated that about 17,500 persons in Beaufort county are poor enough to be eligible for the comprehensive health service that is now beginning to be set up with aid from U. S. Office of Economic Opportunity.

Malnutrition or undernutrition is widespread. Food supplements have been applied for on behalf of about one half of the county's pregnant and nursing mothers and pre-school children (1900 applications, March 1969 to August 1970). Of these more than 1500 in nearly 500 households are certified by the county health office as in need of food supplements, and about 900 collect them each month (about one-quarter of the population group at risk). This program appeals to many otherwise self-supporting families (e.g., those of fishermen), since it is associated with preventive medicine and family planning services (which have 1000 women under advice) and does not have a deterrent means test.

One factor contributing to nutritional deficiencies is believed to be the high incidence of parasites. Worm infestation has been found among one-third of lower-grade children examined in a predominantly black urban school and among two-thirds of preschool children brought for testing on a rural island. The clinical significance of worm infestation is debated in the local medical profession. Its consequences could include debilitation, retardation and lack of energy and initiative. Remedies are treatment and education accompanied by environmental improvement, and especially availability of water and sanitary disposal of water.

Another factor may be that some of the black people of Beaufort County live cut off from ordinary American standards of living. To have running water or a toilet may mean little to some, even in the towns. One black baby in five is delivered without a physician in attendance and one in two without its parents being married. Some poor black people belong to isolated rural "communities", unorganized yet self-sustaining, often based on former plantations. Women, even more than men, may be shut in. In spite of the automobile and television, there is much here that resembles the peasantry of less developed countries. Communication may be made exceptionally difficult for poor people in this estuarine environment by the way the county is cut up and travel distances increased by river and marsh, especially since highways and automobiles were substituted for boats.

On the basis of tests of means and needs, about 1100 cases (3000 persons) receive public assistance. The doubling of the number of the cases during the 1960s was due mainly to a sextupling of recipients of aid to families with dependent children (now 600 cases, 2400 persons), among whom it is estimated that only about a few dozen mothers of school-age children may be employable. The number of recipients might be increased if monetary assistance were extended from virtually unemployable categories to "the working poor" whose earnings are less than minimum family needs, as proposed by the President. The fact that public assistance recipients are not more numerous than they are is attributed to two environmental factors. The principle one is the prevalence of part-ownership of small freeholds and the unwillingness of co-heirs to sign away their rights on applying for old age assistance. (The number of cases receiving old age assistance in Beaufort County fell from 605 in 1956 to 373 in 1957 on enactment of S.C. Code 71-86). The other is the extent to which people qualify for social security (3500 beneficiaries). About 1200 households (4250 persons) are in receipt of food stamps at any one time, among whom 150 households receive them free of cost because their family income is adjudged to be less than $1 a day. One-half of food-stamp recipients overlap with public assistance and about one-quarter with social security, while a few hundred purchase them from time to time on account of seasonally low earnings, as in oyster gathering. In the course of a year there are perhaps 2000 families (6000 population, or more than one in eight, if marine recruits are excluded) who receive either public assistance or food stamps or both.

The black people of the Sea Islands are unique in that many of them are not a propertyless proletariat, but are the owners of town lots or rural small-holdings. In the 1960 and 1970 censuses, three-quarters of black homes in this county have been described as owner-occupied, compared with only one-half the white homes; and, except in the resort areas, the average value of house-and-land has been estimated by tax assessors at about $7500. The poorer among the black people of Beaufort bear more resemblance to the poor whites of Appalachia than to other poor blacks, in that both alike own subsistence holdings; but the poor blacks of Beaufort may have more opportunities to supplement this subsistence with money earned in employment. Deeds to this land go back for the most part to the 1860s, when some 2000 families acquired title to some 20,000 acres. Since then these freeholds have descended intestate and have come to be informally divided or held by coheirs, some of whom have lived on the property while others have become absentees.

This system, known locally as "heirs' land", has had considerable advantages. It has served as a deterrent to the mortgaging and sale of land. It has provided a subsistence base on Hilton Head Island for commercial fishing, and a residential base on St. Helena's and Lady's Islands for commuting to governmental, food-processing and other wage-paying employment, as well as a small labor reserve for nearby seasonal occupations. It has given many families roots in the land, a certain minimal security, and a reason for family cohesion. The value which occupants have attached to their rights was indicated by an abnormally low rate of tax delinquency during the Depression, as indicated by studies made by George Aull. It may also be related to the phenomenon of a higher voter registration rate among the black than among the white population of Beaufort county (4558 out of 10,881 registered voters, 1970).

These advantages are obtained at a certain social cost. This system, along with the possibility of getting a cash income from sources other than the land, seems to have served as an impediment to the formation of agricultural production cooperatives, which alone could have given small scale freeholders the advantages of larger scale equipment and expert management, and are remarkable by their absence. In some instances it has encouraged but in some it may have impeded, home upkeep and improvement, including applications for building permits to add bathrooms. It has also served as a deterrent to obtaining certain public benefits. Persons otherwise eligible for old age assistance have been afraid to give the State a possible claim against the estate. They have not been sure how far Farmers Home Administration attorneys would accept their claims to the land. With property at stake, they have tended to become circumspect and reserved—some say submissive—rather than aggressive in their dealings with the white holders of economic and political power, except for the new-found independence of the shrimping families of Hilton Head Island. There may also be some physical as well as social costs: People are attached to a soil which cannot suffice to give them a living. Low levels of living, including poor health, may be linked to these environment areas. Some health and social programs may therefore have been superficial pallitives focused on relieving symptoms rather than on prevention or cure, because they have neglected the ecological aspects of much Lowcountry poverty.

Their security may also be to some extent illusory. Although tax delinquency is usually avoided, it has occurred, and has resulted in occasional foreclosures and sheriff's sales. For co-heirs to agree to sell may be improbable but is not impossible. As the land market becomes active, developers may risk purchasing heirs' rights even when they cannot be sure of clear title until they have gone through forty years of unchallenged possession. The "ten acres and a mule" of the 1860s and the "black yeomanry" of the 1930s remain today a social reality of which the economic aspects have been largely divorced from the land by wage-earning and food-buying. In the disposal of public land in the 1860s, subsistence minifundia were here substituted for commercial latifundia (plantations): Today there is no policy concerning these holdings, although land-market and municipal processes are at work that could conceivably threaten their survival.

Nor is there much exact knowledge concerning their significance either to these landholders or to the general development of the area. In the absence of an up-to-date social survey and analysis of the system of relationships between land tenure, livelihood and family among this numerous and crucially important segment of the population, all social and governmental programs relating to them are operating in the blind.

Summary of conclusions

1. Persons directly dependent on natural resources for full-time work number between 3000 and 4000 out of a civilian labor force of about 12,000 in Beaufort county.
2. Households beneath various poverty lines number between 3000 and 5000 out of 12,000 (3700 black). Of these between 1700 and 2000 receive public aid in cash (welfare) or kind (food stamps) after investigation of need.
3. Beaufort county differs from other Lowcountry counties in the frequency with which low-income families own land and vote in elections; in lack of evidence of an unemployed labor reserve; and in an increase in public assistance, food stamp and health programs, coinciding with a decline in poverty.

THE GOVERNMENTAL PATTERN IN RELATIONSHIP TO THE ENVIRONMENT

A great change has recently occurred in the role of government in relation to the environment. Formerly government was mainly concerned to provide opportunities for aggrieved parties to obtain compensation for damage done to their persons or properties. Now government is mainly concerned with preventing and reversing the degradation of the environment. The main thrust of governmental action is thus shifted from court decision to administrative management; initiative is shifted from aggrieved parties to public agencies; and consideration is being given to long-term public interest as well as short-term private benefit.

The question has therefore become, to what extent are our governmental agencies organized and functioning in ways that are adequate to this new task of positive management of the environment?

A listing of public agencies whose decisions affect the Beaufort Sound environment indicates the absense of any focal point for careful and informed consideration of all aspects of environmental development. Instead, decision-making power in Beaufort is widely diffused and involves not only a division of labor but also a differentiation of interests and concerns.

The legislative delegation

The principal policy-formulating group is the state Legislative Delegation. Its commitment to development is symbolized by its sharing a manager and a building with its County Development Commission. Among the possible lines of development, it opted in the mid-1960s to have this Commission give priority to industrialization; along with Beaufort Chamber of Commerce, this body promoted an industrial park as a corporate (but until now non-profit-making) enterprise; and the encouragement given to a chemical concern was held to fit into the context of this policy option. Concerned with the tax base for local services, it has welcomed the contribution by Hilton Head Island of one-fourth of the present property tax, as well as the potential augmentation of the tax base by the chemical industry—perhaps its doubling in a decade—and it has supported state investment in the public infrastructure needed to generate a widened tax base (paving and toll-free bridge, and proposed Ports Authority rail spur and docks). Members of the delegation have also been legislatively active in the creation of the state Parks, Recreation and Tourism Department, the consolidation of state pollution control laws, and proposals for the settlement of title to tideland and for making water revenue pay for pollution control. One member of the delegation usually seems to come from south of the Broad River. The delegation officially nominates members proposed for at least thirteen administrative or planning boards, most of which have been established under local legislation initiated by the delegation rather than under general laws published in the Code:

—The County Development Commission;

—The County Board of Health;

—Five Public Service District Boards: Fripp Island, Forest Beach, Hilton Head, Sea Pines, Port Victoria;

—The bicounty Beaufort-Jasper Water Authority which supplies Savannah river water wholesale to Beaufort City, Port Royal Town, four U. S. Department of Defense installations and one rural water corporation, and has considered means of financing a sewage treatment and disposal system;

—The four-county Lowcountry Planning Commission which serves as checkpoint for requests for federal aid from Beaufort, Colleton, Jasper and Hampton counties (District X as established by the Governor in response to a U. S. Bureau of the Budget circular);

—The four-county Lowcountry Comprehensive Health Planning Board, which similarly serves as checkpoint for aid requests and is serviced by a joint health officer for these same counties;

—The four-county Lowcountry law enforcement task force which also serves as clearing-house for aid requests;

—The four-county Coastal Empire Community Mental Health Service Board of Directors;

—The seven-county Lowcountry Resources Conservation and Development Authority, which has the same county representatives as the Lowcountry Planning Commission, along with representatives from Berkeley, Charleston and Dorchester, and was the first in the State established by statute to obtain resource development grants from USDA Soil and Water Conservation Service to local communities and watershed areas for small water control and improvement projects.

Responsibility is so diffused that these commissions are not regularly accountable to or coordinated by any other body.

The county council

Beaufort County Council's administrative officer is responsible for housekeeping for such independently elected county officers as the sheriff, road supervisor, clerk of court, auditor and treasurer. It has provided a few inexpensive and almost incidental environmental amenities such as roadside parks and boat landings (ramps), bridgeside fishing footways (catwalks), refuse dumps (land fills), and a dock; but it has not been generally authorized to provide municipal-type improvements. It is among the first county governing bodies to utilize recent state legislative authorization to pass the following ordinances:

—Prohibiting camping or parking on public boat landings;

—Prohibiting prolonged mooring at Bluffton Dock;

—Requiring a sticker from the county auditor indicating sanitary approval before a mobile home can obtain an electrical connection (subsequently weakened);

—Requiring a license for sanitary installation services and also a sanitary permit when the county auditor (or magistrate on Hilton Head Island) issues a building permit.

The county has not yet adopted building standards.

Increasing activity by the county council poses problems of policing, to ensure compliance with ordinances and to prevent dumping outside public provision for refuse dumps. The county is underpoliced (10 deputies instead of 50 i.e., two on duty at all times instead of 10), and the health department is understaffed (actually, one sanitary inspector for 600 new buildings a year, besides investigation of complaints, and no regular inspection). Public law enforcement is therefore likely to be partial. Private property guards seem to be at least as numerous as public police.

The county council now formulates the county budget and transmits it to the legislative delegation for enactment. The effective rate of county property taxation is low (less than 0.5 percent of market value of realty, i.e., 66 mills outside the municipalities and special districts on a valuation at 8 percent of 1965 full value in spite of the fact that there is little industry on which property tax can fall and that 170 out of some 575 square miles are tax-exempt, mainly as public domain; and some outlay will be required to bring assessed values into line with rising market values. The property tax effort represents less than 1 percent of total personal income in Beaufort county outside the municipalities, but 2 percent of *civilian* income (compared with 2 percent for the State and 4 percent for the nation).

The county council has selected five of the authorized twelve members of the city-county Joint Planning Commission, which initiated preparation of a master land-use plan and accompanying zoning ordinance, beginning with the Bluffton-Victoria Bluff area when industrial development seemed imminent; its proposals would be subject to eventual council approval. This has superseded the former planning commissions for Beaufort City and Sheldon and St. Helena townships, which in the 1950s prepared zoning plans which failed to obtain popular approval by referendum about 1960. Pressure for planning seems to have come more from outside than from inside the county, and to have been particularly related to federal grants and the concern of a capital-intensive industry for orderly development. The commission has not proposed, nor has the council adopted, subdivision standards.

The county council has not yet developed long-range plans for facilities and services in any of its fields of action, except perhaps refuse disposal. Its budget is therefore not yet related to the implementation of a development plan.

There is no arrangement for coordination between county council and county board of health. Each tends to be responsible for making and enforcing its own regulations.

It would probably be more efficient for the county to take over and extend to all its inhabitants such services as are at present provided for less than one-third of them by three little municipalities. It would then become possible to have a well equipped professional fire company to support the township volunteer fire companies; a police force big enough to offer career opportunities and to provide the law-enforcement required among a transient population near defense bases and near an ill-supervised port where sailors can jump ship and black-market goods be smuggled; county-wide building standards, inspectors to enforce them, and a sliding scale for building permits in order to make this a self-balancing service; integration of public health into general county functions; and an outdoor recreation department able to maintain and expand facilities and to support township civic recreational associations.

This municipalization of the county could provide an occasion for modernizing its administrative organization, taking into consideration the proposals made in the Cresap, McCormick and Paget report of about ten years ago. A simple, business-like structure for county administration would not only enable local government to perform its functions more adequately and with more foresighted planning, but would also be attractive to well-managed business corporations.

Perhaps, as part of this process of modernization, the county council might find it useful to re-think its committee structure in terms of the major functions for which it will become the obvious focal point. It might, among other things, find it useful to have a committee for resource management, so that there may be some place in the county where responsible decision-makers become accustomed to thinking in environmental development terms.

Municipalities

Some modern services not yet provided by the county for all its inhabitants are provided for an urbanized minority by politically autonomous bodies in three small towns incorporated long ago by special act of the General Assembly as municipalities with elected mayors and councils: Beaufort (1803), Bluffton (1852) and Port Royal (1874). Sheldon was also formerly incorporated (1914-34) and Yemassee (1904) is now astride the border with Hampton County.

These municipalities provide environmental improvements not available outside city limits, such as street maintenance, lighting and trees, outdoor recreation areas, and garbage collection. This they have hitherto done on their own initiative; and it is only now that they are beginning to be required and aided to comply with state and federal standards.

Beaufort and Port Royal became contiguous in the late 1960s when they annexed all intervening land: Beaufort added 700 to its previous 2100 households, raising its population from 6300 (1960) to 9100 (1970), by annexing 1000 acres of land and 1000 of marsh and water; and Port Royal raised its population from 700 (1960) to 2700 (1970) by annexing nearly 1000 acres of land besides the contiguous rivers to their further banks.

Beaufort city has a small municipal police force, (13), equipment and core personnel for a volunteer fire company, and garbage collection. In its older areas it has provided such environmental amenities as recreational facilities staffed by volunteers and sewage collection for about 1000 households, since the 1930s. It retails water to 3200 properties within city limits and about 1000 domestic users outside, at a surplus of receipts ($200,000) over costs ($150,-000) ; it taps the Authority's water-main west of the city, and is about to develop a major distribution system on Lady's and part of St. Helena's islands. It derives its revenue mainly from property taxes ($250,000 from 60 mill rate), business licenses ($90,000), shared taxes ($50,000), and water surplus ($50,000). Its jurisdiction extends to the far side of the surrounding waterways, on which it imposes speed limits for boats. It cooperates with the county, using its jail and landfill, and contributing to the cost of the county-city Joint Planning Commission to which it appoints four of the twelve members; and it is represented on the Lowcountry Area Planning Commission. It formerly considered investing in a new sewage collection system for all its inhabitants at a capital cost of about $2,500,000, and contracting for sewage treatment by the bicounty Water Authority; but is now exploring engineering design and methods of financing for sewage treatment for half the families who live in the old sewered area and two low-lying areas as well as for the schools, at a cost of perhaps $1.5 million to be defrayed from service charges; it has not yet been ordered by the state Pollution Control Authority to desist from discharging its raw sewage into public watercourses. It has a zoning ordinance but no land-use plan; and it has no personnel or procedures for enforcing its building standards, other than building permits and inspection by the city manager himself.

The town of Port Royal retails water to about 525 customers inside city limits, and purchased a system supplying about 475 outside when substitution of Water Authority surface water for pumped water became necessary; this pays its way. It has a park which serves also as a school playground. It contracts for the collection of garbage, which is then disposed of at the county landfill. It has a volunteer fire company with some county-provided equipment, and a police force of five men, making it possible for one to be on duty at all times. It has virtually no sewer system, and would depend on the Authority for technical supervision if it installed a collection system. It has a zoning map, but has not filled the three seats reserved to it on the county-city Planning Commission. It is too small to afford professional supervision of technical services. If its powers were transferred to the county—the Water Authority and new agencies for safety and recreation—or if it combined with Beaufort to form a single city, it could keep its identity, if it so desired, through a voluntary civic association such as the one which now cooperates with official agencies in providing recreational services.

No adequate steps have yet been taken for the municipalization of what will probably become in fact a new city: Hilton Head Island. In the absence of a public land-use plan, large-scale private land developers have already planned for an Island population of 25,000 by about 1980 and are planning for twice that number before the end of this century.

The idea that a municipality should be confined to urban areas has become out-of-date, since the coming of the automobile obliterated the hard-and-fast distinction between town and country. Perhaps the alternative might therefore be explored of creating a new kind of urban-and-rural municipality, and extending the advantages of municipal management and service to all parts of this district.

State agencies

South Carolina has more than a dozen state administrative agencies empowered by the General Assembly to make decisions directly affecting the physical environment in Beaufort county:

i. Budget and Control Board, which controls permits for use of tidelands, leases tideland phosphate mining rights and sells surplus state land;

ii. Water Resources Commission, which advises the Governor and General Assembly on water policy, serves as state clearing-house for requests for federal aid, is studying the estuarine environment, and is authorized to hold hearings with a view to establishing "capacity use areas" for the rationing of underground water;

iii. Wildlife Resources Commission, which leases oyster beds, marks out public oyster-gathering grounds (6), builds boat landing ramps (12) and artificial fishing reefs (3), licenses hunters (3600), freshwater anglers (1250), and boats (1900), regulates commercial fisheries and polices tidelands;

iv. Ports Authority, which manages the state-owned ports and related facilities, and is authorized to acquire and improve land and tidelands for port purposes and to regulate navigation over estuarine and maritime waters;

v. Parks, Recreation and Tourism Department, which leases Hunting Island State Park to a managing corporation (500,000 visits, 1968-69) and can help counties plan outdoor recreation;

vi. Highway Commission, which builds Interstate, U.S.-aided and, by agreement, municipal highways, and helps prepare a county highway plan;

vii. Forestry Commission;

viii. Development Board, which assists with industrial promotion and related physical planning;

ix. Pollution Control Authority, which is required to classify fresh and salt water according to standards approved by the Environmental Protection Agency for protection of wildlife and other natural resources, to license construction of effluent discharges when these will not impair the quality of the environment, and to restore the quality of the environment by ordering the cessation of the discharge of untreated waste;

x. State Board of Health, whose sanitary engineers protect consumers by licensing such oyster beds as they consider free from pollution and by classifying such as they consider polluted;

xi. Attorney General's office, which advises on rights to use tidelands and on breaches of environmental control legislation and regulations;

xii. Public Service Commission, which passes on location of power plants, and regulates privately owned water, sewer, and other utilities;

xiii. Agricultural Extension Service, which provides full-time county agricultural agents (2) and home demonstrator (1), part-time nutrition aides (20) and a visiting adviser on community development and fisheries, and formerly took the lead in preparing a coordinated annual Technical Action Panel plan for all federally-aided farm programs.

National agencies

The United States has many administrative agencies to which Congress has given ways and means of affecting the physical environment in Beaufort County:

i. Environmental Protection Agency, which administers grants for protecting and restoring wildlife, water quality, estuaries and other natural resources, aids municipal waste treatment, and takes the lead in coordinating national environmental policy;

ii. Department of Agriculture, which aids local soil and water conservation districts and Conservation and Resource Development projects, including drainage planning and tideland reclamation and has recently extended its soil survey to Beaufort and Jasper counties; also Farmers Home Administration which has made loans for low-cost homes (about 300; average 15 per month) and cooperatives (fishery 1, drainage 1), both grants and loans to two water corporations, and a grant for a county sewer and water plan;

iii. Department of Commerce, which operates Coast and Geodetic Survey and Meteorological Service; also Economic Development Administration which supports the tristate Coastal Plains Regional Commission through which project aid is granted;

iv. Department of Defense, of which the Corps of Engineers regulates and aids waterway improvement, dock building, tideland filling and shore protection (in consultation with State Budget and Control Board since 1967); also manages Marine Corps Depot, Marine Air Station, Laurel Bay housing and Naval Hospital;

v. Department of Health, Education and Welfare, which approves state air quality standards and protection of consumers against pollution of food in interstate commerce;

vi. Department of Housing and Urban Development, which aids local waste collection and treatment;

vii. Interstate Commerce Commission, which regulates freight charges on port railroads.

Official and non-official pressures

The question whether a proposed chemical industry would be compatible with such already-developing natural-resource-based industries as resorts and fishing led, in 1970, to a highly vocal polarization of attitudes and interests.

On the one side were all Beaufort's elected state and local officials, along with its news media and a late-organized pressure group (People's Association, chairman Henry Chambers, mayor of Beaufort).

On the other side the spokesmen consisted entirely of private lobbies, pressure groups, individuals and firms (Citizens' Association, president Rufus Taylor, U.S. admiral ret.)

Both sides agreed that future manufacturing industry and existing resort and fishing industries could flourish side by side if the manufacturing industry did not lower the quality of the natural resource environment. Where they differed was in their estimate of probabilities. One side believed that all necessary steps would be taken to keep environmental deterioration within the limits permitted by law, while the other feared that the very nature of chemical industry and petroleum product transportation made the degradation of the environment inevitable. One side believed that a capital-intensive chemical industry would attract complementary labor-intensive industry, while the other side feared there would be no substantial increase in industrial employment opportunities. The conflicting estimates of probabilities affected their calculation of the ratio of total costs to total benefits: The one assumed that the economic and social gains would greatly outweigh the natural resource losses, and the other that irremediable environmental and social losses would more than counterbalance any possible economic gains.

These two conflicting viewpoints reflected different levels of confidence and influence in political and governmental processes: The one identified with state and local decision-makers and with state industrialization policy, while the other put its trust in national concern for the environment and national control over free trade zones and petroleum product import quotas. They cut across color lines, with money-raisers for an all-white private academy making common cause with Penn Center and the NAACP in support of chemical industry, while the resort industry found an ally in black fishermen. They differed in the instruments of power at their disposal: The official side could harass opponents by cutting off or posing unacceptable conditions to the county appropriation to Hilton Head Chamber of Commerce, while retaining the subsidy of equally doubtful constitutionality to the Beaufort Chamber, giving high priority to tidal-land and sewage-disposal law-enforcement against opponents and giving low priority to allocation of scarce police resources to the protection of their persons and property; and the non-official could harass the official side by hiring a public relations firm, initiating court action and lobbying at the federal level. They differed in their conceptions of environmental management, with the elective officials preferring legislative and executive responsibility for public resources, while their private critics tended to have more confidence in quasi-judicial regulation and judicial safeguards. They differed in the aspects of democracy which they emphasized, with one side stressing the prerogatives of lawfully elected officials and the other looking for consultation and consensus among all interests concerned. Not least, they deepened the geographical partition of the county: The one side was centered in Beaufort city with its financial, insurance, legal and real estate by-products of the defense installations, while the other was centered on Hilton Head Island with its shrimping and resort enterprise—a cleavage which has to be taken into consideration when exploring possible lines of organizational development for the future management of the local environment.

Alongside these official and ad hoc non-official combat groups and some voluntary groups authorized to speak only for their own memberships, there has been a notable lack of continuing non-governmental general interest groups capable of uniting rather than dividing the population. Thus there seems to be no civic improvement association either for the county as a whole or for its major geographical subdivisions, except for a Historic Beaufort Foundation and a recently formed Hilton Head Island Community Council.

Summary of conclusions

Environmental management requires consideration of:

1. In Beaufort County:
   a) Municipal power for the county council:
   b) Organization of the county council for resource management:
   c) County-wide unification of provision of local public services and facilities:
   d) Organic relationship between specialized agencies (health, water, police, schools) and county council:
   e) Advance planning and programming of county public services and facilities:
   f) Regulation of real estate development by building code, safety zoning, use-planning, etc.; and,
   g) Increased taxation and appropriations for police, inspection and recreation.
2. In urbanized local neighborhoods:
   Organization of non-governmental community councils to operate neighborhood facilities (recreation, fire protection) with county aid.
3. Statewide:
   a) A substantively qualified agency to manage public property in natural resources;

b) A resource management fund, financed (e.g.) from a severance or depletion charge on heavy water-users; and,

c) Active technical-cooperation with counties in organizing for resource management.

4. In Planning District X:

a) Substitution of multipurpose town-and-country municipalities for limited-purpose counties;

b) Readjustment of present county boundaries when substituting municipalities;

c) Subdivision of present county areas to create workable municipalities;

d) Empowering the district planning body to review all public resource development plans affecting the district.

ENVIRONMENTAL FIELDS IN WHICH COMMUNITY ACTION IS LIKELY TO BE NEEDED AND MEANS BY WHICH IT MAY BE ACHIEVED

Active and foresighted management of the Beaufort Sound environment is required, regardless of the direction in which economic development occurs. If diversified economic development is encouraged, the active management of the way the environment is used becomes particularly urgent, in order that the various kinds of development may be mutually compatible.

Environmental management takes two principal forms: (a) *Specific* problems may be handled case by case as they arise, in accordance with the many federal, state and county laws and regulations now requiring permits and inspection under certain circumstances. The informed application of general rules to specific situations depends on the ready availability of relevant information, such as is only now being brought together in this study. (b) The *general* environmental development of Beaufort County or of the Lowcountry might be so planned in its various aspects as to maximize the social benefits and to minimize the social costs of economic development; but this has barely begun.

Water use

1. Ground water supply

The present situation is one of uncoordinated extraction of underground water by four public service districts on Fripp and Hilton Head islands, several private industrial concerns, an unknown number of private real estate subdividers, some public and private schools, and some home owners as individuals or as groups, besides about 20,000 population dependent on private shallow wells. A fifth public service district for water extraction was authorized in 1969 but has not been activated (Port Victoria).

Problems of quality have already led to a switch by Beaufort and Port Royal cities and U. S. Defense establishments from underground to surface water (see next paragraph).

Problems of quantity could be posed by industrial extraction by both manufacturing and resort enterprises.

Perhaps Beaufort county's potential groundwater problems should be considered in conjunction with those of Chatham county (Savannah), where heavy industrial use of groundwater is permitted by the public authorities.

Perhaps it would be to the advantage of all interests if consideration were given to declaring either Beaufort county or the Lowcountry development planning district a "capacity use area" in which extraction would be regulated by the competent state agency in consultation with actual and potential users. It might be advantageous to do this before the situation becomes critical. This would have the additional advantage of putting South Carolina in a better position for negotiation with Georgia and the U. S. government concerning interstate aspects of groundwater supply.

2. Surface water supply

The initial large-scale demand for a large-scale self-financing supply has come from the urbanized heart of the county: about 20,000 population now served by two municipal distributing systems both inside and outside municipal limits, about 10,000 served by four U. S. Department of Defense distributors, and a few thousand about to be served on Lady's and St. Helena's islands. Some of those thus served receive only a domestic and school supply, while others receive or will receive a supply adequate fir fire-fighting. An additional demand could come from future large industrial users and enlarged residential zones, including perhaps an area around Bluffton.

The principal present supply is by the Beaufort-Jasper Water Authority incorporated in 1964. The capital cost of its canal, water works, and wholesale distribution system was met by long-term revenue bonds at 3.5 percent and a U. S. Defense Department interest-free advance. The present capacity of the waterworks is 8.8 and its peakload 6.2 million gallons a day. Expansion of this Authority's facilities would have to be considered in the event of heavy industrial demand, and would presumably be negotiated on the basis of maintaining the self-financing non-tax-supported character of this undertaking.

Of the 20,000 population dependent on shallow wells, it is not known what proportion is adequately supplied; but it is estimated that up to 1000 households (5000 population) may lack a safe, adequate or convenient supply of water. Nor is it known to what extent it would be economically possible to distribute Authority water into areas not yet served. It is possible that the social need may exceed the economic demand. The substitution of a public surface water supply in the place of private shallow wells in the less urbanized areas might not pay for itself at the same low schedule of charges as suffices for the high-demand urbanized and industrial areas. In some areas, low-use lines might have to be made a charge on the system as a whole. In others, the distribution system might have to be subsidized by grant or low-interest loan from outside the water system, as envisaged in a plan financed by U. S. Farmers Home Administration (Jones and Fellers, 1969). Yet other areas might have to be classified as economically unserviceable even with such modest subsidy as might be available.

3. Water costs

Water costs have to be considered in relation to the dimensions of prevailing monetary incomes. They are in any case unlikely to be less than $50 per family per year and may be much more. Perhaps, in the case of low-income families, the question may have to be faced of whether a public agency should pay the family water bill or provide a free neighborhood pump.

Small water systems can be costly to domestic consumers. The Chechessee Water Corporation serving 48 taps, with a USDA/FHA grant ($22,000) and loan ($24,000), charges a minimum of $4 a month for Authority water; this has apparently deterred its poorer members from filing for FHA housing loans for the bathrooms and flush toilets that have now become possible; some have defaulted on the monthly bills collectible by the Authority; and the Corporation is delinquent on its debt to FHA. Port Royal municipality buys and distributes Authority water for an average of about $100 per household per year.

Extraction and distribution of groundwater may prove still more expensive. Thus, the Eustis-Warsaw Water Corporation is receiving USDA/FHA grant of $72,000 and loan of $75,000 for 90 taps, and the US/OEO-financed comprehensive health service for the poor is paying for about one-third of the connections. The Fripp Island Public Service District requires a tax levy averaging about $200 per household per year to pay for its revenue bonds, as well as a charge averaging about $100 for consumption (33 mills; assumed average market value of properties $75,000, equal to assessed value of $6000).

Water-borne sewage collection and treatment would also be unlikely to cost a family less than $100 a year.

4. Comprehensive water-use planning

The Lowcountry needs a checkpoint where alternative approaches to water-use programming, especially by public agencies, can be considered with full attention to relative cost/benefit ratios.

For example, a state agency operating directly in this county (Parks, Recreation & Tourism) could choose between additional groundwater extraction through a water district supplying a resort area (Fripp Island) or participation in an imminent surface-water extension which would pass through and serve a poor but populous area. For equal cost, the social benefit could be greater in the one case than in the other.

For another example, a federal agency making loans to poor rural communities (USDA/FHA) might choose between high-cost groundwater extraction in a submarginal farming area (Eustis Warsaw) and medium-cost surface-water extension in a less marginal area.

Even the semi-private public service districts might find it convenient to weigh the advantages of extracting groundwater as at present against those of extending the Authority's surface-water supply.

Consideration might also be given to ways of economizing water use, e.g., by using treated sewage water for golf course irrigation, thus also lessening the number of sewage discharge points into tidal water.

Perhaps the Lowcountry Planning Commission could be used by state and federal agencies and public service districts as a forum for consideration of alternatives.

5. Comprehensive water-management

Another possibility might be to make the Beaufort-Jasper Water Authority responsible for all public water supplies and distribution. This could at least make unnecessary the distribution of its water by the cities of Beaufort and Port Royal, or the entry into water-distribution of other localities. It might also conceivably make unnecessary the existence of semi-private public works districts.

Perhaps this substitution of direct for indirect distribution might at least be offered as an opportunity, which some surface-water-using localities might find helpful to accept, either by transferring their distribution systems to Authority ownership, or by remaining owners but contracting with the Authority for management. It is not inconceivable that even some of the ground-water-pumping public works districts might wish to contract for the technical management skills of the Authority.

Coastland use

South Carolina follows the principle common to both English and Roman law under which all land between high and low water and all water between high tide and the territorial limit are presumed to be held in trust by the State as commons on which its people have rights of navigation and fishery.

1. Estuarine land and water

The tidelands of Beaufort county account for about 100 of its approximately 575 square miles: Without them the present county boundaries could not have been so demarcated in 1912 as to reach the constitutional minimum of 500 square miles after cessions to Hampton (1878) and Jasper (1912 and 1952).

Grants of public tidelands to private owners are the exception rather than the rule. Land grants stop at mean high water unless they specifically state otherwise. There has never been a general law for sale of tidelands and no administrative agency has been authorized to sell them. Grants of land below high water have been made only rarely and by the highest authority—the Crown-in-Council or the General Assembly—and their validity has not been determined. To the limited extent to which tidal lands might be equated with other public lands, they would also come under the 1895 constitutional prescription that they must not be donated and may be sold to corporations at only the same price as to individuals—which would be hard to calculate if no market exists and no auction is held. The surveying of granted land is at the expense of the grantee; and the definition of medium high water mark is by his surveyor, subject to final determination by a jury in case of doubt. The state has not mapped and inventoried its grants of tidelands.

It is believed that some tidelands are in adverse possession of private parties. Tacit or explicit acquiescence of state authorities is presumed to have occurred in the past; some unauthorized and invalid grants may have been made by administrative agencies; the U. S. Corps of Engineers has granted permits for private causeways leading to docks and piers; and the state Attorney General's office has sometimes agreed to what it has considered a legally fair exchange or compensatory arrangement. Inscription on the property tax rolls by local assessors was not uncommon when the value of such land was low. Encroachment is presumed to be widespread, as when houses abut on a cove, or refuse is deposited continually by a neighboring business or home, or marsh is cut off from the tide by highway construction. It is only of recent years, since the value of such land has risen, that the State Budget and Control Board has arranged for tidelands to be policed by the air patrol of the Wildlife Resources Commission and for an assistant attorney general to work with that body and take legal action to check encroachment.

Different uses of public tidelands come under different public agencies:

a) Piers and docks do not in themselves interfere with the natural function of tidelands and are ways of implementing the people's right to use them for navigation and fishing. Permits are granted by the State Budget and Control Board Division of General Services.

b) Planting of oyster beds by farmers also does not interfere with natural functions or common-law rights. Leases are granted by the state Wildlife Resources Commission (Division of Marine Resources at Charleston) on a first-come-first-served basis at a fixed rent of $1.50 per acre, instead of the oyster bottoms being marked out into geographical areas appropriate to good management and leased by auction (43 leases for 3147 acres in Beaufort estuaries, out of about 7000 acres for the whole State). Unexpired leases and the hope of automatic renewal may be bought and sold. The Division of Marine Resources also marks out public gathering grounds, but does not manage them in any positive manner (six in Beaufort county). A study of oyster-bottom management is being made with grant aid from the US Bureau of Commercial Fisheries. A revision of USDA/Farmers Home Administration regulations would be needed to permit cooperatives to receive Economic Opportunity loans for oyster-farming. Oyster farming is limited to acres where the State Board of Health Bureau of Sanitary Engineering shellfish patrol has not classified the oyster bottoms as polluted (as it has done with 130 miles of estuarine coast in Beaufort county).

c) Another use which could in a sense intensify rather than altogether destroy the natural function of tidelands could be aquaculture. This may become attractive as a way of rationalizing the production of shellfish and reducing labor costs by increasing productivity. Before experiments already made in South Carolina can be translated into economic enterprises, legislation may be needed to authorize a competent state administrative agency to grant leases of limited areas of public tidelands for the purpose of aquaculture.

d) Filling of saltmarsh fundamentally changes the ecosystem. It is practiced by public agencies in which the General Assembly has vested some of the tidelands. Limited jurisdiction over some tidelands has been vested in municipalities under various acts since 1798, and some in the Beaufort county school board. Some tideland, in which the US Corps of Engineers had formerly dumped hurricane debris, has recently been covered with earth and is being developed into a school playground with federal aid given through the Lowcountry Resource Conservation and Development Authority. Spoil from "dredge and fill" operations has been dumped on marshland by the US Corps of Engineers, regardless of its constituting breeding grounds for mosquitoes, as an alternative to dumping in the ocean. Some tideland was filled for an airfield extension, although in the process it became a flight hazard by reason of birds and smoke, until the process was recently forbidden by the US Corps of Engineers. Some has been used as refuse dumps (solid waste landfill). The state Ports Authority has been empowered to occupy and use any tidelands it needs for port purposes; it has proposed to dredge Colleton river and fill a river-side marsh to make Port Victoria. In one respect these agencies and subdivisions of the State are limited in what they can lawfully do with the tidelands entrusted to them: They cannot sell them to a private party without confirmation by court or legislature. In other respects they seem to have been allowed to do what they like with them, including "reclaiming" them—which raises the question whether the General Assembly ought not provide for continuing state regulation of such tideland administration as it has vested in local bodies and other public agencies. Perhaps such regulation would take account of ecological as well as legal considerations.

Some tideland that has passed quasi-legally or extralegally into private possession is also being "reclaimed," "improved," and "developed" without any limitation. There would seem, however, to be no reason why federal, state and local agencies should not use their "police power" for public regulation of the use of privately held tidelands. This could be done by zoning, to protect fastland property values, wildlife breeding grounds, the carrying out to sea of saltmarsh detritus as fish feed, the purification of the air by marsh life, and the common-law right of navigation and fishing which presumably exists as an easement even if title to the land itself has been impropriated—much as inland waterways remain navigable despite private property in their beds.

If public control of tidelands is needed, it should obviously be applied to all tidelands, whether by way of state ownership, or by way of state regulation of what is allowed to become privately or municipally owned.

2. Littoral land and water

The ocean beaches of Beaufort county may be less important than the estuarine tidelands as wildlife breeding grounds and food sources, but are at least as important for public enjoyment.

Between mean high and low water levels, they are presumed to belong to the people. For their development or improvement a permit has to be sought from the State Budget and Control Board, as for example for the building of a pier, a groin or a seawall.

It seems to be exceptional for beach rights to have been granted to private owners; but grantors purporting to dispose of public beach rights have included not only the colonial Governor-in-Council and the state General Assembly but also the United States in respect of island plantations which passed into its possession in 1861/65 under the federal direct taxation law which was later held unconstitutional.

The ocean beaches vary in accessibility. In some places public access to public beaches is assured, either through a state park (Hunting Island) or through local custom. One of the duties of a county or municipal recreation agency could be to keep these approaches sightly, so that they may be a scenic asset rather than nobody's responsibility.

In many places, on the other hand, the beachfront property is privately owned, so that actual access to the public beach depends in detail on customary easements or on the way in which roads and buildings have been developed. An unknown length of beachfront would seem to have come into the hands of real estate speculators and developers; and, while some of it has been obtained by purchase of large plantations, some has been acquired from smallholders. If public beaches are to be an asset for the enjoyment of the public as well as for the profit of real estate developers, a balance may have to be struck between public and private rights. Perhaps public policy could so regulate private development as to ensure public access to public beaches, as by zoning or subdivision control. Perhaps a competent state agency could help county or municipal authorities plan and implement such regulation, or else assume direct responsibility in consultation with them in places where they choose not to take responsibility.

3. Commercial fishing and fish processing

This is one of the most important fishing counties in the tri-state Coastal Plains region. It produces more crabs and oysters than any other county in South Carolina, and is the only county in the State where 10 percent or more of the civilian work force is in fishing.

Landings of white and brown shrimp are increasing in quantity and value in spite of competition from the shrimp trawlers of Pacific and Indian warm waters, and are believed by the authorities to be reaching their maximum, except for deep-water king-size shrimping or aquaculture. State statute prohibits shrimping in breeding-ground inlets such as Colleton river; and the Wildlife Resources Commission regulates it in Beaufort Sound. Trawlers' licenses are purchased by nearly 100 state residents and about 70 from out-of-state. White shrimpers belong to a state association which is reported to have favored a recent increase in license fees.

Landings of blue crab have shown little change during the 1960s: they remain high in quantity and low in value. Nearly 100 "pot" licenses are sold, each for up to 100 basket-traps. Part-time crabbers are believed numerous. The yield is believed by the authorities to be near its maximum, except for possible aquaculture with a view to year-round soft-shell crab production.

Oyster landings seem to be declining slightly in quantity and value, owing presumably to unsolved problems of labor productivity, although oyster farming is considered to be a field in which the limits to expansion are human (technical and economic) rather than natural.

Average annual shellfish production in Beaufort county 1960-69

(data supplied by Marine Resources Division derived from U.S. Department of Interior. *South Carolina Landings: annual summary;* rounded figures; official values)

Years	*Crab*		*Oyster*		*Shrimp*	
	Tons	*Value($)*	*Tons*	*Value($)*	*Tons*	*Value($)*
1960-4	2,500	250,000	650	600,000	700	500,000
1965-9	2,250	300,000	550	500,000	900	1,000,000

Beaufort is the only county in the State with 5 percent of its "covered" employment in fish processing. In number of persons engaged in fish processing, it is surpassed in the three Coastal Plains states only by neighboring Chatham county, Georgia (Hite and Stepp 1969). Its expanding shrimp fishing depends on out-of-state processing. For crabs a market is provided by a large cannery. For oysters, production and processing have been combined insofar as about two-thirds of the acreage in Beaufort county is under a series of leases held by one mechanized shucking and canning firm and persons connected with it.

Thanks perhaps to the seagoing traditions of Afroamerican Sea Islanders from the Gambia river, the Guinea coast, and Barbados Island, black entrepreneurs have emerged in the shellfish industry, particularly south of the Broad River. Two small beginnings of rational self-organization have recently appeared among them, aided by new possibilities of external financing. The one is a joint subsidiary through which some 25 shrimp-boat owners, half of whom are stockholders, have improved their supporting services and their bargaining position in relation to Florida shrimp processors, with the help of a U. S. Farmers Home Administration loan for $66,000 which they are paying off regularly and on time (Hilton Head Fishing Cooperative). The other is the attempted acquisition by a group of Colleton River oyster gatherers of a shucking "factory" at Bluffton with the help of a U. S. OEO grant for $25,000, loans from customers and neighbors, and an eventual FHA loan, provided it can overcome legal obstacles to FHA aid to cooperative oyster farming.

Fishing and fish-processing have two important implications for social policy. The one is that seasonality and low productivity in crabbing and oyster gathering may be mitigated by such measures as food stamps or President Nixon's proposal of family allowances for low paid workers, but can be cured only by profound changes in productive methods including year-round aquaculture. The other is that the destruction of the fishing industry by chemical pollution from any source would require relief action on behalf of more than 1000 disaster stricken families, including compensation for loss of capital equipment and retraining for loss of skills.

Perhaps the State's policy in relation to fisheries is moving towards a change. Hitherto its action regarding our common property in fisheries has had two sides: It has regulated the take by statute, particularly with regard to closed and open seasons, and it has financed this policing by levying fees which are somewhat of a cross between a severance tax and a service charge. It has not known enough to do more. It may not in fact know to what extent its legal definitions of closed and open seasons are biologically valid, or how far its licenses and taxes help or hinder the industry. Owing to the long neglect of coastal fisheries by the State's universities, there seems to be a lack of firm data concerning the natural resource base of the fisheries, although this is indispensable for policy planning: Until we know what size yield is sustainable, we cannot tell what governmental measures are needed to sustain it. The possibility of federal aid is one of the forces pushing towards a more positive conception of the State's management of its resources: This has shown itself both through the tri-state Coastal Plains Commission (Hite and Stepp 1969) and through the current study of the management of the State's oyster beds. Research in marine biology and an administrative testing laboratory may need to be supplemented by study aimed at enhancing the State's managerial capability. This would be helped, however, by a rise in state and local pride in the achievements and products of what is not only a Beaufort industry but is also an essential part of a long-established Beaufort way of life.

4. The port

Nature made Port Royal Sound an excellent harbor, at least for the less deep draft vessels of earlier days. On the other hand it is not a natural port in the sense of a gateway leading into a river basin such as that of the Savannah, the Santee and the Waccamaw, or terminating a natural highway such as Charleston's Cherokee ridgepath.

Its natural location condemned it to being essentially a local port, trading in the rice, the long-staple cotton or the phosphates of the past, and potentially the industrial raw materials of the future; and even in this respect it is almost bound to be outcompeted by its Savannah and Charleston neighbors with their greater population and more developed industry.

The construction of the Port Royal terminal for some $1,500,000 and the purchase of Victoria Bluff industrial sites by the Ports Authority for some $150,000 in 1960 were therefore acts of faith rather than of economic or geographical necessity. They appear also to have been less than logical, in that it might have been more economical if both investments had been made on the same side of Broad River. Outlays of this kind have helped make it difficult for the State Ports Authority to be self-financing.

This capital investment has sufficed to equip the port since the 1950s with only a single berth served by a channel that can be navigated only by day. It is served by one licensed pilot; but it depends on Charleston for customs and immigration inspectors as needed.

Any development given to this port will have to be completely manmade. One such possibility is military use. The US Defense Department could have chosen to use this port for supplies for the Marine installations, much as it has provided trade for Charleston and Georgetown.

Another possibility is the development of water-using heavy industry. The General Assembly has indicated its willingness to finance a Seaboard Railway spur (13 miles, $2.2 million) and necessary terminal facilities for this purpose.

A third possibility is to tap the Savannah basin by rail or road. This has begun with recent leasing of the Port Royal pier to a stevedoring contractor (100,000 tons of Georgia clay exports for an annual rent of $60,000). If a long lease could be obtained for 500,000 tons at $300,000 this would at least make the investment worthwhile. A longer lease for 1 million tons would permit the building of a berth and rail spur at Port Victoria; since this would not be a priority use of the State's credit, perhaps it could be financed through revenue bonds issued by either a local authority or the Ports Authority.

Related land-use planning

1. Environmental sanitation

Human waste disposal is a serious problem in Beaufort County. It has been estimated that 1000 households are linked to a 60-year-old municipal collection system which discharges raw sewerage into a public watercourse; that 2000 may have reliable septic tanks; that 8000 may have unreliable septic tanks, or else some kind of privy; and that between 600 and 900 may have no sanitary facilities. (The last figure—5 percent of households—was cited by State Senator Waddell at U.S. Congress Select Committee on Nutrition and Human Needs, chairman George McGovern, 18 February 1969. All other figures are from Jones & Fellers, 1969).

Nor is this situation easily remediable. In the absence of a county-wide sanitary survey, it is impossible to say exactly how many homes are poor in basic environmental sanitation. In the judgement of informed residents, however, there may be perhaps 10,000 persons or one fifth of the households who have no present physical possibility of indoor sanitation, either because the water table is too high or because they cannot or do not have enough water. (Where public health surveys have been made, the proportion poor in environmental sanitation is higher and reaches more than half in and around Bluffton. The Hilton Head Island findings are in process of compilation). It is to be hoped that the recent grant from the U.S. Office of Economic Opportunity for a comprehensive health service to poor families will make it possible, among other things, to supplement piecemeal local surveys, by sanitarians obtaining basic data concerning the sanitary situation throughout the county. If they do find any situations that seem remediable, they might perhaps also prepare applications to U. S. Farmers Home Administration for small loans for removal of health hazards—a possibility not yet used in Beaufort County.

Census returns will be of limited value because they will indicate only the presence of sanitary facilities and not their effectiveness.

Major reasons for this situation are to be found in the physical environment. In the urbanized area, the uneven terrain is said to make a sewage collection system expensive. Over much of Beaufort county—as also throughout the Lowcountry—a high water table or an impermeable soil limits percolation; and this can happen in expensive subdivisions as well as among poor smallholders. In some areas the domestic water supply is insufficient to flush a toilet, and in a few areas it cannot be made adequate. Urban roads and rural highways are often so constructed as to interfere with natural drainage patterns. Lack of sanitary habits may be due as much to physical constraints as to defective health education.

These environmental constraints, however, may be more limiting than they need be because of man's selective use of his environment. It seems probable that some of the better-drained land was formerly reserved for plantation agriculture and is now ripe for high-class development, while some of the worse-drained has been sold off to numerous small purchasers, so that a disproportionate part of the population has come to be located on wet land. State legislation authorizes municipalities to make a profit by extending water-lines outside city limits, regardless of the suitability of a development for septic tanks; and the county health department does not seem to have opposed this proceeding by expression of professional doubt as has happened in some other counties. And cost of municipal water distribution and sewage treatment may encourage families with marginal incomes to choose homesites with less adequate sewage treatment possibilities. A county ordinance had recently to be passed requiring dealers in mobile homes to inform each customer that he will have to get a Health Department permit for a septic tank; but no similar obligation has yet been imposed on persons who sell or rent sites for fixed homes, or on municipalities which sell water outside their limits. Land drainage is also but little promoted as a way of facilitating household sewage disposal.

Because of its peculiar sanitary ecology, Beaufort county could perhaps pioneer in what might be called sanitary zoning:

a) Rural residential development zone: To be composed of areas with adequate percolability for septic tanks and with an adequate water supply; to be sub-classified according to the minimum lot size required for a septic tank distribution field, minimum permissible lot size being smaller where piped water is used, and larger where dependence is on a domestic pump; adequacy of percolability and therefore lot-size to be judged by site and soil inspection (not by arbitrary state-wide rule).

b) Rural limited habitation zone: To be composed of areas where a sanitary privy is required and where potable well water is available;

c) Rural non-habitable zone: To be composed of areas where a sanitary privy would be needed but where potable water is not available, and in which building permits should be refused until piped water and sewerage systems become feasible;

d) Urbanized areas where the population is—or is planned to become—sufficiently dense to make it technically and economically feasible to organize public collection, treatment and disposal of waterborne sewage.

The recent completion of a county soil survey by the U. S. Soil Conservation Service has made information readily available for the first time concerning water level and soil percolability, and could provide the occasion for introducing sanitary zoning. If necessary, the U. S. Geological Survey could be requested to supplement the soil survey as a matter of some urgency.

Enforcement of sanitary zoning would be by:

a) prohibiting real estate agents from arranging property transactions without informing the purchaser of the sanitary zone in which the property is located;

b) prohibiting municipalities from selling Authority water to homes that do not meet Health Department standards for waste water and waterborne sewage disposal; and

c) making building permits valid only for the kind of sanitary facilities appropriate to the zone.

If there is delay in general land-use zoning (3 below), sanitary zoning could be undertaken immediately.

2. Beachfront

Not all beachfront is equally habitable. Most is menaced by the steady rising of the sea level and the erosion of the land by the sea. Much is menaced by the severe storms that recur along this coast. If it were all subdivided and built up, much of it could become a disaster-stricken area.

In the presence of these probabilities, there are two possible policies.

The more expensive is for government to be asked to bail out the real-estate developer and his victim by an outlay of tax money on breakwaters, groins, seawalls and other protective devices. Neither the State nor the county shows any sign of giving a high priority to this kind of public outlay for private benefit. There may, however, be some situations in which joint planning in advance of development might justify the State in undertaking protective works at the charge of the developer, perhaps by some variant of the "special assessment" or as a "betterment" charge. Or an experiment might be made in disposal of otherwise indestructible solid waste by means of overground landfill diking.

A less costly policy would be to zone the beachfront according to degrees of habitability. The most exposed and unsafe areas would be declared unfit for human habitation, but could be used as public approaches to the public beach, either by way of easement on private land, or by way of public acquisition. Residential or habitable beachfront, on the other hand, would be zoned according to depths of "safety setback" not from medium but from highest tidemark (which in some places reached 8 feet 7 inches at the 1970 eclipse). This is needed to protect ignorant purchasers against ignorant developers, and to prevent both alike from making a ruinous waste of the seafront.

3. Use planning

As we have seen, not all the land in this county is equally fit for human habitation unless it is urbanized. On the other hand some land can contribute more to development if it is itself left undeveloped.

Land-use has hitherto depended almost entirely on private or public land-ownership. An element of planning has been introduced only by an industrial park and a half-dozen resort developers; and none of this has been on a large enough scale to relate residential to other development in planning a balanced neighborhood or community. Nor is there an effective interest in supplementing private with public resource-use planning, at least outside Beaufort city. The need for public land-use planning might nevertheless become particularly urgent if an influx of construction or industrial workers were to be expected.

The land-use planning that could be envisaged would be not only for the separation of residential from industrial zones, and the reservation of land for both these kinds of development, but above all for the adaptation of human settlement patterns to natural constraints. It could therefore grow out of and be coordinated with the ground water, sanitary and beachfront zoning proposed earlier.

This would imply preparation and adoption of a master plan, zoning ordinance, and subdivision ordinance, for land-use in all parts of the county, based on prior soil, water and coastal study, and perhaps beginning with the area likely to be most affected.

If at a later date the question were to arise of planning the residential or industrial development of an area that is not naturally fit for this kind of use-change without considerable capital investment, the original land-use plan could always be modified in conjunction with the extension of municipal organization and the planning of the water-distribution, sewage collection and other facilities needed to effectuate the change from a natural or rural to an artificial or urban environment.

4. Facilities planning

A very important part of civilized man's environment consists of the improvements he himself constructs. We have inherited, however, an out-of-date distinction between a municipality, which is given wide powers to construct amenities, and a county which has until now been limited to such necessities as roads and bridges.

Beaufort county, like most others, stretches these limited powers so as to provide roadside parks, boat landings, fishing piers and refuse dumps. It may nevertheless need additional powers and funds in order that it may be enabled to acquire, develop and manage property for a wider range of purposes in the interest of its inhabitants.

One direction in which this is needed is the provision of facilities for outdoor recreation. There are no county parks with a wide range of facilities; no public swimming pools; no scenic or historic parks; no real waterfront parks with boat docks and landing ramps; no properly equipped public swimming beaches; too few marinas; and no waterbuses or hydrofoils between the islands. If industry is to come to Beaufort, the county can help it hold its personnel by providing them with facilities for enjoying the natural opportunities it offers. (Jones and Fellers, *Comprehensive Outdoor Recreation Plan,* submitted by County Board, chairman, Charles E. Fraser, to cost $2,645,000 over first decade; but no present plan by state Department of Parks, Recreation and Tourism).

Another direction in which this may be needed is the provision of well planned trailer parks, that attract the traveller and the vacationer, but give them an alternative to filling the roadside rest areas or sleeping on the boat ramps.

When a public agency invests in some kinds of amenities, it does not necessarily have to manage them itself. A county should be able to contract with private enterprises to manage them on its behalf. But in order to do this it should be empowered to use all the advantages that a public agency has in borrowing money.

The supply of schools is crucial, not only in itself, but also for its relationship to several aspects of the pattern of development. The building of well-planned new neighborhoods could be fostered if the principle of the neighborhood school was accepted for the elementary grades. The consolation and integration of high schools requires heavy capital outlay by borrowing, which can be met only by either broadening the tax base or raising the property tax rate.

The supply of health facilities needs to be comprehensively planned on an area-wide basis, in order to meet increasing demand and utilize the special capacities of the various hospitals and clinics. The district ranks second in the state in the degree of need of modernized general hospital beds, in spite of the isolated modernization of the Beaufort hospital. Beaufort County is lacking in long-term care facilities.

Some elaborate facilities planning is subsidized by federal agencies and is aimed at the possibility of attracting federal planning grants. Such are the outdoor recreation, sewage and water, and main drainage plans, prepared by outside contractors. None of these is being implemented. It is not clear how far such planning really represents the intentions of state and local leaders, or how far they are prepared to budget for its execution.

There is much more consideration between facilities programming and resource-use planning possible than is now in existence. The school board plans a new high school, the state Ports Authority projects a new railway, and the state Parks, Recreation and Tourism Department develops a state park and its water supply, all without coordination with the county-city Joint Planning Commission. The state Highway Commission reconstructs Ribaut road (contract cost, over $1.25 million), a regulated public utility corporation reconstructs its power lines overground, (perhaps $150,000 compared with $450,000 underground) and plans are foreshadowed for laying a sewerline and connecting sewers, all without coordination by either Planning Commission or County Council and without any agency being responsible for multipurpose utility tunnels. Facilities planning is still "sectoral" and is unlikely to become "comprehensive" until the County Council charges one of its committees with coordinating responsibility for all resources or facilities, perhaps as a step towards an inclusive capital budget.

5. Urbanization

a. The first stage of urbanization poses serious environmental problems and is a significant factor in biological pollution. Small sewage disposal systems are laid down, usually by real estate developers; and state law now requires a sewage collection and disposal system for every "subdivision" of 25 houses on lots of less than two acres. This has several inconveniences. One is that the developer may disappear, leaving no adequate arrangements for maintenance. Another is that small private systems involve a number of discharge points; but state regulations require that these be into running water; and federal regulations require that oyster-beds within a buffer zone of about one mile radius of the discharge point be closed by 1971 if there is any probability of tertiary treatment being unavailable. Another again is the difficulty in the way of private developers obtaining easements over others' property or over public tidelands or beaches for sewage-disposal. Perhaps the discharge of this publicly required function should therefore be assured by a public body.

b. The normal way of handling problems of urbanization is municipalization: A local public body is empowered to handle these problems in a specifically urban manner.

The first step in the municipalization process in Beaufort county is for the larger and more responsible corporate developer of what is in reality a small garden city not to operate a private or even a private-profit sewer system, but to set up a non-profit "public service district" for waste-disposal as well as for pumping and distributing groundwater. This kind of entity has the advantage of being able to sell tax-free bonds, to pay them off from additional property-tax millage if proceeds from water sales are not adequate, and to qualify for federal aid. The board may be officially nominated by the legislative delegation; but its members may be selected in consultation with the developer. And the bookkeeping, maintenance and management may be contracted back to the development corporation or to some specialized company. The public service board may also discharge other functions, such as material aid to a volunteer fire company or provision of a medical center, so that this semi-private special-purpose public body may be on its way to becoming a multipurpose quasi-municipality. Moreover, collaborative arrangements can be made between such districts, so as to lessen the number of sewage discharge points (Forest Beach and Sea Pines).

One advantage of these public service districts is that they may be sufficiently small and different to make experiments. Thus one is considering the possibility of lessening water consumption by using waterborne waste for spraying golf courses as well as of composting destructible waste for mulch or fertilizer—steps towards economical resource management, as well as towards avoiding wasteful discharge into seawater.

Beyond the public service district there are several possible next steps in the municipalization process. One might be for one or more of them with sufficient population to get chartered as a municipality with elective mayor and council and even broader powers, and to extend water and other services to families outside developments. Another might be for the already incorporated bi-county Water Authority to become able to relieve them of waste collection, treatment and disposal functions. A third possibility would combine these and enable a new municipality to contract with the Authority in those instances in which it might appear better qualified technically.

A disadvantage is the fragmentation of a natural geographic unit, as with the partitioning of Hilton Head Island among four public service districts which fail to serve the area outside the developments.

c. The situation is different in the unorganized "townships" in which population may be becoming dense enough to justify urban-style water supply and water-carriage sewerage but in which there is no development corporation and no independent groundwater supply system. It has been suggested, for example, that priority in installing sewerage systems outside Beaufort city be given to areas with a density of two per acre, beginning with Bluffton and proceeding to Sheldon-and-Dale and Lady's Island.

This would raise in an acute form the question of the relationship between the bi-county Water Authority and the area consumers. In accordance with current water precedent, the wholesale and retail sides of the operation could be distinguished, with the Authority confining itself to the wholesale end of the process (water supply, waste treatment and disposal), while new public service districts or municipalities, or an enlarged existing municipality, or a municipalized county, would take responsibility for the retail end (water distribution, waste collection).

An alternative would be for the Authority to be empowered or required to take over the retail as well as the wholesale end of the water-supply and sewage-disposal operations.

There seems to be very little current interest in having the Water Authority get into any aspect of waste disposal. This could change, however, if the area were faced with the problem of ultimate disposal of treated industrial wastes, or if sewage treatment were required outside Beaufort city.

d. Problems of an already municipalized area are illustrated by Beaufort city where the municipal collecting system of about 1930 has discharged untreated sewage into the watercourses, necessitating their classification by the State Board of Health as polluted. In the subsequently urbanized heart of Port Royal Island, another 3000 households have come to depend on septic tanks, the functioning of many of which has been affected by land level, high water table, and interference by city streets. Beaufort city has considered two approaches. The broader, and one for which extensive federal aid was sought, would have provided for a new municipal collection system extended to reach all the inhabitants and for a treatment contract with the bi-county Water Authority whose powers would be extended to cover also waste treatment. The other, mainly within the city's own means, thanks to a new sewer-user charge and profit from water sales, would restore the quality of the watercourses by municipal collection and treatment in the half of the city that has non-conforming sewers or is unfit for septic tanks.

In either case, Beaufort's capital investment would average about $1000 a connection, while debt service and operating cost would amount to an average of about $100 per household per year. Borrowing would be by revenue bonds secured on user charges, thus avoiding the possibility of rejection by referendum.

Eligibility for all available federal aid for both collection and treatment would more than halve the annual cost per household; but this can be obtained only if there is agreement between the state and the municipalities to set up a state fund earmarked for environmental quality-restoration, enabling localities to be grant-aided up to 20 percent by State and 50 percent (instead of 30) by the United States.

6. Rural neighborhood development

One cannot foresee to what extent low-income rural neighborhoods are doomed to disappear, with the out-migration of their younger members and the buying-up of heirs' rights by developers. Nor do we know to what extent better land would be available to members of low-income rural neighborhoods if they could afford to move there. (The non-existence of branches of statewide banks would suggest the possibility of local credit controls over the land market.) Nor do we have any exact knowledge of the extent to which environmental improvements are possible on present sites. For the present, therefore, we have to deal with the people where they are, knowing that they are attached to their small properties; and, even if possibilities were to arise in the future for helping them move to better sites, it would be helpful to be able to deal with them as groups rather than as individuals.

There is at present no governmental program for helping residents of low-income rural neighborhoods to work together for the improvement of their environment and the raising of their standards and levels of living. The Agricultural Extension service has not regarded this as economic. The bicounty Economic Opportunity Commission has financed the running of a few centers rather than the organization of many neighborhoods—the reverse of standard community action strategy—and only one or two of these centers have become launching pads for dynamic action by their boards of directors. The bicounty Comprehensive Health Service which US-OEO has financed may fill some gaps within its sector, but has not begun with a well-structured user organization. The Farmers Home Administration makes loans available but does not promote the community organization that is basic to many types of loans (drainage, sewerage, watershed and group housing) as well as to the payment of debts to FHA or the non-profit corporations it has financed. More community effort has gone into satisfying paper requirements for US aid to specific projects than into what ought to be its corollary—the counterpart grouping of local people to take responsibility for as many facets as possible of their betterment through on-going organizations.

There is, however, one significant private experiment. The Hilton Head Health Center, aimed at eradicating worm infestations, is directed by a board representing all the "communities" served; it has a women's auxiliary committee in each such rural neighborhood; and it holds most of its educational sessions in these neighborhoods. It has thus taken advantage of the relationships of descent and marriage, as well as geographical propinquity, that separate off each island "community" (probably based on pre-Civil War plantations) and make it less pervious to direct action from outside than to action through its own members. It has also reinforced mutual aid within and between the communities, with exchange of used clothes and joint use of wells, among other forms of collective self-help. It has received services from the county health office and financial support from its neighbors. Having proved its usefulness, it might perhaps be permanently aided from public service district millage or by an eventual muncipality. This may point the way towards at least one approach to helping self-supporting low-income people transform their habitats into as civilized neighborhoods as their resources and those of the environment permit.

7. Urban neighborhood development

There does not seem to have been any public program for helping low-income urban home-owners improve their neighborhood in Beaufort city. It is not even clear to what extent if any improvement may on the contrary have been retarded by removable inhibitions and impediments. An unknown but sizeable proportion of houses in the low-income quarter of the historic area seems to have absentee low-income owners who have neglected maintenance to the point where they risk the destruction of this vacant or rental property by the city as being dangerous or unfit for human habitation (about 100 recently cleared away) and who tend also to become tax-delinquent to the point where they risk losing the site as well as the building. The public housing authority plans to build low-rent housing on these lots. The process is one of piecemeal change, without an overall redevelopment plan.

8. Farmland

Some 450 farmers harvest only 30 out of 150 square miles, which is approximately the same as the 30 square miles of urbanized land. About 150 graze cattle and about 50 raise tomatoes, cucumbers and other crops on a commercial scale. The labor force fluctuates between 1150 in winter and some 4000 at the summer peak. Beaufort is said to be the only county north of Florida in which all-year production is economically possible; if this could be expanded it might provide greater all-year employment for local people, thus lessening the social burdens attendant on seasonal hiring of non-local labor. An increase in contract farming linked with local or other processing plants might also augment agricultural income and employment, and lessen dependence on high prices prevailing during the first or last week of a season. The county agricultural extension agent's office as developed more than 50 years ago for family farm demonstration has not adapted to the current need for rationalizing the structure of the food-production industry. There seems also to be a lack of organizations representing food production interests in Beaufort and the Lowcountry and there is consequently no organized collective reaction of the farming community to heavy industry, although individual farmers may have suffered from pollution from an existing chemical plant. Perhaps consideration should therefore be given to some means of promoting better organization for year-round food production.

9. Property rights

Title to real estate is often very unclear in Beaufort county. Many transactions are entered into without clear title. Payment of property taxes may provide evidence of occupancy but not of ownership. The security of heirs who are occupants may be disturbed by conveyance of rights to some other person without consulting them.

On the part of poor property owners there seems also to be considerable hesitancy about entrusting the fate of their property to lawyers, law courts or courthouse clerks. They could probably benefit from legal aid of good standing in which they have confidence. A request to US-OEO for a grant towards a legal aid society such as has been brought into operation in Charleston seems not to have received the necessary endorsement from the county bar association.

It would seem that the advantages of small property ownership outweigh the inconveniences in the majority of cases, and that it has provided a relatively secure base for a level of living higher than among most black families of the rural South. If this is a social asset, a way should be found of protecting it.

There are several principal forms which title protection might take. One would be a general measure or campaign in favor of registration of title, so that all title might be conclusively settled as of a prescribed date, perhaps with a referee employed to make administrative adjudications. Another would be legal aid for case-by-case settlement as titles come into dispute.

At the same time and in either event one could envisage computerization of real estate records so as to increase the probability of people having confidence in them.

10. Sightliness

Beaufort county contains some of the most scenic areas of the United States. They are characteristic, unique and relatively unspoiled.

It would be possible to enhance their value, perhaps by well-planned and well-controlled development, but certainly by regulating their use. The attractiveness of the approach to Beaufort city has been spoiled by landowners permitting thirty billboards on a half-mile stretch south of the Marine Air Station and four junked car dumps on the half-mile stretch south of the Coosaw River. Perhaps a voluntary organization such as the Chamber of Commerce could induce a less one-sided balance between private property rights and civic pride. Alternatively, perhaps action by the county council may be needed, by way of regulatory ordinance or property tax assessment. Either way, some action seems to be needed to indicate that the development desired by the county is compatible with civilized amenities.

Consultants recently advised the Historic Beaufort Foundation: "Historic preservation must go hand in hand with . . . the creation of an image for the City, which uniquely belongs to it. The approaches and entrances to the city . . . have become standard parts of American ugliness found anywhere . . . Historic values cannot survive in ugly surroundings and neither will Beaufort." (Feiss and Wright 1970, page 18).

In the interest of compatibility between different kinds of development, as well as of its own public image, there is no reason why incoming industry should not comply with aesthetic as well as scientific standards, provided local owners do likewise.

11. A non-nodal region

Of all the ten areas marked out by the Governor for comprehensive planning in connection with local applications for federal aid, the Lowcountry (Area X) stands alone in not containing an urban center that serves as regional capital. Every other area is nodal, in the sense of turning around one or two urbanized counties: Only in the Lowcountry is this not so.

There are also some other areas in which an urbanized node stands out as a growth center, in the midst of a ring of rural counties of low income and declining population. In the lowcountry, the contrasts are less marked, with the mainland counties expanding slowly (1930-60) and not declining until recently, so that this area has not met U. S. Department of Commerce criteria for establishment of an Economic Development Administration area such as the Lower or Upper Savannah.

Beaufort county and city do not give the Lowcountry the services that are normally provided by a regional center. In figures for retail trade, and especially for general merchandise, as well as for service occupations, they have been lower than any regional node in South Carolina. In per capita retail sales, they are lower than the mainland Lowcountry counties. This is in spite of having some of the highest rates of growth and of spending power in the State.

For this anomaly, several reasons may be advanced:

a) U. S. Department of Defense installations are to a large extent self-contained: Post Exchange (sales $15 million) competes with downtown retail stores (sales $23 million, 1967) ; the Naval Hospital (360 beds) is only slightly coordinated with the county hospital (80 beds) ; and it is these U. S. facilities rather than local ones that are among the attractions that draw one or two hundred military retirees here. The main contribution of these installations to local prosperity have probably been a rise in bank deposits, in real estate value and in those construction, financing, insurance, and legal businesses that accompany real estate development. A by-product has been the University of South Carolina regional campus, which would have too few students to be viable if it were not for the U. S. Marines. On the other hand, the military trade has not attracted national motel chains to Beaufort;

b) Beaufort county contains not one but two poles of development: the Beaufort-Port Royal urban complex and Hilton Head Island (Building permits in Beaufort county in 1969 were for $13 million on Hilton Head for 100 buildings, compared with $6 million elsewhere for 470 buildings) ;

c) Beaufort county may be becoming part of an emerging Savannah metropolitan area, in which it has grown more rapidly than Chatham county. It depends on Savannah television, general merchandise shopping, entertainment, U. S. Coast Guard, U. S. Corps of Engineers, many services, and much of the more expensive construction contracting. Hilton Head Island is equidistant from Beaufort City and Savannah; and there is a two-way exchange of commuters between the Island and Savannah. (This may be one reason why Beaufort county retail sales, both civilian and military, average $1000 per person, compared with a South Carolina average of $1200.) The recognition of an interstate Savannah-Beaufort "standard metropolitan statistical area" by U.S. Bureau of the Census, like Augusta-Aiken, would seem to have been rendered difficult by the transfer to Jasper county of the connecting territory (1952) ;

d) State and county agencies have been slow in building up Beaufort city into a regional center: a shorter road could have brought Hilton Head Island nearer to Beaufort city. A technical education center is only now being developed, but has to have dormitories for boarders instead of relying on daily commuting, owing to Beaufort's non-central location as well as to the development of specialized trainings more suited to work elsewhere than at Beaufort. There has been little effort to train Beaufort county inhabitants for the expanding skilled and unskilled construction jobs. Beaufort county hospital seems to meet most of the current county civilian demand, but does not draw from out-of-county, and depends on the Naval Hospital for emergency clinic resident physicians (One Blue Cross patient in ten goes from Beaufort County to Savannah) ;

e) Beaufort county has less manufacturing industry than almost any other county in the State; but even if it had much more, especially south of the Broad River, this would not necessarily affect the tendency to gravitate socially and economically towards Savannah, thus concentrating the local gain on higher land values and a broader property-tax basis;

f) The geographical configuration of the Lowcountry, cut up with islands (nearly 70 islands of ten acres or more in Beaufort County) and intersected by a number of short rivers rising in the sandhills rather than by a single great artery rising in the piedmont, gives the region a certain natural unity but not of the kind that funnels trade and traffic to a great seaport city that dominates its region. The Port Royal pier and transit shed served no hinterland until leased to a Georgia clay-exporting company in 1968 (six ships in 1966, one in 1967; now about six per month) ;

g) Beaufort city—unlike some other places in the Lowcountry which are on U.S. 17 or I-95—is not on the road to anywhere. This is presumably one reason why no national motel chains have located there. Hilton Head Island is similarly at the end of the line. Their further development may well depend on express access.

Key geopolitical problems for Beaufort County and city are: Are there any services they can render the Lowcountry? Can they become to any extent the hub of the region? What public investments would enhance their role in their region? Alternatively, to what extent ought the new Lowcountry area planning body aim at locating regional facilities at some more central and more accessible locality, such as Yemassee? Not least, to what extent must one accept the prospect of Savannah, Georgia, being the regional capital of the South Carolina Lowcountry?

As the 1970 census returns become available we shall gradually acquire a surer basis for analyzing the social structure of Beaufort and the Lowcountry. Meanwhile, on incomes and income distribution we have been dependent on differing private estimations. On total unemployment—as distinguished from that among workers covered by unemployment insurance—we have had only a formula-based guess. Even on population we have had no sure knowledge. The field has therefore been wide open for conflicts of opinion and propaganda.

Into this situation came a project for introducing a capital-intensive industry which would not design its plant or to some extent even its processes until it could be sure of the nature of its site and of the legal standards under which it will operate.

As matters have stood during the past year and as they still stand at the present time, all local administrative agencies have therefore been in the dark as to basic facts to which they could be expected to relate. Water supply, waste disposal, terminal facilities and other services can be planned in concrete engineering, financial or even organizational terms only insofar as information becomes available.

Nor has it yet become possible to estimate the impact of a new port and industrial zone on the Colleton river on natural-resource-based occupations, so as to weigh probable social cost against possible social benefit, and plan appropriate measures for compensating such selfsupporting families as would be likely to be adversely affected.

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Persons Consulted

Prof. George Aull, 223 North Clemson Avenue, Pickens, South Carolina 29671

Mr. Thomas Barnwell, Comprehensive Health Service, Beaufort, South Carolina 29902

Captain Barr, Ports Authority, Charleston, South Carolina 29401

Mr. D. Bashaw, Regional Campus, University of S. Carolina, Beaufort, S. C. 29902

Mr. Charles Bearden, S. C. Marine Resources, 2024 Maybank Highway, Charleston, S. C.

Mr. Edwin Boyer, Executive Director, County Development Commission, Beaufort, S. C.

Mr. W. Campbell, USDA-FHA Agent, Beaufort County, Beaufort, S. C. 29902

Mayor Henry Chambers, City Hall, Beaufort, S. C. 29902

Director, Palmetto Rural Electric Cooperative, Ridgeland, South Carolina

Mr. M. Easterling, Employment Service, Boundary Street, Beaufort, S. C. 29902

Mr. Don Fischer, City Manager, City Hall, Beaufort, S. C. 29902

Mr. J. Gadson, Penn Center, Frogmore, South Carolina

Mr. Gatch, Planning Officer, County Office, Beaufort, S. C. 29902

Mayor Graham, 1404 Tenth Avenue, Port Royal, South Carolina

Mr. Orion Hack, Hilton Head Company, Hilton Head Island, S. C.

Mr. L. Holliday, TEC Center, Ribaut Road, Beaufort, S. C. 29902

Mr. Wilbur Jackson, Auditor, County Courthouse, Beaufort, S. C. 29902

Dr. Jones, County Health Office, Beaufort, S. C. 29902

Mr. Jones, Hilton Head Shrimp Cooperative, Hilton Head Island, S. C.

Mr. Edward Latimer, Assistant Attorney General, 1015 Main Street, Columbia, S. C. 29201

Mr. Littlejohn, Chamber of Commerce, Hilton Head Island, S. C.

Mr. A. R. McAfee, County Administrator, County Office, Beaufort, S. C. 29902

Mr. Rudolf McCormack, Health Office, Green Street, Ridgeland, S. C.

Mr. McLin, Conservation District, Ridgeland, S. C.

Mr. W. Marscher, Sea Pines Plantation, Hilton Head Island, S. C.

Mr. R. C. Martin, Southeastern Maritime Company, 310 E. Bay St., Savannah, Ga.

Mr. H. Harley Mills, County Welfare Office, Beaufort, S. C. 29902

Mr. Edward Pike, County Development Commission, Beaufort, S. C. 29902

Mr. Pittman, USDA-FHA, Federal Building, Columbia, S. C. 29201

Mr. Dean Poucher, Chamber of Commerce, Beaufort, S. C. 29902

Mr. Pringle, County Health Office, Beaufort, S. C. 29902

Mr. Sanders, County Extension Agent, County Office, Beaufort, S. C. 29902

Mr. Charles Simmons, Economic Opportunity Commission, Beaufort, S. C. 29902

Mayor M. R. Smith, P. O. Box 12, Bluffton, S. C. 29910

Prof. J. M. Stepp, Department of Agricultural Economics, Clemson University, Clemson, South Carolina

Admiral Rufus Taylor, P. O. Box 5081, St. Helena's Island, S. C. 29928

Mr. Nat Thompson, Lowcountry Planning Commission, Beaufort, S. C. 29902

Mr. Stanley Waskiewicz, Blue Channel Corporation, Port Royal, S. C. 29935

Mr. Webb, Beaufort-Jasper Water Authority, Beaufort County, S. C.

Mr. M. Woods, Resource Conservation & Development Office, Walterboro, S. C.

The Hon. James M. Waddell, Jr., State Senator, Beaufort, S. C.

The Hon. James W. Graves, State Representative, Hilton Head Island, S. C.

The Hon. Wm. Brantley Harvey, Jr., State Representative, Beaufort, S. C.

Economic and Environmental Evaluation of Development Alternatives for Beaufort County, S. C.

J. C. Hite, W. W. Hall, Jr., and J. M. Stepp

with

M. G. Carmichael, T. C. Meadows, R. M. Pope, M. B. Richardson and W. J. Steele

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Department of Agricultural Economics and Rural Sociology
Clemson University, Clemson, South Carolina

PART 1

Introduction

Nature of the Problem

Economic development has been a major goal of many rural counties in the southern United States in the years since World War II. With few exceptions, these rural counties, faced with mechanization of agriculture and decline in farm employment, have welcomed almost any type of new industry. Although some of the new industry has caused noticeable pollution, southern communities have often overlooked environmental problems in their search for a new economic base.

In the late 1960's, however, a noticeable shift in emphasis began to occur in the search for new industry. The acquisition of industry began to be viewed as a mixed blessing. While many communities continued to search for industry to replace agriculture as the foundation of their economy, more and more local leaders began to demand that new industry take special precautions to avoid excessive pollution of the environment. No longer was just any new industry considered desirable; the new industry must not cause any appreciable damage to the natural environment. This change in emphasis has created frustrations on the part of industrial development organizations and heated controversy in many local communities. Perhaps in no area has the conflict between industrial development and environmental quality been more dramatic than in Beaufort County, South Carolina.

In 1969 it was announced that the Badische Anilin and Soda Fabrik Company (generally designated by its initials, BASF) had acquired a site and was planning to construct a major chemical manufacturing facility at Victoria Bluff on the Colleton River in the southern part of Beaufort County, South Carolina. The site is in a sparsely-settled, undeveloped part of the county and is approximately equidistant (by existing highways) from Beaufort, South Carolina, and Savannah, Georgia (about 30 miles). It is however, only about four straight-line miles from the nearest point on Hilton Head Island and eight to ten miles from the portions of that island which have been developed very substantially as recreation-residential areas, a major attraction of which is the subtropical sea-island environment.

The developers of Hilton Head Island, the fishermen of the Port Royal Sound estuary (of which the Colleton River is a part) and a number of other groups and individuals who were interested in preventing pollution and in preserving natural environmental and ecological systems protested the construction of the proposed industrial plant unless and until they could be assured that it would be constructed and operated in such a way, and under adequate government regulation and supervision, as to prevent any appreciable impairment of the existing economic and environmental attributes of surrounding and nearby areas.

In response to these protests and to requests for an impartial and systematic study of the possible effects of substantial industrial development of the Port Royal Sound area, and especially of developing Port Victoria as proposed, the Governor of South Carolina on January 21, 1970, issued the following directive to Mr. Clair P. Guess, Jr., Executive Director of the South Carolina Water Resources Commission:

> "It has become necessary, in my opinion, to conduct a comprehensive study of the environmental conditions as they exist in the coastal area of the State. This, of course, would be far-reaching and necessitate a considerable amount of time and expense. Because of the proposed industry at Victoria Bluff, I feel that the first step would be that you and the staff complement of the Water Resources Commission should collect and evaluate base line environmental quality information relating to the development of this type of industry. You should utilize the interdisciplinary inputs and facilities of the agencies of the State, such Federal assistance as may be available, and, if necessary, employment of a private consultant firm.
>
> This first effort should commence immediately."

Pursuant to this directive, Mr. Guess created an over-all committee to plan and coordinate the various physical, biological and socio-economic studies which would be made by specific study groups, which were designated by the over-all committee.

In January 1971, the BASF Company announced that it had cancelled plans to construct a plant at Victoria Bluff. Undoubtedly, the protest from conservation-oriented groups in the Hilton Head area, and the resulting delay in the ability of BASF to implement its construction plans, was a significant factor in the company's decision to cancel its original decision.* Yet the decline of agricultural employment in Beaufort County and the inherent uncertainty of the economic activities in the County dependent upon military spending required that community leaders seek new additions to the local economic base or face economic decline or stagnation. It is quite logical for them to look to manufacturing for this additional economic base. This report will deal with the socio-economic aspects of various types of possible industrial development in Beaufort

*The media has reported that both environmental and cost factors forced the BASF Company to cancel its construction plans.

County and some possible environmental repercussions of each type of development. The purpose of the report is to assist Beaufort County citizens and other interested persons in evaluating alternatives for the economic development which almost every resident of the area thinks is needed.

Problem Definition and Objectives

The central problem of this study is to determine the economic and environmental consequences of various types of industrial development in Beaufort County. Consequently, our analysis centers on the question: "What type of industrial development in Beaufort County will provide the greatest economic benefit to local people, and what will be some of the environmental consequences of that development?" This question must be studied within the context of the existing socio-economic conditions in Beaufort County and the viable alternatives for resource development in the area.

In accordance with such a definition of the problem, we have established four specific objectives for this study:

1) To examine the existing economic base and the socio-economic characteristics of the population of Beaufort County relative to the state and the nation.
2) To identify possible types of industrial development for Beaufort County and to estimate the magnitude and geographic distribution of the direct and indirect economic and environmental effects of each of the various types of development.
3) To estimate the effects that various types of development in Beaufort County will have on local and State government revenues and expenditures in both the near and more distant future.
4) To ascertain and evaluate the willingness of members of various social and economic groups to sacrifice pecuniary income in order to protect the environment of Beaufort County against the encroachment of industries which have a potential for environmental pollution.

Plan of the Report

The basic plan of this report follows the strategy implicit in the objectives set forward above. We will first describe in some detail the existing socio-economic conditions of Beaufort County, noting the distribution of the population by income groups, recent demographic trends and the current structure of the County's economy. In Part III, we will outline the development alternatives for Beaufort County and, using the framework of an input-output model, evaluate the economic and environmental impact of each of these alternatives. Objective four will be attacked in Part IV, where we will evaluate the results of a household survey in Beaufort County concerning attitudes toward environmental quality. Finally, in Part V, we will summarize our findings and attempt to identify and evaluate the alternatives for the economic future of Beaufort County.

Basic Concepts and Methodology

The basic premise underlying this study is found in the export base theory of economic development. The essential element of export base theory is that the impetus for regional growth stems from sales made by the region to buyers located outside the region [3]. Such sales bring in "outside money" to support markets for and jobs in local enterprises. These sales include both tangible goods, such as agricultural and industrial products, and intangibles, such as recreation sold to tourists. Although export base theory has been thoroughly critiqued [3] and must be used with a degree of caution, it has found wide acceptance as a planning tool and the basic premises are to be found in almost all regional economic projections [10, 20].

