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ECOLOGICAL CHARACTERIZATION OF THE SEA ISLAND COASTAL REGION OF SOUTH CAROLINA AND GEORGIA. VOLUME I: PHYSICAL FEATURES OF THE CHARACTERIZATION AREA

Marine Resources Division
Charleston, SC

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ECOLOGICAL CHARACTERIZATION OF THE SEA ISLAND COASTAL REGION OF SOUTH CAROLINA AND GEORGIA

VOLUME I: PHYSICAL FEATURES OF THE CHARACTERIZATION AREA

Interagency Energy-Environment Research and Development Program

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
AND
Fish and Wildlife Service

U.S. Department of the Interior

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.

- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.

- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decisionmaking process to prevent or minimize the impact of development on fish and wildlife. Research activities and technical assistance services are based on an analysis of the issues, a determination of the decisionmakers involved and their information needs, and an evaluation of the state of the art to identify information gaps and to determine priorities. This is a strategy that will ensure that the products produced and disseminated are timely and useful.

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The Biological Services Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams, which provide the Program's central scientific and technical expertise and arrange for contracting biological services studies with states, universities, consulting firms, and others; Regional Staffs, who provide a link to problems at the operating level; and staffs at certain Fish and Wildlife Service research facilities, who conduct in-house research studies.

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16. Abstract (Limit: 200 words) The Sea Island Coastal Region extends nearly 300 mi (480 km) along the coast and is typified by numerous islands, inlets, and sounds.

The material in this volume includes specific geological, physical, geographical, and chemical data which are presented to illustrate the current environmental status of the islands, estuaries, and sounds of the Sea Island Coastal Region. Whenever possible, historical data have been included for comparison with current data or to illustrate long-term trends. Future plans for development have also been included.

The material is divided into several major topics. Regional Geology covers the general geology of the Region, ranging from a discussion of the stratigraphy of the area to a description of economic mineral deposits. Significant stratigraphic units and structural features are outlined, e.g., Carolina Bays, the Duplin Formation, and the Southeast Georgia Embayment.

Under Soil Types attention is given to mainland and island soils as well as tidal marsh soils. Climatic Trends includes historical data illustrating trends in winds, minimum and maximum temperatures, and rainfall. Hurricane and tornado statistics are also included, especially data dealing with rates of incidence, general physical characteristics (wind speed, rainfall, and location), and destruction (particularly fatalities).

Physiographic Features and man's impact in terms of physical and chemical environmental alterations are the last two topics covered.

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OF THE SEA ISLAND COASTAL REGION
OF SOUTH CAROLINA AND GEORGIA

VOLUME I

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OF THE
CHARACTERIZATION AREA

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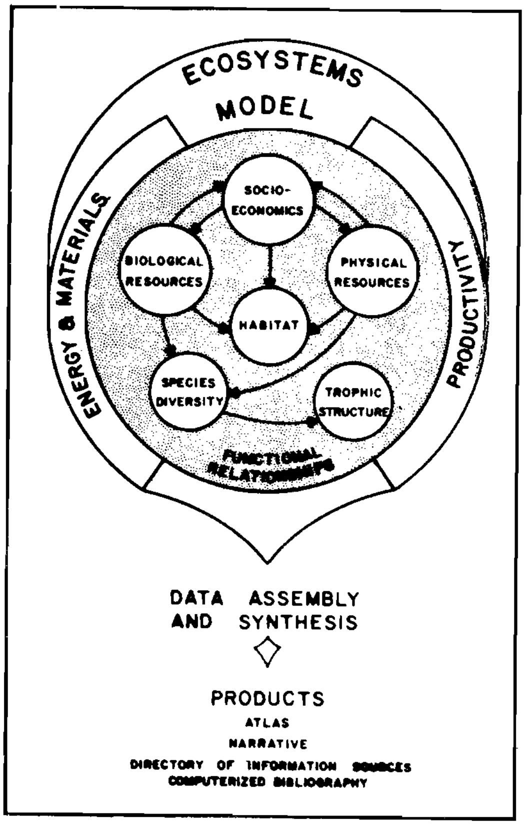
PREFACE

The Sea Island Coastal Region of South Carolina and Georgia is rich in natural resources, including moderate climate, dramatic scenic qualities, fertile soils, water, fish, wildlife, and minerals. These resources are valuable for a variety of often competitive uses, including active and passive recreation, transportation, agriculture, commercial fisheries, industrial development, preservation, and so forth.

A significant trend in the management and development of coastal resources is the growing realization that rational decisions and final judgements can be made only when all available information on local environmental conditions is considered. This trend recognizes the need for a holistic approach and has promoted the ecosystem concept in natural resource management.

Recognition of the need for an ecological approach in managing coastal resources has developed from increasing evidence that man's utilization of this environment has brought about major, yet often subtle, changes in the functioning of ecosystems. In order to perpetuate the economic, aesthetic, and biological values of coastal ecosystems, we must understand their functional relationshps. As expressed by Odum (1964), our modern ecology must be a "systems ecology" or a hybridization of both ecology and systems methodology. The theory behind this approach embodies an important ecological principle: an ecological system is comprised of many components, no one of which can be altered without affecting the total system since no one part functions independently. By including a full assessment of the total ecosystem, management efforts - at both the field and administrative levels - can be designed to maximize the economic, social, and biological benefits derived from natural resources. Recognizing this, the U.S. Fish and Wildlife Service is employing the ecosystem concept as a holistic mechanism for managing natural resources and is developing ecological characterization as one basic tool for this application.

An ecological characterization is a synthesis of existing information and data structured in a manner which identifies functional relationships between natural processes and the various components of an ecosystem (Preface Fig. 1). Specifically, objectives of the Sea Island Ecological Characterization were to 1) assemble, review, and synthesize existing biological, physical, and socioeconomic information and establish a sound information base for decision-making; 2) identify and describe various components (subsystems, habitats, communities, and key species) in this coastal ecosystem; 3) describe major physical, biological, and socioeconomic components and interactions; 4) describe known and potential ecosystem responses to man-induced changes; and 5) identify major information deficiencies for further study and decision-making needs.



Preface Figure 1. Components and final products of an Ecological Characterization of the Sea Island Coastal Region.

Ecological characterizations are designed primarily to assist coastal resource managers engaged in comprehensive planning efforts such as assessment of the environmental impacts of development in the coastal zone. Other applications include the preparation of mitigation procedures and development alternatives. Characterization also provides an immediate data base for specific action programs (offshore oil and gas development, coastal construction permit reviews, etc.) and guidance in selecting parameters that need study in further defining coastal ecological systems.

Detailed discussions of the national coastal ecosystem characterization effort can be found in Tait (1977), Barclay (1978), Johnston (1978), and Palmisano (1978).

SEA ISLAND ECOLOGICAL CHARACTERIZATION

In February 1977, the U.S. Fish and Wildlife Service contracted with the Marine Resources Division of the South Carolina Wildlife and Marine Resources Department to develop an ecological characterization for the Sea Island Coastal Region of South Carolina and Georgia. The project area includes the coastal tier of counties between the Georgetown/Horry county line in northern South Carolina south to the St. Marys River on the Georgia/Florida border, and the three lowland counties of Dorchester, Berkeley, and Effingham (Preface Fig. 2).

The Sea Island Ecological Characterization is designed to yield products that will assist decision makers in evaluating and predicting impacts of man-induced perturbations (e.g., oil and gas development, dredging and filling, water resource projects), and in general coastal zone planning. The study identifies critical habitats and sensitive life history stages of important species, addresses functional interactions at the habitat level, and provides socioeconomic information relative to the coastal environment.

Data assimilated for this project are partitioned into three segments for descriptive purposes: physical features (e.g., geology and hydrology); socioeconomic features (e.g., demographic characteristics and industrial development); and biological features (i.e., an ecological treatment of animals, plants, and their habitats).

The overall framework for the preparation of ecological characterization materials was provided by conceptual models. These conceptual models have been modified for inclusion in the final products to facilitate understanding of ecosystem functions. To accommodate the broadest range of potential users, a three-tier model presentation was used and includes the following elements for each ecosystem: 1) a technical energese model demonstrating energy flow into and within the subject ecosystem, functional relationships among representative components of the system, and flow of energy in various forms from the system; 2) a less technical pictorial model of the same ecosystem illustrating representative flora and fauna; and 3) a representative food web indicating trophodynamics within the subject ecosystem.

Organization of Final Products

Several products are being developed from the Sea Island Ecological Characterization effort as follows:

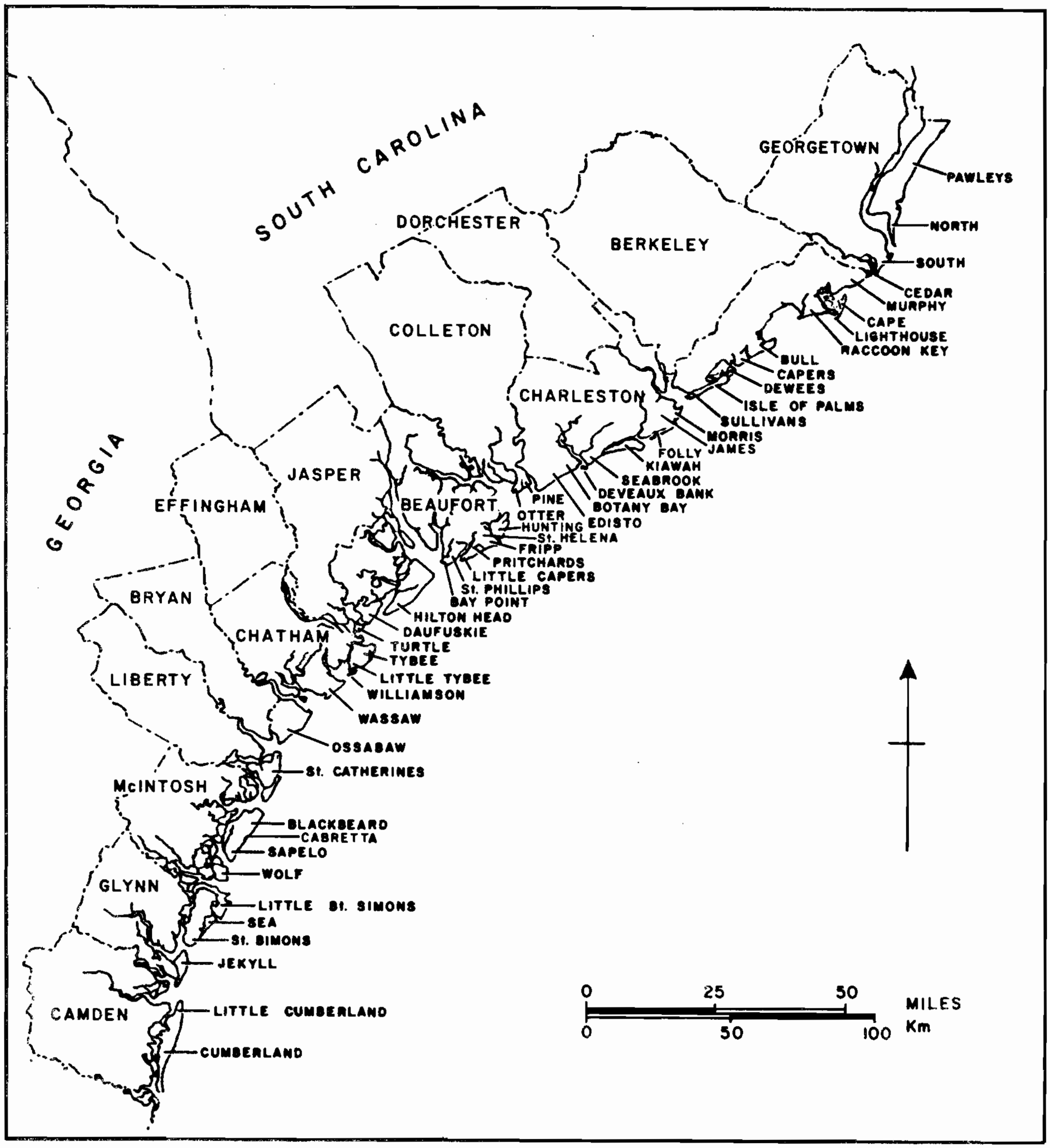
1) Characterization Atlas -- the Atlas is an oversized document (28 x 42 in) that presents data in condensed form in several series at scales ranging from 1:24,000 to 1:1,000,000. The Physiographic Series (1:100,000) describes wetlands, physiographic features, ecological habitats, and land use. The Geology Series presents stratigraphic, structural, and geophysical information about the characterization area at several scales. Two topographic series at 1:250,000 and 1:100,000 depict various wildlife, archaeological and recreational resources, military and educational institutions, water quality, spoil disposal, utilities, railroads and airports. Enlargements of the five major urban areas give more detailed information on industries, point source discharge, power plants, etc. All maps are printed in color.

2) Narrative Volumes -- Detailed narrative treatment is provided for the three major ecosystem components: the physical, socioeconomic, and biological features of the Sea Island Coastal Region. Because conceptual models are particularly valuable in identifying ecosystem components and in relating their functional significance and regulatory processes, appropriate sections of the narrative text are prefaced by exemplary models. These models serve as a tool to promote understanding of the functional relationships within and between systems and the impacts of various impingements and perturbations on their components. Narrative materials are arranged as follows:

a) Physical features section -- Detailed treatment is provided for topical areas such as climate, physiography, geologic history and structure, coastal and nearshore erosion and deposition, hydrology, and descriptions of individual coastal islands of the study area.

b) Socioeconomic features section -- Data are presented on population, labor force characteristics and trends, transportation, industrial development, agricultural practices, public utilities, energy resources, fish and wildlife conservation and utilization, and recreational resources.

c) Biological features -- This section describes biotic components along ecological lines. This approach facilitates the treatment of major community or habitat types, and generally deals with organisms at the population level. Functional relationships and areas of ecological sensitivity are stressed.



Preface Figure 2. Study area of the Sea Island Coastal Region.

3) Directory of Information Sources -- This document identifies and describes major data sources relevant to the ecological characterization of coastal South Carolina and Georgia. The main purpose of the Directory is to guide users to known sources of data pertinent to specific subject areas. It is intended to serve as a referral service between groups or organizations with differing needs.

4) Bibliography -- A computerized bibilography of over 8,000 references has been assembled as a central component of the Sea Island Characterization. The system is designed for periodic updating, and all entries can be retrieved in a variety of ways including key word and author searches.

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CHAPTER ONE

INTRODUCTION

The Sea Island Coastal Region includes the tier of coastal counties in South Carolina and Georgia and the adjacent lowland counties of Dorchester, Berkeley, (South Carolina), and Effingham (Georgia). To the north, the study area is bounded by the Horry/Georgetown County line in South Carolina and bounded to the south by the St. Marys River on the Georgia/Florida border. The east and west boundaries are the seaward 3 mi (4.8 km) territorial limit and the inland county lines, respectively (Preface Fig. 2). The Sea Island Coastal Region extends nearly 300 mi (480 km) along the coast and is typified by numerous islands, inlets, and sounds.

The material in this volume has been provided to complement Volumes II and III. Specific geological, physical, geographical, and chemical data are presented to illustrate the current environmental status of the islands, estuaries, and sounds of the Sea Island Coastal Region. Whenever possible, historical data have been included for comparison with current data or to illustrate long-term trends. Future plans for development, if available, have also been included.

The material contained herein is divided into chapters, each of which deals with a major, broad topic. Chapter Two, Regional Geology, covers the general geology of the Sea Island Coastal Region, ranging from a discussion of the stratigraphy of the area to a description of economic mineral deposits. Significant stratigraphic units and structural features are outlined, e.g., Carolina Bays, the Duplin Formation, and the Southeast Georgia Embayment.

Chapter Three contains a discussion of soil types in the Sea Island Coastal Region. Attention is given to mainland and island soils as well as tidal marsh soils.

Chapter Four is a discussion of climatic trends of the Sea Island Coastal Region. Historical data are presented to illustrate trends in winds, minimum and maximum temperatures, and rainfall. Hurricane and tornado statistics are also included, especially data dealing with rates of incidence, general physical characteristics (wind speed, rainfall, and location), and destruction (particularly fatalities).

Chapter Five describes the physiographic features of the Sea Island Coastal Region. In particular, mainland physical features, major river valleys and river systems, estuaries, coastal inlets, and the islands are discussed. Charleston Harbor and Doboy Sound are discussed in detail as respective examples of a highly industrialized environment and a relatively unmodified, pristine area. Physiographic and statistical data for the 14 counties in the study area are displayed in tables. A brief synopsis of each major river system is also provided. Where available, specific information on sediment transport at tidal inlets is also included.

Chapter Six is basically an overview of man's impact on the Sea Island Coastal Region in terms of physical and chemical environmental alterations and modifications. The chapter describes the causes of the major alterations, i.e., agriculture, urbanization-industrialization, and mining, along with detailed descriptions of historical dredging data for maintenance of harbors and the Atlantic Intracoastal Waterway. Additionally, the Santee-Cooper Diversion and Rediversion projects are presented. Effects of man-induced alterations on air quality and water quality are also discussed.

Appendices A and B are a compilation of county and island descriptions respectively, consisting primarily of physiographic data. The general dimensions and elevation ranges are included for islands and counties. Vegetative types are listed for the islands, while the areal extent and types of marshes are presented for the counties. Appendix C presents historical dredging data for maintenance of harbors in the Sea Island Coastal Region. Appendix D lists private landholdings identified as high priority representatives of unique natural systems which have been targeted for preservation efforts by the U.S. Fish and Wildlife Service.

In general, the data have been presented in the same units as used by the original authors with conversions offered for comparison, i.e., the original data may have been in the English system and converted to metric or vice versa. Most tables and figures, however, were not converted from the original system due to space limitations and difficulties in drafting.

CHAPTER TWO

REGIONAL GEOLOGY

I. INTRODUCTION

Sands, silts, and clays originally derived from the Appalachian Mountains are organized into coastal, fluvial (river), and aeolian (dune) deposits which almost completely blanket the Sea Island Coastal Region. These sediments were transported seaward and eventually deposited during the Quaternary period, which began about 1.8×10^6 years ago. The underlying bedrock strata are eroded, variously lithified, sedimentary rocks of Tertiary and Mesozoic age. These bedrock units are exposed primarily in river banks and bottoms, in deep tidal channels, on the nearshore continental shelf, and in man-made quarries.

The Georgia coastal islands are located in the Southeast Georgia Embayment, a structural basin bounded on the north by the Cape Fear Arch and on the south by the Peninsular Arch-Central Georgia Uplift. The South Carolina coastal islands are located on the southern flank of the Cape Fear Arch. The regional structural pattern is one of gently dipping or inclined beds, sloping seaward. There are no known major faults, either active or inactive, deforming the bedrock. The relatively high level of present and historic seismicity centered around Charleston, South Carolina, is quite anomalous and, at present, little understood.

Economic mineral deposits in the Sea Island Coastal Region include limestone, quartz sand, peat, phosphorite, and groundwater. The Santee Formation (limestone) is quarried in Berkeley, Dorchester, and Georgetown counties, South Carolina, for cement, agricultural lime, and road metal. Quaternary quartz sand deposits, mostly Pleistocene in age, are excavated near major cities, e.g., Charleston and Savannah, and along major highways for road metal and land fill. Phosphorite was first commercially mined in the United States from Quaternary and late Tertiary deposits located around Charleston, South Carolina. Mining in Charleston, Berkeley, Dorchester, Colleton, and Beaufort counties, South Carolina, began in 1867 and terminated in 1938. Groundwater may well be the most important mineral resource in the Sea Island Coastal Region. Approximately 1.44×10^9 l/day (3.8×10^8 gal/day) are being pumped for municipal and industrial use. The estimated annual value of this resource to the region is $19 million (Krause and Gregg 1972, Duke 1977).

II. STRATIGRAPHY

A. MESOZOIC AND TERTIARY

Mesozoic and Tertiary sedimentary rocks are infrequently exposed in the Sea Island Coastal Region with outcrops generally limited to isolated river banks, deep tidal channels, nearshore continental shelf bottoms, and quarries. One example is Grays Reef, an outcrop of the Duplin Formation (Hunt 1974), which occurs on the Georgia continental shelf off Sapelo Island.

This exposure and others scattered throughout the relatively smooth topography of the Sea Island Coastal Region's nearshore continental shelf suggest that Holocene and Pleistocene sediment cover (Atlas plate 21) is rather thin (Woolsey 1977). The Pee Dee Formation, an upper Cretaceous formation, outcrops in Georgetown County while progressively younger Tertiary units are exposed to the southwest in coastal South Carolina. Only upper Tertiary beds (Pliocene and Miocene in age) are exposed in the Georgia Sea Island Coastal Region. Detailed geologic maps have not been made for this region, largely due to the lack of exposures, but regional maps showing a generalized geologic picture have been compiled (Atlas plate 19B).

Deep wells, both water and hydrocarbon (oil and gas), have provided the majority of the Mesozoic and Tertiary stratigraphic information known to date for the Sea Island Coastal Region (Herrick and Vorhis 1963, Maher and Applin 1971, Cramer 1974). The oldest sedimentary rocks are deeply buried lower Cretaceous sandstones, shales, and siltstones ($\leq 1.30 \times 10^8$ years old) resting on an eroded basement of igneous and metamorphic crystalline rocks. Limestone, the dominant rock type underlying the Sea Island Coastal Region, overlies these sedimentary rocks and ranges in age from upper Cretaceous (1.0×10^8 years) to Oligocene ($\approx 3.0 \times 10^7$ years). Miocene and Pliocene beds mark a change to more clastic-rich limestones, i.e., rich in sand, silt, and clay. All of these Mesozoic and Tertiary limestones pass into sandstones, shales, and siltstones in directions tending 1) northwest toward the Georgia-South Carolina Piedmont, and 2) to a lesser degree, northeast onto the Cape Fear Arch. These generalized stratigraphic/lithologic relationships are shown on Atlas plate 21. A correlation chart of the Mesozoic and Tertiary formations known from the Sea Island Coastal Region is presented in Table 2-1.

Major transgressions of the sea over the coastal plain have occurred during the upper Cretaceous, Paleocene,

Table 2-1. Mesozoic and Tertiary formations (Fm.) of the Sea Island Coastal Region (adapted from Cooke 1936, 1943; Herrick and Vorhis 1963; Puri and Vernon 1964; Dubar et al. 1974; Hazen et al. 1977; Baum et al. 1978; P. Huddleston, 1978, Georgia Department of Natural Resources, Atlanta, pers. comm.).

ERA	PERIOD	EPOCH	AGE	SEA ISLAND COASTAL REGION: NORTHEAST FLORIDA	COASTAL GEORGIA	COASTAL SOUTH CAROLINA	COASTAL NORTH CAROLINA
CENOZOIC	TERTIARY	Pliocene	Upper	ABSENT Jackson Bluff Fm.	(see Table 2-2) Duplin Fm.	(see Table 2-2) Duplin Fm.	Bear Bluff Fm. Duplin Fm.
			Lower	ABSENT	"Tybee Beds"[a]	ABSENT	ABSENT
		Miocene	Upper	ABSENT	Charlton Fm.	ABSENT	ABSENT
			Middle	Hawthorn Fm.	Coosawhatchee Fm.	ABSENT	ABSENT
			Lower	Hawthorn Fm.	Marks Head Fm. Parachucla Fm.	ABSENT Cooper Fm.	Belgrade/Silverdale Fm.
		Oligocene	Chickasawhay	Suwannee Fm.	Suwannee Fm.	Cooper Fm.	Trent Fm.
			Vicksburg	ABSENT	ABSENT	ABSENT	ABSENT
		Eocene	Jackson	Crystal River Fm. Williston Fm. Inglis Fm.	Ocala Group	Cooper Fm. Santee Fm.	New Bern Fm.
			Claiborn	Avon Park Fm. Lake City Fm.	Avon Park Fm. Lake City Fm.	Santee Fm.	Castle Hayne Fm.
			Wilcox	Oldsmar Fm. Cedar Keys Fm.	Oldsmar Fm. Cedar Keys Fm.	Black Mingo Fm.	Un-named unit
		Paleocene	Midway	ABSENT(?)	ABSENT(?)	Black Mingo Fm.	Beaufort Fm.

Table 2-1. Concluded

ERA	PERIOD	EPOCH	AGE	NORTHEAST FLORIDA	COASTAL GEORGIA	COASTAL SOUTH CAROLINA	COASTAL NORTH CAROLINA
				SEA ISLAND COASTAL REGION			
MESOZOIC	CRETACEOUS	Gulfian	Navarro	Lawson Fm.	Lawson Fm.	Pee Dee Fm.	Pee Dee Fm.
			Taylor	Taylor-age strata	Taylor-age strata	Black Creek Fm.	Black Creek Fm.
			Austin	Austin-age strata	Austin-age strata	Black Creek Fm.	Black Creek Fm.
			Eagle Ford			Middendorf Fm.	Middendorf Fm.
			Woodbine	Atkinson Fm. (sandstones and shales)	Atkinson Fm. (sandstones and shales)	Cape Fear Fm.	Cape Fear Fm.
		Commanchean		Undifferentiated (red-colored sandstones, siltstones, and shales)			

a. Woolsey (1977)

formations underlined are limestone units

formations broken underlined are terrigenous clastics (calcareous-rich) middle Eocene (Claiborn), upper Eocene (Jackson), Oligocene (Chickasawhay), middle Miocene, and upper Pliocene. These events caused the deposition of marine sediments far up onto the coastal plain. Major regressions, indicated by 1) presumed subaerial erosion of older rocks and 2) deposition of fluvial-lacustrine-deltaic sediment on top of marine sediments, occurred during the Paleocene (Midway), Oligocene (Vicksburg), lower Miocene, and lower Pliocene.

B. PLEISTOCENE

1. Coastal Terrace Complexes

Pleistocene sediments of the Sea Island Coastal Region are organized into topographically distinct, lithologically similar, geomorphic units arranged in a series of terraces parallel to the coast. These terraces decrease in elevation from 100 ft (30.5 m) in Georgia and 215 ft (65.5 m) in South Carolina down to present sea level. Pleistocene sediments were deposited between 1.8×10^6 years and 1.0×10^4 years ago. There are two major geomorphic units, linear sand ridges and broad clayey sand plains. The sand ridges are the remains of barrier islands, and the clayey sand plains are the former back-barrier tidal flat lagoons, or marshes. (See Atlas plate 21 for descriptive cross sections through coastal terraces in northern South Carolina, central South Carolina, and central Georgia.) These coastal terraces are considered to have formed at high stands (interglacials) of the fluctuating, although falling, Pleistocene Atlantic Ocean. Sea level was fluctuating as a result of the intermittent continental glaciation-deglaciation, but with a net decrease from the level of the early upper Pliocene (Duplin Formation) transgression.

The correlating and/or tracing of individual Pleistocene geomorphic units over long distances is difficult, largely due to 1) their discontinuous nature, especially the sand ridges, and 2) the lack of fossils. Topographic elevation has been the basis for most region-to-region correlations of terrace sequences (Cooke 1931, 1932, 1936, 1943, MacNeil 1949, Doering 1960, Hoyt and Hails 1974, Oaks and Dubar 1974). This practice assumes that areas so correlated have suffered no differential tectonic (deformation of the earth's crust) uplift or downwarp. Since Winker and Howard (1977) demonstrated differential uplift of Pleistocene shoreline features using aerial photography and modern detailed topographic maps, these assumptions of Pleistocene tectonic stability are suspect (Fig. 2-1). Thus, it may not be possible to correlate Pleistocene coastal deposits on the basis of topographic elevations.

Exposures of fossil-bearing beds are rare and the stratigraphic ranges of the contained fauna are poorly known. The shell-bearing Waccamaw Formation has been determined to be Calabrian in age (basal Pleistocene, $1.0 - 1.8 \times 10^6$ years old) on the basis of foraminiferal zonation (Akers 1972) and amino acid dating (Belknap 1979). Amino acid determinations on shells from the Canepatch and Socastee Formations in northern South Carolina have yielded tentative ages of 300,000 - 500,000 years and 300,000 years, respectively (Belknap 1979). Shells from the Mt. Pleasant Barrier (Princess Anne Formation) and the Talbot-Pamlico Formation of central South Carolina have produced tentative amino acid ages of 120,000 years and 800,000 - 1,000,000 years, respectively (Belknap 1979). The Pamlico Formation of southern Georgia has yielded tentative amino acid ages of 500,000 - 700,000 years (Belknap 1979). The Anastasia Formation in the Cape Canaveral, Florida region (a Pamlico-Princess Anne correlative) has been determined to be 100,000 - 120,000 years by U/Th (Uranium/Thorium) disequilibrium method of dating shells (Osmond et al. 1970). These problems, anomalies, and contradictions of correlation are reflected in the correlation chart showing the various Pleistocene formations and geomorphic units recognized in coastal Georgia and South Carolina (Table 2-2).

The various Pleistocene geomorphic units, as well as formations recognized in the Sea Island Coastal Region are presented in Atlas plate 19B (a highly generalized and, at present, tentative map description). The geomorphic unit most commonly identified in the Sea Island Coastal Region has been the coastal terrace (Cooke 1936, 1943, Colquhoun 1969, 1974, Dubar et al. 1974, Hoyt and Hails 1974). These terraces are thought to have a complex origin and result from both erosional and depositional processes operating during marine transgressions (ocean encroaching upon the land) and regression (land building out into the ocean and/or ocean retreat). Colquhoun's (1969) detailed interpretation of these processes which interact to produce a coastal terrace is presented in Figure 2-2. Winker and Howard (1977) abandoned the terrace idea in favor of beach ridge-barrier island sequences. They mapped three major groups in the Sea Island Coastal Region: Trail Ridge, Effingham, and Chatham (Fig. 2-3). The correlation between these three groups and the long recognized coastal terraces and formations is shown in Table 2-2.

Utilizing subsurface data from a series of wells, Herrick (1965) found the Georgia Pleistocene to be a sequence of coarse micaceous (mica-rich) sands

Table 2-2. Correlation chart of Pleistocene units (geologic formations, cyclic units, geomorphic units) described from the Sea Island Coastal Region.

EPOCH	AGE	COASTAL GEORGIA		CENTRAL SOUTH CAROLINA	NORTHERN SOUTH CAROLINA
		Hoyt and Hails (1974)[a]	Winker and Howard (1977)	Colquhoun (1974)[a]	Dubar et al. (1974)
Pleistocene		Silver Bluff Fm. (+1)[b]		Silver Bluff cyclic unit (+3)[b]	
		Princess Anne Fm. (+4)[b]		Princess Anne Fm. (+5)[b] (between the Awendaw and Mt. Pleasant Scarps)	
			Chatham Sequence		
		Pamlico Fm. (+8)[b]		Talbot - Pamlico (+14 to +8)[b] cyclic unit (between the Summerville/Bethera and Awendaw Scarps)	Socastee Fm. (Myrtle Beach barrier)
		Talbot Fm. (+15)[b]			Canepatch Fm. (Jaluco, Conway, & Cainhoy barriers)
	Calabrian	Penholoway Fm. (+25)[b]	Effingham Sequence	Wicomico Fm. (+37 to +23)[b] (between the Surrey and Summerville Scarps)	Waccamaw Fm. (Pleasant Hill, Horry, Summerville, Bethera, and Kingstree barriers)
1.8 x 10^6 years					
Pliocene	Upper	Wicomico Fm. (+33)[b]	Trail Ridge Sequence	Okefenokee/Sunderland/ Coharie cyclic unit (between the Orangeburg and Surrey Scarps)	Bear Bluff Fm.

a. Continued Cooke's (1936, 1943) original terminology of Maryland-Virginia terraces.

b. Position of sea level during time of deposition (in meters) relative to present mean sea level.

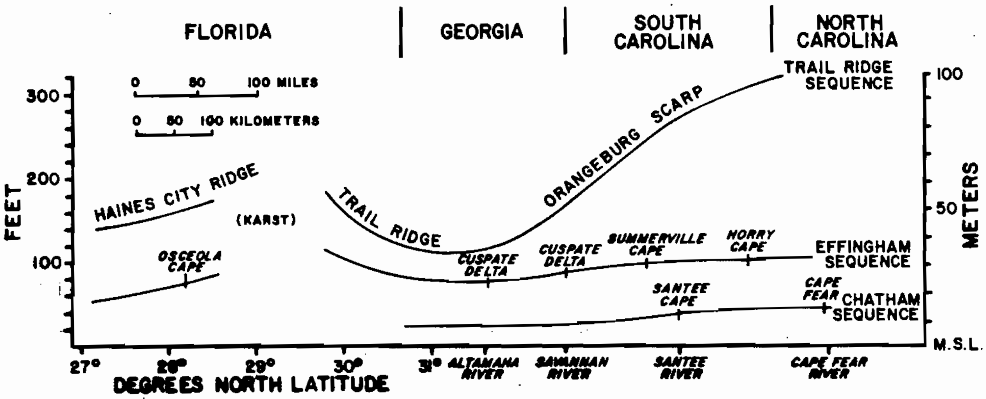


Figure 2-1. Vertical displacement of Pleistocene beach ridges and shoreline scarps in the Sea Island Coastal Region (adapted from Winker and Howard 1977). Note that all three sequences are not found at the same respective topographic elevation. This strongly suggests that differential tectonic uplift and/or downwarp has occurred during the Pleistocene in this region. (MSL = Mean Sea Level.)

thickening seaward and grading into and surrounding a lignitic clay (Fig. 2-4). He identified two major deposition centers: 1) coastal Liberty, Bryan, and Chatham counties and 2) southern Camden County, centered about the St. Marys River (Fig. 2-5).

2. Fluvial Deposits

Pleistocene fluvial (river) deposits, e.g., flood plain, point bar, dune sheet, and terrace features, occur in all the major river valleys. The most extensively studied deposits are those on the Little and Great Pee Dee rivers (Fig. 2-6) (Thom 1967, 1970) and those of the Santee River (Fig. 2-7) (Colquhoun et al. 1972). River Valley dune sheets are present in the Great Pee Dee, Santee, Savannah, and Altamaha river valleys covering the youngest Pleistocene fluvial terraces (Atlas plates 9, 11, 17). These dunes are of late Wisconsin age (20,000 to 10,000 years ago) and represent a time of changing river conditions, i.e., a reduction in overall discharge and/or a change from braided to meandering. These changes would serve to expose bare flood plains to wind action. Thom (1970) further concludes that these are blown-out or degraded parabolic dunes formed by southwesterly and westerly winds. This conclusion is based on geomorphological observations that the dune fields occur as a series of SW/NE to W/E trending ridges located on the eastern sides of the major river valleys (Great Pee Dee, Santee, Savannah, and Altamaha).

3. Carolina Bays

Carolina Bays (shallow, elliptical, poorly drained depressions) occur throughout the Sea Island Coastal Region and are developed on a variety of Pleistocene features: coastal terraces, river terraces, beach ridge plains, and river valley dune sheets (Fig. 2-8). The long axes of these elliptical depressions commonly range between 1 to 4 km (0.6 to 2.5 mi) in length (Kaczorowski 1977). A sand rim surrounds most bays and is typically best developed on the southeastern edge. The common long axis orientation is northwest-southeast in the Carolinas and Georgia (Fig. 2-9). These features support a cypress-tupelo and/or shrub vegetation, and when cultivated, are more fertile and productive than adjacent lands (Kaczorowski 1977). Tuomey (1848) first called attention to the existence of "circular depressions that are scattered over the surface" and which "are not deep and conical like lime-sinks."

Aerial photography more clearly shows the true shape, orientation, positioning, and distribution of Carolina Bays (Fig. 2-10). Subsequent to the early 1930's aerial photography of the Myrtle Beach, South Carolina, region, Melton and Schriever (1933) proposed that these features resulted from an enormous meteorite shower. Cooke (1934) pointed out the following flaws in this theory:

1) The bays are in neat, orderly groups and not randomly scattered.

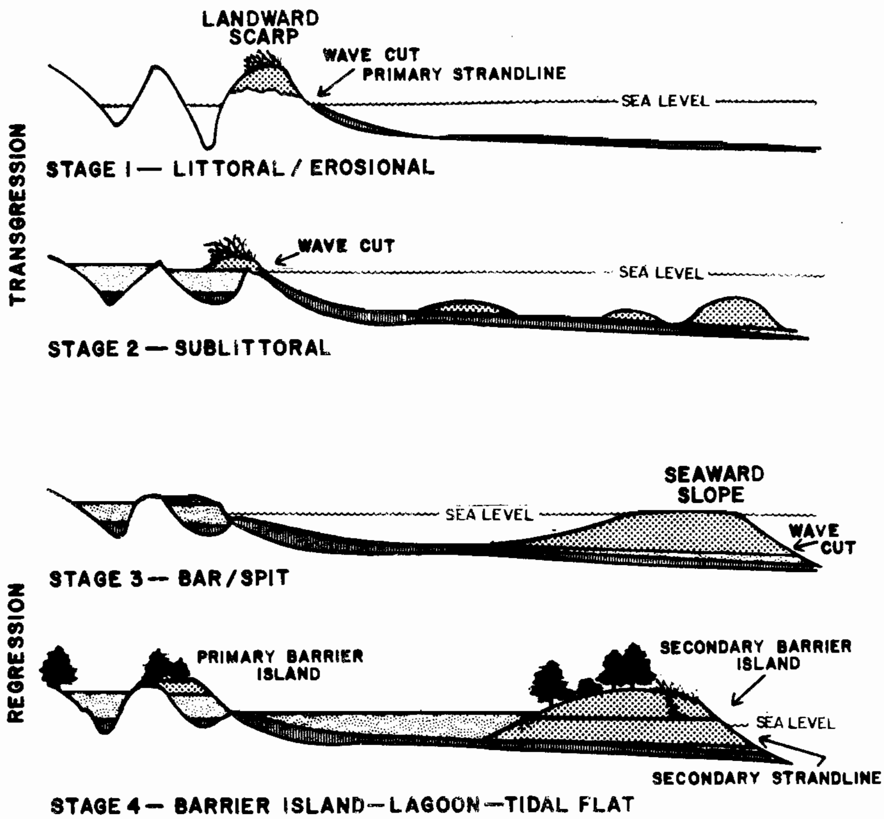


Figure 2-2. The four stages of Pleistocene coastal terrace formation (Colquhoun 1969). Note that both marine transgression and regression are represented as fundamental parameters. In addition, this interpretation accounts for the "paired" nature of many Pleistocene terrace complexes, i.e., two barrier islands are frequently associated with one terrace. The resulting terrace complex contains a complicated arrangement of many sediment types from barrier island to marsh-lagoon deposits.

2) The bays are limited entirely in distribution to the coastal plain.

3) Meteorite craters tend to be round rather than elliptical.

4) No meteoritic material or fused silica has been found in or near the bays.

5) The substrate of the bays is relatively undisturbed.

Prouty (1952) tabulated a list of 38 more obvious facts known about Carolina Bays and presented a strong case for the meteorite origin. He placed considerable emphasis on the probable role of air-shock waves in the formation of elliptical depressions and stated that magnetometer surveys of bays had produced "very favorable results in support of the meteoritic theory." Thom (1970) concluded from an extensive study of Carolina Bays in Marion and Horry counties, South Carolina, that these features ". . . were formed by the enlargement of small ponds during a period of strong south-westerly winds accompanied by cool, pluvial (rainy) conditions and high water tables in the mid- to late Wisconsin." These features were originally shallow ponds subject to wave action which smoothed their shores into regular, elliptical sandy berms

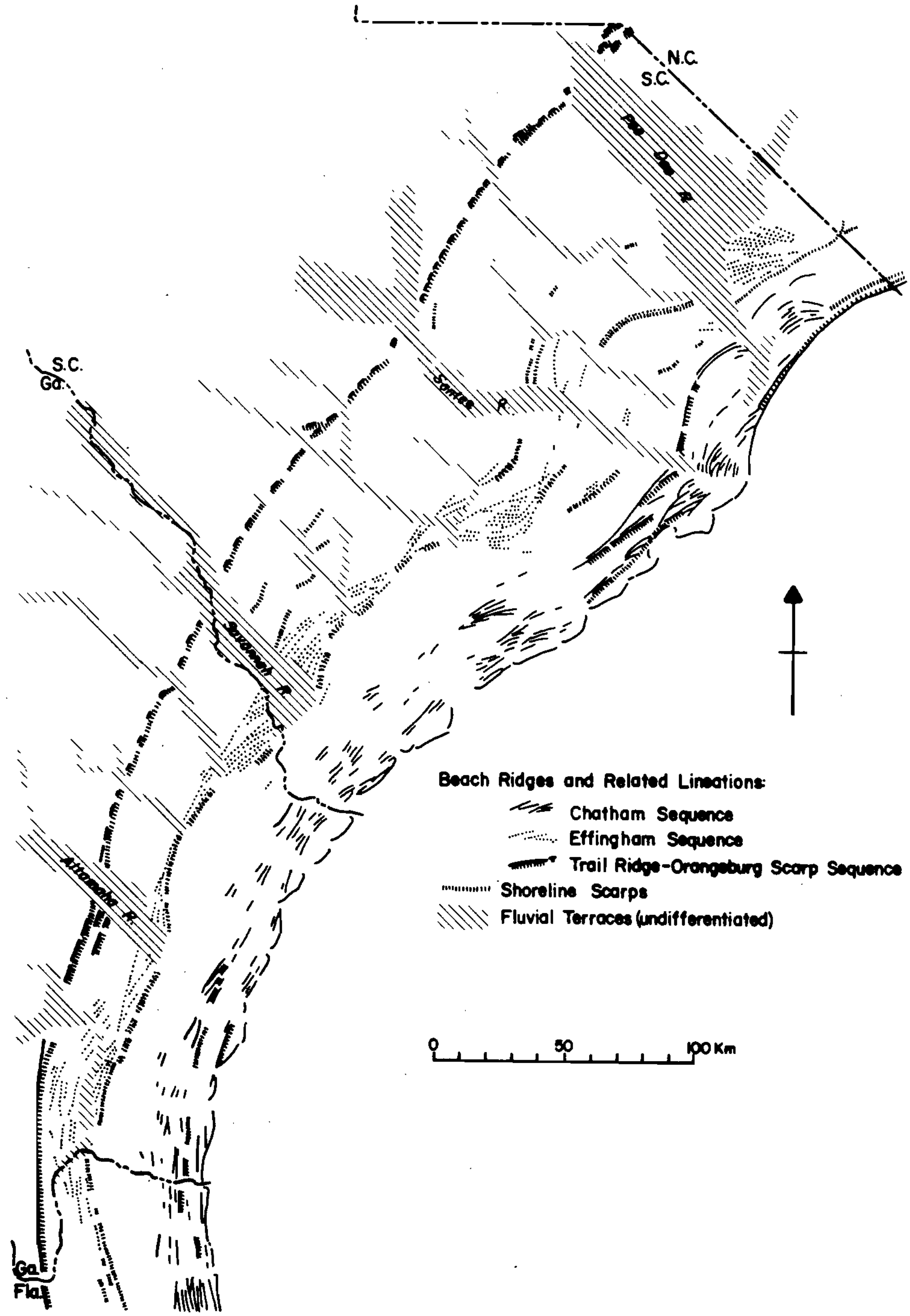


Figure 2-3. Pleistocene beach ridges and shoreline scarps of South Carolina and Georgia (Winker and Howard 1977).

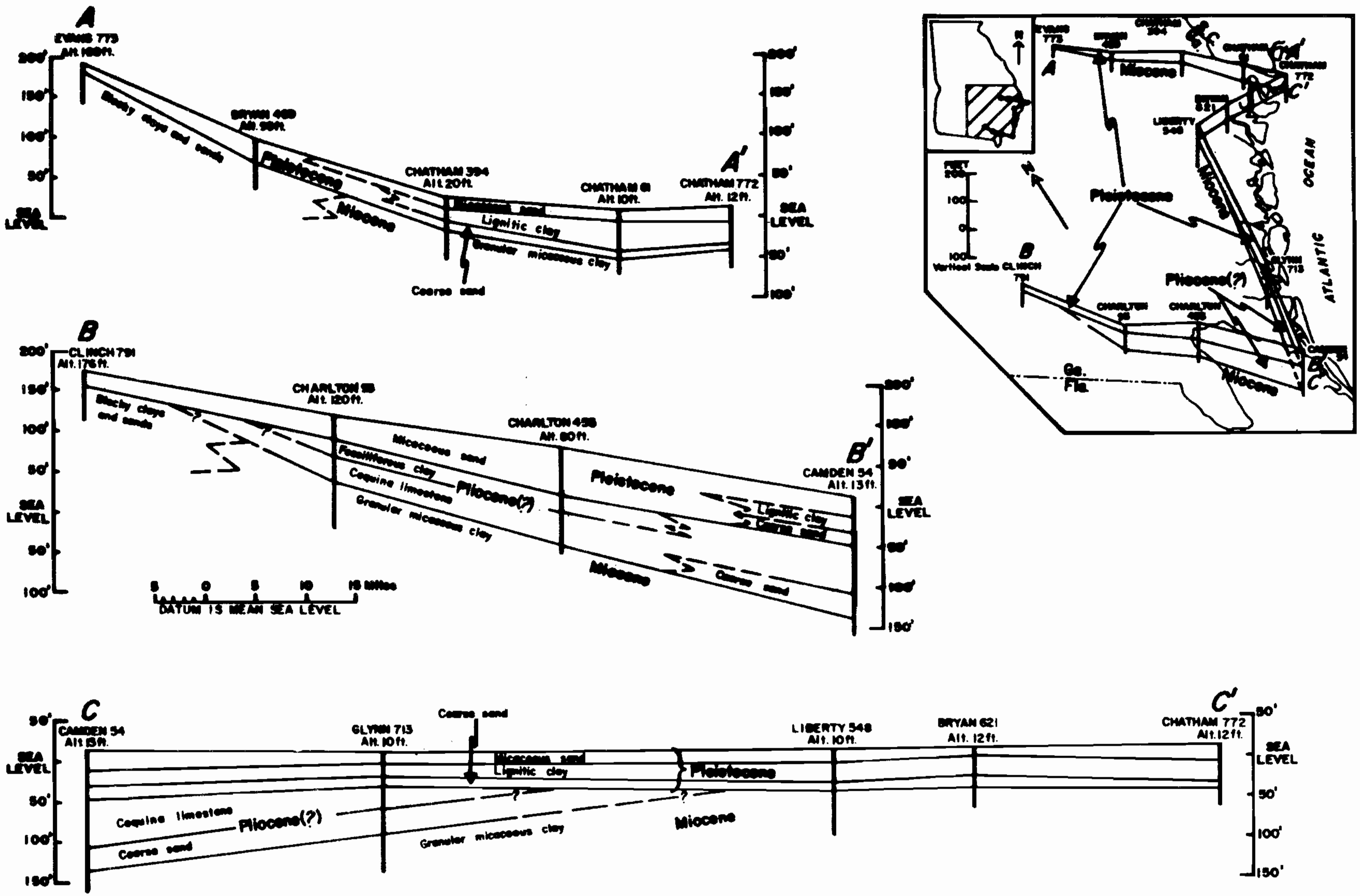


Figure 2-4. Stratigraphic cross sections of the subsurface Georgia Pleistocene (Herrick 1965).