Following export base theory, we are assuming the autonomous factor giving rise to economic growth in Beaufort County is external sales (i.e., sales to buyers located outside the county). Each dollar of external sales generates more than one dollar of income in the county if that dollar (or some portion of it) is spent locally to purchase supplies and/or labor. If the worker spends a part of his paycheck locally, the local merchant also realizes income from the original dollar of external sales. Thus, a dollar of external sales may turn over several times before it gradually "leaks" out of the county through purchases made from external suppliers. The number of times a dollar turns over locally before leaking out is called the local multiplier. This local multiplier varies for different types of enterprises since some activities make extensive use of local inputs and other activities generate purchases of only small quantities of supplies locally. In the Beaufort County input-output model developed for this study, we have assumed external sales to constitute the "final demand" for locally-produced products and have calculated local export-base multipliers for each alternative type of economic development.

Sources of Data

Data used in this study have been obtained from three sources: 1) published and unpublished data collected by various Federal and State agencies; 2) a survey of a random sample of households in Beaufort County taken in the summer of 1970; and 3) a sample survey of business and industrial firms in Beaufort County conducted in the autumn of 1970. We will discuss in some detail the two surveys which were used to obtain primary information.

Household Survey

The household survey consisted of a stratified sample of 162 households, or approximately 1.2 percent of the households in Beaufort County. This sample was selected from a preliminary list of 650 households drawn from the personal property tax rolls in the office of the county treasurer using a systematic procedure based on a random starting point. These 650 households were classified according to the amount of personal property taxes paid in 1969, and a prime sample of 300 households was then chosen using a random procedure within each tax-level category. The original goal was to survey the entire prime sample of 300 households, using random selections from the remaining 350 households when substitutions were deemed necessary. During the course of the survey, however, an unauthorized reproduction and distribution of copies of the survey questionnaire created a possibility of bias*; hence the survey was terminated with only 162 valid interviews having been conducted. The survey was conducted by six local enumerators trained by personnel from Clemson University and working under the supervision of a field director. A copy of the questionnaire is presented in the Appendix.

Business and Industry Survey

The business and industry survey was designed primarily to obtain information on the geographic patterns of sales and purchases by Beaufort County business and industrial firms. An attempt was made to compile as complete a list as possible of such firms, using local telephone directories and the South Carolina State Industrial Directory. All firms on the list were mailed the questionnaire shown in the Appendix. Ninety-three usable questionnaires were returned representing all the principal sectors of the Beaufort County economy. No claim can be made, however, that the return questionnaires represent a random sample, and it is difficult to assess the biases which may be inherent in the returned questionnaires. Nevertheless, the returned questionnaires appear to represent a cross-section of the local economy, and data obtained from them have been used to construct the technical co-efficients matrix of an input-output model for Beaufort County.

*The survey was made before the BASF Company announced the cancellation of its construction plans and while an atmosphere of distrust and suspicion was prevalent among several groups in the County.

PART II

The Economy of Beaufort County

Introduction

This section is concerned primarily with Objective 1 as defined in the preceding chapter. It describes in some detail the existing socio-economic conditions in Beaufort County as a background against which various types of economic development alternatives can be evaluated.

CHARACTERISTICS OF POPULATION

Population Trends

The 1970 Census of Population placed the population of Beaufort County at 51,136, up from 44,187 in 1960. This growth amounted to a 15.7 percent increase in the decade of the sixties, as compared to a 5.9 percent growth over the same period in the State of South Carolina [22]. As evidenced by the data presented in Table 1, there was a rather dramatic shift from a rural to urban setting for the Beaufort County population in the 1960-1970 period. In 1960, only 14.3 percent of the population was classified as urban; in 1970, slightly more than one-half (50.2 percent) was urban. Part of this shift was due to a 49.8 percent increase in the population of the city of Beaufort over the time period, but part of the shift was also due to annexation on the part of the town of Port Royal.

TABLE 1. Rural-Urban Distribution of Population, Beaufort County, South Carolina, 1960 and 1970

Year	*Total Population*	*Total Urban*	*Total Rural*	*Percent Urban*	*Percent Rural*
1960[a]	44,187	6,298	37,889	14.3	85.7
1970[b]	51,136	25,657	25,479	50.2	49.8

SOURCE: [a] U. S. Bureau of the Census, *1960 Census of Population*, U. S. Department of Commerce, Washington, D. C.
[b] U. S. Bureau of the Census, *1970 Census of Population, South Carolina*, Advance Report.

Table 2 reveals the relative growth or decline in population in each of the five census divisions of Beaufort County over the decade of the sixties. About 30 percent of the total population growth of the county in the 1960-1970 period occurred in the Bluffton Division, an area including both the Hilton Head resort community and possible industrial sites at Port Victoria. Much of this growth in the Bluffton Division is undoubtedly due to the development of Hilton Head Island since 1960. The other growth center of the county is the Beaufort Division, which includes the city of Beaufort . All other census divisions had either stable or declining populations during the decade of the sixties.

TABLE 2. Population of County Subdivisions, Beaufort County, South Carolina, 1970 and 1960

County Subdivision	Year 1970	1960	Percent change 1960-1970
Beaufort Division	22,382	16,686	34.1
Bluffton Division	5,252	3,135	67.5
Port Royal Division	15,254	15,025	1.5
St. Helena Division	5,718	6,048	— 5.5
Sheldon Division	2,530	3,293	—23.2
Total	51,136	44,187	15.7

SOURCE: Same as Table 1.

The 1960's saw not only a shift from rural to urban residence in Beaufort County but also a decline in the relative importance of nonwhites in the population. The 1970 Census reported that 34 percent (17,272 persons) in Beaufort County were nonwhite, whereas in 1960, 39 percent (17,104 persons) in the County were nonwhite. For South Carolina as a whole, 31 percent of the population was reported to be nonwhite in 1970 as compared to 35 percent in 1960. Thus, changes in the racial makeup of the Beaufort County population closely approximate the state-wide trend in the decade of the 1960's [22].

Education

In 1968-1969, there were 10,339 students* enrolled in public schools in Beaufort County [15]. Six public high schools enrolled 4,845 students, or an average of 808 students per school, while the 14 public elementary schools had a total enrollment of 5,494 students, or an average of 392 students per school. About 55 percent of the total public school enrollment in the County in 1968-1969 was nonwhite.

It is difficult to estimate the current level of educational attainment of the population of Beaufort County. The most recent concrete data are from the 1960 Census and show that only 14 percent of the population of the County 25 years old or older had completed the 12th grade [22]. This compares to slightly more than 30 percent of the 1960 state population 25 years old or older who had completed the 12th grade. Although educational levels in Beaufort County had undoubtedly improved considerably since 1960, it appears likely that the 1970 Census will show that educational attainment in the County still lags behind that of the State as a whole.

Tax Structure

In South Carolina, the principal source of local government revenue is the property tax. In 1969, personal and real property in Beaufort County was valued at $18,165,100, or $355 per capita. The value of all personal and real property in South Carolina as a whole amounted to $481 per capita in 1969; hence, the local tax base in Beaufort County on a per capita basis is less than 75 percent of the property tax base statewide [18]. Although many of the taxes collected by the State of South Carolina are shared with county governments, the relatively low property tax base in Beaufort County poses significant problems for the operation of county and local government.

*Based on ten-day average attendance.

One of the major expenditures of county government in South Carolina is in the support of the public school system (although the counties do in fact pay less of such costs than the state government). In 1969-1970, Beaufort County spent $1,650,816 of locally-collected county money for school purposes, an average of $155 per pupil [19]. The statewide average expenditure per pupil from locally-collected taxes was $214. The presence of sizeable military installations in Beaufort County, however, made the local school system eligible for assistance from the Federal Government under Public Laws 815 and 874 (hereafter called Impacted Area Funds), and in 1969 Beaufort County received $631,568 in Impacted Area Funds [19]. Given these funds and shared revenue from the State, per pupil expenditures in Beaufort County in 1969-1970 totaled $530 as compared to an average of $457 statewide.

Some insight into the tax structure in Beaufort County and the potential revenue problems facing the county school administrators can be gained by comparing Beaufort County to Pickens County. Table 3 provides some relevant data for such a comparison. In 1970, Beaufort and Pickens Counties had roughly the same population.*

TABLE 3. Comparison of Expenditures Per Pupil and County Per Capita School Taxation, Beaufort and Pickens Counties, South Carolina, 1960 and 1969

Political Entity	Expenditures Per Pupil1 1960-1961	1969-1970	County Per Capita Taxes for Schools2 1960	1969a
Beaufort County	$191.10	$530.70	$14.74	$32.73
Pickens County	191.33	415.23	23.85	38.00

a/Computed by dividing taxes collected during tax year commencing December 1, 1968, by 1960 population plus 9/10 of the increase between 1960 and 1970.

SOURCE: 1/ State Superintendent of Education, *Annual Report*, South Carolina Department of Education, Columbia, 1960-61 and 1969-70.

2/ South Carolina Tax Commission, *Annual Report to the Governor and General Assembly*, Columbia, 1960 and 1969; U. S. Bureau of the Census, *Census of Population*, U. S. Department of Commerce, Washington, D. C., 1960 and 1970 (advanced).

Beaufort has a military complex which results in additional population without an appreciable increase in the tax base; Pickens has Clemson University, which also increases the population and county costs without adding appreciably to the tax base. In 1960, both Beaufort and Pickens were spending approxi-

*In 1970, Beaufort County's population was 51,136 as compared to 58,956 in Pickens County [22].

mately the same per pupil for public education, although per capita taxation for school purposes in Beaufort County in 1960 was only about 62 percent of the per capita school taxation in Pickens County. By 1969-1970, Beaufort County had increased per pupil school expenditures to $530 as compared to $415 in Pickens County. Even if Impacted Area Funds are not considered, Beaufort County was still spending $56 more per pupil in 1969-1970 than was Pickens County. Yet Table 3 shows that per capita taxation for school operations in Beaufort County still lagged behind Pickens County in 1969 by about six dollars per person. If Beaufort County were not receiving Impacted Area Funds, per capita school taxation in the County would need to be raised by 38 percent in order for Beaufort to match the per pupil expenditure of Pickens County in 1969-1970 (assuming the county, not the state, paid the difference). By contrast, if Pickens County residents were to pay taxes high enough to offset the property taxes paid by manufacturing firms in the county, per capita taxes in Pickens in 1969 would also need to be raised by about 38 percent. Thus industrial development is doing for Pickens County, financially, what the Federal Impacted Area Funds are doing for Beaufort County.

Employment and Income

Employment

The average work force in Beaufort County in 1969 amounted to 13,200 persons, as compared with 12,700 in 1968 [16, p. 15]. The rate of unemployment decreased from 1968 to 1969, moving from 5.9 to 4.5 percent. The rate of unemployment in Beaufort County in 1969 was almost one-half a percentage point higher than that for the State. The distribution of employment in the County in 1969 is shown in Table 4. Less than 7 percent of the nonagricultural employment in Beaufort County was in manufacturing, whereas more than 33 percent of the nonagricultural employment was in government.

Table 5 presents data on the age distribution of the Beaufort County population 14 years old or older as determined by the household survey. It is this part of the population that is normally considered the potential labor force. In 1970, there were 36,900 persons in the county 14 years or older, almost 50 percent of whom were over 40 years old. The productivity of the older half of the potential labor force can be expected to decline as its members advance in age; thus a large proportion of the potential work force in the over-40 group will not normally be attractive to industries which must train local workers.

The household survey also revealed that approximately 12,000 persons would be interested in seeking industrial employment should such become available in the Port Victoria area of Beaufort County. Almost one-half of these 12,000 persons was currently employed in the County, or in surrounding counties. Nevertheless, it appears that there is ample potential labor supply in Beaufort County for new industrial enterprises and that perhaps as many as 3,000 to 6,000 workers (depending on age requirements) could be hired without disrupting the existing labor market.

TABLE 4. Work Force Estimates, Beaufort County, South Carolina, 1968 and 1969

Item	Annual average 1968	Annual average 1969	Absolute Change
Civilian work force	12,700	13,200	500
Unemployment	750	600	150
Percent of work force	5.9	4.5	
Employment	11,950	12,600	650
Nonagricultural employment	10,800	11,550	750
Wage and salary workers, except domestics	8,850	9,500	650
Manufacturing	650	800	150
Food and kindred products	300	350	50
Other manufacturing	350	450	100
Contract construction	1,000	900	—100
Transportation, communication and utilities	300	300	0
Wholesale and retail trade	1,400	1,400	0
Finance, insurance, real estate	600	700	100
Service	1,200	1,300	100
Government	3,600	4,000	400
Other manufacturing	100	100	0
Self-employed, unpaid family workers and domestics	1,950	2,050	100
Agricultural employment	1,150	1,050	—100

SOURCE: South Carolina Employment Security Commission, *South Carolina's Manpower in Industry*, Research and Statistics Section, Columbia, May 1970.

TABLE 5. Estimated Potential Labor Force, by Age, Beaufort County, South Carolina, Summer 1970

Age	Number	Percent of Total
14-29	12,000	33
30-39	6,600	18
40-49	7,700	21
50-65	7,800	21
66 and over	2,800	7
Total	36,900	100

SOURCE: Household Survey of Beaufort County, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C., Summer 1970.

Income

On the basis of the household survey, we estimate that total personal income in Beaufort County in 1970 from all sources was approximately $132 million. Given that there were approximately 13,500 households in the county, average income per household was $9,800. Per capita income for 1970 is estimated at $2,500, which is 67 percent of the 1969 U. S. average of $3,676 (no figure for 1970 was available at the time of this writing). In 1969, per capita income in the state of South Carolina was estimated at $2,580, so that, given errors in estimates, we can conclude that average income per capita in Beaufort County was roughly equal to the State average [26, p. 326].

Average income figures may be only partially meaningful, however, since they may reflect a population with both extremely high and extremely low incomes. The household survey revealed that 57 percent of the households had incomes below $6,000. On the extremes, 6 percent of the households had incomes above $21,000 for the year, and 12 percent had incomes below $3,000 in 1970. In contrast, only 39 percent of the households in the Charleston area were found to have had incomes below $6,000 and only 1.5 percent had incomes above $21,000 in 1968 [4, p. 12].

One of the reasons for the relatively low income of residents of Beaufort County is the prevailing low wage rates. Average annual pay per employee in each of several economic sectors has been computed and is shown in Table 6, along with comparable State and national data. In most sectors, pay in Beaufort County is low relative to both the State and the nation. Average annual pay of $3,817 in manufacturing is much lower than the national figure of $7,372. Wide divergence is also found in the food, construction and transportation sectors. All but one of the pay averages for Beaufort County are below the national figures for the same sectors, but the differentials are not as marked as in those mentioned above. These wage differentials could be due to one or more of several factors, among which could be low productivity, lower educational attainment of workers, labor supply and demand relationships, differences in kind of construction, or the effect of unionization.

MAJOR COMPONENTS OF THE ECONOMIC BASE

In Part I it was noted that the export base component of an area's economy consists of those industries producing goods or services for sale to customers living outside the area. On the basis of this criterion, we can identify the major components of the Beaufort County economic base as military activities, tourism and recreation, agriculture, forestry and fisheries, and manufacturing. Table 7 shows estimates of the magnitude of each of these activities in the County in 1970.

Military Facilities

As shown in Table 7, military activity was one of the most important influences on the Beaufort County economy in 1970, accounting for nearly one-half of all sales in the county. The military sector of the County's economy is comprised of the Parris Island Marine Base and the Laurel Bay Marine Air Station. Direct military spending in the County is primarily directed into payrolls totaling almost $83 million in 1970. In addition, more than $1.5 million was spent by the military in the County in 1970 for construction activities. The payroll expenditures are distributed throughout the local economy in the form of payments for retail items and services, and its impact is felt in almost all sectors of the Beaufort economy.

There appears to be no plan to significantly alter military operations in Beaufort County. Even a partial reduction in base operations, however, could have adverse effects on the local economy via the

TABLE 6. Average Annual Pay Per FICA-Covered Employee by Sector, Beaufort County, South Carolina and USA, 1969

Beaufort County as % of U.S	*Industry Group*	*Beaufort County*	*South Carolina*	*USA*
64	Ag., Forestry and Fisheries	$2,635	$3,702	$4,146
42	Food and Kindred Products	2,766	4,845	6,528
59	Construction	4,421	5,191	7,453
52	All Manufacturing	3,817	5,407	7,372
56	Transportation	4,305	6,455	7,625
71	Eating and Drinking Places	1,889	2,100	2,666
77	Hotels and Lodging Places	2,473	2,345	3,213
84	Gasoline Service Stations	2,869	2,950	3,406
73	Other Wholesale and Retail Trade	4,148	4,632	5,675
66	Financial Services	4,965	6,231	7,492
102	Real Estate	4,849	4,082	4,772
58	Other Business and Professional Services	2,862	3,733	4,958
60	All Covered Employment	$3,796	$4,986	$6,277

SOURCE: Computed from U. S. Bureau of the Census, *County Business Patterns, 1969*, U. S. Department of Commerce, Washington, D. C., 1970.

TABLE 7. Estimated Magnitude of Major Components of the Economic Base of Beaufort County, South Carolina, 1970

Activity	*Direct Expenditures (External Sales)*	*Total Sales*[a]	*% of Estimated Gross Sales*[b]
Military	$ 84,661,000[c]	$187,700,000	46
Tourism and Recreation	11,950,000[d]	25,844,000	6
Agriculture, Forestry and Fisheries	7,333,000[e]	19,467,000	5
Manufacturing	5,345,000[f]	12,961,000	3
Totals	111,628,000	245,972,00	60

a/ Based on multipliers derived from input-output matrix in Part III.

b/ Gross sales for Beaufort County were calculated by applying the ratio of personal income to gross sales for the Charleston area [see 5] and were estimated at $408,999,000.

c/ Based on data supplied by the Office of the Assistant Secretary of Defense. The local sales multiplier for military activities is relatively high in Beaufort County because almost all local military expenditures are to households in the form of wages and salaries.

d/ Based on [9]

e/ Based on [6] and [27]

f/ Based on average output per worker in South Carolina in [23] negative multiplier principle resulting directly from a decrease in dollars flowing into the County from Federal sources.

*Tourism and Recreation**

With its subtropical climate and relatively unspoiled estuarine environment, Beaufort County has developed since 1960 a major tourism and recreation industry. The industry is now the second most important component of the County's economic base, accounting for about 6 percent of all gross sales in the County. There are three major sectors which are directly involved in tourism and recreation activities—hotels and lodging places, eating and drinking places, and gasoline service stations [see 1, p. 27]. Yet tourism and recreation activities also have indirect impacts on many other sectors of the local economy, particularly households which supply labor and wholesale and retail trade establishments. The rapid growth of tourism and recreation activities in Beaufort County since 1960 has been, in large part, tied to the development of the Hilton Head resort complex, and it is argued that continued development of this sector might be adversely affected by the development of heavy manufacturing enterprises in the County.

Agriculture, Forestry and Fisheries

Agriculture, forestry and fisheries activities constitute the traditional base of the Beaufort County economy. Yet all of the sectors have been in decline in recent years, and in 1970 they accounted for only about 5 percent of total sales in the County. In 1960, more than 9,500 persons were engaged in agriculture in Beaufort County [22]. By 1969, the number had declined to 1,050 [16]. From 1959 to 1964, the number of farms in the County declined by about 20 percent [24], and this declining trend is probably still operative. The decline in agricultural employment and number of farms would appear to indicate that farm operations have become heavily mechanized, thus releasing human resources to seek other forms of employment. But even though the number of people engaged in farming operations has been decreasing, Beaufort County continues to have a viable agricultural economy, ranking 26th (among 46 counties) in the State in total cash receipts from farming and second in cash receipts from vegetable crops [27].

Although highly visible and colorful, the fishing industry in Beaufort County is relatively small. In 1963, there were an estimated 223 full-time job equivalents available in the industry [6, p. 10], although probably many more than 223 persons were employed in these positions on a part-time basis. The principal types of fishing activities center on shrimp, crabs and oysters. Available studies indicate that there is little potential for substantial growth in the shrimp fisheries on the Carolina coast, but some prospects exist for expansion of crab and oyster operations [6].

Manufacturing

Table 7 shows that the direct and indirect effects of manufacturing currently account for only about 3 percent of all sales in Beaufort County. Earlier, in Table 4, we noted that less than 7 percent of the nonagricultural employment in the County is in manufacturing activities. Current manufacturing operations in the County are geared largely to apparel, food processing and other light industry with traditionally low wages. Growth of manufacturing in the County in the decade of the sixties was slow. The average county in South Carolina gained 1,135 new manufacturing jobs from 1963 to 1967, while Beaufort County gained only 200 jobs [16].

Summary

The preceding description of the current state of the Beaufort County economy presents a picture of a county with a decline in its traditional economic base and in need of a new base to sustain population and community services. Although population has been growing and per capita and average family income in Beaufort County do not appear to be low by regional standards, the County's economy is heavily dependent on military spending. Reductions in military operations in the County would probably have profound effects on local economic activity and the operation of such vital services as public education. The only major component of the current economic base which exhibits growth prospects is the tourism and recreation sector. Although the quality of the resident labor force in terms of educational attainment appears to be relatively low, there is ample local labor available for substantial industrial development. Beaufort County needs economic growth of some sort which will use that labor supply and provide an increased tax base to cushion possible future reductions in the level of military operations in the County.

PART III

Development Alternatives For Beaufort County

Introduction

In the previous chapter we described the existing economic conditions in Beaufort County, noting the decline of the traditional economic base in agriculture, forestry and fisheries and the need to develop a new base. In this chapter, we turn to consideration of some development alternatives for Beaufort County. Particularly, we will focus our attention on the assessment of the economic and environmental impacts which might be expected under seven representative types of development: 1) food and kindred products industry, 2) textiles and apparel in-

*"Tourism and recreation" is defined as an industry serving transients, as opposed to a retirement industry which attracts permanent residents.

dustry (representing light industry), 3) lumber and wood products manufacturing, 4) chemicals manufacturing (representing heavy industry), 5) tourism and recreation, 6) retirement community development, and 7) military activities.*

Tools of Analysis

The basic tool of analysis employed in this chapter is the economic-ecologic linkages model developed by E. A. Laurent and J. C. Hite. We will only briefly sketch the basic elements of this model in this report. The reader who desires a more detailed account of the model and its development should consult the work of Laurent and Hite [7].

There are two essential elements of the economic-ecologic linkages model used in this study: 1) the inverse of an input-output matrix of the area economy, and 2) a matrix showing the inflow from the environment associated with one dollar of gross output in the input-output matrix. The system quantified by the model can be visualized as in Figure 1. Resources are taken from the environment and processed through technology in the economic system, then discharged into the environment in the form of residuals (some of which are classed as pollutants).

The Laurent-Hite model simplifies the system by ignoring the ecologic processes represented by the box in the lower right-hand corner of Figure 1 and by concentrating instead on the inputs to and outputs from the environment to the economic system. Further simplification is achieved by concentrating on only a few of the most critical environmental linkages (e.g., BOD**, SO_2***, particulates**** and solid waste outputs). No attempt is made to analyze the ecologic consequences of these linkages as they are best examined by professional engineers and scientists.

The Beaufort Input-Output Matrix

In order to use the Laurent-Hite model it was necessary to construct an input-output matrix of the Beaufort County economy. Input-ouput matrices are difficult to construct not only because it is expensive to collect all the data needed via a survey, but also because many firms cannot provide the necessary information due to limitations of their accounting systems. As a result, construction from ordinary data of a full-scale input-output model for Beaufort County was deemed impractical, given the limitations of time and funds imposed on this study. However, several successful efforts have been made by researchers in simulating the input-output structures of local economies [see 8, 14]. The availability of a relatively recent (1968) input-output model of the Charleston metropolitan region provided an opportunity to simulate a Beaufort County matrix by recalibrating the Charleston model to account for Beaufort County sales patterns [5].* A detailed description of input-output models and the simulation techniques is included in the Appendix.

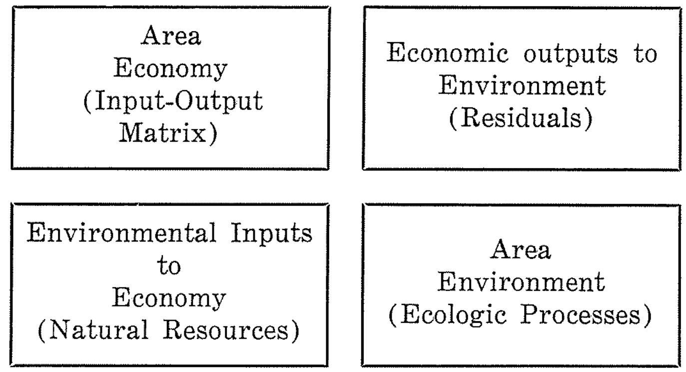

Figure 1. Generalized Economic-Ecologic Linkages Model

In simulating the Beaufort County input-output model, we have omitted the transactions matrix and moved immediately to the construction of the technical or direct coefficients. This move was necessitated by the difficulty of obtaining accurate data on the gross output of each business and industrial firm in the county. Consequently, Appendix Table 3 shows the simulated interindustry and Interregional transactions on a per dollar basis, given the structure of the Beaufort County economy in 1970. The raw data for simulating this table were obtained from the survey of Beaufort County business and industrial firms described in Part 1. Appendix Table 4 shows the inverse of the matrix in Appendix Table 3.

The Environmental Linkages Matrix

The second element of the Laurent-Hite model, the environmental linkages matrix, was developed for Beaufort County by recalibrating the environmental linages matrix constructed for the Charleston area [7]. Adjustments were made in the matrix to eliminate those sectors of the economy which appear in the Charleston area but are not present in Beaufort and to account for differences in the mix of firms which make up sectors which are common to the two areas. The matrix is representative of the 1968 level

*We do not wish to imply that Beaufort County has locational advantages for these specific types of developments. Further studies of comparative costs and markets would be necessary before we could determine if Beaufort County could compete favorably with other areas for these types of activities.

**BOD means Biochemical Oxygen Demand, a common measure of water pollution due to biologically degradable organic wastes.

***SO_2 is sulfur dioxide, a common and important type of air pollutant.

****Particulates are inert materials such as cinders and dust which are common air pollutants.

*The Charleston metropolitan region as defined in [5] is northeast of, and immediately adjacent to, Beaufort County.

of waste treatment characterizing the Charleston area and, for most sectors of the economy, it represents a relatively low level of treatment. This matrix can be found in the Appendix. It is quite likely that any new developments in the Beaufort area would be required to install waste treatment facilities representing a somewhat higher level of residuals removal, and, consequently, the estimate of pollution levels in the following discussion can probably be considered to have an upward bias.

Note on Interpretation of Model's Estimates

One of the chief limitations of the Laurent-Hite model is that it combines rather large groups of industries into a single sectors. For example, "Food and Kindred Products" includes bakeries, dairy processing plants, seafood canneries, etc. The waste output of a bakery is considerably different from the waste output of an ice-cream plant, but the model does not distinguish different types of operations within a particular sector. By the same token, the waste output of a textile dyeing plant is usually far more significant than the waste output of an apparel operation such as a shirt factory. Given this limitation, the estimates produced by the model must be interpreted as *averages* for the sectors and they should not be applied to a specific type of operation without adjustments based on further information.*

Types of Development and Projected Impacts

The seven representative types of economic development in Beaufort County were analyzed with regard to the local impact on 9 different variables. The results of this analysis are summarized in Table 8. All analysis is developed on the basis of 100 jobs, with the exception of analysis of the impact of retirement developments, which is developed on the basis of 100 new residents. Data which support the figures in Table 8 can be found in tables presented in the Appendix.

*For a more complete discussion of the limitations of the model, see [5].

Food and Kindred Products

Given the existing vegetable agriculture and commercial fishing industries of Beaufort County, the development of food processing activities in the County would appear to be a definite possibility for future growth. Table 8 shows that 100 new jobs in this industry could be expected to generate, directly and indirectly, around $1 million in increased local sales and $679,000 in increased personal income. With the local multiplier principle operative, these 100 new jobs would also stimulate 11 additional new jobs in related areas of the local economy, for a total of 111 new jobs. Local taxes generated would amount to $5,100 per year. State taxes resulting from 100 new jobs in food processing would amount to $65,900 per year.

Yet not all the impacts of 100 new jobs in food processing would be positive. Table 8 shows that such development would generate 335,100 pounds of BOD, 4,600 pounds of SO_2, 2,900 pounds of particulate matter and 3,500 cubic yards of solid waste per year.**

*The figures in Table 8 were derived in the following manner. First, output per 100 workers in each of the seven types of development was calculated (see Appendix Table 6). Then a new matrix representing the product of the environmental linkages matrix (Appendix Table 5) and the inverse of the Beaufort County input-output matrix (Appendix Table 4) was constructed. The appropriate columns of this new matrix were then multiplied by the respective total output figures.

**Economists are not really qualified to make judgments as to the severity of the amount of waste which is discharged. Hence, the reader is cautioned that data on waste discharges are presented only for purposes of comparison.

TABLE 8. Projected Effects of 100 "Export" Jobs in Seven Types of Economic Activities on the Beaufort County (South Carolina) Economy, 1969[a]

	Given 100 "Export" Workers in:						
Type of Impact	*Food and Kindred Products*	*Textiles and Apparel*	*Lumber and Wood Products*	*Chemicals*	*Tourism and Recreation*	*Retirement Community*[b]	*Military Base*
Total Sales ($)	1,030,800	1,895,900	2,003,100	2,157,700	2,309,500	870,300	911,000
Total Personal Income Generated ($)	679,400	1,147,200	982,800	1,288,600	1,493,600	670,600	382,000
Total Number of Jobs Created	111	119	114	118	126	15	109
Local, County Taxes Paid ($)	5,100	71,200	11,800	27,000	12,500	4,900	2,800[c]
State Taxes Paid ($)	65,900	113,800	138,400	94,800	151,400	29,200	79,100
Particulate Matter (lbs/year)	2,900	4,700	1,552,200	4,100	19,200	3,800	2,100
SO_2 (lbs/year)	4,600	3,500	3,500	3,900	17,300	2,700	1,500
Five-Day BOD (lbs/year)	335,100	470,200	1,736,000	249,300	131,100	139,300	78,400
Solid Waste (cu yds/year)	3,500	6,900	156,300	5,400	7,600	5,100	2,900

[a]Since these projections are based on the Charleston Input-Output Model which was developed in late 1968, these projections are for the year 1969.

[b]This category represents 100 new residents of the retirement community.

[c]This figure is based on Impacted Area Funds.

SOURCE: Computed from tables in the Appendix.

Textiles and Apparel

The textiles and apparel industry already has some start in Beaufort County. It is an industry which traditionally has been labor-oriented and able to make use of relatively low-skilled workers. Table 8 shows that 100 new jobs in the textiles and apparel industry in Beaufort County would generate, directly or indirectly, almost $2 million annually in increased local sales and slightly more than $1.1 million in increased personal income. These 100 new textiles and apparel jobs would result in a total of 119 new jobs in the County. These jobs would also produce $71,200 in annual local taxes per year. State taxes generated would amount to $113,800 per year.

As noted above, textiles and apparel may have very different effects upon the environment, depending on the type of operations. On the average, 100 new jobs in the textiles and apparel industry would produce 470,200 pounds of BOD, 3,500 pounds of SO_2, 4,700 pounds of particulate matter and 6,900 cubic yards of solid waste per year.

Lumber and Wood Products

Lumber and wood products manufacturing, including pulp and paper operations, is traditionally resource-oriented and tends to locate in areas with a plentiful supply of timber and water. Both of these resources are abundant in the Beaufort County area. Table 8 shows that 100 new workers in the lumber and wood products industry in Beaufort County could be expected, directly and indirectly, to increase local sales by about $2 million and personal income by more than $980,000 per year. These 100 workers in the lumber and wood products industry would generate a total of 114 new jobs in the County. Table 8 also shows that these 100 new jobs would produce $11,800 in local tax revenue and $138,400 in state tax revenue annually.

The lumber and wood products industry has significant environmental impacts. Table 8 indicates that 100 new jobs in the industry will result in 1,736,000 pounds of BOD, 3,500 pounds of SO_2, 1,552,200 pounds of particulates and 156,300 cubic yards of solid waste per year.

Chemicals

Although currently there is only a small chemical manufacturing operation in Beaufort County, the BASF controversy arose out of the announced plans of a chemical manufacturing firm to locate in the County. Table 8 shows that 100 new workers in the chemical industry would generate, directly and indirectly, approximately $2.1 million in increased sales and $1.3 million in increased personal income in the County. These 100 new jobs would result in a total of 118 new jobs in the County. They would also generate around $27,000 in local and county taxes and $94,800 in state taxes per year.

The category of chemical manufacturing is a broad one, encompassing everything from fertilizer operations to organic dyes. Consequently, the environmental repercussions of 100 new chemical jobs are highly sensitive to the type of operation. In general, however, 100 new chemical workers in Beaufort County could be expected to result in increases of about 249,300 pounds of BOD, 3,900 pounds of SO_2, 4,100 pounds of particulates and 5,400 cubic yards of solid waste per year.

Tourism and Recreation

We noted in Part II that tourism and recreation activities have recently become an important component of the economic base of Beaufort County. Further growth of this industry is not only possible but probable if environmental conditions continue to be favorable. Table 8 shows that each 100 new jobs in tourism and recreation activities would stimulate, directly and indirectly, about $2.3 million annually in increased local sales and $1.5 million in increased personal income in Beaufort County. These 100 new jobs would also stimulate 26 additional jobs in related industries in the County, so that for every gain of 100 jobs in tourism and recreation, Beaufort County realizes a total increase of 126 jobs. Tourism and recreation activities also generate tax revenue. For each 100 new jobs, local and county governments will realize approximately $12,500 in increased revenue and State government will realize approximately $151,400 per year.

Generally, tourism and recreation is considered to be a "clean" type of development, i.e., it generates very little environmental pollution. However, Table 8 shows that this may be a misconception. Each 100 new jobs in tourism and recreation activities can be expected to produce 131,100 pounds of BOD, 17,300 pounds of SO_2, 19,200 pounds of particulate matter and 7,600 cubic yards of solid waste per year. These relatively high residual outputs result from the large amount of waste generated by hotels and lodging places and eating and drinking places, and by the large amount of gaseous wastes resulting from automobile traffic. Moreover, the indirect effects of tourism and recreation activities are largely felt locally, which means that most of the pollution is felt locally rather than being exported (as would be the case with industries which purchased most of their inputs outside the County).

Retirement Community Development

Development of real estate for retirement communities has been proceeding at a rather rapid rate in Beaufort County in recent years. Substantial developments have materialized on both Hilton Head Island and Fripp Island. Although the real estate for such development will be eventually exhausted, retirement community development is likely to continue in Beaufort County for several years. To the extent that this development brings in money from outside the County, it is an export activity and a legitimate part of the economic base of the County. Since development of retirement communities is more often thought of in terms of new residents, the estimates shown here are based on 100 new residents rather than 100 new jobs. The initial assumption is that each lot sale potentially secures an average of three new residents.*

Table 8 shows that 100 new residents in retirement community developments in Beaufort County stimulate an increase, directly and indirectly, in annual sales in the County of almost $900,000 and in annual personal income of more than $670,000. Approximately 15 new jobs, spread across several sectors of the local economy, are needed to service these new residents. Under present assessment and millage rates, these 100 new residents can be expected to generate $4,900 in local and county taxes and $29,200 in state taxes annually.

In the main, retirement communities generate only household waste; consequently, the environmental repercussions of such developments are minor. Each 100 new residents could be expected to produce an increase of about 139,300 pounds of BOD, 2,700 pounds of SO_2, 3,800 pounds of particulate matter and 5,100 cubic yards of solid waste per year.

Military Activities

Military activities represent one of the most important components of the economic base of Beaufort County. Such activity is almost inherently unstable, being highly sensitive to political conditions. The estimates in Table 8, therefore, can be interpreted as indicators of the positive impacts of growth in military operations in Beaufort County or, conversely, as a measure of the negative impacts of reductions in military activities in the County. One hundred new jobs in military activities is taken to represent a total of 100 civilian and military personnel (including recruits) stationed in the County.

Table 8 shows that 100 military-related personnel account, directly and indirectly, for around $911,000 in annual sales and almost $400,000 in personal income in Beaufort County. These 100 military-related jobs generate a total of 109 jobs in the County. Since the military does not pay taxes, no local tax revenue is generated directly by military activities, but areas with military bases commonly receive Impacted Area Funds in lieu of taxes. Table 8 shows that these Impacted Area Funds amount to about $2,800 per year for each 100 military-related jobs in the County. Military activities do stimulate sales which produce State taxes, however, and 100 military-related jobs account for about $79,100 in State tax revenue annually.

There are environmental linkages associated with military activities, just as with all other types of human endeavor. Table 8 shows that each 100 military-related jobs in Beaufort County account for 78,400 pounds of BOD, 1,500 pounds of SO_2, 2,100 pounds of particulate matter and 2,900 cubic yards of solid waste per year.

Comparison of Impacts

Although we have examined in Table 8 the impacts of each of the seven types of development on nine economic and ecological variables, we can simplify our comparisons between the seven types of development by concentrating on a few key variables. In Section II, we noted that Beaufort County needs new jobs and an increased tax base. Table 8 shows that tourism and recreation activities will produce more jobs per 100 new jobs in the industry than any of the other six types of developments. In terms of total contributions (i.e., local and state taxes added together), tourism and recreation activities also show up fairly well, as they represent the second most important industry in regard to tax impact. They are surpassed only by the textiles and apparel industry in tax payments. Textiles and apparel, chemicals and lumber and wood products manufacturing follow closely in importance of economic impact. Table 8 shows that between the four abovementioned development alternatives and the remaining three — military, food and kindred products manufacturing and retirement community development—a relatively wide gap in economic impact exists. This is especially true of the amount of local and state tax contributions. Food and kindred products and military activities generate approximately the same amount of jobs and tax payments. Retirement community developments generate not only the least amount of jobs of the seven types of economic development but also make the smallest contributions to local and state taxes.

With regard to ecologic impacts, air and water pollution are probably of greatest interest. While BOD is a measure of only one type of water pollution (and perhaps not the most serious type), we may note that lumber and wood products industries appear to offer the most serious threat to water quality of any of the seven types of developments under analysis. Textiles and apparel and food and kindred products manufacturing are also relatively serious threats to water quality, however. Lumber and wood products industry also produce large quantities of air pollutants in the form of particulates, and tourism and recreation activities produce sizeable quantities of both SO_2 and particulates. Military and retirement community development is consistently low, however, in terms of detrimental ecologic impacts. The projected ecologic impact of chemical manufacturing lies somewhere between the

*This assumption is based on a telephone conversation with Mr. Fred Hack, President of the Hilton Head Company.

extremes of relatively minor and relatively severe pollution threats.

Summary

The analysis of seven types of economic development for Beaufort County presented in this chapter shows that four of the seven types of development examined—tourism and recreation, textiles and apparel, chemical and lumber and wood products industries—would each have beneficial effects upon the local economy of approximately the same magnitude. Yet their development is shown to have some severe environmental disadvantages, at least under conditions of current technology and recent levels of waste treatment. Other types of development of comparable size, such as food processing and military activities and retirement community developments, have less serious environmental consequences, but they also produce fewer economic benefits. Thus, a classic dilemma emerges for Beaufort County: It can opt for economic benefits in the form of development of industries such as tourism and recreation, textiles and apparel, chemical or lumber and wood products and risk environmental pollution, or it can opt for industries with low potential for environmental damage, but also with relatively weak economic benefits. In a very real way, trade-offs between environmental quality and pecuniary economic benefits seem to be necessary in Beaufort County. An assessment of the best course of action for the future of Beaufort County requires, therefore, analysis of the values which local residents place on environmental quality and their willingness to trade greater or lesser quantities of that environmental quality for monetary income. In the next section, we will turn to such an analysis.

PART IV
Attitudes Toward Environmental Quality

Introduction

The first part of this chapter will introduce a conceptual framework within which the demand for and value of environmental goods may be examined. The remaining sections will describe an experiment which was conducted in Beaufort County, South Carolina, in the summer of 1970. This experiment was an attempt to apply the theory to an actual empirical investigation of public attitudes toward environmental goods.

*Willingness-to-Pay as a Measure of the Value of Environmental Goods**

There are no markets, as we commonly define the terms, for environmental goods such as clean air and clean water. We do not go out and purchase so many units of water quality and air quality as we do pounds of hamburger, quarts of milk, and numerous other items.

However, we do know from experience that such environmental goods are desired by the public and that the public is willing to make some sacrifice to obtain these goods. For example, consider the expense in both time and money incurred by inland residents in making vacation trips to the costal areas.

If it were possible to measure the amount of this sacrifice, then we would have some measure of the value the public places on such environmental goods. By the same token, we would also have a measure of the damages which would result if these same environmental goods were denied to society as a result of pollution.

Let us begin the analysis by defining two categories of goods: 1) "marketable" consumption goods for which organized markets exist and price or value can be readily determined; and 2) "nonmarketable" environmental goods for which no organized markets exist and price or value cannot be readily determined.

Given the two categories of goods, we define our measure of the value of a specified amount of environmental goods as the amount of marketable goods which individuals are willing to give up in order to obtain these environmental goods.

In essence, we are postulating a trade-off situation in which marketable consumption goods are traded for environmental goods. Given that the value of a specified amount of marketable goods can be expressed in dollar terms, it is thus possible to define the value of a specified amount of environmental goods in the same terms.

At any point in time, there exists a fixed stock of natural resources, such as clean water and clean air, even in the absence of human polluting activities. For example, at any given point in time under any given atmospheric or hydrologic conditions, only so much clean water and clean air are available for use in a geographic area. There exist competing demands for the use of these resources. On the one hand, individuals want to consume clean water and clean air as environmental goods, e.g., to support basic life processes. In competition with this demand is a demand to use these resources in the production of marketable goods. Because of the nature of most productive processes, the water and air resources used in the production of these latter goods are altered in form through the introduction of materials we call pollutants. Consequently, the use of water and air to produce these marketable goods reduces the quantity of clean water and clean air available for consumption as environmental goods unless the water and air are treated in some way to remove or reduce the polluting materials before such resources are put back into the environment. Because this treatment requires installation of additional

*This section draws heavily from Hite and Laurent [4].

equipment and processes, it increases the monetary costs of producing these marketable goods and reduces the quantity of such goods offered at any given budget level. Hence, the preservation of clean water and clean air as environmental goods reduces the quantity of marketable goods available to individuals with a given budget of total expendable money available. The implication of such reasoning is that additional environmental goods can be obtained only by giving up some marketable goods, and additional marketable goods can only be obtained by giving up some environmental goods.

Empirical Application of the Theory

A household survey was conducted in Beaufort County, South Carolina, during the summer of 1970.* Part of the questionnaire which was administered to the sample households was concerned with respondent attitudes toward environmental goods such as clean water and clear air and the values placed on different levels of purity of water and air.

Analysis of Responses to Two Questions

The analysis which follows is based upon the responses to questions on water and air quality, respectively, which were included in the survey.

The theoretical foundation for these two questions is a variant of the trade-off analysis presented above. In these questions, respondents were asked what percentage of their total income they would be willing to give up (i.e., how much consumption of all other goods they would be willing to forego) in order to obtain water and air of a specified quality.

Willingness-to-Pay for Water Quality

In one question, respondents were confronted with the following situation:

> Assume that the only way you could have clean water in the Beaufort area streams would be for individual citizens such as yourself to go together and pay for it in the form of taxes, or by some other method. For the present, forget about who might be to blame for the pollution.

They were then asked what percentage of their total income they would be willing to give up in order to have (buy) water of each of four qualities: (1) clean enough to have no unnatural smell associated with it; (2) clean enough to fish out of safely; (3) clean enough to swim in safely; and (4) for fresh water, safe to drink with standard treatment. These descriptive criteria were, of necessity, of a non-technical nature; however, comparable technical criteria do exist for each quality level described above. Table 9 shows the correspondence between the nontechnical and technical criteria for each water quality level.

*See Part 1 of this report for a description of this survey.

TABLE 9. Non-technical and Comparable Technical Specifications of Four Levels of Water Quality

Quality Level	*Non-technical Specification*	*Technical Criteria*
Water Quality I	Safe to drink	DO≧5ppm; Coliform≦200/100mℓ
Water Quality II	Clean enough to swim safely	DO≧5ppm; Coliform≦ 20/100mℓ
Water Quality III	Clean enough to fish safely	DO≧4ppm
Water Quality IV	No unnatural smell	DO≧3ppm

SOURCE: South Carolina Pollution Control Authority, *Water Classification Standards System for the State of South Carolina,* Columbia, December 1967.

STATISTICAL ANALYSIS OF RESPONSES

Appropriate statistical tests were employed to analyze the responses.* The tests were conducted in an attempt to ascertain what factor or factors weigh most heavily in an individual's subjective evaluation of the value of the present state of the environment of Beaufort County. Specifically the relationship between the reported figure which indicated willingness-to-pay and each of several variables—income, area of residence, and water quality—was examined.

The levels of willingness-to-pay and income were obtained directly from the survey questionnaire. Area of residence was determined from the Beaufort County property tax rolls, which report personal property by township districts. Except in the case of one township, these townships can be classified into one of two geographic areas or zones of residence. These zones were the part of Beaufort County north of Port Royal Sound and the part south of Port Royal Sound. All respondents were classified into one of these two zones depending on the township designation of the location of the respective personal property. In the case of the one township that did not have a geographic break along Port Royal Sound, respondents were located on a map of Beaufort County and classified according to their relative location with regard to the Sound.

Statistically significant relationships were found

*Specifically analysis-of-variance and least-squares-regression techniques were utilized. See [2].

to exist between willingness-to-pay and each of the following variables—income, zone of residence, and water quality level I (i.e., fresh water safe to drink with standard treatment). In fact, the tests revealed that the odds were only 1 in 20 that random chance would have shown the relationships. Thus, we can be reasonably certain that a significant relationship did exist between willingness-to-pay and each of these variables.

The tests revealed a direct relationship between income and expressed willingness-to-pay. There was an obvious difference in direction of influence of the zone of residence variables as between respondents located north and south of Port Royal Sound. In relation to the total area, the relationship between residence location south of the Sound and willingness-to-pay was a positive one; for residence location north of the Sound, the relationship was a negative one. These relationships can be interpreted as follows: residents who lived south of the Sound appeared to value the environment more highly than residents who lived north of the Sound.*

The relationship between water quality level I, the highest water quality level designated on the questionnaire, and willingness-to-pay was a positive one. The relationships between each of the other three water quality levels and willingness-to-pay were not significant. Thus, it can be surmised that the primary concern of respondents in regards to water quality was to have a supply of safe drinking water. They evidently believed that if water were kept this pure all lower quality levels would be taken care of automatically.

*It should be remembered that both the proposed BASF plant site and the Hilton Head Island resort community are included in the residence zone designated "south of Port Royal Sound."

Willingness-To-Pay For Air Quality

A question, similar to the one on water quality, was asked in regard to air quality. Again, the respondent was confronted with a hypothetical market situation in which, this time, he and his fellow citizens were asked what percentage of their total income they would be willing to give up in order to have (buy) air of each of four qualities: (1) there is no possible threat to health; (2) it does not discolor paint, draperies, and other items; (3) there is no artificial haze in the sky; and (4) there is no noticeable smell as a result of air pollution. Again, comparable technical criteria exist for the descriptive criteria presented in the questionnaire. Table 10 shows the correspondence between the non-technical and technical criteria.

TABLE 10. Non-technical and Comparable Technical Specifications of Four Levels of Air Quality

Quality Level	*Non-technical Specifications*	*Technical Criteria*
Air Quality I	No possible threat to health	Particulates $\leq 80\ \mu g/m^3$ $SO_2 \leq 0.04$ ppm
Air Quality II	No soiling of materials	Particulates 60—180 $\mu g/m^3$; $SO_2 \leq 0.09$ ppm
Air Quality III	No perceptible haze or smog	Particulates $\leq 150\ \mu g/m^3$; $SO_2 \leq 0.10$ ppm
Air Quality IV	No perceptible odor	$SO_2 \leq 0.06$ ppm[a]

[a]Particulates are not normally associated with odor.

SOURCE: National Air Pollution Control Administration, *Air Quality Criteria for Particulate Matter*, Publication No. AP-49, U. S. Public Health Service, Washington, D. C., 1969; and National Air Pollution Control Administration, *Air Quality Criteria for Sulfur Oxides*, Publication No. AP-50, U. S. Public Health Service, Washington, D. C., 1969.

STATISTICAL ANALYSIS OF RESPONSES

As in the water quality analysis, appropriate statistical tests were used in analyzing the responses.* The analysis was again directed toward examining the relationship between expressed willingness-to-pay and each of several variables—income, zone of residence, and quality level.**

The statistical tests yielded results similar to those of the water quality analysis. Significant relationships were found to exist between willingness-to-pay and each of four variables—income, both zones of residence, and air quality level I (i.e., air engendering no threat to health at all). As with the water quality analysis, the tests indicated that the odds were only 1 in 20 that random chance would have shown the relationships. Thus, we can place the same amount of confidence in these relationships as we did in the relationships discussed in the water quality analysis.

Income and expressed willingness-to-pay were found to be directly related, i.e., as income varied so did willingness-to-pay. As with the water quality analysis, there was an obvious difference in direction of influence of the zone of residence variables

*See the preceding explanatory footnote for the type of tests which were administered.

**With the exception of the quality variables and the willingness-to-pay variable, all terms are defined as they were for the water quality analysis. The two exceptions relate to air quality and willingness-to-pay for the same respectively.

as between respondents located north and south of Port Royal Sound. The relationship between residence location south of the Sound and willingness-to-pay was a positive one; the relationship between residence location north of the Sound and willingness-to-pay was a negative one.

In regard to the quality of air, the relationship between air quality level I and expressed willingness-to-pay was a positive one. The relationships between each of the other three air quality levels and willingness-to-pay were not significant. Thus, it can be surmised that the primary concern of respondents in regard to air quality is to protect their health from any and all danger. As with water quality, respondents evidently believed that maintenance of air free from threats to health would insure that all lower air quality levels would be taken care of automatically.

Aggegate Totals

The sample data were "blown up" and thus expanded to the total population of the county. The aggregate sums for water and air quality are shown in Tables 11 and 12 respectively.

In Table 11 the columns are arranged, left-to-right, in ascending order of purity by engineering or technical standards. That is, technically speaking, "safe drinking water" represents the highest quality level and "avoid unpleasant smell" represents the lowest. Examining the column totals, however, we see that the respondent households indicated a different ordering. They rated "safe drinking water" as the most valuable quality level. Next in importance was "clean enough to fish safely," followed by "avoid unpleasant smell" and "clean enough to swim safely" in that order. We note that the difference in totals for these last two categories is minor indeed when compared with the difference in totals for drinking and fishing purposes and the difference between these two totals and the totals for odor and swimming.

TABLE 11. Willingness-to-Pay in Aggregate Sums for Four Alternative Levels of Water Quality by Household Income Class, Beaufort County, South Carolina, 1970

Household Income Class	*Amount to:* Avoid Unpleasant Smell	Clean Enough to Fish Safely	Clean Enough to Swim Safely	Safe Drinking Water
Under $3,000	$ 13,750	$ 18,750	$ 13,750	$ 32,750
3,000- 5,999	60,000	69,410	76,910	163,330
6,000- 8,999	206,250	253,160	221,910	466,330
9,000-11,999	356,250	290,910	367,500	585,660
12,000-14,999	264,410	258,750	264,410	478,160
15,000-17,999	343,750	343,750	357,500	619,160
18-000-20,999	130,000	130,000	130,000	390,000
$21,000 and over	682,500	1,032,500	595,000	1,226,910
Totals	$2,056,910	$2,397,230	$2,026,980	$3,962,300
Per Household	$ 38	$ 45	$ 38	$ 75

SOURCE: Calculated from Household Survey of Beaufort County, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C., Summer 1970.

TABLE 12. Willingness-to-Pay in Aggregate Sums for Four Alternative Levels of Air Quality by Household Income Class, Beaufort County, South Carolina, 1970

Household Income Class	*Amount to:* Avoid Perceptible Odor	Avoid Haze or Smog	Avoid Soiling of Materials	Insure no Threat to Health
Under $3,000	$ 18,750	$ 13,750	$ 13,750	$ 46,750
3,000- 5,999	67,500	37,500	41,250	138,750
6,000- 8,999	156,250	162,500	150,000	860,660
9,000-11,999	389,410	369,250	166,250	853,160
12,000-14,999	374,080	227,830	205,330	385,330
15,000-17,999	343,750	357,500	357,500	632,500
18,000-20,999	177,910	145,410	161,660	405,410
$21,000 and over	673,750	761,250	708,750	1,422,080
Totals	$2,201,400	$2,074,990	$1,804,490	$4,744,640
Per Household	$ 42	$ 39	$ 34	$ 90

SOURCE: Calculated from Household Survey of Beaufort County, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C., Summer 1970.

Table 12 shows willingness-to-pay, in aggregate sums, for four levels of air quality. The tabular ordering of these quality levels represents increasing technical standards as we move from left to right. From an examination of the totals, we can see that the respondent ordering of air quality was different from the technical one. However, this difference was not as evident as that found in the water analysis. By far, "insure no threat to health" rated the highest priority, but the differences in totals among the other three air quality levels were not appreciable.

Possible Sources of Bias in Data

What kind or kinds of bias might we find in the responses to the questions on water and air quality? Several possible sources of bias will be discussed in this section.

It cannot be denied that some respondents, upon being asked the questions, did not take the questions seriously. After all, the questions did force the respondent to place himself in a situation in which he was forced to purchase clean water and clean air or go without these all together.

Moreover, the distinction between what respondents would be willing to pay and what they would actually have to pay should be made. We can surmise that respondents tend to over-estimate the value of environmental goods in the former case and under-estimate in the latter. So long as the respondent is not forced to make an actual payment for these goods and yet is assured of their provision by some regulatory agency, it is to his advantage to over-estimate their value. The higher the value he places on these goods, the more he believes will be provided. However, if he thinks he may be forced to come across with an actual payment, he has a tendency to under-estimate the value in the hope that he can obtain the maximum amount at the minimum price.

The questions on water and air quality asked for expressed willingness-to-pay. Thus, the responses may have over-estimated the value of environmental goods. Conceptually, however, this over-estimation presents few serious problems, provided respondents consistently over-estimate these values.

The figures in both tables were put on a per household basis.* These per household figures are average figures in the sense that they represent what each household in the county, on the average, is willing to pay for each of the water quality and air quality levels.

There exist statistical procedures whereby we can make inferences for the entire population from the estimates our sample of households gives us. We calculate a confidence interval or range for our estimates of per household willingness-to-pay. We can choose any degree of confidence that we desire, but for present purposes we will say that the procedure which leads us to say that the true population value lies within the interval which is calculated will result in our making 95 correct statements out of 100, on the average.* Table 13 shows the intervals which were calculated for the water quality data. Table 14 shows the same for the air quality data.

TABLE 13. Ninety-five Percent Confidence Intervals on Per Household Willingness-to-Pay for Water Quality by Quality Level, Beaufort County, South Carolina, 1970

Quality Level	*Confidence Interval in Dollars*
Water Quality Level I	$ 61-89
Water Quality Level II	31-45
Water Quality Level III	40-50
Water Quality Level IV	34-42

SOURCE: Calculated from Household Survey of Beaufort County, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C., Summer 1970.

TABLE 14. Ninety-five Percent Confidence Intervals on Per Household Willingness-to-Pay for Air Quality by Quality Level, Beaufort County, South Carolina, 1970

Quality Level	*Confidence Interval in Dollars*
Air Quality Level I	$ 68-112
Air Quality Level II	27- 41
Air Quality Level III	31- 47
Air Quality Level IV	37- 47

SOURCE: Calculated from Household Survey of Beaufort County, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C., Summer 1970.

From a cursory examination of both tables we can see that no calculated confidence interval or range includes the value zero. Thus 95 times out of 100, we can expect to be correct when we say that residents of Beaufort County do value the environment and/or are willing to pay something to maintain or enhance it.

Previously in the analysis, we mentioned that residents who lived south of Port Royal Sound appeared to value the environment more highly than did residents who lived north of the Sound. It should be remembered that the household survey was made before the BASF Company announced the cancellation of its construction plans and while an atmosphere of distrust and suspicion was prevalent among several groups in the County. Consequently, it is entirely possible that this situation itself would accentuate the differential in willingness to pay as among residents living north and south of the Sound. Therefore, we may not have a true reading of these atti-

*See last row in each column in both tables.

*In statistical terminology, we are calculating a 95 percent confidence interval.

tudes because of the controversy which was raging in the County at the time the survey was conducted. However, some might argue that the reading of these attitudes is free of such bias because the controversy generates discussion and thought among the residents. It makes them relatively more aware of the "problems" associated with the environment. Their responses, in turn, would reflect their true attitudes.

Summary

One of the main purposes of the household survey was to ascertain attitudes of residents toward the environment of Beaufort County. We have made a somewhat comprehensive analysis of these attitudes in regard to clean water and clean air. One final note of caution in interpreting the estimates of willingness-to-pay reported in this chapter may be in order. As noted earlier, our estimates are based on the response of the interviewee to a hypothetical situation which he may not have understood fully. Moreover, given each interviewee's personal assessment of possible uses of the estimates derived from his response, he may either have inflated his answer above his true willingness-to-pay (on the judgment that he would not, in fact, be forced to pay at all), or he may have deflated his answer (on the judgment that he would possibly have had to actually pay the amount he suggested).

While conceding that estimates are subject to considerable reservation, they show that residents of Beaufort County are willing to make rather sizeable sacrifices in income in order to preserve a high quality environment.

PART V

Summary and Conclusions

Introduction

In the preceding four parts we have noted the existing economic conditions in Beaufort County, analyzed the economic and ecologic impacts of seven different types of activities which might be developed to expand the economic base of the County, and attempted to measure the willingness of the local population to trade off environmental quality for pecuniary income. In this final chapter, we will review our findings and discuss some of the conclusions the findings seem to justify.

Review of Findings

Although all of the analyses which we report are subject to limitations imposed by certain assumptions which we were required to make and by the quality of the data we were able to obtain, the following points now seem rather clear:

1. Beaufort County's traditional economic base of agriculture, forestry and fisheries has been releasing human resources at a rapid rate. These traditional activities are not likely to disappear from the County's economy, but they can no longer be depended upon to support a growing population and the public services which such a population will require. Military activities have largely replaced agriculture, forestry and fisheries in the County's economic base, but the level of local military operations is politically sensitive and likely to be unstable. Beaufort County must seek activities to form a new and expanding economic base if the County is to grow and prosper in the years ahead. These activities must provide both increased jobs and increased tax revenues.
2. To a large extent, economic development in Beaufort County will require trade-offs between environmental quality and pecuniary benefits (e.g., jobs, income, taxes, etc.). Of the seven types of economic development which were examined in Part III, four (tourism and recreation, textiles and apparel, chemicals and lumber and wood products activities) appear to offer the greatest pecuniary returns, but under current technology, such industries will also create a threat of considerable environmental damage. Lnght industry (such as food processing) and military and retirement community developments pose less environ mental threats, but also produce fewer pecuniary benefits.
3. The residents of Beaufort County appear to place a rather high value on environmental quality, especially clean air and clean water, and are willing to make rather sizeable sacrifices in income in order to preserve a high quality environment. There is considerable variation in attitude toward such sacrifices between various income groups and between persons living north and south of Port Royal Sound. Those living south of the Sound indicated a greater willingness to sacrifice income for environmental quality than those living north of the Sound.

The Options for the Economic Future of Beaufort County

Given the findings reported in this study and summarized above, we can identify at least three distinct options for the economic future of Beaufort County:

1. Beaufort County can choose to risk local environmental quality and opt for the development of economic activities which generate relatively high monetary benefits. The payoffs from such an option in terms of income, jobs and tax revenue would probably be sig-

nificant, and the actual damage to the environment might be very slight. But this sort of development, especially that of heavy industry, carries with it the potential for serious pollution problems and, at best, such development carries a risk of at least periodic episodes of air and water pollution.

2. Another option for Beaufort County lies at the opposite extreme to Option #1. The County may chose to do nothing toward attracting activities for a new economic base. If military activities remain at about 1970 levels, such an option may mean that the County will suffer little in the way of population decline or severe economic hardship. But if the military activities in the County are decreased considerably, there would probably be an eventually significant population decline. In addition, a decrease in military activities in the County would result in a curtailment of Impacted Area Funds, necessitating either a substantial increase in the local tax levy or a deterioration in local government services.

3. The third option for Beaufort County involves pursuit of a middle course. The development of light industry such as food processing might be encouraged, as well as further development of retirement-type communities in the County. While these activities will not produce as large a pecuniary payoff in terms of income, jobs and tax monies as those development activities referred to in Option #1, they will, if developed at sufficient scale, provide the economic base needed to sustain a stable or modestly growing population and a level of public services approaching the State average. Although light industry and retirement communities do account for some measure of environmental degradation, the effect on the environment is relatively minor. In fact, if military operations in the County were reduced concurrently with development of such activities, it is quite possible there would be no net reduction at all in environmental quality.

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CHAPTER FIVE

APPENDICES

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Appendix to Geology and Ground Water Hydrology

PART I

Drill Hole Log—
Beaufort County, South Carolina

Drill Hole: Beaufort #1 Date: 5-30-70

Location: On South Carolina 170 about ¼ mile North of Chechessee bridge on south side of the road.

Drilling Characteristics:

Hard	*Easy*
	10′
18′	20′
24′ ledgey	
32′	
42′	
47′ very	
55′ can't penetrate further	pulled at 55′

General Field Description

0-2′ : Gray silty clay.

2-5′ : Bagged as 0-5.

10-26′: Becomes coarser and lighter, light brownish gray.

26-28′: Coarse sand and clay (medium greenish gray) mixed in gradational zone.

28-35′: Silty clay, wood or fossil fragments, medium grayish green tight clay with wood fragments.

35-48′: Clay becomes sandy, still greenish.

48-50′: Sandy clay grades to silty clay from 47′ downwards with chert pebbles, then at 48′ sharp break to very clean coarse sand.

50-55′: Sand as in 48-50′ but contaminated with clay.

On bit were small sliver like pieces of medium grayish buff clay which may be the unpenetratable layer. These were not calcareous.

Laboratory Sample Descriptions

0-5′ : Very fine sand and silt with mica flakes, medium grayish buff, moderate sorting.

5-10′: Fine sand, light buffish gray with minor fines.

10-15′: Fine to medium sand, moderate sorting, some glauconite grains, mica flakes, light buffish gray.

15-20′: Medium sand, well sorted, angular, few mica flakes, light gray or dirty white.

20-25′: Medium to fine sand, moderate sorting, mica flakes and possible? fossil fragments, dirty grayish white.

25-28′: Medium to fine sand with silt and clay, moderate to poor sorting, mica flakes.

28-30′: Mixed clay and sand; sand poor sorted, clay medium to dark greenish gray, transition zone.

30-35′: Tight clay, moderate sorting, contaminated with sand, medium to dark greenish gray.

35-40′: Clayey sand, poor sorting, dark greenish gray with mica flakes, some medium sand.

40-45′: Sandy clay, poor sorting, dark greenish gray, sand fine to medium with lots of heavy minerals.

45-48′: Sandy clay, with coarse to fine sand and a pebble, mica flakes, dark greenish gray.

48-50′: Clean medium to coarse sand, moderate to well sorted, contains mica and feldspar?, light grayish buff.

50-54′: Clayey sand, poor sorting, dark greenish gray with mica, sand coarse to fine with pebbles.

54-55′: Clayey sand, poor to moderate sorting, color slightly lighter than above sand mostly medium but fine to coarse with pebbles and streaks of light grayish buff clay.

Drill Hole: Beaufort #2

Location: Roadside park approximately ½ mile SE of bridge over the Broad River on S.C. 170. Hole is at edge of marsh behind roadside park.

Drilling Characteristics:

Hard	*Easy*
Hard breaks up to 50′ not recorded	9′
50′ (with rock bit)	51′
67′	77′
75′-80′	
81′ bouncing (scraping sounds—like rig on rock)	

General Field Description:

0-6′ : Glauconitic sand.

6-8′ : Sand and clay tightly bound.

8-14′: Sand becomes coarser.

14-15′: Coarse sand falls off rods.

15-24′: Very loose runny sand.

24-25′: Gradual change from light buffish brown to light grayish buff sand.

25-39′: Light gray sand with brown above.

29-37′: Grades back from light gray material similar to 15′-20′.

37-51′: Med. gray sand and silt intermixed and interbedded (some light gray, silt layers seen).

51-55′: Coarse light-med. gray sand with clay.

55-65′: Sand with silt and clay med. dark gray in color. Contaminated with light gray buff clay and sand from above.

65-66′: Sediment becomes more clayey.

66-70′: Sand lens in tight clay.

70-75′: Rod contains all grain sizes—very much contamination.

75-77′: Clay and sand lenses.

Drill Hole: Beaufort #3

Location: To the southeast of the southeasternmost small arms firing range at Paris Island.

Drilling Breaks:

Hard	*Easy*
42′	43′
47′	
52′	
57-58′	
59′ 66′ (sticky)	
72′	
84′	
87-88′ (same as 84′)	
106-109′ (easier than 87-88′)	
127′	

General Field Description

0-27′ : Not recorded.
28-36′ : Gray silty clays, sand becomes more coarse (but same runny material).
36-38′ : Clay content increases, hangs onto rod better.
38-40′ : Olive-green clay, silt (looks like soil with roots).
40-46′ : Gradual increase in dark colored sand grains and clayey consistency.
47′ : Decreased silt and increase clay, becomes more compact, includes a clay sand aggregated pebble and a phosphate pebble.
47-71′ : Silty sand.
71-80′ : Light colored sand-silt (*Contaminated*) fine sand silt, light gray poor to moderately sorted with? fossil frag, lms.
80-105′: Sand with silt and clay poor sorting, white to gray white (*Contaminated.*)
105-110′: Fine sand and silt (*Contaminated.*)

Drill Hole: Beaufort #4

Location: Just off traffic turn-around by golf course at Southeastern part of Paris Island.

Drilling Breaks:

Hard	*Easy*
22′ (slight and momentary)	
44-45′ (progressively stiffer)	
47′	
57′ (bouncy, stalls rotation, resists down pressure)	
62′	59′
70′	75′
85′ (impenetrable—stuck)	87′ easier

General Field Description

0-15′: Coarse sand; possibly fill.
15-20′: Fine sand and silt.
20-25′: Fine sand and silt. Higher % silt than above.
25-31′: Increase in fossil frags. coarse sand size.
32′ : Color change from med. gray to light gray, but sediment same as above.
33-42′: lighter and finer textured—more fines.
42-50′: Gradational change from light to med. gray very fine, fine sand and silt without fossils to a med. gray green sand and silt with fossil frags. (*Contaminated.*)
50-65′: Gradual decrease in sand content. May contain possible burrow structures.
65-67′: Tight gray green silty sand.
75-83′: Slight increase in sand, less runny.
83-85′: Increase in course gravelly material.
85-90′: Limestone—coarse angular gravels in top two feet.
90-95′: Light gray white med. sand with fines, poor sorting, carbonaceous, with fossil fragments.

Drill Hole: Beaufort #5

Location: Approximately 40 yards S 75°E from old water tower on E S E part of Spring Island.

Drilling Breaks:

Hard	*Easy*
48′ slight	
54-55′ progressively stiffer, but not hard	
80′	
100′	

General Field Description

0-25′: Med. buff, clayey fine sand with fossil frags. at 10-15′.
25-43′: Coarser sand with less fines and possibly more fossil frags.
43-50′: Gradual change from light med. gray coarse sand with minor fines to med. gray coarse sand with minor fines.
50-55′: Sand becomes gradually coarser with a few pebbles.
54-70′: Gradual increase in clay.
70-75′: Slight increase in fines, sand appears finer.
75-78′: Sandy clay grading downward into clay.
78-80′: Break back to sand.
80-84′: Grad. change to fine sand with silt and clay.
84-85′: Sharp break to coarse sand.
85-90′: Lenses of coarse sand (8 in.) every 1.5′ in more clayey fine sand.
90-95′: mostly clay and fine sand (*Contaminated.*)

Drill Hole: Beaufort #6 (power auger hole)
Date: 6/16/70 *Total Depth*: 90′

Location: Rose Island

Drilling Breaks:

Hard	*Easy*
10′ slightly	
39-40′ progressively harder	
40½′ impenetratable, pulled out	
47-50′ very hard, slow drilling	
50′ hard	
62′	
70′ very hard, top of limestone?	
	76½′ easy but bouncy
84′ very hard—sticky	

Total depth 90 feet.

General Field Description

0-17': Wood fragments possible soil profile, color changes from green gray above to brown below, sand, clayey to slightly clayer.
17-27': Gray sand becomes clayey with depth.
27-33': Increasing water content otherwise as above.
33-35': Shell, may be contamination.
35-40': Large wood fragments, about 37' becomes medium sand, moderately well sorted, clean.
40-70': As above.
70-75': Cap rock.
75' : Top of limestone layer.
78' : Color change, becomes light gray with shell fragments and pebbles, sample contaminated.

Drill Hole: Beaufort #7 (power auger hole) *Date*: 6/17/70 *Total Depth*: 90'

Location: Daws Island

Drilling Breaks:

Hard	*Easy*
16'	
23'	
40-48' progressively harder	
57' hard, bouncy	
62'	
	63' through bottom of cap rock
71' hard, sticky	
	78' slightly easier

Total depth 90 feet.

General Field Description

0-10': Gray clay, very little sand.
10-23': Increase sand content, high organic.
23-29': Increase in grain size to medium sand.
29-35': Change to dense green clay, silt and fine sand, sample 29-30 contaminated.
35-51': Decrease in water content, sediment densely compacted.
51-56': Clean quartz sand, medium grained, with shell fragments and green clay material.
56-61': Green clay with many shells.
61-64': Green clay as above but with increased water content.
64-70': White marl like clay mixed with green clay clay and silt, very soupy.
70' : Cemented limestone pebbles from cap rock.
70-75': Traces of white to gray limestone but mostly green clay with high water content, probably from up the hole.

Drill Hole: Beaufort #8 (power auger hole) *Date*: 6/18/70 *Total Depth*: 85'

Location: Bay Point

Drilling Breaks:

Hard	*Easy*
22' moderate	
31-35' stiff clay	
40' very	
42' bouncy, coarse sand?, gravel?	43' but hard again, 6" easy 44'
45'	
46' very stiff	
	50' loose
57½' stiff	
64' break, sticky drilling	
	66'
67'	
	68' progressively easier
77' very stiff	

No change to 85', stopped at 85' due to caving hole at ground level.

General Field Descripition:

0-10': Slurry samples, fine to medium gray sand with shell fragments.
10-15': Fine gray-green sand with shell fragments, silghtly argillaceous, dense little water.
15-20': Same as 10-15'.
20-25': Same as 10-15' but slightly greener.
25-30': Fine to medium gray-green sand with some shell fragments and slight H_2S odor.
30-35': Same as 25-30' but slight increase in clay.
35-40': Same as above but lighter in color.
40-45': Same as 35-40'.
45-50': Gray fine sand with some clay off rods at 49'.*
55-60': Same as above but olive-green clay with fine to medium sand off rods at 59'* also mica and some small shell fragments.
75-80': Same as 70-75'.
80-85': Same as 75-80', no limestone encountered in hole.

* This sand is the result of the slip at the ground level when pulling up the auger rods.

Drill Hole: Beaufort #9 (power auger hole) *Total Depth*: 91'

Location: Doggie Island, 15 yards onto island from North side along old road.

Rock bit to start.

Hard	*Easy*
22' stiffer	
30-34' progressive, resistive but drills with rotation, sand?	
37' very hard	
	37' starting to ease a bit
46' sticky	
60' hard but not sticky	
	63'
	70'
73-79' slightly hard and bouncy	
	79'
91' more resistant	pulled at 50'?

General Field Description

0-10': Buff to gray medium and fine sand.
10-15': Buff to gray medium and fine sand slightly more gray in color.
16-25': Gradually coarser sand.
25-35': Sand becomes slightly more clayey and runny.
35' : Clean fine sand and thin (3") clay layer (very hard)
35½-42': Clayey fine sand.
42-44': Gradually changes color from medium gray to a medium lightly greenish gray.
44-50': Grades back to all medium gray.
50-55': Contains some small pebbles.
59' : Limestone material by acid test.
55-60': Shells in medium gray sand matrix.
61-70': Limestone contaminated with medium gray medium sand and some clay.
70-75': Fine sand size limestone, washed off rods.
75-80': As above, mostly contaminated.

Drill Hole: Beaufort #10 (power auger hole)
Date: 6/30/70 *Total Depth*: 90'

Location: Hole placed at Northeast corner of junction of U. S. 278 and Beaufort County road S-7-50, 15 feet West Southwest and level with unmarked USCGS bench mark G-78.

Drilling Breaks:

Hard	*Easy*
52' slight	?
54' slight	
56' becomes slightly sticky	
60' hard but not sticky	
70'	
74'	
91' very resistant to down pressure, stuck in clay so can't rotate very far, on re-entry, hard and bouncy.	

Much migration up rods on first pull.

General Field Description

0-5' : Slurry from under truck buff to gray fine sand and silt.
5-15': Gray fine sand and silt material seems in place.
15-30': Grades into more sticky clayey sand, less water, possibly may have migrated up.
29' : Changes from medium gray runny clayey sand to clayey sand, possibly higher clay content.
30-35': Becomes gradually coarser sand in clayey fine and matrix.
35-40': Still coarse sand but increase in silt clay content of sediment.
39' : Sharp change to greenish gray very fine sand clay.
40-45': Not pure greenish gray clay, contaminated with gray coarse sand and clay from above.
45-56': Greenish gray material gradually becomes more consolidated (sample for micro fossils).
56' : Clean sand, medium to coarse grained well sorted, appears in lenses.
57-60': Greenish gray material becomes less consolidated.
60-65': Three 2" thick lenses of coarse sand, very clean, in compact clay.
65-90': No samples due to much slurrying, pulling up, re-drilling and reverse rotation.

Pulled at 65 feet, total depth 90 feet.

Drill Hole: Beaufort #11 (power auger hole)
Date: 7/2/70 *Total Depth*: 150'

Location: At prescribed location in East part of Fort Walker on Hilton Head.

Drilling Breaks:

Hard	*Easy*
55-60' slightly	
78' sticky	
no drilling breaks recorded between 80' and 100' due to drilling mixup	
118' hard but turns easy, sand?	
144' very hard, impenetrable for about 2 minutes, then very resistant	
	145' easy

Total depth 150. Pulled at 80 feet and re-entered with rock bit.

General Field Description

0-5' : Slurry sample from under truck medium to fine sand and silt.
5-15' : Material brought up from below the water at 15' is not buff but medium gray sand with fines (does not compare to 18' water well).
15-20' : Slight increase in fines in the medium gray clayey medium sand. More clean very fine sand at 15' but may be due to pulling augers out of ground: usually sand is cleaner at joints possibly due to the water going into the auger connections.
20-25' : Large thick shelled clam in sample (remove for CO_3 analysis).
20-24' : More coarse sand with fossil fragments.
24-30' : Becomes more clayey again.
30-35' : Looks like clayey medium sand, fairly compact and plastic, seems in place. Gradational change through interval from medium gray color to medium grayish blue-green.
35-45' : Decreases in clay content and increase in water content.
about 45': Gradual increase in clay content.
45-60' : Becomes coarser, less clay content and more watery.

60-65' : Medium sand, light grayish blue-green inter bedded with medium sand dark greenish gray, in beds from 1 mm to 2 cm thick in random thickness for each material (most beds distorted, some are not) sample contaminated with medium gray clayey sand.
65-70' : Sample is very fine sand, silt and clay greenish gray, tight. All shell fragments are contaminated on outside of augers.
70-95' : Beds of light sand as in 55-60' about 5 mm thick.
95-105': Slightly more sandy.
105-110': Becomes more gritty.
110-115': Becomes more gritty toward bottom, at 114-115' limestone pebbles found on rod.
117' : Limestone on inside of auger flights.

Samples below 80 feet may be much slurried, homogenized and contaminated. Pulled at 80 feet.

Drill Hole: Beaufort #12 *Total Depth*: 62'

Location: At traffic circle at junction of S. C. 71 and 281 about ½ mile north of Broad River.

General Field Description:

0-5' : Slurried up and removed from under truck, orange to tan fine sand and clay.
5-10': Fine buff sand, well sorted, with some black specks, Phosphate?
10-20': Same as above with some shell fragments?
20-26': Fine buff sand, well sorted, with some quartz pebbles. Also clay and silt increases approx. 23'.
26-30': Fine gray sand and clay with quartz shell fragments similar to above. Drill break approx. this depth.
30-35': Fine gray sand and clay with shell fragments and quartz pebbles. Also phosphate granules.
35-40': Dark gray medium to coarse sand with green clay, phosphate granules and coarse grains in ——————.
40-45': Green gray clay, no sand or silt apparent, drilling break at 47', much more difficult to penetrate.
45-50': Dark gray clay, very sticky, no sand or silt.
50-55': Dark gray clay, very sticky, no sand, some coarse grained sand lenses.
55-60': Similar to above but less sticky.
62' : Cap rock, hard drilling.

Drill Hole: Beaufort #14 (power auger hole)
Date: 8/3/70 *Total Depth*: 97'

Location: Parris Island quadrangle (7.5'); at Lands End on St. Helena Island approximately 200' from end of pavement and approximately 200' east of last house at Lands End, about 1.3 miles S. 16°W. of intersection at Lands End Road and Seaside Road and about 2.15 miles E. 31° S. of Ribaut Monument on Parris Island.

Collar Elevation: 4' (est. above MHW).
Logged by: D. A. Duncan.

Description
Depth
0-2' : Dark chocolate-brown fine sand to silty clay with high organic content.
2-5' : Medium brown fine sand with slight organic content. Small percent phosphate noted.
5-20': Fine to medium grained gray-green sand with sparse shell fragments.
20-30': Gray-green fine to medium grained sand with sparse clay lenses and shell material (shell material abundant 25-30').
30-35': Light gray, fine grained sand with clay lenses and shell fragments.
35-53': Light gray, fine to medium grained sand with clay lenses and abundance of shell fragments. Drilling at 46' gets sticky (drills like stiff clay).
53-60': Gray fine to medium grained sand with abundant shell material and sparse gravel and chert fragments (?) and/or phosphate pebbles (?) Slight drilling break at 50' (crunchy).

60-75': Gray with greenish tint, fine grained sand with sparse gravel size material and some clay.

75-97': Light olive green silty clay with fine to medium grained sand stringers and sparse gravel size material which becomes more abundant after 85'.

95-97': Limestone-caprock creamy white. Hard, crunchy drilling. Sample off bit at 97'

Drill Hole: Beaufort #15 (power auger hole)
Date: 8/4/70 *Total Depth*: 67'

Location: On Parris Island at the General's Landing about 1.85 miles S. 1° W. at intersection of Page Field Road and Wake Blvd. and about 1.4 miles N. 67° W. at the Ribaut Monument.

Collar Elevation: 5' (est. above MHW).
Logged by: D. A. Duncan.
Description
Depth
0-10': Tan, fine grained sand.
10-15': Tan to gray fine grained sand.
15-30': Gray fine grained sand with some medium grained sand with clay lenses.
30-50': Gray clay with sparse medium grained sand stringers and abundant wood fragments which increase in abundance from 30'-50'. Drilling break at 50' (log?).
50-66': Olive green silty clay with fine-medium-coarse grained sand with sparse pebbles and white meduim to coarse sand stringers. (Pebbles—phosphate ? and/or limestone ? and/or chert).
66-67': Limestone—caprock. Very hard drilling. Light gray with pebbles.

PART II

RAPID SEDIMENT ANALYSES FROM DRILL HOLES

Beaufort #1

Depth Below Ground Surface	Coarse-grained 5	16	25	Percentiles 50	Fine-grained 75	84	95
0-5	0.5	1.43	1.59	2.16	2.60	3.17	-- ----
5-10	0.35	1.00	1.30	1.81	2.3	2.5	3.0
10-15	0.80	1.20	1.30	1.69	2.26	2.49	3.20
15-20	–1.00	–0.10	0.18	0.73	1.40	1.67	2.08
20-25	0.70	1.20	1.40	1.62	2.05	2.40	3.05
25-30	0.00	0.53	0.74	1.36	1.95	2.40	3.16
28-30	0.00	1.18	1.63	2.30	3.25	3.60	4.00
30-35	0.60	1.55	1.90	2.50	3.10	3.38	3.53
35-40	0.00	0.76	1.10	1.66	2.00	2.10	2.50
40-45	.22	1.35	1.69	2.08	2.50	2.80	3.50
45-48	0.50	1.40	1.55	2.38	2.60	2.89	3.54
48-50	–0.80	0.20	0.50	0.99	1.36	1.61	2.08
50-55	–0.10	0.40	0.80	1.40	2.20	2.40	2.90
55	1.20	1.50	1.69	2.05	2.50	2.77	3.1

Sizes in Ø units
$\text{Ø} = -\log_2 \text{diam. (mms)}$

Beaufort #2

	Coarse-grained			Percentiles	Fine-grained		
Depth Below Ground Surface	5	16	25	50	75	84	95
50-51	>–2.00	2.17	2.30	2.37	2.60	3.00	>3.50
51-55	>–2.00	0.87	1.23	2.07	2.46	2.70	3.20
55-60	>–2.00	1.58	1.95	2.40	2.90	3.20	>3.50
60-65	>–2.00	1.95	2.00	2.10	2.50	3.05	>3.50
66-68	NO DATA						
65-70	>–2.00	2.40	2.52	3.10	3.22	>3.50	-- ----
70-75	>–2.00	0.60	1.52	2.43	2.90	3.15	>3.50
75-77	NO DATA						
77-80	>–2.00	0.50	1.10	1.95	2.54	3.20	>3.50
80-81	>–2.00	0.70	1.20	1.94	2.61	3.30	3.50

Sizes in Ø units

Ø = $-\log_2$ diam. (mms)

Beaufort #3

Representative samples

	Coarse-grained			Percentiles	Fine-grained		
Depth Below Ground Surface	5	16	25	50	75	84	95
30-35	>–2.00	–2.00	–1.50	–1.50	2.40	3.13	3.42
35-40	>–2.00	>–2.00	>–2.00	>–1.50	2.38	3.20	>3.50
45-50	–2.00	0.79	1.02	1.40	2.40	2.60	3.14
50-55	0.50	0.66	0.79	1.18	2.16	2.40	2.28
100-105	>–1.50	–1.20	–1.00	0.78	1.70	2.87	>3.50
105-110	–1.50	1.00	1.60	3.14	3.28	3.41	>3.50

Sizes in Ø units

Ø = $-\log_2$ diam. (mms)

Beaufort #4

	Coarse-grained			Percentiles	Fine-grained		
Depth Below Ground Surface	5	16	25	50	75	84	95
25-30	>–2.00	–1.00	0.80	2.20	2.70	3.03	3.50
30-35	>–2.00	0.00	1.28	2.26	3.00	3.17	>3.50
35-40	>–2.00	0.20	1.30	2.26	3.20	3.34	>3.50
50-55	>–2.00	0.00	1.30	2.87	3.46	3.5	-- ----
80-85	>–2.00	–1.00	–0.30	1.77	2.38	2.84	3.40
90-95	>–2.00	0.18	0.64	1.54	2.80	3.11	3.47
95-100	>–2.00	0.50	0.62	2.17	2.90	3.22	3.44
100-105	>–2.00	–0.50	0.38	1.63	2.60	3.10	>3.50

Sizes in Ø units

Ø = $-\log_2$ diam. (mms)

Beaufort #5

Depth Below Ground Surface	Coarse-grained 5	16	25	Percentiles 50	Fine-grained 75	84	95
10-15	>–2.00	1.13	1.54	2.63	3.43	>3.5	-- ----
15-20	>–2.00	1.26	1.61	2.53	3.00	3.27	3.6
40-45	>–1.50	0.37	0.70	1.68	2.50	3.04	>3.50
50-55	>–2.00	–0.30	0.20	1.16	2.50	3.12	>3.50
60-65	>–1.50	–0.30	0.25	1.07	2.26	2.59	3.11
85-90	>–2.00	>–2.00	–1.50	0.39	2.43	2.77	3.24

Sizes in Ø units
Ø = $-\log_2$ diam. (mms)

Beaufort #6

Depth Below Ground Surface	Coarse-grained 5	16	25	Percentiles 50	Fine-grained 75	84	95
0-5	>–2.00	2.50	2.60	3.02	3.35	3.50	>3.50
5-10	>–2.00	2.50	2.62	3.06	3.30	3.41	>3.50
15-20	>–2.00	2.13	2.38	2.70	3.32	>3.50	-- ----
50-55	1.30	2.34	2.37	3.04	>3.50	-- ----	-- ----
70-75	>–2.00	0.82	2.36	2.76	3.15	3.32	>3.50
75-80	>–2.10	1.05	1.71	2.63	3.05	3.20	>3.50
80-85	>–2.00	–0.40	0.60	1.61	2.63	3.03	3.50

Sizes in Ø units
Ø = $-\log_2$ diam. (mms)

Beaufort #8

Depth Below Ground Surface	Coarse-grained 5	16	25	Percentiles 50	Fine-grained 75	84	95
5-10	>–2.00	1.40	2.03	2.67	3.12	3.26	>3.50
20-25	>–1.50	0.78	1.00	1.77	2.80	3.13	3.46

Sizes in Ø units
Ø = $-\log_2$ diam. (mms)

Beaufort #9

Depth Below Ground Surface	Coarse-grained			Percentiles	Fine-grained		
	5	16	25	50	75	84	95
0-5	>–2.00	2.37	2.39	2.43	2.90	3.02	3.10
5-10	>–2.00	2.21	2.37	2.48	2.91	3.06	3.16
10-15	>–2.00	2.03	2.40	2.53	2.94	3.07	3.20
15-20	>–2.00	0.60	2.36	2.50	2.80	3.03	3.19
20-25	>–2.00	1.17	1.48	3.10	3.22	3.30	3.32
25-30	>–2.00	1.41	1.58	3.20	3.40	3.52	>3.50
30-35	>–2.00	0.63	0.86	1.48	2.40	2.64	3.01
35-40	>–2.00	0.74	1.61	2.42	2.71	3.13	3.50
40-45	>–2.00	1.53	2.06	2.63	2.90	3.20	3.40
45-50	>–1.50	1.62	1.90	2.47	3.00	3.13	3.41
50-55	>–2.00	–0.90	1.33	2.37	2.68	3.00	3.27
55-60	>–2.00	–1.40	0.10	2.14	2.60	3.03	3.41
60-65	>–2.00	–1.60	–1.50	–1.10	1.77	2.40	3.04
65-70	>–2.00	–1.70	–1.40	–0.80	2.20	3.03	3.31
70-75	>–2.00	–2.00	–1.30	1.67	2.60	3.04	3.37
75-80	>–2.00	–1.50	1.23	2.55	3.03	3.16	3.31
80-85	>–2.00	0.70	2.20	2.60	3.00	3.12	3.30
85-90	>–2.00	0.34	1.70	2.41	2.91	3.10	3.24
90-95	>–2.00	–2.00	0.78	1.68	1.81	1.88	2.00
95-100	>–2.00	–2.00	0.63	2.50	2.90	3.18	3.31

Sizes in Ø units
Ø = $-\log_2$ diam. (mms)

Beaufort #10

Depth Below Ground Surface	Coarse-grained			Percentiles	Fine-grained		
	5	16	25	50	75	84	95
0-5	>–2.00	2.32	2.46	2.87	3.10	3.24	3.40
5-10	>–2.00	2.31	2.41	2.82	3.10	3.28	>3.50
10-15	2.36	2.77	2.89	3.13	3.30	3.50	>3.50
15-20	>–2.00	–1.70	2.26	3.36	3.55	>3.50	-- ----
20-25	>–2.00	0.20	1.22	2.13	2.90	3.10	3.43
25-30	0.72	1.29	1.64	1.94	2.12	2.21	2.50
30-35	>–1.00	0.50	1.40	2.34	2.80	3.12	>3.50
35-40	>–2.00	0.70	1.20	1.91	2.41	2.83	3.12
40-45	>–2.00	0.00	0.66	1.80	2.05	2.29	2.78
45-50	>–2.00	–0.40	1.00	2.32	3.01	3.13	3.47
50-55	>–2.00	–1.50	2.74	3.07	3.36	3.41	>3.50
55-57	–1.60	1.96	2.39	3.00	3.27	3.36	3.50
57-60	>–2.00	0.60	1.63	2.46	3.08	3.28	3.47
60-65	>–2.00	0.77	1.53	2.70	3.19	3.41	>3.60

Sizes in Ø units
Ø = $-\log_2$ diam. (mms)

Beaufort #11

Depth Below Ground Surface	Coarse-grained 5	16	25	Percentiles 50	Fine-grained 75	84	95
0-5	>–2.00	2.36	2.38	2.50	2.80	3.02	>3.50
5-10	>–2.00	–0.80	0.17	2.46	2.80	3.10	3.50
10-15	>–2.00	1.75	2.33	2.50	3.00	3.14	3.48
15-20	>–2.00	1.03	2.24	2.80	3.21	3.47	>3.50
20-25	>–2.00	>–2.00	–1.20	2.36	3.00	3.30	>3.50
25-30	>–2.00	>–2.00	>–2.00	1.33	2.88	3.07	>3.50
30-35	>–2.00	–1.00	0.84	2.52	3.03	3.19	3.46
35-40	>–2.00	–0.90	0.52	2.34	2.94	3.13	3.47
40-45	>–2.00	>–1.60	0.70	2.45	2.90	3.12	3.52
45-50	–1.00	1.06	1.76	2.57	3.00	3.13	3.56
50-55	>–2.00	1.42	1.83	2.32	2.60	3.00	3.40
55-60	>–2.00	1.66	2.28	2.55	3.04	3.29	-- ----
60-65	>–2.00	2.46	2.48	2.71	3.09	3.26	>3.50
65-70	–1.00	2.36	2.46	2.73	3.12	3.30	>3.50
70-75	>–2.00	0.00	1.65	2.60	3.07	3.28	3.50
75-80	>–2.00	1.60	2.38	-- ----	-- ----	3.2	>3.50
80-85	>–2.00	0.55	1.10	1.83	2.90	3.06	3.32
85-90	>–2.00	0.77	1.08	1.87	2.80	3.08	3.35
90-95	>–2.00	–0.90	1.24	1.97	2.88	3.06	3.46
95-100	>–2.00	1.00	1.36	2.26	2.70	3.04	3.30
100-105	>–2.00	0.90	1.41	2.54	3.06	3.21	3.57
105-110	>–2.00	0.76	1.15	2.33	2.66	3.02	3.26
110-115	>–2.00	–1.00	0.28	1.40	2.42	2.78	3.53
115-120	>–2.00	–1.20	–0.70	0.48	1.40	1.98	3.06
120-125	>–2.00	–1.50	–1.00	0.56	1.80	2.59	3.13
125-130	>–2.00	–1.50	–0.60	0.48	1.80	2.83	3.42
130-135	>–2.00	–2.00	0.00	1.17	2.54	2.89	3.35
135-140	>–2.00	–1.30	0.00	1.24	2.36	2.54	3.37
140-145	>–2.00	–0.50	0.64	2.04	2.50	3.00	3.41
145-150	>–2.00	>–2.00	1.38	2.33	2.76	3.10	3.53
150	>–2.00	>–2.00	–0.50	1.81	2.62	3.04	3.47

Sizes in Ø units

Ø = $-\log_2$ diam. (mms)

Beaufort #12

Depth Below Ground Surface	5	16	25	50	75	84	95
	Coarse-grained			Percentiles	Fine-grained		
0-5	>–2.00	2.45	2.50	2.78	3.04	3.17	3.31
5-10	>–2.00	2.34	2.37	2.43	2.65	2.97	3.13
10-15	>–2.00	2.35	2.37	2.39	2.72	2.96	3.12
15-20	>–2.00	0.59	1.76	2.41	2.76	2.96	3.15
20-25	>–2.00	0.89	2.04	2.63	2.88	3.10	3.28
25-30	>–2.00	0.90	2.00	2.54	2.91	3.02	3.17
30-35	>–2.00	1.18	1.69	2.38	2.70	3.00	3.27
35-40	>–2.00	1.25	1.51	2.26	2.48	2.66	2.99
40-45	>–2.00	1.05	1.95	2.61	3.00	3.16	3.43
45-50	>–2.00	1.90	2.40	2.88	3.15	3.30	3.70
50-55	2.20	3.05	3.42	3.75	-- ----	-- ----	-- ----
55-60	>–2.00	0.50	1.45	2.32	2.60	2.90	3.25

Sizes in Ø units
Ø = –log₂ diam. (mms)

Beaufort #14

Depth Below Ground Surface	5	16	25	50	75	84	95
	Coarse-grained			Percentiles	Fine-grained		
0-5	>–2.00	1.70	2.16	1.35	2.70	3.10	3.42
5-10	>–2.00	1.08	1.88	2.37	2.70	3.03	3.50
10-15	>–2.00	0.78	1.72	2.36	2.73	2.96	3.20
15-20	>–2.00	1.19	1.74	2.32	2.68	2.89	3.19
20-25	>–2.00	0.58	1.66	2.36	2.50	1.79	3.08
25-30	>–2.00	0.20	0.79	2.33	2.70	3.00	3.43
30-35	>–2.00	1.08	1.82	2.37	2.70	2.98	3.28
35-40	>–2.00	1.28	1.70	2.29	2.69	2.96	3.35
40-45	>–2.00	0.10	0.78	1.71	2.68	2.90	3.17
45-50	>–2.00	–0.80	0.67	1.84	2.40	2.79	3.18
50-55	>–2.00	–1.50	0.48	1.73	2.55	2.68	3.16
55-57	>–2.00	–0.05	0.33	0.86	1.30	1.81	2.73
60-65	>–2.00	0.50	0.75	1.18	1.61	1.89	2.60
65-70	>–2.00	0.60	0.86	1.20	1.76	2.38	2.80
70-75	>–2.00	0.58	0.85	1.30	2.18	2.56	3.15
80-85	>–2.00	0.78	1.16	1.93	2.55	3.00	3.40
85-95	>–2.00	0.80	1.12	1.76	2.56	2.88	3.38
85-90	–2.00	–1.70	0.62	1.50	2.30	2.71	3.30
90-95	–2.00	–0.50	0.40	1.20	2.17	2.38	2.79
95-97	–2.00	0.55	1.18	2.00	2.63	2.85	3.12
97	–2.00	0.90	1.25	1.69	2.40	2.80	3.30

Beaufort #15

Depth Below Ground Surface	Coarse-grained 5	16	25	Percentiles 50	Fine-grained 75	84	95
0-5	>–2.00	2.35	2.30	2.50	2.68	3.05	3.16
5-10	>–2.00	1.50	2.35	2.56	2.90	3.05	3.25
10-15	>–2.00	–0.50	0.50	2.20	2.50	2.76	3.15
15-20	0.30	1.00	1.30	2.36	2.80	3.15	3.80
20-25	>–2.00	0.16	0.68	1.39	2.35	2.50	3.06
25-30	>–2.00	0.38	0.92	1.66	2.38	2.78	3.11
30-35	–1.50	0.20	0.77	1.64	2.59	3.01	3.70
35-40	–2.00	0.00	0.55	1.53	2.50	3.05	3.70
40-45	–1.90	–1.70	0.78	2.22	3.19	-- ----	-- ----
45-50	0.40	1.00	1.38	2.34	3.08	3.20	-- ----
50-55	–1.80	0.23	1.00	2.35	3.05	3.43	-- ----
55-60	–1.20	0.83	1.58	2.42	3.08	3.35	-- ----
60-65	–1.60	–0.20	0.50	1.54	2.58	2.90	3.50
65-70	–1.50	0.35	0.88	1.90	3.00	3.16	3.70

Sizes in Ø units

Ø = $-\log_2$ diam. (mms)

Beaufort Port Royal

Sample No.	Wt. of Sample in Grams	4	15	25	50	75	85	96	Zero
47,302	12.8 grams	0.45	1.18	1.57	2.43	2.51	2.80	3.55	
47,303	12.5 grams	1.10	1.31	1.45	1.68	2.02	2.20	2.40	100/0
47,304	12.4 grams	–0.25	0.14	0.30	0.64	1.00	1.17	1.52	100/0
47,305	12.1 grams	0.00	0.60	1.11	1.79	2.50	2.65	2.99	100/0
47,306	12.6 grams	0.66	0.85	0.98	1.29	1.72	1.97	2.12	100/0
H-47,307	13.5 grams	2.01	2.14	2.35	3.33	3.01	3.50	3.90	100/0
H-47,308	12.6 grams	–0.30	0.11	0.30	0.60	1.24	1.58	0	93/0
H-47,309	12.42 grams	0.71	1.21	1.50	2.01	2.42	2.69	0	95/0
H-47,310	12.0 grams	1.20	1.72	1.87	2.28	2.41	2.61	3.11	98/0
H-47,311	11.4 grams	0.90	1.90	2.31	2.95	3.35	3.68	0	94/0
H-47,312	12.0 grams	0.45	1.01	2.20	2.89	3.18	3.33	3.56	100/0
H-47,313	12.8 grams	1.12	1.60	1.93	2.20	0	0	0	72/0
H-47,314	12.1 grams	1.06	1.93	2.40	3.00	3.30	3.68	0	90/0
H-47,315	12.3 grams	0.03	0.50	0.60	1.17	1.66	1.94	2.36	100/0
H-47,316	12.8 grams	1.82	1.92	2.10	2.45	2.61	2.72	0	95/0
H-47,317	12.5 grams	1.86	2.30	2.33	2.58	2.94	3.22	0	88/0
H-47,318	12.5 grams	2.07	2.29	2.49	2.57	2.96	3.02	3.12	100/0
H-47,319	12.8 grams	1.57	1.70	1.82	2.28	2.39	2.56	2.86	100/0
H-47,320	12.8 grams	2.27	2.65	2.70	3.01	3.13	3.18	3.28	100/0
H-47,321	12.3 grams	0.15	0.88	1.12	1.62	2.18	2.72	2.40	100/0
H-47,322	12.4 grams	1.82	2.03	2.17	2.27	2.43	2.60	3.00	100/0
H-47,323	12.7 grams	0.20	0.32	0.40	0.60	0.91	1.14	1.53	100/0
H-47,324	12.5 grams	0.55	1.02	1.21	1.61	2.09	2.29	2.48	100/0
H-47,325	13.1 grams	0.50	1.00	1.19	1.68	2.11	2.40	2.71	100/0
H-47,326	13.1 grams	1.86	2.38	2.50	2.90	3.19	3.30	3.63	100/0
H-47,327	12.7 grams	2.10	2.38	2.57	3.19	3.32	3.49	3.70	100/0
H-47,328	12.5 grams	2.40	2.50	2.76	3.14	3.36	3.50	3.66	100/0

Sample No.	Wt. of Sample in Grams	4	15	25	50	75	85	96	Zero
H-47,329	12.5 grams	2.40	2.51	2.59	2.91	3.13	3.20	3.32	100/0
H-47,330	12.5 grams	2.41	2.50	2.55	2.88	3.09	3.15	3.77	100/0
H-47,331	12.5 grams	1.20	1.53	1.70	2.20	2.50	2.68	3.10	100/0
H-47,332	12.3 grams	0.53	0.80	0.89	1.1	1.34	1.52	1.70	100/0
H-47,333	12.2 grams	0.40	0.25	0.40	0.89	1.5	1.96	3.17	100/0
H-47,334	12.0 grams	0.12	0.50	0.65	1.02	1.42	1.68	2.40	100/0
H-47,335	12.6 grams	–0.40	0.10	0.40	0.83	1.40	1.55	1.84	100/0
H-47,336	12.5 grams	2.10	2.39	2.48	2.63	2.90	3.00	3.10	100/0
H-47,337	11.5 grams	0.80	1.73	1.97	2.48	2.79	3.05	3.46	100/0
H-47,338	12.0 grams	0.35	1.14	1.50	2.05	2.30	2.42	3.02	100/0
H-47,339	12.0 grams	1.40	1.72	1.86	2.38	2.60	2.76	3.10	100/0
H-47,340	12.5 grams	1.86	2.45	2.55	2.74	3.06	3.16	0	94/0
H-47,341	12.5 grams	1.48	1.56	1.63	1.95	2.40	2.57	3.02	100/0
H-47,342	12.5 grams	0.10	0.50	0.64	1.00	1.57	1.80	2.69	100/0
H-47,343	12.5 grams	1.35	1.57	1.65	1.98	2.16	2.24	3.08	100/0
H-47,344	12.5 grams	– .600	–0.10	0.20	0.80	1.80	2.13	3.20	100/0
H-47,345	12.58 grams	1.67	2.32	2.36	2.65	3.04	3.12	3.59	100/0
H-47,346	13.0 grams	2.36	2.46	2.66	3.10	3.32	3.48	3.69	100/0
H-47,347	12.4 grams	0.30	0.50	0.70	1.25	1.98	2.77	3.10	100/0
H-47,348	12.5 grams	0.10	0.50	0.65	1.00	1.47	1.58	1.94	100/0
H-47,349	12.0 grams	1.71	1.94	2.10	2.40	2.74	2.92	3.11	100/0
H-47,350	12.65 grams	0.51	1.30	1.90	2.70	3.20	3.47	0	95/0
H-47,351	12.2 grams	0.88	1.54	1.73	2.28	2.65	2.90	3.15	100/0
H-47,352	12.5 grams	0.60	1.73	2.20	2.90	3.15	3.24	3.50	100/0
H-47,353	12.45 grams	0	0.24	0.31	0.57	0.96	1.21	1.70	100/0
H-47,354	9.28 grams	0.14	0.72	1.20	1.87	3.10	3.20	0	95/0
H-47,355	10.01 grams	2.37	2.45	2.60	2.90	3.15	3.22	3.90	98/0
H-47,356	12.5 grams	2.12	2.34	2.45	2.77	3.13	3.27	0	85/0
H-47,357	12.5 grams	1.98	2.00	2.04	2.12	2.26	2.36	2.70	100/0
H-47,358	11.5 grams	1.56	1.72	1.88	2.33	2.41	2.55	2.83	100/0
H-47,359	12.5 grams	1.56	1.78	2.14	2.41	2.65	2.80	3.08	100/0
H-47,360	12.5 grams	2.14	2.43	2.49	2.67	3.02	3.09	3.27	100/0
H-47,361	11.26 grams	0.35	1.37	2.25	2.60	3.02	3.15	3.47	100/0
H-47,362	12.5 grams	2.02	2.11	2.21	2.50	2.75	2.89	3.01	100/0
H-47,363	13.0 grams	0.08	0.80	1.14	1.92	2.00	2.05	2.15	100/0
H-47,364	12.7 grams	–0.4	0.20	0.40	0.90	1.42	1.66	2.18	100/0
H-47,365	12.5 grams	2.01	2.11	2.23	2.52	2.80	2.99	3.16	100/0
H-47,366	13.0 grams	1.83	1.96	2.08	2.50	3.00	0	0	80/0
H-47,367	12.5 grams	0.13	0.51	0.68	1.20	1.75	2.22	2.59	100/0
H-47,368	12.5 grams	0.70	2.00	2.42	3.03	3.89	3.72	0	87/0
H-47,369	12.5 grams	0.10	0.53	0.70	1.21	1.83	2.28	0	92/0
H-47,370	12.5 grams	1.72	1.83	1.98	2.27	2.61	0	0	82/0
H-47,371	12.4 grams	1.54	1.68	1.85	2.38	2.65	2.91	0	92/0
H-47,372	12.5 grams	0.10	0.79	1.19	2.40	2.87	3.20	0	92/0
H-47,373	12.5 grams	1.27	1.39	1.50	1.69	2.00	2.22	2.75	100/0
H-47,374	12.5 grams	0	0.63	0.90	1.65	2.35	2.53	2.85	100/0
H-47,375	12.5 grams	0.19	0.65	0.93	1.58	2.49	2.62	3.10	100/0
H-47,376	12.6 grams	0.82	1.50	1.65	2.28	2.40	2.60	3.05	100/0
H-47,377	12.9 grams	–0.32	0	0.05	0.33	0.68	0.95	1.50	100/0
H-47,378	12.4 grams	–0.30	0.37	0.67	1.33	2.50	2.45	2.94	100/0
H-47,379	12.5 grams	1.94	2.08	2.39	2.50	2.69	2.77	2.93	100/0
H-47,380	10.0 grams	0.55	0.93	1.03	1.51	2.2	2.39	3.35	98/0
H-47,381	12.6 grams	0.56	0.80	1.03	1.54	2.02	2.48	3.2	96/0
H-47,382	12.5 grams	1.62	1.73	7.82	2.24	2.38	2.46	2.82	100/0

Sample No.	Wt. of Sample in Grams	4	15	25	50	75	85	96	Zero
H-47,383	12.8 grams	0.92	1.17	1.37	1.73	2.13	2.35	2.52	100/0
H-47,384	9.42 grams	–1.20	–0.40	0.00	0.36	1.00	1.50	0	92/0
H-47,385	12.5 grams	0.50	1.10	1.20	1.58	1.92	2.10	2.60	100/0
H-47,386	10.0 grams	–0.1	0.51	0.94	1.57	2.12	2.49	2.95	100/0
H-47,387	12.0 grams	2.31	2.38	2.46	2.80	3.17	3.46	3.98	97/0
H-47,388	12.5 grams	0.410	1.00	1.23	1.65	2.36	2.8	0	86/0
H-47,389	10.52 grams	1.74	1.85	1.97	2.27	2.60	0	0	80/0
H-47,390	12.5 grams	0.75	1.50	1.60	2.09	2.77	0	0	80/0
H-47,391	12.1 grams	1.88	2.05	2.14	2.60	2.75	2.90	0	94/0

II	Weight	4	15	25	50	75	85	96	Zero
H-47,994	10.3g	0.35	0.65	0.88	1.49	2.23	2.43	0	93/0
H-47,995	10.7g	–0.20	0.42	0.63	1.20	1.98	2.04	2.20	100/0
H-47,996	12.9g	0.67	1.05	1.29	1.82	2.24	2.34	2.78	100/0
H-47,997	12.4g	0.00	0.58	0.94	1.42	2.06	2.33	3.02	100/0
H-47,998	10.2g	0.30	0.90	1.18	1.68	2.17	2.27	3.30	100/0
H-47,999	12.4g	0.43	0.90	1.30	2.25	2.91	3.30	0	90/0
H-48,000	11.52g	0.08	0.56	0.82	1.50	2.07	2.13	0	92/0
H-48,001	10g	0.20	2.18	2.21	2.38	2.82	3.05	0	94/0
H-48,002	13g	0.46	0.70	0.77	1.08	1.52	1.67	2.06	100/0
H-48,003	10.5g	0.11	0.50	0.66	1.35	2.23	2.45	0	93/0
H-48,004	10.6g	0.00	0.42	0.80	1.83	2.34	2.50	3.10	97/0
H-48,005	11.6g	0.36	0.85	1.11	1.97	2.32	2.53	0	94/0
H-48,006	11.33g	–0.30	0.25	0.45	0.71	1.15	1.33	1.72	100/0
H-48,007	9.91g	0.77	1.52	1.85	2.55	3.02	3.24	0	92/0
H-48,008	11.93g	0.50	1.03	1.50	2.21	2.59	3.03	0	95/0
H-48,009	12.98g	–0.20	0.54	0.82	1.63	2.24	2.33	2.66	100/0
H-48,010	11.98g	–0.70	–0.30	0.10	0.85	1.95	2.25	3.03	98/0
H-48,011	7.63g	0.50	1.12	1.24	2.36	3.31	0	0	83/0
H-48,012	13.27g	–0.70	–0.20	1.000	0.70	1.66	1.96	2.33	100/0
H-48,013	12.22g	–1.00	–0.25	0.10	0.95	1.91	2.22	2.61	100/0
H-48,014	12.25g	0.20	0.91	1.80	2.24	2.59	2.83	0	95/0
H-48,015	11.51g	0.40	0.75	1.10	1.95	2.59	3.04	0	94/0
H-48,016	12.60g	0.10	0.68	1.15	1.90	2.26	2.41	3.30	87/0
H-48-017	8.81g	–0.60	0.10	0.26	1.94	1.70	2.21	0	92/0
H-48,018	9.71g	0.48	0.66	1.02	2.31	2.05	2.14	3.78	96/0
H-48,019	12.02g	–0.10	0.60	0.98	2.22	2.58	2.88	3.10	100/0
H-48,020	11.12g	0.50	0.71	1.08	2.35	3.00	3.50	0	95/0
H-48,021	12.74g	2.15	2.25	2.27		2.51	2.60	2.79	100/0

II	Weight	4	15	25	50	75	85	96	Zero
H-48,022	12.22g	–0.50	0.26	0.55	1.20	2.13	2.30	2.60	100/0
H-48,023	10.12g	0.63	1.69	2.26	2.60	3.12	3.55	0	90/0
H-48,024	12.76g	0.30	1.19	1.65	2.25	2.58	2.84	3.13	100/0
H-48,025	11.15g	0.10	0.85	1.02	1.60	1.87	1.94	2.20	99/0
H-48,026	12.36g	0.25	0.75	1.03	1.64	2.18	2.29	3.11	100/0
H-48,027	12.26g	0.60	0.12	0.50	1.21	2.17	2.30	3.03	97/0
H-48,028	12.51g	0.60	1.00	1.62	2.28	2.83	3.20	0	90/0
H-48,029	11.23g	0.25	0.51	0.88	1.35	1.83	2.28	2.90	99/0
H-48,030	11.33g	–0.25	0.37	0.70	1.77	2.24	2.39	0	93/0
H-48,031	12.45g	0.20	0.50	0.63	1.42	3.06	3.83	0	85/0
H-48,032	9.48g	0.60	1.68	1.91	2.17	2.24	2.34	2.67	100/0
H-48,033	11.67g	0.80	1.70	1.94	2.19	2.60	3.17	0	90/0
H-48,034	11.53g	0.21	0.54	0.70	1.18	1.72	2.11	2.7	100/0
H-48,035	12.25g	1.75	1.92	2.05	2.29	2.50	2.69	3.08	100/0
H-48,036	9.75g	0.60	1.63	2.18	2.35	2.90	3.12	0	93/0
H-48,037	11.42g	0.55	1.20	1.63	2.24	2.70	3.07	3.57	96/0
H-48,038	10.73g	–0.25	0.56	0.81	1.30	1.84	2.17	2.56	100/0
H-48,039	12.12g	0.70	0.96	1.72	2.32	2.78	3.13	0	94/0
H-48,040	12.85g	0.40	0.74	1.13	2.11	2.70	3.55	0	86/0
H-48,041	12.50g	–0.30	0.11	0.25	0.97	2.13	2.40	3.10	98/0
H-48,042	11.94g	–0.60	0.00	0.15	0.69	1.40	1.83	3.07	97/0
H-48,043	12.90g	0.00	1.19	0.26	0.49	0.71	0.98	1.53	100/0
H-48,044	11.54g	–0.10	0.37	0.69	1.55	2.17	3.12	0	95/0
H-48,045	9.48g	–0.40	0.56	1.16	1.65	2.21	2.46	0	89/0
H-48,046	12.18g	2.01	2.16	2.20	2.29	2.45	2.57	2.80	100/0
H-48,047	11.25g	0.00	0.62	0.96	2.02	3.00	0	0	81/0
H-48,048	11.10g	0.05	0.74	1.30	1.95	2.11	2.70	0	94/0
H-48,049	12.10g	0.51	1.46	1.63	2.45	3.18	0	0	81/0

II	Weight	4	15	25	50	75	85	96	Zero
H-48,050	9.47g	–1.10	0.00	0.61	1.64	3.00	0	0	83/0
H-48,051	10.77g	–0.40	0.70	1.22	2.22	3.42	4.00	0	85/0
H-48,052	11.86g	0.40	0.90	1.25	2.06	2.25	2.40	3.30	99/0
H-48,053	9.49g	–0.20	0.50	0.79	1.63	2.02	2.29	0	95/0
H-48,054	12.72g	0.42	0.63	0.88	1.60	2.30	2.60	3.40	98/0
H-48,055	11.05g	0.50	1.26	1.62	2.13	2.40	2.51	2.89	100/0
H-48,056	9.50g	0.40	1.03	1.73	2.31	2.85	3.11	3.46	100/0
H-48,057	10.55g	0.10	0.95	1.50	2.05	2.45	2.65	3.12	100/0
H-48,058	12.20g	1.00	1.10	1.21	1.60	2.10	2.26	2.70	100/0
H-48,059	10.49g	0.45	0.80	1.06	1.54	2.00	2.21	2.57	100/0
H-48,060	11.60g	0.53	1.30	1.72	2.20	2.43	2.65	3.08	100/0

Appendix to Water Quality Evaulation

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SAMPLE TIME
FIRST RUN

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	1030	1105	1025	1020	1050	1025		1030	1030	1025	1025	1030	1030	1110
2	1055	1135	1050	1050	1105	1050		1050	1050	1050	1050		1050	1130
3	1135	1205	1125	1125	1145	1125		1130	1125	1125	1125		1125	1200
4	1200	1240	1155	1150	1215	1155	1200	1200	1155	1155	1155		1155	1220
5	1230	1300	1225	1225	1230	1225	1230	1225	1225	1225	1225		1225	1240
6	1310	1330	1255	1300	1300	1300	1300	1300	1300	1300	1300		1300	1300
7	820	820	835	810	810	810	810	800	800	810	805	800	800	815
8	845	840	850	835	830	830	845	830	830	830	830	830	830	835
9	910	910	905		900	900		900	900	900	900	900	900	900
10	1000	1020	950	945	1015	955		1000	955	1000	1000	1000	1000	1030
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	1035	1025	1025	1045	1025	1025		1025	1025	1100	1025	1245	1045	1025
2		1050	1050	1110	1045	1050	1100	1050	1050	1120	1050	1300	1105	1050
3	1130	1130	1133	1145	1125	1150	1135	1130	1125	1230	1125		1150	1125
4	1200	1155	1200	1210	1155	1215	1155	1155	1155	1250	1205	1320	1220	1155
5	1225	1225	1225	1230	1225	1225	1225	1225	1225	1305		1340	1240	1225
6	1300	1300	1300	1300	1300	1300	1300	1300	1300	1330		1355	1300	1300
7	830	825	835	845	825	815	805	805	805	805	805	805	805	805
8	850	830	850		840	835	825	825	825	825	825	825	825	825
9	910			920	900	900	1045	900	900	1055	900		900	900
10	1000	955	1000	1010		955	1025							
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SAMPLE TIME
SECOND RUN

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	1435	1440	1425		1425	1420		1425		1425	1425	1425	1435	1425
2	1450	1505	1450		1450	1450		1450	1450	1450	1450	1450	1455	1450
3	1525	1535	1525		1525	1525		1525	1525	1525	1525	1525	1525	1525
4	1555	1610	1600		1555	1555		1555	1555	1555	1555	1555	1555	1555
5	1625	1635	1625		1625	1625		1625	1625	1625	1625	1625	1625	1625
6	1700	1700	1700	1825	1700	1700		1700	1700	1700	1700	1700	1700	1700
7	1215	1215	1225	1205	1205	1205		1205	1205	1205	1205	1205	1230	1205
8	1255	1245	1245	1230	1230	1235		1230	1230	1230	1230	1230	1305	1230
9	1310	1310	1305	1300	1300	1300		1300	1300	1300	1300	1300	1320	1300
10	1410	1405	1400	1355	1350	1355		1350		1355	1355	1355	1415	
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	1520	1425	1445	1440	1345	1425		1325	1425	1425				
2	1530	1450	1500	1455	1430	1450	1350	1455	1450	1450				
3	1550	1525	1525	1525		1515	1425	1425	1425	1525				
4	1610	1555	1555	1555	1555	1555		1455	1555	1555				
5	1625	1625	1625	1625	1625	1615	1525		1525	1625	1305		1340	
6	1700	1700	1700	1700	1700	1700	1600		1600	1700	1335		1400	
7	1210	1205	1205	1205	1205	1255	1105	1105	1105	1205	1205		1205	
8	1230	1230	1230	1230	1230	1315	1130	1130	1130	1230	1230		1230	
9	1435	1300	1300	1300	1300	1330	1200	1200	1200	1300			1300	
10		1355	1410	1355				1255	1355	1355				
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TEMPERATURE
DEGREES C (FIRST RUN)

DATE ********* STATION	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
1 TOP	16.2	16.6	17.0	17.6	17.7	17.8		18.9	20.6	17.9	18.6	19.7	19.9	20.4
MID	16.2	16.6	16.7	17.4	17.6	17.7		18.3	19.8	18.2	18.6	19.4	19.7	20.3
BOT	16.2		16.7	17.3	17.6	17.6		18.4	19.2	18.3	18.8	19.2	19.6	20.3
2 TOP	16.2	16.9	17.2	18.1	17.7	18.4		19.4	20.2	19.0	18.9		21.0	22.5
MID	16.0	17.0	17.0	17.9		17.9		18.6	20.0	18.9	18.9		20.6	21.6
BOT	16.0	17.0	16.8	17.4		17.8								
3 TOP	16.5	17.0	17.3	18.4	17.5	19.0		19.9	21.4	18.8	19.2		22.0	22.3
MID	16.5	17.0	17.2	18.1	17.5	18.6		19.7	21.2	18.8	19.2		21.1	22.1
BOT	16.5	16.9	17.4	18.0	17.5	18.4		19.3	21.1	18.5	19.2		20.9	21.8
4 TOP	16.0	16.9	17.9	17.9	18.0	18.4	18.0	20.0	20.7	18.8	19.2		20.9	21.6
MID	16.0	16.9	17.5	17.5	18.0	18.2	17.9	19.1	20.2	18.8	19.1		20.4	21.3
BOT		16.8	17.2	17.4	18.0	18.0	17.9	19.0	19.9	18.8	18.8		20.2	21.8
5 TOP	16.0	17.1	17.3	18.8	17.2	18.8	18.3	19.8	20.7	19.4	19.6		21.8	21.3
MID	16.0	17.0	17.2	18.3	17.5	18.2	18.1	19.1	20.0	19.2	19.4		21.0	21.1
BOT		17.0	17.1	17.9	17.0	18.1	18.1	18.9	19.8	19.0	19.1		20.8	21.1
6 TOP	16.5	17.0	18.1	19.1	17.7	19.4	18.6	21.0	22.2	20.0	20.2		23.3	24.0
MID	16.0	17.8	18.0	19.0	18.0	18.9	18.4	20.1	21.6	19.7	19.8		22.2	23.3
BOT		17.6	18.0	18.9	17.5	18.7	18.3	19.8	20.9	19.7	19.7		21.8	22.8
7 TOP	16.0	16.5	16.9	18.1	18.7	18.6	18.4	19.5	20.1	19.1	19.6	18.9	20.0	20.8
MID	16.0	16.5	16.9	18.1	18.6	18.5	18.6	18.8	20.0	19.2	19.4	19.1	19.8	20.5
BOT	16.0	16.5		18.1	18.5	18.5	18.7	18.9	20.0	19.3	19.5	19.1	19.8	20.4
8 TOP	15.7	16.5	16.8	17.6	17.9	17.7	17.6	18.4	18.9	17.7	18.1	18.7	19.7	20.2
MID	15.5	16.1	16.9	17.5	18.0	17.6	17.6	18.0	18.6	18.6	18.3	18.8	19.5	20.2
BOT	15.5	16.2	16.9	17.6	18.0	17.7	17.6	18.2	18.7	18.6	18.7	18.8	19.5	20.1
9 TOP	16.5	16.5	16.9	17.4	17.8	17.6		18.7	19.3	18.0	18.7	18.7	19.4	19.9
MID	16.5	16.5	16.8	17.3	17.9	17.8		18.4	18.9	18.1	18.7	18.7	19.2	19.7
BOT	16.5	16.5	16.8	17.3	17.9	17.8		18.3	18.8	18.5	18.7	18.8	19.1	19.9
10 TOP	16.0		16.7	18.3	18.0	17.9		19.2	20.1	18.7	19.4	19.4	19.9	21.2
MID	16.0		16.5	18.1	17.9	17.8		19.0	19.6	18.8	19.3	19.1	19.6	20.7
BOT	16.5		16.5	17.9	17.9	17.8		18.7	19.6	18.6	19.2	19.1	19.6	20.7
11 TOP														
MID														
BOT														

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TEMPERATURE
DEGREES C (FIRST RUN)

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1 TOP	20.1	21.5	22.1	24.0	23.2	23.3	23.5	23.8	23.9	24.6	24.8	25.0	24.7	24.9
MID	20.0	21.4	21.8	23.1	22.9	23.0	23.2	23.7	23.9	24.3	24.9	25.0	24.7	24.9
BOT	20.0	21.1	21.8	22.8	22.9	22.9	23.1	23.5	23.7	24.2	24.7	24.7	24.6	24.5
2 TOP	20.5	21.8	24.1	23.7	24.0	23.2	23.7	23.7	24.1	24.3	25.4	25.1	25.1	26.6
MID	20.5	21.8	23.4	23.4	23.7	23.3	23.6	23.6	24.1	24.5	25.4	25.1	24.8	26.1
BOT	20.5	21.6	23.0	23.1	23.6	23.2	23.5	23.7	24.0	24.5	25.0	24.8	24.8	25.9
3 TOP	20.9	23.0	24.1	25.4	24.4	25.8	24.5	24.5	24.9	27.0	26.6		26.0	26.5
MID	20.8	22.6	24.3	24.9	24.0	24.7	24.5	24.8	24.9	26.7	26.6		26.0	26.4
BOT	20.8	22.6	23.8	24.9	23.6	24.5	24.5	24.7	24.9	26.7	26.4			26.3
4 TOP	20.7	21.6	22.1	23.0	23.1	24.3	24.5	24.1	24.4	26.6	25.3	25.1	26.1	26.5
MID	20.7	21.4	22.1	22.8	23.2	24.2	24.0	23.9	24.3	25.5	25.3	24.8	25.5	26.4
BOT	20.5	21.4	22.0	22.6	22.5	23.7	24.0	23.7	23.9	24.3	25.0	24.7	25.1	26.2
5 TOP	21.2	22.6	23.0	23.3	24.7	24.4	25.4	24.6	24.8	25.7	26.0	25.5	25.7	26.3
MID	20.9	22.2	22.5	23.3	23.8	23.8	24.8	24.4	24.4	25.7	25.9	25.4	25.6	26.1
BOT	20.8	22.0	22.1	23.2	22.9	23.5	24.5	23.9	24.4	24.9	25.9	25.1	25.6	25.5
6 TOP	22.9	25.6	24.5	25.3	25.8	25.2	25.7	25.8	25.9	26.3	26.5	26.1	26.5	28.5
MID	22.5	24.1	23.9	24.8	25.5	25.0	25.6	25.2	25.8	25.8	26.5	25.9	26.3	28.2
BOT	22.4	23.9	23.7	24.0	25.2	24.5	24.8	24.5	25.6	26.0	26.3	26.0	26.3	27.8
7 TOP	20.4	21.6	22.5	23.6	23.6	24.5	24.5	24.8	24.6	25.3	25.7	25.3	25.1	25.0
MID	20.3	21.2	22.0	22.9	23.2	24.3	24.6	24.7	24.8	25.2	25.8	25.3	25.1	25.0
BOT	20.6	21.5	22.8	22.8	23.6	24.1	24.4	24.7	24.6	25.2	25.8	25.2	25.0	24.7
8 TOP	20.2	21.1	22.2	22.5	23.3	23.1	23.7	23.7	23.7	24.2	24.8	24.2	24.3	24.5
MID	20.2	20.9	21.4	22.5	23.3	23.2	23.6	23.6	23.5	24.1	24.7	24.3	24.4	24.5
BOT	20.2	20.9	21.4	22.2	23.3	23.2	23.7	23.5	23.6	24.1	24.5	24.2	24.4	24.4
9 TOP	20.2	21.1	21.3	22.3	23.0	22.9	23.6	23.9	23.9	25.3	24.5	24.3	24.5	24.6
MID	20.2	20.6	21.1	22.0	22.5	23.0	23.6	23.8	23.8	24.9	24.6	24.3	24.5	24.5
BOT	20.1	20.4	21.0	21.9	22.3	23.0	23.3	23.5	23.5	24.4	24.7	24.2	24.3	24.5
10 TOP	20.2	21.2	22.2	22.6		23.1	23.9	23.8	23.8	24.9	25.1	25.7	24.9	24.5
MID	20.3	21.2	22.0	22.2		22.7	23.5	23.6	23.9	24.9	25.1	25.5	24.7	24.5
BOT	20.2	21.1	21.7	21.7		22.7	23.2	23.6	23.9	24.6	24.9	25.5	24.5	24.4
11 TOP														
MID														
BOT														

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TEMPERATURE
DEGREES C (SECOND RUN)

DATE *********		4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION															
1	TOP	16.0	16.5	16.7		17.3	17.6		18.0		18.3	18.5	18.5	19.3	19.7
	MID		16.5	16.6		17.0	17.1		17.6		18.3	18.3	18.4	18.9	19.5
	BOT		16.5	16.6		17.0	17.0		17.5		18.4	18.3	18.4	18.9	19.5
2	TOP	17.0	17.3	18.2		18.2	18.0		19.1	19.8	18.9	18.8	18.9	19.9	20.4
	MID	17.0	17.1	17.5		17.8	18.0		18.5	18.9	18.6	18.5	18.7	19.6	20.3
	BOT	17.0	17.1	17.4		17.7	18.0		18.4	18.3	18.6	18.6	18.7	19.4	20.3
3	TOP	17.0	18.3	18.5		18.1	18.3		19.7	19.8	19.1	18.9	19.1	20.3	21.6
	MID	16.9	18.3	18.4		18.2	18.3			19.6	19.1	18.9	19.1	20.2	21.4
	BOT	16.8	18.2	18.4		18.2	18.3			19.4	19.1	18.9	19.1	20.2	21.4
4	TOP	17.0	17.1	17.6		18.0	17.8		19.8	18.8	19.0	18.7	19.0	20.7	22.2
	MID	17.0	17.0	17.7		17.5	17.3		18.1	18.6	18.3	18.7	18.8	19.2	20.6
	BOT	17.0	17.0	17.7		17.5	17.3		17.9	18.6	18.2	18.7	18.7	19.5	20.6
5	TOP	17.0	17.1	17.6		17.9	17.8		19.0	18.8	19.0	18.7	18.8	19.3	20.0
	MID	17.0	17.0	17.4		17.8	17.6		18.5	18.8	18.5	18.4	18.8	19.3	20.0
	BOT	17.0	17.0	17.2		17.5	17.5		18.0	18.6	18.5	18.4	18.8	19.3	20.0
6	TOP	17.5	17.8	18.4	19.0	19.0	18.6		19.8	20.1	19.5	19.3	19.2	19.9	20.5
	MID	17.4	17.7	18.3	19.0	18.6	18.4		19.6	19.8	19.3	19.0	19.1	19.9	20.5
	BOT	17.4	17.7	18.3	18.7	18.6	18.4		18.5	19.4	19.2	18.9	19.1	19.9	20.5
7	TOP	16.0	16.9	17.2	17.6	18.2	18.2		19.5	19.6	19.5	19.4	19.6	20.8	21.0
	MID	17.5	16.9	17.2	17.4	18.0	18.0		18.6	19.4	19.0	19.4	19.5	20.6	21.0
	BOT	17.5	17.2	17.2	17.6	17.6	18.0		18.6	19.3	19.0	19.4	19.5	21.9	21.0
8	TOP	17.0	16.7	18.9	18.4	17.8	18.0		19.2	19.7	18.7	18.3	19.0	20.2	20.0
	MID	17.0	16.7	18.0	17.3	17.5	17.8		18.3	19.0	18.3	18.3	19.0	19.6	20.3
	BOT	16.5	16.6	17.2	17.3	17.3	17.5		18.3	19.0	18.5	18.5	19.2	20.0	20.8
9	TOP	16.0	16.7	17.6	17.5	17.4	17.6		18.5	18.9	18.7	18.6	19.0	20.4	19.7
	MID	16.0	16.7	16.9	17.1	17.1	17.2		17.9	18.0	18.3	18.5	18.7	19.1	19.5
	BOT	16.0	16.7	16.9	17.1	17.1	17.1		17.8	18.0	18.3	18.5	18.7	19.1	19.5
10	TOP	16.0	17.2	17.2	18.0	17.6	17.9		18.6		19.0	18.8	19.5	19.6	
	MID	16.0	16.9	17.0	17.9	17.1	17.4		18.2		18.7	18.5	18.7	19.6	
	BOT	16.0	16.9	17.0	17.9	17.1	17.3		18.0		18.7	18.7	18.7	19.6	
11	TOP														
	MID														
	BOT														

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TEMPERATURE
DEGREES C (SECOND RUN)

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1 TOP	20.3	21.0	21.1	21.6	22.1	22.2		22.7	22.7	23.3				
MID	20.2	20.4	20.9	21.4	22.1	22.2		22.8	22.6	23.4				
BOT	20.2	20.4	20.9	21.4	22.2	22.4		22.7	22.5	23.2				
2 TOP	20.3	22.1	22.5	23.6	24.4	23.7	23.8	23.7	23.7	24.9				
MID	20.0	21.4	22.5	23.6	23.5	23.3	23.7	23.0	23.1	23.8				
BOT	20.0	21.4	22.1	22.8	23.5	23.3	23.8	22.9	22.9	23.7				
3 TOP	21.1	22.4	23.0	23.9	23.7	23.9	24.0	23.9	23.9	24.2				
MID	21.1	22.4	22.7	23.7	23.7	23.8	23.8	23.8	23.8	24.2				
BOT	20.9	22.4	22.7	23.4	23.8	23.9	23.8	24.0	23.8	24.1				
4 TOP	20.7	21.4	21.8	22.9	23.2	22.8		23.1	23.8	24.4				
MID	20.4	21.4	21.8	22.7	23.0	22.9		22.8	23.0	23.7				
BOT	20.4	21.4	22.0	22.3	23.0	22.8		22.9	23.2	23.7				
5 TOP	20.4	21.6	22.5	23.0	23.8	23.5	23.3		23.8	24.1	24.5		24.8	
MID	20.4	21.1	22.3	22.7	23.1	23.4	23.0		23.0	23.7	24.5		24.5	
BOT	20.4	21.2	22.3	22.5	23.2	23.1	23.1		23.0	23.8	24.5		24.6	
6 TOP	21.2	22.4	23.1	25.1	25.3	24.5	25.1		24.7	25.3	25.3		25.2	
MID	21.2	22.0	23.1	24.5	24.5	24.5	24.6		23.9	24.3	25.3		25.1	
BOT	21.2	21.9	23.0	24.4	24.5	24.5	24.5		23.7	24.4	25.4		25.1	
7 TOP	21.5	21.7	23.1	22.9	23.5	24.8	23.4	23.8	24.6	25.5	26.0			
MID	21.5	21.6	22.9	22.7	23.4	23.4	23.4	23.8	24.4	25.2	26.2			
BOT	21.5	21.7	22.3	22.7	23.0	23.2	23.4	23.8	24.4	25.2	26.2			
8 TOP	20.3	22.2	22.6	23.5	23.0	24.6	22.8	23.3	23.6	24.4	24.8			
MID	20.3	21.6	22.4	22.7	23.0	22.8	22.8	23.3	23.6	24.4	24.7			
BOT	20.7	20.6	21.1	22.2	23.0	23.0	22.8	23.4	23.7	24.4	24.8			
9 TOP	20.5	20.4	20.9	21.8	22.2	22.7	22.6	22.7	23.3	23.8				
MID	20.1	20.4	20.9	21.8	22.0	22.3	22.4	22.8	23.2	23.7				
BOT	20.1	20.5	20.9	21.8	22.0	22.3	22.4	22.8	23.2	23.7				
10 TOP		21.4	22.0	22.5				23.0	22.7	23.8				
MID		21.1	21.9	22.5				22.8	22.7	23.5				
BOT		21.0	21.8	22.5				22.7	22.8	23.5				
11 TOP														
MID														
BOT														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

PH (FIRST RUN)
STANDARD UNITS

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1 TOP		0.79			7.80	0.79		8.10	7.80	7.90	8.10	8.30	7.70	8.00
MID	8.15		7.80	7.60	8.00	8.00		8.10	7.80	8.10	8.20	8.50	7.70	7.80
BOT					8.10	8.10		8.15	7.80	8.10	8.60	8.70	7.80	7.90
LAB	7.8	7.9	7.8	8.0	8.0	8.0		8.0	8.0	8.0	8.0	7.9	7.9	8.0
2 TOP					7.40	7.90		8.10	7.80	7.90	8.10		7.80	7.80
MID	7.85	7.80	7.60	7.70	7.70	7.90		8.10	7.80	8.00	8.10		7.80	7.70
BOT					7.70	7.90		8.10	7.80	8.10	8.10		7.80	7.70
LAB	7.7	7.7	7.7	7.9	7.5	7.9		7.9	7.9	7.9	7.9		7.8	7.9
3 TOP					6.10	7.90		8.00	8.00	7.90	8.10		7.70	7.80
MID	7.75	7.85	7.60	7.70	8.20	7.90		8.00	8.00	7.90	8.10		7.70	7.50
BOT					8.10	7.90		8.00	8.00	8.00	8.10		7.70	7.60
LAB	7.7	7.7	7.7	7.8	7.9	7.8		7.8	7.9	7.9	7.9		7.8	7.9
4 TOP					6.30	8.00	7.30	8.10	8.00	8.00	8.00		7.60	7.70
MID	7.75	7.65	7.60	7.70	8.20	8.00	7.40	8.00	8.00	8.00	8.00		7.60	7.60
BOT					8.20	8.00	7.40	8.00	8.00	8.10	8.10		7.70	7.70
LAB	7.8	7.8	7.7	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9		7.8	7.9
5 TOP					8.00	7.10	7.50	7.90		7.90	8.00		7.50	7.50
MID	7.50	7.80	7.50	7.60	8.25	7.90	7.50	7.90		7.90	7.90		7.50	7.60
BOT					8.20	7.90	7.40	7.90		7.90	8.00		7.50	7.40
LAB	7.7	7.7	7.7	7.9	7.9	7.8	7.9	7.8	7.8	7.9	7.9		7.8	7.8
6 TOP					7.90	7.90		7.80		7.80	7.80		7.40	7.60
MID	7.80	7.65	7.40	7.50	8.10	7.70		7.80		7.80	7.90		7.40	7.30
BOT					8.30	7.80		7.80		7.90	7.90		7.50	7.50
LAB	7.5	7.5	7.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8		7.7	7.8
7 TOP	7.85	7.30	7.10	7.20	6.00	7.60	7.20	7.30	7.60	7.90	7.60	7.40	6.60	7.70
MID					7.90	7.70	7.20	7.10	7.40	8.00	7.80	7.80	6.60	7.65
BOT					7.90	7.80	7.20	7.10	7.40	7.90	7.90	7.90	6.60	7.70
LAB	7.7	7.7	7.6	7.7	7.7	7.7	7.7	7.7	7.7	7.8	7.8	7.8	7.8	7.8
8 TOP					8.50	7.80	7.70	7.30	7.80	8.10	7.80		7.50	7.80
MID	8.00	7.80	7.60	7.10	7.60	8.10	7.70	7.30	7.80	8.10	8.10		7.50	7.75
BOT					8.30	8.10	7.70	7.30	7.80	8.10	8.00		7.50	7.60
LAB	7.7	7.7	7.7	7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.9	7.8	7.8	7.9
9 TOP					7.80	17.90		7.90	7.80	7.90	6.10	7.80	7.80	7.60
MID	8.15	7.90	7.80	7.60	8.30	8.00		7.90	7.80	8.00	8.70	7.80	7.80	7.80
BOT					8.00	8.10		7.90	7.80	8.10	8.60	7.80	7.80	7.80
LAB	7.8	7.7	7.8	7.8	7.8	7.8		7.8	7.8	7.8	7.9	7.8	7.8	7.9
10 TOP					4.10	8.00		8.10	7.80	8.00	8.10	7.90	7.80	7.60
MID	8.15	7.80	7.80	7.60	8.10	8.10		8.10	7.80	8.00	8.20	7.90	7.80	7.70
BOT					8.10	8.10		8.10	7.80	8.10	8.50	7.90	7.80	7.80
LAB	7.9	7.8	7.8	7.9	7.9	7.9		7.8	7.9	7.9	8.0	7.9	7.9	8.0
11 TOP														
MID														
BOT														
LAB														

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PH (FIRST RUN)
STANDARD UNITS

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1 TOP	7.60	7.80	7.80	7.10		7.60								
MID	7.30	7.80	7.80	7.00		7.60								
BOT	7.50	7.80	7.90	6.40		7.60								
LAB	8.0	7.9	7.9	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
2 TOP	7.40	7.60	7.80	6.30		7.70								
MID	7.10	7.70	7.80	6.30		7.50								
BOT	7.30	7.70	7.70	6.30		8.00								
LAB	7.9	7.9	7.9	7.9	7.9	7.9	8.0	7.9	7.9	7.9	7.9	7.9	7.9	7.9
3 TOP	7.40	7.80	7.80	6.90		7.80								
MID	7.10	7.80	7.80	6.90		7.80								
BOT	7.30	7.70	7.80	7.00		7.80								
LAB	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9		7.8	7.8
4 TOP	7.90	7.80	7.70	7.30										
MID	7.90	7.80	7.70	7.30										
BOT	7.90	7.80	7.80	7.30										
LAB	7.9	7.9	7.9	8.0	8.0	8.0	8.0	7.9	7.9	8.0	7.9	7.9	7.8	7.9
5 TOP	7.80	7.60	7.80	6.90										
MID	7.70	7.60	7.80	7.00		7.70								
BOT	7.70	7.60	7.80	7.30		7.40								
LAB	7.8	7.8	7.8	7.9	7.9	7.9	8.0	7.9	7.9	7.9	7.9	7.8	7.8	7.8
6 TOP	7.70	7.50	7.60	6.70										
MID	7.70	7.50	7.60	6.70										
BOT	7.60	7.50	7.60	6.90										
LAB	7.8	7.8	7.8	7.8	7.8	7.9	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.7
7 TOP	7.50	7.60	7.70	6.40		7.40	7.90							
MID	7.60	7.70	7.70	6.60		8.00	8.20							
BOT	7.70	7.70	7.70	6.90		7.80	8.10							
LAB	7.9	7.8	7.8	7.9	7.8	7.8	7.8	7.7	7.7	7.7	7.8	7.9	7.8	7.8
8 TOP	7.70	7.80	7.70	6.90		7.90	6.70							
MID	7.60	7.80	7.80	6.90		8.00	7.50							
BOT	7.80	7.90	7.80	7.00		7.90	7.20							
LAB	7.9	7.9	7.8	7.9	7.8	7.8	7.8	7.8	7.8	7.8	7.9	7.9	7.9	7.9
9 TOP	7.80	7.80	7.80	6.70		7.70								
MID	7.60	7.80	7.80	7.00		7.80								
BOT	7.70	7.90	7.90	7.00		7.80								
LAB	7.9	7.9	7.8	7.9	7.9	7.9	7.9	7.8	7.8	7.8	7.8	7.9	7.8	7.9
10 TOP	7.50	7.90	7.90	7.10		7.80								
MID	7.40	7.90	7.90	6.70		7.70								
BOT	7.50	7.90	7.80	7.00		7.80								
LAB	8.0	8.0	8.0	8.0		8.0	8.0	7.9	7.9	7.9	7.9	7.9	7.9	7.9
11 TOP														
MID														
BOT														
LAB														

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

PH (SECOND RUN)
STANDARD UNITS

DATE *********		4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION															
1	TOP	8.00	8.00	8.00		7.80	7.90		7.55		8.05	7.90	7.80	7.80	7.80
	MID	8.00	8.00	8.00		7.80	7.90		7.55		8.05	7.90	7.80	7.80	7.80
	BOT	8.00	8.00	8.00		7.80	7.95		7.55		8.05	7.90	7.80	7.80	7.80
2	TOP	8.00	8.00	8.00		7.70	7.75		7.50	7.70	7.95	7.90	7.80	7.80	7.80
	MID	8.00	8.00	8.00		7.70	7.80		7.55	7.70	8.00	7.90	7.80	7.80	7.80
	BOT	8.00	8.00	8.00		7.70	7.75		7.55	7.70	7.95	7.90	7.80	7.80	7.80
3	TOP	7.95	8.10	8.10		7.70	7.80		7.50	7.70	8.00	7.80	7.80	7.80	7.80
	MID	7.95	8.10	8.10		7.70	7.80		7.50	7.70	8.00	7.80	7.80	7.80	7.80
	BOT	7.95	8.10	8.10		7.70	7.80		7.50	7.70	8.00	7.80	7.80	7.80	7.80
4	TOP	7.95	7.95	8.00		7.75	7.80		7.60	7.75	8.10	7.90	7.80	7.80	7.80
	MID	7.95	7.95	8.00		7.75	7.75		7.55	7.65	8.05	7.90	7.80	7.80	7.80
	BOT	8.00	7.90	7.95		7.75	7.80		7.50	7.70	8.05	7.90	7.80	7.80	7.80
5	TOP	7.95	7.90	7.90		7.60	7.65		7.50	7.60	7.90	7.90	7.70	7.70	7.70
	MID	7.95	7.90	7.90		7.60	7.70		7.45	7.60	7.90	7.90	7.70	7.80	7.70
	BOT	7.95	7.80	7.90		7.65	7.70		7.50	7.60	7.90	7.90	7.70	7.70	7.70
6	TOP	7.85	7.85	7.90	7.85	7.65	8.00		7.40	7.70	7.80	7.80	7.60	7.70	7.60
	MID	7.85	7.90	7.90	7.85	7.60	8.10		7.40	7.70	7.75	7.80	7.60	7.80	7.60
	BOT	7.80	7.80	7.90	7.80	7.60	8.10		7.35	7.70	7.75	7.80	7.60	7.80	7.60
7	TOP	7.60	7.60	7.75	7.80	7.60	7.80		7.20	7.60	7.70	7.70	7.50	7.40	7.50
	MID	7.80	7.65	7.80	7.80	7.55	7.80		7.20	7.65	7.80	7.70	7.50	7.50	7.50
	BOT	7.80	7.70	7.80	7.80	7.55	7.80		7.20	7.65	7.75	7.70	7.50	7.40	7.50
8	TOP	7.90	7.95	7.95	7.90	7.60	7.90		7.40	7.65	7.80	7.80	7.70	7.70	7.70
	MID	7.95	7.95	7.95	7.90	7.60	7.85		7.40	7.65	7.90	7.80	7.70	7.80	7.70
	BOT	8.00	7.95	7.95	7.90	7.60	7.85		7.40	7.65	7.90	7.80	7.70	7.70	7.70
9	TOP	7.95	7.95	7.95	7.95	7.70	7.90		7.40	7.60	7.90	7.80	7.70	7.70	7.60
	MID	7.95	7.90	7.95	7.95	7.75	7.90		7.45	7.60	7.90	7.80	7.70	7.70	7.60
	BOT	8.00	7.90	7.95	7.95	7.70	7.90		7.40	7.60	7.90	7.80	7.60	7.70	7.60
10	TOP	7.90	7.95	8.00	8.00	7.80	7.95		7.55		8.00	7.90	7.80	7.80	
	MID	7.95	8.00	7.95	8.00	7.80	7.95		7.60		8.00	7.90	7.80	7.80	
	BOT	7.95	8.00	7.95	8.00	7.80	7.90		7.60		8.00	7.90	7.80	7.80	
11	TOP														
	MID														
	BOT														

A-6a

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

PH (SECOND RUN)
STANDARD UNITS

DATE *********		4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION															
1	TOP	7.80	7.80	7.80	7.60	7.60	7.40		8.00	8.00	8.00				
	MID	7.80	7.80	7.80	7.70	7.60	7.40		8.00	7.90	8.00				
	BOT	7.80	7.80	7.80	7.70	7.60	7.30		8.00	7.90	8.00				
2	TOP	7.80	7.80	7.70	7.70	7.60	7.40	7.80	8.00	7.90	8.10				
	MID	7.70	7.80	7.90	7.70	7.50	7.40	7.70	7.90	7.80	8.00				
	BOT	7.70	7.80	7.90	7.70	7.50	7.40	7.70	7.90	7.90	8.00				
3	TOP	7.70	7.70	7.70	7.80	7.50	7.50	7.70	7.80	7.80	7.90				
	MID	7.70	7.70	7.80	7.80	7.50	7.40	7.80	7.80	7.70	7.90				
	BOT	7.70	7.70	7.70	7.80	7.50	7.40	7.80	7.80	7.80	7.90				
4	TOP	7.80	7.70	7.70	7.70	7.40	7.40		7.90	7.80	8.00				
	MID	7.80	7.70	7.70	7.70	7.50	7.40		7.70	7.90	8.00				
	BOT	7.80	7.70	7.70	7.70	7.50	7.40		7.80	7.90	8.00				
5	TOP	7.70	7.60	7.60	7.70	7.40	7.20	7.70		7.80	8.00	7.90		7.60	
	MID	7.70	7.60	7.80	7.90	7.40	7.40	7.90		7.80	8.00	7.90		7.70	
	BOT	7.70	7.60	7.70	7.90	7.40	7.30	7.80		7.80	8.00	7.90		7.60	
6	TOP	7.60	7.50	7.60	7.60	7.40	7.30	7.80		7.70	7.80	7.80		7.70	
	MID	7.60	7.50	7.60	7.70	7.40	7.30	7.80		7.70	7.90	7.80		7.70	
	BOT	7.60	7.50	7.60	7.80	7.40	7.30	7.90		7.70	7.80	7.80		7.70	
7	TOP	7.40	7.60	7.60	7.50	7.40	7.30	7.60	7.60	7.50	7.80	7.80			
	MID	7.50	7.60	7.60	7.50	7.40	7.30	7.60	7.60	7.70	7.80	7.70			
	BOT	7.50	7.60	7.60	7.50	7.40	7.30	7.60	7.60	7.60	7.80	7.70			
8	TOP	7.60	7.60	7.70	7.60	7.50	7.40	7.60	7.90	7.70	7.90	7.90			
	MID	7.60	7.70	7.70	7.70	7.50	7.40	7.70	7.60	7.70	7.90	7.90			
	BOT	7.60	7.70	7.80	7.70	7.50	7.40	7.70	7.50	7.70	7.90	7.90			
9	TOP	7.70	7.70	7.70	7.60	7.50	7.30	7.70	7.80	7.80	7.90				
	MID	7.70	7.70	7.70	7.60	7.50	7.30	7.70	7.60	7.80	7.90				
	BOT	7.70	7.70	7.70	7.60	7.50	7.30	7.70	7.50	7.80	7.90				
10	TOP		7.60	7.60	7.60				8.00	8.00	8.10				
	MID		7.60	7.70	7.70				7.90	7.80	8.10				
	BOT		7.70	7.70	7.70				8.00	7.80	8.10				
11	TOP														
	MID														
	BOT														

A-6b

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL ALKALINITY
MG/L CALCIUM CARBONATE

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	100	108	108	104	104	102		102	99	98	98	101	99	101
2	98	97	100	97	98	98		99	97	96	96		97	99
3	102	120	97	107	104	101		102	100	99	100		99	101
4	99	115	109	108	106	105	105	103	100	98	99		96	98
5	98	97	97	99	98	94	101	97	95	97	95		93	93
6	86	96	91	95	95	95	94	94	91	91	92		91	92
7	98	94	92	90	90	90	87	86	86	88	90	93	93	93
8	95	100	92	94	95	95	90	88	90	91	92	94	96	95
9	97	93	90	86	87	85		81	79	83	85	89	90	90
10	105	103	104	104	104	103		101	100	102	103	103	101	103
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	103	101	101	101	102	103	103	101	102	103	100	100	100	103
2	99	98	98	99	99	98	101	99	100	98	99	98	98	99
3	101	100	101	102	101	100	98	98	98	99	99		99	100
4	97	98	99	102	101	100	101	98	99	100	99	98	98	98
5	93	94	95	97	97	97	98	97	98	98	97	97	96	97
6	91	91	92	93	94	94	95	95	95	96	95	95	95	95
7	95	94	94	95	94	91	92	91	91	92	94	95	96	98
8	95	96	95	97	96	94	94	89	92	93	95	97	98	98
9	92	92	94	92	91	89	91	85	85	85	89	92	93	95
10	102	102	104	104		102	104	102	102	102	102	104	103	104
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TURBIDITY
JTU

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	25.0	23.0	26.0	19.0	20.0	17.0		20.0	11.0	7.0	8.0	9.1	10.0	12.0
2	16.0	12.0	25.0	11.0	12.0	11.0		6.5	8.8	7.3	6.8		6.7	8.4
3	7.2	6.0	7.2	7.2	9.2	7.7		5.1	4.2	7.5	10.0		6.6	8.7
4	12.0	17.0	17.0	12.0	8.5	8.8	9.0	10.0	5.2	5.3	5.3		8.0	10.0
5	18.0	17.0	18.0	11.0	9.3	10.0	9.8	11.0	7.1	4.8	5.8		6.8	9.1
6	13.0	11.0	8.1	5.8	7.2	5.4	6.8	5.3	5.2	4.2	5.2		5.7	8.0
7	9.8	14.0	10.0	11.0	10.0	8.3	11.0	8.3	6.8	6.7	8.2	8.5	5.9	7.8
8	7.1	10.0	10.0	12.0	11.0	8.2	13.0	13.0	11.0	5.0	6.2	6.4	5.5	8.2
9	5.8	8.0	7.8	7.0	6.7	6.2		5.0	4.2	5.0	4.6	4.7	5.7	8.2
10	13.0	21.0	12.0	11.0	12.0	7.2		5.3	4.2	3.9	5.2	6.3	6.3	8.3
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	12.0	15.0	21.0	30.0	15.0	23.0	18.0	12.0	16.0	16.0	8.5	12.0	12.0	19.0
2	10.0	13.0	11.0	13.0	17.0	12.0	12.0	22.0	15.0	10.0	21.0	14.0	8.6	10.0
3	8.8	7.7	10.0	12.0	10.0	5.8	6.7	5.8	7.2	7.1	11.0		9.0	11.0
4	10.0	11.0	12.0	13.0	11.0	9.6	13.0	11.0	8.8	10.0	10.0	8.5	9.5	12.0
5	10.0	13.0	18.0	17.0	22.0	10.0	12.0	14.0	11.0	10.0	10.0	11.0	10.0	15.0
6	10.0	10.0	12.0	14.0	9.5	10.0	7.4	8.2	8.7	11.0	10.0	11.0	12.0	13.0
7	10.0	11.0	15.0	13.0	10.0	13.0	12.0	10.0	10.0	12.0	12.0	12.0	11.0	8.8
8	10.0	7.7	8.3	10.0	9.2	12.0	11.0	13.0	12.0	13.0	10.0	10.0	10.0	9.7
9	6.7	6.6	6.9	8.0	6.3	6.2	7.3	6.2	6.8	8.0	8.8	6.6	8.4	6.6
10	10.0	7.7	10.0	6.6		7.0	8.1	8.8	7.8	6.4	7.0	10.0	11.0	9.2
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SECCHI DISK
FIRST RUN - FEET

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	2	3	2	2	3	3		4	5	5	5	4		4
2	2	3	4	4	4	4		4	4	4	4			5
3	3	4	4	5	4	5		4	5	5	5			4
4	3	2	4	5	5	5	4	5	5	6	5			3
5	2	3	4	5	4	4	3	5	4	5	5			4
6	3	3	4	5	5	5	4	6	5	6	5			4
7	3	3	3	3	3	5	4	4	4	4	4	4		4
8	3	4	4	3	3	3	3	4	3	4	5	4		4
9	5	4	4	4	5	5		5	5	5	5	5		5
10	4	3	4	3	4	5		6	6	6	5	5		4
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	3	3	3	4	3	3	3	4	3		3	5		4
2	4	3	3	3	3	3	4		4		4	3		3
3	3	3	3	3		3	3		3					3
4	3	3		3	3	3	4	3	4	4		4		
5	4	3		3	4	5	3	4	3	3		3		4
6	3			3	4	3		4	4	3		3		4
7	4	3	3	3	3	3	3	3	3	3	3	3	3	3
8	3	3	3	3	3	4	3	3	3	3	3	3	4	3
9	5	5	3	3	3	4	3	4	4	4	3	3	3	3
10	3	4	4	3		4	3	3	3		4	3	3	3
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SECCHI DISK
SECOND RUN- FEET

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	3	3	3		4	5		5		6	4	5	4	5
2	3	3	4		4	4		5	5	5	4	5	4	5
3	3	3	5		4	4		5	4	6	5	5	5	
4	3	4	3		5	5		6	5	6	5		4	4
5	3	4	3		4	5		5	5	6	5	4	4	4
6	3	3	4	4	5	5		5	5	5	6	5	4	5
7	2	3	3	4	4	4		5	5	5	5	4	4	4
8	2	2	3	4	4	5		5	5	5	5	4	4	4
9	3	3	3	5	5	5		5	6	5	5	5	4	5
10	3	3	4	3	5	6		6		5	5	5	5	
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	4	5	5	4	4	3		5	4	4				
2	4	4	4	4	4	3	3	4	4	4				
3	4	5	4	4	4	3	4	5	4	4				
4		5	5	4	4	3		4	5	5				
5	4	4	4	4	4	4	3		5	4	4		3	
6	4	4	4	4	4	4	3		5	4	3		3	
7	4	3	3	4	4	3	3	3	4	4	3		3	
8	3	4	3	4	4	3	4	4	4	4	4		2	
9	5	5		4	5	5	4	5	5	5			4	
10		4	4	4				5	5	5				
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL SUSPENDED SOLIDS
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	77	62	65	30	49	24		50	30	14	23	12	16	23
2	48	24	66	14	51	18		11	25	15	22		4	26
3	28	36	7	8	32	15		11	15	12	26		11	25
4	40	19	40	19	31	14	1	25	15	9	14		9	32
5	44	30	48	18	29	47	9	32	15	13	18		20	28
6	40	20	19	3	25	9	7	13	11	4	14		18	33
7	22	19	28	14	47	14	22	31	12	24	22	11	23	26
8	19	17	23	23	34	15	47	33	31	7	16	12	24	26
9	14	11	24	10	26	13		16	9	12	12	7	14	25
10	35	44	48	17	35	13		20	11	11	14	21	17	27
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	20	18	42	44	23	48	37	20	28	31	19	23	41	45
2	14	15	16	10	18	21	2	50	31	18	101	25	16	21
3	10	5	15	2	9	18	12	7	14	14	30		16	25
4	15	7	17	17	36	17	21	30	21	19	25	16	17	27
5	17	12	45	2	47	20	32	15	20	21	26	20	19	37
6	23	10	19	4	18	23	16	16	14	24	20	20	13	33
7	11	6	28	2	8	55	22	21	17	17	7	28	23	21
8	14	1	13	10	14	38	18	27	20	29	27	21	22	21
9	10	5	12	32	6	10	14	8	11	16	20	15	19	15
10	10	2	17	4		11	18	21	15	13	16	20	15	24
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 STUDIES

BOD (FIRST RUN)
MG/L

DATE *********		4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION															
1	2 DAY	0.75	0.45	0.43	0.60	0.40	0.68		1.43	0.62	0.55	0.48	0.60	0.50	1.02
	5 DAY	1.15	0.95	0.83	1.20	1.05	1.08		2.43	1.22	0.98	0.88	0.85	1.10	1.52
	7 DAY	1.75		1.53		1.50			2.68		1.03		1.10		
	10 DAY	1.80		1.58		1.65			3.18		1.23		1.40		
2	2 DAY	0.65	0.43	0.50	0.40	0.52	0.40		0.30	0.80	0.40	0.37		0.37	0.73
	5 DAY	1.20	0.98	1.00	0.85	1.07	0.90		0.75	1.05	0.95	0.77		1.12	1.23
	7 DAY	1.50		1.30		1.17			0.90		1.15				
	10 DAY	1.70		1.55		1.37			1.35		1.35				
3	2 DAY	0.72	0.45		0.45	0.50	0.48		0.40	0.70	0.42	0.60		0.48	0.87
	5 DAY	1.32	0.90	1.28	0.95	1.20	0.98		0.75	1.25	0.97	1.00		1.18	1.67
	7 DAY	1.72		1.43		1.40			0.85		1.22				
	10 DAY	1.92		1.38		1.65			1.35		1.43				
4	2 DAY	0.67	0.40	0.25	0.40	0.70	0.20	0.80	0.65	0.70	0.45	0.40		0.50	1.30
	5 DAY	1.27	0.85	0.65	0.80	0.85	0.80	1.35	0.90	1.05	0.90	0.85		0.95	2.75
	7 DAY	1.62		1.00		1.45			0.95		1.05				
	10 DAY	2.07		1.40		1.35			1.10		1.25				
5	2 DAY	0.80	0.48	0.50	0.45	0.70	0.20	0.63	0.43	0.50	0.68	0.38		0.60	0.73
	5 DAY	1.45	0.98	0.95	0.80	1.25	0.65	1.18	0.93	0.90	0.98	0.93		1.10	1.28
	7 DAY	1.60		1.45		1.30			0.98		1.28				
	10 DAY	2.00		1.80		1.65			1.18		1.48				
6	2 DAY	0.77	0.45	0.53	0.55	0.55	0.25	0.65	0.58	0.80	0.43	0.67		0.67	0.58
	5 DAY	1.32	0.95	1.03	1.05	1.05	0.75	1.25	0.93	1.15	0.68	1.02		1.02	1.58
	7 DAY	1.42		1.53		1.40			1.73		0.83				
	10 DAY	1.97		1.73		1.60			1.38		1.08				
7	2 DAY	0.78	0.53	0.45	0.52	0.55	0.45	0.70	0.62	0.80	0.60	0.55	0.83	0.68	0.40
	5 DAY	1.48	1.38	1.15	1.07	1.15	1.70	1.40	1.12	1.35	1.05	0.85	1.33	1.43	1.00
	7 DAY	1.53		1.30		1.35			1.17		1.40		1.53		
	10 DAY	2.08		1.70		1.50			1.57		1.65		1.78		
8	2 DAY	0.70	0.18	0.55	0.45	0.62	0.53	0.55	0.48	0.62	0.35	0.40	0.60	0.50	0.53
	5 DAY	0.95	0.58	1.05	0.85	1.07	1.48	1.25	0.93	1.02	0.60	0.90	1.00	1.25	1.08
	7 DAY	1.35		1.25		1.22			1.18		1.00		1.15		
	10 DAY	1.70		1.50		1.42			1.33		1.00		1.70		
9	2 DAY	0.50	0.50	0.40	0.50	0.55	0.40		0.53	0.60	0.45	0.57	0.45	0.55	0.60
	5 DAY	0.85	0.80	0.80	0.75	0.90	1.35		0.83	0.90	0.75	0.87	0.80	0.90	1.25
	7 DAY	1.30		1.05		1.25			0.83		0.80		1.30		
	10 DAY	1.55		1.30		1.45			1.08		1.05		1.30		
10	2 DAY	0.65	0.28	0.40	0.40	1.25	0.45		0.55	0.60	0.40	0.47	0.45	0.38	0.92
	5 DAY	1.30	0.93	0.65	0.75	2.40	0.80		1.25	0.95	0.60	1.12	0.90	0.78	1.52
	7 DAY	1.50		0.85		3.05			1.20		0.65		1.10		
	10 DAY	1.55		1.25		3.30			1.40		0.90		1.10		
11	2 DAY														
	5 DAY														
	7 DAY														
	10 DAY														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 STUDIES

BOD (FIRST RUN)
MG/L

DATE ********* STATION	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
1 2 DAY	0.28	0.57	0.58	0.68	0.45	0.58	0.45	0.22	0.50	0.50	0.40	0.55	0.55	0.55
5 DAY	0.93	0.97	1.18	1.48	1.00	0.98	0.80	0.67	1.05	0.85	0.75	1.00	0.95	0.95
7 DAY	1.13		1.43		1.40									
10 DAY	1.43		1.58		1.55									
2 2 DAY	0.55	0.60	0.67	0.40	0.53	0.50	0.60	0.40	0.35	0.47	0.25	0.48	0.55	0.45
5 DAY	1.00	1.10	1.12	1.10	1.73	1.10	0.95	1.05	0.70	0.72	0.75	0.78	0.90	0.95
7 DAY	1.25		1.42		2.23									
10 DAY	1.65		1.47		2.78									
3 2 DAY	0.52	0.47	0.55	0.55	0.40	0.52	0.38	0.25	0.33	0.48	0.40		0.33	0.40
5 DAY	1.07	0.72	1.15	1.10	0.95	0.97	0.88	0.85	0.58	0.98	0.80		0.73	1.05
7 DAY	1.42		1.40		1.00									
10 DAY	1.47		1.55		1.30									
4 2 DAY	0.58	0.40	0.80	0.53	0.50	0.58	0.55	0.40	0.40	0.68	0.55	0.57	0.42	0.52
5 DAY	1.03	0.60	1.50	0.83	0.75	1.28	0.95	0.85	0.85	0.98	0.85	1.07	0.82	1.12
7 DAY	1.68		1.55		1.10									
10 DAY	1.43		1.85		1.35									
5 2 DAY	0.40	0.73	0.65	0.32	0.30	0.50	0.45	0.45	0.45	0.52	0.38	0.30	0.58	0.65
5 DAY	0.80	1.28	1.10	0.92	0.75	0.80	1.05	0.70	0.80	0.72	0.73	0.70	1.08	1.15
7 DAY	1.25		1.30		1.15									
10 DAY	1.45		1.85		1.35									
6 2 DAY	0.50	0.55	0.45	0.75	0.43	0.68	0.50	0.43	0.55	0.55	0.40	0.50	0.55	0.70
5 DAY	0.85	0.90	1.10	1.40	0.98	1.03	0.95	1.08	0.90	0.95	0.85	1.10	1.15	1.20
7 DAY	1.05		1.40		1.08									
10 DAY	1.60		1.60		1.38									
7 2 DAY	0.90	0.50	0.70	0.80	0.52	0.67	0.57	0.58	0.60	0.45	0.52	0.50	0.55	1.40
5 DAY	1.35	0.85	1.50	1.45	1.12	0.92	1.22	0.88	1.15	0.95	1.02	1.15	0.80	1.80
7 DAY	1.65		1.80		1.27									
10 DAY	2.50		2.10		1.52									
8 2 DAY	0.50	0.40	0.53	0.45	0.38	0.60	0.47	0.30	0.40	0.40	0.40	0.55	0.32	0.53
5 DAY	0.90	0.60	0.93	0.95	0.93	1.30	0.97	1.05	0.85	0.85	0.80	1.00	0.77	0.88
7 DAY	1.10		0.98		1.18									
10 DAY	1.50		1.28		1.28									
9 2 DAY	0.60	0.53	0.70	0.48	0.17	0.45	0.55	0.27	0.45	0.35	0.55	0.40	0.15	0.27
5 DAY	1.00	0.73	0.95	0.93	0.72	0.80	0.85	0.82	0.70	0.70	0.60	0.80	0.40	0.87
7 DAY	1.30		1.10		0.87									
10 DAY	1.65		1.30		0.87									
10 2 DAY	0.40	0.48	0.50	0.60		0.73	0.45	0.35	0.40	0.35	0.50	0.43	0.55	0.37
5 DAY	1.00	0.58	0.80	1.05		0.98	0.50	1.30	0.55	0.60	0.75	0.88	0.75	0.77
7 DAY	1.25		0.90											
10 DAY	1.55		1.25											
11 2 DAY														
5 DAY														
7 DAY														
10 DAY														

A-12b

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 STUDIES

BOD (LAB. DUPLICATE)
MG/L

DATE ********* STATION		4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
1	2 DAY	0.75	0.50	0.38	0.60	0.65	0.58		1.98	0.62	0.60	0.38	0.65	0.55	1.07
	5 DAY	1.15	0.95	0.83	1.20	1.10	1.08		2.43	1.17	0.93	0.93	1.05	1.15	1.62
	7 DAY	1.35		1.18		1.40			2.73		1.08		1.00		
	10 DAY	1.75		1.43		1.65			3.08		1.23		1.40		
2	2 DAY	0.75	0.43	0.50	0.45	0.47	0.50		0.45	0.70	0.40	0.47		0.42	0.73
	5 DAY	1.30	0.88	1.05	0.95	1.17	0.90		0.75	1.20	0.90	0.82		1.12	1.28
	7 DAY	1.40		1.25		1.17			0.85		1.10				
	10 DAY	2.00		1.65					1.30		1.20				
3	2 DAY	0.72	0.50		0.55	0.50	0.28		0.35	0.85	0.42	0.60		0.58	0.82
	5 DAY	1.37	1.00	0.68	0.85	1.25	0.88		0.85	1.25	0.87	1.05		1.18	1.62
	7 DAY	1.72		0.93		1.40			0.85		1.22				
	10 DAY	1.97		1.48		1.70			1.25		1.53				
4	2 DAY	0.57	0.45	0.15	0.40	0.45	0.30	0.80	0.50	0.60	0.50	0.55		0.50	1.20
	5 DAY	1.32	0.95	0.75	0.70	1.00	0.65	1.25	0.90	1.15	0.85	0.90		1.10	2.45
	7 DAY	1.72		1.05		1.20			1.05		1.10				
	10 DAY	1.97		1.45		1.45			1.25		1.35				
5	2 DAY	0.80	0.53	0.55	0.40	0.70	0.25	0.73	0.43	0.60	0.58	0.43		0.60	0.83
	5 DAY	1.35	0.88	1.00	0.80	1.10	0.70	0.98	0.98	0.85	1.03	0.93		1.10	1.38
	7 DAY	1.70		1.20		1.45			1.08		1.08				
	10 DAY	2.20		1.60		1.60			1.13		1.48				
6	2 DAY	0.67	0.50	0.53	0.45	0.55	0.30	0.65	0.38	0.85	0.48	0.52		0.62	0.78
	5 DAY	1.22	0.85	0.93	1.15	1.05	0.75	1.00	0.88	1.15	0.63	1.02		1.17	1.43
	7 DAY	1.52		1.38		1.30			1.53		0.83				
	10 DAY	1.97		1.93		1.45			1.28		1.23				
7	2 DAY	0.78	0.73	0.45	0.52	0.60	0.70	0.75	0.72	0.80	0.60	0.45	0.78	0.88	0.60
	5 DAY	1.28	1.33	1.00	1.07	1.10	1.40	1.25	1.22	1.10	1.10	0.75	1.23	1.38	1.25
	7 DAY	1.58		1.40		1.35			1.42		1.30		1.43		
	10 DAY	1.53		1.60		1.60			2.27		1.65		1.78		
8	2 DAY	0.65	0.28	0.50	0.60	0.62	0.63	0.45	0.53	0.47	0.35	0.35	0.60	0.60	0.53
	5 DAY	1.20	0.68	1.15	1.00	1.07	1.43	1.20	1.13	1.12	0.70	0.80	1.00	1.15	0.88
	7 DAY	1.35		1.30		1.37			1.13		0.95		1.35		
	10 DAY	1.95		1.45		1.62			1.33		1.05		1.50		
9	2 DAY	0.75	0.60	0.45	0.35	0.50	0.50		0.33	0.50	0.45	0.57	0.35	0.30	0.70
	5 DAY	1.15	0.80	0.75	0.75	0.85	1.15		0.88	0.95	0.75	0.82	0.85	1.10	1.30
	7 DAY	1.55		1.05		1.20			0.98		0.90		0.95		
	10 DAY	1.65		1.30		1.35			1.23		1.00		1.30		
10	2 DAY	0.65	0.33	0.45	0.50	1.25	0.70		0.55	0.55	0.30	0.57	0.30	0.53	0.92
	5 DAY	1.05	0.88	0.85	0.75	2.45	0.80		1.05	0.90	0.70	1.12	0.60	0.78	1.57
	7 DAY	1.55		0.90		2.90			1.20		0.70		0.90		
	10 DAY	1.80		1.25		3.30			1.55		1.10		1.20		
11	2 DAY														
	5 DAY														
	7 DAY														
	10 DAY														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 STUDIES