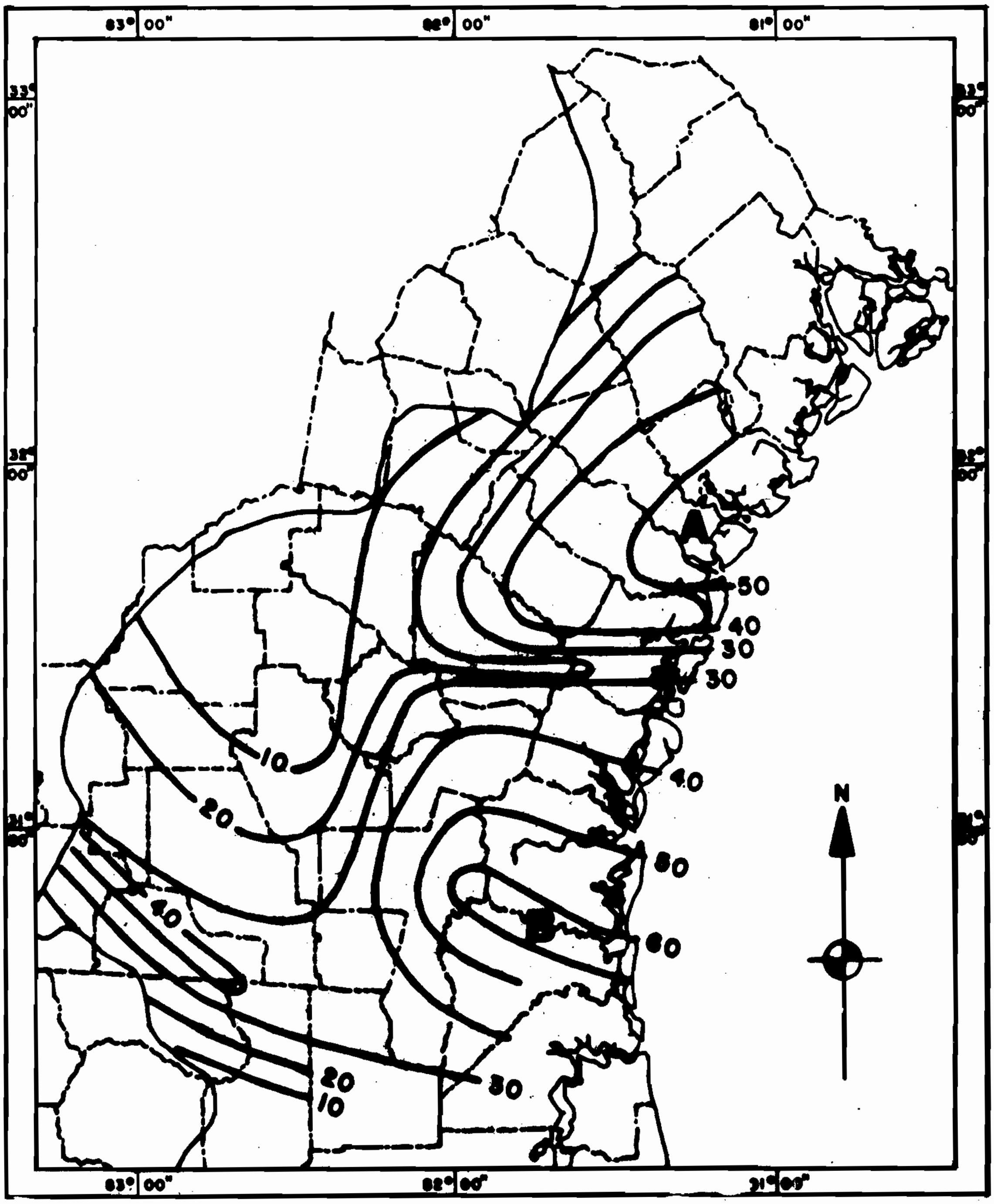


Figure 2-5. Isopach (thickness) map of the subsurface Georgia Pleistocene (Herrick 1965). Note the two major deposition centers: (A) in coastal Liberty, Bryan, and Chatham counties and (B) in southern Camden County, centered about the St. Marys River. Isopach contours are in feet.

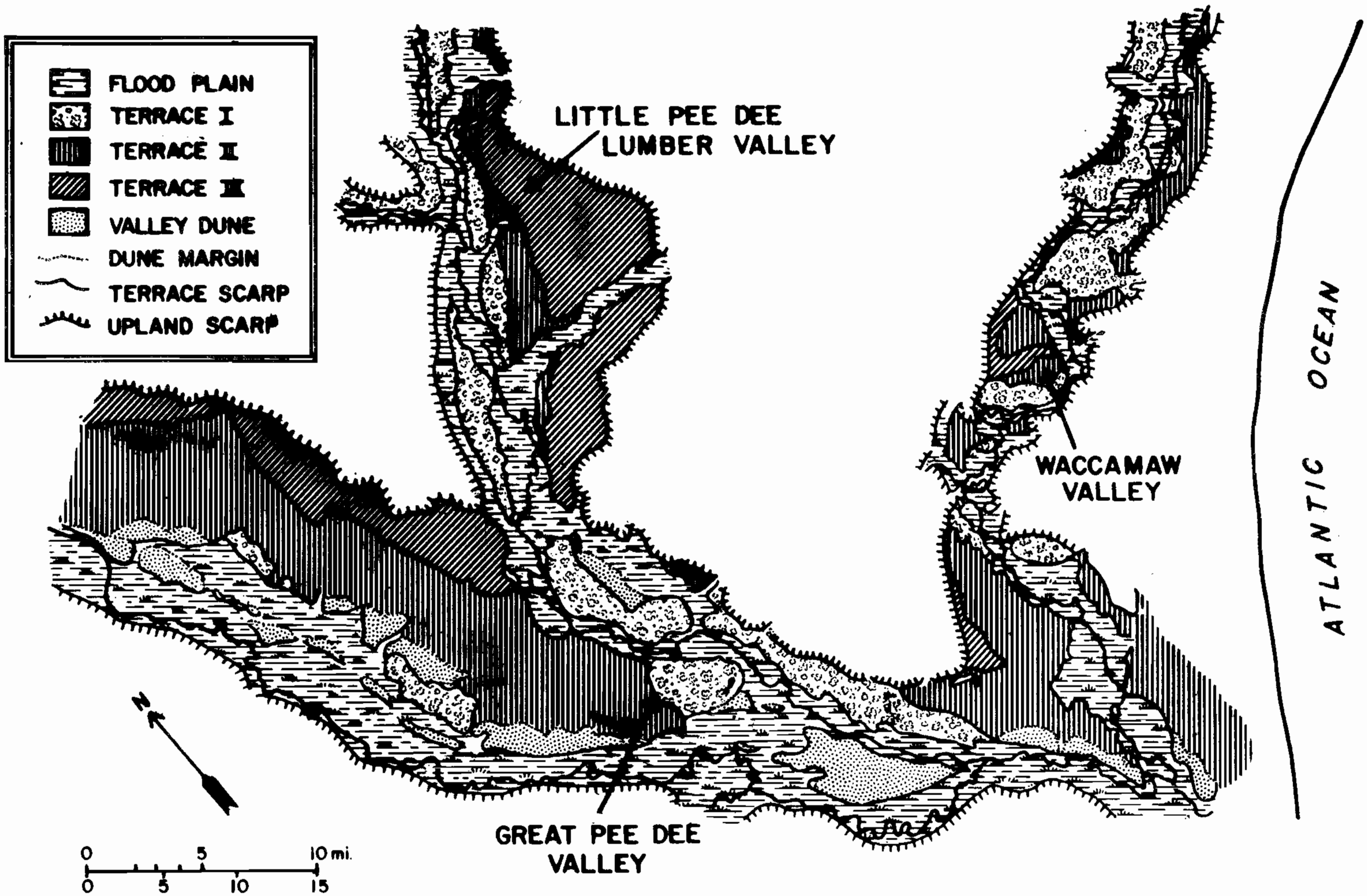


Figure 2-6. Quaternary geomorphic elements of the Great Pee Dee, Little Pee Dee, and Waccamaw river valleys (adapted from Thom 1970).

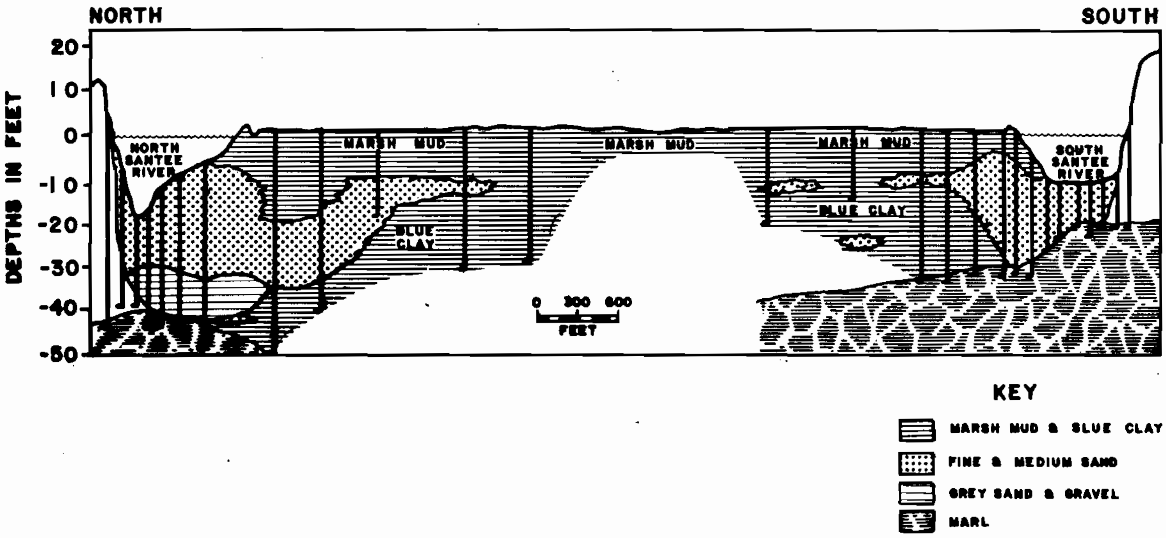


Figure 2-7. Quaternary fluvial deposits of the Santee River Valley (Colquhoun et al. 1972).

(Kaczorowski 1977). The present prevailing/dominant wind directions at southeastern cities is approximately perpendicular to the long axes of their geographically adjacent Carolina Bays (Fig. 2-9). Today very few, if any, contain water and are, rather, filled with a distinctive vegetation. (See Volume III, Chapter Five for a discussion of Carolina Bay vegetation.) Humate cement (Daniels et al. 1976) present in the coastal sands served to restrict overall drainage and to perch local water tables, thus promoting lake or pond formation throughout these Pleistocene terrace complexes. Dating the age of Carolina Bay formation is quite difficult because of poor preservation of organic material and possible confusion and/or contamination of bay-generated organic material with the underlying humate. The available age determinations indicate bay formation prior to 40,000 and extending to 6,000 years ago (Kaczorowski 1977).

C. HOLOCENE

Holocene-age sediments, deposited within the last 10,000 years, comprise the river bottoms, swamps, marshes, beaches, beach and dune ridges, tidal flats, tidal deltas, biogenic reefs, e.g., Crassostrea virginica (oyster) and Dodecaceria sp. (colonial worm) reefs, estuarine bottoms, and the floor of the shallow, nearshore shelf. Selected examples from the Sea Island Coastal Region follow.

1. Santee River Delta

Aburawi (1972) described the Holocene stratigraphy of the lower Santee Delta (seaward of the Atlantic Intracoastal Waterway) from a series of piston cores (Atlas plate 22B). He identified two major sediment facies or types: a delta plain facies of silty clay marsh and swamp deposits, and a delta front facies of marine sands with interbedded clay layers. The delta front facies is located seaward and below the delta plain facies.

Lee (1973) also used piston cores to develop a detailed sedimentary facies map of the North Santee Bay (Fig. 2-11). Along with Mullin (1973), he identified a marine sand lens deposited since the early 1930's after diversion of the Santee River discharge into Charleston Harbor. This marine sand lens transgresses various estuarine facies (Fig. 2-12) and is thought to have formed as a result of decreased scour due to river flow.

2. Winyah Bay

Colquhoun (1973) described the bottom sediments of Winyah Bay (Fig. 2-13) and observed that clay-rich sediment dominated the upper bay while sand-rich sediment dominated the lower bay. Old channels were marked by sand-rich linear deposits.

3. Tybee Island Region

Using archaeologic dating of aboriginal midden deposits, DePratter and Howard (1977) determined the constructional history of the Holocene beach ridge plain extending between the Savannah and Wilmington rivers seaward of Wilmington Island (Fig. 2-14). The oldest recognized Holocene shoreline is 4,500 years old, located immediately in front of Wilmington Island, with the bulk

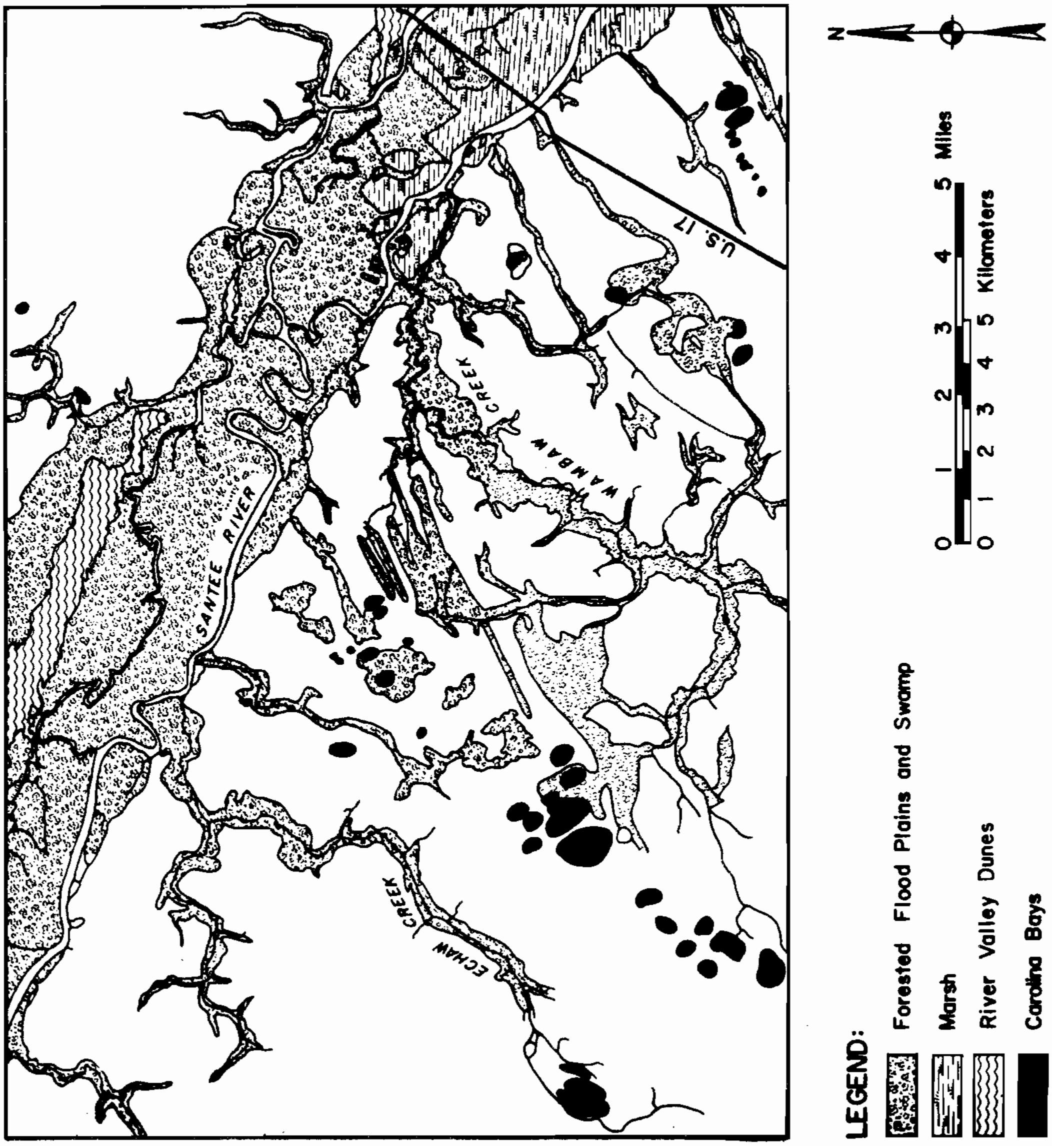


Figure 2-8. Carolina Bays present in northeastern Charleston County, South Carolina. The elliptical outlines and common orientations of long and short axes are characteristic of these features throughout the Sea Island Coastal Region.

of beach ridge construction having taken place since 2,700 years ago. Tybee Island, the site of the City of Savannah Beach, was constructed approximately 675 years ago.

DePratter and Howard's (1977) chronology was developed from aboriginal artifacts whose radiometric ages were determined elsewhere. There is theroretically some finite lag time between beach ridge construction and aboriginal occupation. However, given the potential attractiveness of this environment, this lag time may be much less than errors associated with 1) identification and/or correlation of artifacts and 2) the original radiometric dating of the type artifacts.

4. Charleston County

Stapor and Mathews (1976) determined the constructional history of Kiawah, Seabrook, Botany Bay, and Bay Point (the site of Edisto Beach) barrier islands from radiometric dating of shell beds, supplemented with archaeologic dating of aboriginal midden sites. Barrier island deposition began at least 2,500 years ago on Kiawah Island and was essentially complete by 1,000 years ago. Subsequent fluctuations of the Stono ebb tidal delta have caused local erosion and deposition on the island's northern tip. Seabrook and Botany Bay islands both are no older than 1,200 years, and Edisto Beach is no older than 1,600 years. They also noted the occurrence

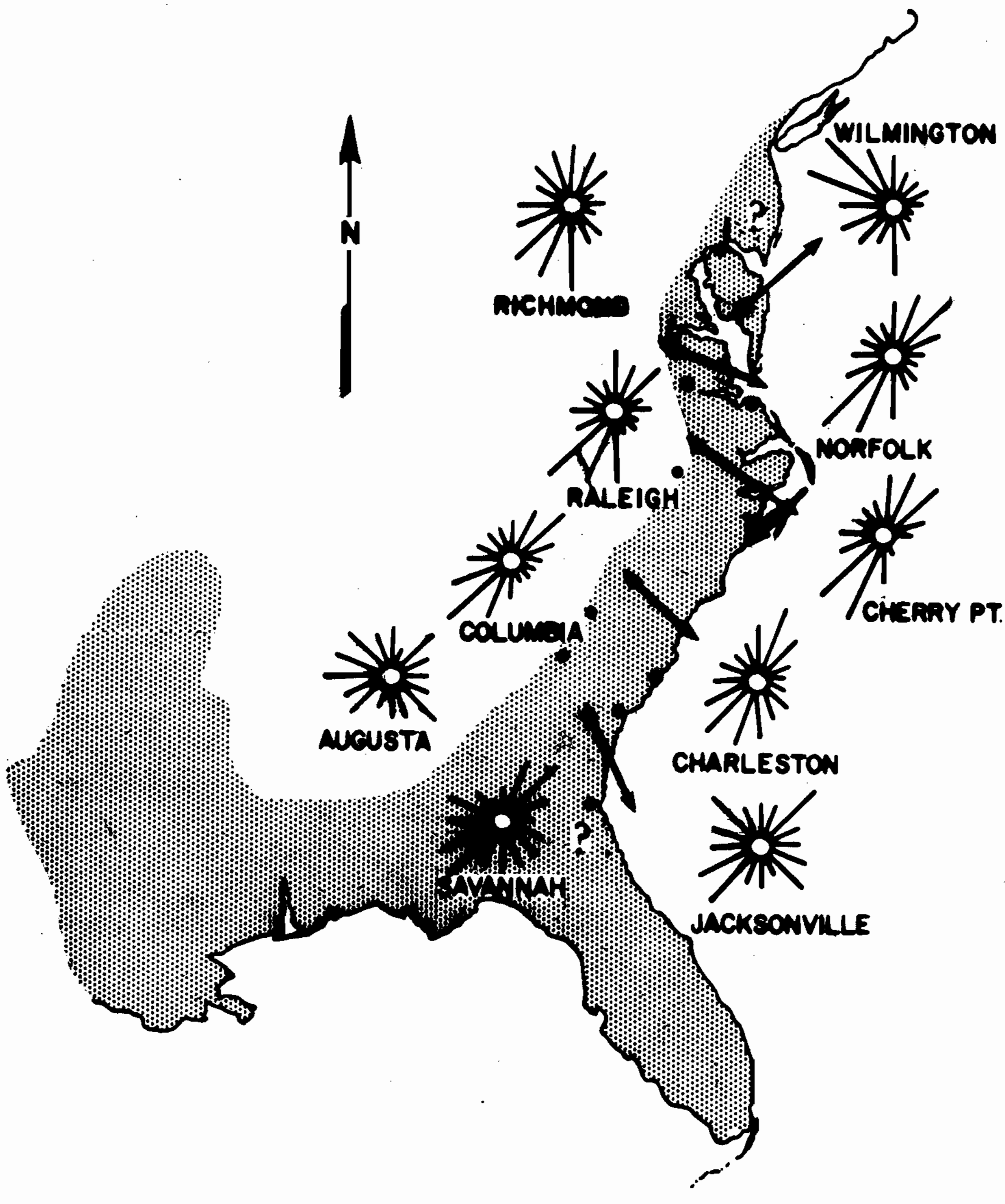


Figure 2-9. Carolina Bay orientations (double-headed arrows) and prevailing/dominant wind directions for major cities within and without the Sea Island Coastal Region (Kaczorowski 1977).

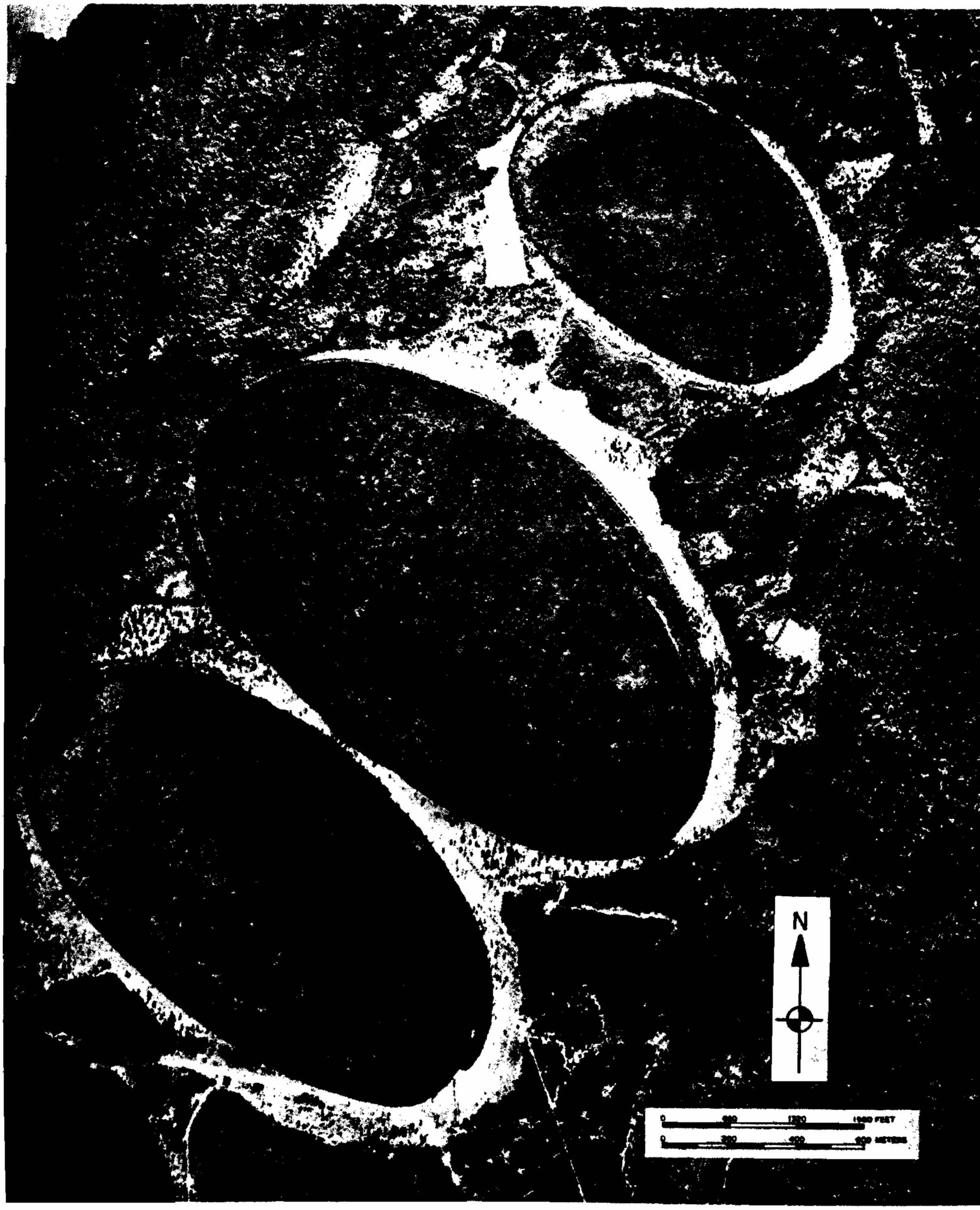


Figure 2-10. **Aerial photograph of representative Carolina Bays in Horry County, South Carolina. (Photo by U.S. Department** of Agriculture, Agricultural Stabilization and Conservation Service, Salt Lake City, Utah.)

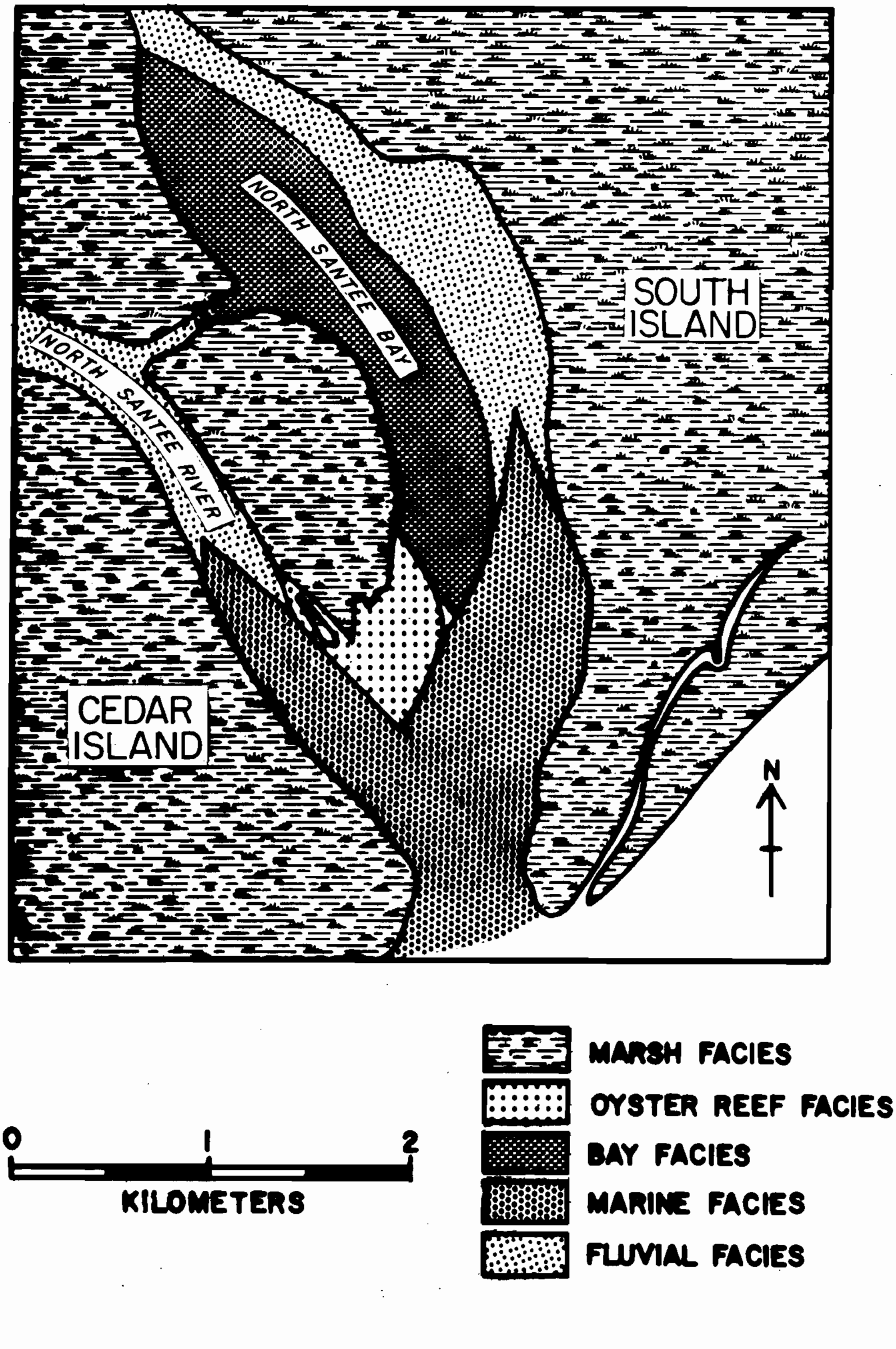


Figure 2-11. Bottom sediments of North Santee Bay (Lee 1973).

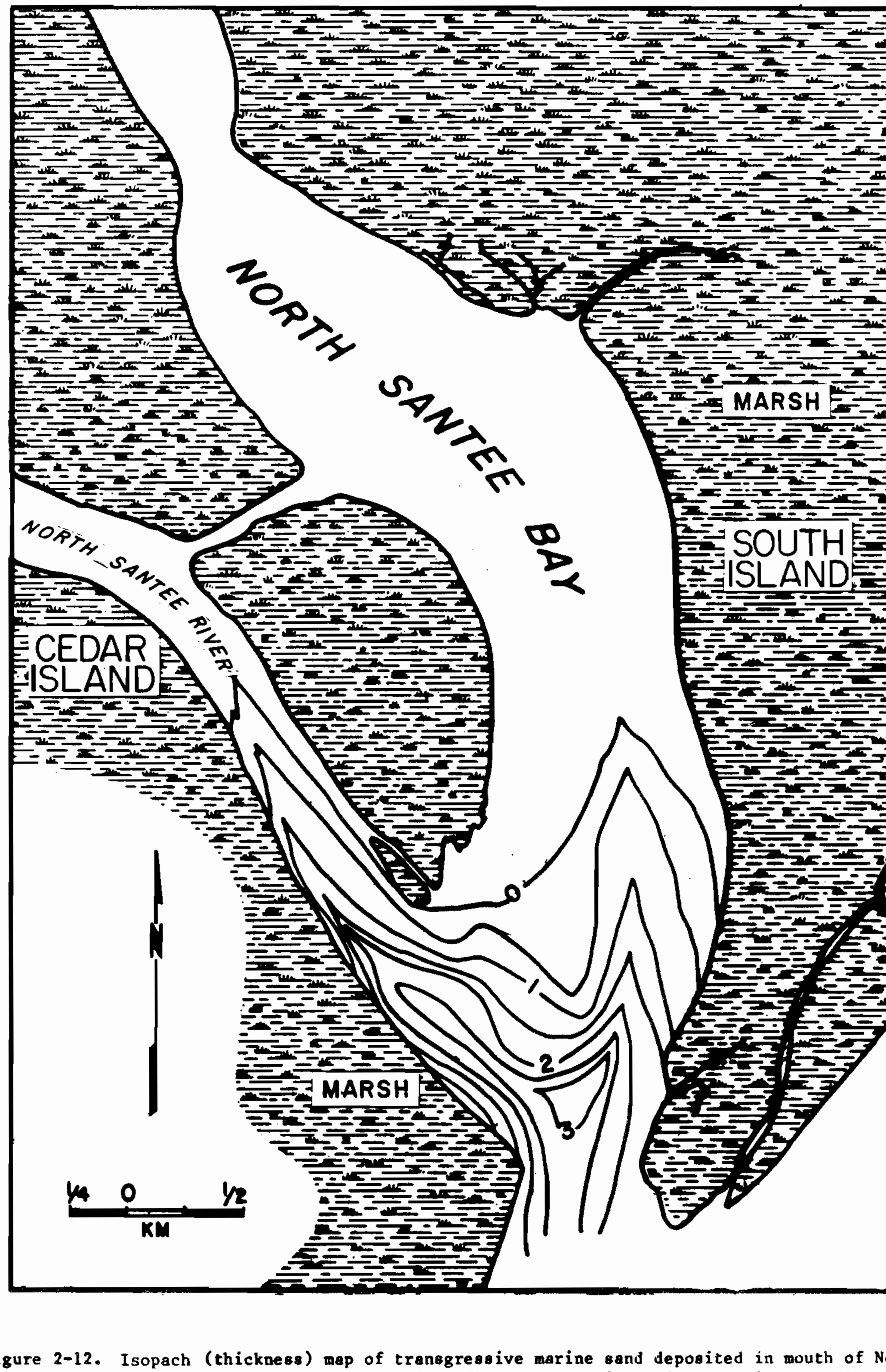


Figure 2-12. Isopach (thickness) map of transgressive marine sand deposited in mouth of North Santee River after the diversion of the Santee River discharge into Charleston Harbor (Mullin 1973). Isopach lines are in meter.

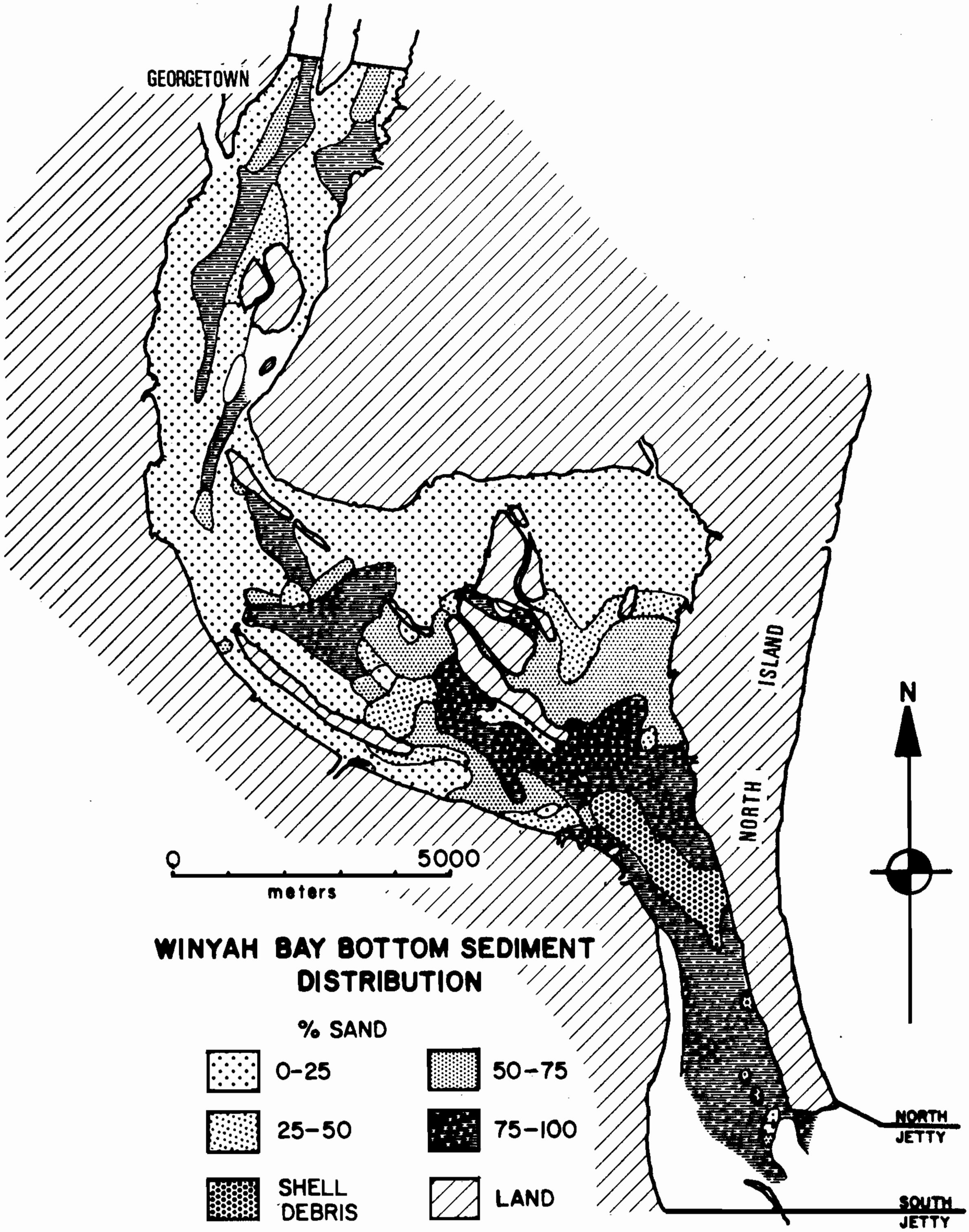


Figure 2-13. Bottom sediments of Winyah Bay (adapted from Colquhoun 1973).

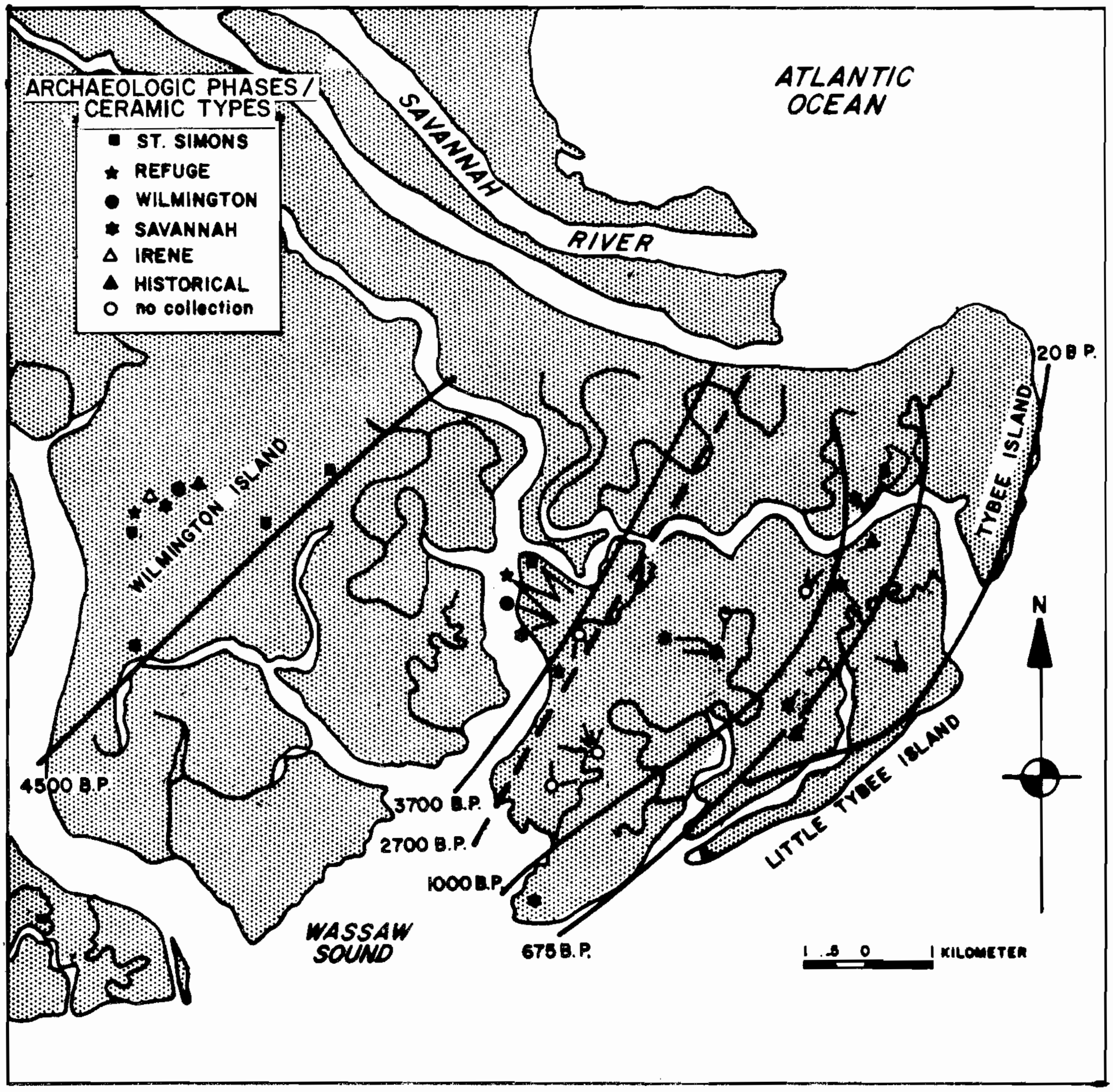


Figure 2-14. Aboriginal occupation sites and Holocene shoreline development, Chatham County, Georgia (DePratter and Howard 1977). The solid and dashed lines are dated shorelines. The archaeologic ceramic types are listed in descending order from oldest to youngest. (B.P.-1 fore Present.)

of Holocene-age colonial worm reefs (Dodecaceria sp.) immediately offshore of Edingsville Beach (central Edisto Island) in waters 2 to 3 m (6.5 to 10.0 ft) deep. Preliminary radiometric determinations indicate that these reefs began forming 4,000 years ago and continued to colonize exposed Pleistocene bedrock (lithified, calcareous beds) up until 600 years ago.

5. Snuggedy Swamp, Colleton County

The Holocene peat deposit at Snuggedy Swamp, Colleton County, South Carolina, has been extensively studied by Staub (1977) and Staub and Cohen (1978, 1979). They determined that this peat, up to 4.5 m (14.8 ft) thick and presently being commercially exploited, began forming approximately 4,000 years ago. This freshwater peat rests on a sequence of silty and clayey saltmarsh deposits (Fig. 2-15).

III. REGIONAL STRUCTURAL GEOLOGY

A. MAJOR STRUCTURAL FEATURES

The three major geologic structures present in and without the Sea Island Coastal Region are the 1) Southeast Georgia Embayment, 2) Cape Fear Arch, and 3) Peninsular Arch-Central Georgia Uplift (Fig. 2-16). The Southeast Georgia Embayment is a depression, plunging gently seaward or to the east and/or southeast, having a basement of Mesozoic and Tertiary sedimentary rocks. Approximately 1,500 m (4,900 ft) of sedimentary rock (mostly limestone) overlie this basement in coastal Georgia (Atlas plate 21). Downwarping began during middle Eocene (Claiborn) time and continued intermittently up through the Miocene (Herrick and Vorhis 1963).

To the southwest of the Southeast Georgia Embayment lies the Peninsular Arch-Central Georgia Uplift which is the major positive tectonic feature in the Southeastern United States. This arch plunges both to the northwest where it terminates in the Central Georgia Uplift and to the southeast where it may become the Bahama Uplift. Early Paleozoic sedimentary rocks make up this arch, and although it is a prominent subsurface feature, it is not revealed by gravity or magnetic data. This uplift was active during the Paleozoic and Mesozoic and perhaps, as Cramer (1974) suggests, the early Cenozoic. Cenozoic tectonism took place along an axis, the Ocala Uplift, located to the southwest of this structure's major trend. Approximately 1,200 m (3,940 ft) of Mesozoic and Tertiary sedimentary rock overlie the crest of the Peninsular Arch-Central Georgia Uplift (Atlas plate 21).

The Cape Fear Arch is an asymmetrical uplift plunging to the southeast. The southwestern limb dips more gently toward the Southeast Georgia Embayment than does the northeastern limb toward the Hatteras Embayment. Seismic refraction data of Meyer (1956) and Hersey et al. (1959) suggest a seaward extension of the Cape Fear Arch across the continental shelf and the Blake Plateau. Approximately 470 m (1,540 ft) of Mesozoic and Cenozoic sediments overlie this arch along its crest at the North Carolina/South Carolina border. The Cape Fear Arch was tectonically active during the Tertiary and into the Quaternary as Winker and Howard (1977) determined by the presence of tectonically deformed Pleistocene shorelines.

Seismic studies by Meyer (1956) identified an uplift of pre-cretaceous basement parallel to the present coast located along the northern flank of the Southeast Georgia Embayment (Fig. 2-16). This Yamacraw Uplift appears to intersect near Charleston with a north-south trending crystalline basement (igneous and metamorphic rocks) structure also identified by Meyer (1956). Cramer (1969) stated that it is not known whether the Yamacraw Uplift is pre-Cretaceous, Cretaceous, or both.

B. MINOR STRUCTURAL FEATURES

Minor structural features affecting only Tertiary rocks of the Southeast Georgia Embayment (Fig. 2-16) have been identified in Beaufort and Jasper counties, South Carolina. Siple (1965) mapped a structural dome on the Eocene-Miocene limestone units in the Beaufort-St. Helena Sound region and called it the Burton High. Herron and Johnson (1966) mapped a structural arch (the Beaufort High) on the middle Eocene Santee Formation in the same area. This arch dips westward into the northeast-southwest trending Ridgeland Basin. Colquhoun and Comer (1973) found an east-west trending arch near Charleston, South Carolina, affecting the upper Oligocene Cooper Formation and possibly the Santee Formation, which they named the Stono Arch. They suggest that this structure is probably related to a basement fault.