BOD (LAB. DUPLICATE)
MG/L

DATE ********* STATION		4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
1	2 DAY	0.53	0.52	0.48	0.63	0.45	0.48	0.45	0.37	0.50	0.50	0.40	0.65	0.45	0.45
	5 DAY	0.78	0.97	1.08	1.23	1.00	0.98	1.00	0.57	1.00	0.75	0.75	0.90	0.85	0.80
	7 DAY	1.28		1.28		1.35									
	10 DAY	1.13		1.53		1.50									
2	2 DAY	0.55	0.60	0.67	0.50	0.58	0.70	0.50	0.25	0.30	0.37	0.40	0.48	0.55	0.53
	5 DAY	1.10	1.20	1.12	1.20	1.63	1.20	0.95	0.95	0.70	0.77	0.75	0.93	0.90	0.85
	7 DAY	1.30		1.52		2.23									
	10 DAY	1.70		1.62		2.68									
3	2 DAY	0.67	0.42	0.50	0.50	0.20	0.62	0.48	0.45	0.33	0.53	0.30		0.43	0.50
	5 DAY	0.92	0.72	1.05	1.35	0.95	0.97	0.88	0.95	0.53	0.93	0.80		0.78	0.95
	7 DAY	1.42		1.35		1.10									
	10 DAY	1.57		1.55		1.30									
4	2 DAY	0.63	0.45	0.85	0.63	0.25	0.73	0.55	0.45	0.50	0.48	0.50	0.57	0.52	0.52
	5 DAY	0.98	0.80	1.40	1.03	0.80	1.08	1.15	0.85	0.90	1.08	0.85	0.87	0.72	1.22
	7 DAY	1.18		1.75		1.00									
	10 DAY	1.48		2.00		1.10									
5	2 DAY	0.35	0.73	0.60	0.42	0.20	0.55	0.35	0.40	0.45	0.57	0.48	0.25	0.58	0.55
	5 DAY	0.75	1.43	1.30	0.92	0.70	0.85	0.90	0.70	0.80	0.82	1.03	0.85	1.08	1.00
	7 DAY	1.05		1.45		1.20									
	10 DAY	1.40		1.85		1.25									
6	2 DAY	0.50	0.45	0.55	0.75	0.43	0.53	0.40	0.53	0.45	0.55	0.60	0.50	0.45	0.65
	5 DAY	0.95	1.00	1.20	1.25	0.68	1.03	1.00	0.88	0.90	1.00	0.85	1.05	1.45	1.20
	7 DAY	1.15		1.60		0.98									
	10 DAY	1.50		1.70		1.28									
7	2 DAY	0.90	0.55	0.75	0.60	0.52	0.77	0.67	0.53	0.60	0.40	0.52	0.55	0.50	1.40
	5 DAY	1.20	0.65	1.45	1.25	1.17	0.92	1.22	0.88	1.05	1.05	0.77	0.95	0.85	1.85
	7 DAY	1.65		1.70		1.37									
	10 DAY	2.40		2.00		1.37									
8	2 DAY	0.50	0.45	0.58	0.40	0.43	0.60	0.47	0.35	0.40	0.50	0.40	0.55	0.42	0.43
	5 DAY	0.90	0.75	0.93	1.00	0.93	1.15	0.97	1.05	0.90	0.95	0.80	0.80	0.87	0.73
	7 DAY	1.10		1.03		1.03	0.03								
	10 DAY	1.45		1.33		1.48									
9	2 DAY	0.50	0.63	0.50	0.53	0.27	0.65	0.55	0.52	0.45	0.35	0.45	0.40	0.15	0.42
	5 DAY	0.85	0.73	0.90	0.93	0.67	0.85	0.90	0.77	0.75	0.70	0.75	0.90	0.55	0.72
	7 DAY	1.50		1.10		0.72									
	10 DAY	1.65		1.15		1.17									
10	2 DAY	0.45	0.58	0.45	0.60		0.63	0.45	0.45	0.40	0.15	0.40	0.43	0.50	0.37
	5 DAY	1.05	0.78	0.80	1.05		1.08	0.55	1.30	0.55	0.55	0.75	1.08	0.70	0.77
	7 DAY	1.15		1.10											
	10 DAY	1.65		1.30											
11	2 DAY														
	5 DAY														
	7 DAY														
	10 DAY														

A-13b

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

DISSOLVED OXYGEN
MG/L(FIRST RUN)

DATE *********		4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION															
1	TOP	7.65	7.90	7.90	8.00	8.00	8.00		8.00	8.10	8.15	8.00	7.90	7.45	7.70
	MID	7.65	7.46	8.52	8.21		7.92		8.10	8.20	7.81	8.10	7.75	7.70	7.70
	BOT	7.88		8.65	8.21		7.66		8.20	8.41	7.59	8.31	7.70	7.75	7.75
	LAB	7.65	7.90	7.90	8.00	8.00	8.00		8.00	8.10	8.15	8.00	7.90	7.75	7.75
2	TOP	7.60	7.75	7.90	8.20	8.30	8.10		8.05	8.25	7.95	8.50		7.50	7.50
	MID	7.60	8.44	8.16	8.43		7.74		8.36	8.35	7.95	8.50		7.70	7.25
	BOT	7.60	8.74	8.56	8.43		7.74		8.46	8.35	7.95	8.60		7.30	7.25
	LAB	7.60	7.75	7.90	8.20	8.30	8.10		8.05	8.25	7.95	8.50		7.50	7.50
3	TOP	7.45	7.90	7.65	7.85	7.65	7.70		7.60	7.55	7.60	7.85		7.60	7.20
	MID	7.45	8.47	8.05	7.85		7.70		7.71	7.55	7.50			7.50	7.35
	BOT	7.54	8.93	8.19	7.85		7.60		7.93	7.46	7.50			7.45	7.35
	LAB	7.45	7.90	7.65	7.85	7.65	7.70		7.60	7.55	7.60	7.85		7.60	7.20
4	TOP	8.00	8.10	8.10	8.10	8.60	8.20	8.50	8.10	8.25	8.05	7.90		7.40	7.55
	MID	7.76	9.28	8.36	7.90		8.11	7.75	8.32	8.25	8.15			7.40	7.45
	BOT	7.03	10.31	8.49	7.60		7.93	9.18	8.53	8.15	8.36			7.50	7.45
	LAB	8.00	8.10	8.10	8.10	8.60	8.20	8.50	8.10	8.25	8.05	7.90		7.40	7.55
5	TOP	7.50	7.65	7.95	8.20	8.05	8.10	7.95	7.75	7.85	8.15	7.85		7.30	7.30
	MID	7.26	8.60	8.22	8.55		8.01	8.89	8.07	7.95	8.26			7.20	7.20
	BOT		9.15	8.48	8.78		7.28	8.55	8.28	7.43	8.26			7.40	7.30
	LAB	7.50	7.65	7.95	8.20	8.05	8.10	7.95	7.75	7.85	8.15	7.85		7.30	7.30
6	TOP	7.45	7.65	7.60	7.85	7.80	7.75	7.60	7.45	7.75	7.75	7.75		7.20	7.00
	MID	6.95	8.34	8.29	8.10		7.66	7.47	7.67	7.75	7.64			7.20	7.00
	BOT		8.90	8.57	8.22		7.66	7.79	7.89	7.22	7.75			7.20	6.90
	LAB	7.45	7.65	7.60	7.85	7.80	7.75	7.60	7.45	7.75	7.75	7.75		7.20	7.00
7	TOP	7.95	7.60	7.95	7.70	7.80	7.60	7.50	7.45	7.30	7.60	7.50	7.40	7.35	7.40
	MID	7.95	8.82	8.46	8.00		7.16	7.50	7.45	7.01	7.38	7.80	7.60	7.30	7.40
	BOT	8.00	9.08	8.87	7.90		5.83	7.60	7.45	7.30	7.06	7.90	7.60	7.50	7.24
	LAB	7.95	7.60	7.95	7.70	7.80	7.60	7.50	7.45	7.30	7.60	7.50	7.40	7.35	7.40
8	TOP	7.80	7.75	7.60	7.75	7.80	7.60	7.85	7.80	7.75	7.95	7.60	7.55	7.35	7.40
	MID	7.89	9.30	8.13	7.85		6.96	7.93	7.74	7.75	7.53	7.50	7.60	7.55	7.26
	BOT	7.80	9.60	8.55	7.85		6.32	8.00	7.80	7.75	7.10	8.00	7.60	7.60	6.85
	LAB	7.95	7.75	7.60	7.75	7.80	7.60	7.85	7.80	7.75	7.95	7.60	7.55	7.35	7.40
9	TOP	8.20	8.25	7.90	7.80	8.30	7.85		7.90	7.85	8.10	7.95	7.80	7.75	7.75
	MID	8.20	9.62	8.50	7.90		7.76		8.09	7.96	7.98	8.26	7.80	7.70	
	BOT	8.36	9.90	8.80	7.80		7.25		8.09	8.27	7.64	8.46	7.75	7.85	
	LAB	8.20	8.25	7.90		8.30	7.85		7.90	7.85	8.10	7.95	7.80	7.75	7.75
10	TOP	8.20	7.90	8.10	7.80	8.00	7.51		7.90	7.80	8.10	7.85	7.65		7.45
	MID	8.06	8.91	7.67	8.01		7.42		8.01	8.24	7.87	7.85	7.50	7.55	7.50
	BOT	8.06	9.22	7.99	8.11		7.08		8.12	8.57	7.64	8.05	7.60	7.60	7.30
	LAB	8.20	7.90	8.10	7.80	8.00			7.90	7.80		7.85	7.65		7.45
11	TOP														
	MID														
	BOT														
	LAB														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

DISSOLVED OXYGEN
MG/L(FIRST RUN)

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1 TOP	7.55	7.25	7.10	7.30	7.25	7.05	6.85	6.80	6.65	7.00	7.00	6.95	7.15	6.70
MID	7.45	6.63	6.77		7.25	7.05	6.96	6.80	6.65	7.00	7.00	6.95	7.15	7.33
BOT	7.55	6.63	5.99		8.24	7.05	6.85	6.80	6.65	7.00	7.65	7.06	7.29	7.54
LAB	7.55	7.25	7.10	7.30	7.25	7.05	6.85	6.80	6.65	7.00	7.00	6.95	7.15	6.70
2 TOP	7.05	7.25	6.90	6.95	7.00	7.30	7.20	7.00	6.75	7.15	6.90	7.05	6.90	6.30
MID	6.95	6.91	6.64		6.15	7.59	7.20	6.30	7.64	7.15	6.90	7.05	6.74	6.40
BOT	7.15	6.91	6.52		6.15	7.44	7.44	7.00	7.64	7.15	6.90	7.05	6.90	7.44
LAB	7.00	7.25	6.90	6.95	7.00	7.30	7.20	7.00	6.75	7.15	6.90	7.05	6.90	6.30
3 TOP	7.40	7.20	6.95	7.60	6.85	6.95	6.40	6.10	6.10	6.35	6.35		6.65	6.50
MID	7.30	6.58	6.82		6.72	6.95	6.40	6.10	6.10	6.15	6.35			6.61
BOT	7.50	6.58	6.82		6.72	6.82	6.40	6.10	6.10	5.67	6.35		6.81	6.61
LAB	6.95	7.20	6.95	7.60	6.85	6.95	6.40	6.10	6.10	6.35	6.35		6.65	6.50
4 TOP	7.35	7.30	7.25	7.50	7.40	7.65	6.95	6.90	7.05	7.40	6.85	7.20	6.75	6.70
MID	7.50	7.20	7.25		7.77	6.88	6.72	6.90	6.44	6.82	6.74	7.20	6.91	6.80
BOT	7.50	7.30	6.28		7.52	6.88	6.72	6.90	6.34	6.82	6.85	7.32	7.85	7.44
LAB	7.40	7.30	7.25	7.50	7.40	7.65	6.95	6.90	7.05	7.40	6.85	7.20	6.75	6.70
5 TOP	7.15	7.45	7.00	7.40	7.00	7.45	7.30	6.90	6.75	6.95	6.70	6.50	6.50	6.35
MID	7.15	6.81	5.88		6.11	7.45	7.18	7.67	6.75	7.70	6.59	6.50	6.82	6.46
BOT	7.30	6.70	6.16		6.01	7.45	7.18	7.67	6.75	7.62	6.59	6.50	7.15	6.77
LAB	7.15	7.45	7.00	7.40	7.00	7.45	7.30	6.90	6.75	6.95	6.70	6.50	6.50	6.35
6 TOP	7.05	7.40	6.85	7.10	6.75	6.90	6.75	6.80	6.40	6.60	6.15	6.45	6.55	6.25
MID	6.95	6.58	6.69		6.75	6.77	6.86	6.67	6.29	6.67	6.27	6.32	6.55	6.35
BOT	7.15	6.47			6.62	6.77	6.75	6.67	6.29	6.74	6.27	6.32	6.88	6.56
LAB	7.05	7.40	6.85	7.10	6.75	6.90	6.75	6.80	6.40	6.60	6.15	6.45	6.55	6.25
7 TOP	7.40	7.15	7.00	6.90	6.70	6.45	6.75	6.20	6.20	6.40	6.25	6.45	6.25	6.55
MID	7.30	7.27	0.63	7.90	6.70	7.48	6.75	6.20	6.20	6.49	6.00	6.24	6.25	7.27
BOT	7.50	7.15	0.62	8.12	6.61	7.48	6.75	6.20	6.45	6.14	5.91	6.24	6.35	7.47
LAB	7.40	7.15	7.00	6.90	6.70	6.45	6.75	6.20	6.20	6.40	6.25	6.45	6.25	6.55
8 TOP	7.35	7.35	0.70	7.15	7.00	6.60	6.60	6.85	6.75	6.85	7.00	6.35	6.90	6.70
MID	7.50	6.52	0.64	6.92	6.87	6.60	6.60	6.85	6.75	6.85	7.00	6.55	7.01	6.89
BOT	7.50	6.43	0.60	6.81	6.87	6.86	6.72	6.85	6.88	7.50	6.90	7.27	7.90	7.74
LAB	7.35	7.35	7.00	7.15	7.00	6.60	6.60	6.85	6.75	6.85	7.00	6.35	6.90	6.70
9 TOP	7.70	7.60	7.50	7.50	7.30	7.35	7.55	6.90	6.90	6.90	6.75	6.95	6.90	6.95
MID	7.60	6.23	7.19		6.57	7.49	7.31	7.84	7.03	6.90	6.57	6.85	7.01	7.14
BOT	7.70	6.65	5.55		7.30	7.49	7.08	7.84	7.16	6.90	6.57	6.85	7.79	0.68
LAB	7.70	7.60	7.50	7.50	7.30	7.35	7.55	6.90	6.90	6.90	6.75	6.95	6.90	6.95
10 TOP	7.30	7.60	7.15	7.50		7.20	7.05	6.75	6.50	6.70	6.30	6.50	6.40	6.40
MID	7.30	8.97	6.33			7.20	7.71	6.75	7.22	6.78	6.40	6.50	6.40	6.22
BOT	7.50	8.72	6.13				7.20	6.88	7.22	6.78	6.51	6.50	6.56	6.31
LAB	7.30	7.60	7.15	7.50		7.20	7.05	6.75	6.50	6.70	6.30	6.50	6.40	6.40
11 TOP														
MID														
BOT														
LAB														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

DISSOLVED OXYGEN
MG/L (SECOND RUN)

DATE ********* STATION	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
1 TOP	7.95	8.05	8.10		8.20	7.73		8.15		8.10	7.95	7.85	7.80	7.85
MID		8.25	8.10		8.10	7.44		7.86		8.10	7.86	7.75		8.10
BOT		8.25	8.10		7.81						7.86	7.75		8.18
LAB	7.95	8.05	8.10		8.20			8.15		8.10	7.95	7.85	7.80	7.85
2 TOP	8.00	8.20	8.40		7.85	7.75		10.30	8.25	8.20	8.25	7.80	8.00	7.85
MID		8.01	8.30		7.85	7.75		9.81	7.82	7.73	8.16	7.61		7.93
BOT		8.01	8.60		7.75									
LAB	8.00	8.20	8.40		7.85	7.75		10.30	8.25	8.20	8.25	7.80	8.00	7.85
3 TOP	7.90	8.90	8.80		8.25	8.00		7.90	7.90	8.10	7.75	7.65	7.50	8.85
MID		8.90	8.70		8.55	7.79		7.70	7.47	8.10	7.75	7.57		8.85
BOT		8.90	8.80		8.45	7.79		7.80	7.36	8.20	7.66	7.57		8.94
LAB	7.90	8.90	8.80		8.25	8.00		7.90	7.90	8.10	7.75	7.65	7.50	8.85
4 TOP	7.85	7.95	8.20		8.30	8.35		8.50	8.30	8.65	8.35	8.25	8.20	7.85
MID		7.95	8.40		8.40	8.13		8.29	8.30	8.45	8.07	8.25		7.69
BOT		8.05	8.40		8.11			8.40						7.62
LAB	7.85	7.95	8.20		8.30	8.35		8.50	8.30	8.65	8.35	8.25	8.20	7.85
5 TOP	7.80	7.90	7.90	8.18	7.95	7.95		8.10	8.15	8.25	7.95	7.80	7.70	7.50
MID		7.90	7.90	8.53	7.85	7.26		8.10	8.15	8.15	7.76	7.80		7.34
BOT		8.00	8.20	8.65	7.66	7.07		8.21						7.26
LAB	7.80	7.90	7.90		7.95	7.95		8.10	8.15	8.25	7.95	7.80	7.70	7.50
6 TOP	7.75	10.85	8.20	8.30	8.30	7.60		8.00	7.90	8.00	7.90	7.80	7.40	7.35
MID		10.98	8.60	8.77	8.30	7.39		7.89	7.63	7.90	7.80	7.80		7.43
BOT		10.98	8.70	9.12	8.30	7.39								
LAB	7.75	10.85	8.25	8.30	8.30	7.60		8.00	7.90	8.00	7.90	7.80	7.40	7.35
7 TOP	7.75	7.80	7.80	8.20	7.85	7.70		7.85	7.65	7.91	7.65	7.70	7.20	8.30
MID	9.48	7.90	7.90	8.30	8.04	7.60		7.85	7.86	7.63	7.56	7.50		8.20
BOT	8.75	7.90	8.09	8.30	7.85			7.65	7.96	7.63	7.38	7.50		8.00
LAB	7.75	7.80	7.80		7.85	7.70		7.85	7.65		7.65	7.70	7.20	
8 TOP	7.95	8.45	8.40	8.35	8.10	7.89		8.00	8.10	8.10	7.85	10.15	7.85	8.95
MID	9.15	8.23	8.40	8.45	7.90	7.42		7.71	8.21	8.10	7.67	10.03		8.95
BOT	9.80	8.45	8.40	8.55	7.90			7.81	8.43	6.98	7.67	9.79		8.95
LAB	7.95	8.45	8.55	8.35	8.10			8.00	8.10	8.10	7.85	10.15	7.85	8.95
9 TOP	8.00	8.00	8.20	8.30	8.30	7.51		8.15	8.20	8.30	8.00	7.80	7.75	7.75
MID	9.75	8.10	8.20	8.49	7.87	7.70		8.15	8.09	7.15	7.81	7.70		7.99
BOT	9.93	8.10	8.49	8.49	7.45							7.33		
LAB	8.00	8.00	8.20	8.30	8.30			8.15	8.20	8.30	8.00	7.80	7.75	7.75
10 TOP	7.65	7.70	7.80	7.91	8.30	8.30		8.10		8.10	7.75	7.85	7.60	
MID	9.12	7.80	7.90	7.91	8.30	7.92		7.82		8.00	7.66	7.48		
BOT	9.49	7.90	7.90	8.01	8.01						7.66	7.29		
LAB	7.65	7.70	7.80		8.30	8.30		8.10		8.10	7.75	7.85	7.60	
11 TOP														
MID														
BOT														
LAB														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

DISSOLVED OXYGEN
MG/L(SECOND RUN)

DATE ********* STATION	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
1 TOP	7.60	7.50	7.50	7.25	7.20	7.25		6.80	6.90	0.69	0.00			
MID	7.60	7.14	7.45	7.30	7.35	7.15		6.60	6.80	6.65				
BOT	7.51	7.14	7.30	7.30	7.35	7.10		6.80	6.80	6.90				
LAB	7.60	7.50	7.50	7.30	7.20	7.25		6.80	6.90	6.90				
2 TOP	7.95	7.50	7.40	7.30	7.60	7.35	7.00	7.40	7.00					
MID	7.86	7.89	7.05	6.75	6.85	6.70	6.75	6.45	6.45	6.65				
BOT	7.86	7.89	7.05	6.75	6.85	6.70	6.75	6.45	6.45	6.65				
LAB	7.95	7.50	7.40	7.30	7.60	7.35	7.00	7.40	7.00					
3 TOP	7.00	7.30	7.25	7.10	7.15	7.10	6.75	6.40	6.50	6.65				
MID	7.00		7.10	7.10	7.35	7.15	6.85	6.55	6.45	6.50				
BOT	7.00		7.25	7.10	7.20	6.85	6.15	6.40	6.50	6.70				
LAB	7.00	7.30	7.25	7.10	7.15	7.10	6.75	6.40	6.50	6.65				
4 TOP	7.80	7.70	7.30	7.10	7.25	7.15		7.10	7.35	7.50				
MID	7.71		7.45	6.90	7.25	7.15		6.85	7.00	7.30				
BOT	7.71		7.50	6.95	7.10	7.20		6.80	7.00	7.00				
LAB	7.80	7.70	7.30	7.10	7.25	7.15		7.10	7.35	7.50				
5 TOP	7.10	7.35	7.30	6.85	6.85	6.60	6.95		7.05	7.35	6.70		6.70	
MID	7.01		7.15	6.75	6.95	6.70	6.80		6.70	6.90	6.65		6.70	
BOT			7.15	6.70	6.85	6.75	7.00		6.70	6.90	6.65		6.40	
LAB	7.10	7.35	7.30	6.85	6.85	6.60	6.95		7.05	7.35	6.70		6.70	
6 TOP	7.10		7.00	6.80	6.75	6.70	6.85		6.70	6.80	6.30		6.20	
MID	7.10		7.00	6.80	6.75	6.70	6.85		6.70	6.80	6.30		6.20	
BOT			7.35	6.75	6.75	6.85	6.75		6.45	6.65	6.35		6.20	
LAB	7.10	7.25	6.95	7.00	7.00	6.70	6.80		6.70	7.00	6.35		6.35	
7 TOP	6.80	6.80	6.80	6.90	7.10	7.00	6.75	6.40	6.50	6.70	6.30		6.25	
MID	6.80	6.80	6.80	6.85	6.95	7.00	6.65	6.40	6.35	6.45	6.20		6.15	
BOT	6.80	6.80	7.35	7.10	7.10	6.90	6.85	6.40	6.30	6.50	6.40		6.00	
LAB	6.80	6.80	6.80	6.90	7.10	7.00	6.75	6.40	6.50	6.70	6.30		6.25	
8 TOP	7.50	7.20	7.40	7.20	7.40	7.35	7.00	6.60	6.60	6.80	6.80		6.75	
MID	7.32	6.05	7.20	7.00	7.50	7.25	7.35	6.70	6.65	6.65	6.80		6.70	
BOT	7.22	5.76	7.30	7.60	7.35	7.25	7.00	6.60	6.45	6.85	6.85		6.65	
LAB	7.50	7.20	7.40	7.20	7.40	7.35	7.00	6.60	6.60	6.80	6.80		6.75	
9 TOP	7.80	7.50	7.45	7.25	7.40	7.35	7.25	7.00	7.00	7.30			6.95	
MID	7.52	7.20	7.65	7.35	7.20	7.20	7.15	6.95	7.20	7.00			6.85	
BOT	7.52	6.90	7.60	8.10	7.15	7.30	7.15	7.05	7.00	7.15			6.80	
LAB	7.80	7.50	7.45	7.25	7.40	7.35	7.25	7.00	7.00	7.30			6.95	
10 TOP		6.90	6.95	6.85				6.90	7.15	7.20				
MID		6.90	7.00	6.95				7.05	7.20	7.15				
BOT			7.15	7.05				6.95	7.00	7.05				
LAB		6.90	6.95	6.85				6.90	7.15	7.20				
11 TOP														
MID														
BOT														
LAB														

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CONDUCTIVITY (FIRST RUN)
UMHOS/CM

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1 TOP		33,550	34,520	34,780	34,550	33,990		33,550	33,740	31,850	33,050	33,800	34,360	34,820
MID		33,820	34,440	34,680	34,310	33,970		33,470	32,980	33,130	33,050	33,790	34,320	34,800
BOT			34,430	34,660	34,620	34,000		33,620	34,000	33,300	33,170	33,830	34,390	34,800
2 TOP		32,100	32,280	32,700	33,000	32,700		32,970	33,650	33,110	33,110		34,450	35,300
MID		31,680	32,280	32,700		32,530		32,820	33,630	33,100	33,010		34,300	34,880
BOT		31,710	32,220	33,000		32,950		32,700	33,290	32,920	33,040		34,240	34,920
3 TOP		30,760	31,340	31,930		31,460		32,400	33,580	32,650	33,000		34,860	35,700
MID		31,180	31,300	31,850		31,420		32,240	33,520	32,430	33,130		34,410	35,580
BOT		30,520	31,400	31,940		31,260		32,100	33,560	32,330	33,000		34,330	35,440
4 TOP		32,700	30,000	33,500		33,030	32,570	32,300	33,230	33,050	32,450		32,600	33,500
MID		32,620	33,200	33,010		33,010	32,660	32,700	33,200	33,010	32,500		32,600	33,900
BOT		32,600	33,200	30,000		33,000	33,710	32,790	33,200	33,050	32,730		32,650	34,320
5 TOP		31,130	32,180	32,900		32,250	32,510	32,300	32,200	32,280	31,550		32,030	32,340
MID		31,200	32,190	32,810		32,200	32,480	32,700	32,400	32,250	31,830		31,900	32,260
BOT		31,300	32,150	32,700		32,200	32,490	32,790	32,470	32,390	32,060		32,230	32,560
6 TOP		29,300	30,040	30,700		30,640	30,950	30,570	31,250	31,000	30,950		31,600	32,000
MID		29,300	30,000	30,650		30,600	30,900	30,450	31,210	30,830	30,800		31,300	31,920
BOT		29,300	29,950	30,720		30,600	30,850	30,550	31,170	30,900	30,810		31,370	32,020
7 TOP		30,800	30,600	29,800	30,050	29,460	29,000	27,940	28,200	28,750	29,830	30,800	31,570	32,640
MID		30,820	30,600	29,810	30,000	29,650	29,030	28,170	28,820	28,880	30,000	30,830	31,710	32,680
BOT		30,830	30,590	29,830	30,010	29,660	20,050	28,410	28,800	29,210	30,200	31,000	31,980	32,720
8 TOP		30,800	30,750	30,920	31,280	30,100	29,000	28,320	29,000	28,030	29,220	31,500	32,620	33,540
MID		31,640	31,260	31,000	31,390	30,360	28,870	28,450	30,200	31,880	29,880	32,320	32,930	33,520
BOT		31,820	31,340	30,940	31,450	30,760	30,370	29,200	30,280	32,000	32,380	32,500	33,000	33,540
9 TOP		30,800	29,870	28,860	28,900	27,900		24,840	24,960	25,230	28,350	29,600	30,180	31,740
MID		31,180	29,900	28,830	28,910	27,760		26,440	25,300	26,130	28,340	29,610	30,630	31,980
BOT		31,300	29,900	28,900	28,910	27,780		27,180	26,170	28,750	28,350	29,630	30,770	32,180
10 TOP		35,250	34,980	35,700	35,400	34,770		34,250	34,380	34,300	34,630	34,850	35,400	35,880
MID		35,160	35,600	35,660	35,480	34,640		34,150	34,540	34,450	34,710	35,130	35,510	36,000
BOT		35,230	35,680	35,690	35,480	34,630		34,400	34,600	34,850	34,860	35,210	35,570	36,200
11 TOP														
MID														
BOT														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CONDUCTIVITY (FIRST RUN)
UMHOS/CM

DATE ********* STATION	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
1 TOP	35,540	35,820	35,840	36,440	38,020	37,820	38,300	38,380	38,100	38,300	37,800	38,320	38,020	39,500
MID	35,560	35,820	36,220	37,040	38,080	37,800	38,320	38,500	38,280	38,260	37,880	38,240	38,000	39,480
BOT	35,580	35,820	36,320	37,080	37,980	37,840	38,340	38,500	38,640	38,300	37,980	38,720	38,100	39,500
2 TOP	35,220	35,740	36,200	36,780	36,900	36,200	37,380	36,540	37,700	37,340	37,780	37,680	37,900	38,540
MID	35,520	35,760	36,180	36,820	37,080	37,040	37,520	37,900	37,500	37,220	37,700	37,600	38,000	38,460
BOT	35,540	35,720	36,120	36,760	37,020	37,120	37,640	37,920	37,420	37,220	38,980	37,700	37,980	38,920
3 TOP	35,500	36,240	36,800	37,340	37,180	37,780	37,440	37,580	37,400	37,840	38,520		38,200	39,120
MID	35,520	36,200	36,780	37,240	37,200	37,400	37,460	37,520	37,400	37,820	38,400		38,200	39,000
BOT	35,520	36,140	36,820	37,240	37,120	37,380	37,440	37,520	37,800	37,820	38,400			38,820
4 TOP	35,760	34,220	34,840	35,580	35,980	36,500	37,560	36,900	37,100	37,780	37,580	37,720	36,900	37,380
MID	33,720	34,200	34,780	35,540	36,520	36,890	37,520	36,920	37,200	37,300	37,500	37,740	36,900	37,340
BOT	33,720	34,200	34,800	35,540	36,660	37,080	37,480	36,900	37,040	37,040	37,520	37,800	36,500	37,380
5 TOP	32,660	32,980	33,820	34,700	35,420	36,220	36,200	36,520	36,680	37,000	37,200	36,320	36,360	36,600
MID	32,540	32,940	33,880	34,680	35,460	36,000	36,320	36,400	36,600	36,880	36,900	36,320	36,600	36,580
BOT	32,880	33,220	33,900	34,700	35,520	35,940	36,120	36,500	36,820	36,900	36,780	36,820	36,600	37,040
6 TOP	32,120	33,060	33,140	34,380	34,320	35,120	35,200	35,800	35,520	35,800	36,100	36,140	36,500	36,440
MID	32,180	32,420	33,140	34,000	34,340	34,980	35,220	35,400	35,600	35,820	36,140	36,160	36,400	36,380
BOT	32,200	32,480	33,200	33,840	34,400	34,800	35,140	35,400	35,580	35,800	36,200	36,200	36,240	36,420
7 TOP	33,000	32,120	33,620	34,140	34,140	33,980	34,120	33,820	33,880	34,600	35,320	35,700	36,400	37,000
MID	33,040	33,220	33,740	34,240	34,500	34,160	34,200	34,140	33,900	34,660	35,300	35,580	36,380	37,100
BOT	33,180	33,240	33,820	34,200	34,520	34,220	34,240	34,100	34,100	34,640	35,500	35,780	36,420	37,120
8 TOP	33,580	33,840	33,440	34,640	34,800	34,700	34,100	32,580	33,000	33,540	35,500	36,000	37,420	37,700
MID	33,680	33,020	34,500	34,680	34,820	34,880	34,280	33,040	33,220	34,580	35,580	36,740	37,400	37,720
BOT	33,740	34,020	34,580	34,740	34,880	34,920	34,580	33,240	33,460	34,540	35,720	37,540	37,480	37,700
9 TOP	32,020	32,320	32,980	33,040	32,780	32,420	33,120	31,120	30,800	31,100	33,100	34,500	35,220	36,220
MID	32,260	32,420	32,900	33,400	32,800	32,420	33,200	31,780	31,260	31,520	33,020	34,500	35,300	36,520
BOT	32,560	33,000	33,260	33,590	32,820	32,480	33,220	31,920	31,840	32,100	33,100	34,480	35,240	36,700
10 TOP	36,500	36,620	38,400	39,040		39,120	39,620	38,420	38,580	38,880	39,220	39,700	39,600	40,500
MID	36,520	36,800	38,140	39,120		39,060	39,760	38,500	38,660	38,660	39,240	39,480	39,680	40,520
BOT	36,520	37,140	38,480	39,220		39,160	39,660	38,420	38,520	38,760	39,200	39,400	39,720	40,520
11 TOP														
MID														
BOT														

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CONDUCTIVITY (SECOND RUN)
UMHOS/CM

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1 TOP	34,170	34,160	34,630		35,210	35,620		37,280		37,160	36,580	36,240	36,660	36,460
MID	34,260	34,180	34,680		35,760	36,200		36,770		37,080	36,620	36,240	36,540	36,240
BOT	33,780	34,240	34,660		35,880	36,200		36,650		37,080	36,660	36,240	36,540	36,240
2 TOP	33,500	33,730	34,360		34,090	33,870		35,740	36,000	35,240	35,020	35,440	36,040	36,260
MID	33,340	33,660	33,740		34,110	34,200		34,830	35,590	35,050	35,220	35,360	35,940	36,260
BOT	33,350	33,640	33,890		34,350	34,440		34,600	35,530	35,300	35,340	35,360	35,840	36,320
3 TOP	32,950	34,220	34,250		34,240	34,140		34,680	34,620	34,400	34,760	35,340	36,540	37,820
MID	32,900	34,240	34,300		34,270	34,200		34,180	34,570	34,620	34,760	35,340	36,500	37,700
BOT	32,960	34,210	34,250		34,270	34,200		34,180	34,630	34,600	34,770	35,320	36,500	37,700
4 TOP	33,260	32,930	33,120		34,130	34,580		36,100	35,320	35,180	34,860	35,340	36,790	38,000
MID	33,240	32,990	33,200		34,220	34,620		34,950	35,390	34,780	34,860	35,440	35,420	36,740
BOT	33,840	33,140	33,220		34,220	34,580		34,850	35,500	34,890	35,040	35,360	35,740	36,740
5 TOP	31,060	30,980	31,940		32,620	33,350		34,620	34,670	34,780	34,820	34,520	34,640	34,880
MID	31,740	31,830	31,960		32,850	33,720		34,480	34,750	34,710	34,540	34,540	34,760	34,860
BOT	31,790	31,890	32,290		33,310	33,880		34,250	34,770	34,630	34,560	34,540	34,760	34,860
6 TOP	30,320	30,440	30,700	31,370	31,700	32,060		32,960	33,100	33,140	33,520	33,440	33,600	34,120
MID	30,430	30,600	30,860	31,590	31,660	32,110		33,020	33,240	33,320	33,390	33,560	33,700	34,120
BOT	30,430	30,550	31,060	31,640	31,680	32,180		32,530	33,300	33,230	33,490	33,560	33,700	34,120
7 TOP	30,260	30,520	31,800	32,680	32,900	33,400		31,510	31,760	31,170	30,380	30,100	30,760	31,740
MID	30,560	30,720	31,860	32,660	32,930	33,430		31,580	31,770	31,230	30,500	30,040	30,660	31,720
BOT	30,330	30,740	31,960	32,680	32,900	33,410		31,590	31,760	31,320	30,460	30,880	31,240	31,700
8 TOP	31,660	32,420	33,560	33,750	32,560	32,680		31,540	33,420	32,860	31,820	30,980	31,580	31,760
MID	33,680	33,520	33,740	33,690	33,260	33,750		33,180	33,320	33,010	32,180	31,580	31,620	32,920
BOT	33,700	33,600	33,610	33,690	33,590	33,750		33,250	33,340	33,040	32,240	32,120	31,820	33,480
9 TOP	29,940	29,680	30,240	31,630	32,270	32,790		31,500	30,140	28,600	29,040	28,600	29,240	28,920
MID	30,070	29,690	30,580	31,970	32,750	32,750		31,270	31,740	30,640	29,700	28,740	29,020	29,040
BOT	30,070	29,720	30,620	32,100	33,220	33,000		32,400	31,700	31,080	30,240	29,180	29,240	29,190
10 TOP	34,900	34,180	35,600	36,770	36,390	36,960		38,630		37,990	37,180	36,940	37,420	
MID	35,020	35,300	35,640	36,700	37,040	36,920		38,680		37,840	37,160	36,760	37,220	
BOT	35,020	35,330	37,730	36,730	37,110	37,800		38,580		37,880	37,160	36,880	37,180	
11 TOP														
MID														
BOT														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CONDUCTIVITY (SECOND RUN)
UMHOS/CM

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1 TOP	36,840	36,920	37,100	37,660	38,960	39,300		40,800	40,840	41,320				
MID	36,740	36,640	37,100	37,600	38,920	39,320		40,800	40,900	41,220				
BOT	36,740	36,680	37,120	37,580	39,000	39,540		40,820	40,820	41,180				
2 TOP	36,300	38,080	38,340	40,060	40,280	39,680	39,740	39,410	39,560	40,800				
MID	36,000	37,540	38,340	39,820	39,600	39,520	39,680	38,920	39,720	40,440				
BOT	36,000	37,700	38,500	39,160	39,400	39,340	39,660	39,800	40,040	40,620				
3 TOP	37,840	38,540	39,160	39,960	39,940	40,090	40,000	39,520	39,580	39,720				
MID	37,880	38,560	38,780	39,960	39,940	40,090	40,020	39,520	39,500	39,740				
BOT	37,880	38,580	38,780	39,840	39,940	40,100	39,400	39,520	39,500	39,720				
4 TOP	36,700	36,140	36,380	37,500	37,380	37,560		38,940	39,360	40,240				
MID	36,700	36,400	36,520	37,120	37,420	37,640		39,300	39,540	40,300				
BOT	36,660	36,440	37,400	37,000	37,420	37,660		39,520	39,620	40,420				
5 TOP	34,840	35,020	35,340	36,180	36,700	36,740	37,620		38,960	39,160	39,240		38,740	
MID	34,820	35,200	35,520	36,220	36,600	36,780	37,700		38,720	39,380	39,020		38,620	
BOT	34,820	35,180	35,620	36,280	36,860	37,000	37,740		38,760	39,500	39,040		38,560	
6 TOP	34,280	34,860	35,400	36,540	37,000	36,600	37,400		37,800	38,700	38,180		38,200	
MID	34,220	34,540	35,300	36,120	36,380	36,620	37,060		37,580	37,900	38,200		38,160	
BOT	34,220	34,520	35,260	36,200	36,540	36,680	37,040		37,580	38,100	38,180		38,140	
7 TOP	32,290	33,160	34,380	35,700	36,760	37,140	37,160	36,240	36,200	36,960	37,300			
MID	32,290	33,140	34,500	35,700	36,760	37,040	37,120	36,240	36,240	36,920	37,300			
BOT	32,290	33,140	34,100	35,700	36,780	37,040	37,080	36,180	36,300	36,920	37,300			
8 TOP	32,760	35,260	36,000	37,640	37,700	38,320	37,920	37,720	37,760	38,340	38,880			
MID	32,940	35,920	35,860	37,500	37,820	37,920	37,980	37,700	37,760	38,320	38,880			
BOT	33,580	35,880	36,580	37,140	37,920	37,960	38,020	37,680	37,740	38,206	38,820			
9 TOP	29,340	31,320	32,280	33,740	34,800	34,740	36,300	35,180	35,520	36,000				
MID	29,660	31,360	32,280	33,880	34,800	35,100	36,580	35,200	35,500	35,900				
BOT	30,600	31,360	32,360	33,920	35,060	35,200	36,700	35,160	35,520	35,880				
10 TOP		37,860	38,640	39,660				41,760	41,890	42,320				
MID		37,860	38,540	39,500				41,800	41,900	42,280				
BOT		38,000	38,540	39,500				40,940	41,940	42,300				
11 TOP														
MID														
BOT														

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SALINITY (FIRST RUN)
PARTS PER THOUSAND

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1 TOP		25.35	26.26	25.91	25.76	25.38		24.03	23.42	23.23	23.91	23.81	24.40	24.02
MID		25.66	26.30	26.10	25.82	25.30		24.35	23.72	24.13	23.93	23.97	24.42	24.54
BOT			26.33	26.00	26.00	25.26		24.50	24.22	24.20	24.30	24.00	24.45	24.56
2 TOP		23.50	23.98	23.98	24.55	23.90		23.60	23.60	23.83	23.72		23.80	23.82
MID		23.87	24.32	24.20		23.83		23.66	23.66	23.60	23.79		23.80	23.74
BOT		23.78	24.37	24.60		24.33		23.55	23.84	23.80	23.76		23.90	23.90
3 TOP		23.05	23.32	23.44		22.60		22.75	23.04	25.50	23.62		23.50	23.94
MID		23.22	23.32	23.34		22.80		22.68	22.96	23.27	23.50		23.60	24.02
BOT		22.95	23.35	23.54		22.62	25.00	22.85	23.10	23.22	23.50		23.60	24.04
4 TOP		24.65	24.13	24.45		24.15	23.88	22.50	23.00	23.60	23.26		22.49	23.20
MID		24.68	24.68	24.55		24.22	23.94	23.30	23.38	23.77	23.33		22.80	23.24
BOT		24.51	24.68	24.50		24.40	24.30	23.61	23.50	23.67	23.54		22.95	23.34
5 TOP		23.23	24.06	23.93		23.30	23.72	22.50	22.20	22.70	22.18		21.44	22.22
MID		23.40	24.03	24.00		23.60	23.70	23.30	22.60	22.90	22.55		21.81	22.02
BOT		23.53	24.06	24.40		23.60	23.75	23.60	22.80	23.20	22.82		22.16	22.24
6 TOP		21.48	21.76	21.83		21.83	22.80	20.90	20.70	21.60	21.44		20.25	20.52
MID		21.50	21.85	22.20		21.90	22.28	21.20	21.00	21.50	21.57		20.92	21.00
BOT		21.40	21.58	22.22		22.08	22.47	21.38	21.35	21.60	21.65		20.07	21.08
7 TOP		23.24	23.10	21.63	21.70	21.30	20.80	19.62	19.50	20.40	20.90	22.12	22.13	22.42
MID		23.24	23.06	21.70	21.73	21.55	20.85	20.02	20.00	20.43	21.20	22.03	22.37	22.76
BOT		23.22	22.98	21.83	21.70	21.44	19.85	20.28	20.00	20.72	21.30	22.10	22.53	23.00
8 TOP		23.40	23.20	22.80	22.98	22.30	21.20	20.32	20.74	20.48	20.20	22.58	23.00	23.86
MID		24.21	23.46	22.91	23.08	22.60	21.30	20.45	21.62	23.03	21.62	23.30	23.47	23.72
BOT		24.34	23.63	22.90	22.93	22.67	22.30	21.20	21.62	23.10	23.33	23.34	23.44	23.68
9 TOP		23.00	22.47	21.44	21.20	23.02		17.60	17.44	18.10	20.22	21.50	21.34	22.20
MID		23.36	22.50	21.34	21.18	20.10		19.00	17.80	18.70	20.19	21.07	21.80	22.32
BOT		23.36	22.50	21.37	21.33	20.23		19.50	18.50	20.69	20.20	21.11	21.94	22.17
10 TOP		27.13	27.20	26.00	26.28	25.83		24.71	24.10	24.88	24.83	25.11	25.30	24.90
MID		27.14	27.30	24.42	26.54	25.80		24.66	24.40	25.05	24.90	25.25	25.47	25.46
BOT		27.15	27.42	26.58	26.60	25.73		25.07	24.60	25.30	25.02	25.43	25.50	25.52
11 TOP														
MID														
BOT														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SALINITY (FIRST RUN)
PARTS PER THOUSAND

DATE *********		4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION															
1	TOP	25.00	24.52	24.24	23.88	25.62	25.28	25.72	25.40	25.20	24.60	24.80	25.22	24.62	25.92
	MID	25.10	24.78	24.82	24.50	25.68	25.72	25.88	25.92	25.60	25.26	24.90	25.12	24.72	25.90
	BOT	25.52	24.68	25.22	24.88	25.50	25.88	26.04	26.00	25.90	25.50	25.20	25.26	24.90	25.72
2	TOP	24.62	24.68	23.62	24.66	24.26	24.30	24.86	24.30	25.00	24.30	24.30	24.70	24.82	24.26
	MID	24.82	24.68	23.80	24.60	24.32	24.92	25.22	25.50	24.18	24.52	24.40	24.52	24.80	24.46
	BOT	24.96	24.74	23.88	24.82	24.42	25.00	25.00	25.44	25.02	24.52	24.52	24.66	24.90	24.90
3	TOP	24.62	24.50	24.20	23.86	24.58	24.00	24.48	24.90	24.00	23.90	24.32		24.90	24.60
	MID	24.54	24.62	24.32	24.00	24.42	25.76	24.52	24.80	24.20	23.90	24.30		24.32	24.82
	BOT	24.62	24.78	24.30	24.00	24.54	24.52	24.50	24.60	24.42	23.92	24.30			24.68
4	TOP	23.62	23.52	24.00	23.78	23.82	24.30	24.50	24.32	24.40	24.02	24.10	24.52	23.52	23.30
	MID	23.64	23.54	23.60	23.84	24.82	24.62	24.82	24.58	24.78	24.02	24.40	24.50	23.62	23.56
	BOT	23.54	23.54	23.54	23.90	24.86	24.90	25.00	24.38	24.78	23.98	24.40	24.44	23.48	23.70
5	TOP	22.34	22.22	22.24	23.26	22.92	23.60	23.26	24.10	23.90	23.60	23.70	23.32	23.70	23.32
	MID	22.40	22.28	22.54	23.24	23.24	23.92	23.88	24.32	24.00	23.80	23.60	23.12	23.72	23.22
	BOT	22.64	22.38	22.58	23.24	23.78	24.28	23.96	24.28	24.50	24.00	23.50	23.68	23.54	23.32
6	TOP	21.18	20.68	21.42	21.64	21.68	22.52	22.50	23.30	22.50	23.04	22.62	22.92	23.10	21.82
	MID	21.34	20.88	21.48	21.72	21.80	22.54	22.82	22.80	22.60	22.90	22.66	22.82	23.30	22.10
	BOT	21.38	21.20	21.64	21.98	22.28	22.70	22.90	23.20	22.50	22.70	22.76	22.82	23.16	22.20
7	TOP	23.10	21.72	22.42	22.80	24.60	22.22	21.82	21.90	21.90	22.20	22.42	23.30	23.82	24.00
	MID	23.22	23.04	22.74	22.88	22.78	22.42	22.14	22.30	22.00	22.28	22.66	22.86	23.66	24.20
	BOT	23.12	22.84	23.00	22.82	22.92	22.50	22.32	22.02	22.10	22.30	22.38	22.80	23.60	24.16
8	TOP	23.66	23.42	22.52	23.18	23.32	23.12	22.22	21.42	21.62	22.10	23.10	23.52	25.00	24.70
	MID	23.68	23.56	23.50	23.58	23.32	23.22	22.80	21.90	21.88	22.80	23.30	24.28	24.42	24.60
	BOT	23.62	23.64	23.76	23.44	23.38	23.14	22.98	22.02	22.44	22.70	23.24	24.62	24.58	24.92
9	TOP	22.64	22.52	22.62	22.32	21.90	21.78	21.98	20.54	20.20	19.98	21.22	22.40	23.00	23.80
	MID	22.72	22.64	22.72	22.66	21.80	21.84	22.00	20.80	20.72	20.20	21.50	22.40	23.20	23.96
	BOT	22.74	23.32	23.02	22.82	22.08	21.84	21.90	21.00	21.00	21.00	21.10	22.24	23.10	24.16
10	TOP	25.64	25.54	26.14	26.42		26.72	26.60	25.82	25.72	25.10	25.42	25.22	25.72	26.90
	MID	25.92	25.66	26.24	26.68		26.78	26.82	25.90	25.88	25.58	25.40	25.56	25.92	26.92
	BOT	25.82	25.86	26.52	27.38		26.80	26.98	25.88	25.70	25.62	25.30	25.60	26.10	26.70
11	TOP														
	MID														
	BOT														

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SALINITY (SECOND RUN)
PARTS PER THOUSAND

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1 TOP	26.18	25.92	27.20		26.33	26.57		27.26		27.20	26.72	26.46	26.44	25.94
MID	26.18	26.12	26.48		26.53	26.85		27.52		27.52	26.92	26.46	26.44	25.86
BOT	26.18	26.04	26.52		27.12	27.35		27.44		27.90	26.92	26.46	26.54	26.14
2 TOP	25.83	25.33	25.34		26.48	26.90		25.83	25.70	25.52	25.20	25.14	25.66	25.64
MID	25.52	25.33	25.72		25.28	25.38		26.06	26.25	25.82	25.80	25.64	25.80	25.64
BOT	25.36	25.28	25.56		25.22	26.43		25.60	26.30	25.89	26.70	26.40	26.42	25.54
3 TOP	25.13	25.18	24.84		25.04	24.96		24.79	24.86	25.00	25.10	25.44	25.84	25.82
MID	24.76	25.15	25.12		25.04	25.00		24.82	24.86	24.98	25.10	25.44	25.84	26.20
BOT	24.85	25.17	25.12		25.12	25.00		24.82	24.79	25.52	25.10	25.44	25.88	24.84
4 TOP	24.65	25.70	25.72		25.49	25.42		24.26	25.31	25.43	25.36	25.58	25.00	25.80
MID	25.47	24.88	24.71		25.50	25.90		25.82	25.93	25.70	25.42	25.62	26.28	25.80
BOT	25.35	24.90	24.60		25.55	25.70		25.60	25.90	25.67	25.42	25.62	26.28	25.82
5 TOP	23.30	23.20	24.55		23.88	24.67		24.90	25.27	25.15	25.16	25.02	25.16	24.50
MID	23.80	23.90	23.68		24.02	24.72		25.08	25.37	25.41	25.24	25.02	25.16	24.72
BOT	23.78	23.88	23.92		24.03	24.87		25.84	25.35	25.84	25.16	25.02	25.02	24.50
6 TOP	22.68	22.77	23.44	23.68	22.59	24.55		23.28	24.58	23.66	23.70	24.00	23.90	23.78
MID	22.73	22.55	22.58	22.61	22.89	23.38		23.53	23.69	23.75	23.92	24.02	23.90	23.78
BOT	23.24	22.57	22.60	22.79	22.89	23.37		23.92	23.79	23.85	25.40	24.82	24.54	23.64
7 TOP	22.76	22.90	23.57	24.26	22.90	24.43		22.36	22.34	22.14	21.60	21.34	21.14	21.76
MID	22.70	22.90	23.60	24.36	24.25	24.64		22.81	22.57	22.44	21.60	21.90	21.54	21.76
BOT	22.56	22.94	23.60	24.47	24.41	24.75		22.79	22.57	22.35	21.64	21.88	20.86	21.70
8 TOP	23.52	24.40	22.84	23.96	23.98	23.96		22.52	23.75	23.85	23.50	22.66	21.94	23.04
MID	23.77	24.36	24.90	25.17	24.00	24.87		22.96	24.02	24.00	23.52	22.58	22.22	23.02
BOT	23.82	25.40	24.97	25.25	24.96	24.18		24.27	24.10	24.00	21.98	21.34	20.88	21.36
9 TOP	25.50	25.20	25.08	23.43	25.02	25.07		22.43	24.08	22.10	20.76	20.18	20.34	20.32
MID	25.50	22.27	22.94	24.09	24.44	24.42		22.90	23.20	22.40	21.80	20.68	20.54	20.56
BOT	22.62	22.27	22.96	23.94	24.50	24.65		23.80	23.22	24.08	21.82	20.82	20.64	20.36
10 TOP	26.46	21.96	26.98	23.00	24.67	24.02		28.05		27.88	27.14	26.44	26.90	
MID	26.64	26.82	26.94	27.46	28.07	28.40		28.75		27.79	27.24	26.89	26.98	
BOT	26.64	26.78	26.94	27.20	27.95	28.64		28.72		27.82	27.24	26.84	26.98	
11 TOP														
MID														
BOT														

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SALINITY (SECOND RUN)
PARTS PER THOUSAND

DATE *********		4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION															
1	TOP	26.24	25.50	25.86	26.02	26.92	26.62		27.66	27.50	27.60				
	MID	26.20	25.86	25.86	26.02	26.92	26.68		27.68	27.50	27.53				
	BOT	26.20	27.30	25.86	25.80	26.92	23.30		27.54	27.48	27.58				
2	TOP	25.40	26.02	26.00	26.30	26.24	25.96	26.14	25.76	26.32	26.38				
	MID	25.40	26.12	25.98	26.14	26.24	25.96	26.20	26.16	26.45	26.90				
	BOT	25.40	26.30	26.18	26.14	26.48	26.12	23.78	27.42	27.45	27.54				
3	TOP	26.30	26.04	26.30	26.36	26.58	26.54	26.12	26.06	26.00	26.16				
	MID	26.30	26.02	26.30	26.36	26.58	26.34	26.02	25.98	25.96	26.12				
	BOT	25.08	25.88	26.24	26.54	26.58	26.04	26.30	26.00	25.92	25.06				
4	TOP	25.48	24.86	25.02	24.92	25.06	25.00		26.38	26.00	26.45				
	MID	25.10	25.08	25.02	25.49	25.06	25.00		26.48	26.44	26.72				
	BOT	25.70	24.98	25.44	25.49	24.76	25.16		26.50	26.44	26.30				
5	TOP	24.54	24.08	24.00	24.34	24.20	24.10	24.88		25.72	25.76	25.70		24.84	
	MID	24.54	24.34	24.10	24.34	24.30	24.18	24.80		25.76	26.18	25.60		24.90	
	BOT	25.26	25.00	24.14	24.36	24.32	25.06	26.76		26.00	26.10	25.40		25.00	
6	TOP	23.54	23.36	23.56	23.56	23.68	23.58	23.84		24.20	24.16	25.58		24.40	
	MID	23.52	22.98	23.44	23.60	23.68	23.66	23.84		24.66	24.62	24.58		24.46	
	BOT	23.50	23.36	23.44	23.60	23.66	23.62	23.74		25.58	25.54	25.20		24.60	
7	TOP	22.02	22.54	22.68	23.98	24.40	23.90	24.50	23.64	23.32	23.54	23.54			
	MID	22.02	22.50	22.68	23.98	24.72	24.42	24.44	23.58	23.44	23.50	23.54			
	BOT	22.02	22.52	22.78	23.98	24.38	24.50	24.26	23.60	23.48	23.54	23.62			
8	TOP	22.60	23.88	24.16	24.96	25.20	24.44	25.44	24.96	24.90	24.90	25.20			
	MID	22.30	24.82	24.06	25.32	25.56	25.38	25.38	25.02	24.86	24.94	25.24			
	BOT	22.02	25.18	23.16	25.32	25.56	24.78	24.96	23.82	23.80	23.86	24.12			
9	TOP	20.14	21.76	22.30	23.04	23.32	23.56	24.44	23.52	23.54	23.42				
	MID	21.42	21.52	22.30	23.18	23.74	23.66	24.60	23.44	23.44	23.36				
	BOT	21.42	21.52	22.30	23.02	23.82	23.70	24.62	23.52	23.60	23.38				
10	TOP		26.28	26.54	27.00				28.14	28.18	28.18				
	MID		26.54	26.48	27.04				28.24	28.28	28.08				
	BOT		26.62	26.48	27.04				23.60	23.68	28.60				
11	TOP														
	MID														
	BOT														

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CHLORIDES
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1			17232	16685	17184	18552	17940	17796	19372	18986	15092	15961	13950	15173
2			12936	17988	17715	15623	14240	16010	14449	14964	15237	14272	15479	14883
3			13677	14578	13516	14624	14465	15479	14143	15189	15543		19179	15269
4			14819	15382	14674	14368	15092	14352	18005	14368	15092	13837	14899	14594
5			13532	15656	14529	14803	14304	14867	14626	15833	15253	15286	13210	14015
6			12969	13178	13405	13652	13850	13850	13801	13752	13753	13850	13702	13652
7			13773	12920	13483	12679	13113	13097	13548	13757	12711	14095	14980	15157
8			14368	13612	14272	13162	14401	14336	14352	13564	12872	16814	15109	
9			14851	14014	14175	13210	14551	14059	13435	14426	14465	16508	15462	
10			14449	15993		18278	16331	15897	16146	15768	16315	15736	15833	
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL DISSOLVED SOLIDS
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	28,500	28,600	29,100	29,100	28,900	31,000		28,500	28,400	27,000	27,500	28,400	28,500	28,000
2	27,000	26,800	27,100	27,400	27,600	28,000		27,800	27,500	27,000	27,000		27,500	27,500
3	26,100	26,000	26,100	26,300	26,400	27,700		26,900	26,900	26,600	27,100		24,900	27,300
4	28,000	27,700	27,900	28,100	27,000	28,300	27,600	27,500	30,200	26,900	26,800		26,400	26,500
5	26,400	26,000	26,900	26,900	27,000	27,600	27,500	27,200	26,400	26,200	26,500		25,600	25,300
6	24,100	24,000	24,500	24,600	25,200	20,600	25,800	25,300	24,800	24,400	24,900		24,600	24,200
7	27,800	26,000	25,600	24,400	24,200	24,500	23,800	23,300	23,200	22,900	24,700	25,400	25,600	25,900
8	26,800	26,300	25,700	25,400	25,400	26,000	25,400	23,900	24,900	25,500	25,300	26,700	26,700	26,700
9	27,900	26,400	24,700	23,600	14,400	23,500		21,800	21,200	21,700	23,100	24,100	27,300	25,300
10	31,700	30,500	28,200	30,000	29,700	29,500		28,500	27,900	28,100	29,100	29,100	29,200	28,600
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	28,200	28,900	29,100	28,800	29,700	29,000	29,600	28,700	29,000	28,100	28,300	28,300	28,000	28,700
2	28,100	28,600	28,700	28,000	28,500	27,900	28,500	27,800	28,200	27,300	27,900	27,500	27,700	27,500
3	27,700	28,000	28,700	28,000	28,300	28,000	28,100	27,700	27,800	27,300	27,900		27,600	27,600
4	26,600	27,000	27,900	27,600	28,500	27,500	28,800	27,800	27,900	27,300	27,900	27,600	26,600	26,700
5	25,100	25,600	26,800	26,700	27,500	27,000	27,700	26,800	27,500	26,900	27,000	26,600	26,000	25,800
6	24,400	24,600	25,600	25,100	25,800	25,500	26,000	26,000	25,900	25,600	25,600	26,000	25,600	25,100
7	25,900	26,000	26,700	26,000	26,100	24,800	25,100	24,400	24,500	24,600	25,300	25,700	26,500	26,400
8	26,900	26,800	27,200	26,700	26,800	25,900	26,000	24,300	25,100	25,100	26,100	26,900	27,400	27,200
9	25,400	25,800	26,600	25,800	25,500	24,200	25,000	23,400	23,000	22,700	24,100	25,000	25,600	26,100
10	29,100	29,200	30,900	30,700		29,800	30,500	28,800	29,000	28,400	28,800	28,700	28,900	29,200
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SULFATES
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	2,280	2,090	2,090	2,090	2,140	2,040		1,950	2,000	2,000	2,160	1,990	2,040	2,230
2	1,950	1,820	2,040	2,000	2,300	2,050		2,000	1,990	1,980	2,000		2,020	1,920
3	2,100	1,850	1,900	1,850	2,180	1,970		1,860	1,880	1,970	1,940		2,060	2,090
4	2,280	2,000	2,090	2,000	1,750	2,090	1,860	1,950	2,040	2,000	2,050		1,960	2,000
5	2,180	1,710	2,000	1,640	2,040	1,960	1,870	1,990	1,830	1,960	1,920		1,950	1,900
6	2,090	1,800	1,830	1,850	2,140	1,920	1,770	1,800	1,820	1,820	1,860		1,820	1,720
7	2,070	1,880	1,940	1,850	2,180	1,830	1,610	1,660	1,700	1,760	1,900	1,910	1,710	1,990
8	2,040	2,000	2,140	1,850	1,900	1,950	1,760	1,750	2,020	1,900	1,960	1,860	1,960	2,210
9	2,090	2,000	1,940	1,800	1,850	1,850		1,610	1,520	1,580	1,760	1,790	1,990	1,900
10	2,400	2,280	2,380	2,280	3,230	2,320		2,090	2,120	2,200	2,140	2,180	2,090	2,230
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	2,040	2,080	2,180	2,090	2,230	2,120	2,080	2,110	2,070	2,090	2,020	2,070	2,130	2,140
2	2,070	2,090	2,100	2,140	2,190	2,080	2,050	2,120	2,040	1,970	2,090	2,040	2,080	2,090
3	2,040	2,160	1,850	2,090	1,560	2,070	2,060	2,080	2,060	2,040	2,060		2,100	2,060
4	1,990	2,090	1,970	2,140	2,140	2,060	2,170	2,080	2,060	2,100	2,070	2,040	2,040	2,060
5	1,960	2,070	2,230	2,150	2,140	2,040	2,040	1,990	1,970	2,140	2,010	2,010	2,040	2,010
6	1,840	1,860	1,760	1,860	1,850	1,960	1,940	1,890	1,940	1,920	1,940	1,880	1,960	1,950
7	1,900	2,000	2,120	1,950	1,950	1,840	1,800	1,820	1,880	1,800	1,920	1,940	2,000	1,960
8	2,080	2,130	2,120	2,080	1,950	1,880	1,960	1,800	1,840	1,850	2,040	2,010	2,120	2,150
9	1,960	2,020	1,920	2,000	1,940	1,850	1,840	1,740	1,660	1,730	1,830	1,940	1,940	2,000
10	2,240	2,190	2,470	2,420		2,230	2,230	2,140	2,020	2,160	2,110	2,190	2,180	2,260
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

ORGANIC NITROGEN
MG/L N

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.8	0.5	0.7	0.3	0.0	0.2		0.5	0.0	0.0	0.4	0.2	0.2	0.5
2	0.0	0.5	0.3	0.2	0.6	0.1		0.8		0.0	0.7	0.7	0.2	0.0
3	0.4	0.5	0.0	0.0	0.0	0.0		0.3	0.6	1.0	0.7		0.3	0.2
4	0.6	2.5	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.1	0.2		0.3	0.5
5	0.1	0.4	0.3	0.3	0.5	0.9	0.8	0.7	0.8	0.7	0.7		0.7	0.7
6	0.4	0.5	0.0	0.5	0.3	0.0	0.2	0.3	0.3	0.3	0.0		0.2	0.0
7	0.4	0.5	0.7	0.5	0.8	0.5	0.0	0.6	0.9	0.7	0.5	0.7	0.6	0.8
8	0.0	0.0	0.0	0.7	0.0	0.0	0.4	0.7	0.6	0.1	0.2	0.3	0.5	0.4
9	0.0	0.0	0.3	0.3	0.7	0.3		0.4	0.0	0.5	0.5	0.4	0.3	0.5
10	0.3	0.5	0.2	0.0	0.0	0.2		0.3	0.0	0.0	0.0	0.0	0.4	0.0
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.2	0.2	0.2	0.2	0.4	0.3	0.9	0.5	0.6	0.2	0.0	0.4	0.0	0.4
2	0.3	1.7	0.6	0.6	0.4	0.1	0.2	0.6	0.5	0.5	0.2	0.0	0.0	0.0
3	0.6	0.6	0.7	0.6	0.6	0.6	0.7	0.7	0.3	0.5	0.7		0.7	0.5
4	0.5	0.0	0.1	0.2	0.0	0.3		1.1		0.5	0.3	0.5	0.0	0.4
5	0.2	0.5	0.7	0.9	0.7	0.7	0.7	0.5	0.4	0.4	0.4	0.4	0.7	0.7
6	0.0	0.1	0.7	0.5		0.3		0.4	0.5		0.4		0.2	0.3
7	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.1	1.0	0.3	0.1	0.0	0.0
8	0.3	0.5	0.8	0.6	0.7	0.8	0.7	0.6	0.6	0.1	0.5	0.7	0.5	0.1
9	0.6	0.4	0.3	0.6	0.5	0.3	0.2	0.0	0.3	0.5	0.5	0.0	0.2	0.4
10	0.0	0.0	0.0	0.0		0.0	0.2	0.0	0.9	0.3	0.7	0.3	1.0	0.2
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

AMMONIA
MG/L N

DATE **********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0							
11														

DATE **********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

NITRATE + NITRITE
MG/L N

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL PHOSPHORUS
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.10	0.11	0.08	0.07	0.06	0.07	0.07	0.07	0.15	0.03	0.04	0.03	0.05	0.04
2	0.07	0.06	0.13	0.06	0.05	0.08		0.04		0.09	0.04	0.03	0.05	0.09
3	0.03	0.03	0.04	0.03	0.04	0.03		0.03	0.03	0.04	0.04		0.03	0.03
4	0.06	0.07	0.06	0.04	0.04	0.04	0.05	0.06	0.03	0.04	0.04		0.03	0.04
5	0.08	0.07	0.06	0.04	0.04	0.04	0.09	0.05	0.05	0.04	0.06		0.04	0.04
6	0.07	0.06	0.06	0.06	0.06	0.04	0.05	0.05	0.05	0.05	0.05		0.05	0.05
7	0.07	0.05	0.07	0.07	0.07	0.05	0.06	0.09	0.05	0.06	0.05	0.10	0.06	0.05
8	0.05	0.04	0.05	0.05	0.05	0.05	0.06	0.05	0.06	0.04	0.07	0.04	0.04	0.03
9	0.04	0.04	0.04	0.04	0.04	0.07		0.04	0.04	0.04	0.04	0.05	0.04	0.04
10	0.05	0.06	0.04	0.04	0.06	0.04		0.05	0.04	0.04	0.04	0.04	0.08	0.07
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.05	0.05	0.08	0.08	0.04	0.07	0.07	0.04	0.05	0.05	0.04	0.05	0.05	0.06
2	0.05	0.06	0.05	0.05	0.08	0.06	0.06	0.07	0.08	0.04	0.08	0.05	0.04	0.04
3	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.07	0.06		0.04	0.06
4	0.04	0.05	0.05	0.07	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.06
5	0.06	0.09	0.09	0.07	0.08	0.05	0.06	0.06	0.06	0.05	0.07	0.18	0.07	0.11
6	0.06	0.06	0.07	0.07	0.07	0.07	0.05	0.06	0.07	0.07	0.06	0.07	0.10	0.08
7	0.05	0.05	0.06	0.08	0.06	0.06	0.05	0.06	0.05	0.06	0.07	0.07	0.05	0.05
8	0.04	0.04	0.04	0.04	0.05	0.05	0.06	0.05	0.05	0.06	0.05	0.06	0.05	0.05
9	0.04	0.04	0.04	0.03	0.05	0.05	0.05	0.04	0.05	0.05	0.06	0.04	0.05	0.04
10	0.05	0.04	0.06	0.04		0.08	0.05	0.14	0.05	0.04	0.06	0.10	0.06	0.08
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE PHOSPHORUS
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02
2	0.03	0.03	0.03	0.02	0.02	0.02		0.03		0.03	0.02	0.02	0.01	0.04
3	0.02	0.02	0.02	0.01	0.02	0.01		0.03	0.03	0.04	0.04		0.03	0.03
4	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02		0.01	0.03
5	0.03	0.03	0.02	0.03	0.03	0.02	0.03	0.02	0.02	0.02	0.03		0.02	0.03
6	0.07	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.04		0.02	0.03
7	0.03	0.04	0.03	0.04	0.04	0.03	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02
8	0.02	0.02	0.03	0.02	0.02	0.03	0.03	0.02	0.04	0.02	0.02	0.02	0.02	0.01
9	0.02	0.03	0.03	0.02	0.04	0.02		0.03	0.03	0.02	0.02	0.02	0.02	0.01
10	0.02	0.02	0.02	0.02	0.04	0.02		0.03	0.04	0.03	0.04	0.02	0.02	0.06
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.03	0.03	0.03	0.02	0.03	0.01	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.04
2	0.03	0.05	0.02	0.04	0.03	0.04	0.03	0.03	0.04	0.02	0.03	0.01	0.02	0.02
3	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.05		0.02	0.03
4	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04
5	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.05	0.05
6	0.03	0.04	0.05	0.05	0.04	0.03	0.03	0.03	0.03	0.05	0.04	0.03	0.04	0.05
7	0.04	0.03	0.02	0.02	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
8	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.03
9	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.04	0.04	0.02	0.02	0.02
10	0.02	0.02	0.02	0.02		0.02	0.02	0.03	0.05	0.03	0.03	0.04	0.04	0.03
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CHLOROPHYLL A
UG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	4.01	3.39	5.40	2.36	0.76	4.03		2.72	2.31	1.28	1.85	1.87	2.46	2.93
2	3.70	1.96	3.83	3.78	1.65	3.02		3.94	1.90	1.71	2.86		2.35	2.44
3	3.25	1.46	1.61	2.26	1.16	2.74		3.19	1.84	1.42	3.17		2.13	1.99
4	4.94	1.80	2.19	3.19	1.92	1.57	2.72	2.08	1.94	1.82	1.77		3.17	2.16
5	4.08	1.77	3.15	2.58	2.30	1.73	2.35	2.58	1.78	1.59	1.59		2.08	2.97
6	3.10	1.82	1.90	1.56	2.33	2.12	1.20		1.90	1.60	2.59		2.00	2.67
7	1.80	2.05	1.72	2.59	2.23	1.26	2.47	1.73	1.71	2.54	1.80	2.58	1.69	2.24
8	1.66	1.74	1.25	2.09	3.00	1.69	3.93	2.37	2.01	1.40	1.77	1.90	1.44	1.82
9	1.38	1.94	2.13	1.62	2.43	1.84		1.70	1.49	1.34	2.97	2.23	1.42	1.95
10	1.94	2.21	1.85	1.80	2.20	1.18		2.43	1.32	1.24	2.17	2.55	2.71	1.95
11				1.97	4.26			1.98	1.84	1.46	1.88	1.54	1.22	1.20

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	3.29	1.88	6.47	5.64	6.54				2.74	5.75	2.71	2.68	5.54	5.68
2	3.96	2.83	4.73	3.78	5.74				1.79	4.59	3.25	4.55	4.55	3.47
3	2.39	2.17	3.14	3.78	4.80				1.65	4.84	2.65		3.89	3.82
4	3.55	2.27	4.81	3.88	4.80				1.83	4.74	3.79	2.67	5.66	3.59
5	1.65	3.36	5.64	4.75	5.64				3.21	3.93	3.83	4.59	4.59	4.93
6	4.02	4.51	3.88	4.83	4.81				1.65	3.93	3.93	3.81	4.64	4.75
7	2.50	2.42	4.81	5.66	3.88				3.44	4.84		4.60	3.69	3.22
8	2.94	2.83	3.87	4.92	3.88				2.24	4.06	2.74	3.81	2.71	3.75
9	1.85	1.74	3.87	3.99	3.92				2.14	3.93	2.16	3.69	2.68	2.81
10		3.00	4.81	3.14					1.50	3.81	2.13	4.49	2.73	3.30
11	2.55													

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CHLOROPHYLL C
UG/L

DATE ********* STATION	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
1	1.31	3.44	3.78	4.01	4.42	0.00		9.14	3.12	1.47	0.17	4.80	1.60	2.24
2	0.50	0.18	1.11	1.94	0.00	5.13		10.22	3.97	0.16	3.86		3.17	0.00
3	0.00	1.67	2.18	0.00	0.10	4.65		13.95	3.85	1.62	2.42		0.20	0.18
4	2.75	0.16	2.23	0.28	1.47	3.28	0.95	7.64	1.26	1.19	0.16		4.28	0.00
5	3.03	0.16	1.75	0.00	1.76	3.62	0.00	5.70	6.60	3.34	3.34		1.36	5.05
6	0.00	0.17	1.99	3.26	0.00	7.77	1.37		6.37	0.15	0.91		1.30	0.00
7	0.16	0.19	1.80	1.98	0.00	1.44	2.59	2.89	5.75	3.44	0.16	5.70	0.15	0.47
8	0.15	0.16	0.81	2.13	0.46	2.85	0.00	4.95	4.20	1.60	1.15	3.97	1.65	1.19
9	0.47	0.18	2.16	0.00	1.30	3.85		0.00	0.14	0.00	7.72	3.01	0.04	2.64
10	0.18	0.20	2.50	0.00	0.00	1.35		0.22	1.51	1.42	1.41	0.00	0.00	1.37
11				0.00	0.86			6.64	3.85	1.67	0.17	0.00	4.10	

DATE ********* STATION	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
1	0.69	1.22	2.90	2.15	5.51				2.87	5.92	0.00	0.25	2.96	0.00
2	2.94	0.00	0.00	6.41	1.20				1.17	6.39	0.00	3.47	3.47	0.00
3	0.00	1.41	0.00	6.41	3.56				1.07	4.92	2.02		0.00	1.56
4	0.00	3.07	0.00	0.00	3.56				0.00	3.62	2.89	5.58	3.03	1.92
5	1.07	2.49	2.15	0.00	2.15				4.34	0.00	2.93	3.51	3.51	1.00
6	0.00	4.54	0.00	2.58	0.00				3.04	0.00	3.00	0.00	3.54	0.96
7	3.38	3.28	0.00	3.15	0.00				3.49	4.92		4.67	3.87	2.46
8	5.68	0.00	3.94	3.65	0.00				0.21	1.42	2.87	0.00	0.25	1.53
9	1.20	1.13	3.94	0.84	3.99				1.39	0.00	0.20	3.87	0.25	0.00
10		1.05	0.00	0.00					1.71	3.99	0.20	7.62	5.70	1.76
11	0.89													

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE SILICA
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.30	0.30	0.40	0.45	0.40	0.40		0.30	0.40	0.40	0.40	0.30	0.30	0.40
2	0.50	0.50	0.50	0.50	0.55	0.50		0.40	0.50	0.40	0.50		0.50	0.50
3	0.50	0.50	0.50	0.50	0.50	0.55		0.50	0.50	0.50	0.50		0.50	0.50
4	0.40	0.50	0.50	0.50	0.50	0.50	0.50	0.60	0.50	0.50	0.50		0.50	0.50
5	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50		0.50	0.50
6	0.60	0.70	0.60	0.60	0.70	0.70	0.60	0.60	0.60	0.65	0.50		0.70	0.70
7	0.60	0.70	0.70	0.60	0.70	0.70	0.70	0.60	0.70	0.60	0.60	0.60	0.70	0.70
8	0.50	0.60	0.50	0.60	0.60	0.60	0.60	0.50	0.60	0.60	0.60	0.60	0.60	0.50
9	0.50	0.50	0.50	0.50	0.60	0.50		0.40	0.40	0.50	0.50	0.55	0.50	0.40
10	0.20	0.30	0.40	0.40		0.40		0.30	0.30	0.40	0.40	0.40	0.40	0.40
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.40	0.40												
2	0.50	0.50												
3	0.50	0.50												
4	0.50	0.50												
5	0.50	0.50												
6	0.60	0.60												
7	0.60	0.60												
8	0.60	0.50												
9	0.40	0.40												
10	0.50	0.30												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE CALCIUM
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	360	360	350	370	360	360		350	350	350	360	350	360	360
2	350	360	350	350	365	350		350	350	350	350		350	340
3	350	350	350	350	345	360		350	350	340	350		350	350
4	350	340	340	350	360	350	350	370	350	350	340		350	350
5	350	350	345	345	360	350	350	350	360	350	350		350	350
6	340	340	345	335	340	340	350	340	345	355	340		340	340
7	340	360	340	335	340	340	350	340	345	340	355	340	340	340
8	350	350	350	350	350	350	340	350	360	350	350	350	360	350
9	310	330	330	320	330	330		330	330	330	330	345	330	330
10	360	350	360	370		360		360	360	350	350	350	360	350
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	360	350												
2	350	340												
3	340	340												
4	340	340												
5	340	340												
6	340	330												
7	350	330												
8	360	340												
9	330	320												
10	365	360												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE MAGNESIUM
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	1,050	1,000	990	1,025	990	1,000		1,000	1,000	1,000	980	990	1,000	1,010
2	1,000	980	980	990	995	990		990	980	990	960		980	970
3	980	970	990	990	980	1,015		990	990	990	970		980	970
4	980	980	990	980	980	990	970	1,020	980	980	980		980	980
5	980	980	990	970	980	980	990	990	995	980	980		980	970
6	1,000	970	980	970	980	980	990	980	960	995	980		970	970
7	970	960	980	960	980	980	960	980	980	980	985	970	970	970
8	970	990	990	990	990	990	990	990	990	990	980	980	995	980
9	960	970	970	960	960	960		970	970	970	960	975	960	960
10	1,020	1,010	1,010	1,000		1,020		1,000	1,000	1,000	1,000	1,000	1,000	1,000
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	1,000	1,000												
2	980	990												
3	960	990												
4	970	990												
5	970	980												
6	970	980												
7	970	980												
8	980	990												
9	960	970												
10	1,005	1,000												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE SODIUM
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	9,000	8,500	8,600	8,700	8,700	8,500		8,600	8,700	8,600	8,600	8,500	8,700	8,600
2	8,500	8,400	8,400	8,400	8,750	8,500		8,500	8,400	8,400	8,500		8,500	8,500
3	8,500	8,300	8,500	8,400	8,400	8,500		8,400	8,400	8,400	8,500		8,400	8,500
4	8,500	8,300	8,400	8,400	8,400	8,400	8,500	8,700	8,400	8,400	8,300		8,400	8,400
5	8,400	8,300	8,500	8,400	8,400	8,300	8,400	8,400	8,600	8,400	8,300		8,500	8,700
6	8,400	8,300	8,500	8,300	8,400	8,300	8,400	8,400	8,400	8,650	8,300		8,400	8,400
7	8,500	8,400	8,500	8,300	8,400	8,300	8,400	8,400	8,300	8,500	8,550	8,400	8,400	8,400
8	8,500	8,400	8,500	8,400	8,500	8,300	8,400	8,400	8,400	8,400	8,400	8,400	8,550	8,400
9	8,400	8,000	8,300	8,200	8,200	8,300		8,200	8,300	8,300	8,400	8,550	8,300	8,200
10	8,700	8,600	8,700	8,600		8,500		8,600	8,600	8,800	8,700	8,600	8,600	8,600
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	8,600	8,600												
2	8,500	8,400												
3	8,400	8,400												
4	8,400	8,400												
5	8,400	8,400												
6	8,400	8,400												
7	8,400	8,400												
8	8,500	8,500												
9	8,400	8,300												
10	8,700	8,700												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE POTASSIUM
MG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	370	370	370	370	370	360		360	360	360	360	360	370	370
2	370	360	350	360	375	360		360	350	350	350		370	350
3	360	360	350	360	360	360		350	350	340	360		360	350
4	350	360	350	360	350	350	350	370	350	340	350		360	350
5	350	370	340	360	350	350	350	350	360	340	340		360	340
6	340	360	350	350	350	350	350	350	340	355	340		350	340
7	350	360	350	350	350	350	350	350	340	340	355	350	350	340
8	350	360	360	350	360	360	360	360	360	350	360	360	360	360
9	340	320	340	340	350	340		340	330	340	330	355	340	350
10	380	380	370	370		360		370	370	360	370	370	380	370
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	370	360												
2	360	350												
3	360	350												
4	360	350												
5	360	360												
6	350	350												
7	350	350												
8	360	350												
9	340	340												
10	375	360												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE COPPER
UG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.01	0.01	0.01	0.01	0.00	0.00		0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	0.01	0.01	0.01	0.01	0.01	0.00		0.01	0.01	0.01	0.01		0.01	0.00
3	0.01	0.01	0.01	0.01	0.01	0.01		0.01	0.01	0.01	0.01		0.01	0.01
4	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01		0.01	0.01
5	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01		0.01	0.01
6	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01		0.01	0.01
7	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.00	0.01	0.01
8	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
9	0.01	0.01	0.01	0.01	0.01	0.01		0.02	0.01	0.02	0.01	0.01	0.01	0.01
10	0.00	0.01	0.02	0.01		0.00		0.00	0.01	0.01	0.01	0.00	0.01	0.01
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.01	0.00												
2	0.01	0.01												
3	0.00	0.01												
4	0.01	0.01												
5	0.01	0.01												
6	0.01	0.01												
7	0.01	0.01												
8	0.02	0.01												
9	0.02	0.01												
10	0.01	0.01												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE CHROME
UG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.00	0.00												
2	0.00	0.00												
3	0.00	0.00												
4	0.00	0.00												
5	0.00	0.00												
6	0.00	0.00												
7	0.00	0.00												
8	0.00	0.00												
9	0.00	0.00												
10	0.00	0.00												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE CADMIUM
UG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.00	0.00												
2	0.00	0.00												
3	0.00	0.00												
4	0.00	0.00												
5	0.00	0.00												
6	0.00	0.00												
7	0.00	0.00												
8	0.00	0.00												
9	0.00	0.00												
10	0.00	0.00												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE MERCURY
UG/L

DATE **********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11														

DATE **********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.00	0.00												
2	0.00	0.00												
3	0.00	0.00												
4	0.00	0.00												
5	0.00	0.00												
6	0.00	0.00												
7	0.00	0.00												
8	0.00	0.00												
9	0.00	0.00												
10	0.00	0.00												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE LEAD
UG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.00	0.00	0.00	0.01	0.01	0.01		0.01	0.01	0.00	0.01	0.00	0.00	0.01
2	0.01	0.00	0.00	0.01	0.01	0.01		0.01	0.01	0.00	0.01		0.00	0.01
3	0.00	0.01	0.00	0.01	0.01	0.01		0.01	0.01	0.00	0.01		0.01	0.01
4	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.01	0.00	0.01		0.01	0.01
5	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.01		0.01	0.01
6	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.02	0.02	0.01	0.01		0.01	0.02
7	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
9	0.01	0.01	0.01	0.02	0.01	0.01		0.01	0.02	0.01	0.01	0.01	0.01	0.01
10	0.00	0.00	0.00	0.01		0.01		0.02	0.01	0.01	0.00	0.01	0.02	0.01
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.01	0.00												
2	0.01	0.01												
3	0.01	0.01												
4	0.01	0.01												
5	0.00	0.01												
6	0.00	0.01												
7	0.02	0.01												
8	0.02	0.01												
9	0.01	0.01												
10	0.01	0.01												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE ZINC
UG/L

DATE *********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.01	0.01	0.02	0.01	0.01	0.01		0.02	0.01	0.00	0.01	0.02	0.00	0.00
2	0.01	0.01	0.01	0.01	0.02	0.01		0.01	0.01	0.01	0.01		0.01	0.01
3	0.01	0.01	0.01	0.01	0.01	0.01		0.01	0.01	0.01	0.01		0.01	0.01
4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01		0.01	0.01
5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01		0.01	0.01
6	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01		0.01	0.01
7	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
8	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
9	0.01	0.01	0.01	0.02	0.02	0.02		0.02	0.01	0.02	0.02	0.01	0.02	0.02
10	0.01	0.02	0.04	0.01		0.01		0.02	0.02	0.01	0.02	0.01	0.02	0.01
11														

DATE *********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.01	0.01												
2	0.01	0.01												
3	0.00	0.01												
4	0.00	0.01												
5	0.01	0.01												
6	0.01	0.01												
7	0.00	0.01												
8	0.01	0.01												
9	0.01	0.01												
10	0.02	0.01												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE MANGANESE
UG/L

DATE **********	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19
STATION														
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11														

DATE **********	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
STATION														
1	0.00	0.00												
2	0.00	0.00												
3	0.00	0.00												
4	0.00	0.00												
5	0.00	0.00												
6	0.00	0.00												
7	0.00	0.00												
8	0.00	0.00												
9	0.00	0.00												
10	0.00	0.00												
11														

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 STUDIES

TRANSMISSION SPECTRUM

PERCENT TRANSMITTANCE VS WAVE LENGTH (MU)

DATE ********* STATION	4/6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1 2 MU	40	36	10	40	36	11		7	9	34				6	6	6
2.15	1	1	2	1	1	2		2	2	1				1	1	2
3	67	65	78	67	65	78		76	75	56				64	70	73
4	92	92	95	92	91	96		95	95	88				89	92	74
5	98	98	98	98	98	99		99	100	97				96	97	99
6	100	100	99	100	100	100		100	100	99				97	99	100
7	100	100	98	100	100	99		99	99	99				96	98	99
8	97	97	96	97	96	97		98	98	95				93	95	98
2 2 MU	34	30	33	38	34	8		8	5					35	6	6
2.15	0	1	1	1	1	2		2	1					1	1	1
3	58	58	59	61	61	73		72	68					55	70	71
4	87	88	90	91	91	95		95	95					86	73	73
5	96	96	98	98	98	99	99	99	97					94	99	98
6	99	98	100	100	100	100		100	98					97	100	100
7	98	98	100	100	100	99		99	97					98	100	99
8	95	94	97	96	96	97		97	95					94	98	97
3 2 MU	33	7	27	34	32	7		7	4	5	6			7	9	8
2.15	1	2	0	1	1	2		2	1	1	1			2	2	1
3	56	66	55	56	55	67		71	68	67	67			70	72	71
4	89	92	88	88	88	93		94	92	93	93			94	94	93
5	97	98	97	96	96	99		99	97	99	99			99	98	99
6	100	99	100	98	99	100		100	98	100	100			100	99	100
7	100	99	100	98	99	99		99	98	100	99			99	98	99
8	95	97	96	94	95	97		98	95	98	97			97	97	98
4 2 MU	37	36	38	38	337	7	36	29	7	4	5			6	6	6
2.15	1	1	1	1	1	2	1	1	2	1	1			2	1	1
3	62	60	63	64	62	73	60	58	70	67	63			64	64	65
4	91	90	92	92	91	94	90	89	94	92	91			93	91	92
5	98	97	98	99	98	99	97	97	99	99	98			99	97	98
6	100	99	100	100	100	100	100	99	100	100	100			100	99	100
7	100	99	100	100	100	99	100	99	99	100	99			99	99	99
8	96	96	97	98	97	97	97	96	97	98	97			97	97	97
5 2 MU	27	30	30	36	31	35	15	8	5	5			4	5	5	10
2.15	1	0	1	1	1	1	1	1	1	1			1	1	1	1
3	58	51	58	58	59	59	59	68	63	62			59	55	56	60
4	91	86	89	89	91	89	89	94	90	92			89	88	89	90
5	99	95	96	96	98	97	97	99	97	99			96	96	96	98
6	100	98	98	98	100	99	99	100	98	100			98	98	98	99
7	100	98	99	98	100	99	99	99	97	100			97	97	97	99
8	98	94	94	94	97	96	96	97	95	98			94	94	95	97

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 STUDIES

TRANSMISSION SPECTRUM

PERCENT TRANSMITTANCE VS WAVE LENGTH (MU)

DATE *********	STATION	4/6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
6	2 MU	26	25	28	25	27	5	30	25	28					5	6	5
	2.15	1	0	0	1	1	1	1	1	0					1	1	1
	3	46	41	45	50	48	60	52	47	47					51	55	56
	4	85	82	85	89	86	91	88	85	85					88	89	90
	5	96	94	95	92	97	98	97	96	96					97	98	97
	6	99	97	98	100	100	100	100	99	99					100	100	99
	7	99	97	98	100	100	99	100	99	99					99	99	99
	8	95	92	93	96	96	96	95	95	95					96	97	97
7	2 MU	35	30	28	26	93	6	24	5	23					4	6	3
	2.15	0	1	1	1	1	1	1	1	0					1	1	0
	3	58	51	50	47	45	54	43	50	40					62	59	58
	4	90	86	86	86	85	90	84	88	82					90	91	90
	5	98	95	96	95	97	98	96	98	95					97	98	98
	6	100	98	99	98	100	99	99	100	98					98	100	100
	7	100	98	99	98	100	99	99	99	98					98	99	100
	8	96	94	95	93	95	96	94	96	93					95	97	98
8	2 MU	32	34	28	6	7	6	5	6	4				5	31	7	6
	2.15	1	1	0	1	1	1	1	1	0				1	1	1	1
	3	56	56	53	62	60	60	54	54	55				65	56	63	64
	4	89	89	88	92	90	91	86	89	89				92	87	92	92
	5	97	97	97	98	98	98	95	98	99				99	95	98	98
	6	99	100	99	100	99	99	97	100	100				100	99	100	100
	7	100	100	99	99	99	99	97	99	100				100	99	100	100
	8	96	96	96	96	96	96	93	96	97				98	94	97	98
9	2 MU	35	30	27	60	60	24		4	20				4	25	8	6
	2.15	1	1	1	1	1	0		0	1				1	1	1	1
	3	60	54	49	53	50	39		40	31				53	51	57	57
	4	90	88	86	89	86	82		84	78				87	87	89	89
	5	97	96	96	98	97	95		97	93				96	97	98	98
	6	99	99	98	100	99	98		99	98				98	100	100	100
	7	99	99	99	99	98	99		99	99				97	100	99	100
	8	96	95	94	96	96	93		95	94				93	95	97	98
10	2 MU	42	42	41	43	33	41		9	6				6	34	10	8
	2.15	1	1	1	2	2	2		2	2				2	1	2	2
	3	71	69	68	70	74	66		78	72				73	53	73	78
	4	92	93	92	93	94	92		96	93				92	87	94	76
	5	97	98	97	98	98	98		100	97				97	94	99	100
	6	99	100	99	100	100	100		100	98				98	97	100	100
	7	99	100	99	100	99	100		99	97				97	97	100	99
	8	96	97	96	96	97	96		97	96				95	93	98	98
11	2 MU																
	2.15																
	3																
	4																
	5																
	6																
	7																
	8																

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SAMPLE TIME
FIRST RUN

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	1105	1130	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045	1045
2	1045	1110	1025		1025	1025	1025	1025	1025	1025	1025	1025	1030	1025
3														
4	1025	1050	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
5	1000	1030	930	930	925	930	930	930	930	930	930	930	930	930
6	930	1000	905	900	900	900	900	900	900	900	900	900	900	900
7	815	815	800	800	800	825	800	800	800	800	800	800	800	800
8	850	930	825	825	825	800	825	825	825	825	825	825	825	825
9	1225	1305	1205	1205	1205	1205	1205	1205	1205	1230	1205	1205	1205	1205
10	1135	1200	1115	1115	1115	1115	1115	1115	1115	1135	1115	1115	1115	1115
11	1315	1340	1250	1250	1250	1250	1250	1250	1250	1315	1250	1250	1250	1250

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SAMPLE TIME
SECOND RUN

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	1440	1445	1445	1445	1445	1415	1445	1455	1440		1450	1515	1445	
2	1425	1425	1425	1425	1425	1400	1425	1445	1430		1435	1450	1425	
3														
4	1400	1400	1400	1400	1400	1345	1400	1425	1400		1420	1435	1400	1400
5	1410	1340	1325	1400	1420	1330	1330							
6	1300	1300	1300	1300	1300	1300	1300	1350	1305	1300	1340	1400	1300	1300
7	1200	1200	1225	1200	1200	1200	1200	1300	1225	1215	1300	1340	1205	1200
8	1225	1225	1200	1225	1225	1225	1225	1325	1245	1235	1315	1300	1230	1225
9	1605	1605	1605	1605			1605				1530	1530	1605	1605
10	1515	1515	1515	1515			1500						1515	
11	1650		1650	1630			1650					1600	1650	

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TEMPERATURE
DEGREES C (FIRST RUN)

DATE *********		7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION															
1	TOP	29	30	30	30	29	29	30	29	28	28	28	29	29	30
	MID	28	28	28	29	29	29	29	29	28	28	28	29	28	30
	BOT	28	29	29	30	29	28	29	29	28	28	28	29	29	29
2	TOP	29	30	29		30		28	29	28	29	29	29	30	30
	MID	28	30	29		29	28	29	28	28	28	28	29	30	30
	BOT	28	29	29		29	28	30	28	28	28	29	30	30	29
3	TOP														
	MID														
	BOT														
4	TOP	28	30	28	29	29	28	29	29	28	28	28	29	30	30
	MID	28	30	30	29	29	28	28	29	28	28	28	29	30	29
	BOT	28	29	29	29	29	28	28	29	28	28	28	30	30	30
5	TOP	29	30	28	29	29	28	28	28	28	28	28	29	30	30
	MID	28	30	28	28	29	28	28	28	28	28	28	29	30	30
	BOT	28	30	28	28	28	28	29	28	28	29	29	30	30	29
6	TOP	28	30	28	28	28	29	29	28	28	29	29	30	29	30
	MID	28	30	28	28	29	29	29	28	28	29	29	30	29	30
	BOT	28	30	28	30	28	29	28	28	28	29	30	30	29	30
7	TOP	28	28	28	27	28	28	28	28	28	29	29	29	29	30
	MID	28	28	28	28	28	28	28	28	28	29	29	29	30	30
	BOT	26	28	29	28	28	28	28	28	28	29	28	29	29	29
8	TOP	28	29	28	28	28	28	28	28	28	28	28	28	28	28
	MID	28	29	28	28	28	28	28	28	28	28	28	28	28	28
	BOT	28	29	28	28	28	28	28	28	28	28	28	28	28	28
9	TOP	30	30	30	30	30	29	30	30	29	29	28	30	30	29
	MID	30	30	31	30	30	30	30	30	29	29	29	30	30	29
	BOT	29	30	32	30	30	29	30	30	29	29	30	30	30	29
10	TOP	28	30	30	29	30	30	30	30	28	28	28	29	30	30
	MID	28	30	30	29	30	29	30	29	28	28	28	29	30	30
	BOT	28	28	30	30	30	30	30	30	29	29	28	29	30	30
11	TOP	30	30	32	31	30	30	30	30	30	30	30	30	30	30
	MID	30	30	32	30	30	30	30	30	30	28	30	30	31	30
	BOT	30	30	32	31	31	30	30	30	30	30	30	30	32	30

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TEMPERATURE
DEGREES C (SECOND RUN)

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1 TOP	29	29	29	31	29	29	29	30	29		29	29	30	
MID	29	29	29	30	29	29	39	30	29		29	29	31	
BOT	29	29	29	31	30	30	31	30	31		29	29	31	
2 TOP	30	29	31	31	29	29	30	31	31		29	29	30	
MID	29	29	30	31	29	29	30	31	31		29	29	30	
BOT	29	29	31	31	30	30	31	31	31		30	29	30	
3 TOP														
MID														
BOT														
4 TOP	30	29	31	31	29	30	31	30	29		29	29	29	29
MID	30	29	30	31	29	30	31	30	29		29	29	30	29
BOT	30	29	30	31	30	30	31	31	30		30	29	29	30
5 TOP	30	29	31	31	30	30	31	31	29	29	29	29	30	30
MID	30	29	31	31	31	30	31	31	29	29	29	29	29	30
BOT	30	29	31	31	31	31	31	31	31	30	30	31	30	30
6 TOP	31	31	31	30	31	31	31	32	31	29	30	30	31	30
MID	29	31	31	30	31	31	31	32	31	30	30	29	30	30
BOT	29	31	31	31	31	31	31	32	31	30	31	31	31	30
7 TOP	29	31	30	29	31	31	31	32	29	29	29	29	30	30
MID	29	31	30	29	30	31	31	32	29	29	29	29	30	30
BOT	29	31	30	30	31	31	31	32	31	30	29	31	31	30
8 TOP	29	31	30	29		30	31	31	29	29	30	30	30	29
MID	29	31	30	29		30	31	31	30	29	29	30	30	29
BOT	29	31	31	30		30	31	31	30	30	30	31	30	30
9 TOP	29	29	29	30			30				29	29	30	30
MID	28	29	29	30			29				29	29	30	30
BOT	28	30	29	30			31				30	29	30	31
10 TOP	29	29	29	30			31						30	
MID	29	29	29	30			31						30	
BOT	29	29	29	31			31						30	
11 TOP	29		29	31			31					29	30	
MID	29		29	31			31							
BOT	29		29	31			30					29	30	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

PH (FIRST RUN)
STANDARD UNITS

DATE ********* STATION		7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
1	TOP	7.6	7.6	7.6	7.5						8.0	7.5			
	MID	7.6	7.5	7.6	7.5						8.0	7.5			
	BOT	7.6	7.5	7.6	7.5						8.0	7.6			
	LAB	8.1	8.2	8.2	8.1	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.1	8.2
2	TOP	7.6	7.5	7.6							7.8	7.1			
	MID	7.6	7.5	7.6							7.8	7.1			
	BOT	7.6	7.5	7.6							7.8	7.1			
	LAB	8.1	8.2	8.1		8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.2
3	TOP														
	MID														
	BOT														
	LAB														
4	TOP	7.7	7.5	7.6	7.5						7.7	7.8			
	MID	7.7	7.5	7.6	7.5						7.7	7.8			
	BOT	7.7	7.5	7.6	7.6						7.7	7.9			
	LAB	8.1	8.2	8.1	8.1	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.1	8.1
5	TOP	7.6	7.4	7.6	7.6						7.7	6.6			
	MID	7.6	7.4	7.7	7.6						7.7	6.4			
	BOT	7.6	7.4	7.7	7.6						7.7	6.7			
	LAB	8.1	8.1	8.0	8.0	8.1	8.2	8.1	8.1	8.1	8.1	8.0	8.0	8.0	8.0
6	TOP	7.7	7.4	7.6	7.6						7.6	7.4			
	MID	7.7	7.4	7.6	7.6						7.6	7.4			
	BOT	7.7	7.4	7.6	7.6						7.6	7.5			
	LAB	8.0	8.0	8.0	7.9	8.0	8.0	8.0	8.0	7.9	8.0	8.0	8.0	7.9	8.0
7	TOP	7.8	7.5	7.5	7.7						8.3	7.4			
	MID	7.8	7.5	7.5	7.7						8.3	7.3			
	BOT	7.7	7.5	7.5	7.7						8.3	7.4			
	LAB	8.0	8.1	8.0	8.0	8.1	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
8	TOP	7.9	7.6	7.7	7.9						7.9	7.0			
	MID	7.9	7.6	7.7	7.9						7.9	6.7			
	BOT	7.9	7.6	7.7	7.9						7.8	7.3			
	LAB	8.1	8.2	8.0	8.1	8.2	8.2	8.1	8.0	8.0	8.1	8.0	8.0	8.0	8.1
9	TOP	7.6	7.5	7.5	7.4						8.0	7.3			
	MID	7.6	7.5	7.5	7.4						8.0	7.3			
	BOT	7.6	7.5	7.5	7.4						8.0	7.4			
	LAB	8.2	8.2	8.1	8.1	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
10	TOP	7.7	7.5	7.5	7.5						8.0	7.6			
	MID	7.7	7.5	7.5	7.5						7.9	7.6			
	BOT	7.7	7.5	7.5	7.5						7.9	7.6			
	LAB	8.2	8.2	8.1	8.1	8.2	8.2	8.3	8.3	8.3	8.4	8.3	8.2	8.2	8.2
11	TOP	7.4	7.3	7.7	7.0						7.8	6.9			
	MID	7.4	7.3	7.7	7.0						7.8	6.9			
	BOT	7.4	7.3	7.7	7.0						7.8	6.9			
	LAB	8.0	8.0	7.8	7.8	7.8	7.9	7.9	8.0	8.0	8.0	8.0	8.0	8.0	7.9

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

PH (SECOND RUN)
STANDARD UNITS

DATE ********* STATION		7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
1	TOP	8.3	5.9	6.5	8.1	8.2	8.0	7.0	7.3	8.1		8.1	8.2	8.2	
	MID	8.3	7.1	6.2	8.1	8.1	8.0	7.0	7.0	8.1		8.1	8.2	8.2	
	BOT	8.3	6.7	8.4	8.1	8.1	7.9	7.1	7.3	8.1		8.1	8.2	8.2	
2	TOP	8.3	6.2	6.7	8.0	8.2	7.9	7.0	7.2	8.1		8.0	8.1	8.1	
	MID	8.3	6.5	6.5	8.0	8.1	7.9	7.0	7.2	8.0		8.0	8.1	8.1	
	BOT	8.2	7.5	6.9	8.0	8.1	7.9	7.0	7.2	8.0		8.0	8.0	8.1	
3	TOP														
	MID														
	BOT														
4	TOP	8.3	7.4	8.2	8.0	8.1	7.9	7.1	7.2	8.1		8.2	8.2	8.1	
	MID	8.3	8.1	7.4	8.0	8.1	7.9	7.1	7.3	8.1		8.1	8.2	8.1	
	BOT	8.3	7.4	8.2	8.0	8.1	7.9	7.1	7.2	8.1		8.2	8.2	8.1	
5	TOP	8.2	8.1	8.1	7.8	8.0	7.8	7.1	7.2	8.0	8.1	8.1	8.1	8.0	
	MID	8.1	8.1	8.1	7.9	7.9	7.8	7.1	7.3	8.0	8.1	8.1	8.1	8.0	
	BOT	8.2	8.1	8.1	7.8	7.9	7.8	7.1	7.3	8.0	8.1	8.1	8.1	8.0	
6	TOP	8.1	8.1	6.9	7.6	7.9	7.7	7.1	7.3	7.9	8.0	7.9	7.9	7.9	
	MID	8.0	8.0	8.0	7.6	8.0	7.7	7.0	7.1	7.9	8.0	7.9	7.9	7.9	
	BOT	8.0	8.0	8.0	7.7	7.9	7.7	7.0	7.4	7.9	8.0	7.9	7.9	7.9	
7	TOP	8.1	8.0	9.2		7.9	7.8	7.0	7.3	8.0	8.0	8.0	8.0	7.9	
	MID	8.2	7.9	8.8		7.9	7.8	7.0	7.3	8.0	8.0	8.0	8.0	7.9	
	BOT	8.2	8.0	8.9		7.9	7.8	7.0	7.3	8.0	8.0	8.0	8.0	7.9	
8	TOP	8.2	8.1	7.8	7.9	8.0	7.9	7.0	7.2	8.1	8.1	8.1	8.1	7.9	
	MID	8.2	8.1	7.4	7.9	8.0	7.8	7.0	7.4	8.1	8.1	8.1	8.0	7.9	
	BOT	8.2	8.1	7.8	7.9	8.0	7.9	7.0	7.2	8.1	8.1	8.1	8.1	7.9	
9	TOP	8.0	5.8	6.5	8.0			7.0				8.1	8.2	8.2	
	MID	8.1	6.7	6.5	8.0			6.8				8.2	8.2	8.2	
	BOT	8.2	6.7	6.3	8.0			7.0				8.2	8.2	8.2	
10	TOP	8.4	7.0	6.5	8.1			7.0						8.3	
	MID	8.4	5.7	6.7	8.1			7.0						8.3	
	BOT	8.4	8.3	7.5	8.1			7.0						8.3	
11	TOP	7.8		6.5	7.6			7.0							
	MID	7.8		6.8	7.6			7.1					7.9	7.9	
	BOT	8.1		6.7	7.7			6.9					7.9	7.9	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL ALKALINITY
MG/L CALCIUM CARBONATE

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	107	106	107	108	108	110	110	117	125	113	112	112	112	111
2	106	105	105		104	106	108	109	110	111	110	110	110	111
3														
4	108	108	108	108	109	108	108	109	110	110	109	110	110	110
5	108	110	109	109	109	109	110	110	111	110	111	111	111	110
6	107	108	108	108	109	109	109	109	110	111	110	109	110	110
7	107	107	109	108	108	109	109	110	111	111	110	109	109	110
8	108	108	108	107	108	108	108	109	111	110	109	109	110	110
9	107	107	107	107	108	109	109	109	109	109	110	110	109	109
10	109	109	110	110	110	110	112	112	114	115	115	113	113	113
11	96	96	95	95	97	99	100	102	104	104	103	103	102	99

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TURBIDITY
JTU

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	5.8	5.7	8.8	20.0	14.0	35.0	41.0	120.0	240.0	85.0	37.0	32.0	41.0	27.0
2	14.0	12.0	9.0		23.0	20.0	32.0	19.0	22.0	40.0	32.0	24.0	30.0	27.0
3														
4	7.8	11.0	7.7	8.0	13.0	19.0	13.0	21.0	23.0	16.0	14.0	17.0	18.0	19.0
5	10.0	13.0	14.0	13.0	9.8	14.0	45.0	52.0	46.0	34.0	34.0	41.0	30.0	23.0
6	12.0	14.0	18.0	15.0	12.0	25.0	24.0	28.0	39.0	40.0	23.0	22.0	19.0	23.0
7	17.0	15.0	14.0	12.0	14.0	15.0	17.0	25.0	26.0	30.0	21.0	18.0	22.0	29.0
8	8.0	7.7	7.1	9.5	9.8	12.0	13.0	23.0	36.0	33.0	16.0	25.0	37.0	42.0
9	1.7	2.1	1.6	2.3	2.7	7.7	7.1	6.8	7.2	9.2	9.0	7.5	6.8	6.5
10	3.5	3.7	10.0	19.0	20.0	12.0	8.8	6.3	10.0	13.0	11.0	16.0	17.0	12.0
11	17.0	21.0	9.1	20.0	21.0	28.0	21.0	18.0	18.0	28.0	31.0	45.0	30.0	18.0

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SECCHI DISK
FIRST RUN - FEET

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1		6	5	2	2	2	2	1	1	1	1	2	4	4
2		3	3		2	2	1	2	2	1	2	3	3	2
3														
4		4	3	2	3	3	3	2	2	1	2	2	3	2
5		3	3	2		2	2	1	1	1	2	3	2	2
6		3	2	2	3	3	2	2	2	2	2	3	2	2
7		2	1	3	2	2	2	2	1	1	2	2	1	2
8		3	3	3	4	3	2	2	1	1	2	1	1	2
9		10	11	10	9	4	4	5	4	4	4	4	5	6
10		5	5	3	2	3	4	5	4	3	3	2	2	4
11		1	2	2	1	1	1	1	2	1	1	1	1	2

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SECCHI DISK
SECOND RUN- FEET

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	6	5	4	5	4	4	3	2	2		3	3	3	
2	4	4	5	4	2	4	4	4	2		2	3	4	
3														
4	8	6	5	4	3	3	2	3	3		5	5	4	5
5								2	4	4	3	3	3	3
6	4	5	6	4	3	2	2	2	3	3	4	4	3	3
7	4	4	4	4	3	2	3	2	4	3	3	3	3	3
8	5	5	5	3	3	3	3	2	3	3	4	4	3	3
9	12	9	9	11			7				7	8	7	7
10	6	4	5	3			3						7	
11	6		5	2			3					5	5	

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL SUSPENDED SOLIDS
MG/L

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	11		17		29			270		180		70		
2	26		16		58			38		83		51		
3														
4	10		17		28			46		46		42		
5	18		26		22			130		82		91		
6	18		33		23			56		92		44		
7	32		27		24			64		79		39		
8	11		12		20			59		93		51		
9	3		4		7			15		23		16		
10	5		21		55			20		24		32		
11	29		16		43			46		66		100		

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 STUDIES

BOD (FIRST RUN)
MG/L

DATE *********		7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION															
1	2 DAY	0.87	0.50	0.59	0.67	0.77	0.95	0.72	1.15	1.22	1.04	1.03	0.55	0.81	0.66
	5 DAY	1.49	1.12	1.11	1.37	1.11	1.58	1.43	1.95	2.30	1.77	1.93	1.10	1.12	1.26
	7 DAY		1.36		1.46		1.95								
	10 DAY		1.50		1.75		1.83								
2	2 DAY	1.60	0.82	0.62		0.91	0.70	0.75	0.72	0.59	0.93	1.00	1.13	0.77	0.75
	5 DAY	2.43	1.40	1.32		1.11	1.12	1.07	1.06	1.07	1.68	1.42	1.86	1.24	1.30
	7 DAY		1.72				1.32								
	10 DAY		1.83				1.71								
3	2 DAY														
	5 DAY														
	7 DAY														
	10 DAY														
4	2 DAY	0.09	0.68	0.69	1.35	0.66	0.84	0.42	0.67	0.76	1.13	0.77	0.84	0.72	0.50
	5 DAY	0.72	1.19	1.24	2.27	1.30	1.41	1.00	1.10	1.08	1.83	1.35	1.39	1.23	1.10
	7 DAY		1.45		2.43		1.45								
	10 DAY		1.57		2.68		1.62								
5	2 DAY	0.72	0.99	0.83	0.61	0.48	0.83	0.54	0.65	0.58	0.75	0.82	0.95	0.55	0.61
	5 DAY	1.37	1.68	1.57	1.22	0.97	1.18	1.09	1.27	1.06	1.41	1.50	1.56	1.18	1.36
	7 DAY		2.01		1.41		1.62								
	10 DAY		2.08		1.62		1.59								
6	2 DAY	0.70	1.19	0.93	0.92	0.63	0.77	0.52	0.53	0.76	0.94	0.68	0.73	0.98	0.81
	5 DAY	1.49	2.00	1.70	1.52	0.98	1.31	0.93	1.06	1.27	1.46	1.24	1.53	1.39	1.56
	7 DAY		2.29		1.93		1.34								
	10 DAY		2.50		1.98		1.61								
7	2 DAY	3.85	0.85	0.90	1.81	0.80	0.65	0.73	0.82	0.87	1.21	0.97	0.97	0.88	0.82
	5 DAY	5.51	1.61	1.55	2.65	1.32	1.17	1.23	1.35	1.65	2.04	1.65	1.71	1.60	1.57
	7 DAY									1.90		3.00		1.32	
	10 DAY		2.02		3.41		1.50								
8	2 DAY	0.90	0.62	0.92	0.76	0.75	0.59	0.57	0.57	0.94	0.93	0.84	1.06	0.87	0.91
	5 DAY	1.55	1.39	1.45	1.38	1.21	1.16	0.90	1.02	1.54	1.65	1.44	1.68	1.42	1.51
	7 DAY		1.41		1.58		1.36								
	10 DAY		1.65		1.79		1.44								
9	2 DAY	0.50	0.73	0.60	0.52	0.63	0.64	0.49	0.58	0.62	0.76	0.65	0.77	0.51	0.90
	5 DAY	1.18	1.32	1.19	1.08	1.12	1.07	0.78	0.94	0.89	1.36	1.15	1.32	0.91	1.30
	7 DAY		1.56		1.24		1.23								
	10 DAY		2.04		1.33		1.41								
10	2 DAY	0.54	0.65	0.76	0.73	0.63	0.70	0.53	0.76	0.79	0.80	1.00	0.60	0.66	0.77
	5 DAY	1.26	1.03	1.33	1.33	1.13	1.20	0.95	1.18	1.11	1.40	1.63	0.99	1.21	1.32
	7 DAY		1.65		1.57		1.34								
	10 DAY		1.69		1.66		1.70								
11	2 DAY	0.80	1.01	0.71	1.03	0.85	0.89	0.58	0.74	0.88	1.00	1.02	0.91	0.62	0.66
	5 DAY	1.51	1.71	1.59	1.86	1.69	1.65	1.37	0.95	1.12	1.81	1.64	1.61	1.32	1.21
	7 DAY		1.71		2.23		1.74								
	10 DAY		2.93		2.48		2.25								

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 STUDIES

BOD (LAB. DUPLICATE)
MG/L

DATE ********* STATION	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
1 2 DAY	0.83	0.60	0.52	0.69	0.63	0.81	0.58	0.92	1.25	0.99	1.00	0.41	0.52	0.81
5 DAY	1.49	1.12	0.91	1.22	1.13	1.58	1.28	2.03	2.45	1.67	1.73	1.10	1.12	1.26
7 DAY		1.40		1.60		1.78								
10 DAY		1.66		1.68		2.13								
2 2 DAY	1.58	0.98	0.71		0.71	0.65	0.75	0.85	0.52	1.04	1.15	1.08	0.84	0.70
5 DAY	2.43	1.47	1.42		1.31	1.10	1.15	1.14	1.02	1.73	1.47	1.96	1.24	1.20
7 DAY		1.67				1.38								
10 DAY		1.97				1.71								
3 2 DAY														
5 DAY														
7 DAY														
10 DAY														
4 2 DAY	0.08	0.71	0.67	1.40	0.76	0.77	0.53	0.69	0.76	1.12	0.82	0.84	0.68	0.60
5 DAY	0.85	1.19	1.30	2.17	1.20	1.33	0.83	1.13	1.25	1.83	1.35	1.49	1.13	1.10
7 DAY		1.44		2.47		1.40								
10 DAY		1.56		2.64		1.52								
5 2 DAY	0.74	0.98	0.86	0.59	0.58	0.83	0.77	0.77	0.63	0.76	0.77	0.88	0.68	0.71
5 DAY	1.54	1.73	1.49	1.20	1.00	1.30	1.09	1.27	1.16	1.36	1.45	1.66	1.28	1.16
7 DAY		2.05		1.60		1.50								
10 DAY		2.18		1.59		1.49								
6 2 DAY	0.88	1.23	1.03	0.87	0.56	0.70	0.63	0.55	0.73	0.96	0.74	0.93	0.94	0.91
5 DAY	1.24	1.99	1.73	1.60	1.14	1.35	0.95	1.03	1.26	1.61	1.29	1.48	1.49	1.46
7 DAY		2.33		1.83		1.38								
10 DAY		2.60		2.00		1.61								
7 2 DAY	3.86	0.83	0.92	1.85	0.80	0.52	0.85	0.71	0.78	1.19	0.92	0.83	0.80	0.92
5 DAY	5.30	1.51	1.56	2.68	1.19	1.19	1.35	1.30	1.68	1.84	1.70	1.61	1.60	1.62
7 DAY		1.90		3.01		1.28								
10 DAY		2.04		3.36		1.45								
8 2 DAY	1.02	0.59	0.87	0.81	0.68	0.75	0.54	0.64	1.03	0.92	0.84	1.10	0.82	0.86
5 DAY	1.37	1.30	1.55	1.41	1.18	1.11	0.96	1.11	1.45	1.65	1.24	1.78	1.52	1.51
7 DAY		1.55		1.43		1.22								
10 DAY		1.59		1.81		1.59								
9 2 DAY	0.50	0.72	0.53	0.55	0.57	0.68	0.40	0.50	0.59	0.86	0.73	0.81	0.56	0.85
5 DAY	1.29	1.37	1.07	1.13	1.06	1.11	0.80	0.84	0.93	1.46	1.25	1.42	0.91	1.30
7 DAY		1.62		1.08		1.20								
10 DAY		1.85		1.22		1.51								
10 2 DAY	0.46	0.54	0.68	0.71	0.49	0.69	0.50	0.78	0.72	0.80	0.98	0.44	0.71	0.87
5 DAY	1.14	1.06	1.22	1.35	1.10	1.36	0.97	1.25	0.96	1.40	1.63	0.99	1.31	1.27
7 DAY		1.39		1.60		1.38								
10 DAY		1.73		1.74		1.50								
11 2 DAY	0.80	1.06	0.85	1.09	0.93	0.94	0.73	0.57		0.92	0.89	1.01	0.62	0.66
5 DAY	1.77	1.65	1.39	1.83	1.63	1.79	1.37	1.08	1.09	1.51	1.74	1.81	1.42	1.31
7 DAY		2.02		2.28		1.67								
10 DAY		2.93		2.52		2.30								

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

DISSOLVED OXYGEN
MG/L (FIRST RUN)

DATE **********		7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION															
1	TOP	6.46	6.57	6.60	6.08	5.85	5.68	5.15	5.21	5.60	5.93	5.69	5.80	5.65	6.05
	MID	6.14	6.45	6.52	5.92	5.75	5.52	5.25	5.19	5.61	5.77	5.55	5.71	5.55	5.67
	BOT	6.05	6.39	6.34	6.20	5.72	5.70	5.40	5.20	5.74	5.30	5.65	5.69	5.40	5.88
2	TOP	6.33	6.89	5.79		5.57	5.09	4.91	5.00	5.20	5.21	5.21	5.35	5.40	6.08
	MID	6.00	6.55	5.30		5.31	4.83	4.88	5.00	5.00	5.16	5.16	5.05	5.35	5.35
	BOT	5.62	5.60	5.68		5.40	5.00	5.01	4.79	4.99	5.08	5.03	5.26	5.30	5.20
3	TOP														
	MID														
	BOT														
4	TOP	6.30	6.63	6.21	6.12	6.30	5.68	5.78	5.48	6.12	6.09	5.70	5.79	5.65	5.37
	MID	6.03	6.27	6.15	6.17	6.30	6.00	5.56	5.64	5.99	5.71	5.91	5.61	5.55	5.67
	BOT	6.15	6.46	6.19	6.41	6.01	6.02	5.53	5.69	5.97	5.90	6.10	5.85	5.50	5.59
5	TOP	5.31	6.40	5.95	5.49	5.71	5.98	5.29	4.86	4.91	4.94	5.24	5.04	5.30	5.12
	MID	5.70	5.99	5.91	5.80	5.88	5.89	5.21	4.94	4.81	4.86	4.91	5.08	5.10	5.04
	BOT	5.61	6.21	5.87	5.47	5.92	5.85	5.31	5.10	5.02	4.89	5.02	4.98	4.80	4.86
6	TOP	6.09	6.17	5.93	5.55	5.46	5.03	4.79	4.41	4.83	4.61	4.82	5.95	5.10	5.72
	MID	5.63	6.10	5.81	5.30	5.42	5.27	4.78	4.57	4.57	4.59	4.71	5.41	5.30	5.39
	BOT	5.70	6.10	5.99	5.57	5.51	5.55	4.87	4.62	4.59	5.00	4.61	5.27	4.95	5.24
7	TOP	6.19	6.14	6.11	5.57	5.90	5.22	4.80							
	MID	6.39	6.21	6.07	5.92	5.89	5.30	4.96	5.01	5.31	5.31	5.50	5.20	5.30	5.65
	BOT	6.02	6.16	6.42	5.82	5.63	5.30	4.94	4.59	4.99	5.01	5.39	5.32	5.35	5.29
8	TOP	6.05	6.16	6.10	6.00	6.18	5.83	5.49	4.93	4.75	5.19	5.51	5.23	5.45	5.20
	MID	6.05	6.30	6.21	6.00	6.20	5.99	5.38	4.87	5.10	5.15	5.41	5.28	5.35	5.18
	BOT	6.26	6.06	5.99	6.01	6.29	5.67	5.42	4.50	5.30	4.87	5.48	5.20	4.90	5.40
9	TOP	6.80	6.80	6.49	6.69	6.36	6.41	6.07	6.21	6.57	6.52	6.14	6.40	6.10	6.17
	MID	6.67	6.63	6.50	6.79	6.30	6.39	6.03	6.10	6.08	6.46	5.94	6.15	6.25	6.34
	BOT	6.43		6.21	6.62	6.33	6.24	6.09	6.05	6.20	6.50	6.00	6.19	6.20	6.25
10	TOP	6.51	6.55	6.04	5.75	5.47	5.55	5.86	6.14	6.12	6.20	6.02	5.66	5.65	6.19
	MID	6.50	6.33	5.77	5.25	5.40	5.61	5.49	5.92	6.12	6.04	5.85	5.80	5.60	5.80
	BOT	6.34	6.12	6.14	5.50	5.50	5.60	5.54	5.79	6.03	6.05	5.81	5.70	5.50	5.50
11	TOP	6.20	5.66	5.09	4.82	4.79	4.89	4.61	4.79	5.30	5.46	5.33	5.20	4.90	5.05
	MID	6.00	5.78	5.20	4.94	4.71	4.70	4.70	4.95	5.36	9.70	5.24	5.10	4.85	4.84
	BOT	6.11	5.70	5.08	4.78	4.70	4.70	4.81	5.00	5.31	5.41	5.17	4.70	4.90	4.86

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

DISSOLVED OXYGEN
MG/L (SECOND RUN)

DATE *********		7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION															
1	TOP	9.80	6.60	6.45	6.06	6.03	6.00	5.58	5.50	5.59		5.58	5.80	5.85	
	MID	6.61	6.40	6.16	6.03	5.77	5.80	9.92	5.30	5.42		5.42	5.40	5.80	
	BOT	6.67	6.50	6.09	5.91	5.80	5.81	5.79	5.28	5.38		5.32	6.18	5.60	
2	TOP	6.80	6.74	6.61	6.39	6.30	5.49	5.22	5.67	6.00		5.68	5.87	5.60	
	MID	6.02	6.30	6.18	6.41	5.67	5.39	4.59	5.17	5.60		5.60	5.81	5.45	
	BOT	6.18	6.30	5.92	6.06	5.53	5.10	4.81	4.93	5.30		5.55	5.49	5.45	
3	TOP														
	MID														
	BOT														
4	TOP	7.57	6.71	6.45	6.15	5.51	5.42	5.22	5.48	5.61		6.28	6.11	5.85	6.40
	MID	7.21	6.74	6.74	6.03	5.54	5.59	5.34	5.45	5.70		5.77	5.98	5.90	6.45
	BOT	7.65	6.46	6.52	5.76	5.70	5.31	9.10	5.59	5.52		5.82	5.80	6.00	6.15
5	TOP	13.03	6.73	6.54	5.63	5.30	5.09	4.90	4.69	5.58	5.59	5.68	5.78	5.60	5.51
	MID	6.17	6.42	6.20	5.68	5.30	4.71	4.60	4.93	5.60	5.35	5.40	5.52	5.45	5.49
	BOT	6.72	6.15	6.21	5.20	4.99	4.89	4.75	5.00	5.40	5.23	5.34	5.42	5.65	5.41
6	TOP	7.42	7.11	5.88	5.70	4.82	4.41	4.56	4.49	4.99	5.16	5.46	5.67	5.30	4.93
	MID	6.41	5.78	5.28	5.21	4.80	4.33	4.69	4.80	5.01	5.00	5.00	5.10	5.30	5.16
	BOT	6.00	5.39	5.20	4.94	4.69	4.50	4.77	4.41	4.80	5.07	5.00	5.20	5.10	4.98
7	TOP	0.00	5.84	5.82	5.10	5.07	4.79	5.33	5.10	5.30	5.50	5.45	5.41	5.65	5.69
	MID	6.40	6.67	5.64	5.09	4.85	5.04	5.20	4.90	5.28	5.51	5.43	5.22	5.60	5.35
	BOT	6.60	6.04	5.54	4.98	5.05	5.05	5.30	4.80	5.37	5.47	5.46	5.28	5.35	5.46
8	TOP	6.90	6.65	6.10	6.15	6.18	5.03	5.80	5.71	5.81	5.81	5.91	6.09	5.80	5.90
	MID	6.57	6.61	6.10	5.98	5.93	5.42	5.60	5.89	5.89	5.89	5.87	5.82	5.55	5.61
	BOT	6.73	6.55	5.90	5.87	5.63	5.30	5.46	5.59	5.75	5.81	5.82	5.89	5.10	5.48
9	TOP	6.71	6.80	6.57	6.47			6.34				6.22	6.35	6.40	6.35
	MID	6.73	6.71	6.50	6.71			10.10				6.26	6.28	6.20	6.27
	BOT	6.76	6.78	6.65	6.52			6.54					6.19	6.20	6.33
10	TOP	6.85	6.63	6.16	5.79			5.19						6.60	
	MID	6.80	6.96	5.98	6.08			5.31						6.65	
	BOT	9.03	6.71	6.11	5.92			6.41						6.45	
11	TOP	6.74		6.00	5.46			4.77					5.63	5.65	
	MID	6.90		6.40	5.40			4.77					5.86	5.30	
	BOT	6.90		6.20	5.33			4.46					5.49	5.35	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CONDUCTIVITY (FIRST RUN)
UMHOS/CM

DATE *********		7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION															
1	TOP	18,000	24,300	25,800	24,700	28,000	28,600	29,500	31,200	29,800	31,800	30,400	34,500	35,200	
	MID	18,500	25,100	26,700	24,500	28,100	28,800	30,100	30,700	30,400	31,200	31,400	34,200	34,500	
	BOT	18,500	26,000	27,100	24,800	28,600	30,200	30,500	30,200	30,500	31,400	31,300	34,100	34,600	
2	TOP	20,600	25,100	26,400		31,100	30,600	28,200	29,400	30,000	29,800	31,100	31,300	34,700	
	MID	18,000	24,300	26,500		31,300	30,800	28,200	31,000	31,000	30,600	31,600	33,700	34,500	
	BOT	18,000	25,100	27,300		31,300	30,800	28,800	30,200	31,400	30,500	32,100	34,200	35,100	
3	TOP														
	MID														
	BOT														
4	TOP	23,800	23,500	27,500	25,100	28,900	29,600	28,200	27,900	29,300	28,700	30,800	31,300	32,200	
	MID	23,800	23,500	27,500	25,100	28,800	29,600	28,200	28,300	31,000	29,600	31,000	32,300	32,700	
	BOT	24,000	23,500	27,200	26,400	30,400	31,300	29,500	29,700	31,300	31,200	31,800	33,900	34,160	
5	TOP	24,700	24,300	26,800	25,100	30,300	28,500	28,900	27,700	29,700	29,300	30,400	32,200	32,100	
	MID	24,900	24,300	26,600	25,300	29,700	30,000	29,700	27,100	30,700	29,800	31,300	31,800	33,200	
	BOT	24,000	24,300	27,100	25,700	30,700	31,500	29,600	27,800	31,500	30,400	31,800	32,600	33,400	
6	TOP	23,200	24,700	26,400	25,300	29,900	28,700	28,100	27,900	31,400	30,700	31,800	31,800	34,600	
	MID	22,000	24,300	27,200	25,200	29,900	28,900	28,400	29,100	31,000	30,400	30,800	31,400	33,300	
	BOT	23,800	24,300	27,400	25,600	30,200	29,100	29,900	27,900	31,400	30,700	31,800	31,800	34,600	
7	TOP	22,500	25,500	27,100	24,900	28,900	31,400	29,500	27,300	30,800	31,000	30,600	31,800	32,500	
	MID	22,500	25,500	27,200	25,100	29,200	31,100	30,100	28,300	31,000	31,800	30,900	32,300	33,900	
	BOT	22,500	25,900	27,400	25,500	28,500	31,800	30,500	29,700	32,100	31,800	31,600	32,900	34,400	
8	TOP	26,600	25,900	26,400	25,800	28,400	28,900	29,600	27,900	31,700	29,800	31,100	32,400	33,600	
	MID	23,800	25,800	27,500	26,400	28,100	31,800	30,300	27,900	31,700	29,800	31,100	32,400	33,600	
	BOT	27,400	25,400	27,300	26,100	29,600	31,300	30,400	29,900	32,300	31,600	30,600	33,700	34,500	
9	TOP	23,500	21,500	25,200	25,300	28,200	28,900	26,900	25,100	27,900	29,700	29,700	31,500	34,100	
	MID	22,800	22,200	26,800	25,700	28,600	29,200	27,800	26,700	29,300	31,000	30,800	32,500	34,500	
	BOT	22,100	22,600	26,400	25,800	29,600	29,700	28,900	27,300	28,600	31,400	31,000	33,900	34,700	
10	TOP	25,800	24,300	28,300	25,900	29,400	29,400	27,300	30,700	30,800	31,000	31,800	34,200	34,400	
	MID	24,300	23,900	27,500	25,800	29,900	30,400	28,600	31,600	30,800	31,200	32,100	34,200	35,300	
	BOT	24,900	24,300	27,700	25,800	29,600	30,800	28,700	32,800	30,800	31,800	33,300	34,400	35,500	
11	TOP	18,500	21,900	25,800	23,900	28,400	28,400	26,000	26,100	26,700	29,600	30,800	31,100	31,200	
	MID	22,100	21,100	23,300	23,400	28,600	28,700	25,000	27,200	27,000	29,800	29,800	31,200	31,300	
	BOT	22,000	22,300	24,200	23,800	28,900	29,400	27,300	27,500	26,900	29,800	30,400	31,300	32,000	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CONDUCTIVITY (SECOND RUN)
UMHOS/CM

DATE ********* STATION		7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
1	TOP	23,300	27,900	30,200	25,400	28,700	31,900	26,900	26,500	30,700		31,100	30,600	33,900	
	MID	23,500	26,500	30,500	25,700	29,200	32,600	29,800	27,000	31,300		31,000	30,500	32,900	
	BOT	25,000	26,500	34,000	25,700	31,300	33,400	30,000	27,500	31,500		32,100	31,500	35,300	
2	TOP	23,300	26,500	33,000	24,700	28,800	31,900	26,400	27,600	29,900		29,800	27,600	32,200	
	MID	26,500	26,500	36,400	25,600	30,500	31,900	27,000	28,000	29,600		30,400	29,300	33,400	
	BOT	24,700	27,900	34,100	25,800	30,200	31,900	27,500	28,000	29,900		30,900	30,200	33,400	
3	TOP														
	MID														
	BOT														
4	TOP	25,000	26,500	33,700	24,700	31,900	32,300	26,700	27,600	28,400		30,000	28,400	31,900	
	MID	25,600	26,500	31,000	25,900	30,800	32,700	27,100	27,900	29,100		31,300	30,400	31,800	
	BOT	25,000	26,500	31,800	27,100	31,300	33,900	27,800	28,000	29,900		31,400	31,400	32,600	
5	TOP	25,800	25,600	34,400	24,900	33,400	31,100	26,500	28,100	29,200	27,900	29,900	30,800	33,100	
	MID	25,600	26,500	33,100	24,700	31,600	31,400	26,400	28,000	28,200	27,700	29,600	30,200	32,900	
	BOT	25,000	25,000	33,600	25,100	32,100	31,600	26,200	28,100	29,200	27,900	29,900	30,800	33,100	
6	TOP	24,700	26,500	33,100	25,200	30,500	32,200	26,700	26,600	28,800	26,700	27,800	28,200	31,600	
	MID	24,700	27,900	31,600	25,100	31,600	32,400	27,000	27,800	30,400	27,700	30,500	29,900	31,300	
	BOT	25,600	25,800	33,500	25,700	34,600	33,450	27,800	27,900	30,100	27,800	30,700	30,100	34,100	
7	TOP	23,500	26,500	27,900	24,500	30,700	29,700	25,900	29,000	28,200	27,900	28,500	29,500	30,600	
	MID	24,200	27,900	35,000	24,400	30,800	31,800	26,400	28,700	30,000	27,500	29,300	29,600	32,500	
	BOT	24,700	26,500	29,100	24,700	31,900	30,600	27,200	30,300	29,700	29,000	30,000	31,000	33,200	
8	TOP	26,500	26,500	31,300	24,300	31,000	30,700	27,600	27,900	28,900	27,700	28,100	28,700	30,400	
	MID	26,100	26,500	32,500	24,700	31,400	32,100	27,800	30,000	28,700	27,900	29,300	29,600	30,600	
	BOT	24,700	25,800	33,500	24,500	31,900	34,000	27,800	30,700	28,800	29,100	30,700	30,700	33,200	
9	TOP	23,300	26,500	30,600	24,400			26,900				31,600	29,300	33,400	
	MID	25,800	26,500	35,700	25,700			28,500				31,600	30,400	33,900	
	BOT	25,000	26,500	33,100	25,900			28,900				33,300	30,800	34,700	
10	TOP	25,000	26,500	25,100	25,700			28,700						34,800	
	MID	26,100	27,300	26,400	25,700			28,800						34,600	
	BOT	27,400	27,300	26,500	26,700			29,100						34,400	
11	TOP	24,700		29,200	22,900			25,200					28,200	32,900	
	MID	24,700		29,600	23,100								28,200	32,800	
	BOT	24,700		30,000	24,200			26,500					28,800	34,600	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SALINITY (FIRST RUN)
PARTS PER THOUSAND

DATE *********		7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION															
1	TOP	20.01	27.03	28.70	27.47	31.15	31.82	32.82	34.71	33.15	35.38	34.60	38.39	39.17	
	MID	20.57	27.92	29.70	27.25	31.26	32.04	33.49	34.16	33.82	34.71	34.94	38.06	38.39	
	BOT	20.57	28.92	30.15	27.58	31.82	33.60	33.93	33.60	33.93	34.94	34.82	37.94	38.50	
2	TOP	22.90	27.92	29.37		34.60	34.04	31.37	32.71	33.38	33.15	34.60	34.82	38.61	
	MID	20.01	27.03	29.48		34.82	34.27	31.37	34.49	34.49	34.04	35.16	37.49	38.39	
	BOT	20.01	27.92	30.37	28.70	34.82	34.27	32.04	33.60	34.94	33.93	35.72	38.06	39.06	
3	TOP														
	MID														
	BOT														
4	TOP	26.47	26.14	30.59	27.92	32.04	32.93	31.37	31.04	32.60	31.93	34.27	34.82	35.83	
	MID	25.80	25.24	29.70	28.03	32.93	33.38	31.04	31.48	34.49	32.93	34.49	35.94	36.38	
	BOT	26.69	26.14	30.26	29.37	33.82	34.82	32.82	33.04	34.82	34.71	35.38	37.72	37.94	
5	TOP	27.47	27.03	29.81	27.92	33.71	31.71	32.15	30.81	33.04	32.60	33.82	35.83	35.72	
	MID	27.70	27.03	29.59	28.14	33.04	33.38	33.04	30.15	34.16	33.15	34.82	35.38	36.94	
	BOT	26.69	27.03	30.15	28.59	34.16	35.05	32.93	30.93	35.05	33.82	35.38	36.27	37.16	
6	TOP	25.80	27.47	29.37	28.14	33.26	31.93	31.26	31.59	33.93	32.60	33.26	33.71	37.16	
	MID	24.46	27.03	30.26	28.03	33.26	32.15	31.59	32.37	34.49	33.82	34.27	34.94	37.05	
	BOT	26.47	27.03	30.48	28.48	33.60	32.37	33.26	31.04	34.94	34.16	35.38	35.38	38.50	
7	TOP	25.02	28.36	30.15	27.70	32.15	34.94	32.82	30.37	34.27	34.49	34.04	35.38	36.16	
	MID	25.02	28.36	30.15	27.70	32.15	34.94	32.82	31.48	34.49	35.38	34.38	35.94	37.72	
	BOT	25.02	28.81	30.48	28.36	31.71	35.38	33.93	33.04	35.72	35.38	35.16	36.61	38.28	
8	TOP	29.59	28.81	29.37	28.70	31.59	32.15	32.93	29.14	33.82	32.60	33.15	35.16	36.38	
	MID	26.47	28.70	30.59	29.37	31.26	35.38	33.71	31.04	35.27	33.15	34.60	36.05	37.39	
	BOT	30.48	28.25	30.37	29.03	32.93	34.82	33.82	33.26	35.94	35.16	34.04	37.50	38.39	
9	TOP	26.14	23.91	28.03	28.14	31.37	32.15	29.92	27.92	31.04	33.04	33.04	35.05	37.94	
	MID	25.36	24.69	29.81	28.59	31.82	32.48	30.93	29.70	32.60	34.49	34.27	36.16	38.39	
	BOT	24.58	25.13	29.37	28.70	32.93	33.04	32.15	30.37	31.82	34.94	34.49	37.72	38.61	
10	TOP	28.70	27.03	31.48	28.81	32.71	32.71	30.37	34.16	34.27	34.49	35.38	38.06	38.28	
	MID	27.03	26.58	30.59	28.70	33.26	33.82	31.82	35.16	34.27	34.71	35.72	38.06	39.28	
	BOT	27.70	27.03	30.81	28.70	32.93	34.27	31.93	36.50	34.27	35.38	37.05	38.28	39.50	
11	TOP	20.57	24.35	29.70	26.58	31.59	31.59	28.92	29.03	29.70	32.93	34.27	34.60	34.71	
	MID	24.58	23.46	25.91	26.02	31.82	31.93	27.81	30.26	30.04	33.15	33.15	34.71	34.82	
	BOT	24.46	24.80	26.92	26.47	32.15	32.71	30.37	30.59	29.92	33.15	33.82	34.82	35.60	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SALINITY (SECOND RUN)
PARTS PER THOUSAND

DATE *********		7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION															
1	TOP	25.91	31.04	33.60	28.25	31.93	35.49	29.92	29.48	34.16		34.60	34.04	37.72	
	MID	26.14	29.48	33.93	28.59	32.48	36.27	33.15	30.04	34.82		34.49	33.93	36.61	
	BOT	27.81	29.48	37.83	28.59	34.82	37.16	33.38	30.59	35.05		35.72	35.05	39.28	
2	TOP	25.91	29.48	36.72	27.47	32.04	35.49	29.37	30.70	33.26		33.15	31.04	35.83	
	MID	29.48	29.48	40.51	28.48	33.93	35.49	30.04	31.15	32.93		33.82	32.60	37.16	
	BOT	27.47	31.04	37.94	28.70	34.71	35.49	30.59	31.15	33.26		34.38	33.60	37.16	
3	TOP														
	MID														
	BOT														
4	TOP	27.81	29.48	37.50	27.47	35.49	35.94	29.70	30.70	31.59		33.38	31.59	35.49	
	MID	28.48	29.48	34.49	28.81	34.27	36.38	30.15	31.04	32.37		34.82	33.82	35.38	
	BOT	27.81	29.48	35.38	30.15	34.82	37.72	30.93	31.15	33.26		34.94	34.94	36.27	
5	TOP	28.70	28.48	38.28	27.70	37.16	34.60	29.47	30.59	30.93	30.15	32.60	33.15	34.82	
	MID	28.48	29.48	36.83	27.47	35.16	34.94	29.37	31.15	31.37	30.81	32.93	33.60	36.61	
	BOT	27.81	27.81	37.39	27.92	35.72	35.16	29.14	31.26	32.48	31.04	33.26	34.27	36.83	
6	TOP	27.47	29.48	36.83	28.03	33.94	35.83	29.70	29.59	32.04	29.70	30.93	31.37	35.16	
	MID	27.47	31.04	35.16	27.92	35.16	36.05	30.03	30.93	33.82	30.81	33.93	33.26	34.82	
	BOT	28.48	28.70	37.28	28.59	38.50	37.22	30.93	31.04	33.49	30.93	34.16	33.49	37.94	
7	TOP	26.14	29.48	31.04	27.25	34.16	33.04	28.81	32.26	31.37	31.04	31.70	32.82	34.04	
	MID	26.92	31.04	38.95	27.14	34.27	35.38	29.37	31.93	33.38	30.59	32.60	32.93	36.16	
	BOT	27.47	29.48	32.37	27.47	35.49	34.04	30.26	33.71	33.04	32.26	33.38	34.49	36.94	
8	TOP	29.48	29.48	34.82	27.03	34.49	34.16	30.70	31.04	32.15	30.81	31.26	31.93	33.82	
	MID	29.03	29.48	36.16	27.47	34.94	35.72	30.93	33.38	31.93	31.04	32.60	32.93	34.04	
	BOT	27.47	28.70	37.28	27.25	35.49	37.83	30.93	34.16	32.04	32.37	34.16	34.16	36.94	
9	TOP	25.91	29.48	34.04	27.14			29.92				35.16	32.60	37.16	
	MID	28.70	29.48	39.73	28.59			31.71				35.16	33.82	37.72	
	BOT	27.81	29.48	36.83	28.81			32.15				37.05	34.27	38.61	
10	TOP	27.81	29.48	27.92	28.59			31.93						38.72	
	MID	29.03	30.37	29.37	28.59			32.04						38.50	
	BOT	30.48	30.37	29.48	29.70			32.37						38.28	
11	TOP	27.47		32.48	25.47			28.03					31.37	36.61	
	MID	27.47		32.93	25.69								31.37	36.49	
	BOT	27.47		33.38	26.92			29.48					32.04	38.50	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CHLORIDES
MG/L

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	16943		17393		17863			17184		18680		19099		
2	16830		17297		17248			17731		17329		17651	19533	17265
3														
4	17860		16235		17989			18584		17908		17844	18713	16557
5	17852		17409		17200			16331		18150		17554	16669	19437
6	17876		16637		16653			17963		18085		17474	20837	15897
7	17876		18310		17377			16862		16637		16743	17055	16106
8	17120		18520		16251			16718		23041		16251	16750	20338
9	17635		17248		16959			16798		18278		18327	17731	16154
10	19987		18568		17651			19260		19984		19437	18064	19292
11	15205		13081		14803			17361		15591		16042	16122	16991

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL DISSOLVED SOLIDS
MG/L

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	31,690		31,920		31,960			32,970		32,890		32,790		
2	31,210		30,880		31,050			32,250		32,700		32,180		
3														
4	31,330		31,480		32,140			32,440		31,630		32,190		
5	31,530		31,340		31,640			32,200		31,980		31,710		
6	30,140		30,610		31,500			31,270		31,490		31,100		
7	30,370		31,340		31,940			31,870		31,340		30,980		
8	30,830		31,380		32,070			31,640		31,550		31,210		
9	30,820		30,840		31,540			31,890		32,480		31,840		
10	32,170		32,720		32,740			35,410		35,520		33,820		
11	27,970		26,330		27,450			29,510		29,750		28,830		

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SULFATES
MG/L

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	2250		2200		2330			2530		2370		2330		
2	2200		2200		2330			2330		2370		2330		
3														
4	2330		2290		2330			2330		2450		2250		
5	2250		2040		2370			2250		2330		2160		
6	2080		2160		2200			2410		2450		2250		
7	2120		2290		2330			2200		2200		2250		
8	2080		2290		2250			2410		2290		2200		
9	2080		2330		2250			2200		2370		2330		
10	2160		2200		2410			2410		2450		2330		
11	1930		1960		1960			2200		2000		2040		

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

ORGANIC NITROGEN
MG/L N

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	0.6	0.4	0.2	0.0	0.5	0.0	0.6	0.2	0.1	0.2	0.2	0.5	0.2	0.5
2	0.6	0.2	0.3		0.6	0.0	0.6	0.0	0.1	0.3	0.5	0.1	0.2	0.4
3														
4	0.1	0.2	0.8	0.0	0.6	0.0	0.1	0.1	0.0	0.6	0.2	0.0	0.4	0.4
5	0.7	0.2	0.2	0.0	0.6	0.0	0.4	0.2	0.2	0.0	0.4	0.3	0.1	0.5
6	0.6	0.9	0.2	0.0	0.0	0.9	0.3	0.4	0.1	0.2	0.2	0.6	0.1	0.5
7	0.2	0.3	0.5	0.0	0.4	0.1	0.0	0.1	0.2	0.0	0.3	0.2	0.7	0.4
8	0.1	0.0	0.2	0.0	0.4	0.0	0.0	0.3	0.0	0.0	0.2	0.3	0.1	0.1
9	0.4	0.1	0.3	0.0	0.6	0.0	0.9	0.0	0.2	0.0	0.0	0.0	0.4	0.0
10	0.0	0.0	0.5	0.1	0.5	0.1	0.2	0.4	0.0	0.0	0.2	0.1	1.7	0.2
11	0.0	0.2	0.6	0.0	0.4	0.4		0.2	0.0	0.0	0.2	1.2	0.4	0.4

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

AMMONIA
MG/L N

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.0	0.0
2		0.0	0.0		0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0
3														
4		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0
5		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.2	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2	0.2	0.1	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.1	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.2		0.0	0.0	0.0	0.2	0.0	0.0	0.0

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

NITRATE + NITRITE
MG/L N

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3														
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL PHOSPHORUS
MG/L

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	0.08	0.05	0.07	0.08	0.07	0.10	0.10	0.40	0.65	0.32	0.21	0.15	0.15	0.15
2	0.09	0.07	0.06		0.09	0.08	0.15	0.14	0.14	0.23	0.25	0.15	0.15	0.15
3														
4	0.08	0.07	0.07	0.10	0.07	0.07	0.10	0.14	0.15	0.15	0.12	0.15	0.15	0.15
5	0.07	0.08	0.08	0.08	0.07	0.07	0.22	0.30	0.24	0.15	0.25	0.24	0.15	0.15
6	0.09	0.06	0.09	0.08	0.07	0.08	0.15	0.20	0.22	0.22	0.23	0.15	0.15	0.15
7	0.08	0.09	0.08	0.08	0.07	0.07	0.15	0.15	0.15	0.25	0.15	0.15	0.15	0.21
8	0.07	0.07	0.07	0.07	0.07	0.06	0.13	0.21	0.22	0.25	0.15	0.15	0.15	0.21
9	0.05	0.05	0.06	0.08	0.06	0.06	0.10	0.09	0.11	0.14	0.10	0.10	0.10	0.13
10	0.05	0.06	0.07	0.06	0.06	0.06	0.10	0.08	0.09	0.12	0.10	0.11	0.13	0.12
11	0.09	0.11	0.09	0.10	0.10	0.11		0.15	0.23	0.15	0.21	0.25	0.21	0.15

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE PHOSPHORUS
MG/L

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	0.04	0.04	0.05	0.04	0.05	0.04	0.04	0.12	0.06	0.08	0.07	0.07	0.05	0.05
2	0.05	0.04	0.05		0.05	0.01	0.07	0.08	0.06	0.09	0.11	0.08	0.10	0.08
3														
4	0.05	0.05	0.06	0.05	0.05	0.04	0.07	0.11	0.06	0.09	0.08	0.08	0.08	0.08
5	0.05	0.04	0.05	0.06	0.05	0.06	0.08	0.08	0.10	0.06	0.12	0.08	0.10	0.10
6	0.05	0.04	0.07	0.06	0.06	0.05	0.10	0.06	0.10	0.20	0.11	0.10	0.10	0.10
7	0.06	0.05	0.06	0.05	0.05	0.04	0.10	0.10	0.08	0.13	0.12	0.05	0.08	0.11
8	0.05	0.05	0.05	0.05	0.05	0.04	0.08	0.11	0.08	0.11	0.13	0.05	0.08	0.08
9	0.06	0.08	0.05	0.05	0.06	0.04	0.08	0.06	0.08	0.08	0.11	0.05	0.05	0.10
10	0.06	0.04	0.06	0.05	0.05	0.03	0.06	0.05	0.05	0.06	0.05	0.05	0.05	0.09
11	0.04	0.07	0.06	0.06	0.06	0.06		0.13	0.11	0.13	0.07	0.10	0.11	0.09

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CHLOROPHYLL A
UG/L

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	4.3	5.0	5.6	8.6	6.5	11.7	12.8	29.5		3.9	12.7	8.5	9.6	6.4
2		9.5	6.4		7.8	4.5	6.6	6.6	9.7	12.0	8.0	8.3	9.9	7.0
3														
4	4.0	6.7	5.6	4.6	4.7	6.5	3.4	5.1	10.1	7.4	8.0	8.5	7.3	7.4
5	5.9	9.2	7.0	5.3	5.3	6.6	7.6	9.5	9.8	6.3	9.5	12.0	10.2	9.9
6	6.7	9.8	7.6	6.4	2.2	5.3	4.5	6.9	7.3	8.1	8.1	9.2	10.0	12.4
7	7.7	9.8	5.9	5.6	1.6	6.1	4.2	7.1	8.3	7.4	10.1	8.6	10.6	10.8
8	3.8	5.7	5.8	4.5	2.0	5.0	3.9	6.6	6.7	9.9	7.3	6.2	13.6	13.7
9	2.0	4.1	3.0	3.8	2.3	5.0	3.8	5.4	6.3	6.0	6.3	3.5	6.2	6.3
10	1.9	3.0	4.2	6.0	3.1	5.4	4.4	5.4	4.4	5.1	6.2	7.0	9.1	8.5
11	7.5	9.8	5.6	9.0	7.2	10.5	7.6	6.7	5.3	8.8	11.5	11.1	10.4	9.4

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CHLOROPHYLL C
UG/L

DATE *********	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26
STATION														
1	1.6	1.4	0.0	0.0	0.0	1.6	0.4	1.8	0.0	0.0	0.0	0.0	0.0	1.0
2		3.1	1.8		0.7	0.0	0.0	0.0		2.4	0.0	0.0	2.0	2.4
3														
4	0.0	0.0	4.0	0.0	1.6	0.0	0.0	0.0	2.0	1.1	1.1	1.7	0.3	0.0
5	0.0	4.3	1.1	0.0	1.0	0.1	0.0	0.0	4.0	0.0	0.0	1.6	1.9	0.0
6	1.4	3.8	0.0	1.2	0.9	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.2	1.7
7	4.3	3.8	0.0	1.6	0.8	2.3	0.0	0.1	0.9	0.0	1.8	0.7	1.9	2.3
8	0.0	1.6	0.0	0.0	1.3	0.0	0.0	0.1	0.0	0.0	0.0	1.8	0.0	2.4
9	0.4	1.2	1.1	1.0	0.0	0.4	0.3	0.0	0.8	2.0	0.0	0.0	0.2	0.5
10	1.2	0.0	0.0	0.9	2.0	0.0	0.8	1.1	0.0	1.7	2.3	0.9	3.0	1.7
11	2.2	0.0	0.0	1.8	5.5	0.0	0.2	3.6	1.8	0.0	0.0	0.0	0.0	2.7

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Appendix Table
Port Royal Sound Environmental Study
Soluble Metals

Sta.	Date	Aluminum mg/1	Barium mg/1	Calcium mg/1	Cadmium mg/1	Chromium mg/1	Copper mg/1	Mercury mg/1	Potassium mg/1	Magnesium mg/1	Manganese mg/1	Sodium mg/1	Nickel mg/1	Lead mg/1	Silica mg/1	Zinc mg/1
1	7-14	0.02	0.	370	0.00	0.00	0.01	0.00	390	980	0.0	8,800	0.00	0.01	0.5	0.01
	7-21	0.01	0.	360	0.00	0.00	0.00	0.00	440	980	0.0	8,600	0.00	0.01	0.5	0.01
	7-26	0.00	0.	360	0.00	0.00	0.01	0.00	420	970	0.0	8,600	0.00	0.00	0.5	0.01
2	7-14	0.02	0.	370	0.00	0.00	0.01	0.00	420	990	0.0	8,800	0.00	0.02	0.5	0.02
	7-21	0.01	0.	360	0.00	0.00	0.00	0.00	450	980	0.0	8,500	0.00	0.01	0.5	0.01
	7-26	0.00	0.	360	0.00	0.00	0.01	0.00	430	970	0.0	8,500	0.00	0.00	0.5	0.02
4	7-14	0.02	0.	370	0.00	0.00	0.01	0.00	430	990	0.0	8,800	0.00	0.00	0.4	0.02
	7-21	0.02	0.	340	0.00	0.00	0.00	0.00	450	980	0.0	8,600	0.00	0.00	0.5	0.02
	7-26	0.01	0.	360	0.00	0.00	0.01	0.00	430	970	0.0	8,600	0.00	0.01	0.5	0.01
5	7-14	0.01	0.	370	0.00	0.00	0.00	0.00	440	990	0.0	8,800	0.00	0.01	0.5	0.02
	7-21	0.01	0.	350	0.00	0.00	0.00	0.00	440	970	0.0	8,600	0.00	0.00	0.5	0.01
	7-26	0.00	0.	360	0.00	0.00	0.00	0.00	440	980	0.0	8,600	0.00	0.00	0.5	0.02
6	7-14	0.01	0.	370	0.00	0.00	0.00	0.00	430	980	0.0	8,800	0.00	0.00	0.5	0.02
	7-21	0.01	0.	360	0.00	0.00	0.00	0.00	430	990	0.0	8,700	0.00	0.00	0.4	0.01
	7-26	0.02	0.	360	0.00	0.00	0.00	0.00	430	980	0.0	8,600	0.00	0.01	0.5	0.01
7	7-14	0.01	0.	370	0.00	0.00	0.00	0.00	420	990	0.0	8,800	0.00	0.00	0.5	0.01
	7-21	0.01	0.	360	0.00	0.00	0.01	0.00	440	980	0.0	8,600	0.00	0.01	0.5	0.01
	7-26	0.00	0.	360	0.00	0.00	0.01	0.00	440	970	0.0	8,500	0.00	0.00	0.5	0.02
8	7-14	0.01	0.	370	0.00	0.00	0.00	0.00	420	970	0.0	8,850	0.00	0.00	0.6	0.01
	7-21	0.01	0.	360	0.00	0.00	0.01	0.00	430	970	0.0	8,700	0.00	0.01	0.5	0.01
	7-26	0.01	0.	360	0.00	0.00	0.01	0.00	420	980	0.0	8,600	0.00	0.00	0.4	0.02
9	7-14	0.01	0.	380	0.00	0.00	0.00	0.00	430	990	0.0	9,050	0.00	0.01	0.5	0.02
	7-21	0.01	0.	360	0.00	0.00	0.00	0.00	440	1000	0.0	8,900	0.00	0.00	0.5	0.01
	7-26	0.01	0.	370	0.00	0.00	0.01	0.00	420	990	0.0	9,000	0.00	0.00	0.5	0.01
10	7-14	0.01	0.	380	0.00	0.00	0.01	0.00	420	1020	0.0	9,200	0.00	0.01	0.5	0.01
	7-21	0.01	0.	360	0.00	0.00	0.00	0.00	440	1050	0.0	9,00	0.00	0.00	0.3	0.02
	7-26	0.01	0.	360	0.00	0.00	0.01	0.00	430	1040	0.0	9,100	0.00	0.01	0.4	0.01
11	7-14	0.01	0.	360	0.00	0.00	0.01	0.00	430	950	0.0	8,350	0.00	0.01	0.5	0.01
	7-21	0.01	0.	360	0.00	0.00	0.00	0.00	400	900	0.0	8,500	0.00	0.01	0.4	0.02
	7-26	0.01	0.	370	0.00	0.00	0.00	0.00	440	910	0.0	8,400	0.00	0.01	0.5	0.01

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SAMPLE TIME
FIRST RUN

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	1045	1055	1045	1045	1045	1045	1050	1045	1140	1045	1045	1045	1045	1045
2	1025	1030	1025	1025	1025	1025	1025	1025	1115	1025	1025	1025	1025	1025
3														
4	1000	1000	1000	1000	1000	1000	1000	1000	1045	1000	1000	1000	1000	1000
5	930	930	930	930	925	930	930	930	930	930	930	930	930	930
6	900	900	900	900	900	900	900	900	900	900	900	900	900	900
7	800	800	800	800	800	800	830	800	800	800	800	800	800	800
8	825	825	825	825	825	825	825	825	825	825	825	825	825	825
9	1205	1215	1205	1205	1220	1255	1210	1205		1205	1205	1205	1205	1235
10	1115	1125	1115	1115	1120	1155	1125	1120		1115	1115	1115	1115	1125
11	1250	1255	1255	1255	1310	1335	1250	1255		1255	1250	1250	1250	1335

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SAMPLE TIME
SECOND RUN

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	1455	1500	1445	1457		1445	1515	1445		1445		1445	1445	
2	1440	1425	1425	1435		1425	1500	1425		1425	1425	1425	1425	
3														
4	1420	1400	1400	1402		1400	1400	1400		1400	1410	1400	1400	
5	1405	1330	1330	1332		1330	1330	1330		1330	1350	1330	1330	
6	1345	1300	1300	1302	1330	1300	1300	1300			1330	1300	1300	
7	1210	1200	1200	1210	1230	1215	1200	1200			1200	1200	1200	
8	1230	1225	1225	1230	1250	1230	1225	1225			1225	1225	1225	
9	1605	1550	1605	1617	1430	1605	1645	1605		1605	1605	1605	1605	
10			1515	1522		1515	1550	1515		1115		1515	1515	
11	1650	1625	1650	1722		1650	1715	1650		1650	1650	1650	1650	

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TEMPERATURE
DEGREES C (FIRST RUN)

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1 TOP	25	25	25	25	26	24	23	22	22	22	22	23	23	23
MID	25	25	25	25	26	24	23	22	22	22	22	22	22	23
BOT	25	25	25	25	26	24	23	22	22	22	22	22	22	23
2 TOP	25	25	25	25	26	23	22	22	22	22	22	22	23	23
MID	25	25	25	25	26	23	22	22	22	22	22	22	22	23
BOT	25	25	25	25	26	22	22	22	22	22	22	22	22	23
3 TOP														
MID														
BOT														
4 TOP	25	25	25	25	26	24	23	23	22	22	22	22	22	23
MID	25	25	25	25	25	24	23	23	22	22	22	22	22	23
BOT	25	25	25	25	25	23	23	23	22	22	22	22	22	23
5 TOP	25	25	25	25	26	24	22	22	22	22	22	22	22	23
MID	25	25	25	25	26	24	22	22	22	22	22	22	22	23
BOT	25	25	25	25	25	24	22	22	22	22	22	22	22	23
6 TOP	25	25	25	25	26	24	22	22	21	21	22	22	22	23
MID	25	25	25	25	26	24	22	22	21	21	22	22	22	23
BOT	25	25	25	25	26	23	22	22	21	21	22	22	22	23
7 TOP	25	25	25	25	26	23	21	21	21	21	22	22	22	23
MID	25	25	25	25	26	23	21	21	21	21	22	22	22	23
BOT	25	25	25	25	26	23	21	21	21	21	22	22	22	23
8 TOP	25	25	25	25	26	23	21	21	22	22	22	22	22	23
MID	25	25	25	25	26	23	21	21	22	22	22	22	22	23
BOT	25	25	25	25	26	23	21	21	22	22	22	22	22	23
9 TOP	25	25	25	25	25	24	23	23		22	23	23	23	23
MID	25	25	25	25	25	24	23	23		23	23	23	23	23
BOT	25	25	25	25	25	24	23	23		23	23	23	23	23
10 TOP	25	25	25	25	26	23	21	21		22	22	22	23	22
MID	25	25	25	25	26	23	21	21		22	22	22	22	22
BOT	25	25	25	25	26	23	21	21		22	22	22	22	22
11 TOP	25	25	25	26	26	24	23	22		22	22	22	23	22
MID	25	25	25	26	26	24	23	22		22	22	22	22	22
BOT	25	25	25	26	26	24	23	22		22	22	22	22	22

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TEMPERATURE
DEGREES C (SECOND RUN)

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1 TOP	25	25	25	25		23	23	22		22		22	22	
MID	25	25	25	25		23	23	22		22		22	22	
BOT	25	25	25	25		23	23	22		22		22	22	
2 TOP	25	26	26	26		22	21	22		22	22	23	22	
MID	25	26	26	26		22	21	22		22	22	22	22	
BOT	25	26	26	26		22	21	22		22	22	22	22	
3 TOP														
MID														
BOT														
4 TOP	25	25	26	26		23	23	22		22	23	23	22	
MID	25	25	25	25		23	23	22		22	23	22	22	
BOT	25	25	25	25		23	23	22		22	23	22	22	
5 TOP	25	25	25	25		23	23	22		22	22	22	23	
MID	25	25	25	25		23	22	22		22	22	22	22	
BOT	25	25	25	25		23	22	22		22	22	22	22	
6 TOP	26	25	25	26	25	23	22	22			22	22	23	
MID	25	25	25	26	25	23	22	22			22	22	22	
BOT	25	25	25	26	25	23	22	22			22	22	22	
7 TOP	25	25	25	25	25	23	22	22			22	22	22	
MID	25	25	25	25	25	23	22	22			22	22	22	
BOT	25	25	25	25	25	23	22	22			22	22	22	
8 TOP	25	25	25	25	25	23	22	22			22	22	23	
MID	25	25	25	25	25	23	22	22			22	22	22	
BOT	25	25	25	25	25	23	22	22			22	22	22	
9 TOP	25	25	25	25	25	24	23	23		23	22	23	23	
MID	25	25	25	25	25	24	23	22		22	22	22	22	
BOT	25	25	25	25	25	24	23	22		22	22	22	22	
10 TOP			25	26		23	22	21		21		22	22	
MID			25	26		23	22	21		21		22	22	
BOT			25	26		23	22	21		21		22	22	
11 TOP	25	25	26	26		23	22	22		22	22	22	22	
MID	25	25	26	26		23	22	22		22	22	22	22	
BOT	25	25	26	26		23	22	22		22	22	22	22	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

PH (FIRST RUN)
STANDARD UNITS

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1 TOP	8.2	8.2	9.8	8.2	8.9	9.2	7.0	9.4		9.3	7.9	8.0	8.0	9.4
MID	8.1	8.1	9.5	8.1	8.6	9.1	6.8	8.5		9.3	7.9	7.9	8.0	9.4
BOT	8.1	8.1	9.9	8.2	9.0	9.4	7.5	9.3		9.4	8.0	8.0	8.0	9.4
LAB	8.2	8.2	8.1	8.1	8.1	8.3	8.0	8.1	8.2	8.1	8.1	8.1	8.1	8.1
2 TOP	8.1	7.9	8.5	8.1	9.2	8.7	7.0	9.4		9.3	8.0	8.1	8.0	9.4
MID	8.1	7.8	8.1	7.8	8.8	8.7	6.4	9.0		9.3	8.0	8.1	8.0	9.4
BOT	8.1	8.0	8.4	8.1	9.2	8.7	7.4	9.5		9.3	8.0	8.1	8.0	10.1
LAB	7.8	8.0	8.0	8.1	7.8	8.0	8.0	8.0	8.1	8.1	8.0	8.1	8.0	8.0
3 TOP														
MID														
BOT														
LAB														
4 TOP	8.2	8.1	8.9	8.1	9.0	9.1	9.3	8.8		7.6	7.9	8.3	8.2	10.2
MID	8.1	8.0	8.9	8.1	8.5	8.1	9.1	8.7		7.4	7.9	8.2	8.2	9.6
BOT	8.2	8.1	9.0	8.2	9.0	9.2	9.3	9.3		7.9	7.9	8.3	8.2	10.2
LAB	7.9	7.9	8.2	8.1	8.1	8.0	8.0	8.0	8.2	8.0	8.0	8.1	8.0	8.1
5 TOP	8.1	7.9	8.4	8.0	9.0	8.7	8.5	9.0	8.8	9.3	7.9	8.5	8.8	10.4
MID	8.1	7.9	8.2	8.0	9.0	8.6	8.5	8.6	8.8	9.2	7.8	8.5	8.7	10.1
BOT	8.2	7.9	8.2	8.0	9.1	8.6	8.6	9.1	8.8	9.3	7.9	8.5	8.9	10.4
LAB	7.8	8.1	8.1	8.1	8.0	8.0	8.0	7.9	8.0	7.9	8.0	8.0	8.0	8.0
6 TOP	8.0	7.9	8.7	8.0	8.8	8.5	8.0	8.8	8.4	7.9	7.9	8.2	8.5	10.2
MID	8.0	7.8	8.6	7.9	8.5	8.0	7.9	8.7	8.4	7.9	8.0	8.0	8.4	9.4
BOT	8.0	8.0	8.8	8.0	8.9	8.6	8.0	9.1	8.1	7.9	8.0	8.2	8.6	10.2
LAB	8.0	8.0	8.0	8.0	7.9	7.9	7.8	7.9	7.9	7.8	7.9	8.0	7.9	7.9
7 TOP	8.1	7.9	8.0	7.9	8.0	9.4	7.8	8.0	9.8	7.9	7.8	7.9	10.8	8.9
MID	8.0	7.9	7.9	7.9	7.9	8.9	7.2	7.7	9.5	7.9	7.8	7.8	10.8	8.7
BOT	8.0	7.9	8.0	7.9	7.9	9.4	7.9	8.0	9.8	7.8	7.9	7.9	10.8	8.8
LAB	8.0	8.0	8.1	8.0	8.0	7.9	7.8	8.0	7.9	7.8	7.9	8.0	7.9	8.0
8 TOP	8.2	7.9	8.4	8.1	8.0	8.2	8.1	8.9	9.6	8.1	8.0	8.0	9.1	9.2
MID	8.2	7.9	8.2	7.9	7.6	8.2	7.8	8.4	9.1	8.1	7.9	7.8	8.9	8.4
BOT	8.2	7.9	8.5	8.1	8.0	8.2	8.1	8.9	9.6	8.1	8.0	8.1	9.2	9.2
LAB	8.2	8.1	8.2	8.1	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.1	8.0	8.0
9 TOP	8.2	8.2	7.6	8.2	9.1	8.7		9.7		9.3	7.9	7.9	7.8	9.4
MID	8.2	8.2	7.6	8.2	8.8	8.6		9.3		9.3	7.9	7.9	7.8	8.8
BOT	8.2	8.2	7.6	8.2	9.3	8.7		9.9		9.4	7.9	7.9	7.8	9.5
LAB	8.1	8.1	8.2	8.2	8.1	8.1	8.1	8.1		8.0	8.1	8.1	8.0	8.1
10 TOP	7.9	8.3	8.1	8.2	9.2	9.2		9.5		9.3	7.9	9.1	8.0	10.4
MID	7.9	8.3	8.1	8.2	8.9	9.2		9.0		9.3	7.9	9.1	8.0	7.8
BOT	7.9	8.3	8.1	8.2	9.3	9.2		9.6		9.3	7.9	9.2	8.0	10.4
LAB	8.0	8.1	8.2	8.2	8.2	8.2	8.1	8.1		8.0	8.0	8.0	8.0	8.0
11 TOP	7.8	7.7	8.1	7.9	8.6	8.7		8.2		9.1	7.6	7.6	7.5	8.0
MID	7.8	7.7	8.1	7.9	8.6	8.7		7.7		9.1	7.7	7.6	7.4	8.1
BOT	7.7	7.7	8.1	7.9	8.6	8.7		8.3		9.1	7.7	7.6	7.4	8.7
LAB	7.6	7.9	7.9	7.9	7.9	8.0	8.0	7.9		7.8	7.9	7.8	7.8	7.7