C. GEOPHYSICS

1. Bouguer Gravity Anomalies

Regional gravity and magnetic data, presented in the form of anomaly maps, are used to infer structural and lithologic properties of the buried crystalline basement. Simple Bouguer gravity anomaly maps (differences in the earth's gravitational acceleration corrected for latitude and elevation) of the Sea Island Coastal Region (Atlas plate 23A) indicate

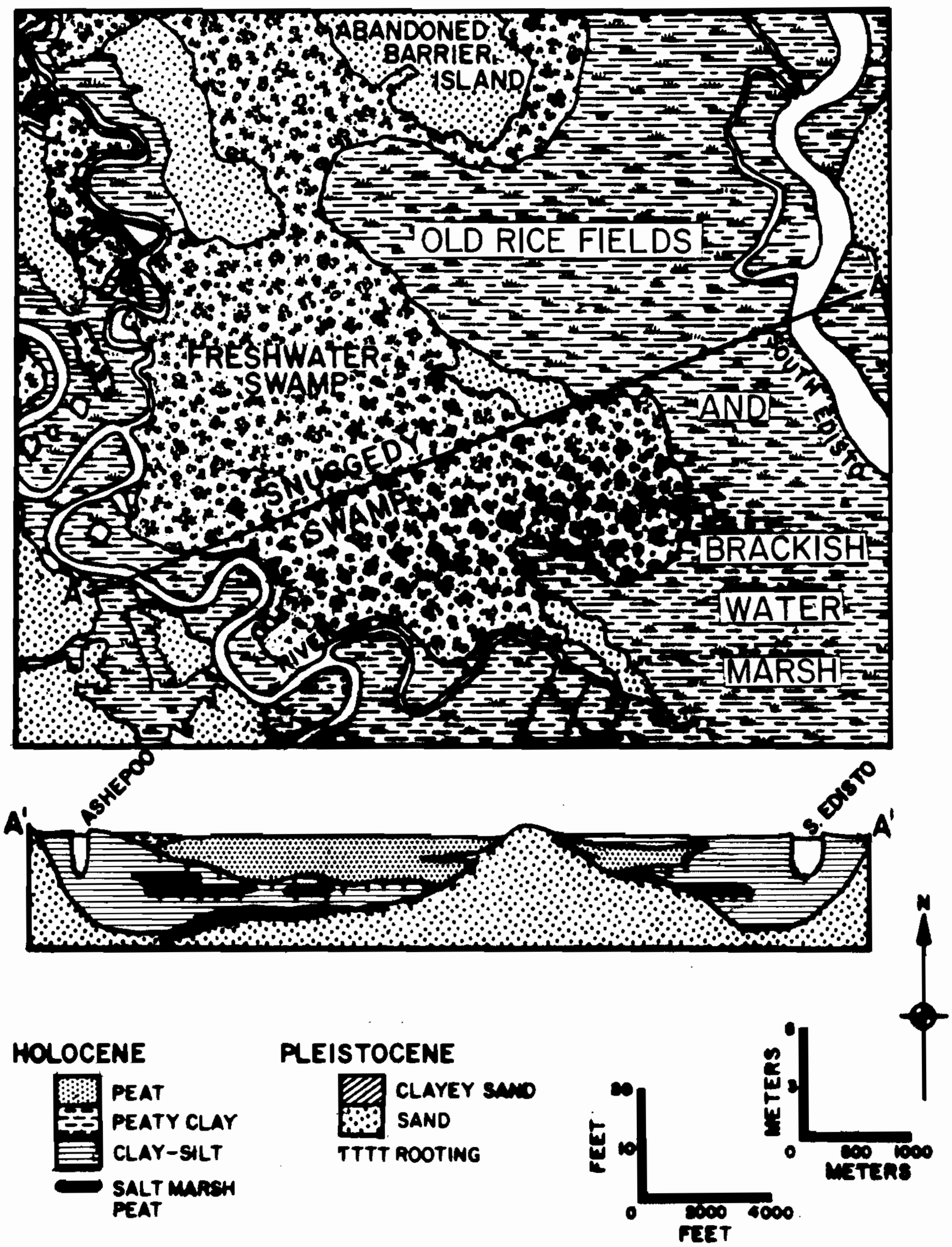


Figure 2-15. Stratigraphy of the Snuggedy Swamp peat deposit, Colleton County, South Carolina (Staub 1977).

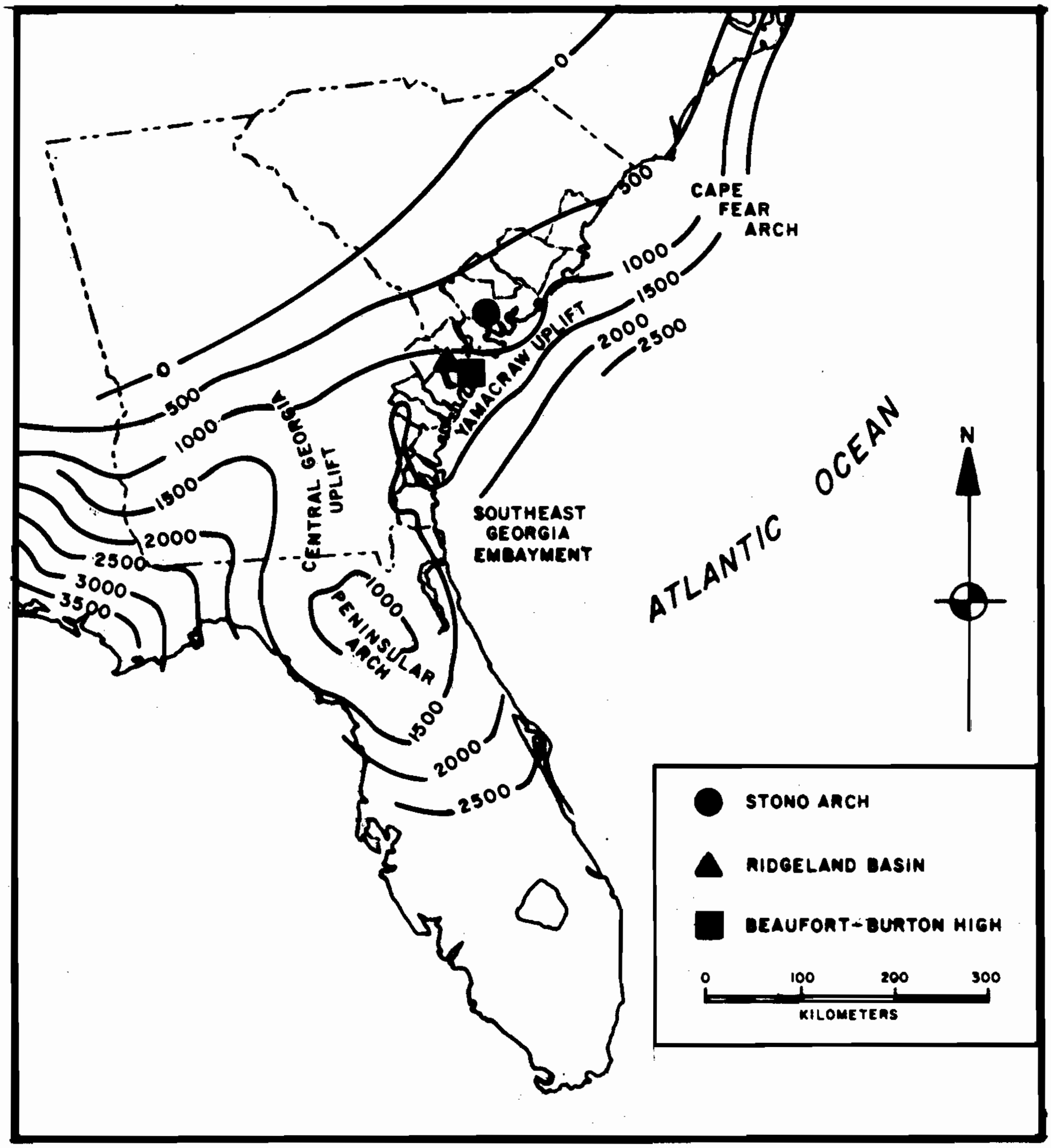


Figure 2-16. Major tectonic elements of the Southeastern United States and minor tectonic features affecting the northern flank of Southeast Georgia Embayment. Structure contours are drawn on the top of the pre-Cretaceous basement with elevations in meters below sea level (adapted from Popenoe and Zietz 1977).

the presence of local positive and negative anomalies, 5 - 50 km (3.1 - 31.1 mi) in dimension, caused by major geologic structures in the upper 10 - 20 km (6.2 - 12.4 mi) of the earth's crust (Long et al. 1972, Talwani et al. 1975). These negative simple Bouguer anomalies could indicate the existence of sedimentary rock basins depressed into more dense surrounding igneous and metamorphic rock; positive anomalies, on the other hand, could indicate intrusions of more dense igneous rock into less dense surrounding sedimentary rock. The negative anomalies of -30 milligal near Georgetown, South Carolina, and offshore of Charleston, South Carolina, are probably small sedimentary basins (possibly Triassic in age). The broader, less intense negative anomaly of -20 milligal in northern coastal Georgia probably reflects granitic crystalline bedrock beneath the Southeast Georgia Embayment. The positive anomalies of +70 milligal offshore of Georgetown, South Carolina, and of +50 and +40 milligal in south central Georgia probably indicate volcanic plugs (igneous rock) within the crystalline basement.

2. Geomagnetic Anomalies

The regional gravity and magnetic anomalies of the Sea Island Coastal Region are distinct from those of the Appalachian Piedmont. This implies that the underlying crystalline basement is not a simple continuation/extension of the Appalachians (Popenoe and Zietz 1977). Aeromagnetic surveys of the eastern United States by the U.S. Naval Oceanographic Office between 1964 and 1966 (Taylor et al. 1968) identified a major magnetic anomaly running along the continental slope and turning westward at the 31st parallel to cross the Georgia coast near Brunswick (Atlas plate 23B). These workers conclude that this anomaly represents a felsite igneous body intruded along the eastern border of the pre-Paleozoic North American landmass. This magnetic anomaly coincides with the east-west trending positive simple Bouguer gravity anomaly in southeastern Georgia. In addition, these magnetic data suggest 1) that a granite crystalline basement in northern coastal Georgia, in agreement with the negative simple Bouguer gravity anomaly and 2) that the isolated, positive magnetic anomalies near Georgetown and Charleston, South Carolina, associated with positive simple Bouguer anomalies, are indeed dense volcanic plugs, dikes, or sills.

D. SEISMICITY

There are no known major faults or even surface exposures of minor ones within the Sea Island Coastal Region. However, Pleistocene and Holocene tectonism has affected and continues to affect this tectonically quiet geologic province. Winker and Howard (1977) have demonstrated tectonic deformation of Pleistocene shoreline deposits, even of the youngest Effingham and Chatham sequences (Fig. 2-I). Uplift of the Cape Fear Arch is probably responsible for their deformation. In 1886, Charleston, South Carolina, experienced a major earthquake whose epicenters were centered in and about Summerville, South Carolina (Figs. 2-17 and 2-18). At the present time the geologic feature responsible for this earthquake of X magnitude on the modified Mercalli scale is unknown. A description of the modified Mercalli intensity scale and its correlation with the Richter magnitude scale is presented in Table 2-3.

In their analysis of the Charleston area gravity data, Long and Champion (1977) identify a northeast-southwest trending fault between Summerville and Charleston (Fig. 2-19). This fault affects the crystalline basement rocks and may serve as the northwest boundary of the deep sedimentary basin, inferred from gravity data, beneath the Charleston area. In addition, they identify an igneous rock intrusion, oriented east-west, located between Summerville and Charleston. Reactivation of this basement fault is a possible cause of the 1886 and subsequent earthquakes, but fracturing of the igneous intrusive mass is the more probable mechanism (Long and Champion 1977, Rankin 1977). Regional stress is concentrated on the peripheries of these intrusive igneous bodies. The release of this stress by fracturing produces the earthquakes. Significant earthquakes occurring in other essentially stable regions as Cape Ann, Massachusetts; New Madrid, Missouri; Attica and Massena, New York; Baie St. Paul, Quebec; and Anna, Ohio, are associated with positive gravity anomalies inferred to represent igneous intrusive bodies (Kane 1977).

E. HISTORIC SEALEVEL CHANGES

Measurements of sealevel position (Hicks 1973) at Charleston, Savannah River Entrance, and Fernandina Beach, Florida, (St. Marys River) indicate a net rise since monitoring began in the early 1920's (Fig. 2-20). Of course, land subsidence cannot be distinguised from net sealevel rise in data obtained at these mareograph or tide gauging stations. Estimates of the net sealevel rise attributed solely to true or eustatic sealevel events center around 1 mm (0.04 in) per year (Fairbridge 1961); thus, measurements made from the Sea Island Coastal Region may reflect a component of land subsidence as well.

Table 2-3. Description of the modified Mercalli intensity scale for earthquakes and its correlation with the Richter magnitude scale (Holmes 1965).

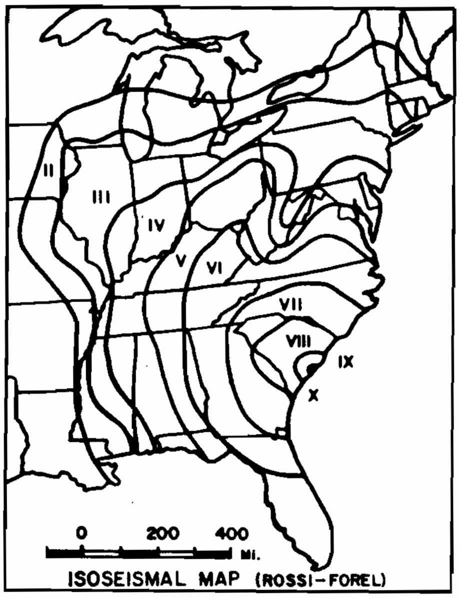
Modified Mercalli Intensity Scale	Description of Characteristic Effects	Maximum Acceleration of the Ground in cm/s^2	Richter Scale Magnitude Corresponding to Highest Mercalli Intensity Scale Reached
I	INSTRUMENTAL: detected only by seismographs	1	3.5
II	FEEBLE: noticed only by sensitive people	2.5	to
III	SLIGHT: like the vibrations due to a passing lorry; felt by people at rest, especially on upper floors	5	4.2
IV	MODERATE: felt by people while walking; rocking of loose objects, including standing vehicles	10	4.3
V	RATHER STRONG: felt generally; most sleepers are wakened and bells ring	25	to 4.8
VI	STRONG: trees sway and all suspended objects swing; damage by overturning and falling of loose objects	50	4.9-5.4
VII	VERY STRONG: general alarm; walls crack; plaster falls	100	5.5-6.1
VIII	DESTRUCTIVE: car drivers seriously disturbed; masonry fissured; chimneys fall; poorly constructed buildings damaged	250	6.2 to 6.9

Table 2-3. Concluded

Modified Mercalli Intensity Scale	Description of Characteristic Effects	Maximum Acceleration of the Ground in cm/s^2	Richter Scale Magnitude Corresponding to Highest Mercalli Intensity Scale Reached
IX	RUINOUS:		
	some houses collapse where ground begins to crack, and pipes break open	500	6.2
			to
X	DISASTROUS:		6.9
	ground cracks badly; many buildings destroyed and railway lines bent; landslides on steep slopes	750	7-7.3
XI	VERY DISASTROUS:		
	few buildings remain standing; bridges destroyed; all services (railways, pipes and cables) out of action; great landslides and floods	980[a]	7.4-8.1
XII	CATASTROPHIC:		
	total destruction; objects thrown into air; ground rises and falls in waves	>980	>8.1 (maximum known, 8.9)

a. Acceleration of gravity is 980 cm/s^2.

CHARLESTON, S.C. EARTHQUAKE - AUGUST 31, 1886



INTENSITY SCALE

ROSSI-FOREL	X	IX+	VIII+ -IX-	VIII	VI- VII	V- VI	IV- V	III	I-II
MOD. MERCALLI	X	IX	VIII	VII	VI	V	IV	III	II

INTENSITY: X FELT AREA: 2 MILLION SQ. MILES

[1811 NEW MADRID EQ.: XII, 2 MILLION SQ. MI.
1906 SAN FRANCISCO EQ.: XI, 375,000 SQ. MI.]

DEATHS: ~ 60 DAMAGE: ~ $5 MILLION

EPICENTRAL EFFECTS

- GROUND FISSURES, AND CRATERLETS
- WATER, SAND, AND MUD FOUNTAINS
- RAILROAD RAILS BENT, TRACKS DISPLACED
- LOUD EARTHQUAKE SOUNDS
- EARTH AND WATER WAVES
- SULFUR GAS RELEASED

UNUSUAL ASPECTS

- REGION ESSENTIALLY FREE OF SHOCKS FOR PRECEDING 200 YRS.
- LARGE FELT AREA
- DUAL EPICENTRAL POINTS
- WEST VIRGINIA LOW INTENSITY

Figure 2-17. Isoseismal map and general description of the 1886 Charleston earthquake (adapted from Bollinger 1972).

IV. ECONOMIC MINERAL DEPOSITS

A. PHOSPHORITE (PHOSPHATE ORE)

The mining of phosphorite or phosphate ore began in the Charleston, South Carolina, region in 1867 and continued up to 1938 (Malde 1959). Two main deposits were mined: 1) land rock, consisting of phosphate nodules, pebbles, and fossils in a matrix of unconsolidated sand or localized, irregular masses of phosphatized limestone and 2) river rock, consisting of phosphate-rich pebble gravels in present stream beds. The land rock was strip mined from various Pleistocene deposits, e.g., the Ladson Formation (Malde 1959), and the river rock was dredged from the Wando, Stono, and Coosaw rivers (Fig. 2-21). Some local processing of phosphorite ore into fertilizer was done at Charleston along the Ashley River. South Carolina phosphate rock production data are presented in Table 2-4.

Phosphorite deposits also occur in coastal Georgia although none has been commercially exploited to date. The recent discovery of a major deposit in eastern Chatham County within the Hawthorn Formation (Georgia Institute of Technology and Georgia Department of Mines, Mining and Geology 1968) has sparked renewed mining interest in the Chatham-Jasper-Beaufort area. Commercial grade deposits are located beneath Little Tybee Island at depths of 70 - 160 ft (21.3 - 48.8 m). The Hawthorn Formation underlies all of the Georgia Sea Island Coastal Region, but only in Chatham and Effingham counties is it within 200 ft (61 m) or strip-mineable distance of the surface (Georgia Department of Mines, Mining and Geology 1969).

B. LIMESTONE

The Santee Formation is quarried for cement, agricultural lime, and road metal in Georgetown, Berkeley, and Dorchester counties, South Carolina. These quarries or open pits are kept dry only by constant pumping. As the Santee Formation is a major aquifer, this pumping has caused local wells to go dry in the immediate vicinity of certain pits

Table 2-4. Phosphate rock, in long tons, sold and mined in South Carolina (Malde 1959).

Year	Amount Sold: Land rock (Pleistocene deposits)	Amount Sold: River rock (Recent deposits)	Total	Amount mined[a]
Ending 31 May:				
1867	6	-	6	-
1868	12,262	-	12,262	-
1869	31,958	-	31,958	-
1870	63,252	1,989	65,241	-
1871	56,533	17,655	74,188	-
1872	36,258	22,502	58,760	-
1873	33,426	45,777	79,203	-
1874	51,624	57,716	109,340	-
1875	54,821	67,969	122,790	-
1876	50,566	81,912	132,478	-
1877	36,431	126,569	163,000	-
1878	112,622	97,700	210,322	-
1879	100,779	98,586	199,365	-
1880	125,601	65,162	190,763	-
1881	142,193	124,541	266,732	-
1882	191,305	140,772	332,077	-
1883	219,202	159,178	378,380	-
1884	250,297	181,482	431,779	-
1885	225,913	169,490	395,403	-
Ending 31 December:				
1885	149,400	128,389	277,789	-
1886	253,484	177,065	430,549	-
1887	261,658	218,900	480,558	-
1888	290,689	157,878	448,567	-
1889	329,543	212,102	541,645	-
1890	353,757	110,241	463,998	-
1891	344,978	130,528	475,506	-
1892	243,652	150,575	394,228	-
1893	308,435	194,129	502,564	-
1894	307,305	142,803	450,108	-
1895	270,560	161,415	431,975	-
1896	267,072	135,351	402,423	-
1897	267,380	90,900	358,280	-
1898	298,610	101,274	399,884	-
1899	223,949	132,701	356,650	-
1900	266,186	62,987	329,173	-
1901	225,189	95,992	321,181	-
1902	245,243	68,122	313,365	-
1903	233,540	25,000	258,540	-
1904	258,806	12,000	270,806	-
1905	234,676	35,549	270,225	-
1906	190,180	33,495	223,675	-
1907	228,354	28,867	257,221	-
1908	192,263	33,232	225,495	-
1909	201,254	6,700	207,954	-
1910	179,659[b]	c	179,659	-
1911	169,156	-	169,156	-
1912	131,490	-	131,490	-
1913	109,333	-	109,333	-
1914	106,919	-	106,919	-
1915	83,460	-	83,460	-
1916	53,047	-	53,047	39,035
1917	33,485	-	33,485	45,541
1918	37,040	-	37,040	33,673
1919	60,823	-	60,823	49,032
1920	44,141	-	44,141	42,709
1921	-	-	-	-
1922	1,500[d]	-	1,500	-
1923-24	-	-	-	-
1925	2,147	-	2,147	2,147
1926-37	-	-	-	-
1938	100	-	100	100

a. No records kept 1867 - 1915.
b. Includes a small amount of river rock.
c. Included in land rock.
d. Sold from stocks of previous years.

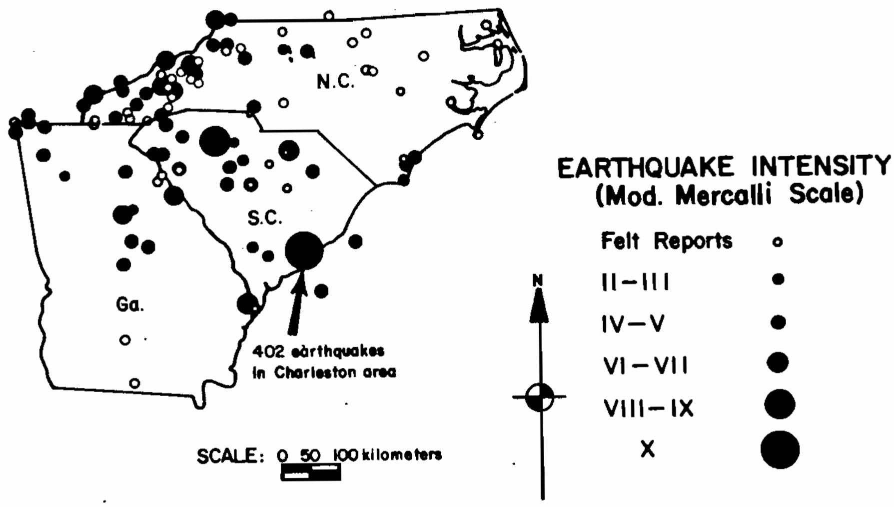


Figure 2-18. Seismicity of South Carolina and Georgia (Bollinger 1972).

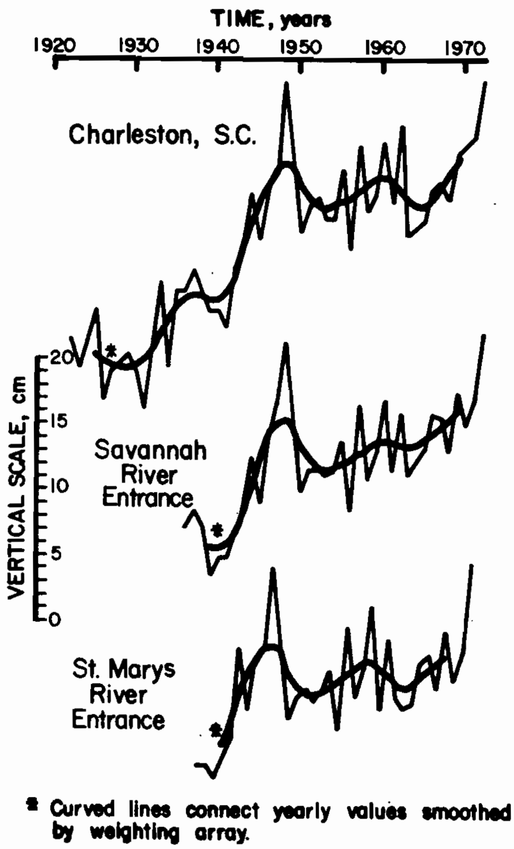


Figure 2-20. Sealevel curves for Charleston, Savannah River Entrance, and St. Marys River Entrance measured by continuous recording tide gauges (Hicks 1973).

(Spigner 1978). Mined material is transported to Charleston and other areas primarily for construction and agricultural purposes. In the Harleyville-Holly Hill region of South Carolina, it is locally converted into Portland cement. This resource is economically very significant since cement production from the Santee Formation ranks first in value of all minerals produced in South Carolina (Sheffer 1974). However, detailed production figures for counties in the Sea Island Coastal Region are not available to the public (Sheffer 1974).

C. SAND

Pleistocene sand deposits are excavated near Charleston and Savannah and along the major highways for road metal, land fill, and construction purposes. Most of these operations are small in scale and operate for relatively short periods of time; detailed production data are not presently available for the Sea Island Coastal Region.

D. PEAT

Peat is mined from Snuggedy Swamp, Colleton County, South Carolina, and sold for use in general soil improvement. Today the U.S. Peat Corporation has 2,200 acres (890 ha) under lease and actively dredges and reclaims 10 acres yr (4.1 ha/yr). Production data for this operation from 1973 to 1977 are given below:

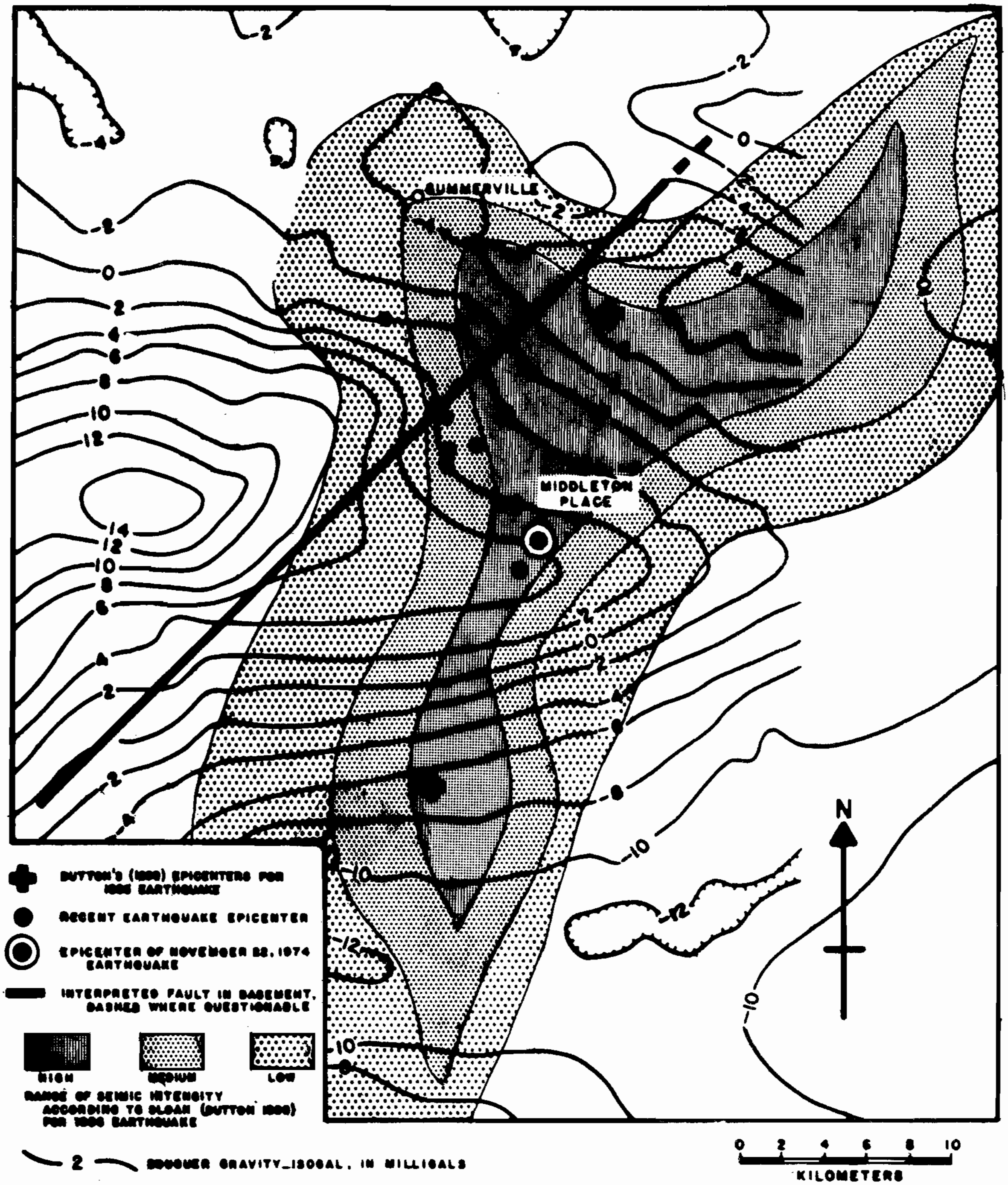


Figure 2-19. Detailed Bouguer gravity map of the Summerville, South Carolina, region encompassing the 1886 Charleston earthquake epicenters (adapted from Long and Champion 1977). The basement fault is one possible cause of the 1886 and subsequent earthquakes.

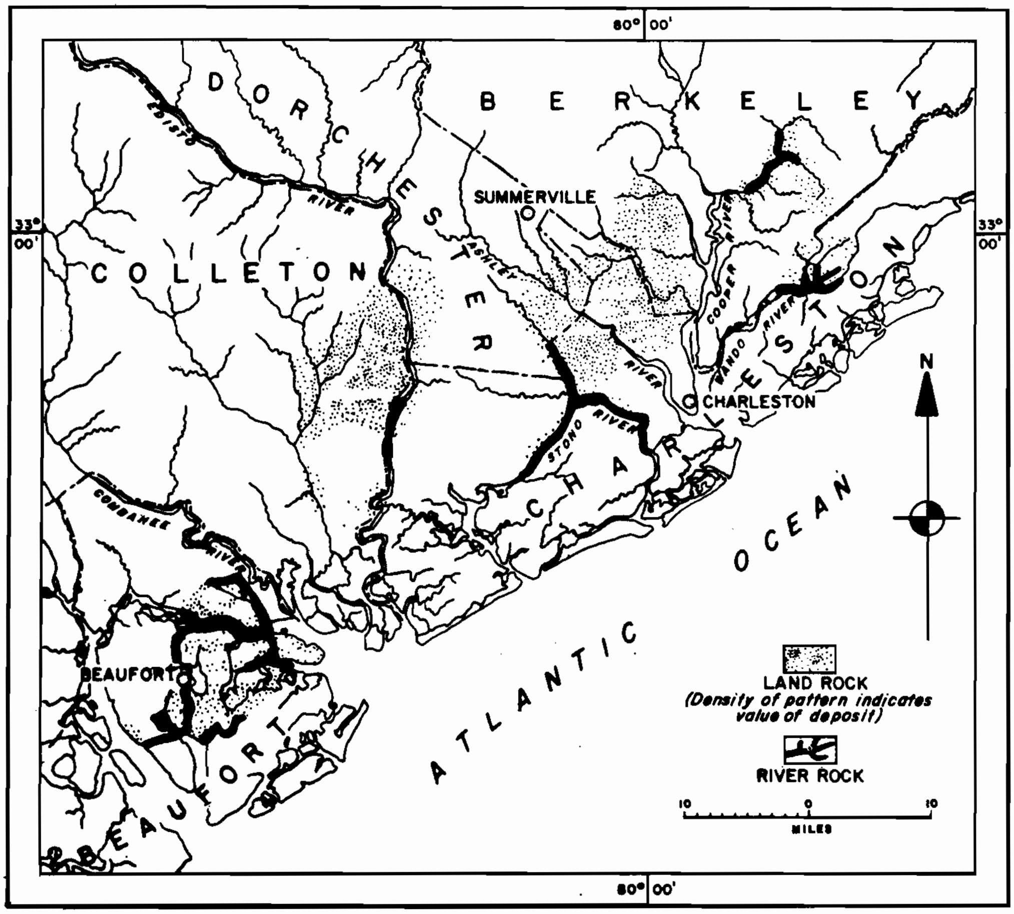


Figure 2-21. Map showing the approximate original distribution of phosphorite deposits in South Carolina (Rogers 1914).

YEAR	SHORT TON
1973	14,000
1974	18,000
1975	12,000
1976	12,000
1977	14,000

This deposit's geology (Fig. 2-15) has been described in some detail by Staub (1977). (See Holocene Stratigraphy for additional information on the geology of this deposit.)

V. GROUNDWATER

Groundwater may well be the most important natural economic rescource of the Sea Island Coastal Region. Abundant quantities of high quality water are available from various aquifers (Atlas plate 20). Information regarding withdrawals, water quality, number of wells, etc. is largely restricted to the deeper aquifers although the shallow or surface aquifers are utilized extensively.

A. PRINCIPAL ARTESIAN AQUIFER

Limestones of upper and middle Eocene age (Santee Formation and the Ocala Group) comprise the Principal Artesian Aquifer of coastal Georgia and southeastern South Carolina. In Florida this aquifer is known as the Floridian Aquifer. The Principal Artesian Aquifer, as the name implies, is under a confining pressure or head such that water in wells rises above the upper surface of the aquifer (Fig. 2-22). Throughout much of the Georgia Sea Island Coastal Region this original head was so great that wells were free flowing at the surface. Extensive utilization of this aquifer has resulted in a continuous decline in head, with marked cones of depression near major well fields at Savannah, Brunswick, and

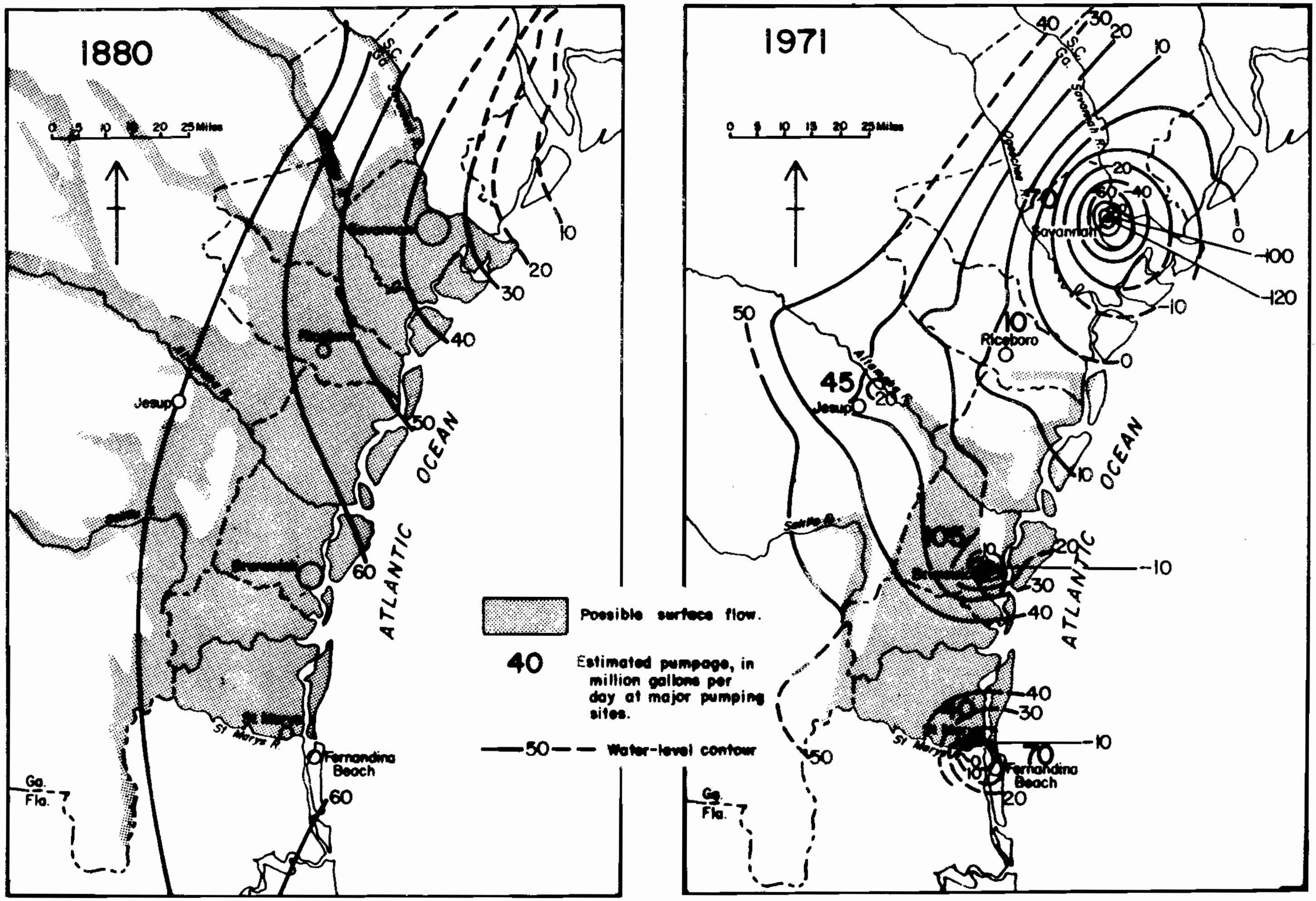


Figure 2-22. Potentiometric (water-level) map of the Principal Artesian Aquifer in coastal Georgia and extreme southeastern South Carolina in 1880 and 1971 (adapted from McCollum and Counts 1964, Krause and Gregg 1972). The datum for the water-level contours is mean sea level; these contours represent the distance in feet above mean sea level that water would rise in wells.

St. Marys, Georgia (Fig. 2-22). The recharge area of the Principal Artesian Aquifer is located in the upper coastal plain beyond the limits of the Sea Island Coastal Region (Fig. 2-23).

B. MESOZOIC SANDSTONE AQUIFERS

Aquifers other than the Principal Artesian Aquifer are exploited in South Carolina. Sandstones within the Cretaceous Tuscaloosa and Black Creek Formation serve as the primary artesian aquifers (Fig. 2-23) in coastal South Carolina (Siple 1975, Spigner et al. 1977, Hayes 1977). The water quality is variable (Fig. 2-24) with certain aquifers suitable for municipal drinking purposes (e.g., the Black Creek Aquifer at Mt. Pleasant, South Carolina), and others only for agricultural purposes (e.g., the Tuscaloosa Aquifer is used to supply water for golf courses). The recharge area of these aquifers is the upper coastal plain, beyond the limits of the Sea Island Coastal Region, and the presence of ancient saline formation waters within them indicates that they have not as yet been uniformly flushed with fresh groundwater.

C. SALTWATER ENCROACHMENT

Saline water encroachment upon the potable water-producing zones of the Principal Artesian Aquifer has been observed in the Hilton Head-Port Royal Sound Region of Beaufort County, South Carolina, and at Brunswick, Georgia. This encroachment results from 1) present-day ocean water entering the aquifer, and/or 2) ancient saline formation water, trapped during deposition of the sedimentary rocks and unflushed by fresh groundwater entering from adjacent aquifers. Using geochemical and isotopic analyses of the saline waters, Back et al. (1970) concluded that present day ocean water is entering the Principal Artesian Aquifer under Port Royal Sound and is moving towards the cone of depression at Savannah (Fig. 2-25). This rate of movement, assuming current pumping levels remain constant, is such that salt water in the upper zones of the Principal Artesian Aquifer should reach Savannah in 400 years and in the lower zones in 90 years (McCollum and Counts 1964). At Brunswick, Georgia, however, Stewart (1960), Wait (1962), and Hanshaw et al. (1965) concluded from geochemical and isotopic evidence that the encroaching saline waters came from deeper aquifers and not the present-day ocean. The presence of ancient saline formation waters in adjacent aquifers (Siple 1967) further complicates the problem of saltwater encroachment (Figs. 2-26 and 2-27). This encroachment can take place anywhere hydrodynamic conditions favor the migration of water from adjacent aquifers into potable water-producing aquifers and not just immediatley along the coast.

D. ECONOMIC VALUE

The economic value of the groundwater resource may be estimated from the present 341.2 million gal/day pumping rate (Park 1979) over the Sea Island Coastal Region (Atlas plate 20). Using a cost figure of $0.13/1000 gal (B. C. Spigner, 1979,

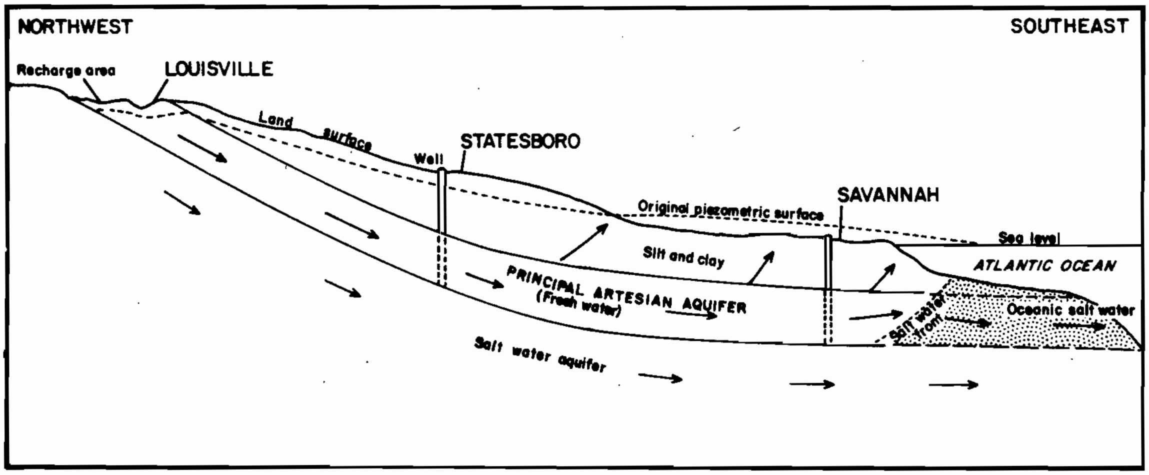


Figure 2-23. Diagrammatic cross section of the Principal Artesian Aquifer from its recharge region to the Georgia coast (adapted from Counts and Donsky 1963).

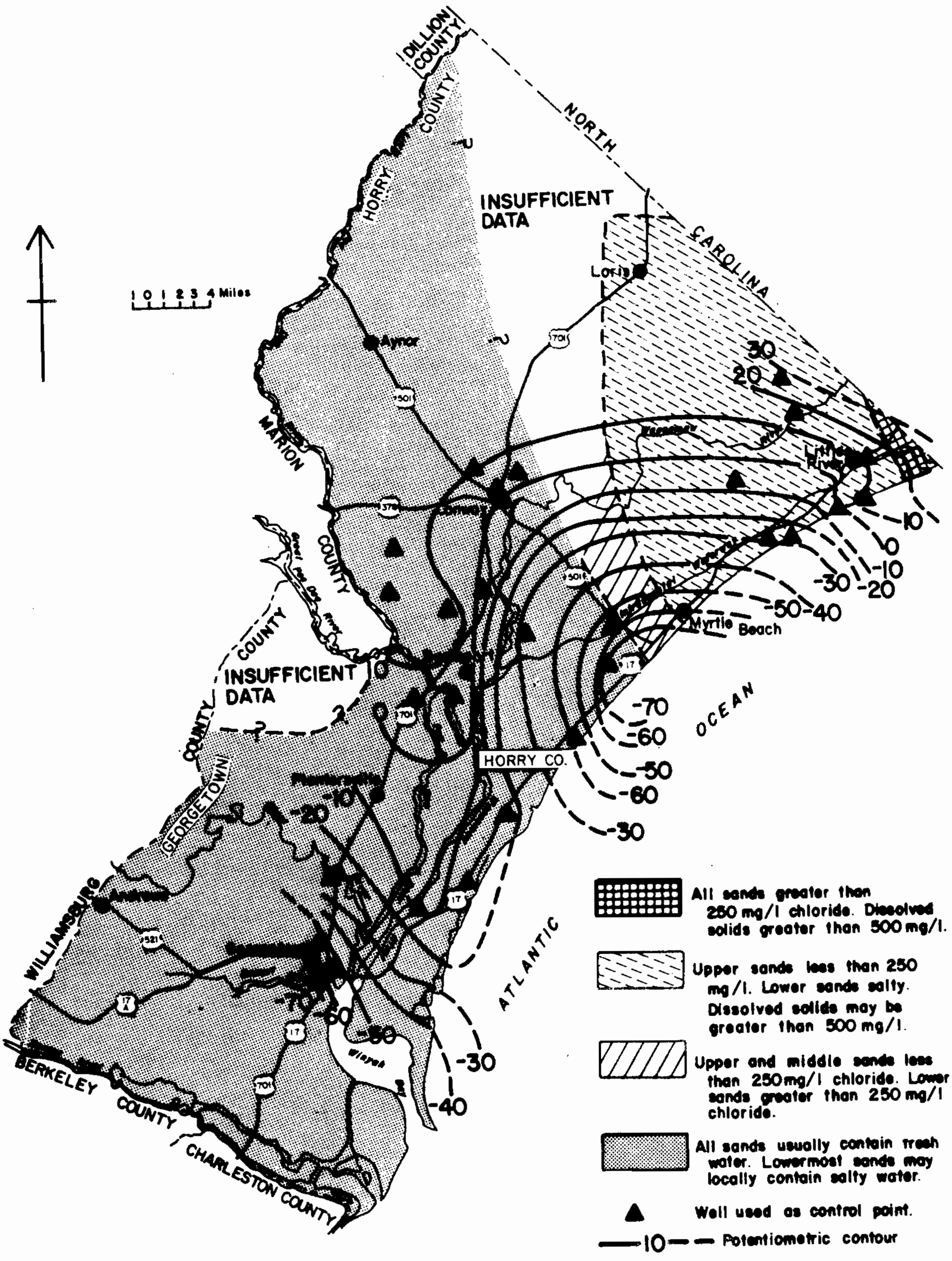


Figure 2-24. Potentiometric and water quality map of major sands in the Cretaceous Black Creek Aquifer system in Horry and Georgetown counties (adapted from Spigner et al. 1977). The potentiometric contours represent the distance relative to mean sea level that water rises in wells.

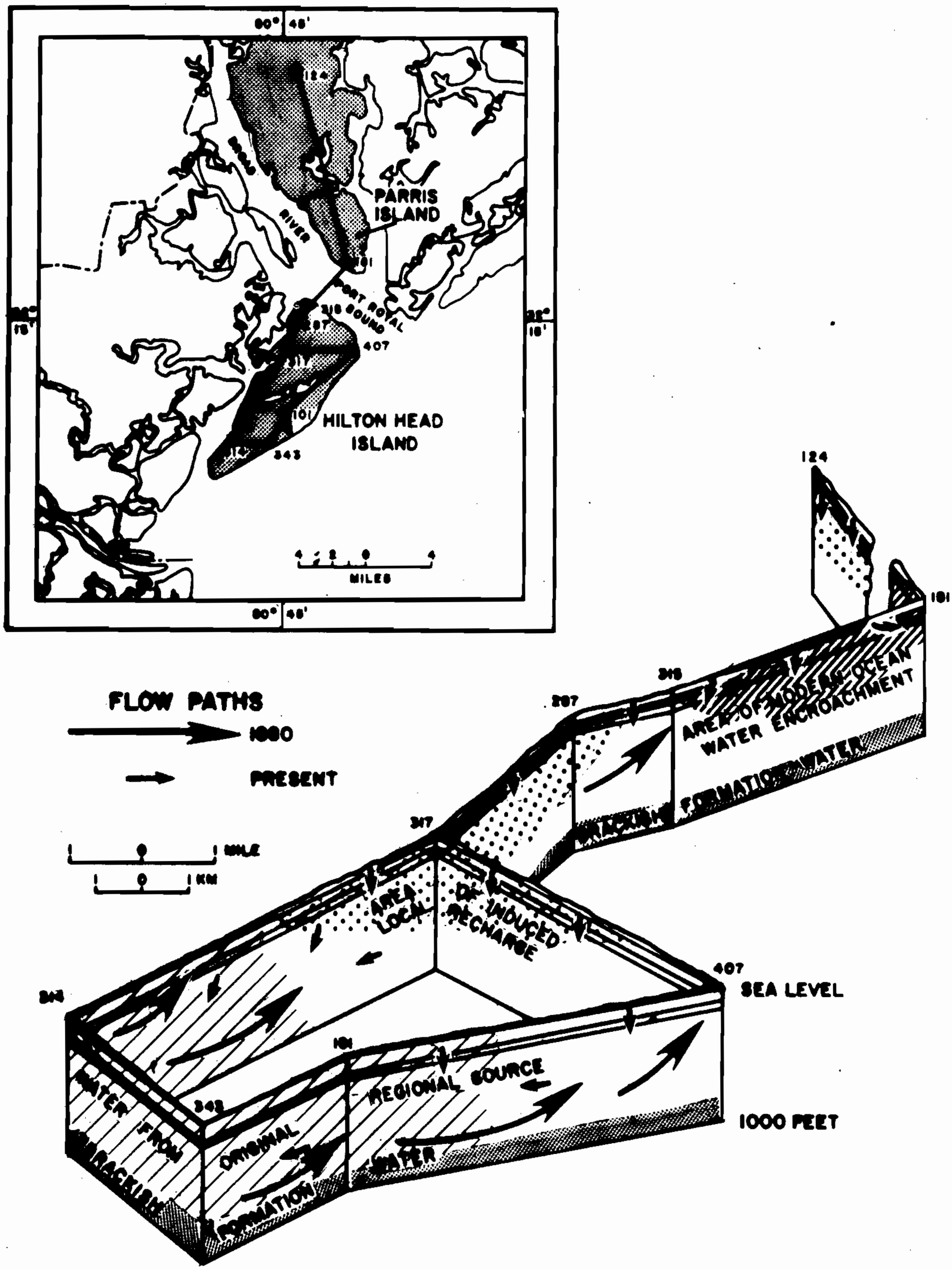


Figure 2-25. Groundwater movement within the Principal Artesian Aquifer in the Hilton Head-Port Royal Sound region of Beaufort County, South Carolina (adapted from Back et al. 1970). The reversal of flow direction, ocean-water intrusion beneath Port Royal Sound, and the freshwater recharge on Hilton Head are all considered to be direct results of the utilization of this aquifer at Savannah, Georgia, since 1880.