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

PH (SECOND RUN)
STANDARD UNITS

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1 TOP	7.8		8.0	7.7		8.1	7.4	7.8		7.9		8.0	7.9	
MID	7.6		7.6	7.8		8.2	7.4	7.8		7.9		8.0	7.8	
BOT	7.6		7.5	7.9		8.1	7.4	7.8		7.8		7.9	7.9	
2 TOP	7.6	7.2	8.2	7.9		8.3	7.8	7.5		8.1	7.9	6.8	7.8	
MID	7.6	7.3	8.0	7.9		8.4	7.0	7.6		7.9	7.8	6.8	7.8	
BOT	7.6	7.3	8.0	7.9		8.2	7.8	7.8		7.9	7.9	6.9	7.8	
3 TOP														
MID														
BOT														
4 TOP	7.6	7.5	8.5	8.0		8.3	7.8	7.6		8.0	8.0	8.0	7.8	
MID	7.5	7.4	8.4	7.9		8.3	7.8	7.8		8.0	8.0	8.0	7.7	
BOT	7.5	7.4	8.4	7.9		8.3	7.9	7.8		8.0	8.0	8.0	7.7	
5 TOP	7.4	7.4	8.3	7.8		8.2	7.9	7.5		7.8	7.9	7.1	7.6	
MID	7.4	7.4	8.6	7.8		8.2	7.9	7.6		7.8	7.9	7.9	7.6	
BOT	7.4	7.4	8.6	7.7		8.1	7.8	7.6		7.6	7.8	7.8	7.7	
6 TOP	7.4	7.2	8.4	7.8	6.5	8.2	7.8	7.4			7.8	7.8	7.5	
MID	7.4	7.4	8.5	7.8	7.3	8.1	7.8	7.3			7.8	7.7	7.4	
BOT	7.4	7.4	8.3	7.8	7.4	8.1	7.8	8.0			7.8	7.8	7.6	
7 TOP	7.6	7.3	8.0	8.0	7.6	8.0	7.8	7.6			7.7	7.8	6.6	
MID	7.6	7.4	8.2	7.8	7.4	7.9	7.8	7.9			7.7	7.8	7.1	
BOT	7.6	7.2	8.4	7.6	7.2	7.8	7.7	7.9			7.4	7.8	7.4	
8 TOP	7.7	7.4	8.5	8.0	7.5	8.2	8.0	7.9			7.8	6.8	7.3	
MID	7.6	7.3	8.4	8.1	7.6	8.2	8.0	7.8			7.9	6.7	7.4	
BOT	7.6	7.3	8.3	8.0	7.4	8.2	8.0	7.8			7.9	6.3	7.6	
9 TOP	7.6			7.8	5.5	8.1	7.9	8.0		8.0	8.0	8.0	7.6	
MID	7.6			7.8	6.0	7.5	8.0	8.0		8.0	8.0	8.0	7.6	
BOT	7.6			7.7	5.1	8.2	8.0	7.6		8.0	8.0	8.0	7.7	
10 TOP				7.7		8.0	7.8	8.0		8.0		7.8	7.8	
MID				7.8		8.0	7.8	8.0		8.0		8.0	7.8	
BOT				7.9		8.0	7.9	7.9		8.0		7.6	7.9	
11 TOP	7.3			7.4		8.0	7.6	7.8		7.8	7.8	7.8	7.6	
MID	7.4			7.3		8.0	7.6	7.8		7.8	7.8	7.8	7.4	
BOT	7.4			7.5		8.0	7.8	7.7		7.8	7.8	7.9	7.6	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL ALKALINITY
MG/L CALCIUM CARBONATE

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	116	113	115	112	114	113	114	113	113	112	111	110	110	111
2	131	112	115	112	111	113	110	111	112	111	110	111	110	109
3														
4	131	115	114	109	111	113	112	110	110	108	109	110	111	110
5	136	114	117	112	111	115	110	110	109	106	108	108	110	108
6	109	112	114	112	110	110	112	110	108	104	107	111	106	107
7	114	113	114	110	110	110	110	109	108	104	106	118	108	108
8	112	112	113	110	110	113	110	112	109	108	109	108	108	110
9	112	111	113	110	112	111	112	110		108	108	110	106	107
10	116	114	115	111	111	113	113	114		113	112	113	113	113
11	98	99	104	102	102	106	105	103		100	96	95	94	90

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TURBIDITY
JTU

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	1.9	3.8	2.8	3.8	3.3	4.0	5.0	4.3	2.2	3.2	2.9	1.7	1.1	1.5
2	1.5	2.5	2.3	2.7	2.3	2.9	2.5	2.0	2.3	1.3	1.2	1.1	0.8	0.8
3														
4	1.8	1.6	0.9	1.6	1.6	1.8	2.0	2.7	3.2	1.6	1.6	1.2	1.2	0.8
5	3.2	1.7	1.8	3.0	3.6	2.4	3.0	3.1	1.7	1.2	1.1	1.4	1.8	1.5
6	1.2	2.1	2.6	2.7	2.2	3.2	2.3	1.5	0.8	0.8	1.2	1.0	1.5	1.0
7	1.3	1.8	2.0	1.9	2.0	2.6	2.2	0.8	1.8	1.2	1.3	0.9	0.9	0.8
8	1.0	1.6	1.9	1.3	1.4	2.5	3.0	2.3	2.2	1.7	3.3	2.0	1.1	0.8
9	0.5	1.0	0.8	0.6	0.8	1.1	1.1	1.0		1.0	0.7	0.6	0.4	0.6
10	3.1	5.6	6.2	2.1	2.1	3.7	4.7	6.2		2.1	1.0	1.0	0.8	1.4
11	1.6	1.9	2.2	1.8	2.2	2.1	1.9	1.8		1.3	1.1	1.5	1.0	0.8

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SECCHI DISK
FIRST RUN - FEET

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	2	1	3	2	1	1	1	2	2	3	5	5	5	3
2	3	2	2	2	3	2	2	3	3	4	4	4	4	5
3														
4	3	3	5	4	3	2	2	3	1	6	6	5	4	4
5	2	3	2	2	1	1	2	2	3	4	5	4	4	2
6	3	2	2	2	2	2	2	3	4	4	4	4	3	4
7	3	2	2	2	2	1	2	4	2	3	3	3	3	3
8	3	3	3	3	3	2	2	2	3	3	2	2	5	4
9	5	4	5	5	6	6	5	5		7	7	8	8	7
10	2	1	1	3	2	2	2	2		3	6	6	5	3
11	2	2	2	2	2	3	2	2		3	4	3	5	4

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SECCHI DISK
SECOND RUN- FEET

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	2	2	2	1		1	1	2		3		4	2	
2	2	2	2	3		2	2	2		4	2	3	4	
3														
4	3	2	2	2		2	3	2		4	4	4	3	
5	2	2	2	1		3	2	2		2	3	3	5	
6	2	1	2	2	2	2	2	2			4	4	4	
7	2	1	2	2	2	2	2	2			4	4	4	
8	2	2	2	2	2	2	2	4			3	3	4	
9	4	4	3	3	4	4	4	3		8	4	6	5	
10			2	2		1	2	2		4		4	3	
11	2	2	2	2		2	2	2		4	4	4	4	

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL SUSPENDED SOLIDS
MG/L

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	60		103		82			95		80		32		
2	39		61		53			49		33		18		
3														
4	18		20		33			63		32		18		
5	96		70		103			63		23		20		
6	28		74		60			34		18		23		
7	32		43		61			20		22		70		
8	22		42		43			45		34		37		
9	29		30		16			22		11		11		
10	63		208		47			162		45		20		
11	50		52		67			46		22		24		

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 STUDIES

BOD (FIRST RUN)
MG/L

DATE ********* STATION		10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
1	2 DAY	0.65	0.65	0.60	0.55	0.50	0.30	0.40	0.50	0.50	0.65	0.45	0.65	0.60	0.45
	5 DAY	0.90	1.25	1.05	1.15	1.05	0.60	1.15	1.10	0.80	0.80	1.00	0.85	0.90	0.95
	7 DAY	0.70	1.45	1.60	1.15	1.20	0.75	1.50							
	10 DAY	1.50	1.80	1.65	1.80	1.55	1.10	1.95							
2	2 DAY	0.50	0.65	0.70	0.40	0.85	0.20	0.35	0.60	0.45	0.75	0.15	0.45	0.55	0.40
	5 DAY	0.75	1.05	0.95	0.85	0.75	0.70	0.95	1.25	0.75	0.55	0.65	0.85	0.80	0.90
	7 DAY	0.70	1.70	1.30	0.75	1.05	0.95	1.10							
	10 DAY	1.15	1.60	1.45	1.25	1.05	1.10	1.50							
3	2 DAY														
	5 DAY														
	7 DAY														
	10 DAY														
4	2 DAY	0.40	0.35	0.45	0.40	0.40		0.70	0.45	0.80	0.45	0.45	0.55	0.35	0.45
	5 DAY	0.75	0.85	0.95	0.75	1.10	0.50	1.15	0.85	1.05	0.75	0.55	0.80	0.65	0.75
	7 DAY	0.95	0.90	0.90	1.15	1.15	0.30	0.95							
	10 DAY	1.15	1.30	1.20	1.10	1.30	1.45	1.35							
5	2 DAY	0.20	0.40	0.60	0.65	0.45	0.40	0.35	0.50	0.35	0.30	0.35	0.10	0.60	0.40
	5 DAY	0.75	0.75	1.00	0.85	1.00	0.75	0.75	0.90	1.00	0.80	0.65	0.60	0.80	0.90
	7 DAY	1.50	0.90	1.40	1.25	1.35	1.10	1.00							
	10 DAY	1.45	1.40	1.80	1.15	1.70	1.20	1.35							
6	2 DAY	0.20	0.65	0.60	0.60	0.50	0.30	0.55	0.50	0.40	0.65	0.50	0.45	0.50	0.60
	5 DAY	0.95	1.00	1.00	1.05	0.95	0.60	0.70	0.90	0.70	1.05	0.90	0.85	1.05	0.90
	7 DAY	0.85	1.20	1.15	1.70	1.15	0.85	1.05							
	10 DAY	1.20	1.50	1.45	1.55	1.25	1.05	1.10							
7	2 DAY	0.65	0.70	0.50	0.45	0.55	0.25	0.35	0.65	0.55	0.50	0.50	0.55	0.65	0.60
	5 DAY	1.10	1.25	0.85	0.95	1.05	1.20	0.85	1.45	1.10	0.85	1.00	0.90	0.95	1.05
	7 DAY	1.15	1.35	1.25	1.55	1.60	1.30	0.90							
	10 DAY	1.65	1.60	1.85	1.25	1.80	1.75	1.10							
8	2 DAY	0.15	0.50	0.60	0.80	0.60	0.30	0.20	0.65	0.60	0.60	0.50	0.40	0.50	0.35
	5 DAY	0.45	1.15	1.00	0.75	0.75	0.70	0.50	1.15	1.20	0.90	1.00	0.80	0.70	0.70
	7 DAY	0.60	0.90	0.90	1.30	1.20	1.15	0.75							
	10 DAY	0.80	1.40	1.50	1.10	1.25	1.10	1.50							
9	2 DAY	0.35	0.35	0.85	0.45	0.40	0.35	0.55	0.45		0.50	0.40	0.40	0.55	0.35
	5 DAY	0.75	0.80	1.30	0.75	0.85	0.65	0.80			0.70	0.75	0.65	0.85	0.75
	7 DAY	1.00	0.85	1.50	1.05	0.90	0.70	1.10							
	10 DAY	1.20	1.35	1.55	0.95	1.05	1.05	1.00							
10	2 DAY	0.60	0.85	0.75	0.65	0.55	0.15	0.40	0.60		0.35	0.55	0.25	0.30	0.45
	5 DAY	1.10	1.30	1.65	1.20	1.25	0.85	0.95	1.05		0.80	0.80	0.60	0.90	0.95
	7 DAY	1.30	1.80	1.75	1.80	1.35	0.85	1.15							
	10 DAY	1.70	2.05	2.55	1.55	1.50	1.15	1.50							
11	2 DAY	0.50	0.55	0.55	1.00	0.50	0.30	0.35	0.50		0.40	0.55	0.50	0.70	0.60
	5 DAY	0.95	1.15	1.35	1.20	0.80	0.70	0.90	1.10		0.85	0.90	0.90	1.10	1.10
	7 DAY	1.30	1.35	1.25	1.40	1.25	1.00	1.00							
	10 DAY	1.40	1.75	1.90	1.75	1.45	1.20	1.15							

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 STUDIES

BOD (LAB. DUPLICATE)
MG/L

DATE ********* STATION	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
1 2 DAY	0.50	0.60	0.70	0.25	0.60	0.20	0.40	0.60	0.25	0.50	0.55	0.55	0.50	0.45
5 DAY	1.05	1.25	1.10	1.15	1.05	0.70	1.00	1.30	0.80	0.90	1.00	1.00	0.90	0.90
7 DAY	1.25	1.45	1.60	1.35	1.40	0.70	1.50							
10 DAY	1.45	1.90	1.65	2.35	1.75	1.10	1.55							
2 2 DAY	0.55	0.65	0.60	0.60	0.35	0.40	0.20	0.45	0.45	0.40	0.15	0.45	0.35	0.45
5 DAY	0.90	1.00	0.90	0.80	0.70	0.70	0.85	1.00	0.90	0.75	0.65	0.70	0.80	0.85
7 DAY	0.60	1.80	1.20	1.15	1.15	1.00	0.80							
10 DAY	1.20	1.60	1.50	1.40	1.15	1.60	1.25							
3 2 DAY														
5 DAY														
7 DAY														
10 DAY														
4 2 DAY	0.40	0.50	0.40	0.45	0.45		0.65	0.35	0.70	0.35	0.45	0.65	0.40	0.60
5 DAY	0.65	0.50	0.95	0.80	0.85	0.60	1.05	0.95	1.15	0.85	0.90	0.95	0.65	0.90
7 DAY	0.85	0.90	1.00	1.00	1.05	0.20	0.95							
10 DAY	1.15	1.40	1.15	1.05	1.35	0.90	1.15							
5 2 DAY	0.20	0.35	0.60	0.45	0.60	0.50	0.45	0.45	0.50	0.40	0.30	0.30	0.50	0.40
5 DAY	0.65	0.65	1.05	0.75	1.05	0.55	0.70	0.85	1.15	0.60	0.80	0.50	0.80	0.70
7 DAY	1.00	0.80	1.40	0.90	1.70	1.20	1.00							
10 DAY	2.00	1.00	1.55	1.30	1.55	1.30	1.25							
6 2 DAY	0.35	0.60	0.65	0.75	0.50	0.50	0.55	0.35	0.50	0.85	0.50	0.50	0.45	0.55
5 DAY	0.95	1.00	0.95	1.10	0.85	0.75	0.80	0.95	1.00	0.95	0.80	0.85	0.75	0.90
7 DAY	0.60	1.30	1.35	1.20	1.30	1.15	0.90							
10 DAY	1.25	1.45	1.45	1.55	1.30	0.95	0.95							
7 2 DAY	0.75	0.80	0.55	0.45	0.65	0.30	0.45	0.75	0.65	0.55	0.50	0.50	0.55	0.55
5 DAY	1.05	1.25	1.15	0.85	1.05	0.95	0.85	1.35	1.10	1.05	1.00	1.00	0.85	1.15
7 DAY	1.30	1.45	1.15	1.45	1.55	1.25	1.10							
10 DAY	1.70	1.80	0.85	1.20	1.55	1.95	1.05							
8 2 DAY	0.20	0.40	0.50	0.40	0.55	0.35	0.20	0.65	0.60	0.60	0.45	0.35	0.40	0.40
5 DAY	0.50	0.90	1.05	0.90	0.95	0.70	0.95	1.20	1.05	1.00	0.90	0.80	0.70	0.60
7 DAY	0.45	1.00	1.20	1.10	1.15	0.70	0.75							
10 DAY	0.90	1.30	1.50	1.05	1.40	1.25	1.50							
9 2 DAY	0.45	0.35	0.85	0.55	0.35	0.30	0.45	0.45		0.40	0.40	0.20	0.45	0.45
5 DAY	0.50	0.80	1.25	0.65	0.65	0.80	0.85			0.80	0.85	0.55	0.75	0.65
7 DAY	1.25	0.80	1.50	0.90	0.95	0.65	1.05							
10 DAY	1.15	1.15	1.55	0.99	1.05	0.90	1.08							
10 2 DAY	0.50	0.90	0.65	0.65	0.45	0.35	0.40	0.50		0.40	0.45	0.35	0.55	0.45
5 DAY	1.15	1.45	1.65	1.20	1.00	0.70	1.00	1.15		0.80	0.70	0.60	0.65	0.85
7 DAY	1.00	1.90	1.65	1.45	1.30	0.70	1.20							
10 DAY	1.50	2.15	2.85	1.65	1.50	1.40	1.50							
11 2 DAY	0.35	0.70	0.70	1.00	0.50	0.50	0.35	0.55		0.65	0.35	0.65	0.65	0.55
5 DAY	1.05	1.15	1.25	1.45	1.10	0.65	0.95	1.10		0.95	1.00	0.95	1.15	1.30
7 DAY	1.20	1.95	1.25	1.60	1.20	1.20	1.00							
10 DAY	1.30	1.70	2.00	1.75	1.40	1.25	1.15							

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

DISSOLVED OXYGEN
MG/L (FIRST RUN)

DATE ********* STATION	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
1 TOP	6.30	6.25	6.10	6.10	6.20	6.40	6.30	6.20	6.80	6.50	6.85	6.65	6.65	6.70
MID	6.50	6.15	5.75	5.70	5.90	6.40	6.70	7.00	6.80	6.60	6.45	6.55	6.65	6.60
BOT	6.20	5.90	6.15	6.10	6.00	6.20	6.50	6.80	6.70	6.60	6.40	6.65	6.60	6.65
2 TOP	5.70	5.60	5.50	5.40	5.70	6.60	6.50	6.90	6.70	6.80	6.60	6.50	6.20	6.25
MID	5.80	5.55	5.50	5.40	5.60	6.40	6.90	6.80	6.55	6.55	6.60	6.35	6.75	6.25
BOT	5.95	5.75	5.55	5.70	5.75	6.80	6.60	6.85	6.65	6.80	6.70	6.40	5.45	5.85
3 TOP														
MID														
BOT														
4 TOP	6.50	6.40	6.40	6.00	5.80	6.50	6.60	6.80	7.00	6.60	6.75	6.75	6.50	6.70
MID	6.40	6.40	6.15	6.20	6.20	6.50	6.80	6.90	6.85	6.50	6.40	6.45	6.40	6.60
BOT	6.40	6.40	6.15	6.00	6.00	6.60	6.70	6.75	7.00	6.70	6.70	6.60	6.40	6.80
5 TOP	6.40	6.25	5.85	5.70	5.80	6.40	6.40	6.65	6.70	6.80	6.60	6.40	6.30	6.50
MID	6.00	6.15	5.80	5.60	6.00	6.40	6.30	6.65	6.65	6.50	6.50	6.30	6.50	6.60
BOT	6.10	6.15	5.85	5.50	5.80	6.40	6.50	7.00	6.50	6.55	6.30	6.35	6.50	6.85
6 TOP	5.60	5.65	5.45	5.60	5.40	5.80	6.00	6.45	6.60	6.60	6.50	6.50	6.50	6.30
MID	5.55	5.85	5.65	5.40		5.70	6.00	6.30	6.50	6.40	6.35	6.45	6.40	6.15
BOT	5.60	5.55	5.65	5.40	5.30	5.80	6.20	6.60	6.40	6.40	6.45	6.40	6.30	6.20
7 TOP	6.20	5.90	5.95	5.50	5.60	6.00	6.40	6.80	6.75	6.50	6.70	6.65	6.40	6.35
MID	6.10	6.25	5.90	5.60	5.40	6.20	6.30	7.10	6.85	6.50	6.55	6.50	6.40	6.45
BOT	6.20	6.35	6.00	5.50	5.50	5.90	6.40	7.20	6.75	6.50	6.50	6.50	6.50	6.45
8 TOP	6.55	6.30	5.90	5.90	5.80	6.20	6.40	6.60	6.90	6.50	6.65	6.25	6.45	6.60
MID	6.35	6.35	6.20	6.00	5.60	6.00	6.40	6.65	6.50	6.70	6.85	6.40	6.30	6.80
BOT	6.50	6.45	6.15	5.90	5.80	5.80	6.40	6.85	6.80	6.80	6.70	6.60	6.50	6.90
9 TOP	6.55	6.50	6.35	6.30	6.60	6.70	6.50	6.90		6.85	7.00	7.00	6.80	6.80
MID	6.60	6.40	6.30	6.40	6.80	6.60	6.80	6.70		6.75	7.00	6.90	6.85	6.90
BOT	6.75	6.50	6.50	6.30	6.80	6.70	6.60	6.80		6.85	6.80	1.05	6.65	6.70
10 TOP	5.55	5.60	6.10	6.70	6.40	7.00	7.00	7.00		6.45	6.50	6.45	6.40	6.40
MID	5.60	5.80	6.00	6.20	6.40	6.90	7.10	7.05		6.40	6.40	6.30	6.40	6.20
BOT	5.50	5.70	6.10	6.10	6.30	6.80	7.10	7.20		6.40	6.30	6.20	6.30	6.20
11 TOP	5.05	5.10	5.10	5.40	5.50	6.20	6.20	6.30		6.50	6.20	5.95	5.80	5.30
MID	4.95	5.10	5.20	5.40	5.50	6.40	6.40	6.35		6.40	6.30	5.95	5.70	5.40
BOT	5.20	5.10	5.40	5.80	5.60	6.20	6.20	6.30		6.30	6.30	6.00	5.70	5.40

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

DISSOLVED OXYGEN
MG/L (SECOND RUN)

DATE ********* STATION		10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
1	TOP	6.50	6.40	5.90	5.80		6.20	6.50	6.60		6.70		6.70	6.80	
	MID	6.30	6.25	6.05	5.80		0.06		6.60		6.60		6.70	6.75	
	BOT	6.30	5.95	5.95	5.70		6.10	6.30	6.55		6.60		6.70	6.80	
2	TOP	6.40	6.20	5.75	5.40		6.60	6.80	6.75		6.70	6.65	6.65	6.80	
	MID	6.35	6.20	5.85	5.50		6.50	6.60	6.50		6.40	6.35	6.65	6.65	
	BOT	6.25	6.10	5.40	5.60		6.60	6.60	7.05		6.40	6.70	6.60	6.35	
3	TOP														
	MID														
	BOT														
4	TOP	6.25	6.00	5.90	6.60		6.70	6.60	6.60		6.85	7.00	7.50	6.70	
	MID	6.10	5.90	6.15	6.30		6.60	6.70	6.50		6.60	6.90	7.35	6.60	
	BOT	6.10	5.95	6.00	6.20		6.60	6.50	6.40		6.55	6.70	6.85	6.60	
5	TOP	5.75	5.35	5.45	5.50		6.90	6.40	6.50		6.50	6.70	6.40	6.80	
	MID	5.65	5.60	5.35	5.30		6.40	6.30	6.50		6.50	6.60	6.50	6.30	
	BOT	5.65	5.30	5.30	5.70		6.40	6.40	6.40		6.40	6.55	6.65	6.20	
6	TOP	5.80	5.40	5.25	5.40	5.20	6.00	6.30	6.50			6.40	6.70	6.75	
	MID	5.60	5.30	4.95	5.20	5.20	6.00	6.20	6.30			6.40	6.15	6.15	
	BOT	5.60	5.35	5.05	5.20	5.20	6.10	6.20	6.40			6.35	6.30	6.85	
7	TOP	5.70	5.60	5.45	6.00	5.80	6.40	6.40	6.40			6.40	6.80	6.50	
	MID	5.60	5.70	5.50	5.90	5.70	6.50	6.70	6.50			6.35	6.65	6.35	
	BOT	5.80	5.50	5.30	5.90	5.80	6.50	6.60	6.40			6.40	6.35	6.20	
8	TOP	6.30	5.75	5.90	6.10	6.20	6.60	6.80	6.60			6.45	6.20	6.80	
	MID	6.10	5.75	6.10	6.10	6.10	6.60	6.80	6.55			6.35	6.40	6.80	
	BOT	6.20	5.80	6.20	6.40	6.10	6.60	6.60	6.50			6.40	6.30	6.70	
9	TOP	6.50	6.50	6.40	6.60	6.20	6.60	6.60	6.65		6.90	6.70	7.00	7.00	
	MID	6.70	6.30	6.35	6.50	6.30	6.60	6.70	6.85		6.50	6.60	6.80	6.90	
	BOT	6.65	6.45	6.35	6.60	6.20	6.60	6.80	6.65		6.70	6.70	7.80	7.00	
10	TOP			5.40	5.20		6.00	6.00	6.30		7.30		7.20	6.90	
	MID			5.40	5.20		6.00	6.60	7.00		6.95		7.00	6.80	
	BOT			5.00	4.80		5.90	6.70	6.95		7.15		7.05	6.80	
11	TOP	5.20	5.00	5.00	5.00		5.90	6.10	7.00		6.65	6.70	6.70	6.70	
	MID	5.25	4.90	5.00	5.00		5.90	6.20	6.20		6.55	6.50	6.75	6.60	
	BOT	5.05	4.90	5.20	5.00		5.80	6.20	6.30		6.80	6.50	6.70	6.70	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CONDUCTIVITY (FIRST RUN)
UMHOS/CM

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1 TOP	47,800	47,800	48,000	48,600	48,400	47,900	46,500	45,300	45,200	44,300	44,600	44,800	45,000	45,000
MID	47,800	47,700	48,200	48,400	48,500	47,900	46,700	45,500	45,300	44,300	44,600	44,600	44,800	45,000
BOT	47,800	47,600	48,200	48,400	48,500	47,900	46,800	45,700	45,300	44,600	44,600	44,600	44,800	44,500
2 TOP	46,700	46,900	47,100	47,300	47,900	45,700	44,900	44,300	43,600	43,800	43,500	43,600	44,000	44,000
MID	46,700	46,900	47,100	47,300	47,900	45,700	44,800	44,300	44,200	43,900	43,700	43,700	43,900	44,100
BOT	46,700	46,900	47,100	47,400	47,900	45,200	44,800	44,300	44,300	43,900	43,900	43,900	44,000	44,200
3 TOP														
MID														
BOT														
4 TOP	47,400	47,800	48,200	48,400	48,300	46,700	45,600	45,300	43,500	43,000	43,300	43,300	43,900	44,500
MID	47,400	47,900	48,200	48,400	48,300	46,700	45,600	45,600	43,500	43,100	43,300	43,500	44,000	44,600
BOT	47,500	48,000	48,200	48,400	48,400	46,700	45,600	45,600	44,100	43,400	43,400	43,600	44,000	44,500
5 TOP	47,000	47,500	47,800	47,900	47,700	46,200	44,600	44,100	42,200	41,400	42,200	42,400	43,600	43,600
MID	47,100	47,500	47,700	47,900	47,700	46,100	44,600	44,200	42,200	42,100	42,500	42,700	45,300	43,600
BOT	47,100	47,600	47,700	47,900	47,700	46,000	44,500	44,200	42,600	42,400	42,500	42,800	43,600	43,800
6 TOP	45,500	46,100	46,400	46,600	46,100	44,300	42,800	42,600	40,800	39,500	40,700	41,000	41,500	42,100
MID	45,700	46,400	46,600	46,600	46,100	44,400	42,800	42,500	41,000	40,100	40,800	41,000	41,500	42,100
BOT	45,700	46,400	46,600	46,600	46,100	44,400	42,800	42,500	41,000	40,400	40,900	40,900	41,600	42,200
7 TOP	46,900	47,000	47,000	46,600	46,300	43,900	42,000	41,900	41,100	39,600	40,400	41,300	42,300	42,900
MID	47,000	47,100	47,000	46,600	46,300	44,000	42,000	41,900	41,400	39,700	40,400	41,300	42,400	43,000
BOT	47,000	47,200	46,900	46,600	46,300	44,000	42,200	42,000	41,800	39,800	40,400	41,300	42,400	42,200
8 TOP	47,300	47,300	47,200	47,200	46,600	44,600	42,100	42,800	42,500	42,200	42,800	42,800	43,300	44,000
MID	47,300	47,300	47,300	47,400	46,700	44,600	42,200	42,800	42,500	42,800	43,000	42,900	43,500	44,100
BOT	47,300	47,300	47,300	47,500	46,700	44,600	42,200	42,800	42,500	43,200	43,200	43,200	43,400	44,200
9 TOP	46,200	46,500	47,100	47,600	47,800	47,100	46,100	45,300		43,700	43,100	43,100	42,800	42,400
MID	46,200	46,500	47,100	47,800	47,900	47,100	46,100	45,300		43,700	43,200	42,900	42,600	42,500
BOT	46,200	46,600	47,100	47,900	48,000	47,100	46,100	45,300		43,600	43,200	42,900	42,700	42,500
10 TOP	48,100	48,800	48,900	49,500	49,600	47,700	44,900	44,800		44,800	44,700	44,700	45,000	45,000
MID	48,000	48,700	48,900	49,500	49,600	47,700	44,900	44,800		44,800	44,600	44,600	44,800	45,000
BOT	48,000	48,700	48,800	49,600	49,600	47,700	44,900	44,700		44,700	44,600	44,700	44,800	45,000
11 TOP	37,700	39,300	40,900	42,200	42,600	42,400	40,900	39,700		37,200	36,300	35,800	34,400	33,300
MID	37,800	39,300	40,900	42,200	42,600	42,500	40,800	39,700		37,300	36,300	35,800	34,800	33,300
BOT	37,800	39,300	40,900	42,200	42,600	42,600	40,700	39,700		37,200	36,300	35,600	34,700	33,200

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CONDUCTIVITY (SECOND RUN)
UMHOS/CM

DATE *********		10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION															
1	TOP	48,200	48,200	48,200	48,600		47,200	46,300	46,600		46,300		46,200	45,800	
	MID	48,200	48,000	48,200	48,600		47,000	46,500	46,500		45,900		46,000	45,800	
	BOT	48,200	48,100	48,200	48,600		47,100	46,500	46,500		45,900		46,000	45,800	
2	TOP	47,900	48,300	48,500	49,300		45,500	44,700	45,300		45,200	45,400	45,700	45,500	
	MID	47,800	48,200	48,300	48,700		45,600	44,700	45,300		44,800	45,200	45,300	45,400	
	BOT	47,700	48,200	48,300	48,700		45,600	44,700	45,200		44,800	45,200	45,200	45,200	
3	TOP														
	MID														
	BOT														
4	TOP	47,200	47,600	48,600	48,800		46,700	46,900	46,600		45,900	46,000	45,700	45,400	
	MID	47,100	47,700	48,500	48,600		46,700	47,000	46,800		45,700	45,800	45,400	45,200	
	BOT	47,700	47,700	48,500	48,600		46,700	47,000	45,100			43,600	41,800	44,300	
5	TOP	46,100	46,300	47,100	47,600		46,900	46,300	45,700		44,800	44,900	44,500	44,500	
	MID	46,100	46,200	47,200	47,700		47,000	46,300	45,800		44,400	44,700	44,300	44,200	
	BOT	46,300	46,300	47,300	47,800		47,000	46,200	45,800		44,500	44,800	44,400	44,300	
6	TOP	45,400	45,600	46,000	46,800	46,600	45,700	44,700	43,900			42,600	42,100	42,800	
	MID	45,200	45,600	46,000	46,800	46,700	45,700	44,700	43,900			42,600	41,900	42,000	
	BOT	45,300	45,600	46,000	46,800	46,700	45,700	44,700	44,000			42,700	42,000	41,900	
7	TOP	45,000	45,900	46,600	47,600	47,400	46,300	45,100	44,400			42,100	43,700	41,900	
	MID	45,000	45,900	46,600	47,700	42,500	46,300	45,100	44,300			42,000	43,700	41,600	
	BOT	45,000	45,900	46,600	47,800	47,500	46,300	45,100	44,300			42,000	43,900	41,600	
8	TOP	45,900	46,700	47,100	48,300	48,000	46,300	45,400	44,400			43,600	41,600	44,100	
	MID	46,100	46,700	47,900	48,300	48,000	46,100	45,400	44,700			43,500	41,700	44,000	
	BOT	46,100	46,700	48,000	48,300	48,000	46,200	45,400							
9	TOP	46,600	45,900	45,800	46,300	47,400	46,600	45,900	45,800		45,000	44,800	44,700	44,600	
	MID	46,500	46,100	45,800	46,300	47,400	46,600	45,900	45,900		44,800	44,800	44,600	44,600	
	BOT	46,500	46,100	45,900	46,300	47,400	46,600	46,000	45,900		44,800	44,900	46,200	44,500	
10	TOP			48,400	49,500		47,800	46,900	45,600		46,000		46,100	46,600	
	MID			48,400	49,500		47,800	47,000	45,600		45,600		46,800	46,600	
	BOT														
11	TOP	38,800	38,400	38,700	39,800		39,800	38,700	40,100		39,500	39,300	39,300	39,600	
	MID	38,700	38,400	38,700	39,800		39,800	38,600	40,100		39,400	39,300	39,400	39,500	
	BOT	38,700	38,400	38,900	39,800		39,800	38,600	40,100		39,500	39,300	39,800	39,500	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SALINITY (FIRST RUN)
PARTS PER THOUSAND

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1 TOP	31.76	31.67	31.75	31.91	31.70	32.63	32.10	31.57	31.75	30.96	31.03	31.09	31.10	31.25
MID	31.75	31.63	31.97	32.03	31.91	32.67	32.22	31.70	31.85	30.97	31.02	31.10	31.15	31.21
BOT	31.03	31.60	31.85	32.05	31.97	32.64	32.19	31.82	31.83	31.10	31.15	31.16	31.12	31.20
2 TOP	30.85	31.04	31.21	31.19	31.50	31.57	31.53	31.37	30.78	30.64	30.33	30.32	30.42	30.37
MID	30.95	31.05	31.18	31.19	31.51	31.55	31.54	31.33	31.12	30.81	30.45	30.47	30.41	30.53
BOT	31.44	31.03	31.16	31.28	31.53	31.59	31.46	31.32	31.18	30.77	30.78	30.65	30.61	30.69
3 TOP														
MID														
BOT														
4 TOP	31.55	31.85	32.06	31.97	31.86	32.07	31.52	31.42	30.58	30.17	30.28	30.21	30.44	30.83
MID	31.51	31.90	32.00	32.04	31.91	32.02	31.61	31.51	30.63	30.25	30.29	30.35	30.52	30.88
BOT	31.24	31.92	32.07	32.08	32.01	32.05	31.60	31.54	31.02	30.42	30.29	30.43	30.54	30.90
5 TOP	31.27	31.42	31.70	31.61	31.38	31.42	31.00	30.87	29.86	29.18	29.50	29.55	29.78	30.22
MID	31.17	31.55	31.70	31.73	31.38	31.43	31.10	30.97	29.77	29.74	29.78	29.76	29.90	30.22
BOT	30.12	31.63	31.72	31.67	31.44	31.59	31.01	30.94	29.95	29.80	29.87	30.00	30.37	30.34
6 TOP	30.24	30.49	30.72	30.64	30.18	30.13	30.05	30.05	29.66	27.76	28.47	28.57	28.74	29.08
MID	30.63	30.78	30.83	30.65	30.16	30.22	30.15	29.93	29.76	28.55	28.63	28.59	28.74	29.11
BOT	31.40	30.80	30.87	30.66	30.19	30.31	30.03	30.03	29.83	28.47	28.66	28.67	28.85	29.14
7 TOP	31.44	31.22	31.19	30.69	30.30	30.22	30.00	29.96	29.49	28.12	28.46	28.82	29.42	29.74
MID	31.23	31.20	31.21	30.74	30.26	30.29	30.10	29.93	29.70	28.14	28.30	28.81	29.42	29.79
BOT	31.50	31.35	31.15	30.71	30.25	30.37	30.07	29.96	29.96	28.22	28.51	28.89	29.45	29.93
8 TOP	31.51	31.45	31.42	31.20	30.67	30.63	30.30	30.52	29.98	29.50	30.03	30.14	30.25	30.48
MID	31.50	31.45	31.45	31.37	30.65	30.68	30.37	30.51	30.02	29.86	30.17	30.10	30.35	30.61
BOT	31.33	31.43	31.51	31.47	30.72	30.87	30.47	30.54	30.17	30.13	30.30	30.45	30.34	30.64
9 TOP	30.41	30.70	31.20	31.36	31.51	31.87	31.47	31.29		30.28	29.72	29.50	29.32	29.17
MID	30.50	30.75	31.17	31.52	31.29	31.91	31.52	31.24		30.27	29.83	29.57	29.40	29.21
BOT	32.17	31.75	31.18	31.62	31.73	31.88	31.63	31.27		30.28	29.83	29.57	29.40	29.31
10 TOP	32.05	32.44	32.46	32.54	32.72	33.25	32.09	32.15		31.63	31.27	31.17	31.17	31.36
MID	31.96	32.36	32.49	32.67	32.72	33.07	32.19	32.27		31.61	31.37	31.27	31.20	31.27
BOT	31.78	32.34	32.46	32.72	32.69	33.25	32.23	32.14		31.46	31.31	31.37	31.24	31.28
11 TOP	24.64	25.70	26.68	27.42	27.73	28.54	27.91	27.54		25.60	24.93	24.63	23.21	22.13
MID	24.62	25.70	26.72	27.37	27.76	28.57	27.89	27.54		25.81	24.93	24.63	23.85	22.13
BOT	24.65	25.64	26.68	27.34	27.68	28.72	27.89	27.55		25.82	24.89	24.31	23.80	22.70

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SALINITY (SECOND RUN)
PARTS PER THOUSAND

DATE ********* STATION	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
1 TOP	31.74	31.55	31.62	31.82		31.88	32.04	32.49		32.20		32.07	31.84	
MID	31.74	31.68	31.62	31.82		31.88	32.04	32.60		32.14		33.56	31.78	
BOT	31.74	31.82	31.52	31.82		31.92	30.74	31.75		32.14		32.15	31.78	
2 TOP	31.42	31.31	31.11	31.75		31.56	31.48	31.64		30.68	31.24	30.75	31.18	
MID	31.40	31.31	31.46	31.60		31.56	31.50	31.75		31.23	31.49	31.26	31.28	
BOT	31.40	31.32	31.46	31.70		32.22	31.55	31.68		31.80	31.39	31.68	31.45	
3 TOP														
MID														
BOT														
4 TOP	30.80	31.32	31.52	31.74		31.84	32.19	32.38		31.63	31.53	31.39	31.18	
MID	31.00	31.21	31.52	31.78		31.84	32.29	32.36		31.63	31.65	31.42	31.19	
BOT	30.12	30.18	31.50	31.78		31.86	31.73	31.53		31.61	31.66	31.42	30.56	
5 TOP	30.14	30.34	30.62	31.08		31.82	31.84	31.84		30.42	30.84	30.56	30.32	
MID	30.30	30.34	30.70	31.12		31.76	31.84	31.85		30.93	30.90	30.60	30.68	
BOT	30.24	30.32	29.80	31.22		30.88	31.90	31.85		31.90	29.27	28.84	30.66	
6 TOP	29.34	29.78	29.97	30.38	30.68	31.02	30.96	30.80			29.44	28.88	28.38	
MID	29.20	29.66	29.97	30.40	30.56	31.09	31.05	30.93			29.62	29.11	29.00	
BOT	29.44	30.52	30.04	30.40	31.26	31.08	31.86	31.08			29.57	29.11	30.62	
7 TOP	29.54	30.05	30.52	31.00	25.24	31.50	31.41	31.04			29.16	28.74	28.40	
MID								31.04			29.25	28.90	28.66	
BOT	29.50	30.00	30.52	31.20	31.10	31.50	31.43	32.21			29.23	28.96	31.81	
8 TOP	30.26	30.57	31.16	31.60	31.38	31.52	31.72	31.13			30.20	30.32	30.30	
MID	30.20	30.70	31.40	31.60	31.38	31.62	31.62	31.63			30.28	30.31	30.54	
BOT	30.20	30.98	29.88	31.62	31.59	31.62	31.72	31.58			29.26	28.80	30.49	
9 TOP	30.68	30.04	29.92	30.05	31.11	31.30	31.16	31.51		30.95	31.04	30.88	30.62	
MID	30.76	30.12	30.02	30.05	31.12	31.30	31.24	31.60		30.95	31.04	32.00	30.56	
BOT	31.84	30.30	30.00	30.08	31.20	31.26	31.97	31.33		30.95	31.03	32.00	34.50	
10 TOP			31.64	32.20		32.58	32.82	32.67		31.90		32.09	32.39	
MID			31.68	32.30		32.62	32.82	32.67		32.40		32.90	32.42	
BOT			32.28	32.30		32.20	32.76	32.64		32.84		32.70	31.90	
11 TOP	25.11	24.70	24.64	25.10		26.78	26.54	27.79		27.10	27.12	27.00	26.99	
MID	25.11	24.68	24.60	25.05		26.68	26.52	27.77		27.11	27.06	31.00	27.01	
BOT	25.11	29.88	26.58	25.05		31.73	26.54	32.16		31.26	31.21	31.12	30.72	

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CHLORIDES
MG/L

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	17892		17952		17860			17940		18439		18701		
2	17458		17844		18310			17779		18069		17928		
3														
4	17747		16927		17989			17779		16814				
5	17313		17844		17779			17576		16589		17200		
6	18053		18841		17088			17039		16042		16637		
7	18729		17184		17361			17007		16026		17522		
8	18906		18584		15570			17281		16814		17458		
9	18133		17844		18733			17667		17361		16959		
10	18053		18584		17989			18327		18021		17860		
11	18101		15350		15237			15430		14980		14433		

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL DISSOLVED SOLIDS
MG/L

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	33,520		33,490		33,630			33,390		33,780		33,820		
2	32,600		33,060		33,730			33,450		33,110		32,940		
3														
4	33,490		33,400		33,960			32,870		32,640		32,860		
5	32,880		33,080		33,450			32,870		31,640		31,790		
6	32,140		32,330		31,990			31,680		30,540		30,450		
7	33,190		32,900		32,180			31,360		30,080		30,760		
8	33,280		33,030		32,440			32,070		32,590		32,260		
9	32,780		33,140		33,650			33,270		32,900		31,890		
10	34,100		34,500		34,490			34,460		34,220		33,880		
11	26,130		28,450		29,610			29,340		27,550		26,500		

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SULFATES
MG/L

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	2,540		2,640		2,580			2,420		2,420		2,320		
2	2,540		2,540		2,440			2,460		2,420		2,340		
3														
4	2,580		2,440		2,540			2,460		2,360		2,320		
5	2,620		2,570		2,480			2,400		2,240		2,360		
6	2,460		2,460		2,300			2,320		2,180		2,140		
7	2,420		2,380		2,400			2,340		2,240		2,240		
8	2,460		2,360		2,520			2,320		2,280		2,320		
9	2,360		2,440		2,440			2,360		2,360		2,200		
10	2,420		2,620		2,600			2,540		2,320		2,320		
11	1,860		1,840		2,000			2,000		2,020		1,860		

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

ORGANIC NITROGEN
MG/L N

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	0.7	0.7	0.4	0.4	0.5	0.5	0.6	0.0	0.3	0.6	0.3	1.0	0.0	0.0
2	0.6	0.2	1.1	0.1	0.4	0.6	0.3	0.0	1.3	0.3	0.1	0.0	0.4	0.0
3														
4	1.3	0.5	0.0	0.4	0.4	0.4	0.6	0.0	0.1	0.2	0.1	0.0	0.2	0.2
5	1.3	0.0	1.0	1.2	0.2	0.6	0.3	0.0	0.0	0.1	0.6	0.2	1.1	0.0
6	0.2	1.0	0.8	0.6	0.0	0.3	0.4	0.0	0.6	0.2	0.2	0.6	0.3	0.3
7	0.9	0.6	0.4	0.2	0.0	0.6	0.5	0.0	0.0	0.2	0.3	0.4	0.0	0.0
8	2.7	0.3	0.6	0.2	0.0	0.9	0.2	0.0	0.4	0.4	0.3	0.4	0.0	0.2
9	1.8	0.6	0.0	0.3	0.3	1.0	0.3	0.0		0.3	0.0	0.3	0.2	0.2
10	0.4		2.9	0.6	0.5	0.7	1.0	0.2			1.0	0.2	0.7	0.0
11	0.9	0.8	0.4	0.6	0.2	0.4	0.4	0.7		0.5	0.0	0.6	0.0	0.0

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

AMMONIA
MG/L N

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3														
4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.0	0.0	0.0

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

NITRATE + NITRITE
MG/L N

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3														
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

TOTAL PHOSPHORUS
MG/L

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	0.08	0.15	0.15	0.20	0.15	0.23	0.14	0.14	0.14	0.13	0.11	0.09	0.09	0.09
2	0.11	0.10	0.20	0.14	0.15	0.15	0.10	0.12	0.14	0.10	0.09	0.08	0.09	0.08
3														
4	0.09	0.09	0.08	0.10	0.08	0.15	0.10	0.11	0.13	0.10	0.09	0.09	0.11	0.10
5	0.15	0.08	0.15	0.35	0.23	0.25	0.12	0.13	0.10	0.09	0.09	0.11	0.10	0.12
6	0.09	0.08	0.15	0.15	0.15	0.15	0.12	0.13	0.10	0.09	0.11	0.10	0.10	0.09
7	0.09	0.10	0.12	0.15	0.15	0.15	0.12	0.12	0.10	0.10	0.10	0.09	0.09	0.12
8	0.09	0.09	0.12	0.10	0.11	0.25	0.22	0.14	0.10	0.11	0.12	0.11	0.08	0.13
9	0.05	0.10	0.09	0.09	0.09	0.11	0.09	0.10		0.08	0.08	0.09	0.08	0.09
10	0.11	0.60	0.45	0.10	0.08	0.11	0.13	0.25		0.11	0.09	0.09	0.09	0.12
11	0.10	0.11	0.15	0.15	0.14	0.15	0.12	0.13		0.11	0.11	0.11	0.11	0.12

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

SOLUBLE PHOSPHORUS
MG/L

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	0.07	0.04	0.05	0.06	0.15	0.09	0.04	0.05	0.07	0.06	0.06	0.07	0.07	0.07
2	0.04	0.04	0.05	0.08	0.09	0.08	0.05	0.08	0.07	0.09	0.05	0.07	0.08	0.07
3														
4	0.07	0.04	0.05	0.08	0.04	0.10	0.05	0.08	0.06	0.07	0.07	0.08	0.07	0.07
5	0.08	0.05	0.09	0.15	0.21	0.09	0.05	0.09	0.07	0.07	0.07	0.07	0.07	0.08
6	0.05	0.06	0.05	0.09	0.09	0.11	0.06	0.09	0.08	0.07	0.08	0.08	0.07	0.08
7	0.08	0.03	0.08	0.08	0.07	0.08	0.08	0.09	0.07	0.07	0.08	0.08	0.08	0.07
8	0.05	0.05	0.05	0.08	0.08	0.08	0.08	0.10	0.07	0.07	0.08	0.08	0.07	0.08
9	0.05	0.05	0.05	0.05	0.06	0.08	0.05	0.09		0.07	0.07	0.07	0.08	0.08
10	0.11	0.06	0.05	0.03	0.06	0.04	0.04	0.05		0.05	0.07	0.07	0.08	0.09
11	0.10	0.05	0.10	0.12	0.08	0.09	0.09	0.11		0.09	0.09	0.09	0.09	0.10

PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CHLOROPHYLL A
UG/L

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	4.72	13.06			8.32	5.24	11.23	15.13	11.25	10.69	9.93	5.36	7.61	8.58
2	3.28	4.61			3.45	2.59	5.34	6.12	10.09	5.94	5.87	3.66	5.27	5.27
3														
4	4.50	6.62			3.93	2.31	3.85	8.18	13.61	5.36	5.56	3.93	5.73	4.79
5	5.74	4.99			5.19	3.07	3.02	6.51	9.56	5.45	5.41	4.48	6.68	7.80
6	2.22	4.62			4.38		2.59	4.79	6.76	6.06	6.55	5.83	7.80	5.29
7	1.65	3.60			4.79	3.23	2.92	5.84	7.82	5.23	7.77	5.26	5.96	5.49
8	1.73	4.97			2.18	2.17	5.01	8.74	10.67	8.72	8.06	5.69	5.41	4.71
9	2.22	4.26			2.02	1.49	3.10	6.70		4.10	4.48	3.92	5.52	4.48
10	4.89	14.19			4.79	3.19	5.14	17.47		9.68	6.64	7.74	5.43	6.98
11	2.83	4.60			5.44	2.77	4.50	5.00		5.90	6.83	5.46	5.63	5.75

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PORT ROYAL SOUND ENVIRONMENTAL STUDY
1970 SURVEYS

CHLOROPHYLL C
UG/L

DATE *********	10/12	10/13	10/14	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22	10/23	10/24	10/25
STATION														
1	0.00	2.52			3.11	0.62	2.77	3.90	0.00	0.00	0.00	2.52	0.00	0.63
2	0.00	0.00			0.28	0.00	1.20	4.18	1.48	4.71	0.47	0.00	0.02	0.00
3														
4	0.11	1.37			0.74	2.20	2.33	3.62	1.52	2.72	0.00	1.50	0.46	0.00
5	1.93	0.00			0.00	0.00	1.61	6.61	1.00	0.67	1.41	0.90	0.00	0.00
6	0.00	0.00			3.03		0.99	1.23	0.50	1.25	0.88	3.85	0.00	0.00
7	0.09	0.95			0.00	0.00	0.59	0.00	1.08	0.00	1.21	1.67	0.37	0.00
8	0.00	0.00			0.00	0.00	0.00	4.90	0.00	5.11	0.33	0.15	0.00	0.34
9	0.00	0.01			0.00	0.00	0.10	3.35		0.34	0.00	1.17	0.68	0.00
10	0.00	0.00			0.98	1.28	0.00	18.31		15.66	1.36	1.02	0.37	0.00
11	0.00	0.00			1.00	0.00	1.76	1.26		1.83	0.00	0.00	0.79	0.00

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Appendix Table
Port Royal Sound Environmental Study
Soluble Metals

Sta.	Date	Aluminum mg/l	Barium mg/l	Calcium mg/l	Cadmium mg/l	Chromium mg/l	Copper mg/l	Mercury mg/l	Potassium mg/l	Magnesium mg/l	Manganese mg/l	Sodium mg/l	Nickel mg/l	Lead mg/l	Silica mg/l	Zinc mg/l
1	10-13	0.01	0.	380	0.00	0.00	0.01	<0.0005	450	1,000	0.0	10,000	0.00	0.01	0.3	0.02
	10-17	0.02	0.	390	0.00	0.00	0.01	<0.0005	440	990	0.0	10,000	0.00	0.01	0.3	0.02
	10-22	0.01	0.	390	0.00	0.00	0.01	<0.0005	440	990	0.0	9,900	0.00	0.01	0.4	0.02
2	10-13	0.00	0.	380	0.00	0.00	0.01	<0.0005	450	1,000	0.0	9,800	0.00	0.00	0.4	0.01
	10-17	0.01	0.	380	0.00	0.00	0.00	<0.0005	430	980	0.0	9,800	0.00	0.00	0.4	0.01
	10-22	0.01	0.	380	0.00	0.00	0.01	<0.0005	450	980	0.0	9,800	0.00	0.01	0.4	0.01
4	10-13	0.01	0.	380	0.00	0.00	0.00	<0.0005	460	1,000	0.0	9,800	0.00	0.01	0.3	0.02
	10-17	0.01	0.	390	0.00	0.00	0.01	<0.0005	430	990	0.0	9,800	0.00	0.00	0.2	0.01
	10-22	0.01	0.	380	0.00	0.00	0.01	<0.0005	450	1,000	0.0	9,700	0.00	0.01	0.4	0.01
5	10-13	0.00	0.	390	0.00	0.00	0.01	<0.0005	450	1,020	0.0	9,800	0.00	0.00	0.4	0.01
	10-17	0.01	0.	390	0.00	0.00	0.01	<0.0005	440	1,000	0.0	9,800	0.00	0.01	0.3	0.01
	10-22	0.01	0.	380	0.00	0.00	0.01	<0.0005	450	990	0.0	9,700	0.00	0.01	0.4	0.01
6	10-13	0.01	0.	380	0.00	0.00	0.01	<0.0005	440	1,000	0.0	9,700	0.00	0.01	0.4	0.01
	10-17	0.01	0.	380	0.00	0.00	0.01	<0.0005	420	1,000	0.0	9,600	0.00	0.01	0.5	0.01
	10-22	0.00	0.	370	0.00	0.00	0.01	<0.0005	440	980	0.0	9,500	0.00	0.01	0.5	0.01
7	10-13	0.01	0.	390	0.00	0.00	0.02	<0.0005	440	1,000	0.0	10,000	0.00	0.00	0.3	0.01
	10-17	0.00	0.	390	0.00	0.00	0.00	<0.0005	450	1,010	0.0	9,500	0.00	0.01	0.4	0.01
	10-22	0.01	0.	380	0.00	0.00	0.00	<0.0005	450	990	0.0	9,800	0.00	0.00	0.4	0.01
8	10-13	0.00	0.	390	0.00	0.00	0.01	<0.0005	450	1,000	0.0	9,800	0.00	0.01	0.3	0.01
	10-17	0.01	0.	380	0.00	0.00	0.01	<0.0005	440	1,020	0.0	9,600	0.00	0.01	0.4	0.01
	10-22	0.01	0.	390	0.00	0.00	0.01	<0.0005	450	990	0.0	9,700	0.00	0.01	0.3	0.02
9	10-13	0.01	0.	390	0.00	0.00	0.01	<0.0005	450	970	0.0	9,800	0.00	0.00	0.3	0.01
	10-17	0.01	0.	380	0.00	0.00	0.01	<0.0005	430	990	0.0	9,200	0.00	0.01	0.2	0.02
	10-22	0.01	0.	390	0.00	0.00	0.01	<0.0005	440	980	0.0	9,500	0.00	0.00	0.3	0.02
10	10-13	0.01	0.	400	0.00	0.00	0.01	<0.0005	480	1,050	0.0	10,200	0.00	0.01	0.4	0.02
	10-17	0.01	0.	400	0.00	0.00	0.01	<0.0005	460	1,020	0.0	10,200	0.00	0.01	0.3	0.01
	10-22	0.01	0.	400	0.00	0.00	0.01	<0.0005	460	980	0.0	10,000	0.00	0.01	0.4	0.01
11	10-13	0.01	0.	360	0.00	0.00	0.01	<0.0005	400	960	0.0	9,200	0.00	0.01	0.4	0.02
	10-17	0.01	0.	350	0.00	0.00	0.01	<0.0005	420	970	0.0	9,000	0.00	0.01	0.4	0.02
	10-22	0.00	0.	370	0.00	0.00	0.01	<0.0005	430	990	0.0	9,100	0.00	0.01	0.3	0.01

Appendix C

PORT ROYAL SOUND WITH ACTUAL TIDES OF APRIL 1970
05-28-71

FEDERAL WATER QUALITY ADMINISTRATION
DYNAMIC FLOW IN A TWO-DIMENSIONAL SYSTEM

JUNCTIONS	CHANNELS	CYCLES	OUTPUT INTERVAL	TIME INTERVAL	INITIAL TIME	WRITE BINARY TAPE	RESTART INTERVAL	START PRINT
100	115	4410	18 CYCLES	100. SEC.	2.500 HRS.	CYCLES 2610 TO 4410	1800 CYCLES	CYCLE 2610

** JUNCTION DATA **

JUNCTION	INITIAL HEAD	SURFACE AREA	INPUT-OUTPUT	CHANNELS ENTERING JUNCTION				
1	-3.8000	27111104.	0.0	1	2	0	0	0
2	-3.8000	41666656.	0.0	1	3	0	0	0
3	-4.1000	133333328.	0.0	4	103	0	0	0
4	-3.9000	41700000.	0.0	5	6	7	0	0
5	-3.9000	58777776.	0.0	2	8	9	0	0
6	-3.9000	53777776.	0.0	3	8	10	76	0
7	-4.0000	61222208.	0.0	9	11	12	0	0
8	-4.0000	61888880.	0.0	10	11	13	0	0
9	-4.0000	51888880.	0.0	12	14	15	0	0
10	-4.0000	63111104.	0.0	13	14	16	0	0
11	-4.1000	35222208.	0.0	15	17	92	0	0
12	-4.1000	78111104.	0.0	16	19	20	0	0
13	-4.1000	40888880.	0.0	18	19	0	0	0
14	-4.1000	48666656.	0.0	17	18	21	93	0
15	-4.1000	49333328.	0.0	21	22	0	0	0
16	-4.1000	35555552.	0.0	22	23	24	25	0
17	-4.1000	27333328.	0.0	23	26	27	0	0
18	-4.1000	19888880.	0.0	27	28	0	0	0
19	-4.2000	14333333.	0.0	28	29	0	0	0
20	-4.2000	21777776.	0.0	29	30	0	0	0
21	-4.3000	27444432.	0.0	30	31	32	0	0
22	-4.3000	18222208.	0.0	31	33	0	0	0
23	-4.3000	8666667.	0.0	32	34	0	0	0
24	-4.3000	24444432.	0.0	33	34	35	0	0
25	-4.5000	9333333.	0.0	35	36	0	0	0
26	-4.5000	35555552.	0.0	36	0	0	0	0
27	-4.1000	13444444.	0.0	25	43	0	0	0
28	-4.1000	16777776.	0.0	24	26	61	0	0
29	-4.2000	17111104.	0.0	61	62	63	0	0
30	-4.2000	27333328.	0.0	63	64	66	0	0
31	-4.2000	5777778.	0.0	64	65	0	0	0
32	-4.2000	10222222.	0.0	65	0	0	0	0
33	-4.2000	7222222.	0.0	66	67	0	0	0
34	-4.2000	10777778.	0.0	67	68	69	0	0
35	-4.2000	9888889.	0.0	68	0	0	0	0
36	-4.1000	86777776.	0.0	20	37	0	0	0
37	-4.1000	80888880.	0.0	37	38	0	0	0
38	-4.1000	72222208.	0.0	38	39	0	0	0
39	-4.1000	53888880.	0.0	39	40	41	0	0

40	-4.1000	18666656.	0.0	41	42	43	62	0
41	-4.2000	56444432.	0.0	40	42	44	0	0
42	-4.2000	50555552.	0.0	44	45	46	0	0
43	-4.2000	19444432.	0.0	45	72	73	0	0
44	-4.2000	14111111.	0.0	73	74	0	0	0
45	-4.2000	11222222.	0.0	71	72	0	0	0
46	-4.2000	10666667.	0.0	70	74	75	0	0
47	-4.2000	7222222.	0.0	69	70	71	0	0
48	-4.2000	13888889.	0.0	75	0	0	0	0
49	-4.2000	58333328.	0.0	46	47	0	0	0
50	-4.3000	52000000.	0.0	47	48	0	0	0
51	-4.3000	45555552.	0.0	48	49	0	0	0
52	-4.3000	89444432.	0.0	49	50	0	0	0
53	-4.3000	33333328.	0.0	50	51	54	55	0
54	-4.3000	33333328.	0.0	51	52	0	0	0
55	-4.3000	37333328.	0.0	52	53	0	0	0
56	-4.3000	63666656.	-100.00	53	0	0	0	0
57	-4.3000	9333333.	0.0	55	57	0	0	0
58	-4.3000	15555556.	0.0	54	56	0	0	0
59	-4.3000	13000000.	0.0	57	58	56	0	0
60	-4.3000	25777776.	0.0	58	59	0	0	0
61	-4.2000	17222208.	0.0	59	60	0	0	0
62	-4.1000	15444444.	0.0	60	114	0	0	0
63	-3.8000	66555552.	0.0	76	77	0	0	0
64	-3.8000	56777776.	0.0	77	78	0	0	0
65	-3.9000	40444432.	0.0	78	79	0	0	0
66	-3.9000	36444432.	0.0	79	80	81	0	0
67	-3.9000	35888880.	0.0	80	82	84	0	0
68	-3.8000	22222208.	0.0	81	82	83	0	0
69	-3.8000	43555552.	0.0	83	0	0	0	0
70	-3.9000	40000000.	0.0	84	85	86	0	0
71	-3.9000	73555552.	0.0	86	0	0	0	0
72	-3.9000	24444432.	0.0	85	87	0	0	0
73	-4.0000	19111104.	0.0	87	88	0	0	0
74	-4.0000	14333333.	0.0	88	89	0	0	0
75	-4.0000	17111104.	0.0	89	90	0	0	0
76	-4.0000	10888889.	0.0	90	91	0	0	0
77	-4.0000	30111104.	0.0	91	115	0	0	0
78	-3.9000	33111104.	0.0	109	115	0	0	0
79	-4.1000	22111104.	0.0	92	94	0	0	0
80	-4.1000	21000000.	0.0	93	95	0	0	0
81	-4.1000	20000000.	0.0	94	96	0	0	0
82	-4.1000	15444444.	0.0	95	97	0	0	0
83	-4.2000	26333328.	0.0	96	98	0	0	0
84	-4.2000	37777776.	0.0	97	99	0	0	0
85	-4.2000	35666656.	0.0	4	98	99	0	0
86	-4.2000	32111104.	0.0	100	0	0	0	0
87	-4.2000	27222208.	0.0	103	104	0	0	0
88	-4.2000	27777776.	0.0	104	105	0	0	0
89	-4.3000	13333333.	0.0	105	106	0	0	0
90	-4.3000	12888889.	0.0	106	107	0	0	0
91	-4.3000	13333333.	0.0	107	108	0	0	0
92	-4.3000	19555552.	0.0	108	0	0	0	0
93	-4.2000	78333328.	0.0	101	102	0	0	0
94	-4.1000	65555552.	0.0	100	101	102	0	0
95	-3.9000	9666667.	0.0	109	110	0	0	0
96	-3.9000	13777778.	0.0	5	110	0	0	0
97	-4.0000	9333333.	0.0	6	111	112	0	0
98	-4.0000	16777776.	0.0	7	112	113	0	0
99	-4.0000	18888880.	0.0	111	0	0	0	0
100	-4.0000	16222222.	0.0	114	113	0	0	0

** CHANNEL DATA **

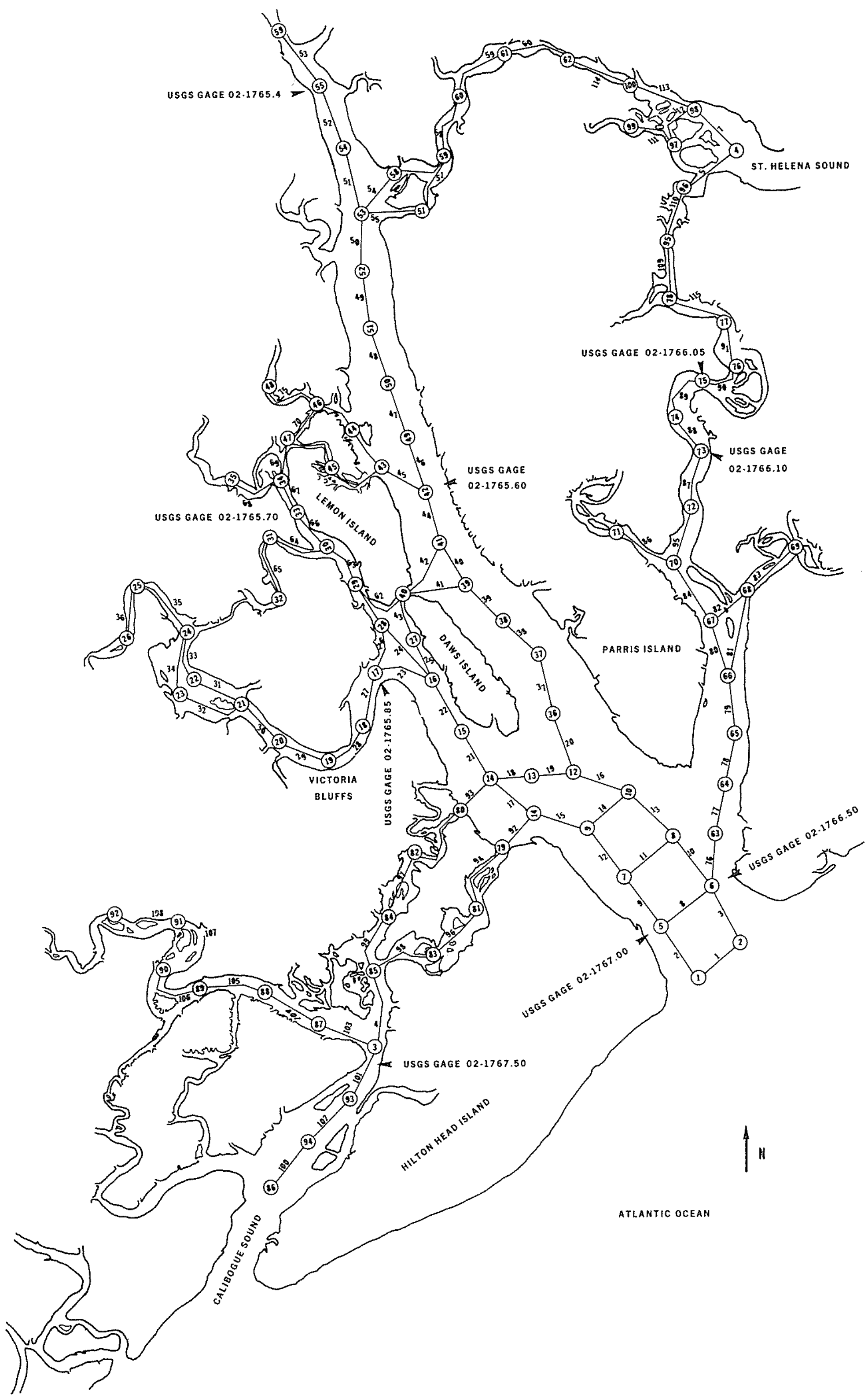
CHANNEL	LENGTH	WIDTH	AREA	MANNING	VELOCITY	HYD RADIUS	JUNCTIONS AT ENDS	
1	6600.	7333.	305052.0	0.034	0.0	41.6	1	2
2	7000.	7250.	214600.0	0.034	0.0	29.6	1	5
3	7833.	7250.	213875.0	0.034	0.0	29.5	2	6
4	7500.	7333.	125394.0	0.034	0.0	17.1	3	85
5	9667.	667.	5269.0	0.049	0.0	7.9	4	96
6	8533.	667.	4135.0	0.049	0.0	6.2	4	97
7	7500.	2000.	14400.0	0.039	0.0	7.2	4	98
8	7333.	7500.	289500.0	0.034	0.0	38.6	5	6
9	8267.	7250.	229825.0	0.034	0.0	31.7	5	7
10	7633.	5000.	169000.0	0.034	0.0	33.8	6	8
11	6000.	7833.	248306.0	0.034	0.0	31.7	7	8
12	7667.	7667.	194742.0	0.034	0.0	25.4	7	9
13	7833.	7000.	208600.0	0.034	0.0	29.8	8	10
14	6600.	6917.	222727.0	0.034	0.0	32.2	9	10
15	7500.	4667.	112941.0	0.034	0.0	24.2	9	11
16	6667.	6667.	212010.0	0.034	0.0	31.8	10	12
17	6333.	4667.	107808.0	0.034	0.0	23.1	11	14
18	4867.	2667.	41872.0	0.039	0.0	15.7	13	14
19	6133.	2333.	39194.0	0.039	0.0	16.8	12	13
20	7933.	9000.	252000.0	0.034	0.0	28.0	12	36
21	7033.	5000.	108000.0	0.034	0.0	21.6	14	15
22	7600.	4667.	101741.0	0.034	0.0	21.8	15	16
23	5833.	2000.	50400.0	0.034	0.0	25.2	16	17
24	9667.	1667.	24838.0	0.039	0.0	14.9	16	28
25	5667.	2000.	29200.0	0.039	0.0	14.6	16	27
26	6333.	1833.	31710.0	0.039	0.0	17.3	17	28
27	7133.	3000.	60900.0	0.049	0.0	20.3	17	18
28	6500.	2000.	53600.0	0.049	0.0	26.8	18	19
29	6967.	2267.	44887.0	0.049	0.0	19.8	19	20
30	6600.	1833.	36293.0	0.049	0.0	19.8	20	21
31	7100.	1667.	20171.0	0.049	0.0	12.1	21	22
32	8833.	1667.	14503.0	0.049	0.0	8.7	21	23
33	6000.	1000.	10500.0	0.049	0.0	10.5	22	24
34	7667.	1000.	12400.0	0.049	0.0	12.4	23	24
35	6667.	1000.	10000.0	0.049	0.0	10.0	24	25
36	7333.	1333.	7500.0	0.049	0.0	5.6	25	26
37	7833.	9667.	226207.0	0.034	0.0	23.4	36	37
38	6200.	9667.	216541.0	0.034	0.0	22.4	37	38
39	6467.	8833.	205809.0	0.034	0.0	23.3	38	39
40	6467.	7333.	192124.0	0.034	0.0	26.2	39	41
41	8033.	667.	8137.0	0.039	0.0	12.2	39	40
42	7600.	667.	5736.0	0.039	0.0	8.6	40	41
43	7167.	500.	7450.0	0.049	0.0	14.9	27	40
44	7000.	7333.	225133.0	0.034	0.0	30.7	41	42
45	5967.	1667.	42175.0	0.039	0.0	25.3	42	43
46	7167.	6667.	147340.0	0.034	0.0	22.1	42	49
47	7333.	6667.	103333.0	0.034	0.0	15.5	49	50
48	7333.	6667.	109339.0	0.034	0.0	16.4	50	51
49	7333.	7000.	91700.0	0.034	0.0	13.1	51	52
50	7333.	5000.	48000.0	0.034	0.0	9.6	52	53
51	8100.	4667.	45737.0	0.034	0.0	9.8	53	54
52	8333.	3667.	35203.0	0.034	0.0	9.6	54	55

53	8333.	3000.	32100.0	0.034	0.0	10.7	55	56
54	6667.	1667.	18503.0	0.039	0.0	11.1	53	58
55	7000.	1000.	13000.0	0.049	0.0	13.0	53	57
56	7633.	667.	9338.0	0.049	0.0	14.0	58	59
57	8833.	667.	10338.0	0.049	0.0	15.5	57	59
58	8333.	1500.	14100.0	0.049	0.0	9.4	59	60
59	9500.	1167.	9686.0	0.049	0.0	8.3	60	61
60	8000.	667.	6403.0	0.049	0.0	9.6	61	62
61	6000.	1333.	24660.0	0.039	0.0	18.5	28	29
62	8000.	333.	3330.0	0.049	0.0	10.0	29	40
63	5000.	1667.	23838.0	0.049	0.0	14.3	29	30
64	8667.	967.	10443.0	0.049	0.0	10.8	30	31
65	9333.	567.	8108.0	0.049	0.0	14.3	31	32
66	6967.	1333.	13730.0	0.049	0.0	10.3	30	33
67	4500.	1333.	15596.0	0.049	0.0	11.7	33	34
68	7333.	1000.	9400.0	0.049	0.0	9.4	34	35
69	5333.	667.	5070.0	0.049	0.0	7.6	34	47
70	5667.	500.	2900.0	0.049	0.0	5.8	46	47
71	7667.	667.	6203.0	0.049	0.0	9.3	45	47
72	8333.	667.	13874.0	0.049	0.0	20.8	43	45
73	7333.	1667.	16003.0	0.049	0.0	9.6	43	44
74	4333.	1000.	8800.0	0.049	0.0	8.8	44	46
75	8333.	800.	7280.0	0.049	0.0	9.1	46	48
76	7000.	5000.	131000.0	0.039	0.0	26.2	6	63
77	7167.	6000.	102000.0	0.039	0.0	17.0	63	64
78	7333.	6667.	109339.0	0.039	0.0	16.4	64	65
79	5167.	5000.	92500.0	0.039	0.0	18.5	65	66
80	7167.	3333.	56661.0	0.039	0.0	17.0	66	67
81	11333.	1667.	27005.0	0.039	0.0	16.2	66	68
82	6167.	667.	8537.0	0.039	0.0	12.8	67	68
83	8500.	1333.	27866.0	0.049	0.0	20.9	68	69
84	8833.	2667.	49873.0	0.039	0.0	18.7	67	70
85	7500.	2575.	33990.0	0.039	0.0	13.2	70	72
86	8833.	1208.	18487.0	0.049	0.0	15.3	70	71
87	7667.	2358.	36318.0	0.039	0.0	15.4	72	73
88	5500.	2000.	26000.0	0.049	0.0	13.0	73	74
89	7167.	1500.	22800.0	0.049	0.0	15.2	74	75
90	5500.	1333.	21061.0	0.049	0.0	15.8	75	76
91	6667.	1333.	24667.0	0.049	0.0	18.5	76	77
92	6067.	1233.	11840.0	0.039	0.0	9.6	11	79
93	5500.	667.	5603.0	0.039	0.0	8.4	14	80
94	9333.	1333.	17196.0	0.049	0.0	12.9	79	81
95	10500.	750.	10725.0	0.049	0.0	14.3	80	82
96	8000.	1333.	11997.0	0.049	0.0	9.0	81	83
97	8667.	667.	10005.0	0.049	0.0	15.0	82	84
98	8667.	667.	14407.0	0.049	0.0	21.6	83	85
99	5333.	1500.	18150.0	0.049	0.0	12.1	84	85
100	10667.	2000.	39800.0	0.039	0.0	19.9	86	94
101	7833.	2833.	91781.0	0.039	0.0	32.4	93	94
102	7333.	5433.	111376.0	0.034	0.0	20.5	93	94
103	8167.	3000.	44400.0	0.039	0.0	14.8	3	87
104	7833.	2333.	44560.0	0.039	0.0	19.1	87	88
105	8167.	2000.	27400.0	0.049	0.0	13.7	88	89
106	8333.	2000.	29800.0	0.049	0.0	14.9	89	90
107	10333.	1333.	13730.0	0.049	0.0	10.3	90	91
108	8333.	1333.	11597.0	0.049	0.0	8.7	91	92
109	7167.	833.	10917.0	0.049	0.0	13.1	78	95
110	7667.	667.	8600.0	0.049	0.0	12.9	95	96
111	6667.	667.	3867.0	0.049	0.0	5.8	97	99
112	8333.	333.	2331.0	0.049	0.0	7.0	97	98
113	8667.	1000.	12300.0	0.049	0.0	12.3	98	100

114	8833.	1133.	13487.0	0.049	0.0	11.9	62	100
115	5000.	1333.	13197.0	0.039	0.0	9.9	77	78

APPENDIX C

PORT ROYAL SOUND ENVIRONMENTAL STUDY MATHEMATICAL MODEL NODES AND CHANNEL LOCATIONS



Appendix D

Table
Port Royal Sound Environmental Study
Bottom Sediment Analysis
1970 Surveys

Station	Date	Barium mg/kg	Cadmium mg/kg	Chromium mg/kg	Copper mg/kg	Mercury mg/kg	Manganese mg/kg	Nickel mg/kg	Lead mg/kg	Zinc mg/kg
1	4/19	0.	<0.5	5.	3.6	0.03	45.	8.	8.	6.
2		0.	<0.5	10.	2.8	0.04	50	10.	13.	12.
3		0.	<0.5	13.	3.0	0.03	80.	6.	13.	15.
4		0.	<0.5	18.	3.0	0.03	100.	15.	10.	9.
5		0.	<0.5	13.	2,8	0.03	160.	6.	13.	15.
6		0.	<0.5	8.	2.0	0.03	100.	8.	10.	10.
7		0.	<0.5	10.	3.0	0.03	100.	7.	10.	11.
8		0.	<0.5	10.	4.0	0.03	85	7.	10.	9.
9		0.	<0.5	12.	4.0	0.03	85	10.	12.	10.
10		0.	<0.5	6.	2.0	0.03	85	3.	10.	6.
2	7/16	0.	<0.5	12.	4.	0.03	60.	10.	7.	13.
4	7/16	0.	<0.5	30.	8.	0.04	120.	20.	15.	18.
5	7/15	0.	<0.5	16.	4.	0.03	80.	8.	8.	10.
6	7/16	0.	<0.5	15.	6.	0.03	120.	8.	10.	15.
7	7/16	0.	<0.5	15.	4.	0.03	60.	10.	10.	15.
8	7/16	0.	<0.5	10.	4.	0.03	100.	10.	11.	15.
9	7/15	0.	<0.5	18.	5.	0.03	80.	10.	9.	14.
10	7/14	0.	<0.5	4.	2.	0.03	100.	3.	7.	6.
11	7/15	0.	<0.5	19.	4.	0.03	60.	10.	10.	15.
1	10/16	0.	<0.4	8.	2.0	0.04	44.	1.0	3.7	10.
2		0.	<0.4	6.	1.8	0.02	48.	1.2	3.8	10.
4		0.	<0.4	8.	2.2	0.02	70.	2.8	3.7	15.
5		0.	<0.4	5.	2.4	0.02	90.	2.9	3.5	15.
6		0.	<0.4	6.	2.1	0.02	45.	2.7	3.0	14.
7		0.	<0.4	5.	2.2	0.02	48.	2.6	3.0	13.
8		0.	<0.4	6.	1.7	0.02	46.	1.7	3.2	12.
9		0.	<0.4	5.	1.8	0.02	55.	2.0	3.4	14.
10		0.	<0.4	5.	1.8	0.01	60.	2.0	3.5	11.
11		0.	<0.4	6.	1.8	0.02	53.	2.0	3.5	11.