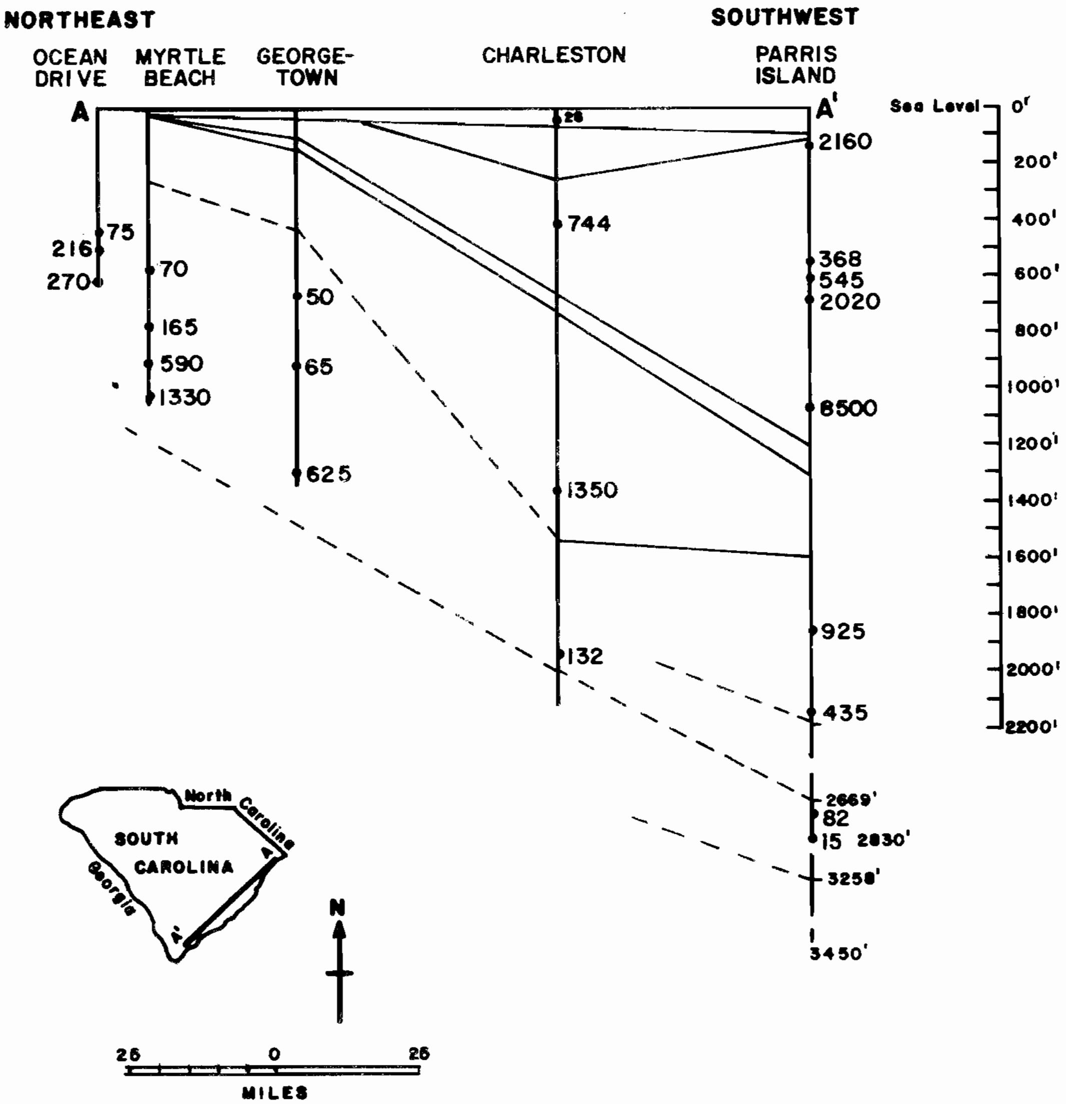


Figure 2-26. Quality of the groundwater in coastal South Carolina (adapted from Siple 1967). The salt waters present are primarily ancient, unflushed formation waters and not recently intruded, present-day ocean waters. Numbers refer to chloride concentration in parts per million.

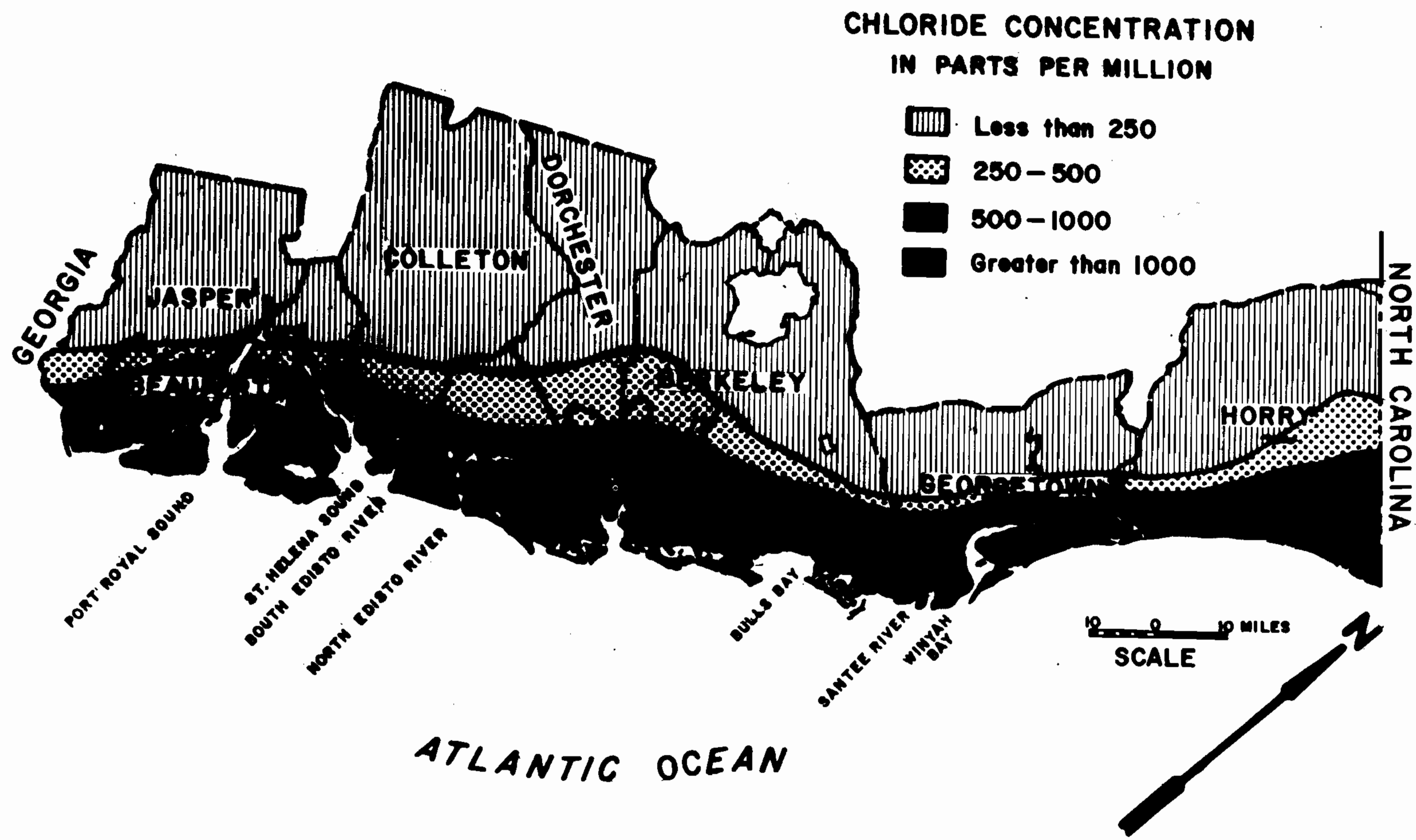


Figure 2-27. Chloride concentration of the groundwater in coastal South Carolina (adapted from Siple 1967).

South Carolina Water Resources Commission, Columbia, pers. comm.) the annual value of this resource is $16 million. This amount does not take into account the value of industrial production located in this region because of the abundant quantities of high quality groundwater or the potential cost to municipalities for alternate water supplies if potable groundwater were not available. Surface water utilization, according to Park (1979), is 778 million gal/day over the Sea Island Coastal Region (Atlas plate 20A).

E. MANAGEMENT

The Georgia Environmental Protection Division has formulated its management plans for groundwater management from data supplied by the Georgia Geological Survey Branch and the United States Geological Survey. The Georgia Groundwater Use Act of 1972 was amended in 1973 to eliminate capacity use areas and to require all groundwater users withdrawing more than 100,000 gal/day (except for agriculture and poultry processing) to obtain a permit.

Management activities in South Carolina have been conducted primarily through technical assistance programs of the South Carolina Department of Health and Environmental Control (SCDHEC) and the South Carolina Water Resources Commission (SCWRC). Authority to manage groundwater quality is available to the SCDHEC through the South Carolina Groundwater Use Act of 1969. This Act allows the SCWRC to request designation of "capacity use areas" and require current and prospective users to obtain permits. No such area has been designated in South Carolina as yet, but one has been recommended for the Horry County and Georgetown County region (Spigner et al. 1977).

Park (1979) designated four levels of groundwater data for the Sea Island Coastal Region:

1) Field data: various file data exist but have not been completely field checked and verified for accuracy.

2) Reconnaissance: generalized groundwater studies have been completed and published or open-file reports are available.

3) Planning: the hydrology of aquifer systems and the relationship between hydro-geology and groundwater quality is known and described in published reports.

4) Management: a descriptive or computer analog model of all principal aquifer systems is available to describe the water balance, the surface water-groundwater relationship, and the man-made and natural stresses on hydrologic conditions and water quality.

Field data exist for Colleton and Jasper counties, South Carolina, and for Camden and Effingham counties, Georgia. Reconnaissance-level data exist for Beaufort County, South Carolina. Management-level data are available for Chatham, Bryan, Liberty, McIntosh, and Glynn counties, Georgia. These levels of groundwater data for the Sea Island Coastal Region are presented on Atlas plate 20F.

CHAPTER THREE

SOILS

I. INTRODUCTION

A knowledge of soils found within the Sea Island Coastal Region is important to sound land use planning and habitat evaluation. The physical and chemical properties of soils strongly influence the distribution of plants and animals within the region. The depth of the water table and drainage characteristics are particularly important in determining the value and vulnerability of Sea Island Coastal Region soils to potential uses by man.

A. SOIL STRUCTURE

Soil, when viewed in vertical section as on a cut bank or ditch, is composed of three distinct horizontal layers which often are discernible by differences in color. These layers are referred to as "horizons" (Fig. 3-1). The sequence of horizons from surface to unmodified parent material is referred to as the soil profile. The topsoil layer which is composed primarily of the remains of plants and animals undergoing humification is termed the A horizon. The A horizon can be subdivided into A_{01} (litter), A_{02} (duff), A_{03} (leaf mold), A_1 (humus), and A_2 (leached zone). Each of these subdivisions represents a stage of progressive humification increasing from A_{01} to A_2. Beneath the A horizon is the B horizon or zone of mineralization which is composed of mineral soil in which the organic compounds have been converted into inorganic compounds by decomposers, and mixed with finely divided parent material. The water soluble materials present in the B horizon frequently are formed in the A horizon and "leached" by the downward movement of water into the B horizon. Below the B horizon is the parent material or C horizon. The parent material of the C horizon may have been transported to its present site by gravity (colluvial deposit), water (alluvial deposit), glaciers (glacial deposit), wind (aeolian deposit or loess), or it may be an original mineral formation subjected to the soil-forming process (Odum 1971, Wilkes et al. 1974).

B. SOIL CLASSIFICATION

Many dozens of soil types occur within a given county as a result of variations in parent material, topography, and vegetative community. These types are called soil series. Each soil series name usually includes the geographical locality where the series was first described and an indication of the texture of soil, for example, "Pelham Loamy Sand." Soil series are sometimes grouped into "associations" which occur together in certain areas, such as the "Crevasse-Dawhoo" or "Lakeland-Chipley" associations.

Classification of soil types has become a highly complex and empirical subject, a detailed description of which is beyond the scope of this chapter. A detailed description of soil taxonomy can be found in Soil Taxonomy (U.S. Department of Agriculture, Soil Conservation Service 1975).

II. SOIL FORMATION

Biotic and abiotic components of soil are intimately related. Soil is an important environmental factor for the resident biota and is in turn influenced by them. Permanent differences in biotic communities are directly correlated with differences in soil series (Odum 1971). (See Volume III, Chapter Six, Upland Ecosystem for a discussion of soil fauna.) Soil is the net result of the actions of climate and organisms on the parent material of the earth's crust over time (Fig. 3-1).

Soils of the Sea Island Coastal Region are formed from materials that were deposited during the various stages of coastal submersion (Hoyt 1968). During each stage of submersion the formation of new lagoons, marshes, and barrier islands promoted sorting and mixing of the coastal deposits. As the sea retreated during the late Pleistocene, the soil forming processes began to develop the soils we observe today. The soils vary from sand-clay mixtures with distinct horizon development to soils of predominantly quartz sand with indistinct horizon development. (For a more detailed discussion of Pleistocene geologic history, see Chapter Two of this volume.)

The Sea Island Coastal Region is warm and humid with long hot summers and mild winters. Rainfall is abundant [45 - 50 in (17.7 - 19.7 cm) per year] and the soils are moist or saturated most of the year. This climate favors rapid decay of organic materials and minerals, solution of bases, and translocation of clays. Soils with high permeability are highly leached. Abundant rainfall increases leaching of cations like Mg^{++} and Ca^{++} from surface layers, replacing them with H^+ and increasing acidity (Wilkes et al. 1974).

Relief affects soil formation through influence on drainage, runoff, erosion, and percolation of water and air. Narrow ridges and slopes are

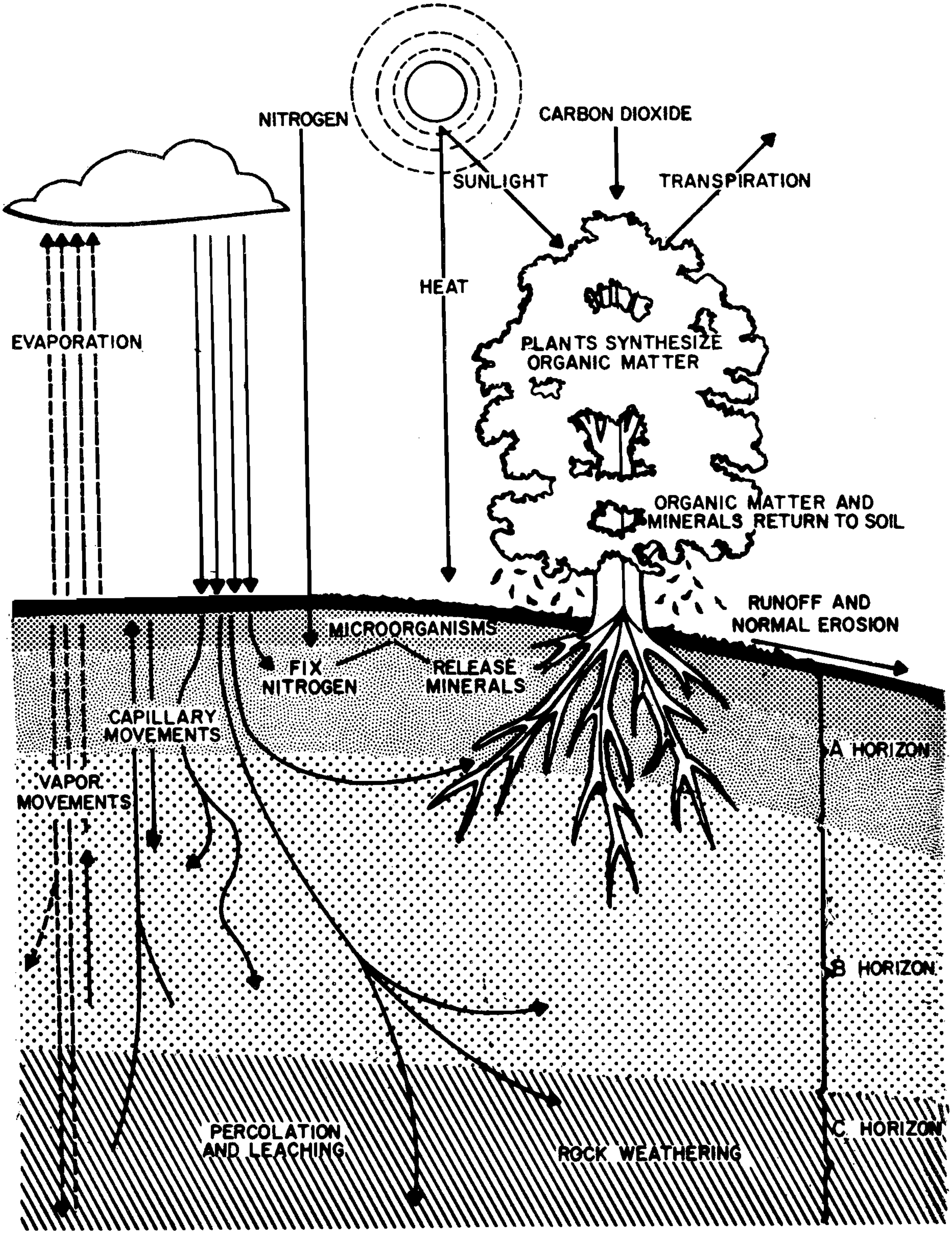


Figure 3-1. Physical and biological processes within the three horizons of soil (Kellog 1950).

characteristically low in organic accumulations. Low areas and depressions may tend to accumulate organic materials since the soils are poorly drained and remain wet for extended periods. Decompositional processes are subsequently retarded and peat formation results. The gray mottles or gray coloration observed in poorly drained soils are the result of oxygen removal from aluminum and iron compounds. Well-drained soils have oxygen-rich conditions and tend to exhibit yellow to red colors with no gray mottles to a depth of 3 - 4 ft (0.9 - 1.2 m) (Byrd et al. 1961).

Plants supply organic material through decomposition of surface litter by soil organisms, including fungi, bacteria, and small animals. The accumulation of surface litter is essentially a function of the type of plant community present. Accumulated humus can act as an effective nutrient trap preventing nutrients from leaching out of the surface layers of the soil. Sandy soils are particularly subject to excessive nutrient leaching in the absence of a humus layer (Odum 1971).

The alteration of parent material by soil forming processes over time results in horizon development. The features of the various soil types or series in a given area are the result of the dominating soil forming processes in that area. The length of time that geologic materials have remained in place is reflected in the distinctness of the horizons in the soil profile.

III. SOILS OF SEA ISLAND COASTAL REGION

Within the Sea Island Coastal Region, the soils found are Pleistocene and Holocene in age. The soils of the mainland and the sea islands, as well as some of the barrier islands, were laid down during the Pleistocene period at least 25,000 to 35,000 years ago (Hoyt 1968). Other barrier island soils are of more recent origin, having been laid down during the recent or Holocene period within the last 4,000 to 5,000 years. Marshland soils are also of Holocene origin (Hoyt 1968). For an overview of the soils found in the Sea Island Coastal Region, see Table 3-1 and Atlas Plate 19A.

A. PLEISTOCENE AND HOLOCENE SOILS

1. Mainland

Pleistocene mainland soils exhibit more distinct horizon development and diversity of soil series than Pleistocene soils of the sea islands. Sandy to loamy acid soils predominate in level to gently sloping mainland areas. Horizon development and the presence of loam are indicative of these more mature soils. Sandy surface layers over loamy subsoils predominate in some areas, while soils sandy throughout predominate in other areas. The soil series characteristic of the mainland areas are closely associated with natural drainage characteristics. Generally, the soils are saturated or seasonally wet except on the slight ridges where drainage is good. Most of the soils are acid to strongly acid, and moderately to poorly suited for farming and woodland development (Miller 1971, Wilkes et al. 1974).

2. Island

The soils of the islands are less diverse and horizon development is less distinct than in mainland soils (Johnson et al. 1974). Relief is slight and the soils are level to depressional sandy surface layers over sandy to loamy subsoil. The soils are acid except where quantities of shell are present. Accumulations of organic materials are slight except in the depressional areas where the soil is saturated during much or all of the year. Many of the soils lack a well-defined B horizon (Miller 1971, Wilkes et al. 1974). The types or series of soils present are closely related to drainage and the proximity to the surface of the island water table.

The seaward fringes of the sea islands, and in some cases entire barrier islands, are composed of Holocene deposits of almost pure quartz sand. Due to the comparatively recent origin of the soils, horizon development is slight and consequently the soil series are diverse. The soils are acidic and sandy throughout, with only slight accumulations of organic material. The topography is dominated by a complex of dune ridges and swales or bays. The dune ridges are excessively drained to well-drained, and the swales are moderately to poorly drained. Standing water is basically indicative of the water table rather than impervious soil layers (Miller 1971, Wilkes et al. 1974).

3. Tidal Marsh

The tidal marsh soils are of Holocene origin and consist of a sediment layer deposited over an older Pleistocene sand layer (Hoyt 1968). The marsh sediments are fine sand, clay, and organic deposits in various percentages (Teal and Kanwisher 1961). The higher marsh areas contain up to 70% (wet weight) water.

Sediments in tidal marsh consist of two distinct layers. The top few centimeters are subject to aeration and

Table 3-1. Representative soils of the Sea Island Coastal Region of South Carolina and Georgia, and suitability for select uses (adapted from Perkins and Shaffer 1976, Smith and Hallbick 1979).

	SOIL ASSOCIATION	SOIL SERIES	SUITABILITY: ROW CROPS	PASTURES	WOODLAND	RESIDENCES	SEPTIC TANK FIELDS	PICNIC AND CAMPSITES	PERMEABILITY	SHRINK-SWELL POTENTIAL
I. Loamy and Clay Soils of Wet Lowlands and Level Upland	A. Mascotte, Pelham, Leon	Mascotte	P	F	F	P	P	P	M	L
		Pelham	P	P	G	P	P	P	M	L
		Leon	P	P	P	P	P	P	M	L
	B. Bladen, Bayboro	Bladen	P	F	G	P	U	P	L	M
		Bayboro	P-F	F	G	P	U	P	L	M
	C. Chewacla, Wehadkee, Rains	Chewacla	F-P	F	G	P	U	P	M	L
		Wehadkee	P	F	G	U	U	P	M	L
		Rains	F-P	G	G	P	U	P	M	L
	D. Istokpoga, Rutlege	Istokpoga	U	U	U	U	U	U	H	L
		Rutlege	P	P	P	U	U	P	H	L
	E. Wahee, Bethera	Wahee	G	G	G	P	P	P	L	M
		Bethera	G	G	G	P	P	P	L	M
	F. Meggett, Santee	Meggett	G	G	G	P	P	P	L	H
		Santee	G	G	G	P	P	P	L	H
	G. Goldsboro, Rains, Norfolk	Goldsboro	G	G	G	G	P	G	M	L
		Rains	F-P	G	G	P	U	P	M	L
		Norfolk	G	G	G	G	F	G	M	L
II. Wet Sandy Soils of Broad Ridges	A. Seabrook, Yonges, Sewee	Seabrook	F	G	G	F	P	F	H	L
		Yonges	G	G	G	P	P	P	M	L
		Sewee	F	G	G	P	P	P	M	L
	B. Lynn Haven, Leon, Rutlege	Lynn Haven	F	F	F	P	P	P	M	L
		Leon	P	P	P	P	P	P	M	L
		Rutlege	P	P	P	U	U	P	H	L
	C. Lakeland, Chipley, Surrency	Lakeland	P	F	F	F	G-F	P	H	L
		Chipley	F-P	F	G	F	P	P	H	L
		Surrency	U	F	G	P	U	P	H	L

Table 3-1. Concluded

	SOIL ASSOCIATION	SOIL SERIES	SUITABILITY							
			ROW CROPS	PASTURES	WOODLAND	RESIDENCES	SEPTIC TANK FIELDS	PICNIC AND CAMPSITES	PERMEABILITY	SHRINK-SWELL POTENTIAL
III. Soils of Flood Plains on the Coastal Plain										
	A. Johnston, Rains, Ellabelle	Johnston	P	P-F	G	P	U	P	H-M	L
		Rains	F-P	G	G	P	U	P	M	L
		Ellabelle	P	P-F	G	P	P	P	M	L
	B. Tawcaw, Chastain	Tawcaw	G	G	G	P	P	P	L	M
		Chastain	F	F	G	P	P	P	L	M
IV. Level to Sloping Dunes and Beaches Underlain by Sandy Sediments										
	A. Kershaw, Pelham	Kershaw	P	P	P	G	G	P	H	L
		Pelham	P	P	G	P	P	P	M	L
	B. Fripp-Beach	Fripp	P	P	P	P	F	P	H	L
V. Tidal Marshes Underlain by Clayey Sediments										
	A. Capers, Bohicket	Capers	P	P	P	P	P	P	L	H
		Bohicket	P	P	P	P	P	P	L	H

KEY: U-unsuited, P-poor, F-fair, G-good, L-low, M-medium, H-high leaching and exhibit a dark brown color. Below the aerated layer are black sediments rich in reduced compounds resulting from anaerobic decomposition of organic matter. These are principally the sulfides of iron and other metals in the soils.

The pH of the marsh sediments of the anaerobic layer is neutral to slightly alkaline. If the sediments are subjected to drying and consequent aeration, the pH is lowered as the sulfides are oxidized to form sulfates, including sulfuric acid. In diked and drained areas, the pH may drop to 2.0 and the resulting soil is known as cat clay, a soil in which plant growth can be inhibited for many years (Edelman and Van Staveren 1958). Cat clays usually result from attempts to utilize marshlands for agriculture or other land-use practices. Cat clays or acid sulfate soils may result from impoundment construction or management when the marsh sediments are allowed to dry for as little as 3 - 4 months (Czyscinski 1975). On refilling, the cat clay soil may result in acidification of the water, limiting the uses of the impoundments.

Neutralizing the cat clay acid sulfate soils may require as much as 20 tons of lime/acre (44 metric tons/ha) (Wilkes et al. 1974) or 3 - 4 years of tidal flushing (Czyscinski 1975). Drying may not be a prerequisite for oxidation and consequent cat clay development. Introduction of oxygenated fresh water into impounded marshes may result in oxidation and acidification without drying (Czyscinski 1975). Potential formation of cat clays must be considered in land-use planning. Additionally, formation of cat clays is a potential impact of Santee Rediversion. See Chapter Six of this volume for a discussion of physical impacts of the Corps of Engineers' Santee Rediversion Project.

B. NUTRIENT DYNAMICS

The sandy soils of the Sea Island Coastal Region tend to be droughty or low in water retention when well-drained, particularly on the barrier islands where quartz sand is predominant. Capillary action in sandy soils is low while percolation is rapid. Consequently, the water retention qualities of the soils are low in the well-drained areas (Buckman and Brady 1968).

Nutrients are rapidly leached from the surface layer of sandy soils to subsurface layers or to the water table. The ion exchange capacity of sand is low, since sand grains have few binding sites to which K^+, Na^+, Ca^{++}, and Mg^{++} ions can be bound. Nutrients may be leached before becoming available t the root systems of plants and soil fungi.

The presence of clay or loam in mainland soils retards the leaching of nutrients which then accumulate in the B horizon and are thus available to plants. The B horizon is absent entirely in the sandy Holocene soils of the barrier islands, and plants are primarily dependent on a continuous nutrient input from decaying surface litter. If the surface litter is removed, nutrient depletion generally is the result (Buckman and Brady 1968).

C. BIOLOGICAL IMPACTS OF ACID SOILS

The general acidity of the soils of the Sea Island Coastal Region is an indication of the following conditions (Buckman and Brady 1968):

1) a loss of exchangeable bases (Ca^{++}, Mg^{++}) from well-drained soils;

2) increased solubility of trace elements resulting in potentially toxic levels of Al, Fe, and Mn for some plant species;

3) a loss of available phosphate since low pH causes phosphate to complex as insoluble compounds; and

4) reduced bacterial nitrogen fixation, resulting in reduction in total soil nitrogen.

The well-drained sandy soils of the sea islands, and particularly the Holocene barrier island soils, are low in inherent buffering capacity. Consequently, they are vulnerable to rapid pH changes initiated by disturbance of the soil. Landscaping, sewage disposal, and agricultural practices may have drastic effects on soil pH (Buckman and Brady 1968). Plants are sensitive to changes in soil pH (Russell and Russell 1950). Sensitive ecological elements may be adversely affected by intensive management or development of the island soils.

IV. SUMMARY: USE AND MANAGEMENT OF SOILS

Soil properties, such as permeability, size of soil particle, bearing strength, pH, and depth to water table, impose limitations on land use. Therefore, soil surveys, containing highly specific information on soil properties, are of interest in agriculture, engineering and construction, and other land uses such as recreation, wildlife management, and woodland development. Because of the great diversity of soil types or series in relatively small areas, these detailed surveys must be consulted prior to ecological studies or management decisions. The soil surveys, prepared by the U.S. Department of Agriculture, Soil Conservation Service, and cooperating agricultural experiment stations, are either published or in progress for the counties within the Sea Island Coastal Region. Addresses of local Soil Conservation Service offices in the Sea Island Coastal Region are presented in the Directory of Information Sources.

CHAPTER FOUR

REGIONAL CLIMATIC TRENDS

I. INTRODUCTION

The climates of South Carolina and Georgia are generally pleasant with short, mild winters and warm, humid summers. In both States the southerly latitude, proximity of the ocean, and elevation are the determining climatic factors. Mountains up to 1067 m (3500 ft) in South Carolina and 1524 m (5000 ft) in Georgia are located about 387 km (240 mi) and 290 km (180 mi) from the coast, respectively. The mountains in South Carolina tend to serve as a barrier to cold air masses from the north and west, whereas Georgia mountains have less of an influence.

The mountains and the Bermuda high pressure system tend to retard the progress of cold fronts into coastal areas of both States, producing relatively mild, temperate winters. Summer, though warm and humid, is relatively moderate in contrast to more inland areas outside the influence of the ocean.

II. TEMPERATURE

A. MAXIMA AND MINIMA

Temperatures in the Sea Island Coastal Region are moderated primarily by marine influences, as described above. For the most part, temperature maxima are lower and minima higher along the coast than inland, as illustrated by 30-year average temperatures (Atlas plate 26A,B,C,D). In general, temperature extremes have not occurred along the coast, i.e., maximum summer and minimum winter temperatures have been at inland locations (Tables 4-1 and 4-2). Maximum winter temperatures have, on the other hand, occurred at coastal sites or near coastal sites (Tables 4-1 and 4-2).

Additional examples of the marine influence on climate are evident in the freeze-free or growing period. In South Carolina, the freeze-free period is 225 days in Greenville (U.S. Department of Commerce, NOAA 1976a) and 294 days in Charleston (U.S. Department of Commerce, NOAA 1976b). A similar effect is evident in Georgia, where the freeze-free period varies from 170 days in the mountains to about 300 days along the coast (Carter 1974).

The region best illustrating the climatic moderating effects of the ocean is the Golden Isles of Georgia. On the average, only 15 days a year have temperature minima as low as freezing (Carter 1967). Temperature maxima are also moderated by the ocean, since the Golden Isles are the only location in Georgia south of Atlanta with a July average maximum <33°C (90°F) (Carter 1967).

B. NEGATIVE TEMPERATURE DEPARTURES FROM NORMAL

While the weather tends to be mild overall, the 15-year period from 1958 - 1972 was colder than usual for South Carolina and Georgia. Using temperature normals for the 1931 - 1960 period for comparison purposes, Landers (1973) has shown that South Carolina temperatures were 0.7° - 1.1°C (1.3° - 1.9°F) below normal while Georgia temperatures were 0.7° - 1.3°C (1.2° - 2.3°F) below normal. The average annual negative temperature departure from normal for 1958 - 1972 indicates that the Sea Island Coastal Region exhibited a somewhat lower temperature departure than did inland areas, where the temperature departures averaged 0.8°C (1.5°F) or more (Landers 1973). Although the reasons for the lower temperatures are not known at this time, it may be that such phenomena are quite common, following a cyclic schedule in the same manner as sunspots or periods of drought.

III. RELATIVE HUMIDITY

Even though temperatures are not extreme, relative humidity in South Carolina and Georgia is frequently high enough to produce very muggy conditions in the summer and dank conditions during the winter. Relative humidity varies less from location to location than diurnally (Tables 4-3 and 4-4). Humidity is generally highest during the summer throughout each State, but summer humidity is not necessarily as high on the coast as inland (Table 4-4).

IV. RAINFALL

A. VARIABILITY

Rainfall, unlike humidity, varies greatly with location and season (Tables 4-5 and 4-6). General trends for South Carolina and Georgia indicate maximum rainfall in mountainous areas, minimum rainfall inland along the coastal plain, and moderate rainfall elsewhere (Atlas plate 26E). Spring is normally the driest period of the year in both States, especially along the coast (Tables 4-5 and 4-6).

Rainfall, though usually moderate in South Carolina and Georgia, has at

Table 4-1. Temperature extremes by month in South Carolina, 1887 - 1974 (Purvis and Rampey 1975).

Month	Location	Maximum Temperature	Year	Location	Minimum Temperature	Year
January	Beaufort[a]	31.2°C (88°F)	1950	Long Creek	-25.0°C (-13°F)	1940
February	Walterboro[a]	31.2°C (88°F)	1945	Santuck Shaws Fork	-23.9°C (-11°F)	1899
March	Blackville	37.2°C (99°F)	1907	Caesars Head	-15.9°C (3°F)	1943
April	Society Hill Blackville	37.2°C (99°F)	1925	Caesars Head	- 7.8°C (18°F)	1944
May	Santuck	41.1°C (106°F)	1911	Greenville	- 2.8°C (27°F)	1899
June	Camden	43.9°C (111°F)	1954	Chester	3.3°C (38°F)	1966
July	Chester	43.2°C (110°F)	1887	Greenville	4.4°C (40°F)	1889
August	Blackville Calhoun Falls Society Hill Trenton	42.8°C (109°F)	1925	Union	7.8°C (46°F)	1968
September	Blackville Calhoun Falls	43.9°C (111°F)	1925	Long Creek	- 1.1°C (30°F)	1974
October	Little Mountain	39.4°C (103°F)	1954	Chester	- 8.9°C (16°F)	1965
November	Garnett	33.3°C (92°F)	1919	Caesars Head	-18.3°C (-1°F)	1950
December	Georgetown[a]	32.2°C (90°F)	1929	Landrum	-21.1°C (-6°F)	1917

a. Located within the Sea Island Coastal Region.

Table 4-2. Temperature extremes by month in Georgia, 1899 - 1966 (Carter 1970a).

Month	Location	Maximum Temperature	Year	Location	Minimum Temperature	Year
January	Bainbridge	31.2°C (88°F)	1952	Blairsville Exp. Sta.	-26.7°C (-16°F)	1940
February	Glennville	32.2°C (90°F)	1918	Tallapoosa	-24.4°C (-12°F)	1949
March	Miller	36.1°C (97°F)	1907	Dahlonega Clayton	-17.8°C (0°F)	1899
April	Dublin Hawkinsville Monticello	37.2°C (99°F)	1925	Blairsville Exp. Sta. Clayton	- 8.9°C (16°F)	1960 1923
May	Bainbridge	42.2°C (108°F)	1953	Blairsville Exp. Sta.	- 3.9°C (25°F)	1963
June	Eastman Louisville Warrenton	43.3°C (110°F)	1954 1952 1959	Blairsville Exp. Sta.	1.1°C (34°F)	1966
July	Louisville	44.4°C (112°F)	1952	Blairsville Exp. Sta.	4.4°C (40°F)	1937
August	Milledgeville Americus	43.3°C (110°F)	1925	Blairsville Exp. Sta.	6.1°C (43°F)	1961
September	Americus	43.9°C (111°F)	1925	Blairsville Exp. Sta. Clayton	- 0.6°C (31°F)	1962 1947
October	Fort Gaines	40.6°C (105°F)	1954	Blairsville Exp. Sta.	-10.0°C (14°F)	1961
November	Brooklet	33.9°C (93°F)	1961	Blairsville Exp. Sta. Jasper	-17.8°C (0°F)	1950
December	Waycross	30.6°C (87°F)	1950	Blairsville Exp. Sta.	-22.8°C (-9°F)	1962

Table 4-3. South Carolina average relative humidity at 1300 hours (Landers 1974).

Location	Month	Relative Humidity (%)	Diurnal Range (%)
Columbia	April	54	28
	July	58	35
	October	51	40
	December	52	35
Charleston[a]	April	50	30
	July	64	28
	October	56	33
	December	54	30

a. Located within the Sea Island Coastal Region.

Table 4-4. Georgia average relative humidity at 1300 hours (Carter 1966).

Location	Season	Relative Humidity (%)	Diurnal Range (%)
Atlanta	Spring	54	31
	Summer	63	31
	Fall	53	34
	Winter	58	24
Savannah[a]	Spring	51	38
	Summer	59	34
	Fall	54	36
	Winter	57	32

a. Located within the Sea Island Coastal Region.

Table 4-5 South Carolina precipitation averages in cm (in), 1941 - 1970 (U.S. Department of Commerce, NOAA 1973a).

Location	January	April	July	October	Annual
Beaufort[a]	7.90 (3.11)	6.88 (2.71)	18.3 (7.22)	6.63 (2.61)	124.7 (49.08)
Caesars Head	15.80 (6.23)	16.00 (6.29)	20.3 (8.00)	13.90 (5.48)	196.0 (77.17)
Charleston City[a]	6.81 (2.68)	6.86 (2.70)	19.3 (7.60)	7.65 (3.01)	124.3 (48.92)
Columbia	8.74 (3.44)	8.92 (3.51)	14.4 (5.65)	6.55 (2.58)	117.8 (46.36)
Spartanburg	9.88 (3.89)	10.70 (4.23)	11.5 (4.54)	7.85 (3.09)	121.4 (47.78)

a. Located within the Sea Island Coastal Region.

times reached extreme proportions (Tables 4-7 and 4-8). The coastal region of each State (Atlas plate 26E) generally receives about 127 cm (50 in) per year, with the state-wide annual averages being about the same. Variability in rainfall with time and location is quite high; hence, deviations from normal rainfall are not rare or unusual.

B. OCCURRENCES OF DROUGHT CONDITIONS

In spite of the apparent abundance of precipitation in South Carolina and Georgia, droughts are by no means rare. The problem is one of distribution, i.e., some months receive excessive amounts of rain, while others scarcely have a shower. Utilizing 25 years of data from 32 stations, Van Bavel and Carreker (1957) found that in 5 out of 10 years in Georgia there are usually 60 - 70 days of drought in the central portion of the State and 50 - 60 in the lower third of the State. Examples of extremely dry conditions can be seen in the records of several stations in the Sea Island Coastal Region (Tables 4-9 and 4-10).

V. OTHER PRECIPITATION

Other forms of precipitation, such as snow and hail, are normally negligible in South Carolina and Georgia. Except in thunderstorms, hail is rare and normally not large in size. Snow, although somewhat uncommon, occurs occasionally in conjunction with freezing rain and sleet, usually as scattered snow flurries. Along the coast snowfall seldom is great and generally does not accumulate on the ground. An exception occurred during February 1973 when 12.7 - 45.7 cm (5.0 - 18.0 in) of snow fell in the low country of South Carolina, with 25.4 cm (10.0 in) falling on 1 day in Walterboro (U.S. Department of Commerce, NOAA 1975). During this same snow storm, 8.1 cm (3.2 in) of snow fell in Savannah, Georgia (U.S. Department of Commerce, NOAA 1976c), while Macon, Georgia, received 41.9 cm (16.5 in) (U.S. Department of Commerce, NOAA 1976d).

VI. WIND PATTERNS

Wind data for South Carolina and Georgia indicate a high degree of variability, although some recognizable trends do exist (Atlas plate 26G). In South Carolina the inland wind regime is one of southwesterlies and northeasterlies, while coastal winds are more evenly distributed over all directions. Georgia wind patterns are generally different from those in South Carolina, although some similarities exist (Atlas plate 26G). A comparison of several locations is presented in Table 4-11.

VII. TORNADOES

A. INCIDENCE

Storms of many types have played an important part in the history of the Sea Island Coastal Region, ranging from dramatic, but generally nondestructive, thunderstorms to devastating tropical cyclones. Tornadoes have occasionally hit coastal counties in conjunction with thunderstorms and hurricanes, with the most frequent occurrence being in conjunction with violent spring thunderstorms. For the period 1950 - 1976, only six South Carolina counties had 10 or more confirmed tornadoes, two of which were coastal counties (Atlas plate 26F). During the period 1953 - 1976, South Carolina had 2.95 tornadoes per 25,900 km^2 (10,000 mi^2), whereas Georgia had 3.62 per 25,900 km^2 (U.S. Department of Commerce, NOAA 1977). In comparison, the average for the nation was 1.96 tornadoes per 25,900 km^2 for the period 1953 - 1976, while the maximum average was 7.90 tornadoes per 25,900 km^2 for Oklahoma during the same period (U.S. Department of Commerce, NOAA 1977).

B. GEORGIA TORNADO BELT

In Georgia, unlike South Carolina, most tornadoes appear to occur in a "tornado belt" about 97 km (60 mi) wide, parallel to and slightly south of the Appalachian Mountains (Armstrong 1953). There has been a concentration of tornadoes in the general area around Atlanta, with few occurring along the coast (Atlas plate 26F). While it is true that sparsely populated areas have fewer tornado sightings due to a lack of observers, other populous areas besides Atlanta, such as Augusta and Savannah, have experienced a significantly lower number of tornadoes. Hence, the concept of a "tornado belt" is reasonable for Georgia.

C. HISTORICAL DATA

Although tornadoes accompanying hurricanes are not common, there have been several occurrences reported in South Carolina. There were four tornadoes associated with a hurricane in 1935, two with Hurricane Connie in 1955, and six with tropical storm Cleo in 1964 (Purvis 1977). For hurricane-spawned tornadoes and tornadoes in general, the data for South Carolina suggest that there have been more tornadoes in the last two decades than during similar periods in previous years, i.e., 208 for 1956 - 1976 (Purvis 1977) compared with 252 for 1916 - 1970 (Landers 1974). The same situation exists in Georgia, where about 227 tornadoes were reported between 1884 and 1952 (Armstrong 1953) and 511 between

Table 4-6. Georgia precipitation averages in cm (in), 1941 - 1970 (U.S. Department of Commerce, NOAA 1973b).

Location	January	April	July	October	Annual
Atlanta	11.00 (4.34)	11.70 (4.61)	12.4 (4.90)	6.35 (2.50)	122.8 (48.34)
Clayton	15.40 (6.08)	15.20 (5.99)	16.8 (6.60)	11.70 (4.61)	176.4 (69.45)
Brunswick[a]	7.04 (2.77)	7.65 (3.01)	19.4 (7.62)	10.20 (4.03)	138.9 (54.69)
Savannah Beach[a]	6.93 (2.73)	5.92 (2.33)	16.7 (6.59)	7.80 (3.07)	114.1 (44.93)
Bainbridge	10.30 (4.06)	12.20 (4.79)	17.7 (6.98)	6.30 (2.48)	132.0 (51.98)

a. Located within the Sea Island Coastal Region.

Table 4-7. Maximum amounts of rainfall in South Carolina.

Location	Amount cm (in)	Period	Reference
Kingstree	79.1 (31.13)	July 1916	Landers 1974
Charleston[a]	69.0 (27.24)	June 1973	U.S. Department of Commerce, NOAA 1976b
Charleston[a]	26.8 (10.57)	24 hr, Sept. 1973	U.S. Department of Commerce, NOAA 1976b
Georgetown[a]	28.4 (11.18)	24 hr, June 1945	Kronberg et al. 1955
Edisto Island[a]	29.6 (11.64)	24 hr, 1969	Purvis and Rampey 1975

a. Located within the Sea Island Coastal Region.

Table 4-8 Maximum amounts of rainfall in Georgia.

Location	Amount cm (in)	Period	Reference
Savannah[a]	58.1 (22.88)	Sept. 1924	U.S. Department of Commerce, NOAA 1976c
St. George	45.7 (18.00)	17 hr, Aug. 1911	Carter 1974
Blakely	76.8 (30.23)	24 hr, July 1916	Carter 1974
Brunswick[a]	26.1 (10.27)	24 hr, Oct. 1944	Carter 1971
Golden Isles[a]	53.8 (21.20)	Sept. 1962	Carter 1967

a. Located within the Sea Island Coastal Region.

Table 4-9. Minimum amounts of rainfall in the South Carolina Sea Island Coastal Region.

Location	Amount cm (in)	Period	Reference
Charleston	0.03 (0.01)	April 1972	U.S. Department of Commerce, NOAA 1976b
Charleston	0.20 (0.08)	October 1943	U.S. Department of Commerce, NOAA 1976b
Beaufort	0.28 (0.11)	October 1961	U.S. Naval Weather Service Command 1973
Beaufort	0.20 (0.08)	October 1972	U.S. Naval Weather Service Command 1973
Walterboro	0.05 (0.02)	October 1953	U.S. Department of Commerce, NOAA 1975
Walterboro	0.08 (0.03)	October 1961	U.S. Department of Commerce, NOAA 1975

Table 4-10. Minimum amounts of rainfall in the Georgia Sea Island Coastal Region.

Location	Amount cm (in)	Period	Reference
Golden Isles	0.30 (0.10)	February 1945	Carter 1967
Golden Isles	0.30 (0.10)	November 1956	Carter 1967
Golden Isles	0.30 (0.10)	December 1956	Carter 1967
Savannah	0.15 (0.06)	October 1943	U.S. Department of Commerce, NOAA 1976c
Savannah	0.23 (0.09)	October 1961	U.S. Department of Commerce, NOAA 1976c
Savannah	0.05 (0.02)	October 1963	U.S. Department of Commerce, NOAA 1976c
Savannah	0.25 (0.10)	October 1974	U.S. Department of Commerce, NOAA 1976c
Brunswick	0.00 (0.00)	March 1967	Carter 1971

Table 4-11. Wind statistics for selected locations in South Atlantic States.