Appendix to Seasonal Distribution and Relative Abundance of Fishes in the Channel Reaches and Shore Areas of Port Royal Sound

TABLE 1.—Species, Numbers, and Length Measurements (TL) of Fish Taken from Anchored Gill Net Sets in Channel, Port Royal Sound, South Carolina, April, 1970

Number of Fish is Subtended by Length Mean (inches) and by Length Range (inches)

	Station Number and (No. Net Days)									
Species of Fish	1 (5–days)	2 (5–days)	3 (6–days)	4 (6–days)	5 (5–days)	6 (6–days)	7 (6–days)	8 (6–days)	9 (4–days)	10 (6–days)
Carcharhinidae–requiem sharks										
Aprionodon isodon	2		2		1					3
finetooth shark	32.1		24.4		—					31.5
	28.8–35.4		12.7–36.0		25.8					29.8–34.6
Sphyrnidae–hammerhead sharks										
Sphyrna lewini	3	1								7
scalloped hammerhead	36.0	—								35.3
	30.8–44.8	46.0								25.0–44.8
Sphyrna tiburo			1	2	1	1				1
bonnethead			—	40.3	—	—				—
			40.4	40.2–40.3	33.3	48.0				34.8
Rhinobatidae–guitarfishes										
Rhinobatos lentiginosus	1	1		11						
Atlantic guitarfish	—	—		24.1						
	24.8	24.4		23.6–24.8						
Dasyatis, stingrays										
Lasyati sabina		1	1	1			3	1		
Atlantic stingray		—	—	—			22.2	—		
		19.7	25.8	38.0			15.2–28.0	24.4		
Acipenseridae–sturgeons										
Acipenser oxyrhynchus							2			
Atlantic sturgeon							23.2			
							20.4–26.0			
Lepisosteidae–gars										
Lepisosteus osseus		7	1	3	7	4	9	43	3	
longnose gar		34.8	—	27.3	31.7	32.0	30.9	31.1	35.1	
		25.3–39.3	43.2	24.3–33.2	24.6–36.8	24.2–37.4	28.3–34.2	24.0–38.2	28.3–40.8	
Clupeidae–herrings										
Brevoortia tyrannus	2	11	128	48	12	14	5	30	26	38
Atlantic menhaden	5.4	7.3	6.3	5.2	6.4	5.8	6.1	5.6	4.8	6.3
	5.2–5.6	5.7–9.2	5.4–11.8	4.1–8.4	5.2–9.2	5.3–7.4	5.0–8.1	5.0–6.0	4.6–6.0	5.3–8.6
Ariidae–sea catfishes										
Galeichthys felis	2	5					2		1	
sea catfish	12.2	12.8					8.6		—	
	12.0–12.4	11.2–14.0					8.2–9.0		12.8	
Gadidae–codfishes and hakes										
Urophycis regius			1	17	2				4	2
spotted hake			—	4.6	7.6				5.6	5.6
			4.4	4.0–5.4	7.4–7.8				4.2–8.2	5.5–5.6
Serranidae–sea basses										
Centropristis striatus			1	3						
black sea bass			-	5.2						
			7.2	4.3–7.0						
Pomatomidae–bluefishes										
Pomatomus saltatrix	1	1	17	3			1			1
bluefish	—	—	8.6	9.2			—			—
	7.0	6.2	6.7–10.8	7.6–12.1			8.6			6.2

Sciaenidae–drums										
Bairdiella chrysura		30		3	2			7		
silver perch		5.6		4.6	6.4			6.1		
		5.2–6.0		5.0–5.6	5.6–7.1			5.1–8.0		
Cynoscion regalis	1									
weakfish	—									
	12.4									
Meticirrhus saxatilis	2	8		11	2		1	1	1	7
northern kingfish	10.8	10.2		8.4	8.4		—	—	—	7.8
	8.6–13.0	8.6–12.0		4.4–12.0			8.6	12.0	13.2	4.1–12.0
Trichiuridae–cutlassfishes										
Trichiurus lepturus				1						
Atlantic cutlassfish				—						
				8.0						
Triglidae–searobin										
Prionotus carolinus				2						
northern searobin				3.3						
				2.8–3.7						
Stromateidae–butterfishes										
Poronotus triacanthus	2					1				
butterfish	4.8					—				
	4.6–5.0					4.8				
Bothidae–lefteye flounders										
Etropus crossotus				2						
fringed flounder				3.6						
				3.2–3.9						
Paralichthys dentatus		3			1				2	
summer flounder		6.9			—				9.2	
		5.9–8.7			8.2				9.1–9.3	
Paralichthys lethostigma		3			2			1		
southern flounder		9.3			9.9			—		
		8.6–10.4			8.3–11.5			10.6		
Soleidae–soles										
Trinectes maculatus							1			
hogchoker							—			
							5.8			
Cynoglossidae–tonguefishes										
Symphurus plagiusa		8	1	19			4	1	8	1
blackcheek tonguefish		5.4	—	4.1			6.2	—	4.2	—
		4.9–6.0	4.8	4.1–4.2			4.8–6.8	4.6	4.1–5.0	5.2
Diodontidae–porcupinefishes										
Chilomycterus schoepfi							1			
striped burrfish							—			
							5.8			
Total species	9	12	9	14	9	4	10	7	7	8
Total fishes	16	79	153	126	30	20	29	84	45	60

TABLE 2.—Species, Numbers, and Length Measurements (TL) of Fish Taken from Anchored Gill Nets in Channel, Port Royal Sound, South Carolina, July, 1970

Number of Fish is Subtended by Length Mean (inches) and by Length Range (inches)

	Station Number and (No. Net Days)								
Species of Fish	1 (4-days)	2 (5-days)	4 (5-days)	5 (6-days)	6 (6-days)	7 (6-days)	8 (6-days)	9 (6-days)	10 (5-days)
Carcharhinidae–requiem sharks									
Aprionodon isodon	9	16	12	33	14	7	19	9	
finetooth shark	28.0	25.0	29.4	26.8	24.8	24.5	29.0	26.6	
	23.2–50.3	23.0–27.1	24.4–36.9	23.2–36.2	23.0–26.6	22.1–26.8	25.0–36.2	20.2–29.4	
Sphyrnidae–hammerhead sharks									
Sphyrna lewini	8	28		6	7	7	6	1	5
scalloped hammerhead	21.6	19.8		19.6	22.7	22.7	20.7	—	24.7
	17.3–35.4	17.3–23.2		17.0–23.0	16.9–35.0	17.8–36.8	18.6–22.6	20.4	19.8–34.6
Lepisosteidae–gars									
Lepisosteus osseus					1		1		
longnose gar					—		—		
					34.5		27.2		
Clupeidae–herrings									
Brevoortia tyrannus	305	152	9	17	100	31	10	3	3
Atlantic menhaden	6.7	6.7	7.8	7.1	6.9	6.8	9.1	6.8	6.0
	5.0–8.1	5.9–7.8	6.3–10.6	6.6–7.7	6.3–7.5	5.9–7.9	5.6–11.0	6.6–6.9	5.5–6.7
Opisthonema oglinum			2	7			6	10	
Atlantic thread herring			6.5	7.1			6.8	7.5	
			6.3–6.7	6.3–7.9			4.9–7.5	7.3–7.7	
Ariidae–sea catfishes									
Bagre marinus				1	3				
gafftopsail catfish				—	17.6				
				9.7	17.0–18.0				
Galeichthys felis			9	7	2	2	1	1	7
sea catfish			9.5	9.8	10.7	10.5	—	—	9.4
			5.9–11.4	6.5–11.8	8.4–12.9	10.4–10.5	9.8	13.6	7.1–14.3
Pomatomidae–bluefishes									
Pomatomus saltatrix		3						1	
bluefish		86						—	
		7.0–9.4						12.8	
Carangidae–jacks, scads and pompanos									
Chloroscombrus chrysurus					1				
bumper					—				
					5.4				
Sciaenidae–drums									
Bairdiella chrysura				12		2	1		
silver perch				6.7		6.1	—		
				5.7–11.0		5.8–6.3	5.6		
Cynoscion nebulosus							1		
spotted seatrout							—		
							10.6		
Leiostomus xanthurus		1	3				10		5
spot		—	4.3				5.7		6.3
		6.9	2.4–5.5				5.1–7.1		5.1–7.1
Micropogon undulatus		1	1		1	1			
Atlantic croaker		—	—		—	—			
		5.9	4.7		6.3	6.7			
Menticirrhus saxatilis		1	3	4		4	5		4
northern kingfish		—	8.7	9.4		10.2	9.7		9.6
		5.9	7.7–9.5	7.7–10.2		9.7–10.6	7.7–12.6		9.6–9.7
Trichiruidae–cutlassfishes									
Trichiurus lepturus	1								
Atlantic cutlassfish	—								
	21.0								
Scombridae–mackerals and tuna									
Scomberomorus maculatus		3							
Spanish mackeral		9.1							
		7.9–9.8							
Echeneidae–remoras									
Echeneis raucrafes									1
shark sucker									—
									5.3
Total species	4	8	7	8	8	7	10	6	6
Total fishes	323	205	39	87	129	54	60	25	25

TABLE 3.—Species, Numbers, and Length Measurements (TL) of Fish Taken from Drift Nets Sets in Channel, Port Royal Sound, South Carolina, July, 1970

Number of Fish is Subtended by Length Mean (inches) and by Length Range (inches)

Species of Fish	Stations * 1	2	4	5	6	7	8	9	10
Carcharhinidae–requiem Sharks									
Aprionodon isodon	11	5	4	8	7	6	6		2
finetooth shark	25.1	26.0	29.8	26.7	23.7	24.4	26.9		27.5
	21.9–28.3	24.0–29.8	17.0–40.1	23.8–37.0	19.3–26.8	23.4–25.6	23.6–27.9		26.9–28.2
Sphyrnidae–hammerhead sharks									
Sphyrna lewini	6	12		5	2	8	1		
scalloped hammerhead	27.3	21.1		17.1	18.9	20.3	—		
	17.5–37.7	16.4–22.5		14.3–18.5	17.7–20.7	17.8–23.2	20.6		
Sphyrna tiburo							1		
bonnethead							—		
							24.7		
Dasyatidae–stingrays									
Dasyatis sabina						1			
Atlantic stingray						—			
						20.1			
Clupeidae–herrings									
Brevoortia tyrannus	144	29	3	5	8	7	4		6
Atlantic menhaden	6.7	6.9	9.8	8.2	6.8	8.4	10.4		7.4
	5.1–8.3	5.3–7.5	9.2–10.9	6.7–10.6	6.3–8.3	6.6–9.8	9.9–10.3		5.9–10.6
Opisthonema oglinum	2			2			3		
Atlantic thread herring	7.2			8.0			6.6		
	7.0–7.4			7.9–8.1			6.1–7.3		
Ariddae–sea catfish									
Bagre marinus					1				
gafftopsail catfish					—				
					11.8				
Galeichthys felis			8	7	1	3	1		
sea catfish			9.4	9.9	—	8.6	—		
			6.3–13.4	6.4–11.9	12.9	6.3–10.2	11.8		
Pomatomidae–bluefishes									
Pomatomus saltatrix	1								
bluefish	—								
	9.9								
Carangidae–jacks, scads and pompanos									
Chloroscombrus chrysura						3		1	
bumper						5.9		—	
						5.8–6.0		6.7	
Sciaenidae–drums									
Bairdiella chrysura	1			17			1		
silver perch	—			6.1			—		
	6.1			5.0–7.9			5.9		
Leiostomus xanthurus		5	18		3	3	9		
spot		6.0	5.8		5.6	5.4	5.7		
		4.7–7.3	2.6–6.8		5.9–6.0	4.7–6.5	4.7–7.3		
Micropogon undulatus	3				1			4	1
Atlantic croaker	6.5				—			6.8	—
	5.9–6.9				7.1			6.7–6.9	6.1
Menticirrhus saxatilis			2	1		5		1	1
northern kingfish			8.2	—		9.4		—	—
			7.7–8.6	8.6		7.7–12.5		8.6	9.7
Trichiuridae–cutlassfishes									
Trichiurus lepturus				1					
Atlantic cutlassfish				—					
				21.5					
Scombridae–mackerals and tunas									
Scomberomorus maculatus			2						
Spanish mackeral			14.0						
			9.0–18.7						
Triglidae–searobins									
Prionotus scitulus			6						
leopard searobin			6.1						
			4.6–6.7						
Stromateidae–butterfishes									
Poronotus triacanthus	2					3	1		
butterfish	5.6					6.3	—		
	5.5–5.7					5.9–6.4	5.5		
Bothidae–lefteye flounders									
Etromus crossotus	1								
fringed flounder	—								
	2.8								
Total species	9	4	7	8	7	9	9	3	4
Total fishes	175	51	43	46	23	39	27	6	10

* Four hours drift time per station

TABLE 4.—Species, Numbers, and Length Measurements (TL) of Fish Taken from Drift Net Sets in Channel, Port Royal Sound, South Carolina, October, 1970

Number of Fish is Subtended by Length Mean (inches) and by Length Range (inches)

Species of Fish	Stations * 1	2	4	5	6	7	8	9	10
Sphyrnidae–hammerhead sharks *Sphyrna tiburo* bonnethead shark				1 — 15.7					
Lepisosteidae–gars *Lepisosteus osseus* longnose gar					2 32.3 31.6–33.0	2 31.8 31.6–32.0			
Elopidae–tarpons *Megalops atlantica* tarpon			1 — 7.5						
Clupeidae–herrings *Brevoortia tyrannus* Atlantic Menhaden	91 7.4 6.4–10.4	86 7.2 6.6–8.3	92 7.3 6.7–8.1	5 7.3 4.7–8.1	2 7.4 7.0–7.7	9 7.3 6.4–7.7	95 7.3 6.8–7.9	10 8.7 7.9–10.3	101 7.4 6.9–8.3
Opisthonema oglinum Atlantic thread herring	8 6.9 6.3–7.3							1 — 4.9	
Ariidae–sea catfishes *Bargre marinus* gafftopsail catfish						1 — 8.1			
Pomatomidae–bluefishes *Pomatomus saltatrix* bluefish	1 — 12.6		7 9.0 9.4–11.4				7 8.9 9.6–10.9		
Carangidae–jacks, scads and pompanos *Chloroscombrus chrysurus* bumper						2 4.6 4.4–4.7			
Sciaenidae–drums *Bairdiella chrysura* silver perch			1 — 5.9		1 — 7.3	1 — 7.3			
Cynoscion nebulosus spotted sea trout					2 9.3 8.4–9.8				
Leiostomus xanthurus spot		4 6.9 6.3–8.4	8 6.9 6.1–9.0		2 6.9 6.7–7.1	11 6.1 5.1–7.1	4 6.5 6.1–6.9	14 6.6 6.3–7.2	11 6.8 6.6–7.1
Menticirrhus saxatilis northern kingfish	3 9.5 7.9–11.4	8 9.7 7.5–12.6			2 8.7 8.6–8.8	4 8.4 7.3–10.8	4 10.8 9.4–12.2	2 12.5 12.5–15.6	6 12.0 10.4–13.4
Scombridae–mackerals and tunas *Scomberomorus maculatus* Spanish mackeral			1 — 7.8						
Triglidae–searobins *Prionotus scitulus* Leopard searobins						1 — 7.1			
Stromateidae–butterfishes *Paprilus alepidotus* southern harvestfish	1 — 7.1								
Bothidae–lefteye flounders *Etropus crossotus* fringed flounder				1 — 3.5					
Cynoglossidae–tonguefishes *Symphurus plagiusa* blackcheek tonguefish				3 4.9 4.5–5.1	2 5.3 5.2–5.3	1 — 4.9			
Echeneidae–remoras *Echeneis raucrates* sharksucker				1 — 8.3		1 — 7.0			
Total species	5	3	6	5	7	10	4	4	3
Total fishes	**104**	**98**	**110**	**11**	**13**	**33**	**110**	**27**	**118**

* Four hours drift time per station

TABLE 5.—Species, Numbers and Length Measurements (TL) of Fish Taken from Near-Shore Gill Net Sets, Port Royal Sound, South Carolina, October, 1970

Number of Fish is Subtended by Length Mean (inches) and by Length Range (inches)

Species of Fish	Stations * 2	4	5	6	7	8	9
Carcharinidae-requiem sharks							
Megaprion brevirostric lemon shark		2 33.2 31.8-34.6				2 33.9 33.6-34.2	
Dasyatidae-stingrays							
Dasyatis sabina, Atlantic stingray	1 — 20.2				1 — 27.9	1 — 24.0	
Lepisosteidae-gars							
Lepisosteus osseus longnose gar		1 — 41.3	10 29.7 22.8-36.6	4 32.7 27.5-39.1	3 33.3 31.4-36.5	2 37.8 37.7-37.9	4 33.2 26.3-38.5
Elopidae-tarpons							
Elops saurus ladyfish	1 — 12.8						4 12.4 11.8-12.8
Clupeidae-herrings							
Brevoortia tryannus Atlantic menhaden	1 — 13.2		1 — 7.1				
Synodontidae-lizardfishes							
Synodus foetens, inshore lizardfish			1 — 7.9	3 10.6 10.2-11.4			1 — 13.0
Ariidae-sea catfish							
Bagre marinus, gafftopsail catfish				1 — 17.2			
Galeichthys felis, sea catfish		2 11.1 10.2-12.0	13 11.9 10.2-11.0	3 10.6 6.8-11.8			
Pomatomidae-bluefishes							
Pomatomus saltatrix bluefish					1 — 10.6	1 — 13.4	1 — 10.4
Pomadasyidae-grunts							
Orthopristis chrysopterus pigfish	1 — 6.1	2 6.1 5.5-6.7	1 — 7.3			1 — 7.1	3 7.5 7.2-7.7
Scinenidae-drums							
Bairdiella chrysura silver perch			1 — 7.3			4 6.3 5.3-7.1	1 — 10.9
Cynoscion nebulosus spotted seatrout	4 10.1 8.6-12.8		4 9.8 9.0-11.0		1 — 11.0	4 10.4 9.8-11.0	2 16.0 12.8-19.3
Cynoscion regalis weakfish	1 — 12.2						
Leiostomus xanthurus spot	15 6.6 5.3-8.6		12 6.9 6.5-7.5	7 6.0 5.1-6.3		9 8.0 8.3-9.4	
Menticirrhus saxatilis northern kingfish	4 11.0 9.2-12.6				1 — 12.6	3 12.1 11.8-12.2	3 11.7 9.4-13.4
Pogonias cromis, black drum		3 10.2 8.6-12.0	4 7.9 4.7-10.4	3 9.2 8.6-9.8	1 — 9.8		
Selaenops ocellata, red drum	2 20.0 16.7-23.4	2 16.8 16.7-16.9					

TABLE 5 — (Continued

Species of Fish	Stations * 2	4	5	6	7	8	9
Sparidae porgies							
Archosargus probatocephalus sheepshead		1 — 9.0			3 8.8 7.2-10.6		
Lagodon rhomboides pinfish		1 — 6.5		1 — 6.3			1 — 7.3
Ephippidae-spadefishes							
Chaetodipterus faber Atlantic spadefish					1 — 4.0		
Scombridae-mackerals and tunas							
Scomberomorus maculatus Spanish mackeral						1 — 8.0	
Triglidae-searobin							
Prionotus scitulus leopard searobin	1 — 5.5						2 6.3 6.1-6.5
Stromateidae-butterfishes							
Poronotus triacanthus butterfish	1 — 4.5						
Mugilidae-mullets							
Mugil cephalus striped mullet	1 — 6.9			2 8.7 8.6-8.8			4 8.8 8.6-8.9
Bothidae-lefteye flounders							
Paralichthys albigutta gulf flounder		1 — 13.8				1 — 8.4	
Paralichthys lethostigma southern flounder		1 — 12.6		2 9.4 7.9-11.0			
Echeneidae-remoras							
Echeneis naucrates sharksucker			1 — 7.9				
Tetraodontidae-puffers							
Sphaeroides maculatus northern puffer						1 — 6.9	
Diodontidae-porcupine fish							
Chilomycterus schoepfi striped burrfish	1 — 8.3					2 8.3 8.3-8.4	
Total species	13	10	10	9	8	13	11
Total fishes	34	16	48	26	12	32	26

* Four hour netting period.

Appendix to A Study of the Primary Productivity of Port Royal Sound

Table 1. Incubation Periods, Light Energy Received and Depth of Euphotic Zone Port Royal Sound — 1970

	April					July					October				
Sta.	Date	Light Energy gm cal/cm²/day	Incubation Period	Light Energy for Incubation	Depth of Euphotic Zone in Feet	Date	Light Energy gm cal/cm²/day	Incubation Period	Light Energy for Incubation	Depth of Euphotic Zone in Feet	Date	Light Energy gm cal/cm²/day	Incubation Period	Light Energy for Incubation	Depth of Euphotic Zone in Feet
1	4/17	401	1130-1640	197	12	7/21	579	1035-1345	193	6	10/17	500	1215-1620	270	5
1	4/18	502	1055-1620	282	9	7/22	482	1010-1445	225	8	10/18	421	1145-1600	240	4
1	4/19	560	1045-1600	357	10	7/23	407	1035-1335	85	6	10/19	135	1130-1520	75	4
2	4/20	489	1010-1540	340	12	7/21	579	1010-1340	214	6	10/17	500	1245-1615	232	8
2	4/21	652	1010-1545	440	8	7/22	482	0940-1430	225	6	10/18	421	1130-1610	259	13
2	4/22	657	1040-1620	414	8	7/23	407	1010-1315	107	8	10/19	135	1055-1545	90	6
3	4/20	489	1130-1605	315	10										
3	4/21	652	1100-1615	398	12			Station Deleted					Station Deleted		
3	4/22	657	1120-1640	382	12										
4	4/20	489	0910-1530	369	10	7/21	579	0940-1325	214	6	10/17	500	1130-1430	323	7
4	4/21	652	0930-1540	469	12	7/22	482	0900-1410	257	6	10/18	421	1130-1630	298	8
4	4/22	657	0900-1600	509	12	7/23	407	0940-1300	107	6	10/19	135	1025-1605	100	7
5	4/23	666	0900-1515	468	7	7/24	385	1005-1420	204	6	10/17	500	0950-1735	463	3
5	4/24	494	0830-1545	401	7	7/27	461	0935-1410	268	6	10/18	421	1030-1710	340	6
5	4/25	465	0940-1520	303	10	7/28	279	0935-1245	182	6	10/19	135	0955-1620	108	5
6	4/23	666	1005-1535	423	9	7/24	385	1050-1430	171	6	10/17	500	1030-1720	421	5
6	4/24	494	0910-1600	375	9	7/27	461	1010-1420	246	7	10/18	421	1000-1655	355	4
6	4/25	465	1025-1540	278	7	7/28	279	1008-1305	171	6	10/19	135	0935-1635	125	7
7	4/23	666	1130-1615	354	7	7/24	385	0940-1410	225	6	10/14	331	1000-1600	254	6
7	4/24	494	1050-1640	304	8	7/27	461	0850-1435	311	5	10/15	398	0925-1420	244	6
7	4/25	465	0840-1530	362	8	7/28	279	0920-1235	171	5	10/16	135	0920-1420	75	5
8	4/23	666	1045-1605	403	12	7/16	600	0955-1455	343	10	10/14	331	1030-1555	241	8
8	4/24	494	1010-1630	335	10	7/17	482	0950-1420	246	10	10/15	398	0955-1430	234	8
8	4/25	465	1130-1740	205	11	7/20	546	0840-1320	236	10	10/16	135	0945-1430	79	8
9	4/17	401	0930-1545	251	12	7/16	600	1055-1510	311	25	10/14	331	1100-1705	245	14
9	4/18	502	0920-1520	349	12	7/17	482	1020-1435	225	20	10/15	398	1030-1440	230	13
9	4/19	560	0850-1435	364	12	7/20	546	0915-1335	246	15	10/16	135	1020-1500	78	14
10	4/17	401	0930-1545	251	12	7/21	579	1120-1405	182	13	10/18	421	1230-1535	174	7
10	4/18	502	0920-1520	349	12	7/22	482	1050-1515	214	9	10/19	135	1215-1525	64	7
10	4/19	560	0955-1530	385	12	7/23	407	1105-1350	85	9					
11						7/16	600	1150-1535	278	4	10/14	331	1155-1750	215	4
11						7/17	482	1100-1500	225	5	10/15	398	1145-1525	202	6
11						7/20	546	0950-1410	257	5	10/16	135	1115-1540	94	4

Table 2. Primary Production
Daily and 3-day Averages
Port Royal Sound—April 1970

			Primary Production			Measured Primary Productivity 3 Day Averages			Primary Production Corrected for Light Variation 3 Day Averages		
Station	Date	Depth	Sample A	Sample B	Average	mg C/m^3/ day	mg C/m^3/ day	mg C/m^2/ day	mg C/m^3/ day	mg C/m^3/ day	mg C/m^2/ day
1	4/17	0	171	151	161	75	97	302	125	131	414
		4	104	66	85						
		8	57	45	51						
		12	21	18	20						
1	4/18	0	161	168	165	103			137		
		3	98	114	106						
		6	77	98	88						
		9	73	61	67						
1	4/19	0	182	195	188	112			133		
		3	146	105	125						
		6	110	109	110						
		10	40	40	40						
2	4/20	0	231	225	228	93	121	291	127	134	327
		2	98	93	95						
		5	81	77	79						
		8	26	31	28						
2	4/21	0	321	304	312	102			104		
		2	129	99	114						
		5	53	54	53						
		8	36	45	41						
2	4/22	0	409	379	394	168			170		
		2	198	201	199						
		5	115	156	135						
		8	31	27	29						
3	4/20	0	244	255	249	106	109	377	144	124	424
		3	112	160	136						
		6	58	52	55						
		10	57	30	44						
3	4/21	0	278	292	285	93			95		
		4	61	55	58						
		8	65	60	62						
		12	33	34	33						
3	4/22	0	315	344	330	130			132		
		4	166	182	174						
		8	35	47	41						
		12	17	24	21						
4	4/20	0	183	178	181	67	70	242	91	79	272
		3	77	73	75						
		6	36	40	38						
		10	13	22	18						
4	4/21	0	167	196	181	67			68		
		4	53	62	57						
		8	28	41	35						
		12	29	29	29						
4	4/22	0	220	213	217	78			79		
		4	84	61	72						
		8	48	36	42						
		12	25	23	24						
5	4/23	0	473	471	472	175	101	225	175	119	278
		2	142	228	185						
		5	133	66	99						
		7	53	40	46						
5	4/24	0	144	139	141	73			99		
		2	102	97	100						
		5	40	44	42						
		7	15	11	13						
5	4/25	0	174	240	207	57			82		
		3	53	39	46						
		6	33	38	35						
		10	0	0	0						

Station	Date	Depth	Primary Production Sample A	Primary Production Sample B	Primary Production Average	Measured Primary Productivity 3 Day Averages Mg C/M³/ day	Measured Primary Productivity 3 Day Averages Mg C/M³/ day	Measured Primary Productivity 3 Day Averages Mg C/M²/ day	Primary Production Corrected for Light Variation 3 Day Averages Mg C/M³/ day	Primary Production Corrected for Light Variation 3 Day Averages Mg C/M³/ day	Primary Production Corrected for Light Variation 3 Day Averages Mg C/M²/ day
6	4/23	0	400	679	540	128	90	224	128	109	277
		3	82	72	77						
		6	31	29	30						
		9	19	14	16						
6	4/24	0	314	244	279	65			88		
		3	41	24	33						
		6	22	21	21						
		9	4	5	5						
6	4/25	0	217	173	195	77			110		
		3	66	61	64						
		5	38	37	38						
		7	11	17	14						
7	4/23	0	402	377	389	174	95	204	174	110	252
		2	195	273	234						
		5	85	83	84						
		7	23	47	35						
7	4/24	0	157	143	150	64			86		
		2	87	124	106						
		5	30	26	28						
		8	6	16	11						
7	4/25	0	264	167	215	49			70		
		2	28	—	—						
		5	28	35	31						
		8	5	13	9						
8	4/23	0	154	152	153	43	67	239	43	89	295
		4	24	22	23						
		8	14	42	28						
		12	2	4	3						
8	4/24	0	134	152	143	48			65		
		3	58	46	52						
		6	30	23	26						
		10	7	10	8						
8	4/25	0	370	462	416	110			158		
		4	57	88	73						
		8	23	23	23						
		11	2	8	5						
9	4/17	0	201	189	195	55	71	260	91	97	356
		4	53	34	44						
		8	33	23	28						
		12	10	11	105						
9	4/18	0	199	219	209	91			121		
		4	88	110	99						
		8	60	57	59						
		12	27	25	26						
9	4/19	0	174	161	168	66			78		
		4	61	—	—						
		8	49	37	43						
		12	24	22	23						
10	4/17	0	184	181	182	67	80	297	111	111	407
		4	97	52	75						
		8	28	30	29						
		12	13	13	13						
10	4/18	0	179	177	178	107			142		
		4	163	124	143						
		8	68	87	78						
		12	20	21	20						
10	4/19	0	181	—	—	68			81		
		4	43	62	52						
		8	54	57	56						
		12	7	15	11						
Mean of All Stations							90	266		110	330

Table 3. Primary Production
Daily and 3-day Averages
Port Royal Sound—July 1970

Station	Date	Depth	Primary Production Sample A	Primary Production Sample B	Primary Production Average	Measured Primary Productivity 3 Day Averages mg C/m³/day	Measured Primary Productivity 3 Day Averages mg C/m³/day	Measured Primary Productivity 3 Day Averages mg C/m²/day	Primary Production Corrected for Light Variation 3 Day Averages mg C/m³/day	Primary Production Corrected for Light Variation 3 Day Averages mg C/m³/day	Primary Production Corrected for Light Variation 3 Day Averages mg C/m²/day
1	7/21	0	827.34	—11.57	407.88	1155	784	1429	1197	937	1743
		2	11.57	5.78	8.67						
		4	0.00	109.92	54.96						
		6	133.06	109.92	121.49						
1	7/22	0	612.30	655.69	633.99	643			800		
		2	159.10	197.67	178.38						
		4	77.14	48.21	62.67						
		6	96.42	24.10	60.26						
1	7/23	0	175.06	818.33	496.69	554			816		
		2	4.07	191.35	97.71						
		4	0.00	40.70	20.30						
		6	52.92	—	52.92						
2	7/21	0	386.84	636.41	509.12	709	562	1085	735	701	1324
		2	409.92	219.85	314.0						
		4	3.64	—	3.64						
		6	28.92	23.14	26.03						
2	7/22	0	376.06	506.23	441.14	304			378		
		2	77.14	106.06	91.60						
		5	19.28	19.28	19.28						
		8	14.46	4.82	9.64						
2	7/23	0	—	480.41	480.41	673			992		
		2	93.63	187.27	140.45						
		4	65.14	362.34	213.74						
		6	44.78	36.64	40.71						
4	7/21	0	711.62	728.98	720.30	1152	732	1334	453	955	1761
		2	5.78	—5.78	0.00						
		4	219.85	—	219.85						
		6	—5.78	—5.78	—5.78						
4	7/22	0	444.47	472.48	458.47	564			702		
		2	120.53	212.13	166.33						
		4	120.53	62.67	91.60						
		6	53.03	—9.64	21.69						
4	7/23	0	423.41	333.84	378.62	482			710		
		2	69.21	130.28	99.74						
		4	—36.64	130.28	46.82						
		6	12.21	69.21	40.71						
5	7/24	0	335.55	389.55	362.55	482	502	915	751	767	1464
		2	188.99	138.85	163.92						
		4	65.66	65.56	65.56						
		6	30.85	77.14	53.99						
5	7/27	0	608.12	663.40	635.76	772			1005		
		2	179.67	152.03	165.85						
		4	230.35	152.03	191.09						
		6	41.46	69.10	55.28						
5	7/28	0	245.13	284.13	264.63	254			546		
		2	75.21	61.28	68.24						
		4	58.49	—5.57	26.46						
		6	—5.57	30.64	12.53						
6	7/24	0	296.98	482.12	389.55	607	694	1342	946	1155	2147
		2	235.27	104.13	169.70						
		4	115.71	111.85	113.78						
		6	46.28	50.14	48.21						
6	7/27	0	631.15	718.69	674.92	769			1001		
		2	327.09	373.16	350.12						
		4	55.28	69.10	62.19						
		6	64.49	78.31	71.40						
6	7/28	0	518.12	604.47	561.29	706			1510		
		2	289.70	167.13	228.41						
		4	116.99	128.13	122.56						
		6	47.35	44.56	45.95						

Station	Date	Depth	Primary Production Sample A	Primary Production Sample B	Primary Production Average	Measured Primary Productivity 3 Day Averages Mg C/M³/day	Measured Primary Productivity 3 Day Averages Mg C/M³/day	Measured Primary Productivity 3 Day Averages Mg C/M²/day	Primary Production Corrected for Light Variation 3 Day Averages Mg C/M³/day	Primary Production Corrected for Light Variation 3 Day Averages Mg C/M³/day	Primary Production Corrected for Light Variation 3 Day Averages Mg C/M²/day
7	7/24	0	709.68	748.25	728.96	528	672	1073	823	1085	1717
		2	69.42	92.56	80.99						
		4	69.42	53.99	61.70						
		6	15.42	19.28	17.35						
7	7/27	0	741.72	824.65	783.18	904			1176		
		1	382.38	359.34	370.86						
		3	170.45	179.67	175.06						
		5	69.10	78.31	73.70						
7	7/28	0	412.26	376.05	394.15	584			1256		
		1	373.27	284.13	328.70						
		3	97.49	55.71	76.60						
		5	76.60	11.14	43.87						
8	7/16	0	269.99	185.99	227.99	219	231	702	219	262	772
		3	17.99	29.99	23.99						
		6	11.99	29.99	20.99						
		10	5.99	407.99	206.99						
8	7/17	0	327.84	361.59	344.71	310			386		
		3	0.00	24.10	12.05						
		6	24.10	19.28	21.69						
		10	—	—	—						
8	7/20	0	491.76	169.38	330.57	165			181		
		3	158.45	76.49	117.47						
		6	16.39	27.32	21.85						
		10	10.92	10.92	10.92						
9	7/16	0	149.99	—	149.99	99	258	1385	99	291	1524
		8	11.99	11.99	11.99						
		16	11.99	11.99	11.99						
		25	0.00	5.9	2.99						
9	7/17	0	260.35	163.92	212.13	218			271		
		6	96.42	81.96	89.19						
		12	19.28	24.10	21.69						
		20	19.28	14.46	16.87						
9	7/20	0	475.32	349.70	412.53	459			504		
		5	169.38	152.99	161.18						
		10	76.49	16.39	46.44						
		15	10.92	16.39	13.65						
10	7/21	0	—5.78	—11.57	—8.67	756	639	2051	783	795	2502
		4	—11.57	329.77	15.91						
		8	237.20	202.88	222.74						
		13	—11.57	—11.57	—11.57						
10	7/22	0	414.63	429.09	421.86	475			591		
		3	91.60	192.85	142.22						
		6	125.35	81.96	103.65						
		9	53.03	57.85	55.44						
10	7/23	0	447.84	109.92	278.88	686			1011		
		3	146.56	500.76	323.66						
		6	134.55	317.56	225.95						
		9	65.14	81.42	73.28						
11	7/16	0	527.98	437.98	482.98	1063	687	933	1063	750	1026
		1	0.00	515.98	257.99						
		2	221.99	257.99	239.99						
		4	71.99	77.99	74.99						
11	7/17	0	520.70	303.74	412.22	607			755		
		1	351.95	313.38	332.66						
		3	91.60	101.24	96.42						
		5	24.10	24.10	24.10						
11	7/20	0	224.02	278.66	251.34	393			432		
		1	185.77	196.70	191.23						
		3	81.96	81.96	81.96						
		5	21.85	21.85	21.85						
Mean of All Stations							576	1225		770	1598

Table 4. Primary Production
Daily and 3-day Averages
Port Royal Sound—October 1970

			Primary Production			Measured Primary Productivity 3 Day Averages			Primary Production Corrected for Light Variation 3 Day Averages		
Station	Date	Depth	Sample A	Sample B	Average	mg C/m³/ day	mg C/m³/ day	mg C/m²/ day	mg C/m³/ day	mg C/m³/ day	mg C/m²/ day
1	10/17	0	392	374	383	686	641	853	686	1163	1211
		2	277	212	244						
		4	106	—	106						
		6	22	39	30						
1	10/18	0	345	—	345	709			842		
		1	246	—	246						
		3	—	—	—						
		5	136	158	147						
1	10/19	0	326	—	326	530			1962		
		1	237	246	241						
		2	98	—	98						
		4	58	—	58						
2	10/17	0	250	306	278	238	179	524	238	434	744
		2	51	92	71						
		5	43	38	40						
		8	7	7	7						
2	10/18	0	194	216	205	185			219		
		4	58	73	65						
		8	15	16	15.5						
		13	0	2	1						
2	10/19	0	154	189	171	115			425		
		2	22	15	18.5						
		4	21	27	24						
		7	8	0	4						
4	10/17	0	211	—	211	330	366	854	330	740	520
		2	139	—	139						
		5	70	76	73						
		8	15	25	20						
4	10/18	0	433	273	353	379			450		
		2	151	—	151						
		5	50	61	55.5						
		8	24	20	22						
4	10/19	0	306	333	219.5	389			1441		
		2	139	105	122						
		4	—	—	—						
		7	14	13	13.5						
5	10/17	0	382	340	361	379	311	465	379	556	660
		1	136	—	136						
		2	51	—	51						
		4	60	86	72						
5	10/18	0	374	237	305.5	304			361		
		2	51	71	61						
		4	52	40	46						
		6	33	—	33						
5	10/19	0	214	292	253	251			929		
		1	121	—	121						
		3	42	38	40						
		5	15	12	13.5						
6	10/17	0	240	355	297	254	215	350	254	331	497
		1	115	91	103						
		3	44	36	40						
		5	3	3	3						
6	10/18	0	355	294	324.5	284			337		
		1	103	78	90.5						
		3	52	70	61						
		5	20	70	45						
6	10/19	0	88	148	118	109			403		
		2	63	29	46						
		4	8	10	9						
		7	0	2	1						

Station	Date	Depth	Primary Production Sample A	Primary Production Sample B	Primary Production Average	Measured Primary Productivity 3 Day Averages Mg C/M³/ day	Measured Primary Productivity 3 Day Averages Mg C/M³/ day	Measured Primary Productivity 3 Day Averages Mg C/M²/ day	Primary Production Corrected for Light Variation 3 Day Averages Mg C/M³/ day	Primary Production Corrected for Light Variation 3 Day Averages Mg C/M³/ day	Primary Production Corrected for Light Variation 3 Day Averages Mg C/M²/ day
7	10/14	0	171	118	144.5	208	233	471	314	507	815
		2	48	26	37						
		4	50	56	53						
		8	13	19	16						
7	10/15	0	208	204	206	251			315		
		2	72	57	64.5						
		4	48	57	52.5						
		6	24	22	23						
7	10/16	0	14	271	142	241			892		
		2	54	50	52						
		4	26	31	27.5						
		6	12	12	12						
8	10/14	0	168	166	167	208	190	473	314	346	818
		2	100	105	102.5						
		5	21	22	21.5						
		8	8	7	7.5						
8	10/15	0	189	146	167.5	251			315		
		2	187	82	134.5						
		5	40	34	37						
		8	2	1	1.5						
8	10/16	0	179	—	179	111			411		
		2	27	45	36						
		5	10	9	9.5						
		8	4	3	3.5						
9	10/14	0	287	—	287	277	227	1038	418	441	1796
		5	65	58	61.5						
		10	35	43	39						
		15	19	22	20.5						
9	10/15	0	218	174	196	244			306		
		5	87	73	80						
		10	32	41	36.5						
		15	19	14	16.5						
9	10/16	0	159	—	159	162			600		
		5	16	65	40.5						
		10	22	—	22						
		15	9	15	12						
10	10/18	0	27	89	58	198	219	469	235	563	840
		2	58	102	80						
		4	58	73	65.5						
		7	37	29	33						
10	10/19	0	212	247	229.5	241			892		
		2	73	84	78.5						
		4	48	38	43						
		7	15	—	15						
11	10/14	0	257	221	239	214	169	278	323	317	481
		1	87	—	87						
		3	35	28	31.5						
		5	11	15	13						
11	10/15	0	122	79	100.5	188			236		
		2	68	52	60						
		4	12	—	12						
		6	11	10	10.5						
11	10/16	0	153	116	134.5	106			392		
		1	48	64	56						
		3	10	—	10						
		5	1	—	1						
Mean of All Stations							275	578		540	838

Appendix to
Analysis of Phytoplankton Standing Crop

Port Royal Sound
Phytoplankton Populations
Spring 1970
Refrigerated samples cells/ml

Stations	1	2	3	4	5	6	7	8	9	10
DIATOMS (Chrysophyta)										
Date collected	4-18-70	4-18-70						4-16-70		
Date analyzed	4-19-70	4-19-70						4-19-70		
Centrate										
Chaetoceros compressus										
Chaetoceros gracilis		24						74		
Chaetoceros subtilis										
Chaetoceros sp.	24									
Cyclotella										
Diatoma										
Leptocylindrus										
Rhizosolenia										
Skeletonema	96	48						74		
Stephanopyxis										
Pennate										
Asterionella								122		
Fragilaria										
Gyrosigma										
Meridion										
Navicula	48	72						122		
Nitzschia longissima	144	120						98		
Nitzschia sp.	24	72								
Raphoneis										
Synedra	24									
Tabellaria										
Thalassiothrix	48									
Unknown Diatoms	24	72								
FLAGELLATES (Pyrrhophyta)										
Amphidinium										
Unknown dinoflagellates	144	216								
Desmidium	24									
Exuviella										
Euglena										
Unknown green flagellates	24	72								
Total count	624	696						490		
Analyst	DL	DL						SK		

Phytoplankton Populations
Port Royal Sound
Spring 1970
Fresh counts cells/ml

Station	1	2	3	4	5	6	7	8	9	10
DIATOMS (Chrysophyta)										
April 19, 1970										
Centrate										
Chaetoceros compressus				48			49			
Chaetoceros gracilis	24			48	24	24		49		
Chaetoceros subtilis									72	
Chaetoceros sp.					24	24	172		48	
Cyclotella					48	24			24	
Diatoma										
Leptocylindrus	48									
Rhizosolenia						24				48
Skeletonema	120	25					74	25		72
Stephanopyxis				72	24	24				120
Pennate										
Asterionella		74					25	49		
Fragilaria										
Gyrosigma	24					24	25	25		24
Meridion										
Navicula	72	49		24	168	168	294	147	192	192
Nitzschia longissima	24	74	49	48	24	72	196	123	96	48
Nitzschia sp.			49	48			25	123		
Raphoneis	24	25								
Synedra	24			24	24	48			24	
Tabellaria										
Thalassiothrix	48			24						24
Unknown Diatoms	120			24						
FLAGELLATES (Pyrrhophyta)										
Amphidinium									24	
Unknown dinoflagellates	72		25	168	96	168			120	168
Desmidium										
Exuviella							24			
Euglena								25		
Unknown green flagellates		49			24	72	74	25	24	
Total count	600	296	123	528	456	696	934	591	624	696
Analyst	DL	SK	SK	DL	DL	DL	SK	SK	DL	DL

Phytoplankton Populations
Port Royal Sound
Spring 1970
Fresh counts cells/ml

Station	1	2	3	4	5	6	7	8	9	10
DIATOMS (Chrysophyta)										
April 21, 1970										
Centrate										
Chaetoceros compressus		24								
Chaetoceros gracilis		24			25		24			72
Chaetoceros subtilis										
Chaetoceros sp.	49							24		
Cyclotella									25	
Diatoma	25									
Leptocylindrus										
Rhizosolenia										
Skeletonema	25	24					24	48		48
Stephanopyxis		48								24
Pennate										
Asterionella	25									
Fragilaria		48								
Gyrosigma			25							
Meridion	25			24		24				
Navicula	123	144	147	98	123	313	72	144	98	72
Nitzschia longissima		48	49	49	49	48		96	73	24
Nitzschia sp.	74	24	74	24	49	24	48	24	25	24
Raphoneis										
Synedra		48			25		96	48		48
Tabellaria					73					
Thalassiothrix										24
Unknown Diatoms							24			
FLAGELLATES (Pyrrhophyta)										
Amphidinium										
Unknown dinoflagellates		144				144	48	48		48
Desmidium										
Exuviella										
Euglena					25					
Unknown green flagellates	74			49	49	96			25	
Total count	420	576	295	269	393	649	336	432	246	384
Analyst	SK	DL	SK	SK	SK	DL	DL	DL	SK	DL

Percentage composition of the
Phytoplankton Community
Port Royal Sound
Spring 1970

	1	2	3	4	5	6	7	8	9	10
April 18-19, 1970 (refrigerated samples)										
Centrate diatoms	19.2	10.3	–	–	–	–	–	30.2	–	–
Pennate diatoms	50.0	48.3	–	–	–	–	–	68.8	–	–
All diatoms	69.2	58.6	–	–	–	–	–	100.0	–	–
Flagellates	37.8	41.4	–	–	–	–	–	0	–	–
April 19, 1970										
Centrate diatoms	32.0	8.4	0	31.8	26.3	17.2	31.6	12.5	23.0	34.5
Pennate diatoms	56.0	75.0	79.7	36.4	47.4	44.8	60.5	79.0	50.0	41.4
All diatoms	88.0	83.4	79.7	68.2	73.7	62.0	92.1	91.5	73.0	75.9
Flagellates	12.0	16.6	20.3	31.8	26.3	37.9	7.9	8.5	27.0	24.1
April 21, 1970										
Centrate diatoms	23.6	20.8	0	0	6.4	0	14.3	16.7	10.2	37.5
Pennate diatoms	58.8	54.2	100	72.5	81.2	63.0	71.4	72.2	79.7	50.0
All diatoms	82.4	75.0	100	72.5	87.6	63.0	85.7	88.9	89.9	87.5
Flagellates	17.6	25.0	0	27.5	12.4	37.0	14.3	11.1	10.2	12.5

Diversity Indices of Phytoplankton Populations
Port Royal Sound
Spring 1970

$$d = \frac{S-1}{\log e\ N} = \frac{(\text{No. of Kinds})\ -1}{\log e\ \text{Total Count}}$$

	1	2	3	4	5	6	7	8	9	10
4/18-19										
S-1	10	7	–	–	–	–	–	4	–	–
N = Total Count	624	696	–	–	–	–	–	490	–	–
log e N	6.436	6.545	–	–	–	–	–	6.194	–	–
d =	1.55	1.07	–	–	–	–	–	0.64	–	–
4/19/70										
S-1	10	5	2	9	8	11	9	8	8	7
N	600	296	123	528	456	696	934	591	624	696
log e N	6.397	5.690	4.812	6.269	6.122	6.545	6.839	6.382	6.436	6.545
d =	1.56	0.88	0.42	1.44	1.31	1.68	1.32	1.17	1.24	1.07
4/21/70										
S-1	7	9	3	5	7	5	6	6	4	8
N	420	576	295	269	393	649	336	432	246	384
log e N	6.040	6.356	5.687	5.594	5.974	6.475	5.817	6.068	5.505	5.950
d =	1.16	1.42	0.53	0.89	1.17	0.77	1.03	0.99	0.73	1.43

Phytoplankton Counts
Port Royal Sound
Summer 1970

Date collected 7/19/70
Date analyzed 7/21/70

Refrigerated Count Cells/ml Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Asteromphalus										
Biddulphia				25				25		
Biddulphia alternas										
Chaetoceros						25			25	
Chaetoceros concavicornis										
Chaetoceros gracilis										
Corethon hystrix						25				
Coscinodiscus		49								49
Hemiaulus										
Melosira										
Rhizosolenia	25									
Rhizosolenia alata										
Skeletonema									49	
Stephanopyxis				49		25				
Unknown CENTRATES	98		25					25		
PENNATE DIATOMS										
Asterionella										
Cymbella										
Diatoma										
Diploneis			49							
Epithemia										
Fragilaria										
Gyrosigma				25						25
Navicula						123	25			
Nitzschia		25	25			98	25		25	
Nitzschia longissima										
Pleurosigma										
Tabellari										
Thalassionema										
Thalassionema nitzschioides										
Unknown PENNATES										25
GREENS										
Actinastrum										
Chlamydomonas						25				
Euglena										
Micratinium										
Prorocentrum										
Unknown GREENS						25				
DINOFLAGELLATES										
Unknown DINOS	25									
Gymnodinium										
TOTAL COUNTS	147	74	98	98	0	343	49	49	98	98
ANALYST	DHW	MLC	DHW	MLC	DHW	SMK	DHW	DHW	MLC	MLC

Phytoplankton Counts
Port Royal Sound
Summer 1970
Date collected 7/20/70
Date analyzed 7/20/70

Fresh Count Cells/ml

Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Asteromphalus										
Biddulphia							25	25		
Biddulphia alternas										
Chaetoceros	147	25	25				25	49	25	25
Chaetoceros concavicornis									49	
Chaetoceros gracilis						25	98		74	
Corethron hystrix										
Coscinodiscus	25		123							25
Hemiaulus										
Melosira	98									
Rhizosolenia						25	25		49	25
Rhizosolenia alata									25	
Skeletonema	294	25	98			25	74		123	123
Stephanopyxis						25				
Unknown CENTRATES								49		
PENNATE DIATOMS										
Asterionella										
Cymbella									98	
Diatoma										
Diploneis										
Epithemia										
Fragilaria										
Gyrosigma				25						
Navicula							25		49	49
Nitzschia	123	25	98	49		147	123		49	49
Nitzschia longissima	172		98				25		49	25
Pleurosigma										
Tabellaria									25	
Thalassionema							49		25	
Thalassionema nitzchioides	25									
Unknown PENNATES	74		49			25				
GREENS										
Actinastrum	25	25								
Chlamydomonas										
Euglena										
Micratinium	49									
Prorocentrum							25			
Unknown GREENS	49		49				25		25	98
DINOFLAGELLATES										
Unknown DINOS										25
Gymnodinium										
Dead DINOS				172		98				
TOTAL COUNTS	1081	98	539	246		368	519	123	622	444
ANALYST	MLC	DHW	MLC	DHW		DHW	SMK	DHW	SMK	SMK

Phytoplankton Counts
Port Royal Sound
Summer 1970

Fresh Count Cells/ml Date collected 7/21/70
Date analyzed 7/21/70

Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Asteromphalus										
Biddulphia										
Biddulphia alternas			25							
Chaetoceros	25	49		49		25	25		221	
Chaetoceros concavicornis										
Chaetoceros gracilis									25	
Corethron hystrix										
Coscinodiscus	25			25	25	98	25	25		74
Hemiaulus									25	
Melosira										
Rhizosolenia	49								147	
Rhizosolenia alata										
Skeletonema	221								49	
Stephanopyxis			25				25		25	
Unknown CENTRATES	25							25		74
PENNATE DIATOMS										
Asterionella	123								74	
Cymbella										
Diatoma										
Diploneis	25			25		25				
Epithemia									25	
Fragilaria										
Gyrosigma										
Navicula		25		74					98	
Nitzschia	147	25	25	98	25	25	25	98	49	25
Nitzschia longissima				74		74	74		245	25
Pleurosigma				25						
Tabellaria										
Thalassionema				25					25	
Thalassionema nitzchioides										
Unknown PENNATES		25								
GREENS										
Actinastrum		25								
Chlamydomonas				25						
Euglena									25	
Micratinium										
Prorocentrum										
Unknown GREENS				25					25	
DINOFLAGELLATES										
Unknown DINOS										
Gymnodinium										
TOTAL COUNTS	637	147	49	466	49	245	172	147	1058	196
ANALYST	DHW	MLC	MLC	SMK	DHW	MLC	MLC	DHW	SMK	DHW

Phytoplankton Counts
Port Royal Sound
Summer 1970

Fresh Count Cells/ml
Date collected 7/22/70
Date analyzed 7/22/70

Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Asteromphalus										
Biddulphia			25					25		
Biddulphia alternas										
Chaetoceros	147		74			98	25	49	25	25
Chaetoceros concavicornis										
Chaetoceros gracilis	74		25	98						
Corethron hystrix										
Coscinodiscus				49	25		74	49	25	
Hemiaulus										
Melosira									49	
Rhizosolenia									99	
Rhizosolenia alata										
Skeletonema	74	49	25	49			25		49	
Stephanopyxis										
Unknown CENTRATES		25				25			49	
PENNATE DIATOMS										
Asterionella	98	98							74	
Cymbella									25	
Diatoma										
Diploneis						25		49		
Epithemia										
Fragilaria									49	
Gyrosigma										
Navicula	172	98	25	196					49	25
Nitzschia	123	98	98	147	48	74		25	74	49
Nitzschia longissima	172	98	49	147		25	74		49	
Pleurosigma				25						
Tabellaria										
Thalassionema			123	25						
Thalassionema nitzchioides										
Unknown PENNATES		25						25	49	25
GREENS										
Actinastrum										
Chlamydomonas										
Euglena										
Micratinium										
Prorocentrum			25							
Unknown GREENS	25		25	74	25				49	
DINOFLAGELLATES										
Unknown DINOS										
Gymnodinium				25						
TOTAL COUNTS	885	490	494	834	98	245	196	221	711	123
ANALYST	SMK	DHW	SMK	SMK	MLC	MLC	MLC	MLC	MLC	DHW

Phytoplankton Counts
Port Royal Sound
Summer 1970

Fresh Count Cells/ml
Date collected 7/23/70
Date analyzed 7/23/70

Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Asteromphalus									25	
Biddulphia			25							
Biddulphia alternas										
Chaetoceros	25	25	25				49	49	196	49
Chaetoceros concavicornis										
Chaetoceros gracilis			25			123				
Corethron hystrix										
Coscinodiscus	25		25	49	25	25		25		
Hemiaulus										
Melosira	221						25		98	
Rhizosolenia	25	25	49						25	
Rhizosolenia alata										
Skeletonema			123			123				
Stephanopyxis									25	
Unknown CENTRATES		49			25			25		25
PENNATE DIATOMS										
Asterionella	25								147	
Cymbella										
Diatoma										
Diploneis				25					25	25
Epithemia										
Fragilaria				49			25		74	
Gyrosigma	49			25					25	25
Navicula	74	25		25		147			74	
Nitzschia	74		25			147	49		25	
Nitzschia longissima	49	49	25	25		319	49		25	
Pleurosigma			98							
Tabellaria										
Thalassionema		25	49						49	
Thalassionema nitzchioides										
Unknown PENNATES	25						25			
GREENS										
Actinastrum	25			25						
Chlamydomonas										
Euglena			25							
Micratinium										
Prorocentrum										
Unknown GREENS		25	74							25
DINOFLAGELLATES										
Unknown DINOS										
Gymnodinium										
TOTAL COUNTS	613	223	568	223	49	884	221	98	809	149
ANALYST	MLC	MLC	SMK	MLC	MLC	SMK	MLC	MLC	MLC	MLC

Phytoplankton Counts
Port Royal Sound
Summer 1970

Fresh Count Cells/ml Date collected 7/24/70
Date analyzed 7/24/70

Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Asteromphalus										
Biddulphia							25			
Biddulphia alternas										
Chaetoceros	74	74	25		172	147	74	25	98	
Chaetoceros concavicornis										
Chaetoceros gracilis					25	74				
Corethron hystrix										
Coscinodiscus			25	49		49	49			
Hemiaulus										
Melosira		25	49				25		25	
Rhizosolenia						25	25		74	
Rhizosolenia alata										
Skeletonema					25	172				
Stephanopyxis	25			25			25			
Unknown CENTRATES	49	25	25							
PENNATE DIATOMS										
Asterionella	49	49	98		25	25	74		98	
Cymbella										
Diatoma				25						
Diploneis			25			25				
Epithemia										
Fragilaria		25	25							
Gyrosigma		25	25							
Navicula					123	123				
Nitzschia	49	74		25	98	172	25		25	25
Nitzschia longissima	49	74			196	319			25	74
Pleurosigma						74			25	
Tabellaria										
Thalassionema					25					
Thalassionema nitzchioides		25								
Unknown PENNATES									49	
GREENS										
Actinastrum										
Chlamydomonas									25	
Euglena					74	25				
Micratinium									25	
Prorocentrum										
Unknown GREENS					49	49				
DINOFLAGELLATES										
Unknown DINOS							25			
Gymnodinium										
TOTAL COUNTS	294	396	294	123	809	1279	343	25	469	98
ANALYST	DHW	MLC	MLC	MLC	SMK	SMK	MLC	DHW	MLC	DHW

Percentage Composition of the Phytoplankton Community Port Royal Sound Summer 1970

Date	Station Number	1	2	4	5	6	7	8	9	10	11
7/19/70 7/21/70	Centrate Diatoms (refrigerated count)	83 %	67 %	25 %	75 %	—	21 %	0	100 %	75 %	50 %
	Pennate Diatoms		33 %	75 %	25 %	—	64 %	100 %	0	25 %	50 %
	All Diatoms	83 %	100 %	100 %	100 %	—	85 %	100 %	100 %	100 %	100 %
	Greens	0	0	0	0	—	14 %	0	0	0	0
	Flagellates	17 %	0	0	0	—	0	0	0	0	0
	Total Count	147	74	98	98	0	343	49	49	98	98
7/20/70	Centrate Diatoms	52 %	50 %	45 %	0	—	20 %	47 %	100 %	52 %	44 %
	Pennate Diatoms	36 %	25 %	45 %	30 %	—	53 %	42 %	0	44 %	27 %
	All Diatoms	88 %	75 %	90 %	30 %	—	73 %	89 %	0	96 %	71 %
	Greens	11 %	25 %	9 %	0	—	0	9 %	0	3 %	22 %
	Flagellates	0	0	0	70 %	—	26 %	0	0	0	5 %
	Total Count	1081	98	539	246	—	368	519	123	662	444
7/21/70	Centrate Diatoms	54 %	33 %	50 %	21.2%	50 %	43.6%	34 %	48.9%	46.5%	75 %
	Pennate Diatoms	46 %	51 %	50 %	68.9%	50 %	57.5%	66 %	51.3%	48.7%	25 %
	All Diatoms	100 %	84 %	100 %	90.1%	100 %	100 %	100 %	100 %	95.2%	100 %
	Greens	0	16 %	0	10.7%	0	0	0	0	4.7%	0
	Flagellates	0	0	0	0	0	0	0	0	0	0
	Total Count	637	147	49	466	49	245	172	147	1058	196

Percentage Composition of the Phytoplankton Community Port Royal Sound Summer 1970

Date	Station Number	1	2	4	5	6	7	8	9	10	11
7/22/70	Centrate Diatoms	33.3%	15.1%	30.1%	23.5%	25.5%	50.2%	63.2%	55.6%	31.2%	20.3%
	Pennate Diatoms	63.8%	85.1%	59.7%	64.7%	50 %	50.6%	37.7%	47.7%	62.3%	80.4%
	All Diatoms	97.1%	100 %	89.8%	88.2%	75.5%	100 %	100 %	100 %	93.5%	100 %
	Greens	2.8%	0	10.1%	8.8%	25.5%	0	0	0	6.8%	0
	Flagellates	0	0	0	2.9%	0	0	0	0	0	0
	Total Count	885	490	494	834	98	245	196	221	711	123
7/23/70	Centrate Diatoms	44.2%	33.1%	39.2%	22.9%	100 %	30.6%	33.4%	100 %	42.5%	49.6%
	Pennate Diatoms	52.3%	55.6%	43.3%	66.8%	0	69.3%	66.9%	0	57.9%	33.5%
	All Diatoms	96.5%	88.7%	82.5%	88.7%	100 %	100 %	100 %	0	0	83.2%
	Greens	4 %	11.2%	17.4%	11.2%	0	0	0	0	0	16.7%
	Flagellates	0	0	0	0	0	0	0	0	0	0
	Total Count	613	223	568	223	49	884	221	98	809	149
7/24/70	Centrate Diatoms	50.3%	31.3%	42.1%	60.1%	27.4%	36.5%	65 %	100 %	26.2%	0
	Pennate Diatoms	50 %	68.6%	58.8%	40.6%	57.7%	57.7%	28.8%	0	63.1%	100 %
	All Diatoms	100 %	100 %	100 %	100 %	85.1%	94.2%	93.8%	100 %	89.3%	100 %
	Greens	0	0	0	0	15.2%	5.7%	7.2%	0	10.6%	0
	Flagellates	0	0	0	0	0	0	0	0	0	0
	Total Count	294	396	294	123	809	1279	343	25	469	98

Diversity Indices of Phytoplankton Populations Port Royal Sound Summer 1970

$$\text{diversity, d} = \frac{\text{No. of kinds} - 1}{\log e \text{ Total count}}$$

Date Station	1	2	4	5	6	7	8	9	10	11
7/19/70	0.40	.23	.44	.44	–	1.03	.26	.26	.23	.23
7/20/70	1.33	.65	.96	.36	–	1.02	1.60	.42	1.77	1.31
7/21/70	1.08	.80	.26	1.63	.26	.73	.78	.40	1.78	.57
7/22/70	1.03	.97	1.45	1.34	.23	.73	.57	.93	2.13	.62
7/23/70	1.56	1.11	1.73	1.11	.26	.74	.93	.23	1.79	.83
7/24/70	.88	1.35	1.23	.62	1.34	1.80	1.37	0	1.49	.22
Mean	1.05	.85	1.01	.92	.52	1.01	.92	.37	1.53	.63

Phytoplankton Counts
Port Royal Sound
Fall 1970

Date collected 10/14/70
Date analyzed 10/15/70

Cells/ml

Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Biddulphia sp										
Biddulphia longicruris										
Chaetoceros sp									25	
Chaetoceros gracilis			25		49		25	25		
Corethron hystix										
Coscinodiscus sp		25	49	25		49	25		25	74
Coscinodiscus marginatus										
Cyclotella			25							
Ditylum brightwelli										
Leptocylindrus						25			25	25
Rhizosolenia			25					25		
Skeletonema	25	25	49		25				49	
Stephanopyxis	25				25			25	49	
Unknown CENTRATES								25		
PENNATE DIATOMS										
Asterionella		74	25					25		
Campylosira cymbelliformis								25		
Navicula	49	25	49	49	25	49	74	49	25	123
Nitzschia	172			147	49			74	123	49
Nitzschia longissima	123	25	147	98	74	123	25	49	613	
Pleurosigma				25	25	25	25			25
Rhaphoneis										
Striatella										25
Synedra										
Thalassiontrix				25						
Unknown PENNATES						25				
GREENS — Coccoid										
Ankistrodesmus										
Calothrix										
Oocystis	74					25				
Motile										
Chlamydomonas							98			
Euglena										
Unknown					25				25	98
DINOFLAGELLATES										
Gymnodinium										
Peridinium										
Unknown	25			25			49			49
TOTAL	490	172	392	368	294	319	319	343	1127	466
Analyst	DL	SK	SK	DL	DL	SK	SK	SK	DL	DL

Phytoplankton Counts
Port Royal Sound
Fall 1970

Date collected 10/15/70
Date analyzed 10/15/70

Cells/ml Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Biddulphia sp						25				
Biddulphia longicruris										
Chaetoceros sp							25	25	49	
Chaetoceros gracilis								49		
Corethron hystix										
Coscinodiscus sp					49	25	25			
Coscinodiscus marginatus										
Cyclotella										
Ditylum brightwelli										
Leptocylindrus		25								
Rhizosolenia										
Skeletonema	49						25		25	
Stephanopyxis		49		49	25	25			74	
Unknown CENTRATES	25	25		49					25	
PENNATE DIATOMS										
Asterionella	25									
Campylosira cymbelliformis										
Navicula	49	25	49	49	25	123	123	25	25	49
Nitzschia	123		25			25	123	49	49	25
Nitzschia longissima	98	74	98	49	196	74	98	74	49	74
Pleurosigma		25					49			
Rhaphoneis										
Striatella										
Synedra	49		25	147						
Thalassiontrix	49	25	49	25		74	25	25	25	
Unknown PENNATES										
GREENS — Coccoid										
Ankistrodesmus								25		
Calothrix										
Oocystis										
Motile										
Chlamydomonas										
Euglena						25				25
Unknown		49	25	25	25			25	49	49
DINOFLAGELLATES										
Gymnodinium										
Peridinium										
Unknown	25	25	49		49					25
TOTAL	490	319	319	392	368	392	490	294	392	147
Analyst	DL	DL	DL	DL	DL	SK	SK	SK	DL	SK

Phytoplankton Counts
Port Royal Sound
Fall 1970

Date collected 10/16/70
Date analyzed 10/16/70

Cells/ml Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Biddulphia sp										
Biddulphia longicruris										25
Chaetoceros sp				25				74	49	
Chaetoceros gracilis										
Corethron hystix										
Coscinodiscus sp								25	49	
Coscinodiscus marginatus								25		
Cyclotella										
Ditylum brightwelli						25				
Leptocylindrus		25		25		25				74
Rhizosolenia										
Skeletonema	74		74	25		49			25	
Stephanopyxis		98	25		49		25	98		49
Unknown CENTRATES	25		74	25		25		25	25	
PENNATE DIATOMS										
Asterionella	25								25	
Campylosira cymbelliformis										
Navicula	49	25	49			74		25	49	
Nitzschia	25	25	49	49	49	98	49	25	49	
Nitzschia longissima	74	49	25	25	74	74	25		49	25
Pleurosigma	25		25						25	
Rhaphoneis	25		49							
Striatella										
Synedra	49				25	49			25	
Thalassiontrix		25		25	25	25	25		74	25
Unknown PENNATES										25
GREENS — Coccoid										
Ankistrodesmus										
Calothrix										
Oocystis										
Motile										
Chlamydomonas										
Euglena	25						25			25
Unknown	49	98		49	172	319	74	49	74	123
DINOFLAGELLATES										
Gymnodinium										
Peridinium										
Unknown	25	49	49		25		49		49	
TOTAL	441	417	417	245	417	760	270	343	564	368
Analyst	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL

Phytoplankton Counts
Port Royal Sound
Fall 1970

Date collected 10/17/70
Date analyzed 10/17/70

Cells/ml Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Biddulphia sp										
Biddulphia longicruris										
Chaetoceros sp	123		49			74	25	49	49	25
Chaetoceros gracilis										
Corethron hystix										
Coscinodiscus sp		49	49	49				25		25
Coscinodiscus marginatus										
Cyclotella										
Ditylum brightwelli										
Leptocylindrus		49		25	25					
Rhizosolenia	25									
Skeletonema	74		49							
Stephanopyxis	25		49	25	25	74			49	25
Unknown CENTRATES				98	49				74	
PENNATE DIATOMS										
Asterionella	49		49				74	49		74
Campylosira cymbelliformis										
Navicula	147	25	25	74	25	98	98	25	49	25
Nitzschia	98	49	147	98		123	123	25	49	49
Nitzschia longissima	123	74	147	49	49	123	74	123	123	25
Pleurosigma	25						25	25	49	
Rhaphoneis	123	49			25	25	74		25	
Striatella										
Synedra		49		25	49				25	
Thalassiontrix	25	25		74			49		25	
Unknown PENNATES										
GREENS — Coccoid										
Ankistrodesmus										
Calothrix										
Oocystis										
Motile										
Chlamydomonas	25									
Euglena										
Unknown		49	123	25	147				49	
DINOFLAGELLATES										
Gymnodinium							25			
Peridinium				25						
Unknown		123	25	98	98				25	
TOTAL	858	539	735	662	490	515	564	319	588	245
Analyst	SK	DL	SK	DL	DL	SK	SK	SK	DL	SK

Phytoplankton Counts
Port Royal Sound
Fall 1970

Date collected 10/18/70
Date analyzed 10/18/70

Cells/ml Station Number	1	2	4	5	6	7	8	9	10	11
CENTRATE DIATOMS										
Biddulphia sp										
Biddulphia longicruris										
Chaetoceros sp		25								
Chaetoceros gracilis								25		25
Corethron hystix					25					
Coscinodiscus sp										
Coscinodiscus marginatus										
Cyclotella				25				25		
Ditylum brightwelli			25							
Leptocylindrus	74		49			25	49			
Rhizosolenia								25		
Skeletonema			25	25		25		25	25	
Stephanopyxis	74		49	25	25	98	49			98
Unknown CENTRATES	25						25			25
PENNATE DIATOMS										
Asterionella	49	25						25	25	
Campylosira cymbelliformis										
Navicula	147	49	74	25	49	25	74	74	98	74
Nitzschia	196	49	74	147	25	25	74	147		
Nitzschia longissima	221		147	172	147	123	74	25	172	74
Pleurosigma			25	25	25	25			25	
Rhaphoneis			49		25	25			25	
Striatella										
Synedra	74		25			25				25
Thalassiontrix				98	25	25	49	49		74
Unknown PENNATES			25							
GREENS — Coccoid										
Ankistrodesmus										
Calothrix			25							
Oocystis										
Motile										
Chlamydomonas		25								
Euglena										
Unknown			147	25	25	25		25	98	172
DINOFLAGELLATES										
Gymnodinium										
Peridinium										
Unknown			49			25	25			
TOTAL	858	172	784	564	368	466	441	441	466	539
Analyst	DL	SK	DL	SK	SK	DL	DL	SK	SK	DL

Percentage Composition of the Phytoplankton Community
Port Royal Sound
Fall 1970

	Station Number	1	2	4	5	6	7	8	9	10	11
10/14	Centrate Diatoms	10.2%	28.9%	44.1%	6.3%	33.3%	23.1%	15.6%	28.8%	15.4%	15.9%
	Pennate Diatoms	70.2%	71.1%	56.3%	87.3%	58.2%	69.4%	38.5%	63.9%	67.5%	52.6%
	All Diatoms	80.4%	100 %	100 %	93.7%	91.6%	92.5%	54.2%	92.7%	82.9%	68.5%
	Greens	15.1%	0	0	0	0	7.7%	0	7.2%	17.4%	0
	Flagellates	5.1%	0	0	6.3%	8.4%	0	46.1%	0	2.2%	31.5%
	Total Count	490	173	392	394	297	319	319	347	1127	466
10/15	Centrate Diatoms	15.1%	22.9%	0	24.9%	20.1%	18.8%	15.1%	25.1%	43.8%	0
	Pennate Diatoms	80.0%	54.0%	76.1%	68.7%	60.0%	75.0%	84.9%	58.5%	37.5%	60.0%
	All Diatoms	95.1%	77.0%	76.1%	93.6%	80.1%	93.8%	100 %	83.6%	81.3%	60.0%
	Greens	0	0	0	0	0	0	0	8.5%	0	0
	Flagellates	5.1%	22.9%	23.1%	6.3%	20.1%	6.3%	0	8.5%	18.8%	40.0%
	Total Count	490	322	320	392	368	392	490	294	392	247
10/16	Centrate Diatoms	22.4%	29.4%	41.2%	30.2%	11.7%	16.1%	9.2%	71.4%	26.1%	20.1%
	Pennate Diatoms	61.2%	29.7%	47.0%	50.2%	41.2%	42.1%	36.2%	14.2%	52.1%	39.9%
	All Diatoms	83.6%	59.2%	88.2%	80.4%	52.9%	58.2%	45.5%	85.7%	78.1%	60.0%
	Greens	0	0	0	0	0	0	0	0	0	0
	Flagellates	16.7%	41.2%	11.7%	20.0%	47.2%	41.9%	54.4%	14.2%	21.8%	39.9%
	Total Count	441	417	417	245	417	760	270	343	564	368
10/17	Centrate Diatoms	28.5%	18.2%	27.5%	29.7%	20.2%	28.5%	4.4%	23.1%	29.2%	30.2%
	Pennate Diatoms	68.5%	50.2%	51.6%	48.0%	30.2%	71.4%	91.3%	76.8%	58.3%	70.2%
	All Diatoms	97.0%	68.4%	79.2%	77.7%	50.4%	100 %	95.7%	100 %	87.5%	100 %
	Greens	0	0	0	0	0	0	0	0	0	0
	Flagellates	2.9%	31.9%	20.7%	22.3%	50.0%	0	4.4%	0	12.5%	0
	Total Counts	858	539	712	662	490	515	564	319	588	245
10/18	Centrate Diatoms	20.0%	14.5%	12.5%	13.1%	13.3%	26.4%	29.4%	22.2%	5.3%	26.1%
	Pennate Diatoms	80.0%	71.5%	59.4%	82.6%	79.8%	63.1%	64.6%	72.3%	73.6%	43.5%
	All Diatoms	100 %	86.0%	71.9%	95.7%	93.2%	89.5%	94.0%	94.5%	78.9%	69.6%
	Greens	0	0	3.1%	0	0	0	0	0	0	0
	Flagellates	0	14.5%	25.0%	4.4%	6.8%	10.5%	5.9%	5.6%	21.0%	30.3%
	Total Counts	858	172	784	564	368	466	419	441	446	567

Diversity Indices of Phytoplankton Populations
Port Royal Sound
Fall 1970

$$d = \frac{S-1}{\log e\ N} = \frac{(\text{No. of kinds}) - 1}{\log e \text{ total count}}$$

	Station Number	1	2	4	5	6	7	8	9	10	11
10/14	S–1	6	4	7	6	7	6	6	8	8	7
	N = total count	490	173	392	394	297	319	319	347	1127	466
	log e N	6.194	5.153	5.971	5.976	5.694	5.765	5.765	5.849	7.030	6.144
	d =	.96867	.77624	1.17233	1.00401	1.22936	1.04076	1.04076	1.36775	1.13798	1.13932
10/15	S–1	8	8	6	6	5	7	7	7	9	5
	N	490	322	320	392	368	392	490	294	392	247
	log e N	6.194	5.774	5.768	5.971	5.971	5.971	6.194	5.683	5.908	5.509
	d =	1.29157	1.38552	1.04022	1.00485	.84631	1.17233	1.13012	1.23174	1.52335	.90760
10/16	S–1	10	8	8	7	6	9	6	7	12	7
	N	441	417	417	245	417	760	270	343	564	368
	log e N	6.089	6.033	6.033	5.501	6.033	6.623	5.598	5.838	6.334	5.908
	d =	1.64230	1.32604	1.32604	1.27249	.99453	1.35890	1.07181	1.19904	1.89453	1.18483
10/17	S–1	11	9	9	11	8	5	8	6	11	6
	N	858	539	712	662	490	515	564	319	588	245
	log e N	6.754	6.290	6.417	6.495	6.194	6.495	6.334	5.765	6.371	5.501
	d =	1.62866	1.43084	1.40252	1.69361	1.29157	.76982	1.26302	1.04076	1.72657	1.09071
10/18	S–1	7	4	13	8	8	11	7	9	6	7
	N	858	172	784	564	368	466	419	441	466	567
	log e N	6.754	5.147	6.671	6.334	5.908	6.144	6.038	6.089	6.144	6.340
	d =	1.03642	.77715	1.94873	1.26302	1.35409	1.79036	1.15932	1.47807	.97656	1.10410

Appendix to
Seasonal Abundance and Distributions of the Benthic Invertebrates Community

TABLE 1

Numbers and Species of Bottom Organisms
Collected from Each Sampling Station on Port Royal Sound
April, 1970

Organisms	Station 1 H-1-A	Station 1 H-1-C	Station 1 H-1-D	Station 1 H-1-E	Station 2 H-2-A	Station 2 H-2-B	Station 2 H-2-C	Station 3 H-3-A	Station 3 H-3-B	Station 3 H-3-C	Station 4 H-4-A	Station 4 H-4-B	Station 4 H-4-C	Station 4 H-4-E	Station 5 H-5-A	Station 5 H-5-B	Station 5 H-5-C	Station 5 H-5-D
MOLLUSCA																		
Pelecypoda																		
Solen sp	2	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—
Ensis sp	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	10	—	—
Mulinia sp	—	—	—	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tellina sp	—	—	3	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Semele sp	—	—	—	—	7	2	—	—	—	2	—	—	—	12	—	—	—	—
Abra sp	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Arca sp	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—
Donax sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mactra sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gastropoda																		
Anachis sp	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	2	—	—
Mitrella sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Olivella sp	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Terebra sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nassarius sp	—	—	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—
Marginella sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Melampus sp	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Epitonium sp	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
Cerithiopsis sp	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	2	—	—	—	2	—	—	—	—	—	—	—	—	—
ARTHROPODA																		
Amphipoda																		
Ampelisca sp	—	—	—	—	37	372	241	73	36	938	80	8	—	218	10	158	5	231
Corophium sp	—	—	—	—	—	—	5	48	2	—	—	5	—	—	—	—	—	37
Microprotopus sp	—	—	—	—	5	10	48	112	7	15	3	3	—	143	—	221	445	175
Haustorius sp	—	20	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—
Byblis sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	(3 Species) 48	(3 Species) 7	—	—	—	—	—	—	—	—	—
Cumacea																		
Diastylidae	—	—	2	2	12	7	8	34	27	—	—	—	—	122	—	—	—	—
Bodotridae	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—	—	—	—
Caprellidea	—	—	—	2	—	—	2	8	8	7	—	—	—	41	—	12	2	—
Decapoda																		
Pinnixa sp	—	—	—	—	—	—	—	—	—	—	1	—	—	8	—	—	—	2
Lophapanopius sp	—	—	—	—	5	—	2	—	—	—	—	—	—	—	—	—	—	—
Cancer sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rithropanopus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hemigrapsus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—
Isopoda																		
Cyathura sp	—	—	—	—	—	—	—	2	—	—	—	—	—	11	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
COELENTERATA																		
Anthozoa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Renilla sp	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	5	2	2	—	3	—	48	—	5	—	—
ECHINODERMATA																		
Ophiuroidea																		
Amphiodia sp	—	—	—	—	—	37	—	—	—	—	—	—	—	8	—	—	—	—
Ophiothrix sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	58	—	—	2	2	3	17	—	—	—	—	—	5	—
NEMERTEA	—	—	—	—	3	(2 Species) 24	—	—	15	27	7	—	—	(2 Species) 82	16	—	22	19
ANNELIDA																		
Polychaeta (Species)	2	—	4	3	11	9	10	11	11	7	7	8	4	9	6	7	7	4
(Number)	4	—	9	26	61	171	83	110	174	47	65	33	8	1005	107	18	22	21
Total Species/ft²	3	1	7	7	23	19	16	23	25	14	12	12	6	22	8	13	12	9
Total Number/ft²	6	20	16	41	198	629	389	445	289	1041	173	52	13	1711	133	426	501	485
Station Total Species				11			29			28				26				17
Station Total Numbers				83			1216			1775				1949				1545
Station Average/ft²				21			405			592				487				386

TABLE 1 continued
April, 1970

	Station 6			Station 7				Station 8			Station 9				Station 10				
Organisms	H-6-A	H-6-B	H-6-C	H-7-A	H-7-B	H-7-C	H-7-D	H-8-A	H-8-B	H-8-C	H-9-A	H-9-C	H-9-D	H-9-E	H-10-A	H-10-B	H-10-C	H-10-D	H-10-E
MOLLUSCA																			
Pelecypoda																			
Solen sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ensis sp	2	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Mulinia sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tellina sp	—	—	—	—	3	—	—	—	—	—	—	—	—	2	2	—	—	—	7
Semele sp	—	—	—	—	—	—	—	—	—	—	—	2	2	—	5	—	2	—	3
Abra sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arca sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Donax sp	—	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mactra sp	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Gastropoda																			
Anachis sp	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Mitrella sp	—	—	—	—	—	2	10	—	—	2	—	—	—	—	—	—	—	—	—
Olivella sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Terebra sp	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	2	—
Nassarius sp	—	—	—	—	2	3	—	—	—	8	3	3	—	—	—	—	—	—	—
Marginella sp	—	—	—	—	—	—	—	—	—	5	8	2	—	—	5	—	—	—	3
Melampus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Epitonium sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cerithiopsis sp	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	2	2	—	—	—	10	—	—	2	—	—	—	—	—	—	—
ARTHROPODA																			
Amphipoda																			
Ampelisca sp	121	2	29	17	12	102	129	303	27	27	7	12	—	41	5	2	7	—	5
Corophium sp	—	—	3	2	2	5	4	10	7	—	—	46	2	—	2	—	2	—	—
Microprotopus sp	53	2	20	39	46	36	48	—	—	—	—	—	—	—	—	—	—	—	—
Haustorius sp	—	—	—	—	—	—	—	6	—	—	—	—	—	—	—	17	—	—	—
Byblis sp	—	—	—	—	—	—	—	—	3	—	2	—	—	—	—	—	—	—	—
Unknown	(2 Species) 3	3	(3 Species) 7	—	14	2	6	—	—	—	—	—	2	—	—	—	—	—	—
Cumacea																			
Diastylidae	37	2	2	2	12	19	24	10	15	2	—	2	—	2	24	2	2	3	7
Bodotridae	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	2	—	—
Caprellidea	12	—	—	2	2	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Decapoda																			
Pinnixa sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lophapanopius sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cancer sp	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rithropanopus sp	—	—	2	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Hemigrapsus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Isopoda																			
Cyathura sp	2	2	—	—	—	2	4	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
COELENTERATA																			
Anthozoa	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—
Renilla sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	2	—	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ECHINODERMATA																			
Ophiuroidea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Amphiodia sp	—	—	—	—	—	—	—	—	25	—	2	—	—	—	—	—	—	—	—
Ophiotrix sp	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	3	—	4	—	—	—	—	—	—	—	—	—	—	—	—
NEMERTEA	14	3	(4 Species) 53	5	(4 Species) 42	(4 Species) 27	(3 Species) 44	—	—	—	—	—	—	—	—	—	—	—	—
PLATYHELMINTHES	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ANNELIDA																			
Polychaeta (Species)	9	7	10	6	11	11	10	6	10	9	8	8	4	10	7	—	8	5	9
(Number)	57	22	150	21	140	93	606	94	103	91	85	99	9	538	399	2	148	94	157
Total Species/ft²	18	15	22	15	26	27	22	10	17	14	14	16	7	15	14	4	13	7	15
Total Number/ft²	301	40	266	100	296	299	883	423	192	135	109	170	15	587	444	23	163	99	187
Station Total Species			27				34			21				25					19
Station Total Number			607				1578			750				881					916
Station Average/ft²			202				394			250				220					183

TABLE 2
Numbers and Kinds of Bottom Organisms Collected From Each Sampling Station on Port Royal Sound July, 1970

	Station 1					Section 2			Station 4				Station 5			
Organisms	H–1–A	H–1–B	H–1–C	H–1–D	H–1–E	H–2–A	H–2–B	H–2–C	H–4–A	H–4–B	H–4–C	H–4–D	H–5–A	H–5–B	H–5–C	H–5–D
MOLLUSCA																
Pelecypoda																
Arca sp	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—
Ensis sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Modiolus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tellina sp	—	—	—	—	—	3	2	—	3	—	—	2	—	—	2	2
Mulinia sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Semele sp	—	—	—	—	—	—	2	—	—	2	—	—	—	2	2	—
Tagelus sp	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—
Donax sp	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
Astarte sp	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—
Gastropoda																
Nassarius sp	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	3
Mitrella sp	—	—	—	—	—	—	—	—	—	—	—	—	14	2	—	—
Marginella sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Polinices sp	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—
Anachis sp	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—
Terebra sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cresidula sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ARTHROPODA																
Amphipoda																
Ampelisca sp	—	—	—	—	—	3	—	—	—	—	—	12	14	—	8	83
Haustorius sp	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gammarus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Microprotopus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15	29
Corophium sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	8	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Caprellidea	—	—	—	—	—	—	—	—	—	—	—	5	20	—	7	5
Cumacea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Diastylidea	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—
Decapoda																
Rhithropanopeus sp	—	—	—	—	—	3	—	—	—	—	—	—	5	—	2	1
Cancer sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arenaeus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—
Upogebia sp	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Pagurus sp	—	—	19	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown shrimp	—	—	—	2	—	—	2	—	4	—	—	—	3	—	2	—
Stomatopoda																
Squilla sp	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—
Isopoda																
Cyathura sp	—	—	—	—	—	—	—	—	5	—	—	—	7	—	—	7
Unknown	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
COELENTERATA																
Actiniaria sp	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—	—	31	—
ECHINODERMATA																
Amphiodia sp	—	—	—	—	—	8	12	—	15	—	—	22	—	—	—	—
Ophiotrix sp	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—
NEMERTEA	2	—	—	3	3	—	5	7	—	—	—	—	—	—	—	—
ANNELIDA																
Polychaeta (Species)	3	—	—	3	3	9	8	5	10	—	5	10	13	5	5	8
(Number)	9	—	—	18	8	53	96	58	65	2	10	68	51	15	11	34
Total Species/ft^2	6	1	1	5	6	16	13	6	14	2	5	17	23	9	14	15
Total Number/ft^2	34	2	19	23	15	75	119	65	92	4	10	115	123	23	82	164
Station Total Species					11			19				20				30
Station Total Number					93			259				221				392
Station Average/ft^2					19			86				55				98

TABLE 2 Continued
July, 1970

Organisms	Station 6			Station 7				Station 8		
	H-6-A	H-6-B	H-6-C	H-7-A	H-7-B	H-7-C	H-7-D	H-8-A	H-8-B	H-8-C
MOLLUSCA										
Pelecypoda										
Arca sp	—	—	—	—	—	—	—	—	—	2
Ensis sp	—	—	—	—	2	—	—	—	—	—
Modiolus sp	—	—	—	—	—	—	—	—	—	—
Tellina sp	—	—	—	2	—	2	—	—	—	—
Mulinia sp	—	—	—	—	—	—	—	—	—	—
Semele sp	—	—	—	2	—	—	—	—	—	—
Tagelus sp	3	—	—	—	—	2	—	—	—	—
Donax sp	—	—	—	—	—	—	—	—	—	—
Astarte sp	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—
Gastropoda										
Nassarius sp	5	—	—	—	—	2	2	—	5	—
Mitrella sp	—	5	2	3	—	—	—	2	2	7
Marginella sp	5	—	—	—	2	3	—	—	—	—
Polinices sp	—	—	—	—	—	—	—	—	—	—
Anachis sp	3	—	—	—	—	—	—	—	—	2
Terebra sp	—	—	—	2	—	—	—	—	—	—
Cresidula sp	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	22	—	—	—	—	—	—	3
Arthropoda	—	—	—	—	—	—	—	—	—	—
Amphipoda										
Ampelisca sp	2	—	603	10	7	—	7	—	—	5
Haustorius sp	—	—	—	—	—	—	—	—	—	—
Gammarus sp	—	—	—	—	—	—	—	—	—	—
Microprotopus sp	—	—	51	3	—	—	—	—	—	20
Corophium sp	—	—	—	32	—	—	—	—	—	—
Unknown	—	—	—	(3 Species)	5	—	2	—	—	2
				54						
Caprellidea	—	—	—	2	—	—	—	—	—	—
Cumacea										
Diastylidea	—	—	—	—	—	—	—	—	—	—
Decapoda										
Rhithropanopeus sp	—	2	8	13	2	—	2	2	—	2
Cancer sp	—	—	2	—	—	—	—	—	—	—
Arenaeus sp	—	—	—	—	—	—	—	—	—	—
Upogebia sp	—	—	—	—	—	—	—	—	—	—
Pagurus sp	—	—	—	—	—	—	—	—	—	—
Unknown shrimp	—	—	3	7	—	—	—	—	2	—
Stomatopoda										
Squilla sp	—	—	—	—	—	—	—	—	—	—
Isopoda										
Cyathura sp	5	—	10	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—
COELENTERATA										
Actiniaria sp	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	105	—	—	—	—	2	—	—
ECHINODERMATA										
Amphiodia sp	—	—	—	—	—	—	—	—	3	5
Ophiotrix sp	—	—	—	—	—	—	—	—	—	—
NEMERTEA	—	—	—	—	3	—	—	—	—	—
ANNELIDA										
Polychaeta (Species)	8	9	10	9	11	5	10	7	8	7
(Number)	27	14	106	59	71	22	23	69	154	108
Total Species ft/²	14	11	19	22	17	9	14	10	12	16
Total Number ft/²	50	23	912	189	92	31	36	75	166	156
Station Total Species			23				28			20
Station Total Number			985				348			397
Station Average/ft²			328				87			132

Organisms	Station 9					Station 10					Station 11		
	H-9-A	H-9-B	H-9-C	H-9-D	H-9-E	H-10-A	H-10-B	H-10-C	H-10-D	H-10E	H-16-A	H-11-B	H-11-C
MOLLUSCA													
Pelecypoda													
Arca sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Ensis sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Modiolus sp	—	—	—	—	—	—	—	—	—	—	2	3	7
Tellina sp	—	—	14	—	3	—	7	7	—	3	—	2	10
Mulinia sp	—	—	—	—	—	—	—	—	—	—	—	—	7
Semele sp	—	2	—	—	—	3	2	—	—	2	2	—	—
Tagelus sp	—	—	—	—	—	2	—	—	—	—	—	—	—
Donax sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Astarte sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—
Gastropoda													
Nassarius sp	—	—	—	—	—	—	—	—	—	2	—	—	2
Mitrella sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Marginella sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Polinices sp	—	—	—	—	—	2	—	—	—	—	—	—	—
Anachis sp	5	—	2	—	—	—	—	—	—	—	—	—	—
Terebra sp	—	—	—	—	—	2	—	—	—	—	—	—	—
Cresidula sp	3	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	2	—	—	—	—	—	—	—
Arthropoda	—	—	—	—	—	—	—	—					
Amphipoda													
Ampelisca sp	3	2	—	2	—	3	—	—	—	—	—	14	3
Haustorius sp	—	—	—	—	—	—	—	—	—	19	—	—	—
Gammarus sp	—	2	—	—	—	2	—	—	—	5	—	—	—
Microprotopus sp	119	—	—	8	—	—	—	—	—	—	—	56	—
Corophium sp	—	—	—	—	—	—	—	—	—	—	—	7	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—
Caprellidea	—	—	—	—	—	—	—	—	—	—	—	—	—
Cumacea													
Diastylidea	—	—	—	—	—	—	—	—					
Decapoda													
Rhithropanopeus sp	3	—	—	2	—	—	—	—	—	2	8	3	—
Cancer sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Arenaeus sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Upogebia sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Pagurus sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown shrimp	2	—	—	2	—	—	2	—	—	—	—	2	—
Stomatopoda													
Squilla sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Isopoda													
Cyathura sp	3	—	—	—	—	—	—	—	2	—	—	3	2
Unknown	—	—	—	—	—	—	—	—	—	—	—	2	—
COELENTERATA													
Actiniaria sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	2	—	—	2	—	—	2	—	—	—	—	—	—
ECHINODERMATA													
Amphiodia sp	—	—	—	—	—	—	—	—	—	—	—	—	—
Ophiotrix sp	—	—	—	—	—	—	—	—	—	—	—	—	—
NEMERTEA	—	—	—	—	—	—	—	—	—	—	—	—	—
ANNELIDA													
Polychaeta (Species)	7	3	1	5	3	8	4	1	9	6	5	5	5
(Number)	30	6	3	10	7	62	21	7	27	17	16	21	26
Total Species ft/²	15	6	3	10	4	15	8	1	10	12	8	14	11
Total Number ft/²	170	12	19	26	10	78	34	7	29	50	28	113	57
Station Total Species					18					23			17
Station Total Number					237					,98			198
Station Average/ft²					47					40			66

TABLE 3
October, 1970

	Station 1				Station 2			Station 4				Station 5			Station 6			
Organisms	H-1-A	H-1-B	H-1-C	H-1-E	H-2-A	H-2-B	H-2-C	H-4-A	H-4-B	H-4-C	H-4-D	H-5-A	H-5-B	H-5-C	H-6-A	H-6-B	H-6-C	H-7-A
MOLLUSCA																		
Pelecypoda																		
Donax sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Siliqua sp	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tellina sp	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—
Macoma sp	—	—	—	2	—	5	—	—	—	3	—	—	—	—	—	—	2	—
Chione sp	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—
Tracia sp	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—
Lucina sp	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—	—
Modiolaria sp	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—
Trachycardium sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mulnia sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Crassotrea sp	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—	—
Gastropoda																		
Epitonium sp	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Terebra sp	—	—	—	4	—	—	—	—	2	—	—	—	—	—	—	—	—	—
Mitrella sp	—	—	—	—	—	—	—	10	7	—	—	—	—	—	—	—	—	2
Mitra sp	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Nassarius sp	—	—	—	—	—	5	—	3	—	—	—	—	—	2	3	—	2	12
Tornatina sp	—	—	—	—	—	—	—	—	7	—	20	—	—	—	—	—	—	—
Crepidula s	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
Cymatium sp	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—
Turbonilla sp	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—
Cerithiopsis sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mangilia sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Littorina sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Anachis sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Urosalpinx sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eupleura sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ARTHROPODA																		
Amphipoda																		
Gammarus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Haustorius sp	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potogeneria sp	5	—	—	—	32	3	—	17	7	—	6	-	2	—	—	—	—	14
Microprotopus sp	—	—	—	—	—	—	—	2	3	—	—	—	—	—	3	—	—	3
Ampelisca sp	—	—	—	—	—	—	—	—	—	—	27	—	—	—	—	—	7	2
Melita sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—
Corophium sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—
Unknown	—	—	—	—	—	2	—	—	2	—	58	—	—	3	—	3	—	—
Caprellidea	—	—	—	—	—	—	—	—	—	—	14	—	—	—	—	—	—	—
Stomatopoda																		
Squilla sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—
Mysidacea																		
Mysis sp	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cumacea																		
Diastylidea	—	—	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—	—
Decapoda																		
Acetes sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Latreutes sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Peneus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Leptochela sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pilumnus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Pinnixa sp	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	2
Callinectes sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Panopeus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hyas sp	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—
Upogebia sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—
Pycnogonida	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—
Isopoda																		
Cyathura sp	2	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—
Chirodotea sp	—	2	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
COELENTERATA																		
Renilla sp	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—
Unknown anemone	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17	—
ECHINODERMATA																		
Hemipholis sp	72	—	—	—	12	8	—	—	2	—	4	—	—	—	—	—	—	—
Amphiodia sp	—	—	—	—	2	15	—	—	12	—	—	—	—	—	—	—	—	—
Ophiothrix sp	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—
NEMERTEA	—	—	—	—	—	(2 Species) 8	(3 Species) 10	3	—	2	(2 Species) 8	2	(2 Species) 4	—	—	—	—	—
PLATYHELMINTHES	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ANNELIDA																		
Polychaeta (Species)	7	—	1	—	9	16	4	2	5	—	4	4	3	5	4	2	3	7
(Number)	40	—	10	—	54	56	66	33	14	—	52	43	7	21	21	4	12	63
Sipunculida	—	—	—	—	—	—	—	—	7	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	2	—	—	—	—	16	5	—	—	—	—	—	2
Total Species/ft²	11	1	1	4	13	31	7	8	18	2	23	6	7	7	8	3	8	15
Total Number/ft²	121	2	10	10	102	118	76	70	72	5	235	45	15	26	31	7	43	101
Station Total Species				16			31				36			12			13	
Station Total Number				143			296				382			86			81	
Station Average/ft²				36			99				95			29			27	

TABLE 3 continued
October, 1970

Organisms	H-7-B	H-7-C	H-7-D	H-8-A	H-8-B	H-8-C	H-9-A	H-9-C	H-9-D	H-9-E	H-10-A	H-10-B	H-10-C	H-10-D	H-10-E	H-11-A	H-11-B	H-11-C
MOLLUSCA																		
Pelecypoda																		
Donax sp	—	—	—	—	—	—	2	—	—	—	2	—	—	—	—	—	—	—
Siliqua sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Macoma sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—
Tellina sp	—	3	—	2	—	—	—	—	—	—	—	—	12	2	—	—	—	—
Chione sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tracia sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lucina sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Modiolaria sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trachycardium sp	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
Mulnia sp	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gastropoda																		
Epitonium sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Terebra sp	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Mitrella sp	—	—	2	14	3	5	—	—	—	—	—	—	—	—	—	12	—	—
Mitra sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nassarius sp	—	7	—	8	3	—	—	—	—	—	—	—	—	—	2	—	—	—
Tornatina sp	—	—	—	—	5	—	—	—	—	—	3	—	—	—	—	—	—	—
Crepidula s	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cymatium sp	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Turbonilla sp	—	—	—	—	3	—	—	—	—	—	20	—	—	—	—	—	—	—
Cerithiopsis sp	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—
Mangilia sp	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
Littorina sp	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
Anachis sp	—	—	2	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—
Urosalpinx sp	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—
Eupleura sp	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
ARTHROPODA																		
Amphipoda																		
Gammarus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Haustorius sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potogeneria sp	—	10	—	12	—	—	5	—	—	—	333	—	—	—	—	—	—	—
Microprotopus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ampelisca sp	5	19	8	—	—	—	—	—	—	—	—	—	—	—	—	7	—	—
Melita sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Corophium sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7	5	—
Unknown	2	3	—	—	—	—	29	—	—	—	15	—	—	—	2	22	27	—
Caprellidea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Stomatopoda																		
Squilla sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mysidacea																		
Mysis sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cumacea																		
Diastvlidea	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Thoracica																		
Balanus sp	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—
Decapoda																		
Acetes sp	—	—	10	—	—	8	—	—	—	—	—	—	—	—	—	—	—	—
Latreutes sp	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Peneus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—
Leptochela sp	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pilumnus sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—
Pinnixa sp	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Callinectes sp	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
Panopeus sp	—	—	—	7	—	—	2	—	—	—	—	—	—	—	—	10	—	—
Hyas sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Upogebia sp	—	—	—	—	—	—	—	—	—	—	3	—	2	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pycnogonida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Isopoda																		
Cyathura sp	2	2	—	2	—	—	3	—	—	—	—	—	—	—	—	—	—	—
Chirodotea sp	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—
COELENTERATA																		
Renilla sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown anemone	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	56	—
ECHINODERMATA																		
Hemipholis sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Amphiodia sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ophiothrix sp	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unknown	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NEMERTEA	3	—	—	—	—	—	—	—	7	—	—	—	—	—	—	5	—	—
PLATYHELMINTHES	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—
ANNELIDA																		
Polychaeta (Species)	4	4	6	5	4	—	6	—	—	—	—	2	3	—	—	4	4	3
(Number)	13	16	70	15	18	30	33	—	17	3	2	4	12	3	—	581	35	9
Sipunculida	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Unknown	—	—	2	—	—	4	—	—	—	—	—	—	—	—	—	—	—	2
Total Species/ft²	8	11	11	13	10	6	17	0	3	1	11	3	5	4	1	11	8	4
Total Number/ft²	25	62	92	64	36	51	88	0	27	3	386	6	26	9	2	646	126	9
Station Total Species			22			21				19					17			14
Station Total Number			280			151				118					429			781
Station Average/ft²			90			50				29					86			260

Appendix to
Air Quality Evaluation

Table 1. Data Summary
June 1970

	Suspended Particulates $\mu gm/m^3$	Sulfates $\mu gm/m^3$	Phosphates $\mu gm/m^3$	Nitrates $\mu gm/m^3$	Settleable Particulates $gm/m^2/mo.$	Sulfur Dioxide ppm (est.)
Beaufort Health Dept.	42.6	0.38	0	0.06	1.7	.003
Bluffton	42.9	0.38	0.005	0.05	4.2	.003
Palmetto Bay Marina	34.3	0.36	0.001	0.05	2.4	.006
Victoria Bluff	29.9	0.35	0.04	0.05	3.1	.002
Pinckney's Plantation	31.3	0.42	0	0.09	2.5	.002

Table 2. 24 Hr. Gaseous Sampling for Sulfur Dioxide, Nitrogen Dioxide, Total Oxidants, Aldehydes, Ammonia and Hydrogen Sulfide

April 20 - 29, 1970

24 Hr. Gaseous Sampling

Beaufort Co. Health Dept.	High	Low	Average
SO_2	.002	ND	ND
NO_2	ND	ND	ND
Ox	.032	ND	.009
Aldehydes	.048	.007	.024
NH_3	.12	.010	.044
Bluffton Health Center			
SO_2	.002	ND	ND
NO_2	.006	ND	ND
Ox	.044	ND	.008
Aldehydes	.025	.007	.013
NH_3	.188	.061	.001
Mr. Pinckney's			
SO_2	.004	ND	ND
NO_2	ND	ND	ND
Ox	.053	ND	.012
Aldehydes	.010	ND	.004
NH_3	.051	ND	.017
Victoria Bluff			
SO_2	.004	ND	.002
NO_2	ND	ND	ND
Ox	.018	ND	.006
Aldehydes	.010	.001	.005
NH_3	.135	.009	.044
Palmetto Bay Marina			
SO_2	.004	ND	ND
NO_2	.008	ND	ND
Ox	.030	ND	.007
Aldehydes	.013	ND	.004
NH_3	.530	.022	.101

August 4-12, 1970

24 Hr. Gaseous Sampling

Palmetto Bay Marina	High	Low	Average
SO_2	.001	ND	ND
NO_2	.011	.003	.007
Ox	.021	ND	.008
Aldehydes	.026	ND	.007
NH_3	.023	ND	.007
Victoria Bluff			
SO_2	ND	ND	ND
NO_2	.029	.003	.008
Ox	.030	ND	.013
Aldehydes	.038	ND	.006
NH_3	.095	ND	.013
H_2S	ND	ND	ND
Bluffton Health Center			
SO_2	.001	ND	ND
NO_2	.018	.002	.011
Ox	.027	ND	.010
Aldehydes	.006	ND	.003
NH_3	.016	ND	.007
Mr. Pinckney's			
SO_2	ND	ND	ND
NO_2	.008	.002	.006
Ox	.011	ND	.005
Aldehydes	.021	ND	.009
NH_3	.048	ND	.013
Beaufort Co. Health Dept.			
SO_2	.001	ND	ND
NO_2	.020	ND	.010
Ox	.031	.003	.021
Aldehydes	.004	ND	.002
NH_3	.011	ND	.003

Table 2 continued

Oct. 20 - 28, 1970
24 Hr. Gaseous Sampling

	High	Low	Average
Beaufort Co. Health Dept.			
SO_2	.001	ND	ND
NO_2	.020	ND	.010
Ox	.031	.003	.017
Aldehydes	.004	ND	.002
NH_3	.011	ND	.003
Mr. Pinckney's			
SO_2	ND	ND	ND
NO_2	.008	.002	.006
Ox	.011	ND	.005
Aldehydes	.021	ND	.009
NH_3	.048	ND	.013
Bluffton Health Center			
SO_2	.001	ND	ND
NO_2	.018	.002	.011
Ox	.027	ND	.003
NH_3	.016	ND	.006
Victoria Bluff			
SO_2	ND	ND	ND
NO_2	.029	.001	.008
Ox	.030	.001	.013
Aldehydes	.038	ND	.006
NH_3	.095	ND	.013
Palmetto Bay Marina			
SO_2	.001	ND	ND
NO_2	.011	.003	.007
Ox	.021	ND	.008
Aldehydes	.026	ND	.007
NH_3	.023	ND	.007

H_2S was sampled at Victoria Bluff with results of Analysis being Non Detectable.