Location	Mean Speed km/h (mi/h)	Prevailing Direction	Reference
Charleston[a]	14.2 (8.8)	NNE	U.S. Department of Commerce, NOAA 1976b
Columbia	11.1 (6.9)	SW	U.S. Department of Commerce, NOAA 1976e
Greenville	10.9 (6.8)	NE	U.S. Department of Commerce, NOAA 1976a
Savannah[a]	13.0 (8.1)	SW	U.S. Department of Commerce, NOAA 1976c
Macon	12.6 (7.8)	WNW	U.S. Department of Commerce, NOAA 1976d
Atlanta	14.6 (9.1)	NW	U.S. Department of Commerce, NOAA 1976f
Jacksonville	13.7 (8.5)	NW	U.S. Department of Commerce, NOAA 1976g

a. Located within the Sea Island Coastal Region.

1953 and 1976 (U.S. Department of Commerce, NOAA 1977). There are probably two explanations for this: reliable data are lacking from earlier periods and increased sightings are likely to be a result of a larger population in the area.

VIII. TROPICAL CYCLONES

A. CRITERIA

While there is some inconsistency in terminology, "tropical cyclone" generally refers to all storms with counterclockwise winds originating near the North Atlantic subtropical convergence zone, i.e., east of the West Indies. Cry (1967) and Ludlum (1963) used the following system: tropical depression - wind speeds <63 km/h (39 mi/h), tropical storm - wind speeds 63 - 117 km/h (39 - 73 mi/h), and hurricane - wind speeds >117 km/h (>74 mi/h). For this discussion, the system of Cry (1967) has been utilized except when a reference did not distinguish between the various terms, e.g., the use of storm in the most general sense.

B. EARLY HISTORY

In spite of the undeniably destructive nature of tornadoes, tropical cyclones historically have been far more devastating in the Sea Island Coastal Region. Reliable information on tropical cyclones occurring prior to 1900 is understandably meager, since there were few weather stations or reliable observers. However, hurricanes have been reported as early as 1686 in South Carolina and 1752 in Georgia (Ludlum 1963). Earlier storms in Florida, as described in Spanish accounts, may have affected southern Georgia, e.g., the tropical storms at Pensacola in 1528 and St. Augustine in 1565 (Ludlum 1963).

C. OCCURRENCE

Regardless of the paucity of early data on hurricanes, it is evident that South Carolina has a higher rate of incidence of hurricanes than Georgia. Due to the curvature of the coastline and proximity to the Gulf Stream, South Carolina has been struck by more hurricanes than Georgia. Most hurricanes impacting Georgia have arrived after passing over the panhandle of Florida. Under such circumstances, most tropical cyclones lose much of their destructive force, since winds usually decrease in intensity as the storm moves over land. Tremendous amounts of rain usually accompany even the most diminished tropical cyclone resulting in severe flooding with concomitant destruction of crops, livestock, and buildings.

D. CLASSIFICATION

When discussing tropical cyclones of hurricane force, it is customary to rank them according to size and intensity. Sugg and Carrodus (1969) and Purvis and Landers (1973) classify tropical cyclones as hurricane, major, great, or extreme. Another classification system is that of Saffir/Simpson in which hurricanes are given a numerical ranking of 1 - 5. The ranking is based on wind speed, storm surge, central atmospheric pressure, and destruction, with the most intense storms receiving higher numerical ranking (Hebert and Taylor 1975). Without adequate, reliable data, it is difficult to rank hurricanes by either scale; hence, most hurricanes prior to 1900 can only be roughly categorized.

Some hurricanes affecting the coastal regions of South Carolina and Georgia are shown on Atlas plate 26H. Ranking post-1900 hurricanes according to the Saffir/Simpson scale, Hebert and Taylor (1975) rank Cindy in 1959 (South Carolina) as a one, the October 1947 hurricane near Savannah as a two, Gracie in 1959 (South Carolina) as a three, and Hazel in 1954 (South Carolina) as a four. No hurricanes since 1900 were ranked extreme or five on the Saffir/Simpson scale. A listing of hurricanes of the Sea Island Coastal Region is provided in Tables 4-12 and 4-13, showing available data on each significant storm. At first glance, some of the wind speeds may appear insignificant, but this is misleading due to the fact that the areas most affected did not always have anemometers and available instruments may not have been reliable or even functioning during the height of the storm. In addition, much actual destruction is due to storm surges and floods, especially in low-lying areas. The resulting destruction can be far more severe than statistics alone would indicate.

E. STORM TIDES

As mentioned above, storm tides or surges add substantially to the destruction caused by hurricane-force winds. Myers (1975) has defined a storm tide as the height of the sea surface above local MSL during a storm, and a surge as the increase (or decrease) of the height of the sea surface due to a storm. Table 4-13 lists the maximum storm tides for significant hurricanes in the Sea Island Coastal Region after 1872. Much information relating to storm tides along the South Carolina and Georgia coasts can be found in Ho (1974) and Myers (1975). One of the best documented storm tides in the Sea Island Coastal Region was that of the August 1940 hurricane, which struck the Georgia-South Carolina coast just north of

Table 4-12. Significant hurricanes of the Sea Island Coastal Region before 1872.

Date	Location	Classification[a]	Damage	Reference
25 August 1686	Charleston	Major Hurricane	Flooding and wind damage.	Ludlum 1963
14/16 September 1700	Charleston	Great Hurricane	Street flooding and about 97 lives lost in ship wreck.	Ludlum 1963, Purvis and Landers 1973
5-6 September 1713	Charleston	Major Hurricane	Extensive inundation and possibly 70 lives lost.	Ludlum 1963
13-14 September 1728	Charleston	Major Hurricane	23 ships damaged or lost.	Ludlum 1963
15 September 1752	Charleston	Great or Extreme Hurricane	Extensive damage to low-lying structures and to ships. Unknown number drowned.	Ludlum 1963
7 September 1804	Savannah	Great Hurricane	2.1 m (7 ft) storm tide in Georgia. About 500 deaths in South Carolina.	Carter 1970b Ludlum 1963
27 August 1813	Charleston	Great Hurricane	Extensive damage to rice crop, wharves, and warehouses due to severe winds and storm tide.	Ludlum 1963
27 September 1822	Charleston and Georgetown	Major Hurricane	Extensive crop damage with about 300 deaths.	Ludlum 1963
14-15 September 1824	Darien	Major Hurricane	Tremendous freshet in most rivers with extreme crop damage inland.	Ludlum 1963
7-9 September 1854	Between Brunswick & Savannah	Major Hurricane	145 km/h (90 mi/h) winds at Savannah. Considerable property damage along the Georgia coast.	Ludlum 1963

a. Based on early accounts.

Table 4-13. Significant hurricanes of the Sea Island Coastal Region after 1872.

Date	Location	Wind Speed km/h (mi/h)	Storm Tide m (ft)	Fatalities	Classification	Reference
27 August 1881	Georgia	129 (80)[a]	4.94 (16.2)[b]	700 (Georgia and South Carolina)	Major	Sugg and Carrodus 1969, Ho 1974
25 August 1885	South Carolina-Georgia	202 (125)[c]		21 (Charleston)	Extreme	Sugg and Carrodus 1969, Purvis and Landers 1973, Ho 1974
27 August 1893	South Carolina-Georgia	194 (120)[d]	5.18 - 5.94 (17.0 - 19.5)[e]	1000 - 2000 (South Carolina)	Extreme	Sugg and Carrodus 1969, Purvis and Landers 1973, Ho 1974
13 October 1893	South Carolina			Several	Major	Purvis and Landers 1973
28-29 September 1896	Georgia	121 (75)[a]		12	Hurricane	Carter 1970b
31 August 1898	Georgia	161 (100)[b]			Hurricane	Carter 1970b
2 October 1898	Georgia		3.69 (12.1)[f]	179	Extreme	Sugg and Carrodus 1969, Carter 1970b, Ho 1974
31 October 1899	South Carolina				Major	Sugg and Carrodus 1969, Purvis and Landers 1973
7 September 1906	South Carolina				Great	Sugg and Carrodus 1969, Purvis and Landers 1973
19-20 October 1910	South Carolina-Georgia		2.6 (8.5)[d]		Great	Sugg and Carrodus 1969, Purvis and Landers 1973
28 August 1911	South Carolina-Georgia	171 (106)[d]		17 (Charleston)	Major	Sugg and Carrodus 1969, Carter 1970b, Purvis and Landers 1973
18 September 1928	South Carolina-Georgia			5 (South Carolina)	Great	Sugg and Carrodus 1969, Carter 1970b, Purvis and Landers 1973
11-15 August 1940	South Carolina-Georgia		4.9 (16)[g]	34	Major	Sugg and Carrodus 1969, Carter 1970b, Purvis and Landers 1973, Myers 1975
15 October 1947	Georgia	161 (100)[b]	3.7 (12)[h]	1	Hurricane	Sugg and Carrodus 1969, Carter 1970b, Purvis and Landers 1973
15 October 1954	South Carolina	171 (106)[i]	5.15 (16.9)[i]	1	Great	Dunn and Miller 1960, Sugg and Carrodus 1969, Purvis and Landers 1973
29 September 1959	South Carolina	226 (140)[d]	2.62 (8.6)[d]	7	Major	Sugg and Carrodus 1969, Purvis and Landers 1973
29 August 1964	Georgia	145 (90)[j]	4.3 (14)[j]		Major	Sugg and Carrodus 1969, Carter 1970b.

a. at Savannah, Georgia
b. at Tybee Island, Georgia
c. at Smithville, North Carolina
d. at Charleston, South Carolina
e. at Fernandina Beach, Florida
f. at Isle of Hope, Georgia
g. at Lemon Island, Jasper County, South Carolina
h. at Parris Island, South Carolina
i. at Myrtle Beach, South Carolina
j. at Brunswick, Georgia

Savannah. High-water marks were measured in 1971, utilizing the National Geodetic Vertical Datum of 1929 (Myers 1975). Flooding from Savannah to Charleston occurred with storm tides of 2.3 m (7.4 ft) at Savannah, 4.4 m (14.5 ft) at Beaufort, and 2.7 m (8.9 ft) at Charleston being recorded (Ho 1974, Myers 1975). Even higher storm tides have been recorded (Table 4-13), thus illustrating the potential for severe destruction along the South Carolina-Georgia coast.

F. PROBABILITY

Although hurricanes have often been called "September gales," they have occurred along the South Carolina coast as early as 28 May and as late as 23 October (Simpson and Lawrence 1971). This represents a fairly narrow time frame, since tropical cyclones have hit the Gulf or Atlantic coasts as early as 2 February or as late as 2 December (Fig. 4-1). The Sea Island Coastal Region is a moderately high risk zone with respect to tropical cyclone occurrences and destruction (Figs. 4-2 and 4-3). Purvis and Landers (1973) report that 169 hurricanes hit the South Carolina coast from 1686 to 1972 for an average of 0.59 per year. Hurricanes on the average have entered or affected Georgia about once every 10 years, although tropical cyclones of less than hurricane force have averaged 1.1 per year (Carter 1970b).

G. PRECIPITATION

Even though the obvious effects of hurricanes include flooding, property damage, etc., hurricanes also have a significant climatic effect. Cry (1967) reported that hurricane-related precipitation in the Sea Island Coastal Region is about 15% of the total rainfall (Fig. 4-4). The reason for this is clear when the courses of several hurricanes are plotted. Many hurricanes either hit the Sea Island Coastal Region directly or pass close to the area (Fig. 4-5). On 9 July 1916, a hurricane entered Georgia after traversing Mississippi and Alabama, producing large amounts of rainfall in Georgia and, to a lesser extent, South Carolina. As a result of the storm, Blakely, Georgia, received 55.09 cm (21.69 in) of rain in 4 days producing a monthly total of 76.78 cm (30.23 in). A record rainfall occurred when another hurricane passed inland over Bulls Bay, South Carolina, on 14-15 July 1916, during which Effingham received 33.66 cm (13.25 in) of rain in 24 hours (Purvis and Landers 1973). The flooding and ensuing crop and property damage were quite extensive due to the volume of rain and to the runoff caused by the Georgia storm only 5 days earlier.

H. DESTRUCTIVE POTENTIAL

As destructive as many of the South Carolina-Georgia hurricanes and tornadoes have been, the potential for property damage and loss of life is far greater today than ever before. This is particularly true along the coast where populations have grown tremendously since the last great hurricane (< three on the Saffir/Simpson scale), e.g., from 344,700 in 1959 to 429,900 in 1970 for South Carolina (Hebert and Taylor 1975). Since Georgia has not experienced a hurricane of major intensity in modern times (when a census has been taken), it is not possible to evaluate accurately the population growth since the last major hurricane. However, the 1970 Georgia coastal population of 281,108 (Hebert and Taylor 1975) is undoubtedly much larger than the pre-1900 coastal population. It is clear that severe storms such as those of 1752, 1804, 1885, and 1893 (Tables 4-12 and 4-13) could produce phenomenal destruction and great loss of life if adequate warning were not provided. The damage resulting from storms as intense as Camille (August 1969 in the Gulf of Mexico), with a storm tide > 7.3 m (> 24 ft), or the "Labor Day" hurricane (1935 in the Florida Keys) with 322 km/h (200 mi/h) winds is almost inconceivable in the Sea Island Coastal Region. Ho et al. (1975) have calculated that there is a relatively high probability that an intense hurricane like Camille could in fact hit the Georgia-South Carolina coast. Although this may never occur, the extreme hurricane of 27 August 1893 is the closest to the above for comparison purposes. As shown in Table 4-13, between 1000 - 2000 people died as a result of the severe flooding caused by the storm tide of > 5.18 m (> 17 ft) and the high wind speeds associated with this storm.

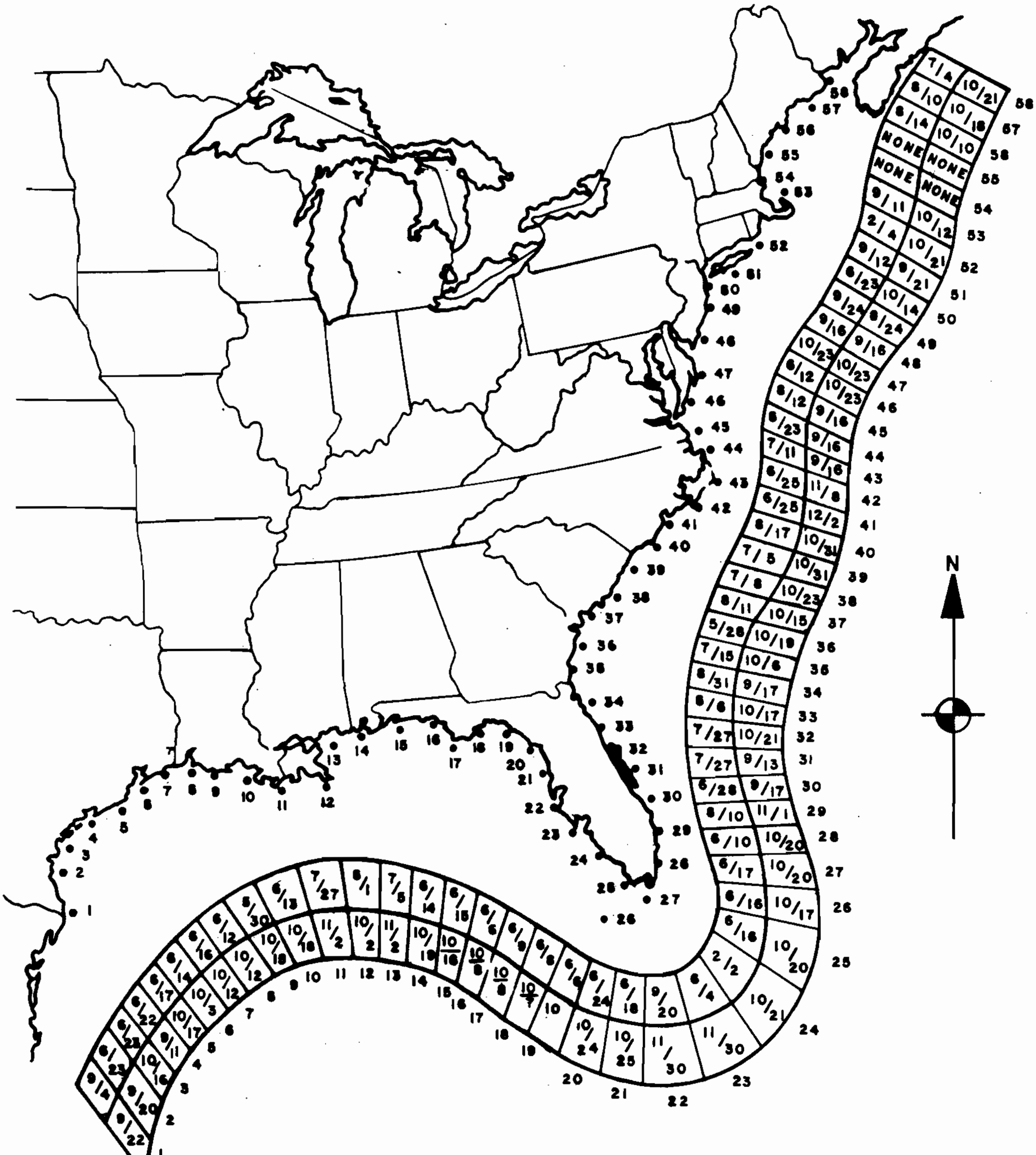


Figure 4-1. The date (month/day) of the earliest and latest hurricane occurrences for 50 nautical mile segments of coastline for 1886 - 1970 (Simpson and Lawrence 1971).

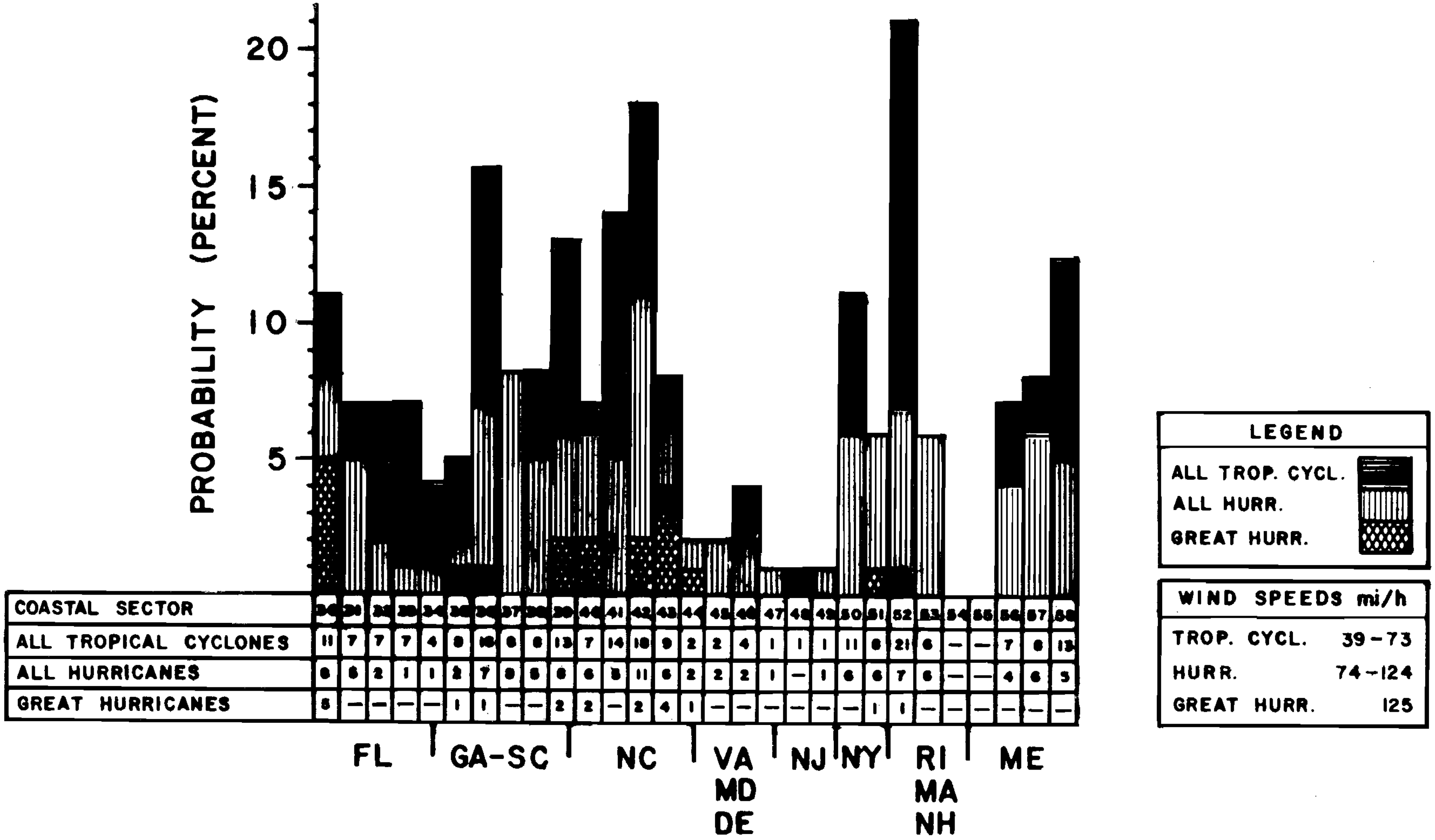


Figure 4-2. Frequency of tropical cyclones along the United States Atlantic coastline (Simpson and Lawrence 1971). (Coastal sector numbering refers to Figure 4-1.)

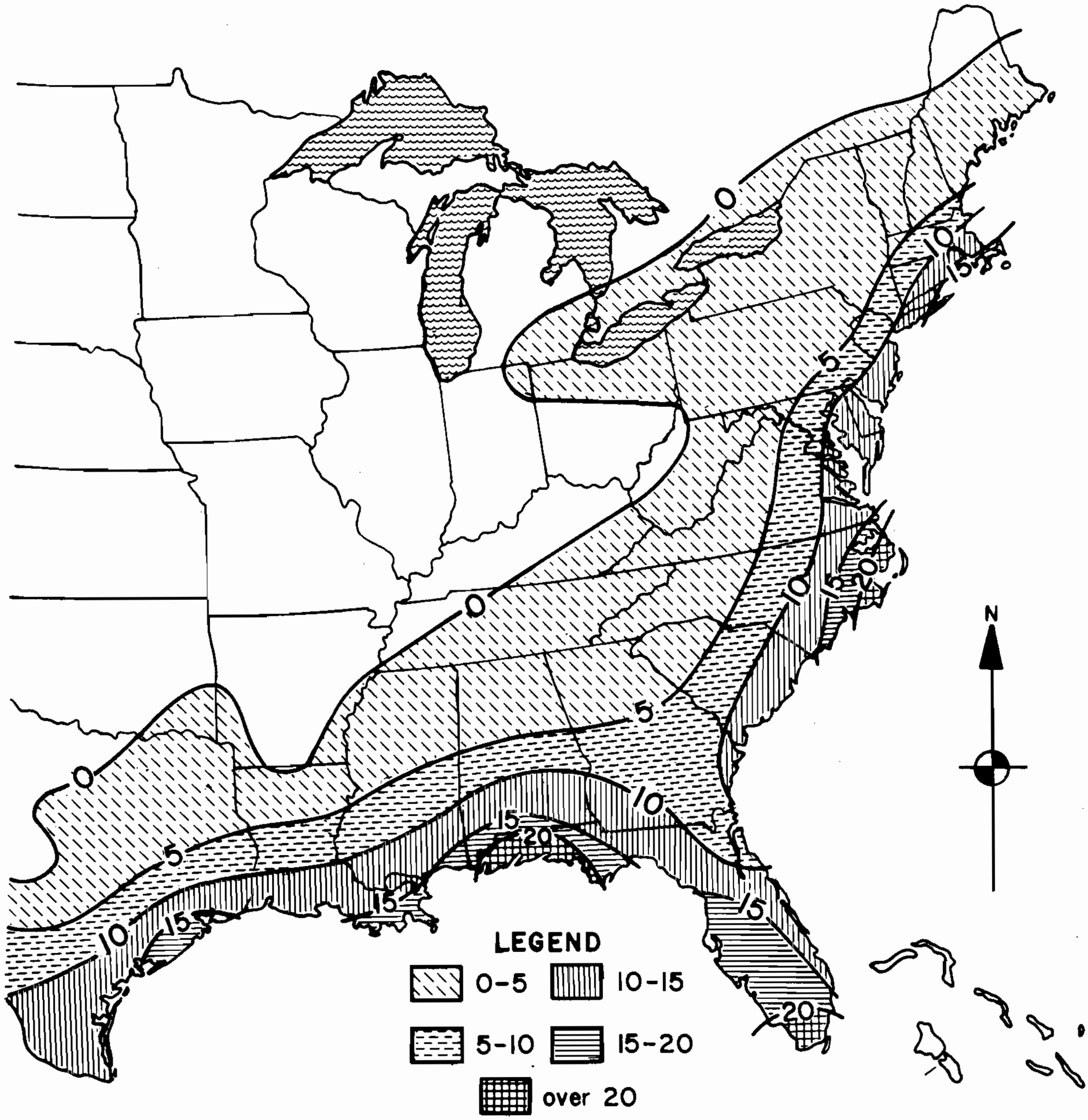


Figure 4-3. Number of times destruction was caused by tropical storms for the period 1901 - 1955 (Landers 1974).

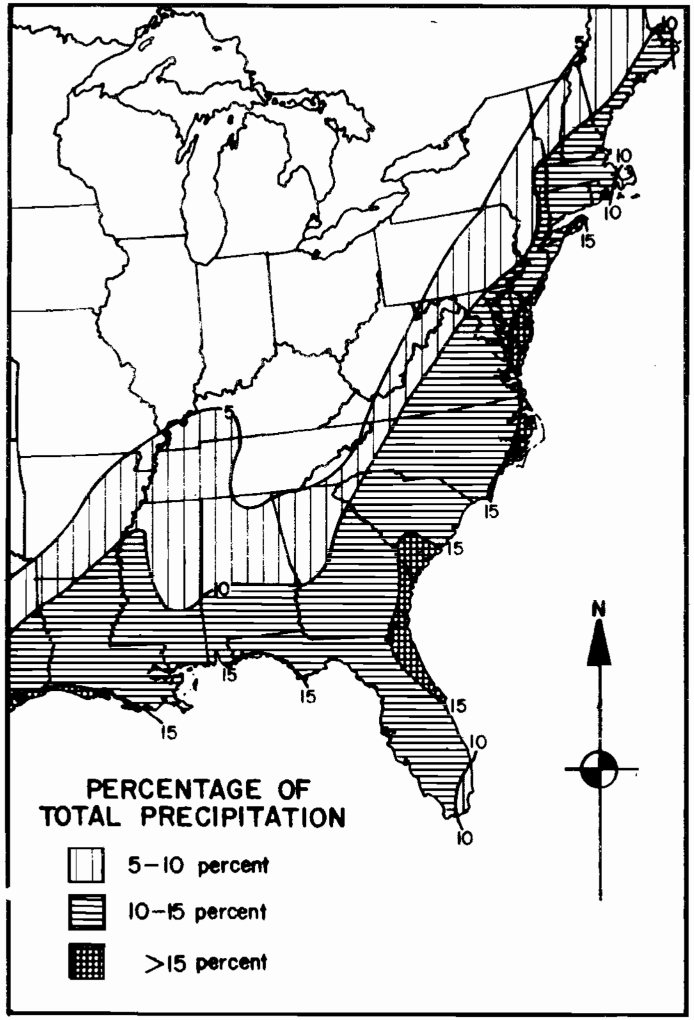


Figure 4-4. Tropical cyclone precipitation shown as the percentage of total precipitation for the period 1931 - 1960 (Cry 1967).

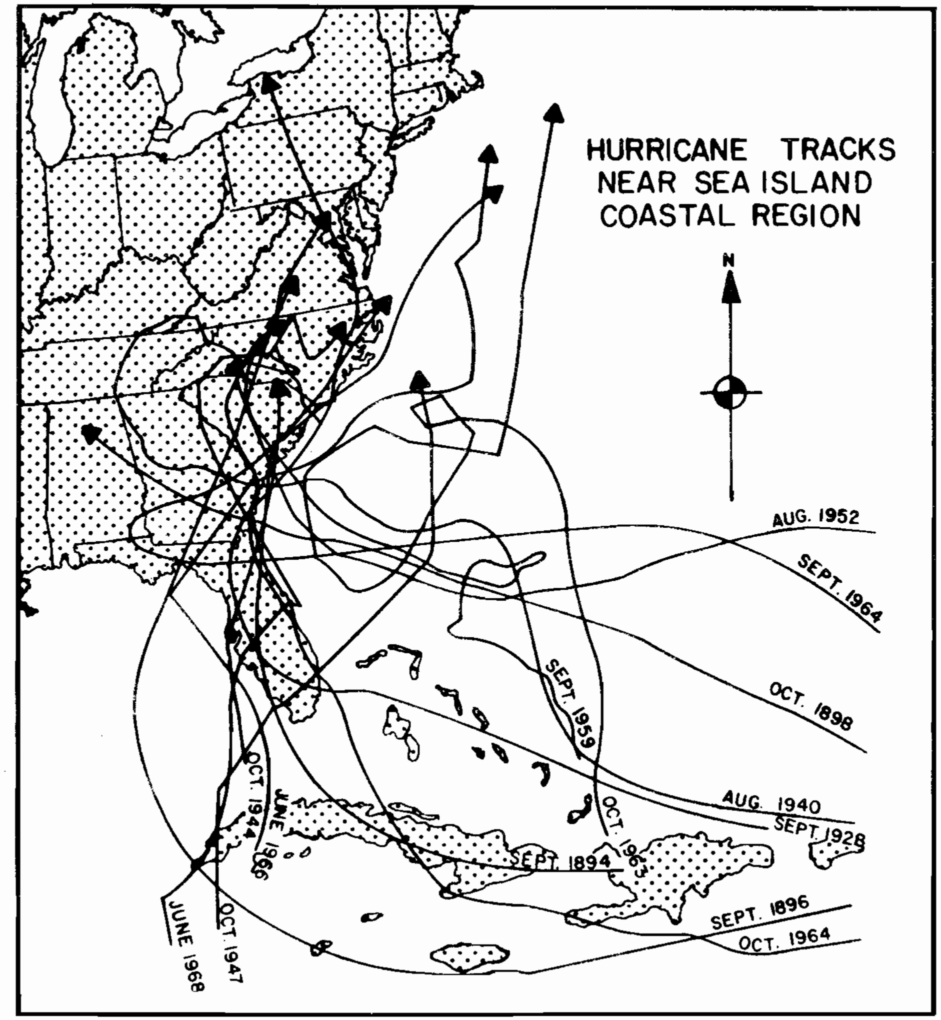


Figure 4-5. Hurricane tracks near the Sea Island Coastal Region (Sugg and Carrodus 1969).

CHAPTER FIVE

PHYSIOGRAPHY

I. INTRODUCTION

The Sea Island Coastal Region of South Carolina and Georgia is characterized by low, sandy islands which are covered by maritime forests and are partially surrounded by marsh. The whole area is a portion of the Atlantic Coastal Plain physiographic province in which the topography is basically broad depositional terrace surfaces, aligned in belts subparallel to the present shoreline. These terraces are Pleistocene coastal deposits, such as barrier islands, spits, shoals, marshes, and lagoons.

The seaward edge of the mainland is bordered by large areas of marsh, composed predominantly of salt marsh with limited amounts of freshwater and brackish marsh. These marshes cover many of the sand ridges, terraces, and major river flood plains to varying degrees. While tracts of marshland have been altered for rice cultivation, in the construction of the Atlantic Intracoastal Waterway (AIWW), or in dredge and fill operations for land development, large amounts of undeveloped marsh still exist in South Carolina and Georgia.

The Sea Island Coastal Region is also punctuated by numerous estuaries, some with significant freshwater discharge (major rivers) and some with very minor amounts of freshwater input (minor rivers). The former group occupies drowned river valleys while the latter group consists of bar-built estuaries located behind Pleistocene and Holocene barrier islands. The major rivers drain the Appalachian Mountains and Piedmont Plateau. These rivers occupy broad valleys with meandering channels, oxbow lakes, distributaries, and extensive sand dune fields, and the valleys typically cut straight across the Pleistocene depositional terraces of the coastal plain. Minor rivers, whose drainages originate within the coastal plain, are generally deflected by these Pleistocene coastal bodies in their paths to the coast and therefore do not have extensive sand dunes developed on their flood plains.

The coastal islands as a group consist of: 1) sea islands, erosion remnants of much older islands (Fig. 5-1) with an oceanward fringe of marsh and/or beach dune ridges constructed since the middle Holocene (≤5,000 yr ago); 2) sandy barrier islands with extensive dune ridges (Fig. 5-2); and 3) marsh islands with widely spaced dune ridges surrounded by marsh (Fig. 5-3). The barrier and marsh islands are Holocene in age, while the sea islands are Pleistocene. All three types which face the ocean have experienced erosion and deposition, while serving as protective barriers for the mainland.

The whole Sea Island Coastal Region is quite complicated with respect to geology, chemistry, and ecology. Geologically, the islands and marshes are unstable, being subject to migration due to natural forces such as waves, tides, currents, and winds. Man-induced alterations have further complicated the situation by locally accelerating rates of deposition and erosion. Jetties, sea walls, breakwaters, and groins have in many areas caused significant alteration of natural movements of sand by increasing deposition in one area and erosion in another. Upstream dams have altered discharge rates and sediment loads of rivers such as the Savannah and Cooper, the latter being an example of extreme alteration. The results of these man-induced changes are often quite significant in terms of environmental impact and cost to taxpayers. The Cooper River-Charleston Harbor System is a classic example, with the flow of the Santee, a major river, being diverted through a series of lakes into the Cooper, a coastal plain river. (See Chapter Six for a detailed discussion of the Santee Diversion and Rediversion projects.)

II. ISLANDS

A. ISLAND TYPES

Coastal islands are generally classified by either functional or structural criteria, and several island classification systems are currently in use. Functionally, islands of the Sea Island Coastal Region can be divided into two types: barrier islands and sea islands. In this regard, barrier islands are those islands fronting the open ocean and having high-energy beaches, while sea islands do not front the open ocean and consequently lack high-energy beaches. These simplistic, functional definitions have been used worldwide and were recently applied to the South Atlantic coast by Warner and Strouss (1976).

Geologists and other scientists have applied various technical criteria in developing structural classification schemes for coastal islands. The basis for these structural classifications is usually geological, since age and formation processes are so important to the overall character of any coastal island. Because these technical definitions are more precise in defining the nature and history of coastal islands,

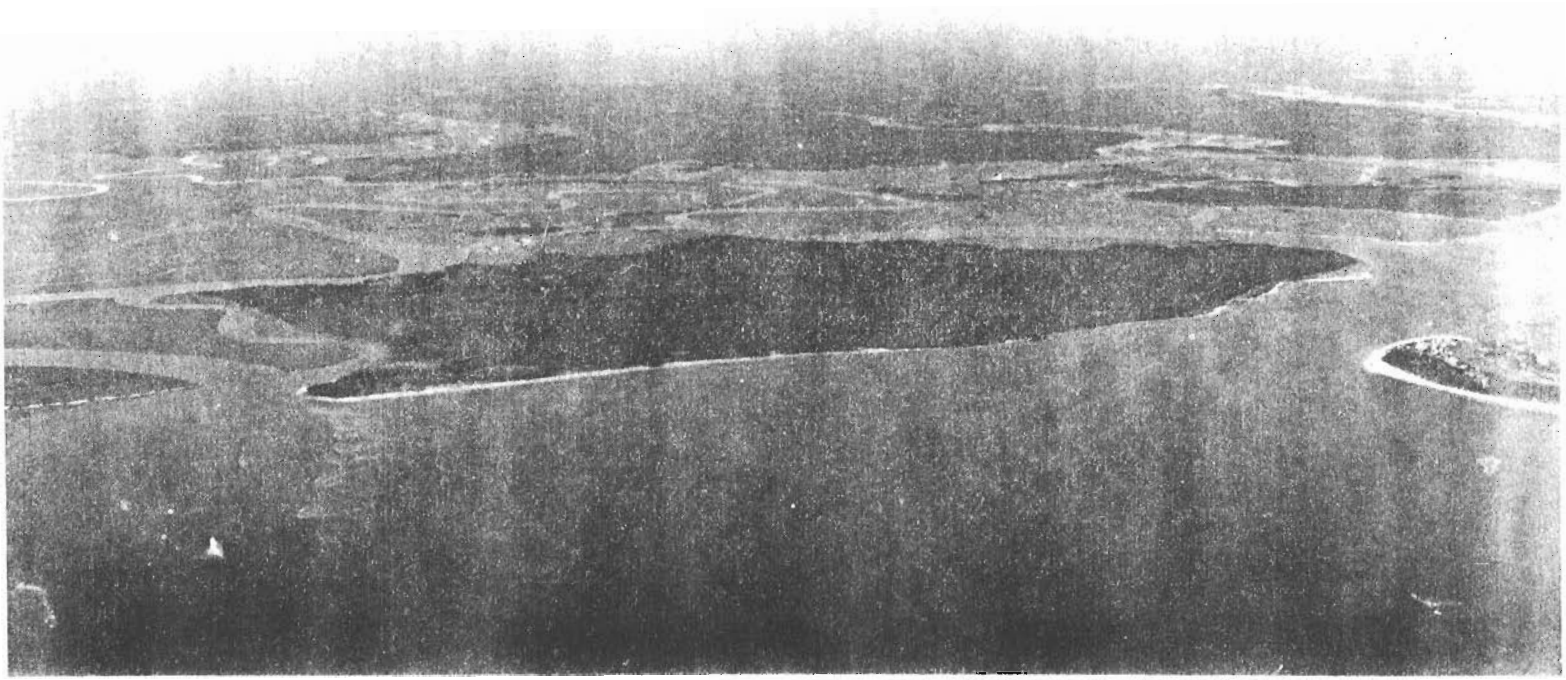


Figure 5-1. A representative sea island of the coastal area - Daufuskie Island, Beaufort County, South Carolina.

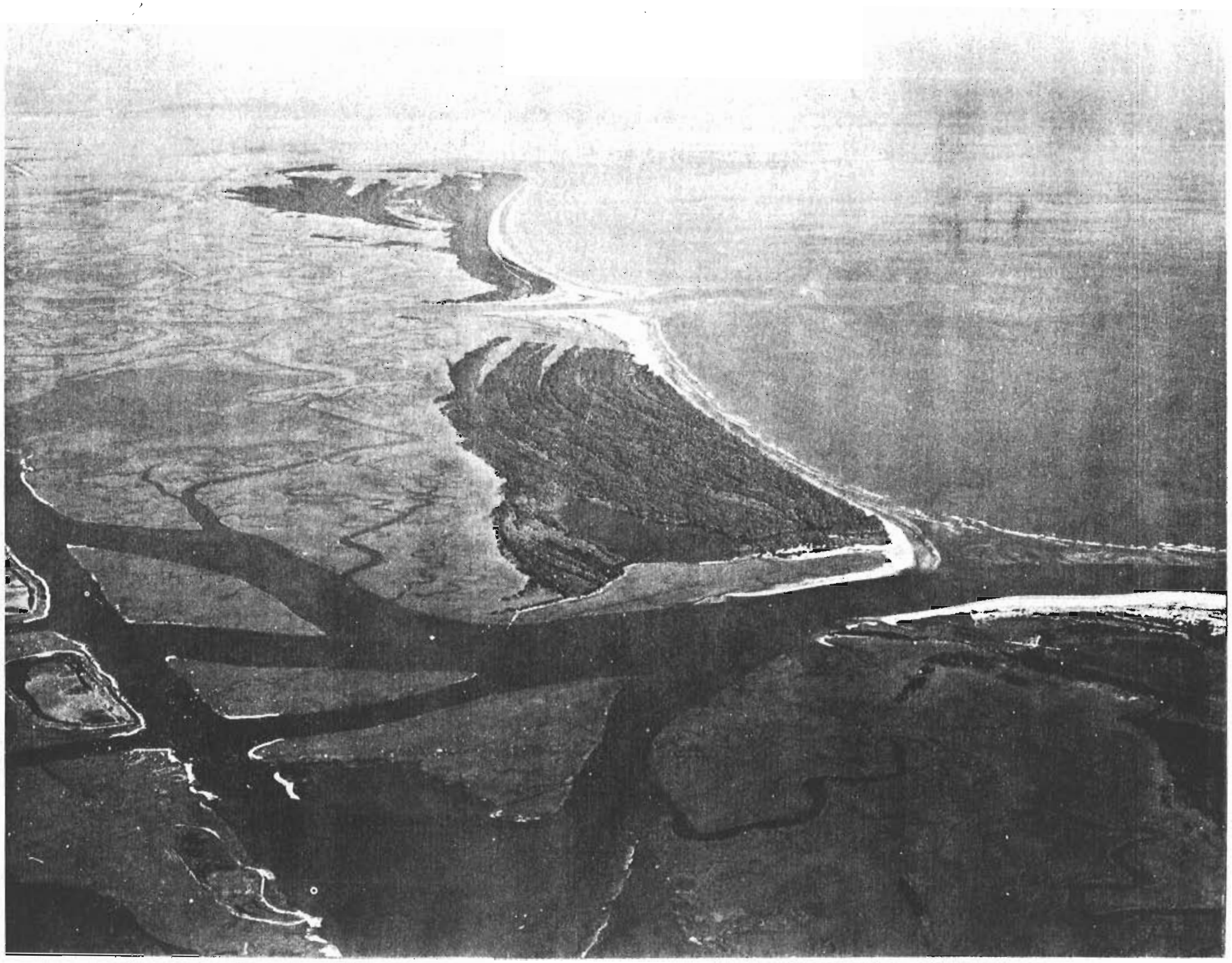


Figure 5-2. A representative barrier island of the coastal area - Capers Island, Charleston County, South Carolina.

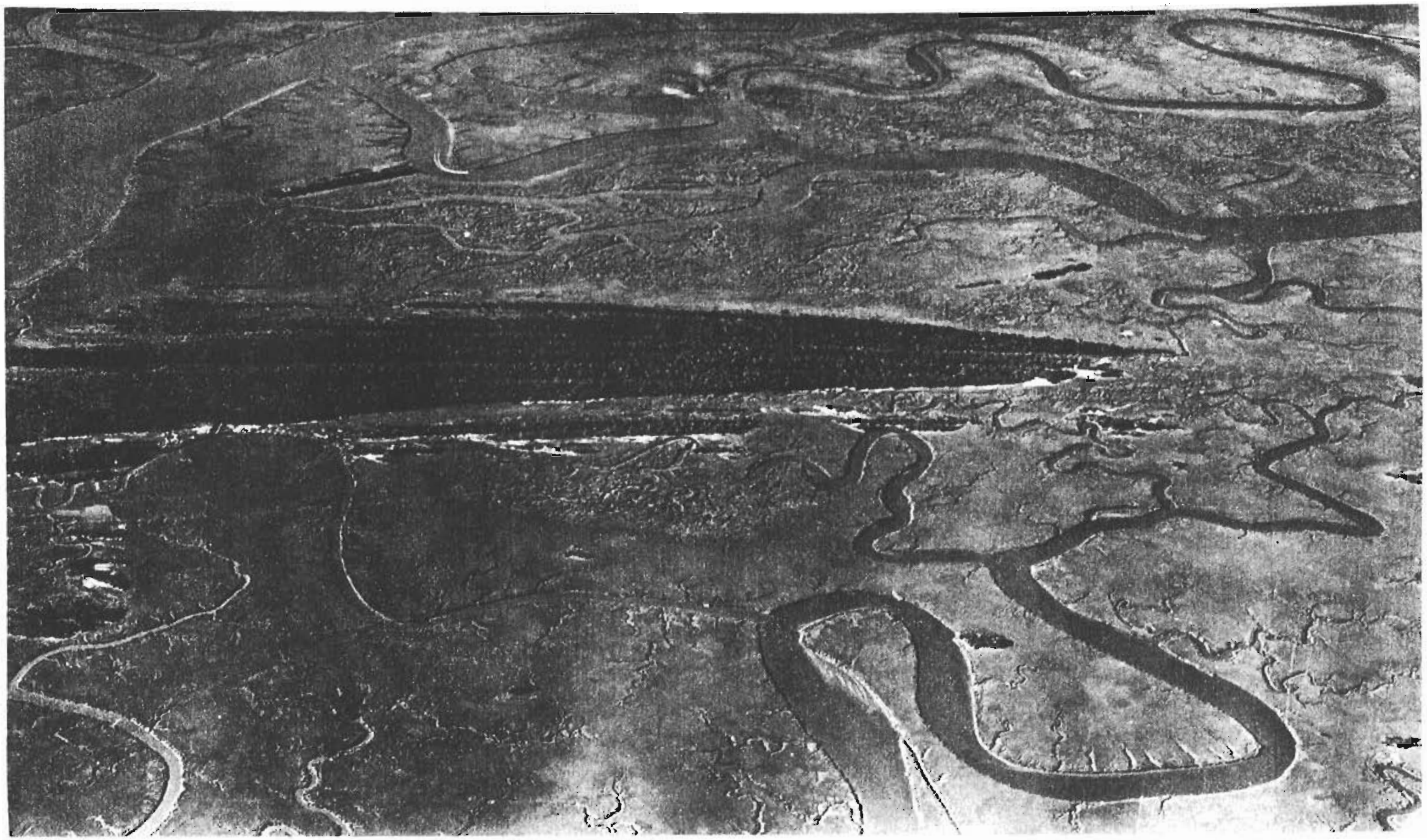


Figure 5-3. A representative marsh island of the coastal area - Little Tybee Island, Chatham County, Georgia.

a structural classification scheme has been adopted for use in the Sea Island Ecological Characterization. This scheme is described in the following pages, and is followed throughout the characterization documents.

The Sea Island Coastal Region is characterized by low-lying, sandy islands bordered by salt marsh. These islands can be classified into three major groups based on geomorphology, geologic age, bulk sediment composition, and environment of deposition. The classic sea islands of colonial and nineteenth-century fame (Fig. 5-1) are erosional remnants of coastal sand bodies deposited during the Pleistocene high sealevel stands (Zeigler 1959, Hoyt and Hails 1969). Those sea islands adjacent to the Atlantic Ocean (e.g., Hilton Head and Cumberland islands) have an oceanward fringe of beach dune ridges that were constructed during the present or Holocene high sealevel stand. Barrier islands (Fig. 5-2), composed of beach dune ridges oriented parallel to subparallel with the present shoreline, separate saltmarsh-vegetated lagoons from the open Atlantic Ocean. These barrier islands were deposited during the Holocene high sealevel stand. Marsh islands, composed of isolated or widely spaced Holocene sand ridges surrounded by Holocene salt marsh, are located in the filled lagoons behind the barrier islands and are demarcated by tidal creeks (Fig. 5-3). Where Holocene barrier islands have been removed by erosion, marsh islands front the Atlantic (e.g., Raccoon Key, Morris Island, and Wolf Island).

B. PHYSIOGRAPHY

1. Sea Islands

These erosional remnants of Pleistocene coastal sand bodies are crudely 1) elongate, parallel to the present day shoreline, and 2) rectangular in outline. Their topography is characterized by gentle slopes organized into wide, poorly defined ridges and troughs or swales (Fig. 5-4). Maximum elevations typically range between 5 to 35 ft MSL (4.5 to 10.5 m). The sandy soils support a maritime forest. (See Volume III, Chapter Three for detailed discussion of this maritime forest.) Detailed physiographic data for selected sea islands are presented in Table 5-1.

2. Barrier Islands

These islands are composed of beach dune ridges oriented parallel to subparallel with the present shoreline. The beach dune ridges are organized into discrete geographic sets in the more complex barriers. The ridge and swale topography contains locally steep slopes, e.g., the back beach dunes (Fig. 5-4). These islands are elongate parallel to the present shoreline and are crudely rectangular in outline. Maximum beach

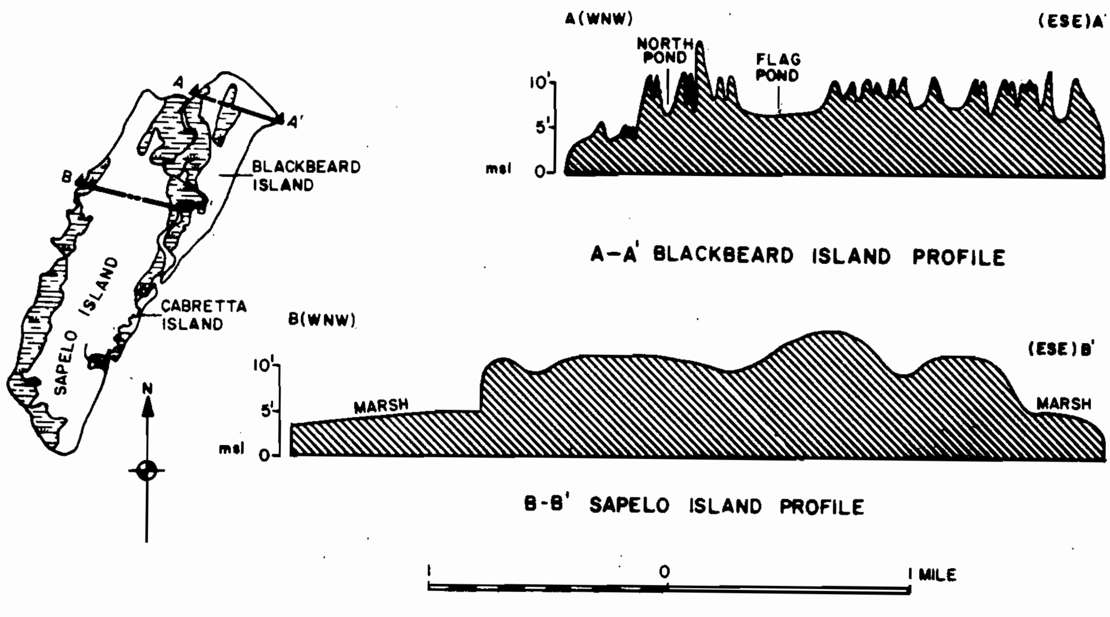


Figure 5-4. Topographic profiles across a representative sea island (B - B') and a representative barrier island (A - A').

Table 5-1. Physiographic data and development status for select barrier, marsh, and sea islands of South Carolina and Georgia.

County / Island	Length (Miles)(a)	Width (Miles)(b)	Miles of Ocean Shoreline	Max. Eleva. ft. above MSL	Tidal Range	Physiographic Type (c)	Geological Age (d)	Erosional Status (e)	Adjacent Major Inlets	Vegetative Cover (f)	Acres of High Land	Acres of Marsh	Impoundments present acreage	Acres of Developed High Land	Acres of Undeveloped High Land	Ownership	Access (g,h)	Future Development Status
Georgetown																		
Pawleys	3.5	0.5	3.5	13	4.8-5.6	B	H	E	Midway Pawleys	MF	170	640	0	162	8	private	bridge	limited
North	8.3	2.0	8.0	42	4.5-5.3	B	H	S	North Winyah Bay	MF	701	5,329	0	1	700	state	boat	unknown
South	5.5	2.0	5.5	21	4.6-5.4	M	H	D	Winyah Bay N. Santee Bay	MF	870	3,450	2,355	0	870	state	ferry	none
Cedar	4.8	4.1	3.0	16	4.1-4.8	M	H	E	N. Santee Bay S. Santee R.	MF	280	3,770	2,700	0	280	state	boat	none
Charleston																		
Murphy	6.0	3.3	4.1	16	4.1-4.8	M	H	E	S. Santee R. Cape Romain Hbr.	MF	690	7,340	5,547	0	690	state	boat	none
Cape	5.3	1.3	5.3	10	4.7-5.5	B	H	E	Cape Romain Hbr., Key Inlet	MSS MF	875	625	192	0	875	federal	boat	none
Lighthouse	2.4	0.9	7.0	10	4.7-5.5	M	H	E	Cape Romain Hbr., Key Inlet	MSS	37	906	0	0	37	federal	boat	none
Raccoon Key	5.5	1.4	5.4	5	4.9-5.8	M	H	E	Key Inlet Bulls Bay	MD	25	140	0	0	25	federal	boat	none
Bull	6.8	1.9	6.8	27	4.8 5.8	B	H	S&E	Bulls Bay Price Inlet	MF	1,980	2,520	620	0	1,890	federal	ferry	none
Capers	3.4	1.5	3.3	15	5.0-6.1	B	H	E	Price Inlet Capers Inlet	MF	850	1,090	110	0	850	state	boat	none
Dewees	2.2	1.4	2.2	10	5.0-5.9	B	H	S	Capers Inlet Dewees Inlet	MF	290	650	296	5	285	private	boat	125 units
Isle of Palms	6.3	0.9	6.2	45	5.2-6.1	B	H	E&D	Dewees Inlet Breach Inlet	MF	1,700	520	0	1,300	400	private	bridge	in progress
Sullivans	3.5	1.0	3.0	10	5.2-6.1	B	H	D	Breach Inlet Chas. Harbor	MF	830	480	21	809	21	private federal	bridge	none

Table 5-1. Continued

County Island	Length (Miles)(a)	Width (Miles)(b)	Miles of Ocean Shoreline	Max. Eleva. ft. above MSL	Tidal Range	Physiographic Type (c)	Geological Age (d)	Erosional Status (e)	Adjacent Major Inlets	Vegetative Cover (f)	Acres of High Land	Acres of Marsh	Impoundments present acreage	Acres of Developed High Land	Acres of Undeveloped High Land	Ownership	Access (g,h)	Future Development Status
Charleston (cont.)																		
Morris	3.5	1.6	3.5	10	5.0-5.9	M	H	E	Chas. Harbor Lighthouse	MSS	120	1,390	640	0	120	private & state	boat	none
James	7.0	7.0	0	30	5.0-5.9	S	P	S	Stono Inlet Chas. Harbor	CP	11,000	4,800	50	*	*	private	bridge	yes
Folly	6.0	0.5	6.0	20	5.2-6.1	B	H	E	Lighthouse Inlet & Stono Inlet	MD	710	690	0	500	210	private	bridge	yes
Kiawah	9.1	2.0	9.0	25	5.2-6.1	B	H	S	Stono Inlet, Kiawah River & Captain Sams Inlet	MF	3,300	3,730	281	50	3,250	private	bridge	7,000 units
Seabrook	3.5	2.8	2.5	27	5.8-6.8	B	H	D	Captain Sams Inlet, Kiawah River & North Edisto River	MF	2,610	2,710	0	1,000	1,610	private	bridge	yes
Deveaux Bank	<1.0	<1.0	<1.0	10	5.8-6.8	SB	H	E	N. Edisto R.	MSS	81	0	0	0	81	non-profit	boat	yes
Botany Bay	1.2	0.7	1.0	5	5.8-6.8	B	H	E	N. Edisto R. South Creek	MF	260	212	0	1	259	private	ferry & boat	yes
Colleton																		
Edisto Beach	4.4	1.5	4.0	30	5.9-6.9	B	H	E	Jeremy Inlet S. Edisto R.	MF	920	464	0	870	50	private & state	bridge	yes
Pine	1.7	1.0	1.6	10	6.1-7.2	M	H	S	S. Edisto R. Fish Creek	MSS MF	40	900	0	0	40	private	boat	none
Otter	2.0	1.2	1.8	10	6.2-7.3	M	H	S	Fish Creek, Jefford Creek & St. Helena Sound	MF	250	2,000	0	0	250	private	boat	none

County Island	Length (Miles	Width (Mile	Miles Ocean Shore	Max. ft. MSL	Tida Rang	Phys ic T	Geo Age	Ero Sta	Ad Ma In	Ve Cc	A H							
Beaufort																		
St. Helena	13.0	2.0	0	20	6.2-7.3	S	P	S	St. Helena Sound Beaufort R.	CP	21,053	13,125	*	*	*	private	bridge	unknown
Hunting	4.1	1.1	4.0	20	6.2-7.3	B	H	E	Johnson Creek Fripp Inlet	MF	1,420	270	0	100	1,320	state	bridge	none
Fripp	3.3	1.4	3.0	25	6.2-7.3	B	H	E	Fripp Inlet Skull Inlet	MF	1,030	840	49	100	930	private	bridge	yes
Pritchards	2.5	1.6	2.5	10	7.0-8.3	B	H	E	Skull Inlet Pritchards Inlet	MF	370	1,150	0	1	369	private	boat	unknown
Little Capers	2.5	1.2	2.5	<10	6.9-8.1	M	H	E	Pritchards Inlet Trenchard Inlet	MF	120	680	0	10	110	private	boat	unknown
St. Phillips	6.0	1.6	1.0	10	6.9-8.1	M	H	E	Trenchard Inlet Morse Is. Cr.	MF	1,230	4,180	0	0	1,230	private	boat	yes
Bay Point	2.6	0.5	2.5	10	6.6-7.8	M	H	E	Morse Is. Cr. Port Royal Sound	MF	235	215	0	0	235	private	boat	none
Hilton Head	11.5	6.8	11.5	21	6.6-7.8	S	P&H	E	Port Royal Sound Calibogue Sound	MF	19,460	2,400	19	13,460	6,000	private	bridge	yes
Daufuskie	5.0	2.7	3.0	30	7.2-8.4	S	P&H	S	Calibogue Sound New River	MF	5,200	950	0	160	5,040	private	boat	yes
Jasper																		
Turtle	2.5	1.9	2.5	10	7.1-8.3	M	H	S	New River Wright River	MSS	120	1,600	0	0	120	state	boat	none

Table 5-1. Continued

County Island	Length (Miles)(a)	Width (Miles)(b)	Miles of Ocean Shoreline	Max. Eleva. ft. above MSL	Tidal Range	Physiographic Type (c)	Geological Age(d)	Erosional Status(e)	Adjacent Major Inlets	Vegetative Cover(f)	Acres of High Land	Acres of Marsh	Impoundments present acreage	Acres of Developed High Land	Acres of Undeveloped High Land	Ownership	Access(g,h)	Future Development Status
GEORGIA																		
Chatham																		
Tybee	3.4	4.0	3.4	18	6.8-8.0	B	H	E	South Channel to Sav. R. & Little Tybee	MF	1,500	1,930	*	1,000	500	private	bridge	none
Little Tybee	5.6	4.0	5.0	10	6.8-8.0	M	H	E	Tybee Creek Wassaw Sound	MF	600	6,180	*	0	600	private	boat	unknown
Wassaw	6.0	2.0	6.0	10	7.6-8.9	B	H	D&E	Wassaw Sound Ossabaw Sound	MF	2,358	7,692	*	5	2,353	federal	boat	none
Ossabaw	9.5	4.0	9.5	25	7.2-8.4	S	H&P	D	Ossabaw Sound St. Catherines Sound	MF	8,700	12,350	*	50-100	8,600	state	boat	unknown
Williamson	1.7	0.2	1.7	6	6.8-8.0	M	H	D	Little Tybee Cr. Wassaw Sound	MSS	256	unknown	*	0	256	disputed	boat	none
Liberty																		
St. Catherines	11.0	3.3	11.0	23	6.9-8.1	S	H&P	E	St. Catherines Sound Sapelo Sound	MF	6,870	7,772	*	100	6,770	non-profit	boat	none
McIntosh																		
Blackbeard	6.4	2.6	6.3	30	6.9-8.1	B	H	E	Sapelo Sound Blackbeard Inlet	MF	3,620	2,000	*	0	3,620	federal	boat	none
Cabretta	2.5	0.5	2.5	14	6.8-8.0	B	H	E	Cabretta Inlet Big Hole Inlet	MSS	688	201	*	0	688	state	boat	unknown
Sapelo	8.6	3.0	3.0	27	6.8-8.0	S	P	D	Blackbeard Cr. Doboy Sound	MF	10,900	7,050	*	200-300	10,600	state	ferry	none
Wolf	3.0	3.0	0	10	6.6-7.7	M	H	E	Doboy Sound Altamaha Sound	MSS	250	4,876	*	0	250	federal	boat	none

Table 5-1. Concluded

County Island	Length (Miles)(a)	Width (Miles)(b)	Miles of Ocean Shoreline	Max. Eleva. ft. above MSL	Tidal Range	Physiographic Type (c)	Geological Age (d)	Erosional Status(e)	Adjacent Major Inlets	Vegetative Cover (f)	Acres of High Land	Acres of Marsh	Impoundments present acreage	Acres of Developed High Land	Acres of Undeveloped High Land	Ownership	Access(g,h)	Future Development Status
Glynn																		
Little St. Simons	10.5	3.0	5.4	28	6.8-8.0	M	H	D	Doboy Sound Hampton R.	MF	2,300	6,500	*	1	2,299	private	boat	none
St. Simons	11.0	3.0	3.0	25	6.5-7.7	S	P	E	Goulds Inlet St. Simons S.	MF	12,300	13,329	*	2,500	9,800	private	bridge	yes
Sea	4.6	2.0	4.5	22	6.6-7.8	B	H	S	Hampton River Goulds Inlet	MF	1,100	800+	*	736	364	private	bridge	yes
Jekyll	8.0	1.5	8.0	35	7.2-8.4	S	H&P	E	St. Simons Sound St. Andrews Sound	MF	4,300	1,400	*	3,700	600	state (leased by private owners)	bridge	yes
Camden																		
Little Cumberland	3.5	1.4	2.4	55	6.8-8.0	S	H&P	S	St. Andrews Sound Christmas Creek	MF	1,410	1,000	*	200	1,210	private	boat	limited
Cumberland	17.0	4.0	17.0	55	6.8-8.0	S	H&P	S	Christmas Creek Cumberland Sound	MF	15,150	8,050	*	0	15,150	private & federal	ferry	unknown

a. Length: Includes high land and marsh.

b. Width: Includes high land and marsh.

c. Physiographic Types: B-Barrier Island; M-Marsh Island; S-Sea Island; SB-Sand Bar.

d. Geologic Age: H-Holocene; P-Pleistocene.

e. Erosional Status: E-Erosional; D-Depositional; S-Stable.

f. Vegetative Cover: MF-Maritime forest; MSS-Maritime shrub scrub; MD-Maritime dune; CP-Coastal pine-mixed hardwood.

g. Ferry: Scheduled ferry or toll boat.

h. Boat: Unscheduled private or passenger boat.

* Data not available.

dune ridge elevations typically range between 10 and 25 ft MSL (3 and 7.5 m) with back beach dune crests going as high as 55 ft MSL (16.5 m). The sandy soils of these islands support a maritime forest. (See Volume III, Chapter Three for a detailed discussion of this maritime forest.) Detailed physiographic data for all the barrier islands in the Sea Island Coastal Region are presented in Table 5-1.

3. Marsh Islands

These islands are composed principally of tidal marsh and are geographically demarcated by tidal creeks, with many islands containing isolated or widely spaced Holocene sand ridges. The sloping nature of the tidal marsh surface is so flat and gentle that the topography is not usually depicted on even the most detailed Geological Survey topographical maps. Marsh islands, with the exception of any sand ridges, are periodically flooded by tidal waters. Detailed physiographic data for the marsh islands fronting the Atlantic Ocean are presented in Table 5-1.

C. GEOLOGIC FACTORS

The extremely wide, shallow, and gently sloping continental shelf; the relative shortage of sand, compared with silt and clay, available for coastal deposition; and the Holocene sealevel rise are the major geologic factors controlling deposition in the Sea Island Coastal Region. The character of the continental shelf produces lower waves and a higher tidal range for this area as compared with adjacent North Carolina and Florida. Rivers draining the Appalachian Piedmont, as well as the coastal plain, supply the silts and clays of the marshes. Most sand contained in coastal deposits, although originally land-derived and transported to the ocean by rivers, probably came directly from those offshore areas of the continental shelf immediately adjacent to the coast (Pilkey and Field 1972).

D. BARRIER ISLAND FORMATION

1. Proposed Mechanisms

The mechanisms responsible for coastal island formation have been topics of much discussion among geologists, geographers, and engineers since the pioneering study of de Beaumont in 1845. Bars emerging from the ocean by natural deposition (Fig. 5-5), spits migrating along the shore (Fig. 5-6), and the submerging of pre-existing coastal sand ridges by a rising sea (Fig. 5-7) are some of the more important mechanisms suggested by

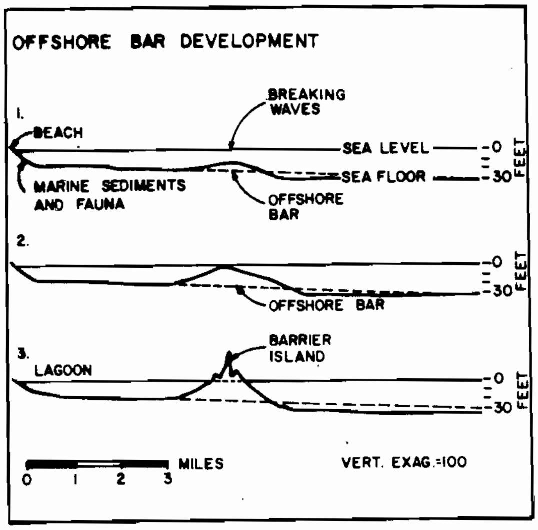


Figure 5-5. Idealized cross sections of barrier island formation from an offshore bar (Hoyt 1967). 1. Waves agitate sea floor and deposit sediment to form offshore bar. 2. Sediment builds offshore bar to near sea level. 3. Offshore bar is converted to island with lagoon on landward side. This idea was first proposed by de Beaumont (1845).

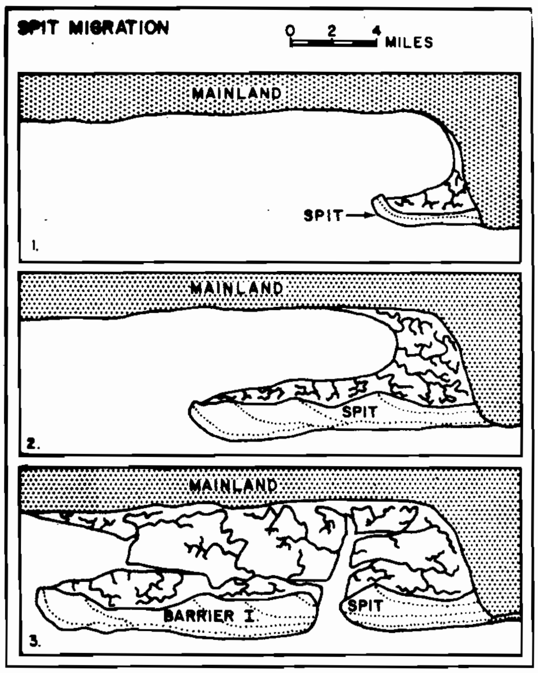


Figure 5-6. An idealized diagram showing barrier island formation from a migrating spit (Hoyt 1967). 1. and 2. Spit develops in the direction of longshore sediment transport. 3. Spit breached to form barrier island. This idea was first proposed by Gilbert (1885).

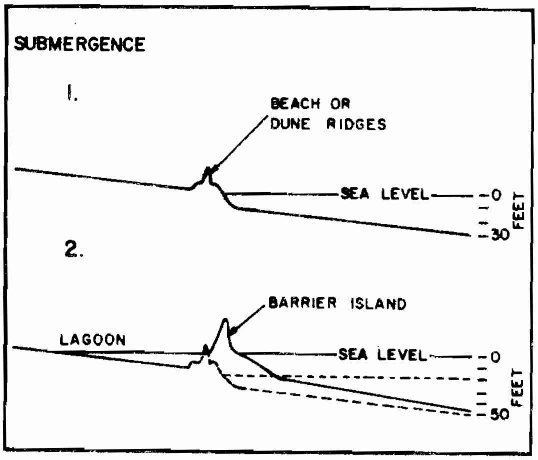


Figure 5-7. An idealized diagram showing the formation of barrier islands by submergence (Hoyt 1967). 1. Beach or dune ridge forms adjacent to shoreline. 2. The rising sea floods area landward of ridge to form barrier island and lagoon.

researchers [see Schwartz (1973) for historical review]. Hoyt (1967) developed a model of barrier island formation using, among others, examples from the Georgia coast. His model stresses the importance of 1) slow submergence of a pre-existing coastal sand ridge (Fig. 5-7) and 2) island migration parallel and perpendicular to the shore.

2. Observations from Sea Island Coastal Region

The following observations are pertinent to understanding the origin and development of the Sea Island Coastal Region barrier islands and to evaluating proposed mechanisms or processes of their formation:

1) These islands are composed of parallel beach dune ridges, some of which are organized into distinct groups or sets (e.g., Bull and Little St. Simons islands). This indicates that seaward progradation or growth, punctuated by periods of erosion, has been of primary significance. These islands have not migrated landward by overwash processes, as is the predominant condition along North Carolina's Outer Banks. Spit-type migration has occurred, especially adjacent to major tidal inlets, but has been usually accompanied by net seaward growth.

2) There have been several periods of barrier island formation in the Sea Island Coastal Region. This is indicated by sequences of sand ridge islands extending from the Pleistocene mainland across the marsh-filled lagoon to the present Holocene barrier islands fronting the Atlantic. Beaufort County, South Carolina, has perhaps the best developed example. Between Ladies Island (a Pleistocene erosional remnant or sea island) and Fripp and Pritchard islands (the Holocene barriers fronting the Atlantic) are found St. Phillips (Atlas plate 6) and Old islands, which could be considered marsh islands. However, as both St. Phillips and Old islands are composed of many sand ridges (the former organized into several distinct groups and the latter showing a spit geomorphology), they should be recognized as Holocene barrier islands stranded in the marsh-filled lagoon by subsequent coastal progradation.

3) The lagoon between the Pleistocene mainland and the ocean-fronting Holocene barrier islands is not filled exclusively with silt and clay. Preliminary work done by Van Dolah et al. (1979) in the marsh behind Bull Island, Charleston County, South Carolina, indicates that extensive subtidal to intertidal sand sheets containing estuarine and marine mollusk assemblages underlie the marsh silts and clays. Similar results have been obtained in the Charleston, South Carolina, region (F. W. Stapor, 1978, South Carolina Marine Resources Division, Charleston, unpubl. data) and in the Savannah, Georgia, region (G. F. Oertel, 1978, Old Dominion University, Norfolk, Virginia, pers. comm.; F. W. Stapor, 1978, South Carolina Marine Resources Division, Charleston, unpubl. data).

E. EROSION

1. Barrier Islands

The sandy barrier islands and the marsh islands facing the open Atlantic Ocean, subject to waves and tidal currents, are experiencing erosion and deposition. The Holocene sandy barrier islands, being separated from each other by tidal inlets and sounds, tend to form independent littoral drift systems or cells having minimal net exchange (Oertel and Howard 1972, Oertel 1975a, Stapor and Murali 1978). Shore-parallel or littoral transport is thus not a simple, integrated river-of-sand flowing south, but rather a complicated series of short cells transporting material to the north and south (see discussion of littoral drift of coastal inlets, page 88). The ebb-tidal deltas separating these barrier islands appear to be serving as significant deposition sites for sand eroded off the adjacent islands (Olsen 1977).

The jetties employed in navigation projects at Winyah Bay Entrance, Charleston Harbor, and St. Marys River Entrance have had measurable impacts on the adjacent barrier island beaches. Stapor (1977) demonstrated that the jetties at Charleston Harbor have induced deposition on their adjacent barriers. The jetties at St. Marys Entrance have probably accelerated erosion on portions of their barriers as well as deposition (Olsen 1977).

2. Marsh Islands

Coastal erosion is locally severe along the marsh islands. Since these marsh islands are largely undeveloped and hence uninhabited, little attention has been drawn to their plight. Some of the most extreme shore retreat measured in the Sea Island Coastal Region has been measured on these islands (Stephen et al. 1975).

3. Control Measures

Erosion of certain sandy barrier islands has so threatened houses, roads, and public recreation facilities that extensive control measures have had to be taken. The U.S. Army Corps of Engineers has beach nourishment projects underway at Hunting Island, Beaufort County, South Carolina, and Tybee Island, Chatham County, Georgia. Groin fields have been installed with mixed results at Pawleys Island, Georgetown County, South Carolina; Folly Beach, Charleston County, South Carolina; Edisto Beach, Colleton County, South Carolina; Hilton Head Island, Beaufort County, South Carolina; and Tybee Island, Chatham County, Georgia. Bulkheads and revetments are in place along the Isle of Palms, Charleston County, South Carolina, and St. Simons and Jekyll islands, Glynn County, Georgia. Some of this accelerated erosion appears to be in response to man-induced alterations which intercept littoral drift (e.g., jetties, groins, etc.), indicating that at least some of the erosion control measures are doing more long-term harm than good.

III. MAINLAND PHYSICAL FEATURES

The mainland portions of the South Carolina and Georgia counties covered in this study are part of the Atlantic Coastal Plain physiographic province and consist of low-lying broad sand ridges and terraces covered principally with pine and pine-hardwood forests. These ridges and terraces are relict Pleistocene coastal deposits, e.g., beach ridges, marine scarps, coastal dunes, barrier islands, and back-barrier lagoons/flats (Colquhoun 1974, Dubar et al. 1974, Hoyt and Hails 1974). Regional topographic relief is measured in tens of meters, but slopes are very gentle except where rivers have cut steep banks. Maximum topographic elevations for the tier of coastal counties range between 10 and 20 m (33 and 66 ft) and for the inland counties of Effingham, Dorchester, and Berkeley range between 30 and 45 m (98 and 148 ft).

The seaward edges of these sand ridges and terraces are buried by salt, brackish, and freshwater marshes, giving the impression of an eroded land mass submerged beneath a marsh sea. This results in a highly complex, digitate interface between the sandy high lands and the coastal marsh. Coastal marsh occupies the intertidal areas of the major river flood plains, grading from salt, to brackish, to fresh water in an upstream sequence (Atlas plates 9 - 18). These marshes are middle to late Holocene in age (less than 5,000 years old). Colonial and nineteenth-century rice cultivation resulted in the impounding of extensive tracts of coastal marsh (Atlas plates 9 - 18). The creation of dredge spoil areas, necessary for harbor navigation projects and the Atlantic Intracoastal Waterway, has resulted in the impounding of significant areas of coastal marsh during the twentieth century.

Carolina Bays are developed throughout the region on the major sand ridges, sandy terraces, and some river flood plains. (See Chapter II for a detailed discussion.)

The major rivers, those originating beyond the coastal plain, all have wide flood plains and exhibit evidence of being underfit or too small for their flood plains. The Pee Dee, Santee, Savannah, and Altamaha flood plains contain localized dune sheets (Thom 1970). The Pleistocene dunes have relief of 10 to 25 m (33 to 82 ft), and their crests are roughly oriented east-west (Atlas plates 9,11,and 17).

The two main geomorphic units of the Sea Island Coastal Region are 1) the quartz sand ridges and terraces, and 2) the silty, clayey marsh plains. Tables 5-2 and 5-3 present acreages of marsh, impoundments, forest, farmland, and developed land, which are mapped on Atlas plates 9 - 18.

IV. MAJOR RIVER VALLEYS

A. INTRODUCTION

The Sea Island Coastal Region is laced with numerous rivers and creeks, mostly tidal, with minimum freshwater discharge. These rivers, meandering across marsh plains, served during the colonial period and the nineteenth century as major communication arteries. Today they serve primarily a

Table 5-2. Physiographic data for 14 counties included in the Sea Island Coastal Region.

Counties	Acres Urban Land	Approx. Mi. of Shore-line	Acres Forested	Acres Agri-culture	Total Acres Coastal Marsh	Acres Brackish & Saltwater Marshes	Acres Fresh-water Marshes	Acres Tidal Swamp	Acres Impound-ments
Georgetown	21,801[a]	36.2[b]	391,300[c] (1968)	34,953[a] (1967)	56,244[d]	20,540[d]	23,764[d]	*	11,940[d]
Berkeley	29,546[a]	none	583,300[c] (1968)	63,617[a] (1967)	29,057[d]	7,252[d]	17,511[d]	*	4,294[d]
Dorchester	5,041[a]	none	263,200[c] (1968)	64,716[a] (1967)	1,346[d]	439[d]	862[d]	*	45[d]
Charleston	45,416[a]	c.75[b]	391,300[c]	29,390[e]	170,400[d]	142,401[d]	5,000[d]	*	22,999[d]
Colleton	26,885[a]	4[b]	484,500[c] (1968)	131,300[a] (1967)	59,845[d]	30,641[d]	8,608[d]	*	20,596[d]
Beaufort	18,543[a]	36.1[b]	157,000[c] (1968)	54,381[a] (1967)	135,816[d]	130,015[d]	1,523[d]	*	4,278[d]
Jasper	10,600[a]	2.8[b]	312,900[c] (1968)	48,215[a] (1967)	48,774[d]	36,014[d]	6,536[d]	*	6,224[d]
Chatham	61,074[f]	c.23[g]	109,779[f]	21,197[f]	106,145[h]	91,965[h]	12,180[h]	2,000[h]	*
Effingham	7,294[f]	none	247,811[i] (1973)	126,975[i] (1969)	0	*	*	*	*
Liberty	7,946[j]	c.10.5[g]	278,753[j] Combined (1978)		42,261[h]	39,761[h]	1,500[h]	1,000[h]	*
Bryan	7,840[k]	none	161,310[k] Combined (1970)		26,200[h]	20,495[h]	2,020[h]	3,685[h]	*
McIntosh	3,760[j]	c.14[g]	171,715[j] Combined (1978)		97,165[h]	77,485[h]	5,647[h]	14,033[h]	*
Glynn	24,935[j]	c.21[g]	155,109[j] Combined (1978)		83,636[h]	74,236[h]	4,700[h]	4,700[h]	*
Camden	5,392[j]	c.17.5[g]	292,253[j] Combined (1978)		120,275[h]	78,275[h]	21,000[h]	21,000[h]	*

a. South Carolina State Soil and Water Conservation Needs Committee 1970.
b. U.S. Army Corps of Engineers 1972a.
c. Welch 1968.
d. Tiner 1977.
e. U.S. Department of Agriculture Extension Service, 1978, Clemson University, Clemson, unpubl. data.
f. Wilkes 1978.
g. South Carolina Marine Resources Division, 1978, Charleston, unpubl. data.
h. Wilkes 1976.
i. Coastal Area Planning and Development Commission 1975b.
j. Coastal Area Planning and Development Commission 1978.
k. Coastal Area Planning and Development Commission 1975a.
* Data not available.

Table 5-3. Statistical data for 14 counties included in the Sea Island Coastal Region.

Counties	Area Miles^2	Approx. Maximum Elevation (feet)	Total Population (1970)	County Seat	River Systems
Georgetown	813[a]	75	33,500[b]	Georgetown	Pee Dee/Waccamaw, Black, Santee, Sampit
Berkeley	1,100[a]	105	56,199[b]	Moncks Corner	Wando, Cooper
Dorchester	569[a]	130	32,276[b]	St. George	Ashley, Edisto
Charleston	940[a]	70	250,000[b]	Charleston	Santee, Wando, Cooper, Ashley, Stono, N. & S. Edisto
Colleton	1,048[a]	125	27,622[b]	Walterboro	S. Edisto, Edisto, Ashepoo, Combahee, Salkehatchie
Beaufort	581[a]	40	51,136[b]	Beaufort	May, Combahee, Broad, Pocotaligo, Coosawhatchie, New, Colleton
Jasper	661[a]	105	11,885[b]	Ridgeland	New, Savannah
Chatham	441[c]	70	187,767[d]	Savannah	Savannah, Little Ogeechee, Ogeechee, Canoochee, Wilmington
Effingham	480[e]	135	13,632[d]	Springfield	Savannah, Ogeechee
Liberty	514[e]	70	17,569[d]	Hinesville	Medway/Jericho, Canoochee, Medway, N. & S. Newport
Bryan	443[f]	150	6,539[d]	Pembroke	Ogeechee, Medway, Canoochee, Jericho
McIntosh	426[e]	80	7,371[d]	Darien	S. Newport, Altamaha, Sapelo
Glynn	c. 491[e]	50	50,528[d]	Brunswick	Altamaha, Turtle/Brunswick, Little Satilla
Camden	653[e]	80	11,334[d]	Woodbine	Little Satilla, Satilla, Crooked, St. Marys

a. South Carolina State Soil and Water Conservation Needs Committee 1970.
b. South Carolina Budget and Control Board 1977.
c. Wilkes et al. 1974.
d. Coastal Area Planning and Development Commission 1973.
e. Coastal Area Planning and Development Commission 1975b.
f. Coastal Area Planning and Development Commission 1975a.

recreational function. Superimposed on this network of tidal rivers and creeks are the major water courses draining the coastal plain and/or the Appalachian Mountains and Piedmont. These major rivers can be broken down into two classes: 1) those originating in the coastal plain and 2) those originating in the Appalachian Mountains and Piedmont. The former class includes the Black, Waccamaw, Cooper, and Combahee-Salkehatchie of South Carolina and the Satilla and St. Marys of Georgia. The Pee Dee, Santee, Edisto, Savannah, Ogeechee, and Altamaha comprise the latter class. All of these major rivers served as arteries of communication during the colonial period and the nineteenth century. Additionally, the coastal flood plains of these rivers were also valuable as sites for rice cultivation. Today, the major rivers continue to serve, although to a more limited extent, as communication arteries. Additionally, the high volume and quality freshwater discharge of those rivers draining the Appalachians is a major industrial resource.

The Pee Dee, Black, Satilla, and St. Marys are deflected around various Pleistocene sand bodies (possibly relict barrier islands) in their oceanward courses. In addition, the Waccamaw flows parallel to the coast between two such sand bodies before emptying into Winyah Bay. The Pee Dee and Black rivers also empty into Winyah Bay, which is essentially a Pleistocene estuary reoccupied by the present ocean.

B. FLUVIAL DEPOSITS

The major river valleys are composed of broad flood plains containing oxbow lakes, meander scroll or point bar deposits, natural levees, and sand dunes. The river channels meander and, as a result, have cut steep banks or bluffs into the Tertiary bedrock. Near their mouths, these valleys are covered by coastal marsh and typically widen as they merge into their associated deltas or estuaries.

C. DELTAS

The largest of these major rivers, the Pee Dee, Santee, Savannah, and Altamaha, have not constructed deltas extending significant distances out onto the nearshore shelf despite 1) their considerable sediment load and 2) the relatively low wave energy available to distribute sediment along the coast. The Pee Dee flows into an ancient estuary separated from the ocean by Pleistocene barrier island deposits. The Altamaha, Savannah, and Santee flow directly into the Atlantic Ocean, but their deltas may more closely resemble sediment-filled, drowned valleys than depositional centers spreading or prograding oceanward over the nearshore shelf. The Cape Romain region, now undergoing net erosion, has an extensive coastal marsh which directly fronts the open ocean with no seaward sand barrier. This area has long been considered an earlier Holocene delta of the Santee River; Aburawi (1972) and Woollen (1976) indicate that the Santee Delta has been in its present position since at least 4500 years ago. The extensive Holocene barrier island and marsh plain directly south of the Savannah River has also been considered its delta. Plains of similar and even larger size occur adjacent to the mouth of the Cooper River at Charleston and between tidal Morgan-Coosaw and Broad rivers in Beaufort County, South Carolina, streams carrying much less sediment than the Savannah, Santee, or Altamaha.

D. PLEISTOCENE HISTORY

1. Sealevel Change

During the Wisconsin glacial event of the late Pleistocene, these major rivers flowed into an ocean 100 to 200 m (328 to 656 ft) below its present level. As a consequence, major river gradients across the Sea Island Coastal Region may have been steeper, resulting in valley floor downcutting. These incised valleys would have been filled as sea level rose during the last Wisconsin and early Holocene. A section across the Santee River valley (Fig. 2-7, page 13) showing the nature and thickness of this fill was developed by Colquhoun et al. (1972) from South Carolina Highway Department bore hole data. Sub-bottom profiles of the lower Savannah River and Winyah Bay depicting their respective incision and valley fills are presented on Atlas plate 22-A and in Fig. 5-8.

2. River Valley Dunes

Late Wisconsin time (15,000 to 10,000 years ago) saw the formation of the various river valley dune sheets (Thom 1970). These dunes represent a time of changing river conditions, i.e., a reduction in overall discharge and/or a shift from a wide, sandy braided bed to a narrow meandering channel, serving to expose bare flood plain to wind action. Another such indication of a change in river condition is the underfit nature of the flood plain character of some major rivers, especially the Combahee-Salkehatchie. The river channel, as defined by the meander belt width, does not fill the existing flood plain, or the valley appears to be too wide to have been cut by the present stream.

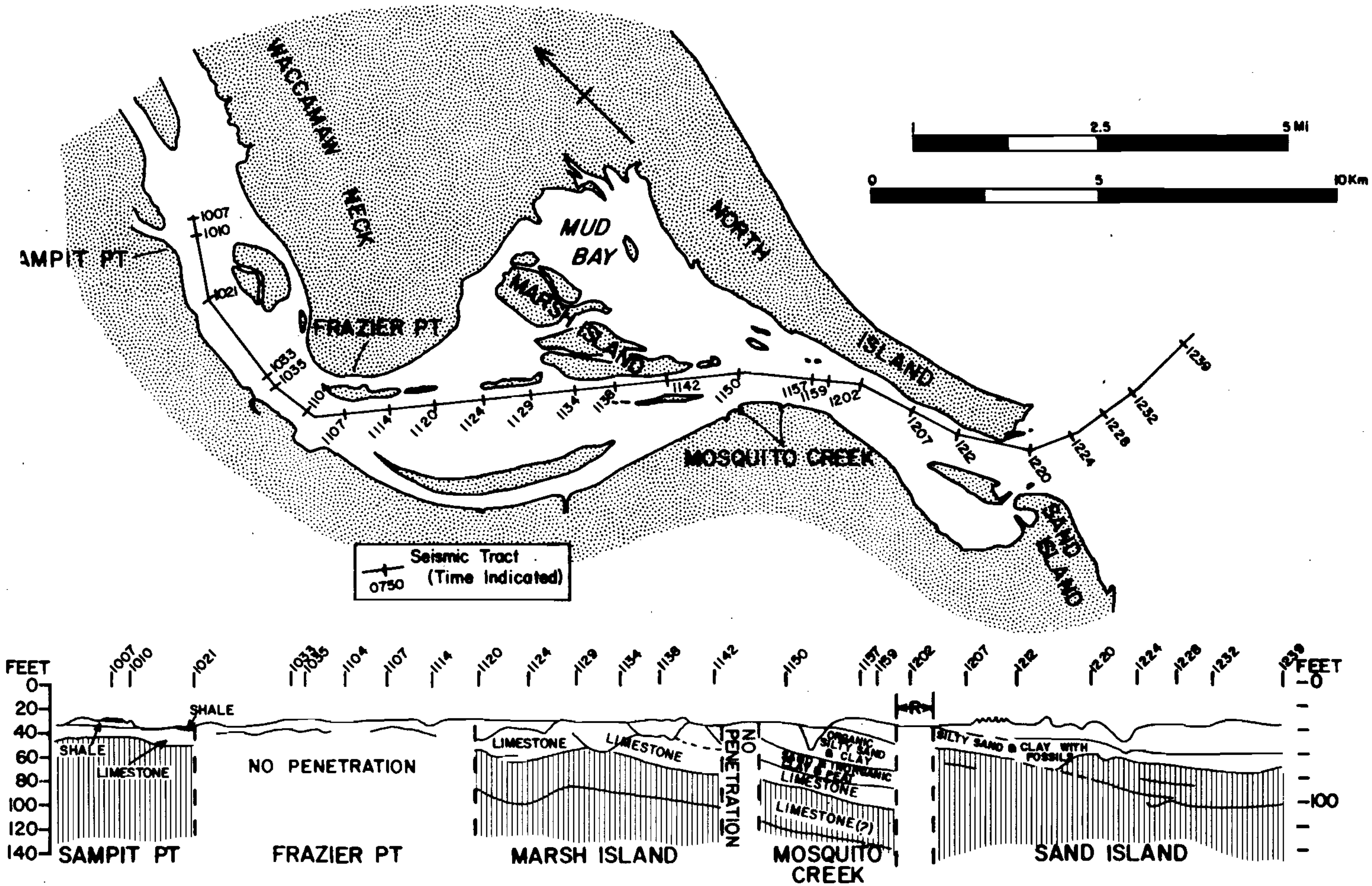


Figure 5-8. Sub-bottom profile of Winyah Bay (adapted from Colquhoun 1973). The full extent of Pleistocene valley fill is not shown because the survey ship stayed within the man-made navigation channel. The numbers along the seismic tract are projected into the sub-bottom profile to better locate the cross section.

E. RIVER SYSTEM DESCRIPTION

The major river systems of the Sea Island Coastal Region are briefly described. Table 5-4 presents the detailed physiographic data pertinent to each river system. The data include the drainage basin area, discharge, tidal extent in river miles, sediment load, water quality, and width of flood plain for these 12 major rivers.

1. Pee Dee

The area drained by the Pee Dee, Waccamaw, and Black rivers defines the Pee Dee River basin. The river becomes the Pee Dee at the confluence of the Yadkin and Uwharrie rivers. The Pee Dee flows some 200 mi (320 km) from this point to empty into Winyah Bay, then into the Atlantic Ocean near Georgetown.

2. Santee-Cooper

The basin of the Santee-Cooper originates on the eastern slopes of the Blue Ridge Mountains in western North Carolina and flows some 300 mi (480 km) southeasterly to the coast to empty between Charleston and the south edge of Winyah Bay. The Santee River basin has been dammed at River Mile 87 to form Lake Marion. The lake occupies the upper 56 mi (90 km) section of the 143 mi (230 km) length of the Santee River. The Cooper River has been dammed at the headwaters in Berkeley County to form Lake Moultrie. Both dams provide hydroelectric power and are operated by the South Carolina Public Service Authority. The impoundment at Lake Marion is utilized for release of a minimum of 500 ft^3/s (14.2 m^3/s) discharge into the Santee River. The remaining flow is diverted by a canal to Lake Moultrie and the Cooper River to be discharged near Charleston. See Chapter Six for a more detailed discussion of the Santee-Cooper Diversion and Rediversion projects.

3. Edisto-Combahee-Salkehatchie

The Edisto-Combahee-Salkehatchie River basin originates in the west central portion of South Carolina and extends approximately 100 mi (160 km) in a southeasterly direction to empty between Morgan Island and the western end of Seabrook Island. There are no hydroelectric plants on the Edisto-Combahee River basin.

4. Savannah

The headwaters of the Savannah River are high on the forested slopes of the Blue Ridge Mountains in North Carolina, South Carolina, and Georgia. The two principal headwater streams, the Seneca and Tugaloo rivers, join near Hartwell, Georgia, to form the Savannah. The river flows some 300 mi (480 km) through the Appalachian Piedmont and the Atlantic Coastal Plain, forming the boundary between South Carolina and Georgia, to discharge near Savannah, Georgia. Two sections of the Savannah River, Hartwell Lake and Clark Hill Reservoir, are presently being used for hydroelectric power production and for recreation.

5. Ogeechee

The Ogeechee River basin is adjacent to the Savannah River and is wholly in Georgia. The river flows 245 mi (395 km) to empty into the Atlantic Ocean at Ossabaw Sound between Wassaw Sound and St. Catherines Sound. A chain of islands, Wassaw, Ossabaw, Sapelo, and Blackbeard, are all included in the Ogeechee River basin. There are no hydroelectric facilities on the Ogeechee River.

6. Altamaha

The Altamaha River is formed by the confluence of the Ocmulgee and Oconee rivers 137 mi (221 km) above the mouth and flows across the coastal plain until it empties into the Atlantic Ocean near Darien, Georgia. With the exception of 6,000 acres (2,430 ha) of cleared land, the flood plain is covered with a dense growth of timber and underbrush. Five hydroelectric plants are operated in the basin by the Georgia Power Company and three power plants are operated by industrial companies.

7. Satilla

The Satilla River rises in Coffee and Ben Hill counties, Georgia, and flows generally southeasterly about 260 mi (420 km) to empty into the Atlantic Ocean at St. Andrews Sound. The coastal plain portion of the river basin is flat and has much low wetland and marshes. There are no hydroelectric generating facilities located within the Satilla basin.

8. St. Marys

The St. Marys River originates in the Okefenokee Swamp and flows some 125 mi (200 km) to the ocean. The river flows to the south from the swamp, then turns to the north near Folkston, Georgia; then it turns in an eastward direction toward the Atlantic Ocean. The river forms the boundary between Georgia and Florida. There are no hydroelectric plants in the St. Marys River basin.

Table 5-4. Physiographic data for nine major river systems included in the Sea Island Coastal Region.