Table 3. Settleable Particulates and Sulfation Rate

Date	Locale*	gm/m²/mo.	(PbO$_2$ Cylinders) μg/100cm²/day	SO_2 Est. ppm.
April	PM	2.5	.21	.008
	MP	3.4	.11	.004
	VB	3.0	.06	.002
	B	5.1	.12	.005
	CHD	1.8	.09	.004
May	PM	2.4	.11	.004
	MP	1.5	ND	ND
	VB	3.2	.05	.002
	B	3.4	.01	.004
	CHD	1.6	.07	.003
June	PM	0.8	.11	.004
	MP	3.3	.089	.004
	VB	2.5	.044	.001
	B	1.2	.065	.003
	CHD	4.0	.07	.003
July	B	2.6	.086	.003
	VB	2.4	.054	.002
	MP	ND	.077	.003
	PM	2.2	.115	.005
	CHD	1.9	.08	.003
August	B	2.4	.048	.001
	VB	0.7	.021	.001
	MP	1.3	.155	.006
	PM	0.3	.170	.007
	CHD	—	.05	.002
September	B	1.6	.04	.002
	VB	—	.02	.001
	MP	1.4	ND	ND
	PM	1.0	.13	.005
	CHD	2.0	.10	.004
October	B	2.6	.25	.010
	VB	.1	.08	.003
	MP	2.8	.06	.002
	PM	1.8	.18	.007
	CHD	4.4	.10	.004

*PM Palmetto Bay Marina
MP Mr. Pinckney's
VB Victoria Bluff
B Bluffton
CHD Beaufort County Health Dept.

Table 4. Corrosion Rate in Beaufort County

Location	Metals	Weight loss in grams
	Fe I (exposed 3 months)	
4-29-70 to 7-30-70	PM	1.5364
	VB	1.0317
	MP	1.3015
	B	.9469
7-30-70 to 11-02-70	PM	.7096
	VB	.9155
	MP	.8938
	B	.6603
	Fe II (exposed 6 months)	
4-29-70 to 11-02-70	PM	1.4390
	VB	.5010
	MP	1.1199
	B	1.2824

Table 5. Suspended Particulate Summary Data
April - October, 1970

Station	# Samples	$\mu g/m^3$ High	Low	AA	Gm	Beta Radioactivity PC/M^3
Beaufort Co. Health Dept.	60	81.1	10.6	42.9	40.4	0.41
Mr. Pinckney's	59	63.4	11.1	33.0	30.7	0.45
Bluffton Health Center	67	74.3	17.7	39.4	36.9	0.43
Victoria Bluff	65	126.5	12.4	34.5	31.3	0.46
Palmetto Bay Marina	68	70.0	14.7	34.5	32.8	0.41

Table 6. Metal Survey

		$\mu g/M^3$		
Beaufort County Health Dept.	# samples	Average	High	Low
Cr	64	0.005	0.253	ND
Mn	64	0.009	0.085	ND
Fe	63	0.159	0.666	ND
Pb	62	0.207	0.582	ND
Cu	64	3.72	10.4	0.219
Cd	62	0.001	0.010	ND
Zn	64	0.256	2.54	ND
Mg	64	0.520	5.31	ND
Ca	64	0.961	10.6	ND
Bluffton Health Center				
Cr	71	0.005	0.043	ND
Mn	71	0.008	0.023	ND
Fe	71	0.152	0.554	ND
Pb	70	0.258	0.991	0.010
Cu	71	0.559	3.58	0.035
Cd	68	0.002	0.046	ND
Zn	71	0.233	2.091	ND
Mg	71	0.546	7.29	ND
Ca	71	1.482	17.25	ND
Mr. Pinckney's				
Cr	60	0.006	0.021	ND
Mn	60	0.007	0.018	ND
Fe	60	0.103	0.693	ND
Pb	60	0.090	0.937	ND
Cu	60	0.514	3.029	0.0002
Cd	60	0.001	0.007	ND
Zn	60	0.383	4.194	ND
Mg	60	0.427	2.451	ND
Ca	60	1.087	12.48	ND
Victoria Bluff				
Cr	64	0.006	0.025	ND
Mn	63	0.011	0.039	ND
Fe	64	0.128	0.369	ND
Pb	64	0.115	0.987	ND
Cu	65	0.489	2.056	0.127
Cd	64	0.001	0.007	ND
Zn	64	0.249	2.665	ND
Mg	65	0.838	9.847	ND
Ca	64	1.872	22.03	ND
Palmetto Bay Marina				
Cr	68	0.004	0.017	ND
Mn	68	0.007	0.024	ND
Fe	68	0.150	0.375	ND
Pb	68	0.114	0.276	ND
Cu	68	0.316	1.883	0.070
Cd	68	0.001	0.010	ND
Zn	68	0.136	2.007	ND
Mg	68	0.622	7.647	ND
Ca	68	0.985	12.07	ND

Table 7. Anion Aanlysis Summary

	# samples	Hi (μg/m³)	Low	Average
Beaufort Co. Health Dept.				
Sulfates	65	19.2	1.64	8.57
Phosphates	65	1.08	ND	0.04
Nitrates	65	8.00	ND	0.86
Mr. Pinckney's				
Sulfates	60	43.53	0.94	10.46
Phosphates	60	2.24	ND	0.09
Nitrates	60	14.54	ND	0.87
Bluffton Health Center				
Sulfates	70	23.94	ND	8.31
Phosphates	70	1.66	ND	0.08
Nitrates	71	3.88	ND	0.73
Victoria Bluff				
Sulfates	63	18.74	ND	9.76
Phosphates	62	2.17	ND	0.18
Nitrates	63	2.63	ND	0.49
Palmetto Bay Marina				
Sulfates	68	17.27	2.05	7.92
Phosphates	68	0.64	ND	0.06
Nitrates	68	4.75	0.02	0.74

Table 8. Other Samples

Benzene Extractable organics from Hi-Vol filters

	# Samples	Hi	Low (μg/M³)	Average
Beaufort Co. Health Dept.	18	21.4	ND	3.6
Bluffton Health Center	16	16.0	ND	2.6
Mr. Pinckney's	20	244	ND	3.5
Victoria Bluff	22	15.1	ND	0.31
Palmetto Bay Marina	23	17.5	ND	2.4

Chlorides

Beaufort Co. Health Dept.	7	3.00	ND	1.18
Bluffton Health Center	7	1.22	ND	0.31
Mr. Pinckney's	8	2.90	ND	0.58
Victoria Bluff	7	3.64	ND	0.78
Palmetto Bay Marina	9	2.41	ND	0.93

Appendix to Economic and Environmental Evaluation of Development Alternatives for Beaufort County, S. C.

PART I

CONFIDENTIAL

Socio-Economic Study of Development of Port Victoria Area of Beaufort County South Carolina

Sample Survey of Households

Summer of 1970

Household sample number ______________

Enumerator ________________________

Department of Agricultural Economics and Rural Sociology
Clemson University
Clemson, South Carolina 29631

DO NOT DISCLOSE TO UNAUTHORIZED PERSONS

Enumerator please note about respondent:

Race: ______ Caucasian
______ Negroid
______ Other

Approximate age: ______ Adolescent (Under 18)
______ Young adult (Under 40)
______ Middle aged (40-65)
______ Elderly (Over 65 or retired)

Sex: ______ Male
______ Female

Type of house: ______ Frame
______ Brick
______ Cement block
______ Mobile home
______ Other

Condition of house: ______ Excellent
______ Good
______ Fair
______ Poor

Researchers at Clemson University are making a study of the economic effects of industrial growth and development in the Beaufort area. Such growth could possibly cause some reduction in the quality of water and air in the county although it would increase employment opportunities. I am working for Clemson to obtain some information from a sample survey of households, and I would like to ask you a few questions, if you can spare me about 30 minutes. We promise you that any information you give us is strictly confidential and will not be turned over to any government or business agency.

SOCIO-ECONOMIC DATA

1. a. Would you say that you do most of the buying for your household?
____ Yes ____ No (If *yes*, go to Question 2.)

b. Is the person who does most of your family's buying present here now?
____ Yes ____ No (If *no*, go to Question 1d.)

c. Would it be possible for the person doing most of the buying to help answer some of these questions?
____ Yes ____ No (If *yes*, go to Question 2 after that person is present.)

d. Are you familiar enough with the spending habits of your household to answer a few questions about those habits?
____ Yes ____ No (If *no*, interview terminated)

2. How long has this household been living in Beaufort County?
____ Years (or ____ months)

3. Did you spend your childhood in Beaufort County?
____ Yes ____ No

4. How many members were there of this household on April 1, 1970? ______________

	Household Members 1	2	3	4	5
5. What is the first name of each member 14 or over? (If family exceeds 5, use additional schedule).					
(For each person listed, ask questions 6—10.)					
6. Age, last birthday (Years)					
7. Sex (0=Male, 1=Female)					
8. What is the highest grade of school completed?					
9. Was ________________ employed all of the past 12 months? (0=fulltime, 1=part time, 2=unemployed)					
10. Which of the following describes the kind of jobs held during the past 12 months? (Use X to mark all jobs held.) Also, what percentage of your total household income did each of the jobs held account for in 1969? (Enumerator, please note percentage in extreme right-hand column.)					
a. Agriculture, Forestry, and Fisheries					
b. Construction					
(1) General Building Construction					
(2) General Construction except Building (e.g., Ashphalt Paving, Earth Moving)					
(3) Special Construction (e.g., Electrical, Plumbing, Painting)					

	Household Members 1	2	3	4	5
c. Manufacturing					
(1) Textile					
(2) Food Processing (e.g., Seafood, Vegetables)					
(3) Lumber (e.g., Paper Mills)					
(4) Chemical					
(5) Other					
d. Transportation					
e. Communication					
f. Utilities (e.g., Gas, Electricity, Sanitary Services)					
g. Trade					
(1) Eating Places					
(2) Lodging Places (e.g., Motels, Hotels)					
(3) Marinas and Marine Equipment Sales					
(4) Gasoline Service Stations					
(5) Other					
h. Financial (e.g., Banks, Insurance Agencies)					
i. Real Estate					
j. Services					
(1) Medical					
(2) Recreation					
(3) Other					

	Household Members 1	2	3	4	5
k. Government					
(1) Local and State					
(2) Defense (e.g., Military)					
(3) Other federal agencies other than Defense					

11. In the past 12 months, did you, or any member of this household, receive income from sources such as:

	Income Source	*Yes*	*No*
a.	Unemployment Insurance	____	____
b.	Social Security or Other Retirement Benefits (Include Death Benefits)	____	____
c.	Veterans' Pensions	____	____
d.	Workmen's Compensation	____	____
e.	State Old-Age Pension	____	____
f.	Aid to Dependent Children	____	____
g.	Aid to Permanently Disabled	____	____
h.	Aid to Blind	____	____
i.	Rent or Royalties	____	____
j.	Savings	____	____
k.	Other (______________)	____	____

12. Of your total 1969 income, what percentage of it was (Enumerator, read entire list before beginning to take answers)

a. ________ Deposited in savings accounts
b. ________ Spent in Beaufort County
c. ________ Spent in Jasper County
d. ________ Spent in rest of S. C.
e. ________ Spent in Savannah, Ga.
f. ________ Spent in rest of world
   100% Total

13. How many members of this household would try to get an industrial job if such were available in the Port Victoria area in the reasonable future?

________ (If none, go to Question 15.)

How many of those who might be interested in taking such a job are at present

a. ______ unemployed
b. ______ employed in Beaufort County
c. ______ employed in Savannah, Ga.
d. ______ employed elsewhere
e. ______ student

Attitudes Toward Environmental Quality

Now, we need some information about your attitudes toward clean air and clean water and the values you place on different levels of purity of water and air.

14. Assume that the *only* way you could have clean water in the Beaufort area streams would be for individual citizens such as yourself to go together and pay for it in the form of taxes, or by some other method. For the present, forget about who might be to blame for the pollution. What percentage of your total income would you be willing to give up in order to have local bodies of water: (Enumerator, read all responses before beginning to take answers.)

a. ____ clean enough to have no unnatural smell associated with them
b. ____ clean enough to fish out of safely
c. ____ clean enough to swim in safely
d. ____ for fresh water, safe to drink with standard treatment

15. Let's make the same assumption about clean air as we did about clean water. Again, forget about who might be the blame for air pollution. Assume that the only way to have clean air is for you to pay for it (in cooperation with your neighbors). What percentage of your total income would you be willing to give up in order to have the air in your area so clean that: (Enumerator, read all responses before beginning to take answers.)

a. ____ there is no possible threat to health
b. ____ it does not discolor paint, draperies, and other items
c. ____ there is no artificial haze in the sky
d. ____ there is no noticeable smell as a result of air pollution

16. How often do you ordinarily visit the beaches during warm weather? (Enumerator, read entire list before beginning to take answers.)

a. ____ more than once a week
b. ____ about once a week
c. ____ about once a month
d. ____ once or twice a season
e. ____ rarely or never

(If answer to Question is *rarely or never*, omit Questions 17 and 18.)

17. Which of the following beaches do you visit most often? (Enumerator, read entire list.)

a. ____ Hunting Island
b. ____ Fripp Island
c. ____ Northern Part of Hilton Head
d. ____ Southern Part of Hilton Head
e. ____ Other (Specify) ______________

18. In the previous question you said you visited ______________ beach most often. I now want you to compare this beach with other beaches such as Myrtle Beach, the Isle of Palms, Folly Beach, Edisto Island, and Tybee (Savannah) Beach. Is this beach

a. Better than ______________
(*Name of Beach*)

b. About the same as ______________
(*Name of Beach*)

c. Worse than ______________
(*Name of Beach*)

d. Can't tell ______________

e. Never been to other beaches ______________

19. I now want to list several ways beaches may be made ugly or useless. I want you to rank these beaches from the most worst to the least worst. (Enumerator, read all five responses and use 1-5 for ranking.)
   a. —— Beaches coated with oil and tar
   b. —— Beaches littered with paper bags, beer cans, and other human trash
   c. —— Beaches washed by water containing household and industrial waste which waste you could not see
   d. —— Beaches with well-kept beach-front buildings (e.g., houses, motels)
   e. —— Beaches with abandoned beach-front buildings

20. Let's now suppose that you and others had to pay to keep the beaches in Beaufort County usable. Also suppose that this was worked out in such a way that you had to pay only your fair share.

   a. How much would you be willing to pay to keep the beaches as clean as they are now?
   (1) —— $500 or more a year ($42 or more a month). If more, please specify ——————.
   (2) —— $400 a year ($33 a month)
   (3) —— $300 a year ($25 a month)
   (4) —— $200 a year ($17 a month)
   (5) —— $100 a year ($9 a month)
   (6) —— $ 50 a year ($4 a month)
   (7) —— $ 25 a year ($2 a month)
   (8) —— $ 10 or less a year ($.83 or less a month). If less, please specify ——————.

   b. How much more would you be willing to pay to have the beaches cleaner than they are now?
   (1) —— $500 or more a year ($42 or more a month). If more, please specify ——————.
   (2) —— $400 a year ($33 a month)
   (3) —— $300 a year ($25 a month)
   (4) —— $200 a year ($17 a month)
   (5) —— $100 a year ($9 a month)
   (6) —— $ 50 a year ($4 a month)
   (7) —— $ 25 a year ($2 a month)
   (8) —— $ 10 or less a year ($.83 or less a month). If less, please specify ——————.

   c. Suppose some person or group wanted to buy your right to use the beaches in Beaufort County. How much would you have to be paid to sell your right, that is, what is the lowest price you would accept for your right to use them?
   (1) —— $ 10 or less a year ($.83 or less a month). If less, please specify ——————.
   (2) —— $ 25 a year ($2 a month)
   (3) —— $ 50 a year ($4 a month)
   (4) —— $100 a year ($9 a month)
   (5) —— $200 a year ($17 a month)
   (6) —— $300 a year ($25 a month)
   (7) —— $400 a year ($33 a month)
   (8) —— $500 or more a year ($42 or more a month). If more, please specify ——————.

   d. Suppose it was decided that the care, policing (i.e., picking up trash), and maintenance of beaches should be financed by a charge on the people who use the beaches. How much would you be willing to pay for a permit to use these beaches for a season?
   (1) —— $500 or more a year ($42 or more a month). If more, please specify ——————.
   (2) —— $400 a year ($33 a month)
   (3) —— $300 a year ($25 a month)
   (4) —— $200 a year ($17 a month)
   (5) —— $100 a year ($9 a month)
   (6) —— $ 50 a year ($4 a month)
   (7) —— $ 25 a year ($2 a month)
   (8) —— $ 10 or less a year ($.83 or less a month). If less, please specify ——————.

21. Now let's talk about the coastal waters such as Calibogue Sound, the Broad River and Port Royal Sound, and St. Helena Sound. The growth of cities, residential areas, and industrial plants requires spending on waste treatment if these waters are to be kept clean. Suppose that these costs are to be paid by you and others in the community on a fair basis.

   a. How much would you be willing to pay to keep these waters as clean as they are now, that is, they would be open to almost all uses (fishing, boating, etc.) and there would be no danger to health?
   (1) —— $500 or more a year $42 or more a month). If more, please specify ——————.
   (2) —— $400 a year ($33 a month)
   (3) —— $300 a year ($25 a month)
   (4) —— $200 a year ($17 a month)
   (5) —— $100 a year ($9 a month)
   (6) —— $ 50 a year ($4 a month)
   (7) —— $ 25 a year ($2 a month)
   (8) —— $ 10 or less a year ($.83 or less a month). If less, please specify ——————.

b. How much would you be willing to pay to have these waters made cleaner than they are now, that is, there would be no further pollution, dredging, or filling in of marshlands with trash and junk?
(1) —— $500 or more a year ($42 or more a month). If more, please specify ——————.
(2) —— $400 a year ($33 a month)
(3) —— $300 a year ($25 a month)
(4) —— $200 a year ($17 a month)
(5) —— $100 a year ($9 a month)
(6) —— $ 50 a year ($4 a month)
(7) —— $ 25 a year ($2 a month)
(7) —— $ 25 a year ($2 a month)
(8) —— $ 10 a year or less ($.83 or less a month). If less, please specify ——————.

22. Now suppose some city, industrial plant, or development agency wanted to use these coastal waters for waste disposal and was willing to pay people for the inconvenience this waste caused them.

a. How much would you have to be paid if the waste made it illegal and unsafe to take oysters from these waters?
(1) —— $ 10 or less a year ($.83 or less a month). If less, please specify ——————.
(2) —— $ 25 a year ($2 a month)
(3) —— $ 50 a year ($4 a month)
(4) —— $100 a year ($9 a month)
(5) —— $200 a year ($17 a month)
(6) —— $300 a year ($25 a month)
(7) —— $400 a year ($33 a month)
(8) —— $500 or more a year ($42 or more a month). If more, please specify ——————.

b. How much would you have to be paid if the waste made it unhealthy to swim or water-ski in these waters?
(1) —— $ 10 or less a year ($.83 or less a month). If less, please specify ——————.
(2) —— $ 25 a year ($2 a month)
(3) —— $ 50 a year ($4 a month)
(4) —— $100 a year ($9 a month)
(5) —— $200 a year ($17 a month)
(6) —— $300 a year ($25 a month)
(7) —— $400 a year ($33 a month)
(8) —— $500 or more a year ($42 or more a month). If more, please specify ——————.

c. How much would you have to be paid if the waste made these waters unfit for any purpose at all, except waste disposal, that is, made them a sewer?
(1) —— $ 10 or less a year ($.83 or less a month). If less, please specify ——————.
(2) —— $ 25 a year ($2 a month)
(3) —— $ 50 a year ($4 a month)
(4) —— $100 a year ($9 a month)
(5) —— $200 a year ($17 a month)
(6) —— $300 a year ($25 a month)
(7) —— $400 a year ($33 a month)
(8) —— $500 or more a year ($42 or more a month). If more, please specify ——————.

23. Suppose an industrial firm wanted to build a plant in Beaufort County. The plant would employ between 500 and 1,000 people and pay a substantial amount of property taxes. Suppose you and others in the community decide by voting whether the plant should be built.

a. Let's say there is no chance that waste from the plant will pollute the air or water in any way. How much would the plant have to increase your income to cause you to vote for it?
(1) —— $0 a year
(2) —— Less than $100 a year (less than $9 a month). Please specify ——————.
(3) —— Between $100 and $250 a year ($9 and $20 a month)
(4) —— Between $250 and $500 a year ($20 and $42 a month)
(5) —— Between $500 and $1,000 a year ($42 and $84 a month)
(6) —— Between $1,000 and $2,000 a year ($84 and $167 a month)
(7) —— More than $2,000 a year (more than $167 a month). Please specify ——————.

b. Suppose there was a *chance* that the operation of the plant might result in some pollution one or two weeks out of the year in the immediate vicinity of the plant. How much would the plant have to increase your income to cause you to vote for it?
(1) —— $0 a year
(2) —— Less than $100 a year (less than $9 a month). Please specify ——————.
(3) —— Between $100 and $250 a year ($9 and $20 a month)
(4) —— Between $250 and $500 a year ($20 and $42 a month)

(5) —— Between $500 and $1,000 a year ($42 and $84 a month)
(6) —— Between $1,000 and $2,000 a year ($84 and $167 a month)
(7) —— Between $2,000 and $3,000 a year ($167 and $250 a month)
(8) —— More than $3,000 a year (more than $250 a month). Please specify ——————.

c. Suppose that waste from the plant made it illegal and unsafe to take oysters from the coastal waters within a 10-mile radius of the plant. How much would the plant have to increase your income to cause you to vote for it?

(1) —— $0 a year
(2) —— Less than $100 a year (less than $9 a month). Please specify ——————.
(3) —— Between $100 and $250 a year ($9 and $20 a month)
(4) —— Between $250 and $500 a year ($20 and $42 a month)
(5) —— Between $500 and $1,000 a year ($42 and $84 a month)
(6) —— Between $1,000 and $2,000 a year ($84 and $167 a month)
(7) —— Between $2,000 and $3,000 a year ($167 and $250 a month)
(8) —— Between $3,000 and $4,000 a year ($250 and $333 a month)
(9) —— More than $4,000 a year (more than $333 a month). Please specify ——————.

d. Suppose that waste from the plant made it unhealthy to swim or water-ski in the coastal waters within a 10-mile radius of the plant. How much would the plant have to increase your income to persuade you to vote for it?

(1) —— $0 a year
(2) —— Less than $100 a year (less than $9 a month). Please specify ——————.
(3) —— Between $100 and $250 a year ($9 and $20 a month)
(4) —— Between $250 and $500 a year ($20 and $42 a month)
(5) —— Between $500 and $1,000 a year ($42 and $84 a month)
(6) —— Between $1,000 and $2,000 a year ($84 and $167 a month)
(7) —— Between $2,000 and $3,000 a year ($167 and $250 a month)
(8) —— Between $3,000 and $4,000 a year ($250 and $333 a month)
(9) —— Between $4,000 and $5,000 a year ($333 and $417 a month)
(10) —— More than $5,000 a year (more than $417 a month). Please specify ——————.

e. Suppose that waste from the plant made the coastal waters within a 10-mile radius of the plant unfit for any purpose at all, other than waste disposal, that is, made them a sewer. How much would the plant have to increase your income to persuade you to vote for it?

(1) —— $0 a year
(2) —— Less than $100 a year (less than $9 a month). Please specify ——————.
(3) —— Between $100 and $250 a year ($9 and $20 a month)
(4) —— Between $250 and $500 a year ($20 and $42 a month)
(5) —— Between $500 and $1,000 a year ($42 and $84 a month)
(6) —— Between $1,000 and $2,000 a year ($84 and $167 a month)
(7) —— Between $2,000 and $3,000 a year ($167 and $250 a month)
(8) —— Between $3,000 and $4,000 a year ($250 and $333 a month)
(9) —— Between $4,000 and $5,000 a year ($333 and $417 a month)
(10) —— Between $5,000 and $6,000 a year ($417 and $500 a month)
(11) —— More than $6,000 a year (more than $500 a month). Please specify ——————.

24. Do you consider the quality of schools, hospitals, and other public services in Beaufort County satisfactory at the present time?

a. —— Yes
b. —— No

25. Let's talk about the same plant we discussed in an earlier question. Remember it will provide between 500 and 1,000 jobs and will pay a substantial amount of taxes. These taxes could be used to provide more public services and/or better public services (e.g., improved schools and hospitals). How much would you be willing to pay *in addition* to your present county property taxes in order to provide these services and keep the plant out?

a. —— $100 or more a year. If more, please specify ——————.
b. —— $ 50 a year
c. —— $ 25 a year
d. —— $ 10 a year
e. —— $ 5 a year

f. —— $ 3 or less a year. If less, please specify ——————.
g. —— $ 0 a year

26. Would you please indicate which letter on the card I am about to give you comes closest to estimating the total income of this household, before taxes, from all sources in 1969?
a. —— Under $3,000
b. —— $ 3,000-$ 5,999
c. —— $ 6,000-$ 8,999
d. —— $ 9,000-$11,999
e. —— $12,000-$14,999
f. —— $15,000-$17,999
g. —— $18,000-$20,999
h. —— Over $21,000

27. Roughly, what level of total income, before taxes, do you consider necessary to provide you and your household with a satisfactory level of living?
$——— year or $——— month or $——— week or $——— day or $——— hour

PART II

September 1970

CONFIDENTIAL

Socio-Economic Study of Development of Port Victoria Area of Beaufort County, South Carolina

— Survey of Business and Industrial Firms —

Department of Agricultural Economics and Rural Sociology
Clemson University
Clemson, South Carolina 29631

DO NOT DISCLOSE TO UNAUTHORIZED PERSONS
CONFIDENTIAL

Socio-Economic Study of Development of Port Victoria Area of Beaufort County, South Carolina

— Survey of Business and Indutsrial Firms —

1. Type of Business (check one which best describes your firm)
——a. Agriculture and Forestry
——b. Fisheries
——c. General Building Construction
——d. General Construction except Building (e.g., asphalt paving, earth moving)
——e. Special Trades Construction (e.g., Electrical, Plumbing, Painting)
——f. Textile Manufacturing
——g. Food Processing
——h. Lumber and Wood Products Manufacturing
——i. Chemicals
——j. Other Manufacturing
——k. Transportation (passenger or freight)
——l. Communications (e.g., radio, telephone, newspapers, etc.)
——m. Utilities (e.g., gas, electrical, sanitary services)
——n. Eating and Drinking Places
——o. Hotels and Lodging Places
——p. Gasoline Service Stations
——q. Other wholesale or retail trade
——r. Financial services (e.g., banking, insurance services)
——s. Real Estate
——t. Medical Services
——u. Recreation and Amusement Services (e.g., theaters, billiard parlors, pin-ball machines, etc.)
——v. Other non-governmental services
——w. Local and State government
——x. Defense-related federal government
——y. Other federal government
——z. Any other (please specify ——————.)

2. What was your average employment in *August 1969?* ——————

3. What was your total *1969 payroll?* ——————

4. Please estimate what percentage of all your business *purchases in 1969* were made in:
——a. Beaufort County
——b. Jasper County
——c. Rest of South Carolina
——d. Savannah, Georgia
——e. Rest-of-world.

5. Please estimate what percentage of all your *1969 sales* were to customers in:
——a. Beaufort County
——b. Jasper County
——c. Rest of South Carolina
——d. Savannah, Georgia
——e. Rest-of-world.

6. For each type of business listed below, to which you made any sales in 1969, please indicate the approximate percentage of these sales to firms located in Beaufort County and to firms outside Beaufort County. (Businesses to which you made no sales in 1969 should be left blank.)

Type of Business	*Percentage to firms in Beaufort County*		*Percentage to firms outside Beaufort Co.*	
a. Agriculture and Forestry	________	+	________	= 100%
b. Fisheries	________	+	________	= 100%
c. General Building Construction	________	+	________	= 100%
d. General Construction except Building	________	+	________	= 100%
e. Special Trades Construction	________	+	________	= 100%
f. Textile Manufacturing	________	+	________	= 100%
g. Food Processing	________	+	________	= 100%
h. Lumber & Wood Products Manufacturing	________	+	________	= 100%
i. Chemicals	________	+	________	= 100%
j. Other Manufacturing	________	+	________	= 100%
k. Transportation	________	+	________	= 100%
l. Communications	________	+	________	= 100%
m. Utilities	________	+	________	= 100%
n. Eating and Drinking Places	________	+	________	= 100%
o. Hotels and Lodging Places	________	+	________	= 100%
p. Gasoline Service Stations	________	+	________	= 100%
q. Other wholesale or retail trade	________	+	________	= 100%
r. Financial services	________	+	________	= 100%
s. Real Estate	________	+	________	= 100%
t. Medical Services	________	+	________	= 100%
u. Recreation and Amusement Services	________	+	________	= 100%
v. Other non-governmental services	________	+	________	= 100%
w. Local and State government	________	+	________	= 100%
x. Defense-related federal government	________	+	________	= 100%
y. Other federal government	________	+	________	= 100%
z. Any other (please specify)	________	+	________	= 100%

7. For each type of business from which you made any purchases in 1969, please indicate the approximate percentage of those purchases that were from firms in Beaufort County or from firms outside Beaufort County (businesses from which you made no purchases in 1969 should be left blank).

Type of Business	*Percentage to firms in Beaufort County*		*Percentage to firms outside Beaufort Co.*	
a. Agriculture and Forestry	______	+	______	= 100%
b. Fisheries	______	+	______	= 100%
c. General Building Construction	______	+	______	= 100%
d. General Construction except Building	______	+	______	= 100%
e. Special Trades Construction	______	+	______	= 100%
f. Textile Manufacturing	______	+	______	= 100%
g. Food Processing	______	+	______	= 100%
h. Lumber & Wood Products Manufacturing	______	+	______	= 100%
i. Chemicals	______	+	______	= 100%
j. Other Manufacturing	______	+	______	= 100%
k. Transportation	______	+	______	= 100%
l. Communications	______	+	______	= 100%
m. Utilities	______	+	______	= 100%
n. Eating and Drinking Places	______	+	______	= 100%
o. Hotels and Lodging Places	______	+	______	= 100%
p. Gasoline Service Stations	______	+	______	= 100%
q. Other wholesale or retail trade	______	+	______	= 100%
r. Financial services	______	+	______	= 100%
s. Real Estate	______	+	______	= 100%
t. Medical Services	______	+	______	= 100%
u. Recreation and Amusement Services	______	+	______	= 100%
v. Other non-governmental services	______	+	______	= 100%
w. Local and State government	______	+	______	= 100%
x. Defense-related federal government	______	+	______	= 100%
y. Other federal government	______	+	______	= 100%
z. Any other (please specify)	______	+	______	= 100%

8. To the nearest thousand, what was the total value of dollars of your gross sales *in 1969?* $______________.

PART III

Technical Descriptive Presentation of the Input-Output Model

Introduction

Input-output analysis is a popular technique for regional analysis. Models have been developed which range in size from the national level down to the local level. In this study an input-output model of a small homogeneous area, the Port Victoria, Beaufort County area of South Carolina, was developed. An input-output analysis can provide valuable insight into the directions of the future development of a region or area through use of the three basic tables resulting from application of the technique. The technique and its component parts are verbally described in the following section. A mathematical presentation of an input-output model completes this appendix.

An input-output analysis consists of four parts: first, development of a specific model; second, the collection of data summarized into a table which describes the economy under consideration; third, estimation of coefficients using appropriate analytical techniques; and fourth, numerical solutions to those problems posed.

Assumptions of Input-Output Model

The input-output model represents the economic activities of a given geographical area for a given time period, usually one year. Although the input-output model has several assumptions, there are two fundamental or critical assumptions. Both of these assumptions are concerned with the nature of production:

(1) Input-output coefficients are assumed to be fixed. This is the most restrictive assumption. It means that technology remains constant, there are no external economies or diseconomies and substitution of inputs due to changes in relative prices or availability of new materials will not take place. Although restrictive as this assumption is, empirical studies have shown that the assumption of fixed production coefficients is reasonable in the short-run.[1, 2]

1. B. Cameron, "The Production Function Leontief Models," *The Review of Economic Studies*, Vol. XX, No. 1, 1952-53, pp. 62-69.

2. Hollis B. Chenery and Paul G. Clark, *Interindustry Analysis*, New York, John Wiley and Sons, Inc., 1959.

However, it is suggested that the coefficients be adjusted or up-dated every five years.

(2) The other essential assumption is that there are no errors of aggregation in combining various elements of the regional economy into the various sectors. Each sector is assumed to be homogeneous and different from other sectors. This implies that a product is produced only by one sector and ignores problems relating to secondary products. Although problems raised by this assumption have no solution, they can be alleviated to a certain extent by disaggregation. That is, the more sectors that are included in the model, the less likely problems of aggregation.

In constructing an input-output model for a small area such as Beaufort County it should be kept in mind that although the analysis attempts to cover only those activities relevant to that area and even though the geographic area is clearly defined, there are flows of outputs outside the area and flows of inputs into the area which the data may not reveal.

Uses of Input-Output Analysis

Interest in input-output analysis has become widespread in both the public and private sectors of the economy. The attention given to input-output analysis centers around using the tool for economic forecasting and planning. Typical uses of input-output analysis are (a) economy models for economic development studies, (b) sector and economy models for setting market strategy, (c) sector and economy models for making impact projections for policy uses, and (d) regional models for regional impact studies. The latter use is the principal concern of this study.

A reliable input-output table of an economy provides a wealth of information concerning results (in quantitative terms) of alternative development policies for an economy. Because aggregates are generally more available than industry, region, or firm statistics, economic development analyses have been more fruitful in the past than other uses of input-output tables.

Use of input-output analysis to estimate the economic impact of a given change in an economy can be applied using either an aggregate model or a model for one firm or one region. By tracing all the inter-relationships of consumption throughout the economy, input-output techniques can help the user make better estimates of the impact of change in areas only indirectly related to his own business.

The application of input-output analyses to study economic impacts has been fairly successful. Regional, state, and one-industry models are becoming more numerous. Economies of several states have been studied through input-output models. In addition, the tool is useful in studying intraregional structural relationships. The following quote from a symposium on input-output applications succinctly summarizes the usefulness of the technique in regional analysis:

> "Many regional planners have found the input-output table an extremely valuable tool in measuring the degree of "imports" or "exports" of products and services transported from one region to another. It is possible through the use of sales and purchase data gathered from a region's business occupants to determine what goods are being shipped into the region and what goods the region is exporting to other regions. Certainly a company considering moving into a new geographical area would be interested in utilizing a sectional input-output table as a guide in determining size and proximity of markets and competition within the area."[3]

This brief review of the uses of input-output analysis serves not only to point out the versatility of the techniques but also to give an indication of its current rather widespread use. Thus, it appears that input-output analysis should be particularly useful in estimating the magnitude of the direct and indirect economic effects of various kinds of growth and development in the study area, including the construction of industrial facilities and the projected future development of Port Victoria.

Verbal Presentation of Hypothetical Transactions Table

The basis of the input-output system is the transactions table or input-output table. The table shows how the input of any particular sector is distributed among all other sectors and final demand. This matrix covers all the goods and services produced in the economy. Each sector appears twice in the system, as a producer of output and as a user of input. A hypothetical example of a transactions table is given in Appendix Table 1.[4] The method for reading the table is simple. From this table it is seen that for the 80 units of total available production of sector A, 10 units are bought by sector A itself, 20 units by sector B, and 40 units by sector C for a total of 70 units used in intermediate or interindustry transactions. The remainder of the output is bought by final demand, which consists of government consumption, exports, personal consumption expenditures, and investment. Sector A is also a user of inputs. Reading down column A, this sector purchases 10 units from itself, 6 units from B, and 4 units from

3. Institute for Interindustry Data, *Business Applications of Input-Output Analysis*, New York, December 1967.

4. The following hypothetical example comes from Robert H. Elrod, *Development and Use of Updated Input-Output Tables in Economic Forecasting and Planning*, Unpublished Ph.D. dissertation, Department of Agricultural Economics and Rural Sociology, Clemson University, Clemson, S. C., 1969.

C for a total purchase of 20 units. The remaining 60 units consist of primary or unproduced inputs. The direct payments for primary inputs, which are land, labor, and capital, make up the value added row.

After an input-output table has been constructed for a given time period, technical or input coefficients can be derived from this table. A technical coefficient is defined as the amount of input required from a particular industry (i) to produce one dollar's worth of the output of a given industry (j). These technical coefficients are computed for processing industries only. The conventional notation for this coefficient is a_{ij}

To derive the coefficients for column j, each entry in the processing sector of that column is divided by the sum of the column. The technical coefficients for Table 1 are shown in Table 2. From this Table, we see that each dollar of production by industry A requires direct purchases from itself and from B and C as follows:

Table 1. A Hypothetical Transactions Table

		Using Sectors A.	B	C	*Total Inter. Use*	*Final Demand*	*Total Production*
Producing	A	10	20	40	70	10	80
	B	6	8	6	20	20	40
	C	4	4	2	10	40	50
Total Pur.		20	32	48			
Value Add.		60	8	2		70=GNP	
Total Use		80	40	50			170

Table 2. Technical Coefficients for the Industries Assumed in Table 1

		Industries Purchasing A	B	C
Industries Producing	A	.125	.500	.800
	B	.075	.200	.120
	C	.050	.100	.040

Purchases from itself = 12.5¢
Purchases by industry A from industry B = 7.5¢
Purchases by industry A from industry C = 5.0¢
Total direct purchases = 25.0¢

This total direct purchases figure is indicative of how much must be bought from other industries by industry A in order for industry A to produce one dollar of production. The sum of these technical coefficients for any one column must be less than or equal to one. A sum greater than one would indicate that the cost to an industry for producing a dollar of production is greater than a dollar.

Technical coefficients must meet one other criterion in order to be used in an analysis such as the present one. The criterion is that at least one column in the table must sum to less than unity.

The usefulness of these coefficients is apparent. By making use of such a table, the management of a particular industry could tell how much would have to be bought directly from each of its supplying industries when the industry adds to its own production. By using the notation for the technical coefficient (a_{ij}), an equation can be written for the demand (X_{ij}) of each industry (j) for each commodity (i) as a function of its own legal level of output (X_j).

$$X_{ij} = a_{ij} X_j$$

The direct purchases that will be made by a particular industry from other industries in the processing sector to enable that particular industry to produce one dollar of production are shown in Table 2. However, this does not represent the total addition to output resulting from additional sales to final demand. It sales to final demand increase for a sector in the processing section of the table, this will lead to indirect as well as direct increases in the output of all industries in the processing section. For example, if sales from sector A to final demand increase, A will increase purchases from B and C. In addition, as industry B sells more output to industry A, B then buys more from industries C and A. These effects will occur continuously throughout the economy.

To isolate these indirect and direct changes is one of the main functions of input-output analysis. The sum of these two effects shows the total expansion of output in all industries as a result of the delivery of one dollar of output outside the processing sectors by each industry. A delivery outside the processing sector is a sales to households (personal consumption expenditures), investors, exporters, a government agency or any other buyer included in the final demand sector.

A numerical example will illustrate. Assume a one dollar increase in the final demand for the products of industry A. This will increase intra-industry transactions by 12.5¢ (see row 1, column 1, of Appendix Table 2). Therefore, the gross output of industry A will be increased by at least \$1.125. However, when the output of industry A increases, purchases from B by A will be increased also. Sales from industry B to industry A will go up an additional 8¢ (=.075 x 1.125). This occurs as a result of the increased activity in industry A. Likewise, sales from industry C to industry A will increase 6¢ (=1.125 x .050). These repercussions will continue on down column 1.

The indirect effects will not cease here, however. Industry B will expand its production as a result of increased final demand in industry A. This higher production by B will be felt by all other sectors which sell to B. The same type calculations could be made for B and likewise for every other sector in the processing portion of the table.

A method exists as an alternative to the above calculations which allows one to ascertain these direct and indirect effects. The method involves inversion of a matrix which consists of the matrix of technical coefficients subtracted from the identity matrix. This procedure is discussed in the mathematical presentation at the end of this section. These elements in the inverse represent the total requirements, direct and indirect, per dollar of delivery outside the processing sector.

Mathematical Presentation of the Input-Output Model[5]

The Transactions Table

To simplify the following discussion, the analysis is given for three-sector regional economic system. The transactions taking place within this economy can be described by the following system of equations:

$$(1)\qquad \begin{aligned} X_1 &= x_{11} + x_{12} + x_{13} + Y_1 \\ X_2 &= x_{21} + x_{22} + x_{23} + Y_2 \\ X_3 &= x_{31} + x_{32} + x_{33} + Y_3 \\ R_0 &= y_{01} + y_{02} + y_{03} + Y_0 \end{aligned}$$

where:

X_i = gross output of the i^{th} sector;

X_{ij} = purchases of the j^{th} sector from the i^{th} sector when production equals X_i;

y_{oj} = purchases of imported inputs by the j^{th} sector when production equals X_i;

Y_i = final demand or export sales;

R_0 = imported inputs; and

Y_0 = final demand for imported inputs.

Technical Coefficients

The technical or direct coefficients are computed by dividing the total input figure of a column sector into each entry of that sector. This division process is carried out for each column sector in the endogenous or processing section of the input-output table. This procedure can be shown mathematically as:

$$(2)\qquad a_{ij} = \frac{X_{ij}}{X_j}$$

The technical coefficient (a_{ij}) is the ratio of the purchase of output of industry i by industry j over the gross output of industry j. That is, the sum of a_{ij}'s for a given industry represent the direct purchases of that industry *from all other industries* for each dollar of output.

Direct and Indirect Coefficients

The calculation of the direct and indirect coefficients is more complex than the procedure used to derive the direct coefficients. The first step involves substituting the a_{ij}'s into the set of equations listed in (1):

$$(3)\qquad \begin{aligned} Y_1 &= X_1 - a_{11}X_1 - a_{12}X_2 - a_{13}X_3 \\ Y_2 &= X_2 - a_{21}X_1 - a_{22}X_2 - a_{23}X_3 \\ Y_3 &= X_3 - a_{31}X_1 - a_{32}X_2 - a_{33}X_3 \end{aligned}$$

The above equations are rewritten and solved for Y_i as follows:

$$(4)\qquad \begin{bmatrix} 1-a_{11} & -a_{12} & -a_{13} \\ -a_{21} & 1-a_{22} & -a_{23} \\ -a_{31} & -a_{32} & 1-a_{33} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

In matrix notation,—*, it would be presented as:

$$(\underline{I} - \underline{A}) = \underline{Y} \text{ where } \underline{I} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\text{and } \underline{A} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

The solution to the set of equations presented in (4) is accomplished by calculating the inverse of the ($\underline{I}$–$\underline{A}$) matrix. This solution is as follows:

5. Gerald A. Docksen and Charles H. Little, *An Input-Output Analysis Model for Regional Economic Development Research,* Oklahoma Station Project #1232, Oklahoma State, Stillwater, November 1967, Appendix A, pp. 1-3.

*The underscore denotes a matrix.

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \cdot \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

In matrix notation the equation is:

$$\underline{X} = (\underline{I} - \underline{A})^{-1} \ \underline{Y}.$$

Each A_{ij} which is an element of the $(I\text{–}A)^{-1}$ matrix, shows the sum of the direct and indirect requirements of a column for a row output per dollar of output delivered to final demand.

Derivation of Beaufort Coefficients

The foregoing discussion of technical coefficients and the procedure for deriving them implies a lengthy and somewhat involved process of calculations. Also implied is the need for rather detailed data. In an effort to overcome these restraints a modified procedure was developed to generate technical coefficients for the Beaufort County input-output model (See Table 3... The procedure for generating these coemmicients was as follows. A sample of business and industrial firms and households in Beaufort County was surveyed to determine what percentage of their respective total purchases were made from firms located in the County. The appropriate columns of technical coefficients derived for the Charleston area economy were then multiplied by these percentages to calibrate the Charleston model for Beaufort County sales patterns.

The interdependence coefficients in Table 4 indicate the total change in input requirements as a result of a one dollar change in external sales in a sector. The total change includes both the direct and indirect impacts generated by the initial dollar change. To illustrate, consider a one dollar change in the external sales for products of the Lumber and Wood Products sector of Beaufort County. The strongest effect of a change in this sector is reflected in the impact on the household sector where it generates additional spending of almost 35 cents. The initial dollar change in the Lumber and Wood Products sector also has a fairly strong link with the sector titled Other Wholesale and Retail Trade where an addition 15 cents is generated as a result of the stimulus provided by the initial change. This brief illustration from Table 4 should serve to demonstrate the use and method of reading this table. From this table, the effects of a change in the Beaufort County economy can be determined.

A cursory examination of Table 4 reveals that a on dollar change in any of the sectors generates a

Table 3. Simulated Technical Coefficients, Beaufort County Input-Output Matrix, 1970

Producing Sector \ *Purchasing Sector*	*Ag, Forestry and Fisheries (1)*	*Food and Kindred Products (2)*	*Construction (3)*	*Textiles and Apparel (4)*	*Lumber and Wood Products (5)*	*Chemicals (6)*
1. Ag, Forestry and Fisheries	.0326	.0099			.0548	
2. Food and Kindred Products						
3. Construction	.0004		.3889		.0162	.0001
4. Textile and Apparel						
5. Lumber, Wood			.0069		.0212	.0001
6. Chemicals						
7. Other Manufacturing						
8. Transportation	.0001	.0001	.0001		.0021	.0002
9. Communications		.0009	.0002	.0003		.0001
10. Utilities	.0026	.0096	.0001	.0001	.0029	
11. Eating and Drinking Places				.0001		
12. Hotels and Lodging Places						
13. Gasoline Service Stations	.0164					
14. Other Wholesale and Retail Trade	.3072		.0213	.0333	.0047	
15. Financial Services	.0108	.0053	.0041	.0002	.0001	.0001
16. Real Estate			.0030	.0010		
17. Other Business and Professional Ser.	.0475	.0083	.0190	.0060	.0005	.1401
18. Local and State Government	.0200	.0022	.0005	.0005	.0001	.0012
19. Federal Government						
20. Households	.3973	.3613	.2060	.6163	.2048	.2804
TOTAL DIRECT	.8349	.3976	.6501	.6578	.3075	.4233

SOURCE: Business and Industrial Survey of Beaufort County, 1970.

Table 3—*Continued*

	Other Manufacturing (7)	*Transportation* (8)	*Communication* (9)	*Utilities* (10)	*Eating and Drinking Places* (11)	*Hotels and Lodging Places* (12)	*Gasoline Service Stations* (13)
1.					.0200	.0366	
2.					.0131	.0121	.0040
3.		.0276	.0014	.0437	.0004	.0085	
4.							
5.						.0002	
6.							
7.							
8.	.0001	.0319			.0001	.0002	.0008
9.	.0001	.0029		.0006	.0001	.0016	.0007
10.	.0015	.0018	.0082	.0042	.0496	.0268	.0200
11.				.0001			
12.					.0009		
13.		.0055	.0019	.0002		.0001	.0011
14.		.0266	.0062	.1847	.0260	.1577	.4992
15.	.0003	.0016		.0008	.0001	.0042	.0017
16.		.0007	.0011				
17.	.0120	.0017		.0066	.0001	.0002	.0050
18.	.0006	.0003	.0048	.0149	.0281	.0148	.0065
19.							
20.	.3907	.7702	.4521	.3163	.1762	.4279	.1934
TOTAL DIRECT	.4053	.8708	.4757	.5723	.3147	.6909	.7324

Table 3—*Continued*

	Other Wholesale and Retail Trade (14)	*Financial Services* (15)	*Real Estate* (16)	*Other Business and Professional Services* (17)	*Local and State Govt.* (18)	*Federal Govt.* (19)	*Households* (20)
1.	.0003			.0683		.0001	.0010
2.	.0110			.0016	.0008	.0001	.0044
3.	.0001	.0024	.5871	.0112	.0031	.0014	.0052
4.		.0007		.0038	.0001		
5.	.0008	.0005	.0003		.0001		.0039
6.			.0006	.0046	.0009		
7.		.0004	.0001		.0001		.0006
8.	.0128			.0020	.0018		.0001
9.	.0003	.0057	.0011	.0012	.0009		.0017
10.	.0065	.0010	.0010	.0185	.0036		.0086
11.				.0192	.0001	.0025	.0072
12.					.0002		.0001
13.		.0185			.0019		.0170
14.	.0287	.1308	.0037	.1969	.0183	.0075	.3334
15.	.0124	.0417	.0277	.0129	.0019		.0189
16.	.0006	.0226	.0170	.0347	.0057		.0155
17.	.0207	.0201	.0543	.0641	.0156		.0297
18.	.0152	.0060	.0029	.0067	.0130		.0201
19.							
20.	.1080	.3703	.0351	.1900	.8244	.5443	.1748
TOTAL DIRECT	.2174	.6207	.7309	.6357	.9225	.5685	.6422

relatively strong linkage with the household sector. This is to be expected, given that wages and salaries constitute a major portion of industrial spending not only in the Beaufort County area, but in the entire U. S. economy. The table also reveals a consistently high impact of a dollar change in any sector upon the sector titled Other Wholesale and Retail Trade.

Table 4. Direct and Indirect Beaufort County Impact per Dollar of External Sales by Sector, Beaufort County, South Carolina, 1970

	Ag, Forestry and Fisheries (1)	*Food and Kindred Products* (2)	*Construction* (3)	*Textiles and Apparel* (4)	*Lumber and Wood Prods.* (5)
1. Ag, Forestry and Fisheries	1.0416	0.0134	0.0055	0.0046	0.0599
2. Food and Kindred Products	0.0102	1.0047	0.0049	0.0080	0.0033
3. Construction	0.0278	0.0171	1.6452	0.0273	0.0380
4. Textiles and Apparel	0.0003	0.0001	0.0007	1.0002	0.0001
5. Lumber and Wood Products	0.0035	0.0024	0.0138	0.0040	1.0234
6. Chemicals	0.0005	0.0002	0.0003	0.0002	0.0001
7. Manufacturing	0.0004	0.0003	0.0003	0.0005	0.0002
8. Transportation	0.0086	0.0030	0.0034	0.0050	0.0044
9. Communications	0.0018	0.0021	0.0015	0.0022	0.0008
10. Utilities	0.0158	0.0167	0.0076	0.0117	0.0079
11. Eating and Drinking Places	0.0068	0.0044	0.0047	0.0072	0.0029
12. Hotels and Lodging Places	0.0001	0.0001	0.0001	0.0001	0.0000
13. Gasoline Service Stations	0.0299	0.0096	0.0090	0.0154	0.0071
14. Other Wholesale and Retail Trade	0.6145	0.2030	0.2299	0.3582	0.1539
15. Financial Services	0.0356	0.0196	0.0212	0.0234	0.0103
16. Real Estate	0.0159	0.0102	0.0156	0.0173	0.0066
17. Other Business and Professional Ser.	0.0922	0.0326	0.0564	0.0449	0.0196
18. Local and State Government	0.0465	0.0172	0.0155	0.0249	0.0112
19. Federal Government	0.0000	0.0000	0.0000	0.0000	0.0000
20. Households	0.7028	0.5256	0.4982	0.8697	0.3445
Local Multiplier	2.6548	1.8823	2.7787	2.4248	1.6942

Table 4—*Continued*

	Chemicals (6)	*Other Manufacturing* (7)	*Transportation* (8)	*Communications* (9)	*Utilities* (10)	*Eating and Drinking Places* (11)	*Hotels and Lodging Places* (12)	*Gasoline Ser. Sta.* (13)
1.	0.0129	0.0035	0.0056	0.0031	0.0036	0.0227	0.0419	0.0035
2.	0.0047	0.0049	0.0103	0.0057	0.0068	0.0165	0.0203	0.0133
3.	0.0221	0.0172	0.0813	0.0234	0.0893	0.0162	0.0387	0.0165
4.	0.0007	0.0002	0.0002	0.0001	0.0002	0.0001	0.0002	0.0002
5.	0.0022	0.0025	0.0055	0.0029	0.0031	0.0016	0.0037	0.0023
6.	1.0008	0.0002	0.0003	0.0002	0.0002	0.0001	0.0002	0.0002
7.	0.0003	1.0003	0.0007	0.0004	0.0003	0.0002	0.0004	0.0003
8.	0.0034	0.0030	1.0393	0.0035	0.0054	0.0025	0.0063	0.0099
9.	0.0013	0.0013	0.0054	1.0014	0.0019	0.0009	0.0032	0.0018
10.	0.0091	0.0089	0.0170	0.0167	1.0127	0.0548	0.0377	0.0293
11.	0.0066	0.0047	0.0092	0.0052	0.0046	1.0027	0.0058	0.0036
12.	0.0000	0.0001	0.0001	0.0001	0.0001	0.0009	1.0001	0.0000
13.	0.0083	0.0098	0.0258	0.0133	0.0096	0.0063	0.0133	1.0085
14.	0.2040	0.2075	0.4545	0.2473	0.3922	0.1671	0.4439	0.6743
15.	0.0147	0.0149	0.0320	0.0169	0.0177	0.0098	0.0258	0.0195
16.	0.0138	0.0106	0.0220	0.0130	0.0107	0.0065	0.0136	0.0087
17.	0.1714	0.0368	0.0528	0.0283	0.0362	0.0177	0.0378	0.0353
18.	0.0156	0.0158	0.0320	0.0227	0.0328	0.0395	0.0383	0.0263
19.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20.	0.4547	0.5514	1.1359	0.6431	0.5264	0.3328	0.7023	0.4029
Local Multiplier	1.9466	1.8936	2.9299	2.0473	2.1538	1.6989	2.4335	2.2564

Table 4—*Continued*

	Other Wholesale and Retail Trade (14)	*Financial Services* (15)	*Real Estate* (16)	*Other Business and Professional Ser.* (17)	*Local and State Government* (18)	*Federal Government* (19)	*Households* (20)
1.	0.0032	0.0050	0.0081	0.0792	0.0071	0.0038	0.0066
2.	0.0134	0.0072	0.0042	0.0087	0.0117	0.0069	0.0122
3.	0.0110	0.0477	0.9899	0.0730	0.0974	0.0249	0.0413
4.	0.0001	0.0010	0.0004	0.0042	0.0004	0.0001	0.0003
5.	0.0019	0.0036	0.0091	0.0027	0.0060	0.0035	0.0063
6.	0.0002	0.0003	0.0011	0.0051	0.0013	0.0002	0.0003
7.	0.0001	0.0008	0.0004	0.0003	0.0008	0.0005	0.0009
8.	0.0149	0.0053	0.0030	0.0079	0.0085	0.0040	0.0072
9.	0.0009	0.0074	0.0025	0.0025	0.0035	0.0016	0.0029
10.	0.0103	0.0110	0.0083	0.0290	0.0198	0.0100	0.0180
11.	0.0022	0.0054	0.0047	0.0244	0.0101	0.0086	0.0112
12.	0.0000	0.0001	0.0000	0.0001	0.0003	0.0001	0.0002
13.	0.0042	0.0302	0.0078	0.0096	0.0232	0.0135	0.0246
14.	1.1195	0.3843	0.1961	0.4190	0.4719	0.2899	0.5156
15.	0.0196	1.0627	0.0458	0.0318	0.0343	0.0199	0.0362
16.	0.0059	0.0365	1.0313	0.0473	0.0289	0.0140	0.0256
17.	0.0334	0.0548	0.0988	1.1024	0.0713	0.0331	0.0601
18.	0.0224	0.0259	0.0160	0.0262	1.0467	0.0210	0.0380
19.	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
20.	0.2163	0.6084	0.3950	0.4443	1.2012	0.7614	1.3929
Local Multiplier	1.4797	2.2976	1.8265	2.3177	3.6444	2.2170	2.2004

Source. Computed from Table 3.

Output multipliers are computed directly from the interdependence coefficients. They measure the amount of output generated by a one dollar change in final demand for products of a particular sector. These are computed by summing the values in the column of each sector to obtain the output multiplier of that purchasing sector. For example, in Table 4, by adding down the column for Agriculture, Forestry and Fisheries sector we obtain a local Koutput multiplier of 2.65. This indicates that a one dollar change in final demand for the products of this sector will result in a change in total output in the Beaufort County area of $2.65.

The output multipliers for all sectors of the Beaufort County economy are listed at the foot of each olumn in Table 4. The sector titled Local and State Government has the largest multiplier (3.64). The sector titled Other Wholesale and Retail Trade has the smallest mulplier (1.48).

PART 5

Table 5. Beaufort County Environmental Linkages Matrix[a]

	Ag, Forestry and Fisheries (1)	*Food and Kindred Products* (2)	*Construction* (3)	*Textiles and Apparel* (4)	*Lumber and Wood Prods.* (5)	*Chemicals* (6)
1. Particulates (lbs)	0.0240	0.0000	0.0000	0.0000	1.2790	0.0000
2. SO_2 (lbs)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3. 5-Day BOD (lbs)	0.0000	0.3264	0.0000	0.3834	1.3501	0.1062
4. Solid Waste (cu yds)	0.0000	0.0000	0.0011	0.0009	0.1260	0.0006
5. Sales/$ Output[b]	0.4126	0.2655	0.4130	0.3804	0.3430	0.4680
6. Jobs/$ Output[b]	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001
7. Local Taxes/$ Output[b]	0.0237	0.0017	0.0002	0.0832	0.0053	0.0193
8. State Taxes/$ Output[b]	0.0506	0.0602	0.0324	0.0982	0.0911	0.0544

Table 5—*Continued*

	Other Manufacturing (7)	*Transportation (8)*	*Communications (9)*	*Utilities (10)*	*Eating and Drinking Places (11)*	*Hotels and Lodging Places (12)*	*Gasoline Ser. Sta. (13)*
1.	0.0000	0.0213	0.0000	0.0119	0.0000	0.0000	0.0340
2.	0.0000	0.0000	0.0000	0.3743	0.0000	0.0000	0.0030
3.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4.	0.0000	0.0000	0.0006	0.0043	0.0038	0.0045	0.0002
5.	0.4029	0.6071	0.5141	0.5606	0.6175	0.6745	0.4680
6.	0.0003	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001
7.	0.0393	0.0074	0.2076	0.0203	0.0008	0.0169	0.0004
8.	0.0125	0.1022	0.0157	0.0706	0.0698	0.1488	0.0839

Table 5—*Continued*

	Other Wholesale and Retail Trade (14)	*Financial Services (15)*	*Real Estate (16)*	*Other Business and Professional Ser. (17)*	*Local and State Government (18)*	*Federal Government (19)*	*Households (20)*
1.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.2413
4.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0085
5.	0.7245	0.5602	0.7223	0.5120	0.0000	0.0000	0.8500
6.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000
7.	0.0025	0.0001	0.0054	0.0003	0.0000	0.0000	0.0068
8.	0.0356	0.0168	0.0218	0.0155	0.1261	0.1519	0.0286

[a]In the original Charleston Environmental Linkages Matrix from which the Beaufort County matrix was calibrated, 16 ecological variables were examined. For present purposes, only the multipliers for the four ecological variables shown in Table 8 are shown.

[b]Although this variable is not an "ecological" variable, its multipliers are presented here to explain the computations found in Table 8.

Source: Charleston Area Input-Output Model.

Table 6. Annual Output per 100 Workers Used to Compute Economic and Environmental Impacts, Charleston Metropolitan Area and Beaufort County, South Carolina, 1968-1969

Sector	*Annual Output per 100 Workers*
Food and Kindred Products	$ 735,000
Textiles and Apparel	782,000
Lumber and Wood Products	1,211,900
Chemicals	1,129,900
Tourism and Recreation	1,090,900
Retirement Community	399,600[a]
Military Base	411,000[b]

Source: Laurent, E. A., and J. C. Hite, *Economic-Ecologic Analysis in the Charleston Metropolitan Region: an Input-Output Study,* Water Resources Research Institute, Clemson University, Clemson, S. C., Report No. 19, April 1971, Table 1, pp. 27-28.

[a]Based on a telephone conversation with Mr. Fred Hack, President of the Hilton Head Company.

[b]Based on information contained in a letter from Senator J. Strom Thurmond, dated March 3, 1971.

Species List of Fishes and Macroinvertebrates Collected During Port Royal Sound Environmental Study

Species List
Fishes and Macroinvertebrates
Collected During Port Royal Sound Environmental Study

Fishes

Acipenseridae—sturgeons
  Acipenser oxyrhynchus—Atlantic sturgeon
Anguillidae—freshwater eels
  Anguilla rostrata—American eel
Antherinidae—silversides
  Membras martinica—rough silverside
  Menidia menidia—Atlantic silverside
Ariidae—sea catfishes
  Bagre marinus—gafftopsail catfish
  Galeichthys felis—sea catfish
Balistidae—triggerfishes and filefishes
  Alutera schoepfi—orange filefish
  Monocanthus hispidus—planehead filefish
  Monocanthus setifer—pygmy filefish
  Stephanolephis hispidus—triggerfish
Batrachoididae—toadfishes
  Opsanus tau—oyster toadfish
Belonidae—needlefishes
  Strongylura marina—Atlantic needlefish
Blenniidae—combtooth blennies
  Hypsoblennius hentzi—feather blenny
Bothidae—lefteye flounders
  Ancylopsetta quadrocellata—ocellated flounder
  Citharichthys spilopterus—bay whiff
  Etropus crossotus—fringed flounder
  Paralichthys albigutta—Gulf flounder
  Paralichthys dentatus—summer flounder
  Paralichthys lethostigma—southern flounder
  Paralichthys squamilentus—broad flounder
  Scophthalmus aquosus—window pane flounder
Carangidae—jacks, scads, and pompanos
  Caranx hippos—crevalle jack
  Caranx latus—horse-eye jack
  Chloroscombrus chrysurus—bumper
  Oligoplites saurus—leatherjacket
  Selene vomer—lookdown
  Trachinotus carolinus—Florida pampano
  Trachinotus falcatus—round pampano
  Trachinotus goodei—great pampano
  Vomer setapinnus—Atlantic moonfish
Carcharhinidae—requiem sharks
  Apriondon isodon—finetooth shark
  Negaprion brevirostris—lemon shark
Clupeidae—herrings
  Alosa aestivalis—summer herring
  Brevoortia tyrannus—Atlantic menhaden
  Dorosoma cepedianum—gizzard shad
  Opisthonema oglinum—Atlantic thread herring
Cynoglossidae—tonguefishes
  Symphurus plagiusa—blackcheek tonguefish
Cypinodontidae—killifishes
  Cyprinodon variagatus—sheepshead minnow
  Fundulus heteroclitus—mummichog
  Fundulus majalis—striped killifish
Dasyatidae—stingrays
  Dasyatis americana—southern stingray
  Dasyatis sabina—Atlantic stingray
  Dasyatis sayi—southern stingray
  Gymnura micrura—butterfly ray
Diodontidae—porcupine fishes
  Chilomycterus schoepfi—striped burrfish
Echeneidae—remoras
  Echeneis naucrates—sharksucker
Elopidae—tarpons
  Elops saurus—ladyfish
  Megalops atlantica—tarpon
Engraulidae—anchovies
  Anchoa hepsetus—striped anchovy
  Anchoa mitchilli—bay anchovy
Ephippidae—spadefishes
  Chaetodipterus faber—Atlantic spadefish
Gadidae—codfishes and hakes
  Urophycis regius—spotted hake
  Urophycis tenuis—white hake
Gerreidae—mojarras
  Eucinostomus argenteus—spotfin mojarra
  Eucinostomus gula—silver jenny
Gobiesocidae
  Gobiesox strumosus—cling-fish
Gobiidae—gobies
  Gobiosoma bosci—naked goby
  Microgobius gulosus—clown goby
  Microgobius thalassinus—green goby
Hemiramphidae—halfbeaks
  Hyporhamphus unifasciatus—halfbeak
Labridae
  Halichoeres bivittatus—wrasse fish
Lepisosteidae—gars
  Lepisosteus osseus—longnose gar
Lutjanidae—snappers
  Lutjanus grisseus—grey snapper
Mugilidae—mullets
  Mugil cephalus—striped mullet
  Mugil curema—white mullet
Ophichthidae—snake eels
  Ophichthus gomesi—sea serpent (shrimp eels)
Ophidiidae—cusk-eels
  Rissola marginata—striped cusk-eel
Poecilidae—livebearers
  Poecilia latipinna—sailfin molly
Pomadasyidae—grunts
  Orthopristis chrysopterus—pigfish
Pomatomidae—bluefishes
  Pomatomus saltatrix—bluefish

Rajidae—skates
Raja eglanteria—clearnose skate

Rhinobatidae—guitarfishes
Rhinobatos lentiginosus—Atlantic guitarfish

Sciaenidae—drums
Bairdiella chrysura—silver perch
Cynoscion nebulosus—spotted seatrout
Cynoscion nothus—bastard weakfish
Cynoscion regalis—weakfish
Larimus fasciatus—banded drum
Leiostomus xanthurus—spot
Menticirrhus americanus—sand whiting
Menticirrhus littoralis—surf whiting
Menticirrhus saxatilis—northern kingfish
Micropogon undulatus—Atlantic croaker
Pogonias cromis—black drum
Sciaenops ocellata—red drum
Stellifer lanceolatus—star drum

Scombridae—mackerels and tunas
Scomberomorus maculatus—Spanish mackerel

Serranidae—sea basses
Centropristis striata—black sea bass

Soleidae—soles
Trinectes maculatus—American sole

Sparidae—porgies
Archosargus probatocephalus—sheepshead
Lagodon rhomboides—sailor's choice

Sphyraenidae—barracudas
Sphyraena barracuda—great barracuda

Sphyrnidae—hammerhead sharks
Sphyrna lewini—scalloped hammerhead
Sphyrna tiburo—bonnethead shark

Squalidae—sharks
Squalus acanthias—dogfish shark

Stromateidae—butterfishes
Peprilus alepidotus—southern harvestfish
Peprilus triacanthus—butterfish
Poronotus triacanthus—butterfish

Syngnathidae—pipefishes and seahorses
Hippocampus erectus—seahorse
Syngnathus fuscus—common pipefish
Syngnathus louisianae—chain pipefish

Synodontidae—lizardfishes
Synodus foetans—inshore lizardfish

Tetraodontidae—puffers
Sphoeroides maculatus—northern puffer

Trichiuridae—cutlassfishes
Trichiurus lepturus—Atlantic cutlassfish

Triglidae—searobins
Prionotus carolinus—northern searobin
Prionotus scitulus—leopard searobin
Prionotus tribulus—searobin

Uranoscopidae—stargazers
Astroscopus y-graecum—southern stargazer

Macroinvertebrates

Class Pelecypoda
Crassostrea virginica—Atlantic oyster
Modiolus demissus—Atlantic ribbed mussel
Mercenaria mercenaria—hard shell clam

Class Gastropoda
Littorina irrorata—common marsh periwinkle
Megalampus lineatus—snail
Nassarius obsoleta—eastern mud snail

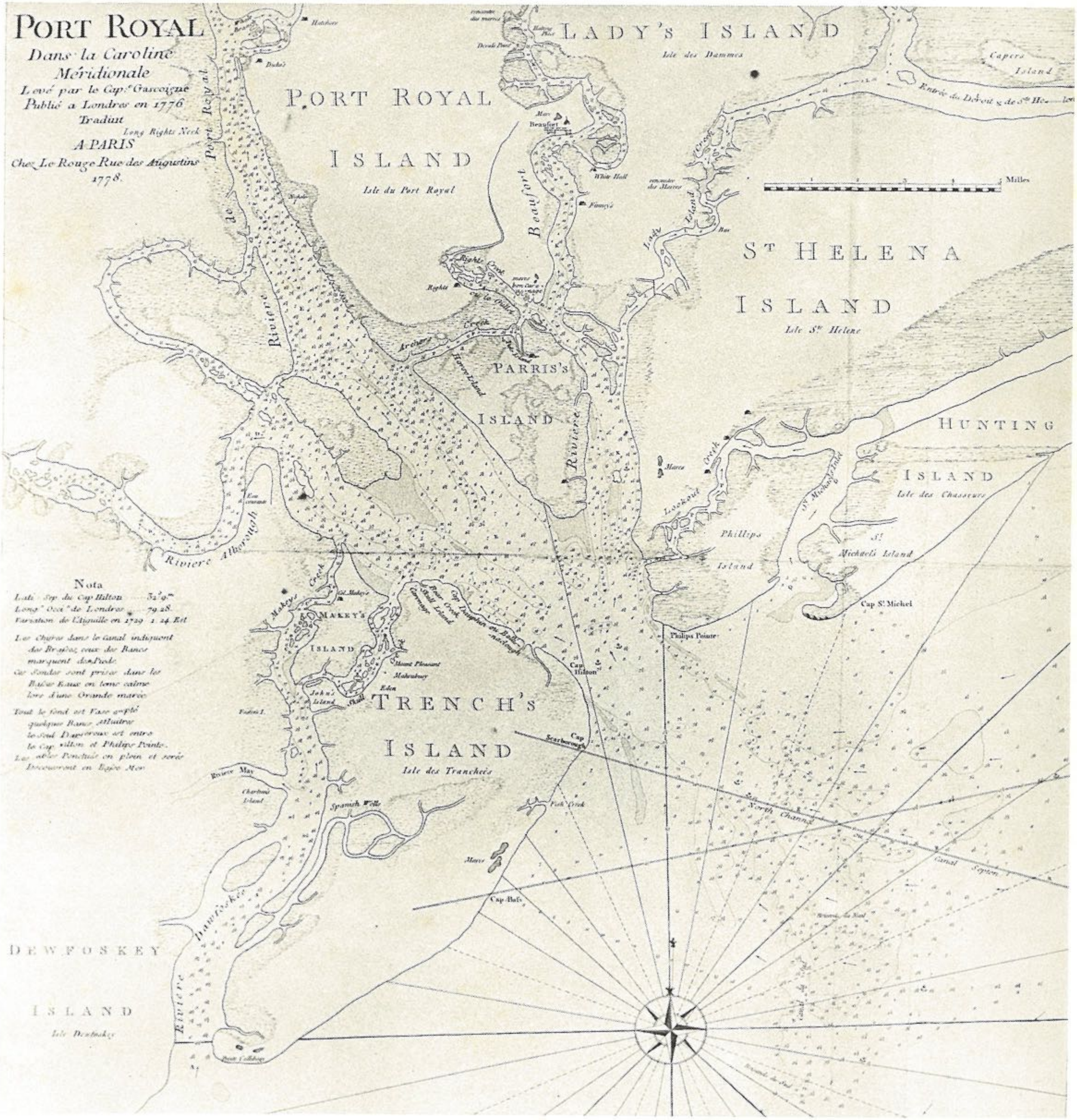
Class Asteroidea
Asterias fobesi—starfish
Luidia sp.—starfish

Class Cephalopoda
Loligo sp.—squid
Loliguncula brevis—squid

Class Merostomata
Limulus polyphemus—horseshoe crab

Class Polychaeta
Diopatra cuprea
Goniada maculata
Glycera dibranchiata
Laeonereis culveri
Lumbrinereis tenuis
Nereis succinea
Phyllodoce fragilis
Scoloplos fragilis

Class Crustacea
Callinectes ornatus—swimming crab
Callinectes sapidus—blue crab
Cancer irroratus—cancer crab
Chthamalus fragilis—barnacle
Clibanarius vittatus—hermit crab
Cyathura carinata—marine Isopod
Eurypanopeus depressus—hermit crab
Libinia dubia—spider crab
Menippe mercenaria—stone crab
Pagurus spp.—hermit crab
Palaemonetes spp.—grass shrimp
Panopeus herbstii—mud crab
Penaeus aztecus—brown shrimp
Penaeus duorarum—brown spotted shrimp
Penaeus setiferous—white shrimp
Sesarma cinereum—wharf crab
Sesarma reticulatum—square back crab
Squilla empusa—mantis shrimp
Talorchestia longicornis—beach flea
Trachypenaeus constrictus—shrimp
Uca pugilator—sand fiddler crab
Uca pugnax—mud fiddler crab
Upogebia affinis—burrowing shrimp



Map of the Port Royal Sound area in 1776.