River System	Approx. Width of Flood Plain (mi)	Length of Flood Plain (mi)	Area of Drainage Basin (mi^2)	Average Annual Discharge (m^3/s)	Tidal Range (Feet)	Tidal Extent River (mi)	Sediment Load Tons/mi^2/yr* Tons/yr**	Water Quality	Extent of Salt Wedge (mi)	Acres of Impound-ments	Dredging	River Valley Dunes
Pee Dee/ Waccamaw/ Black	1-9[a]	205[b]	14,014[b]	428[c] 34 26.5	3.3-3.9[d] 2.3-3.8 3.3-3.9	38[b] 82 46	not available	B[e] A A,SB	17[f] 18 17	4,005[g]	AIWW	Yes[h] No No
Santee/ Cooper	1-6[a]	300[i]	16,800[i]	84[j] 442	4.1-5.3[d] 3.3-6.3	48[i]	4.7×10^3 [f]** 400×10^3 [j]**	SA,B,SB[e] B,SC	13[f] 33	24,948[g]	AIWW Harbor Project	Yes[h]
Edisto	1-13[a]	200[k]	3,100[k]	79.4[c]	6.7-7.2[d]	40[k]	17×10^3 [c]**	A,SA[e]	17[f]	13,465[g]	AIWW	No[h]
Combahee/ Salkehatchie	1-5[a]	125[k]	1,325[k]	10[c]	6.2-7.5[d]	36[k]	not available	A,SA[e]	20[f]	10,360[g]	None	No[h]
Savannah	1-12[a]	300[l]	10,577[l]	343[c]	6.9-8.1[d]	20[l]	1200×10^3 [c]**	A,B[e]	18-20[l]	4,321[g]	AIWW Harbor Project	Yes[h]
Ogeechee	1-7[a]	170[m]	5,535[m]	68[n]	6.9-8.1[d]	30-35[m]	5-15 ton[m]*	recrea-[o] tional	30-35[m]	2,300[p]	AIWW	Yes[h]
Altamaha	1-7[a]	137[m]	14,564[m]	391[n]	5.2-7.7[d]	42[m]	not available	recrea-[o] tional	12[m]	4,300[p]	None	Yes[h]
Satilla	1-6[a]	110[m]	3,530[m]	63[n]	6.7-7.8[d]	67[m]	5.6×10^3 [c]**	recrea-[o] tional	67[m]	not available	None	Yes[h]
St. Marys	1-3[a]	110[m]	1,510[m]	19.3[n]	5.8-6.8[d]	60[m]	2.5×10^3 [c]**	recrea-[o] tional	60[m]	not available	Yes	Yes[h]

a. South Carolina Marine Resources Division, 1979, Charleston unpubl. data.
b. S.C. Department of Health and Environmental Control [1975a].
c. U.S. Department of Interior, Geological Survey 1977.
d. U.S. Department of Commerce, NOAA 1978.
e. S.C. Pollution Control Authority 1972.
f. South Carolina Marine Resources Division, 1979, Charleston, unpubl. data.
g. Tiner 1977.
h. F.W. Stapor, 1977, South Carolina Marine Resources Division, Charleston, unpubl. data.
i. S.C. Department of Health and Environmental Control [1975b].
j. U.S. Army Corps of Engineers 1966a.
k. S.C. Department of Health and Environmental Control [1975c].
l. S.C. Department of Health and Environmental Control [1975d].
m. U.S. Study Commission, Southeast River Basins 1963.
n. U.S. Department of Interior, Geological Survey 1976.
o. Georgia Department of Natural Resources 1977.
p. Love 1978.

Key to Water Quality (see Chapter Six for discussion of water quality):
A=fresh waters suitable for swimming
B=fresh waters suitable for domestic supply after treatment
SB=salt waters suitable for swimming
SA=salt waters suitable for commercial shellfishing
SC=salt waters suitable for crabbing and commercial fishing

V. ESTUARIES

A. DEFINITION

The Sea Island Coastal Region contains numerous estuaries or ". . .semi-enclosed coastal bodies of water having free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage" (Pritchard 1967). Estuaries serve as nursery grounds and/or habitats for important commercial and recreational species of fish, clams, oysters, crabs, and shrimp. In addition, their shores are the sites of cities, factories, and ports. Estuaries are extremely important resources which must serve a variety of interdependent, often competitive interests.

B. CLASSIFICATION AND GENESIS

Geomorphologically, these estuaries are either 1) drowned river valleys, 2) bar-built or the result of migrating barrier islands separating nearshore regions from the open ocean, or 3) some combination of both. Charleston Harbor and Port Royal Sound are classic examples of drowned river valleys; Murrells Inlet, Bulls Bay, Calibogue Sound, and Cumberland Sound are examples of bar-built estuaries; and Winyah Bay, Sapelo Sound, and St. Andrews Sound are examples of the drowned valley-barrier island combination. The rise in sea level over the past 10,000 years has submerged the sub-aerially eroded continental land mass, drowning river valleys and flooding low-lying regions. In addition, concomitant erosion of local headlands and offshore bottoms has provided sediments for the construction of coastal barriers which separate nearshore regions from the open ocean.

C. SEDIMENTATION

Estuaries are traps for terrigenous (land-derived) sediments coming down rivers, sediments moving along the open ocean beaches, and sediments moving onshore from the immediate offshore region. Clay-size material is trapped within estuaries by tidal and nontidal circulation patterns. Flocculation (Ippen 1966), internal shearing (Krone 1962), and biologic processes (Schubel 1971) interact to increase the grain size of this material sufficient for deposition during periods of slack current. Estuarine deposits include tidal flats, marshes, and inlet-associated deltas to name just a few. Most of the marsh-covered plains characteristic of the Sea Island Coastal Region are sediment-filled (or essentially filled) Pleistocene estuaries, now covered with a Holocene marsh veneer.

D. WATER CIRCULATION PATTERNS

Water circulation within an estuary results from the interaction of numerous processes, including river flow, tidal conditions, wind regime, and the estuary's physical dimensions. Fresh water, being lighter than ocean water, tends to flow seaward over an estuary in a surface sheet, while denser sea water flows upstream in a bottom layer in a counter-current response to the river flow. Tidal and wind actions tend to promote mixing of the two layers. An estuary's physical dimensions determine 1) the effect of the earth's rotation (Coriolis force), which can be significant in wide estuaries and negligible in narrow ones, and 2) the degree of tidal mixing, extensive in shallow estuaries and limited in deep ones. Table 5-5 presents a classification of estuaries based on circulation patterns determined by these interactions.

Circulation patterns in estuaries of the Sea Island Coastal Region are primarily dependent on the amount of freshwater discharge. Where discharge is significant, the resulting pattern is that of two-layer flow with vertical mixing. Charleston Harbor, Winyah Bay, the Savannah River, and the Altamaha River fall into this category. Where freshwater discharge is minimal, a vertically homogeneous salinity pattern results, e.g., Bulls Bay, Port Royal Sound, Wassaw Sound, and Sapelo Sound.

Circulation patterns do influence estuarine sedimentation processes and major changes in these patterns can have significant results. The diversion of the bulk of the Santee River's discharge into Charleston Harbor converted a vertically homogeneous estuary into one characterized by two-layer flow. Clays and silts introduced along with the fresh water were, and continue to be, rapidly deposited; 25 years after diversion, plans were begun to redivert this flow back into the Santee River in order to continue commercial navigation in Charleston Harbor. (See Chapter Six for a detailed discussion of the Santee-Cooper Diversion and Rediversion projects.)

E. CHARLESTON HARBOR

1. Introduction

Charleston Harbor is an estuary located midway along the South Carolina coastline at the confluence of the Ashley, Cooper, and Wando rivers (Atlas plate 43B). The harbor is bounded on the north by Sullivans Island and Mt. Pleasant, and on the south by Morris and James islands. The City of Charleston is located at the western end of the harbor on a peninsula between the Ashley and Cooper rivers.

Table 5-5. Types of estuarine circulation (adapted from Bowden 1967).

Type	Physical processes	Forces	Examples from Sea Island Coastal Region
1. Salt wedge	River-flow dominant	Pressure gradients, field accelerations, Coriolis effect, interfacial friction	
2. Two-layer flow with entrainment, including fjords	River-flow, modified by tidal currents	Pressure gradients, field accelerations, Coriolis effect, entrainment	
3. Two-layer flow with vertical mixing (partially mixed)	River-flow and tidal mixing	Pressure gradients, field accelerations, Coriolis effect, turbulent shear stresses	Charleston Harbor, Winyah Bay, Savannah Harbor, Altamaha River
4. Vertically homogeneous (a) with lateral variation (b) laterally homogeneous	Tidal currents predominating	Pressure gradients, field accelerations, turbulent shear stresses, Coriolis effect in vertically homogeneous type with lateral variation	Port Royal Sound, St. Simons Sound, Wassaw Sound, St. Helena Sound

The area surrounding the harbor is heavily populated and highly developed, with numerous urban, suburban, and industrial sites located on the harbor perimeter. Because of this high degree of development, Charleston Harbor was chosen as an example of an extensively modified estuary. The extent of modifications can be seen in the many potential sources of pollution, i.e., runoff from municipal and suburban areas, septic tank overflows, sewage discharges, industrial outfalls, and runoff from agricultural zones. Undoubtedly, the single most significant modification affecting water chemistry was the Santee River diversion in 1942, which resulted in greatly increased maintenance dredging requirements. The diversion did, however, provide industry with a source of extremely pure fresh water and an increased flushing action for the lower Cooper River and the harbor itself.

Specific information for Charleston Harbor is provided in the following sections, ranging from physical dimensions to water quality. Both historic data, where available, and recent data are shown for the harbor and its immediate surroundings.

2. Size

The tidal prism (volume) of Charleston Harbor is 4.3×10^8 m^3 (3.5×10^5 acre-ft) (U.S. Army Corps of Engineers 1966a). Freshwater discharge into Charleston Harbor is primarily from the Cooper River with small amounts being contributed by the Ashley and Wando rivers. Nominal discharge from Lake Moultrie into the Cooper River is 425 m^3/s (15,000 ft^3/s), with amounts >566 m^3/s (>20,000 ft^3/s) being common. The harbor area is approximately 36 km^2 (14 mi^2), with depths ranging from 3.0 to 7.6 m (10 - 25 ft) at low tide (U.S. Army Corps of Engineers 1966a). The main harbor channel is maintained by dredging at 10.6 m (35 ft). Large shoals exist near Ft. Sumter, Shutes Folly Island (Castle Pinckney), and Crab Bank, where water depths are <1.0 m (<3.3 ft) in many places.

3. Salinity Distribution

Charleston Harbor changed from a well-mixed to a highly stratified estuary when the Santee River flow was diverted in 1942. Zetler (1953) reported that the average surface salinity in Charleston Harbor was 25°/oo - 32°/oo for the period 1923 - 1941. From 1942 to 1951, the average surface salinity in the harbor dropped to about 15°/oo - 20°/oo (Zetler 1953). Similar results were obtained by the Coast and Geodetic Survey from 1942 to 1952, when the average surface salinity at the U.S. Customs House in Charleston was 16.7°/oo, ranging from 14.2°/oo to 19.2°/oo (Bears Bluff Laboratories, Inc. 1964).

In general, isohalines are very compressed from the lower reaches of the harbor to the mouth of the Cooper River. Mean surface salinities at the mouth of the Cooper River were 4.5°/oo for 1973 and 5.3°/oo for 1974, as compared to 16.0°/oo for 1973 and 18.5°/oo for 1974 at Cummings Point near the mouth of the harbor (Mathews and Shealy 1978). The salt wedge can be detected up the Cooper to North Charleston, where mean bottom salinities were 4.0°/oo for 1973 and 5.1°/oo for 1974 (Mathews and Shealy 1978).

Overall salinity variations in Charleston Harbor are great, depending on tide stage, runoff, and precipitation. A typical salinity variation from high to low tide at Ft. Johnson on the southwest side of Charleston Harbor is about 10°/oo - 12°/oo for bottom waters, with surface to bottom variation on the order of 14°/oo (T. D. Mathews, 1978, South Carolina Marine Resources Division, Charleston, unpubl. data). Bears Bluff Laboratories, Inc. (1964) reported surface salinities 9.2°/oo and 7.4°/oo lower than bottom salinities at the mouth of the Cooper River and near Hog Island, respectively.

The effects of runoff on salinity can be quite significant, e.g., during 1973 surface salinity at Ft. Johnson varied from about 6°/oo to 28°/oo, while bottom salinity ranged from 10°/oo to 30°/oo (Mathews and Pashuk 1977). During the same period salinity ranges at the mouth of the Cooper River were 0.7°/oo - 13.5°/oo (surface) and 2.0°/oo - 26.2°/oo (bottom). Tidal salinity fluctuations are often quite significant also, with surface salinity variations ≤13°/oo being recorded in May 1975. Bottom tidal salinity fluctuations were also considerable (i.e., 10°/oo - 15°/oo), but even higher ranges have been recorded (e.g., 22°/oo in February 1975) (T. D. Mathews and M. H. Shealy, Jr., 1975, South Carolina Marine Resources Division, Charleston, unpubl. data).

4. Temperature Distribution

Large variations in water temperature are not common in Charleston Harbor, although measurable differences in surface and bottom values are common. As a general rule, fresh water is cooler in winter than salt water, since oceanic water tends to have smaller seasonal temperature variations.

February 1973 produced unusally cold water throughout the Cooper River due to large amounts of snow and ice; otherwise, the temperature difference between February and August is approximately 16° - 18°C (29° - 32°F) (Mathews and Shealy 1978).

Surface to bottom variations in temperature are generally on the order of 1°C (1.8°F) or less, although variations > 2°C (>3.6°F) have been recorded in the harbor (Mathews and Shealy 1978).

Diurnal temperature variations are generally < 1.5°C (< 2.7°F), although local weather conditions such as precipitation and winds can have a noticeable influence. For surface water, the greatest diurnal variation in Charleston Harbor was about 2.5°C (4.5°F) in May 1976, while the greatest diurnal variation for bottom waters was 2.7°C (4.9°F), also in May 1976 (T. D. Mathews and M. H. Shealy, Jr., 1976, South Carolina Marine Resources Division, Charleston, unpubl. data).

5. Bottom Sediment

There are no sediment maps for Charleston Harbor.

6. Suspended Sediment

Since diversion of the Santee River in 1942, silting has been an increasing problem due to the greatly increased amounts of suspended sediments in the Cooper River. Sediment or solids concentrations in the harbor are highly variable, due in part to the variability of analytical methods. Total solids for surface samples ranged from 17.46 to 57.84 mg/l and from 22.96 to 103.24 mg/l for bottom samples (U.S. Army Corps of Engineers 1966a). Nelson (1974) reported total nonfilterable residue concentrations of 12 - 63 mg/l with an average of 37 mg/l upstream from the mouth of the Cooper River. Mathews and Shealy (1978) found even greater variation in solids concentrations, e.g., total solids (bottom) ranged from 14.0 to 144.4 mg/l at the Cooper River mouth during the period of February 1973 through January 1974.

7. Tidal Currents

Studies of tidal currents in Charleston Harbor have been made by U.S. Department of Commerce (1967), U.S. Army Corps of Engineers (1966b), and Neiheisel and Weaver (1967). Surface tidal current velocities range from 103 to 155 cm/s (2.3 to 3.5 mi/h) in the main channels during maximum ebb, and from 51 to 124 cm/s (1.1 to 2.8 mi/h) during maximum flood. Water moves with higher velocities over the northern portion of the harbor during maximum flood than over the southern, with the reverse occurring during maximum ebb. Neiheisel and Weaver (1967) concluded from current measurements made throughout the entire water column that the harbor's general circulation is counterclockwise (Fig. 5-9).

Stapor (1977) measured bottom currents in front of Sullivans and Morris islands in an attempt to analyze sand

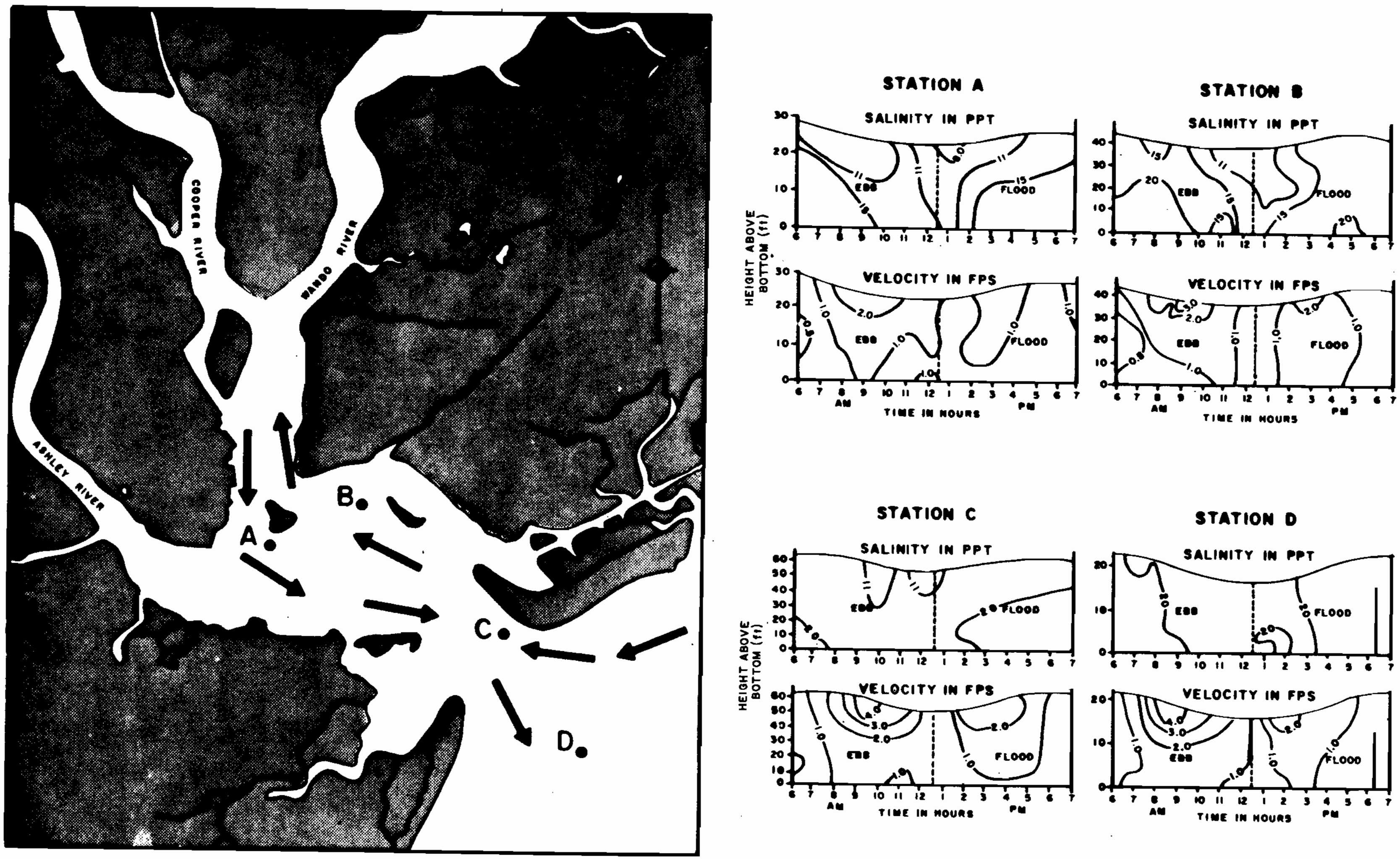


Figure 5-9. Tidal flow in lower Charleston Harbor (adapted from Neiheisel and Weaver 1967). Salinity values are in parts per thousand (PPT) and current velocities in feet per second (FPS).

transport. His results (Atlas plate 43B) show flood-oriented transport occurring in front of Morris Island, sweeping sand toward Charleston Harbor Entrance.

8. Water Quality

The water quality in Charleston Harbor has been a highly controversial topic during the recent past. Industrial and municipal wastes were formerly emptied directly into the harbor or into one of the adjacent tributary rivers or streams. Due to stringent pollution regulations, waste treatment facilities have been installed in the area, resulting in improved water quality overall. The U.S. Army Corps of Engineers (1966c) found, however, that even with the present high flow conditions, the effects of waste outfalls were detectable, i.e., dissolved oxygen percent saturation for bottom waters was 52% in the upper harbor and 77% in the lower harbor. Similar, though improved, conditions were reported by Mathews and Shealy (1978), e.g., dissolved oxygen percent saturation ranged from 80% near the mouth of the Cooper River to 90% or 95% at the mouth of the harbor.

Robison and Himelright (1963) found 12 untreated domestic sewage outfalls along the Cooper River with a biochemical oxygen demand (BOD) range of 110 - 205 mg/l. Fish kills occurred occasionally through the 1960's, prior to the enactment and enforcement of various pollution regulations and laws. A similar case was noted in the Ashley River, where several industrial plants and 24 untreated domestic sewage outfalls polluted the water (Robison and Himelright 1963). Fish kills also occurred in the lower reaches of the river, with an unusually severe occurrence on 22 June 1964, resulting in a large kill of menhaden, spot, croaker, blue crabs, and porpoises (Bears Bluff Laboratories, Inc. 1964).

More recent studies indicate a significant improvement in Charleston Harbor waters with respect to some parameters. The BOD near the mouth of the Cooper River was 0.6 - 1.4 mg/l in October 1971 during high flow conditions of 566 m^3/s (20,000 ft^3/s) and 0.8 - 1.0 mg/l in November 1971 during low flow conditions of 279m^3/s (3,000 ft^3/s) (Nelson 1974). The average range in percent saturation of dissolved oxygen at this same station was 70.7% - 74.2% for October and November 1971 (Nelson 1974). Nelson (1974) also reported no pesticide residues above the detection limit for the 18 pesticides analyzed.

Trace metals in the harbor and surrounding waters are highly variable, depending on location and, to some extent, salinity. Relatively low concentrations of iron, copper, lead, mercury, and cadmium have been found in shellfish in the Charleston area. Elevated copper concentrations have been detected in oysters near river miles 8 - 10 on the Wando River (Mathews et al. 1979). The oysters from this zone averaged 106.0 - 118.0 µg/g copper, as compared with 17.9 µg/g at Ft. Johnson and 29.9 µg/g at the old Ashley River bridge. Lead, mercury, and cadmium were all below the analytical detection limit on oyster samples from Ft. Johnson and the Wando River (T. D. Mathews, 1975, South Carolina Marine Resources Division, Charleston, unpubl. data).

While trace metals in general may not be a serious threat in Charleston Harbor during high flow conditions, concentrations may rise significantly during low flow conditions. During October 1971, Nelson (1974) found average mercury, iron, lead, and copper levels of 0.20, 1070, 170, and 45 µg/l, respectively. However, during low flow conditions in November 1971, average mercury, iron, lead, and copper concentrations were 0.30, 2212, 232, and 67 µg/l, respectively (Nelson 1974). It appears that maximum regulation of industrial and municipal effluents will have to be exercised after rediversion of the Santee River flow to avoid large increases in many pollutants, especially in trace metals.

Another measurement relating to pollution in Charleston Harbor is fecal coliform concentration. Fecal coliform counts were frequently very high before untreated domestic sewage outfalls were eliminated. During a South Carolina Water Resources Commission study, fecal coliforms ranged from 330 - 7900/100 ml with a geometric mean of 830/100 ml during high flow conditions in October 1971 (Nelson 1974). Low flow conditions resulted in fecal coliform levels of 130 - 1700/100 ml with a geometric mean of 460/100 ml (Nelson 1974). These values represent a distinct improvement in water quality when compared with earlier results. The U.S. Army Corps of Engineers (1966c) conducted a survey of Charleston Harbor and found surface fecal coliform counts of 14,650 and 13,800/100 ml at a station several miles above the mouth of the Cooper River and at the mouth, respectively. At a station near Shutes Folly Island a surface count of 24,040/100 ml was measured (U.S. Army Corps of Engineers 1966d).

F. DOBOY SOUND

1. Introduction

Doboy Sound is an estuary located on the central Georgia coast, south of Sapelo Island. It is bounded on the south and west by a series of marsh islands and by Sapelo Island to the north and east. Doboy Sound is relatively pristine when compared to estuaries in highly developed areas. Since development has been minimal in the immediate area around the sound, Doboy Sound was chosen as an example of an unmodified estuary.

The following sections include data on the size of Doboy Sound; distributions of salinity, temperature, and suspended sediment; and tidal currents. A section is also included on alterations (dredging) in the sound.

2. Size

Oertel (1971) defined the lower reaches of Doboy Sound as being seaward several km beyond the coastline and the head of the sound above the mouths of the Duplin and North rivers. The length of the sound is about 10 km (6.2 mi), while the mouth is approximately 3.2 km (2.0 mi) wide. Depths in most areas are <8 m (<26 ft) with relatively steep slopes on the southwestern sides of the main channel (Oertel 1971).

3. Salinity Distribution

Relatively low salinity water ($20^{o}/oo$ - $27^{o}/oo$) is introduced to Doboy Sound via the North, Back, and South rivers (Oertel 1971). Water of about $18^{o}/oo$ is also found at the upper end of the Duplin River (Kjerfve 1973) possibly providing a small supply of low salinity water to Doboy Sound. Brackish water ponds on Sapelo Island also contribute small amounts of relatively fresh water ($25^{o}/oo$), some of which moves up the Duplin River as a surface lens (Remmer 1972).

The difference in salinity between Doboy Sound and adjoining waters is evident in Table 5-6. Salinity trends were similar to those in other southeastern locations, i.e., lowest in winter, lower in the sound than in coastal waters, and lower in creeks and rivers.

4. Temperature Distribution

Water temperatures in Doboy Sound and adjacent areas followed similar trends with minima being recorded in February and maxima in July and August (Table 5-7). Minimum temperatures of <14°C (<57°F) and maximum temperatures >29°C (>84°F) were recorded by Mahood

Table 5-6. Average monthly surface water salinities ($^{o}/oo$) for indicated sections in the Doboy Sound estuary (October 1971 to September 1972) (Mahood et al. 1974).

Month	Upper creeks	Large creeks & rivers	Sound	Outside
October	11.4	16.3	19.4	26.4
November	12.4	19.2	23.7	24.8
December	10.3	21.5	21.3	19.4
January	9.6	17.3	18.0	26.2
February	6.7	14.2	17.1	25.7
March	14.8	13.9	15.5	31.0
April	12.5	20.6	19.9	29.1
May	13.8	20.9	21.8	29.5
June	12.3	23.3	26.9	26.4
July	15.1	22.9	23.3	30.3
August	17.2	24.8	26.8	32.3
September	21.5	26.1	27.9	32.6

et al. (1974) (Table 5-7). Oertel (1971) reported summer temperatures in 1970 ranging from 27.9° to 31.2°C (82° to 89°F). Surface waters are somewhat variable in temperature in Doboy Sound, since wind and precipitation can significantly affect temperatures.

5. Suspended Sediment

Oertel (1971) found that suspended matter decreased overall from the North River to the South River, with mean concentrations of 123.7 and 58.6 mg/l, respectively. Suspended matter content was highest during race tides and lowest at slack water, e.g., in the North River suspended matter was 248.0 mg/l during ebb race and 74.7 mg/l at low water (Oertel 1971). The concentration of suspended matter generally increased with depth, although turbulence and vertical mixing caused significant variations.

Suspended matter in Doboy Sound exhibited several distinctive trends different from those of the North, Back, and South rivers. Oertel (1971) found that the distribution of suspended matter at the head of Doboy Sound was similar for high and low tides, while the central region of the sound had lower suspended matter concentrations at high tide. During flood race, the sediment load was lower than at low tide, except at the mouth of the sound where values at the bottom reached 440 mg/l (Oertel 1971). The ebb race sediment concentrations were highest (520 mg/l) at the head and central portion of Doboy Sound (Oertel 1971).

6. Tidal Currents

In general, tidal currents in Doboy Sound tend to follow set patterns, depending on the effect of low salinity water via North, Back, and South rivers. Flood currents enter Doboy Sound along the southeastern tip of Sapelo Island, through the main channel, and over the Wolf Island shoal. Flood water is deflected northward by South River water to some extent, and complex mixing patterns occur due to the influence of the North and Back rivers (Oertel 1971). Where flood water interacts with South, Back, and North river waters, foam lines form along current gyres.

Ebb currents, while weak, have little effect on the flow of the North, Back, and South rivers. Oertel (1971) found that as ebb currents strengthened, the flows from these rivers were deflected towards the main channel of Doboy Sound. Turbid mixing of the respective water masses increases as the ebb progresses, and salinity and temperature gradients along the channel axis reach minima after the maximum ebb race (Oertel 1971).

Table 5-7. Average monthly surface water temperatures (°C) for indicated sections in the Doboy Sound estuary (October 1971 to September 1972) (Mahood et al. 1974).

Month	Upper Creeks	Large creeks & rivers	Sound	Outside
October	22.1	23.9	23.9	23.4
November	15.7	22.1	24.0	16.5
December	15.0	14.1	15.1	15.5
January	17.8	16.4	16.5	16.6
February	11.6	12.8	13.3	10.8
March	18.7	15.6	15.6	14.6
April	24.4	18.8	17.6	17.3
May	24.7	23.5	23.1	24.5
June	28.8	24.6	25.0	24.9
July	29.3	28.5	28.9	27.5
August	28.0	29.5	29.5	29.3
September	29.3	26.0	26.1	27.5

Current velocities in the sound are quite variable. As in other tidal areas, there is little or no slack water at high or low tides. This is particularly true due to the discharge of the North, Back, and South rivers. Highest current velocities are found during the ebb race in surface waters near the center of Doboy Sound, while maximum flood water velocities occur at the southwest surface part of Doboy Sound.

7. Alterations

Man-induced alterations of Doboy Sound have been few in comparision to heavily industrialized sites such as Charleston, Savannah, and Jacksonville. The population density is also low; hence, there has been little man-induced change in the sound itself. Since the Atlantic Intracoastal Waterway (AIWW) was constructed across Doboy Sound from Old Teakettle Creek to the North River in 1942, there has been a history of maintenance dredging, beginning in 1943 (Table 5-8). Approximately 608,047 m^3 (795,295 yd^3) of material were removed from 1943 to 1977, most of which was silts and clays with some sand (Tinkler 1976). The dredge spoil has been dumped at dumping area 28, an open water site on the northern side of Commodore Island. Tract 28-A, a 63.0 ha (155.6 acre) site at the southwestern end of Little Sapelo Island, was designated but never used for the dredge spoil. (For additional dredging data for the Atlantic Intracoastal Waterway, see Chapter Six and Appendix C.)

Natural migration of shoals at the mouth of Doboy Sound occurs frequently, due to a combination of wave and current action. Oertel (1971) reports that geometry of these shoals is affected more by the refraction patterns of waves than by tidal currents, although tidal currents are important in intrashoal sediment transport. Maximum sand transport appears to occur on topographic highs in association with breaking waves (Oertel 1971). Longshore drift within the breaker zone and tidal currents beyond the breakers are influential in the southward dispersion of sediment along Sapelo Beach, although topographic shielding by shoals restricts intense longshore currents from the beach during much of the tidal cycle (Oertel 1971).

VI. COASTAL INLETS

A. DEFINITION

Coastal inlets are the conduits connecting the open oceans with estuaries and lagoons. Through them passes water carrying the sediment, pollutants, marine-estuarine biota, and navigation exchanged between oceans and estuaries. The Sea Island Coastal Region inlets are all mesotidal with a 2 - 4 m (6.6 - 13.1 ft) tidal range. Large ebb-tidal deltas or shoals, extending well into the open Atlantic Ocean, flank the various main channels. The estuaries served by these inlets all contain extensive intertidal marshes.

B. DYNAMICS

1. Introduction

A tidal inlet is in a state of dynamic equilibrium responding to longshore transport, variations in the tidal prism, shoaling of its ocean and estuary termini, and man-made modifications. Changes in channel geometry, cross-

Table 5-8. Volumes of maintenance dredge spoil in Doboy Sound at Dump Site 28 (Tinkler 1976).

Year	Amount in m^3	Amount in yd^3
1943	121,356	158,718
1946	82,943	108,485
1949	265,074	346,704
1963	16,463	21,533
1967	13,244	17,323
1970	37,371	48,880
1974	63,088	82,516
1977	10,808	14,136
TOTAL	608,047	795,295

sectional area, longitudinal profile, and geographic position are the usual responses of a tidal inlet to the complex interactions of the dynamic factors affecting it. An empirical relationship has been developed by O'Brien (1967), relating an inlet's cross-sectional area to tidal prism (Fig. 5-10).

2. Littoral Drift

Littoral drift or longshore sand transport by waves is at present poorly known for the Sea Island Coastal Region. A computer simulation model has been made for South Carolina by Stapor and Murali (1978). They used the significant wave heights measured by the U.S. Army Corps of Engineers at Holden Beach, North Carolina, and the Savannah Light Tower (Thompson 1977) and the approach direction frequencies presented by the U.S. Naval Oceanographic Office (1963). Their results indicate a complicated pattern of cells or compartments rather than one well integrated "river-of-sand" flowing from northeast to southwest. Individual cells or compartments have sand moving northeast as well as southwest and experience little transfer of sand from cell to cell. Magnitudes of net littoral transport predicted under this computer simulation model range between 5,000 m^3/yr (6,540 yd^3/yr) and 40,000 m^3/yr (52,300 yd^3/yr), with most values less than 10,000 m^3/yr (13,080 yd^3/yr).

The above-mentioned values are significantly lower than littoral drift estimates made by University of South Carolina researchers using site specific, short-term wave climate data (Table 5-9). These workers employ the same formula as do Stapor and Murali (1978) to calculate the volume of sediment moved for given wave heights and approach directions. This difference emphasizes the importance of wave climate data to quantitative littoral drift determinations.

A sand tracer study conducted on the Bull Island east-facing beach yielded littoral drift estimates of 93 000 m^3/yr (121,630 yd^3/yr) and 185,000 m^3/yr (241,960 yd^3/yr) for the months of April 1977 and June 1977, repectively (Knoth and Nummedal 1977). Wave climate differences between these 2 months are most likely the explanation for the range of values. Once again, the importance of wave climate to littoral drift determination is apparent.

a. Wave Heights. Relatively small waves affect the Sea Island Coastal Region. Wave monitoring stations operated by the Coastal Engineering Research Center (CERC) of the U.S. Army Corps of Engineers are located at Holden Beach, North Carolina [16 miles (26 km) north of the North Carolina/South Carolina border], and at the Savannah Coast Guard Light Tower, 9 nautical miles (16.7 km) offshore of Tybee Island in 52 ft (15.8 m) of water. The next closest monitoring stations are at Wrightsville Beach, North Carolina, and Daytona Beach, Florida. Significant wave heights (the average height of the one-third highest waves) and significant periods for waves measured at these stations are presented in Table 5-10. The value obtained from the Holden Beach gage more likely reflects overall Sea Island Coastal Region significant wave heights along the beaches than does the value measured at the Savannah Light Tower. The former was measured very close to shore at a fishing pier while the latter was measured offshore in 52 ft (15.8 m) of water.

b. Wave Approach Directions. Waves approach the Sea Island Coastal Region from only four major directions: northeast, east, southeast, and south. Stapor and Murali (1978) concluded from a computer simulation of wave refraction for South Carolina that waves approaching from the northeast are not refracted sufficiently to hit South Carolina. However, given the north-south shoreline orientation of coastal Georgia, northeast waves will hit and influence littoral drift. Waves approaching from the south probably do affect the South Carolina coast but not the Georgia coast. Waves approaching the Sea Island Coastal Region from the east and southeast affect the entire coast and influence littoral drift. Waves approaching from the northeast probably affect only coastal Georgia and those from the south probably affect only coastal South Carolina. Frequencies of occurrence of these wave approach directions are known only from offshore observations collected by ships and summarized for relatively large areas. No long-term directional data are available from shore-based observations. Figure 5-11 presents the available long-term wave climate data, broken down into sea and swell components, for the Sea Island Coastal Region.

c. Summary. The exact nature of the wave-induced littoral drift affecting the tidal inlets is poorly and contradictorily known at best. Given the relatively low wave energy incident upon the Sea Island Coastal Region, the estimates of Stapor and Murali (1978), using long-term wave climate data, may be closer to the true order of magnitude than those of Finley (1976), Nummedal and Humphries (1978), Knoth and Nummedal (1977), or Kana (1976).

C. MORPHOLOGIC CLASSIFICATION

Morphologically, the Sea Island Coastal Region inlets can be classified

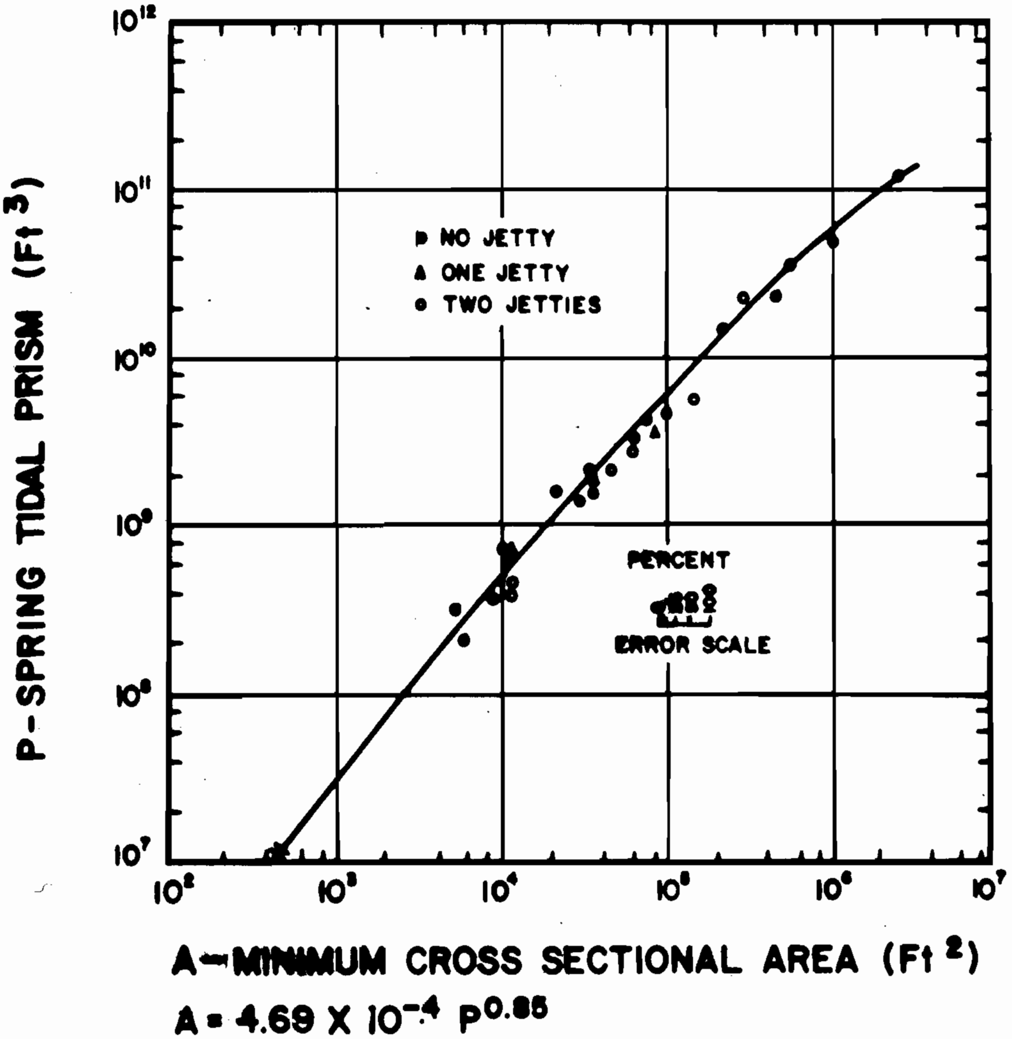


Figure 5-10. The empirical relationships between an inlet's cross-sectional area and spring tidal prism (adapted from O'Brien 1967). This curve relates the spring tidal prism (volume of water exchanged on each tide) with the cross-sectional area of the inlet's throat or narrowest region.

Table 5-9. Littoral drift estimates for selected South Carolina beaches made by University of South Carolina researchers. These values are based on site specific, short-term wave climate data.

Location	Direction of Net Transport	Rate (m^3/yr)[a]	Reference	Period of Wave Climate Data
North Inlet, Georgetown County	S	150,000	Finley (1976)	1974 - 1975
North Inlet, Georgetown County	S	87,000	Nummedal and Humphries (1978)	1974 - 1975
	S	512,000	Nummedal and Humphries (1978)	1975 - 1976
Bull Island, Charleston County (beach facing east)	N	190,000	Knoth and Nummedal (1977)	April 1977
	N	230,000	Knoth and Nummedal (1977)	June 1977
Bull Island, Charleston Couty (beach facing SE)	SW	128,000	Kana (1977)	August - November 1975
Capers Island, Charleston County	SW	140,000	Kana (1977)	August - November 1975

a. 1 m^3 = 1.3 yd^3.

Table 5-10. Average significant wave heights and periods measured at wave monitoring stations within and adjacent to the Sea Island Coastal Region (adapted from Thompson 1977). Average significant height and period are the average values of the one-third highest waves measured. The Savannah Coast Guard Light Tower is the only station within the Sea Island Coastal Region. However, since it is located offshore in 52 ft (15.8 m) of water, the measured values probably do not accurately reflect wave conditions at the shore. Therefore, the values from Holden Beach, North Carolina, the station closest to the Sea Island Coastal Region measuring waves at the shore, more likely represent wave conditions at the shore along the Sea Island Coastal Region.

LOCATION	AVERAGE SIGNIFICANT WAVE HEIGHT	AVERAGE SIGNIFICANT WAVE PERIODS
Wrightsville Beach, North Carolina	2.6 feet (0.79 m)	7.75 seconds
Holden Beach, North Carolina	1.99 feet (0.61 m)	7.38 seconds
Savannah Coast Guard Light Tower	2.95 feet (0.90 m)	6.64 seconds
Daytona Beach, Florida	2.37 feet (0.72 m)	8.38 seconds

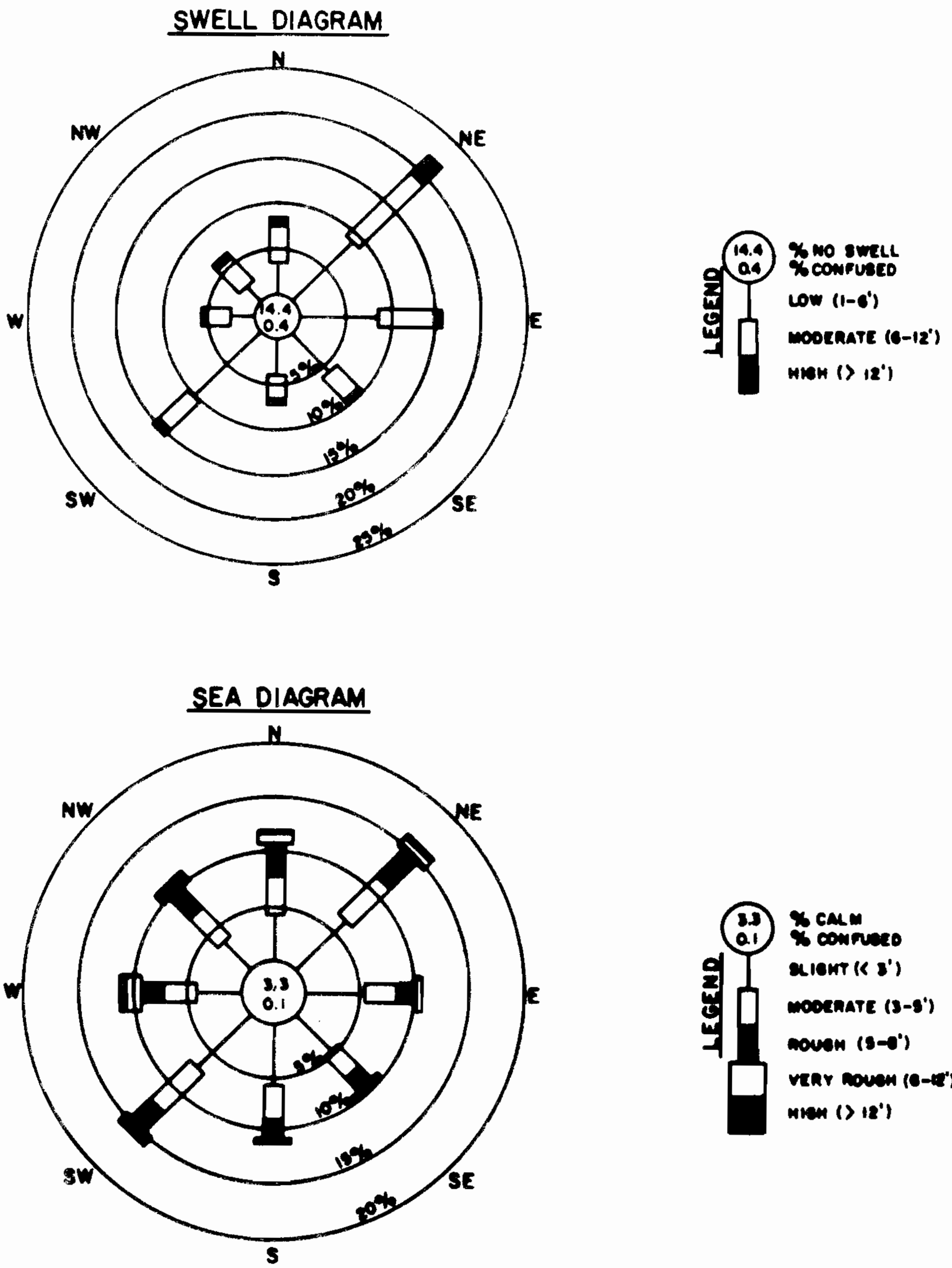


Figure 5-11. Sea and swell data for the Sea Island Coastal Region, from U.S. Naval Oceanographic Office (1963). These data were obtained from observations collected offshore. Sea refers to "waves caused by winds at the place and time of observation" (American Geological Institute 1962) and swell refers to "waves that have passed beyond the region of the winds which formed them . . ." (Strahler 1971).

into three groups: 1) those inlets whose main ebb channel is aligned perpendicular to the coast (class D of Oertel 1977), 2) those inlets in which this channel is aligned subparallel to the coast (class B of Oertel 1977), and 3) those inlets in which there is no one main ebb-channel (class A of Oertel 1977). A class D inlet has an ebb-tidal delta symmetrically arranged about the main ebb-channel (Fig. 5-12), while that of a Class B inlet is crescent-shaped, attached to one barrier island, running in front of the other island. Lighthouse Inlet, Jeremy Inlet, St. Catherines Sound, and McQueen Inlet are examples of Class D inlets (Atlas plates 3, 6, 8, and 9). Winyah Bay Entrance (prior to jetty construction), Capers Inlet, Tybee Creek Inlet, and Hampton River Inlet are examples of Class B inlets (Atlas plates 1, 5, 8, and 9).

Class A inlets have no single, well-developed, ebb-channel crossing the ebb-tidal delta. This type is typically found where small tidal creeks emerge directly into the open Atlantic; however, the deltas of larger tidal creeks may also exhibit this form. The Folly and Christmas Creek are examples of Class A inlets (Atlas plates 6 and 10). Table 5-11 classifies all Sea Island Coastal Region inlets as belonging in Class A, B, or D and, in addition, presents data from Nummedal et al. (1977) on estuary-lagoon size, maximum main channel depth, and flood-tidal delta area.

D. EBB-TIDAL DELTAS

1. Origin

All inlets of the Sea Island Coastal Region are characterized by extensive ebb-tidal deltas or shoals projecting out into the open Atlantic Ocean and the near absence of flood-tidal deltas protruding into the estuaries. This situation has been directly related to, among other factors, the time-velocity asymmetry of tidal currents. The flood tide operates over a longer portion of the tidal cycle than does the ebb tide and in order to balance the respective tidal prisms (the volume of water exchanged on each tide), the ebb velocities are significantly greater than flood velocities (Postma 1967, Nummedal et al. 1977). This asymmetry is thought to be primarily caused by the geometry of the estuary (Nummedal et al. 1977). In an estuary with extensive intertidal marshes and mudflats, the inlet is much less efficient in transporting water to flood the vast expanses of broad, intertidal flats. As a result, estuarine high water lags behind oceanic high water. No such lag exists at low water because only the narrow creeks are involved in moving water throughout the estuary. Thus, the inlet channel becomes ebb-dominant, favoring the creation of ebb-tidal deltas over flood-tidal deltas.

2. Symmetry

The overall symmetry of the ebb-tidal delta is largely a function of the relative magnitudes of 1) longshore or littoral transport (wave-induced sand transport parallel to shore), and 2) the strength of the ebb-tidal jet. The dominance of longshore transport produces crescent-shaped deltas attached to the updrift shore and curving in the downdrift direction across the inlet. Dominance of the ebb-tidal jet produces a delta symmetric about the main ebb channel which is oriented perpendicular to the coast.

3. Geomorphic Nomenclature

Nomenclature describing ebb-tidal delta morphology has been developed by Hayes (1969) and Oertel (1972) and is presented in Figure 5-12. The main ebb channel is flanked by the ebb-tidal delta or ramp margin shoals upon which are found swash platforms, channel margin linear bars, and swash bars. The delta has a terminal lobe or distal shoals at its oceanward end. Marginal flood channels typically occur between the delta proper and the adjacent beaches. Oertel (1972) noted from observations made in the Sea Island Coastal Region that ramp margin shoals may be either attached to the barrier island or segmented from it by marginal flood, spillover, and funnel channels. Ebb-directed tidal currents predominate in the main ebb channel and flood-directed ones predominate in the marginal flood channels. Wave activity is at least as important as tidal current activity in constructing the swash platforms and predominates in the formation of swash bars (Oertel 1972, Fitzgerald 1977). Interaction between waning, ebb-directed tidal currents, and ocean waves determines the geometry and geographic location of the terminal lobe.

4. Sediments

The nature and distribution of sediments comprising a Sea Island Coastal Region ebb-tidal delta complex have been described by Howard and Reineck (1972), Oertel (1975b), and Frey and Pinet (1978). A generalized picture of bottom sediment types in presented in Figure 5-13. Typically, sand is the dominant sediment comprising the ebb-tidal delta or ramp margin shoal and the terminal lobe. Sand mixed with mud or clay characterizes the sloping sides of the main ebb channel with the mud content increasing toward the bottom of the channel. A lag gravel of very coarse sand and shell overlying

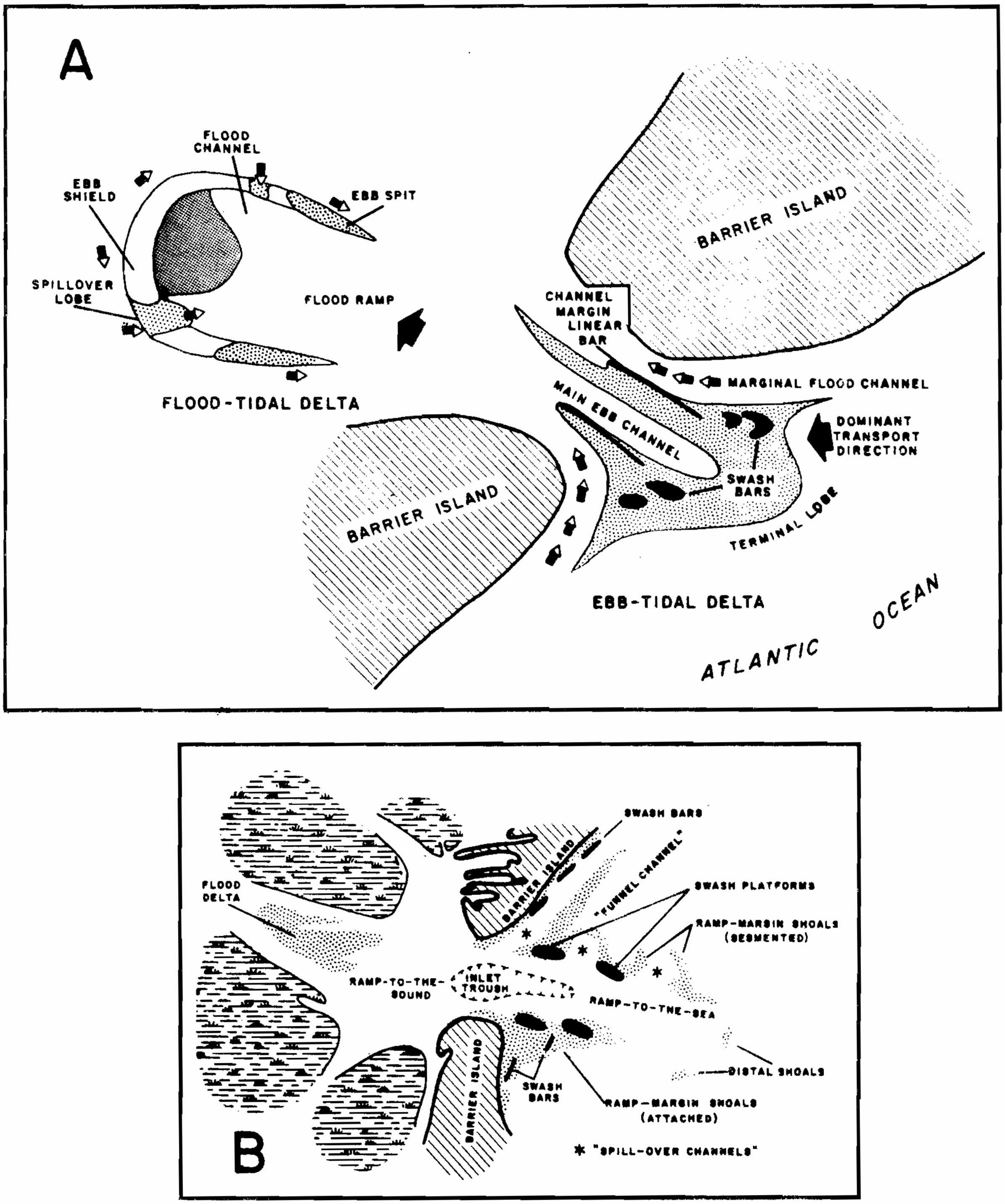


Figure 5-12. Tidal delta morphology nomenclature according to Hayes (1969) and Oertel (1972).

Table 5-11. Morphology classification of Sea Island Coastal Region inlets and data on lagoon-estuary size, open water in lagoon-estuary, inlet throat maximum depth, ebb-tidal delta area, and flood-tidal delta area. Areas are given in m^2 ($1\ m^2 = 1.2\ yd^2$).

Inlet	Class[a]	Total Lagoon Area, ...X $10^6\ m^2$	Open Water Area, ...x $10^6\ m^2$	Maximum Throat Depth (m,MLW)	Ebb-tidal delta Area, ...x $10^6\ m^2$	Flood-tidal delta Area, ...x $10^6\ m^2$
Murrells[b]	B	14	4.8		4.3	0.3
Midway	B					
Pawleys	B					
North[b]	D	24	6.3	8.00	3.8	0.1
Winyah Bay	B	221	183.0	Jettied	88.0	--
N. Santee River	D/B			6.67		
S. Santee River	B			5.00		
Cape Romain Harbor	B			5.00		
Key	D			7.33		
Five-Fathom Creek	B			10.00		
Bull Creek	B			7.00		
Price[c]	D	21	--	8.00	2.1	--
Capers[b]	D	21	--	7.50	3.7	--
Dewees[b]	D/B	31	--	12.00	10.0	--
Breach[b]	B	16	--	10.00	2.0	--
Charleston Harbor[d]	B[e]	188	88.0	Jettied	92.0	3.0
Lighthouse[b]	D	25	--	8.6	4.8	--
Stono[b]	D	95	19.0	10.00	27.0	--
Captain Sams	B					
North Edisto[b]	D	132	28.0	22.00	50.0	--
South Creek	B			2.70		
Frampton	D					
Jeremy	D					
South Edisto	D			11.70		
St. lena Sound[b]	D	535	109.0	14.00	218.0	--
Fripp	D	38	7.7	7.30	7.4	--
Skull	D			.70		
Trenchards	D			12.70		
Port Royal Sound[b]	D	407	134.0	20.00	269.0	--
The Folly	A					
Calibogue Sound[b]	B	119	36.0	16.00	37.0	--
New River	B/A			7.70		
Wright River	B[e]			2.70		
Tybee Creek	B/A			4.30		
Wassaw Sound[b]	D	128	25.0	12.00	59.0	4.3
Ossabaw Sound[b]	D	224	72.0	10.00	74.0	5.8
St. Catherines Sound[b]	D	273	61.0	20.00	85.0	2.3
McQueens	B					
Sapelo Sound[b]	D	273	47.0	26.00	86.0	--
Cabretta	B					
Doboy Sound[b]	D	156	28.0	14.00	45.0	--
Altamaha River[b]	D	84	19.0	7.00	46.0	5.9

Table 5-11. Concluded

Inlet	Class[a]	Total Lagoon Area, ...X 10^6 m^2	Open Water Area, ...x 10^6 m^2	Maximum Throat Depth (m,MLW)	Ebb-Tidal delta Area, ...x 10^6 m^2	Flood-tidal delta Area, ...x 10^6 m^2
Hampton River	B			11.00		
Goulds	B			2.00		
St. Simons Sound[b]	D	219	47.0	25.00	60.0	1.0
St. Andrews Sound[b]	D	336	77.0	23.00	76.0	4.2
Christmas Creek,	A			1.00		
St. Marys River[b]	D[e]	189	40.0	Jettied	76.0	.0

a. Classification of Oertel (1977).
b. Nummedal et al. (1977).
c. Fitzgerald (1977).
d. Bishop and Shealy (1977).
e. Prior to inlet improvement.

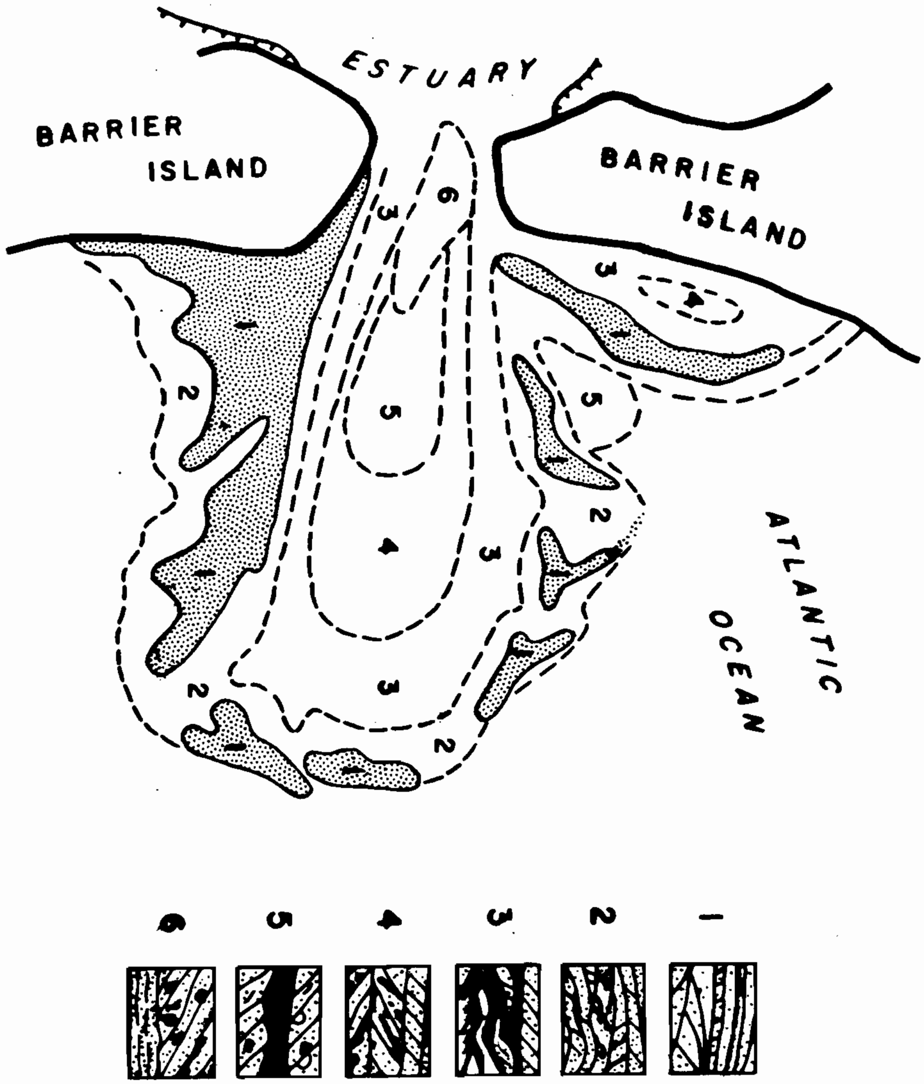


Figure 5-13. Textural and structural characteristics of the sea bed adjacent to Georgia estuary entrances (Oertel 1975b): 1. clean sand, 2. clean sand with mud lenses, 3. interbedded sand and mud, 4. mud pebbles in clean sand, 5. interbedded mud and poorly sorted sand, 6. coarse sediment "lag gravel" over Tertiary bedrock outcrop.

exposed Tertiary bedrock frequently occurs at the deepest part of the main ebb channel.

5. Dynamics

The sands comprising these ebb deltas are not redistributed up and down the coast. These deltas or shoals remain essentially in their original location, changing in geometry under the influence of waves and tidal currents, and dominate their immediate region (Oertel and Howard 1972, Hayes 1977, Olsen 1977, Stapor 1977, and Finley 1978). They cause wave refraction and establish local, inlet-directed littoral drift reversals, insuring inlet-directed sand transport from waves as well as tidal currents.

a. Erosion and Deposition Rates. Stapor (1977) has measured volumes of sand eroded and deposited over the past 100 years at the Stono Inlet, and Olsen (1977) has done the same for the St. Marys Entrance (Figs. 5-14, 5-15, and 5-16). Both studies indicate extensive reworking of the respective ebb-tidal deltas by 1) shifts in the main ebb channel, and 2) wave action moving sand across the delta. A major conclusion drawn by Oertel and Howard (1972), Stapor (1977), and Olsen (1977) is that the larger ebb deltas are essentially complete littoral traps, intercepting sand moving up and down the coast and holding it in the delta. Modifications to the main ebb channel, such as jetties, greatly enhance the trapping effectiveness of these larger deltas (Olsen 1977).

b. Evolutionary Changes. The ebb-tidal deltas of these coastal inlets are in a state of dynamic equilibrium, changing their geometries in response to fluctuations in littoral sand supply (direction and amount), wave climate, tidal prism, and freshwater discharge, to name just a few of the major parameters. Oertel's (1977) classification for Sea Island Coastal Region inlets uses the relative importance of onshore, offshore, and longshore currents (Fig. 5-17). Furthermore, he recognizes that Class A

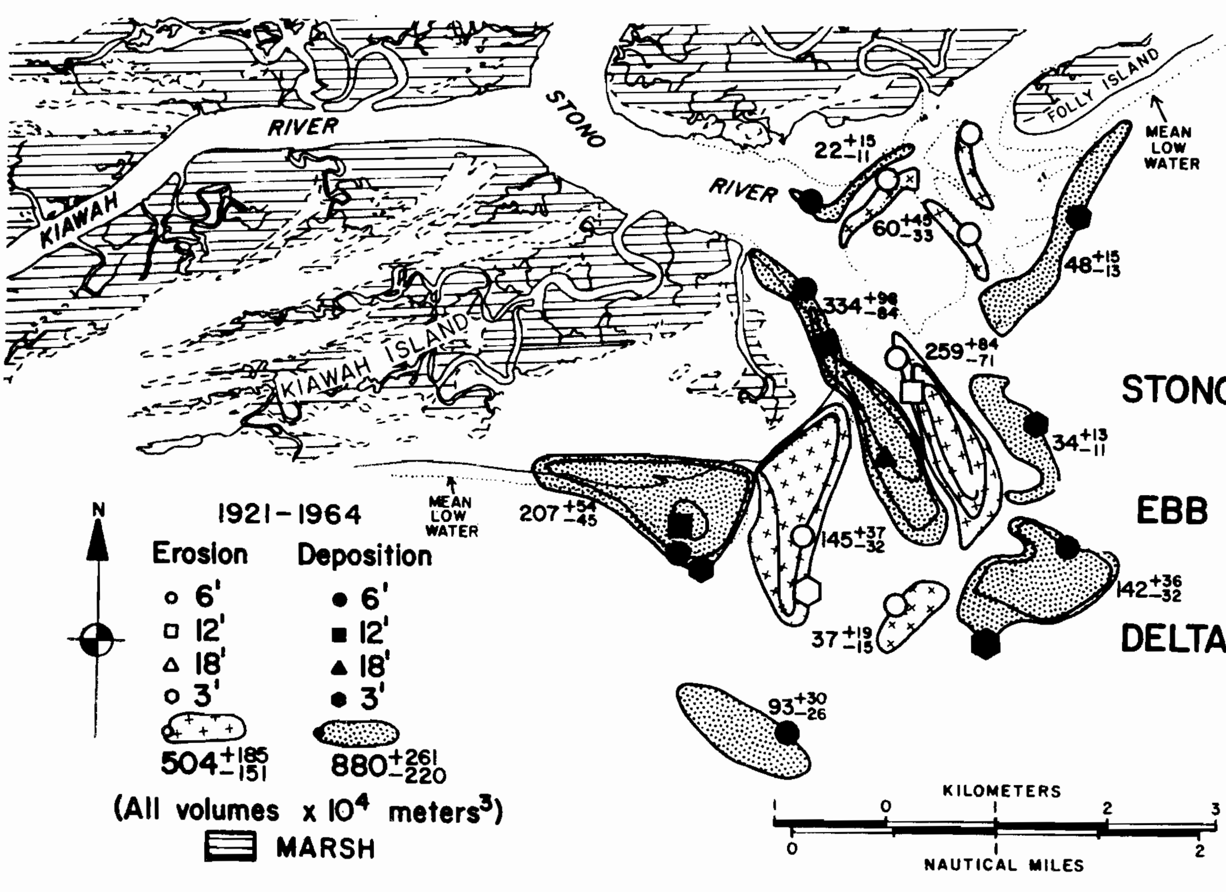


Figure 5-14. Net volumes of sediment deposited and eroded at the Stono Inlet between 1862 and 1921 (Stapor 1977). Net erosion and deposition are balanced, suggesting that significant quantities of littoral drift are either 1) not moving into the inlet-delta system or 2) completely bypassing it.

inlets can change into Class B and vice versa. This genetic interrelationship is presented in the geomorphic cycles of ebb deltas in Figure 5-17. Class A deltas progress from youth to maturity to old age and then to Class B deltas. Class D deltas move through youth-maturity-old age stages as they change from being attached to separated from the ramp margin shoals (Figs. 5-12 and 5-17).

E. MAN'S MODIFICATION

The migrating habit of these inlets and ever-increasing vessel size have necessitated that modifications be undertaken at inlets serving major ports and even fishing villages. Winyah Bay Entrance, Charleston Harbor Entrance, and St. Marys River Entrance have been modified with stone jetties, all begun in the late nineteenth century and completed in the early twentieth century, with deepened channels extending out onto the nearshore continental shelf. These structures have affected the adjacent islands, resulting in significant erosion and deposition. The Charleston Harbor jetties have probably caused significant deposition to take place on Morris Island (Stapor 1977), and those at St. Marys Entrance have caused both erosion and deposition to take place on Cumberland and Amelia islands (Olsen 1977). The Winyah Bay Entrance jetties have resulted in deposition on both North and South islands. Natural channels have been deepened and are, with variable success, maintained at Murrells Inlet, Five Fathom Creek (Bulls Bay), the Stono Inlet, Port Royal Sound, Tybee Roads (Savannah River Entrance Channel), St. Simons Sound (Brunswick Harbor Entrance Channel), and St. Marys River Entrance (Cumberland Sound).

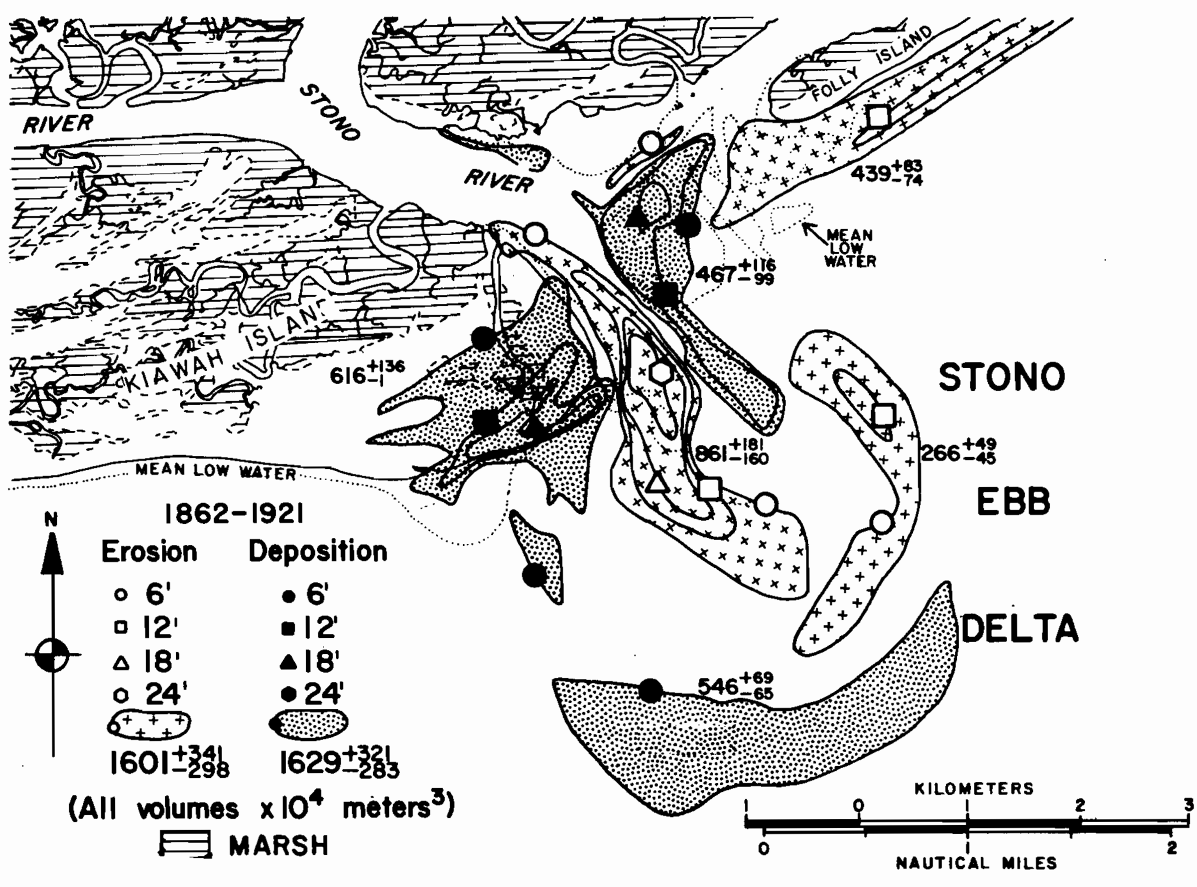


Figure 5-15. Net volumes of sediment deposited and eroded at the Stono Inlet between 1921 and 1964 (Stapor 1977). Net erosion and deposition are balanced, suggesting that significant quantities of littoral drift are either 1) not moving into the inlet-delta system or 2) completely bypassing it.

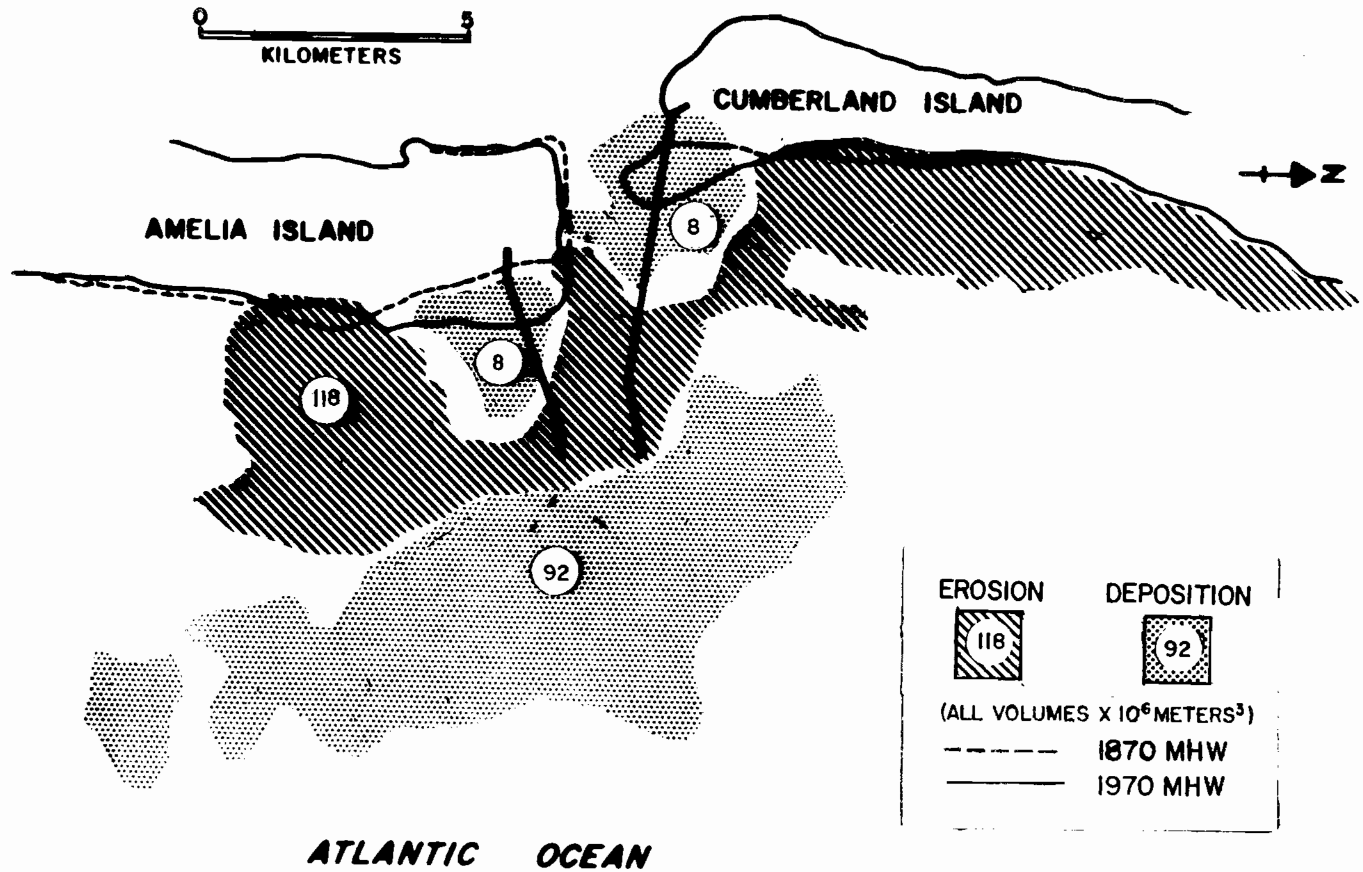
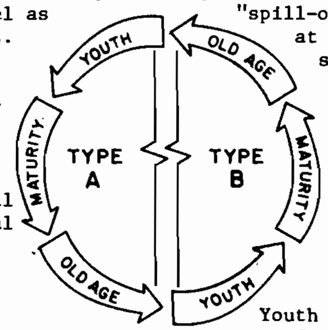


Figure 5-16. Net volumes of sediment deposited and eroded over a 100-year period at St. Marys Entrance (adapted from Olsen 1977). Net erosion and deposition are essentially balanced and suggest that significant quantities of littoral drift are either 1) not moving into the inlet-delta system or 2) completely bypassing it. The numbers in each of the shaded regions refer to the volume of sediment eroded or deposited.

Youth - Broad, short, triangular sand body, hummocky surface with elevated swash bars and swash platforms; submarine part of sand body extends toward axis of inlet channel as offshore; stable shoreline features.

Maturity - Narrow, long, triangular sand body, surface hummocky with elevated swash bars and platforms. Submarine portion of sand body extends primarily offshore. Erosional retreat of channelward side of shoal and island; development of several narrow "spill-over" channels which terminate in center of shoal.

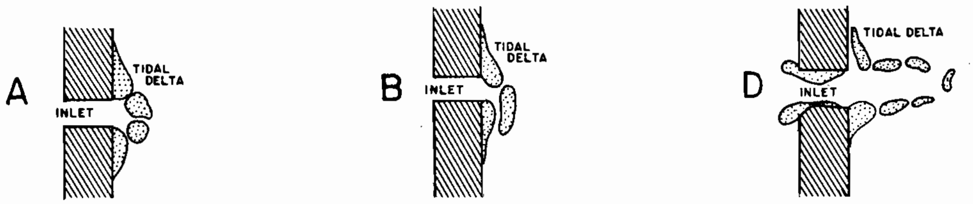
Old Age - Narrow, long, triangular sand body; extensive erosion along channelward side of shoal and island.



Old Age - Broad, short, triangular sand body separated from island by broad, shallow "spill-over" channel; extensive shoaling in "spill-over" channels; extensive accretion at beach adjacent to proximal end of shoal.

Maturity - Broad, segmented shoal separated from island by well developed "spill-over" channels, extensive longshore development of shoal and beach adjacent to proximal end of shoal.

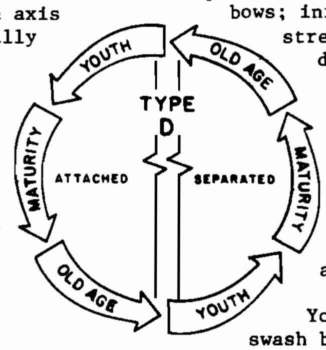
Youth - Narrow, segmented shoal separated from island; initial dissection of sand body by "spill-over" channels; initial reconstruction of beach at proximal end of shoal: erosion of beach in lee of the shoal.



Youth - Broad, shortened arcuate delta with numerous "spill-over" channels and reentrants evenly distributed along the axis of the delta; adjacent beach generally accreting.

Maturity - Elongated arcuate delta; reentrants on the upstream part of delta becoming shallow, restricting water flow; initial erosion at downstream channel bank.

Old Age - Elongated, hummocky spit with shallow reentrants, one relatively deep reentrant at downstream (distal) end of downstream channel bank at proximal end of spit.



Old Age - Narrow, elongated spit with small "spill-over" channels extending from scour bows; initial beach development on downstream channel bank, stable beach at distal end of spit.

Maturity - Narrow, elongated spit with scour bows on landward side, spit is displaced landward and downstream from its youthful position; flow restricted to one or two channels at distal end of spit; extensive erosion of beach at proximal end of spit.

Youth - Broad, elongated spit with swash bars and platforms and no obvious "spill-over" channels or reentrants, flow restricted to one or two main channels at distal end of spit; extensive erosion along downstream channel bank and beach at proximal end of spit.

Figure 5-17. Ebb-tidal delta geomorphic cycles, after Oertel (1977). Littoral drift is a significant parameter in types A and B but is not in type D.

CHAPTER SIX

SUMMARY OF PHYSICAL AND CHEMICAL ALTERATIONS

Basically, environmental alterations can be classified as natural and man-induced. The purpose of this chapter is to summarize those physical and chemical changes which have occurred within the Sea Island Coastal Region, with special emphasis on estuarine areas. While many ecological interactions are implied in this section, the reader should refer to Volume III (Biological Features) for more detailed discussions on functional relationships and pertinent literature sources. Much information in this chapter was written from first-hand experience by the authors and from information gathered from the other volumes of this study. Therefore, references are not extensively cited throughout this section.

I. NATURAL ALTERATIONS

It is well recognized that if an equilibrium exists in the Sea Island Coastal Region, it is a dynamic equilibrium, and that short-term deviations from this equilibrium can be expected. Many times these variations are extreme and relate heavily to man's use of the coastal environment.

The major "natural" forces exerted on this region include waves, tide, winds, currents, rainfall, river discharge, temperature, and other meteorological phenomena. These forces are responsible for the basic physical character of the region, and cause short- and long-term variations in the coastal environment (see Chapter Four).

Among the most important natural factors affecting the Sea Island Coastal Region are the tidal and wind-generated currents which play a key role in making the sea edge a highly variable and complex environment (see Chapter Five). Not only do currents constitute the principal mechanism by which interchanges of fresh and salt water occur, but the resulting circulation patterns also are known to greatly influence the distribution of 1) other chemical components of the water in addition to salinity, 2) physical properties such as temperature, 3) suspended matter, and 4) biological populations.

Another physical fact that relates to the natural characteristics of this region is that the Atlantic Ocean is not a limitless reservoir, and individual estuaries are not totally independent of one another. Materials dispersed via individual estuarine systems into the ocean are exchanged between one estuarine system and another along the coastline of the Sea Island Coastal Region (Neiheisel and Weaver 1967). Therefore, estuarine pollution must be considered on a regional basis rather than on the basis of political boundaries. Pollutants dumped into Charleston Harbor may be carried southward with the littoral current and eventually into Savannah and Brunswick harbors. Also, estuaries are not "open-ended" systems, and pollutants released into these systems may remain there through tidal oscillations and the same mechanisms that trap nutrients (see Chapter Five). Pollutants may simply move back and forth within estuaries.

The effects of natural environmental perturbations can be quite important with respect to natural resources, tourism, etc. The extremely cold winters of 1977 and 1978 killed shrimp crops and caused economic hardship for shrimpers. Excessive freshwater runoff has seriously depleted oyster populations on occasion, and has driven many marine and estuarine organisms from tidal creeks. Cold weather has also damaged coastal agricultural crops and hurt tourism. Overall, the impact of natural perturbations can seriously affect the coastal region, especially in a financial sense. However, these are exceptions rather than the rule, and the weather of coastal South Carolina and Georgia is an asset in attracting out-of-state tourists in winter along with respective upstate citizens in summer (see Volume II, Chapter Nine).

II. MAN-INDUCED ALTERATIONS

Man-made coastal alterations in the Sea Island Coastal Region are related primarily to 1) agriculture; 2) dredging and filling in coastal waters for navigation, water transportation, housing and industry; 3) dune destruction in development of barrier islands; 4) water utilization for effluent discharge, power generation, and related water development projects; 5) insect control activities; 6) various upstream activities; and 7) recreation. The reader should refer to Volume III (Chapters Three and Four) for detailed discussions on ecological effects of the above physiochemical activities.

A. CAUSES

1. Agriculture

Much of the land area in the Sea Island Coastal Region is used for agriculture (see Volume II, Chapters Three and Six). While the impact of agriculture on the region's physiography is obvious through such activities as land clearing, soil cultivation, irrigation, drainage, etc. (Clark 1977), it is the insidious effects on water quality that have demanded the most attention in the estuarine environment.

Clearing land of trees and other vegetation to plant crops alters the land surface. Without vegetative cover, soil erosion by wind or water takes place. The amount of soil erosion depends upon rainfall patterns, wind patterns, slope of the land, soil permeability, land use practices employed, and the amount of vegetative covering (U.S. Department of Agriculture 1975). In the coastal plain, soils are underlain by marine sands, loams, and/or clays, with good surface and internal drainage (Georgia Department of Natural Resources 1976). Erosion can be a problem, especially on sandy hills, if fields are fallow.

Cultivation alters the structure of the soil by compressing, lifting, and moving particles. If moisture in the soil is such that plowing can be accomplished without compaction, minimal damage occurs. However, high amounts of subsoil moisture can cause the farming implement to compact soil so that drainage and aeration are impaired. The land ideally should be cultivated when soil moisture is minimal, such as at the end of the crop season (U.S. Department of Agriculture 1975). Improper use of machinery, such as the disk harrow, may cause reduction of particle size (U.S. Department of Agriculture 1975). Soil particles become so fine that soil pore sizes decrease to the point that rain can no longer percolate through the soil but must run off the surface, which in turn increases the sediment load in natural surface waters.

Important alterations result from implementation of supporting practices for agricultural land such as channeling, contour plowing, stripcropping, terracing, and diversion terracing. Each method is designed to improve soil conditions and reduce soil and water loss. On sloping land, canals serve as outlets for terraces and contour rows by funneling water without erosion of soil. Stripcropping, the practice of cultivating parallel to land contours, is effective on well-drained cultivated soils on sloping land where rainfall causes erosion (U.S. Department of Agriculture 1957). These methods apply to parts of the coastal plain with gentle to moderate slopes. Terraces or ridges built across a slope help contain water long enough for it to soak into the soil or to flow off the field at a slower rate. These methods were used for many years, but were inadequate to protect soils of the coastal watershed of Georgia, even when residues were left on the land (Georgia Department of Natural Resources 1976).

Agriculture and silviculture practices can significantly decrease the quality of water flowing into coastal areas and cause drastic adverse reactions in aquatic life (Butler 1968). Land runoff from agricultural areas carries fertilizers (nitrates and phosphates), herbicides, pesticides, and silt, any of which acting alone or in combination may be lethal to aquatic life, particularly larval forms. Nitrates and phosphates may not be toxic directly, but high concentrations encourage algal blooms which lead to eutrophication and possible oxygen depletion. Pesticides and herbicides can be toxic in concentrations of parts per million, and concentrations of parts per billion are known to cause behavior and reproduction abnormalities.

Pesticides most commonly enter the coastal waters in runoff from agriculture and forest lands (Butler 1968). The reader is referred to Volume III for discussions on biological magnification of the chlorinated hydrocarbons and their effects on marine and estuarine organisms.

The use of chemicals to control fire ants, saltmarsh mosquitoes, flies, and other noxious insects has been of special concern in the study area. Mirex, a chlorinated hydrocarbon compound, was used over vast marshland areas to eradicate fire ants in the late 1960's and early 1970's (McKenzie 1970). Today, due to Federal restrictions, this pesticide is used only inland on agricultural lands. Thus, mirex enters the estuarine food chain through agriculture runoff. This compound has been found to be lethal to fish and wildlife when applied at standard rates (Mahood et al. 1970, McKenzie 1970).

Chemical control of saltmarsh mosquitoes has caused pesticide pollution in the study area. Formerly, DDT was the most commonly used compound in coastal South Carolina and Georgia for adult mosquitoes. Its effects on aquatic organisms have been well documented (Lowe 1965, Butler 1963). Present methodology involves the use of malathion or Paris green (copper acetoarsenite) vermiculite pellets or No. 2 fuel oil with a surfactant in the marshes to kill mosquito larvae (see Volume III).

General and site-specific cases of agriculture pollution are included in the following section on water quality of river basins of the study area.

2. <u>Urbanization and Industrialization</u>

Urbanization and industrialization are responsible for both short- and long-term effects on the study area. Demographic and socioeconomic trends in South Carolina and Georgia project a rapid increase of private waterfront development for residential purposes (see Volume II, Chapter Three). Thus, water-oriented housing developments will increasingly become a major concern in estuarine areas. Sheer population numbers, coupled with growth of estuary-oriented economic centers, will place heavy demands on estuarine lands. Land will be needed for housing, industry, commerce, transportation terminals, and recreational facilities. Urbanization and industrialization will affect estuaries in three primary ways: 1) competitive demands for existing waterfront will greatly increase; 2) waste disposal problems will become greater and will constitute an even more serious estuarine pollution problem; and 3) urban demands will multiply the number of space-demanding power generating, water, and waste disposal facilities within estuarine areas.

Concomitant with demands of urbanization are those for recreation (see Volume II, Chapter Nine). The economic importance of water-oriented recreational activities to coastal communities cannot be overstated. Recreation and tourism often rank at least third in terms of income for even large, diversified, urban economies. Many forms of recreation including swimming, sport fishing, sail boating, sight-seeing, and bird watching have little effect on aquatic resources. Other forms (e.g., power boating) may have indirect effects such as harassment and noise pollution. Support facilities for boats affect water quality. Marinas are point sources for the introduction of hydrocarbons, solid waste, and domestic waste. The effects of leached chemicals from treated pilings from piers and marinas also contribute to the chronic, low concentration of dissolved foreign materials in estuarine waters. Socio-economic effects of urbanization and industrialization in the Sea Island Coastal Region are discussed in Chapters Two through Four of Volume II.

3. Mining

Mining industries are few in South Carolina and Georgia coastal areas, with limestone, coquina, and sand mining receiving the most attention. Currently, there are several large coquina pits in the Little River area which have destroyed emergent marsh and interrupted natural water circulation. The largest of these is about 20 acres (8 ha). Sand is the only mineral mined commercially in the Georgia coastal region. In 1972, a total of seven mining companies were operating along the major coastal rivers for sand (see Chapter Two).

Phosphate has not been mined in South Carolina since 1938, but the potential exists for mining phosphate in Georgia. Although no operations exist at the present time, mining could be accomplished presently or in the near future at a known phosphate ore-body deposit in the area of Chatham County, south of the South Carolina line and north of Ossabaw Sound. If phosphate mining is proposed, in addition to potential impacts on coastal marshlands, fisheries, and air and water resources, mining activities could adversely affect the groundwater aquifer that is important to coastal Georgia.

Although oil and gas exploration has only recently commenced in outer continental shelf waters off South Carolina and Georgia, petroleum-related activities will probably have greater impact onshore than offshore. Impacts ranging from oil spills to development of major production facilities, and from navigational hazards to pipeline corridors could drastically alter the environment and economy of the Sea Island Coastal Region of both States (see Volume II, Chapter Four).

4. Dredging and Filling - Navigation Projects

Dredge and fill activities in the Sea Island Coastal Region are most often associated with urbanization and navigation. The general impacts of coastal development and urbanization have been discussed previously. For a more detailed discussion on ecological effects of dredging and filling, the reader is referred to Volume III. Coastal alterations related to navigation and water transportation in the study area are emphasized in this section.

There are seven major navigation projects within the Sea Island Coastal Region which have large-scale physical impacts: 1) the Georgetown Harbor-Winyah Bay Project, 2) the Charleston Harbor Project, 3) Port Royal Harbor Project, 4) the Savannah Harbor Project, 5) the Brunswick Harbor Project, 6) Kings Bay-St. Marys Entrance Project, and 7) the Atlantic Intracoastal Waterway Project. The disposal of dredged material during construction and maintenance of the first six projects has resulted in the diking of over 14,000 acres (5,656 ha) of coastal marsh. This is approximately 1.5% of the total Sea Island Coastal Region marsh acreage. The seventh project, the Atlantic Intracoastal Waterway, potentially can impact 2.6% of the total Sea Island Coastal Region marsh acreage if all easements were to be fully utilized.

The following sections present historical data on the seven major navigation projects in the study area. Unless otherwise noted, data presented in this section pertaining to navigation projects were obtained from the annual report series of the Chief of Engineers on Civil Works Activities, U.S. Arm Corps of Engineers, for the years 1878 - 1977. Annual dredging data for the first six of these navigation projects are presented in Appendix C of this volume. Summaries of these data, by project depth, are shown in Table 6-1.

a. Atlantic Intracoastal Waterway. The Intracoastal Waterway is a system of dredged channels cut through rivers, estuaries, sounds, and uplands to provide a protected inside passage, as opposed to an outside passage in the open Atlantic Ocean and Gulf of Mexico, from New England to Texas. The Atlantic Intracoastal Waterway (AIWW) is the east coast portion of this important navigation system. The present 12 ft MLW x 90 ft (3.7 m x 27.4 m) channel was completed in 1940 in South Carolina and 1941 in Georgia. The AIWW is used by both commercial and recreational vessels. The channel is largely cut through coastal salt marsh in the Sea Island Coastal Region (see Atlas plates 31 - 40), with only short lengths cut through sandy high land except for the stretch in Horry County, South Carolina, which traverses sandy high land for a distance of 22 mi (35 km). The Charleston District, U.S. Army Corps of Engineers, has responsibility for construction and maintenance of the AIWW from the North Carolina/South Carolina State line near Little River, South Carolina, to Port Royal Sound, Beaufort County, South Carolina. The Savannah District, U.S. Army Corps of Engineers, has AIWW construction and maintenance responsiblity from Port Royal Sound to the Georgia/Florida State line.

The earliest construction along the present-day AIWW occurred in the late 1850's when the State of South Carolina dredged Elliots Cut between Wappoo Creek and the Stono River, Charleston County (U.S. Army Corps of Engineers 1976a). Table 6-2 presents a history of the AIWW in South Carolina and Georgia as well as the lengths of respective segments, volumes of material removed during initial construction (new work) and maintenance dredging, and disposal easement acreages. Tinkler (1976) presents a detailed history of the AIWW in Georgia and the U.S. Army Corps of Engineers (1976b) does the same for South Carolina.

Construction and maintenance of the AIWW have resulted in the destruction and/or alteration of much of the terrain it traverses, particularly the coastal marshes of South Carolina and Georgia. Disposal easements located along the canal include some 25,000 acres (10,100 ha) of salt marsh which are designated as disposal sites for dredged material. (See Table 6-2 and Atlas plates 31 - 40.) Disposal of material dredged from the channel poses a continuous threat to the saltmarsh habitat. At present, the most economical method of disposal (U.S. Army Corps of Engineers 1976a,b,c) is to place dredged material on adjacent marshes. Of the 25,000 acres (10,100 ha) of salt marsh disposal easements in the Sea Island Coastal Region, 2,365 acres (957 ha) are presently diked, a method which completely destroys the salt marsh (see Table 6-2). Diking of saltmarsh disposal easements is commonly employed in South Carolina, but rarely practiced in Georgia.

Arguments for and against diking of saltmarsh disposal easements center around retention effectiveness and water quality. The former has been used as a major argument by the Charleston District Corps of Engineers to justify the diking of disposal areas (U.S. Army Corps of Engineers 1976a). However, the Savannah District Corps of Engineers has not advanced this argument, even in the face of its significantly greater maintenance problem. The Savannah District uses unconfined disposal areas, advancing the argument that unconfined disposal minimizes marsh alteration (U.S. Army Corps of Engineers 1976b). The water quality question has been investigated to some extent by the Savannah District (Windom 1972a,b, 1975). These studies suggest that retention of water and dredged material within a diked area prior to water release does not improve its quality, and in polluted areas, quality may be impaired (U.S. Army Corps of Engineers 1976b).

Vessels using the AIWW have caused locally serious bank erosion, resulting in significant shoreline retreat. This erosion is most prevalent where the AIWW crosses sandy high land, as in Horry County, South Carolina, and Goat Island, Charleston County, South Carolina. Waves (wakes) generated by passing boats and barges are responsible for most of the bank erosion.

b. Georgetown Harbor-Winyah Bay. Georgetown Harbor proper lies in the lower reaches of the Sampit River, a tidal stream flowing into Winyah Bay. Early bathymetry charts (pre-navigation projects) show controlling depths of 9 - 12 ft (2.7 - 3.7 m) MLW separating sinuous channels with depths to 18 - 20 ft (5.5 - 6.1 m) MLW in the bay and lower Sampit River (U.S. Coast and Geodetic Survey 1853).

Construction began on the existing 27 ft (8.2 m) MLW project in 1947 and was completed in 1951. Although the project depth of 27 ft (8.2 m) MLW is presently being maintained, project widths along the entire channel length are not. A detailed map of this area showing harbor bathymetry and spoil areas is presented on Atlas plate 43-A).

Annual dredging data from 1885 - 1977 are presented in Appendix Table C-1.

Table 6-1. Summary of dredging data for the major harbor projects in the Sea Island Coastal Region.

	Years	Project Depth	New Work Dredging (yd^3)	Maintenance Dredging (yd^3)	Avg. Annual Maintenance Dredging (yd^3)
Georgetown Harbor Project	1885 - 1911	15'	2,497,783	838,457	32,248
	1912 - 1946	18'	10,427,611	12,715,202	373,977
	1947 - 1977	27'	14,603,963	42,824,560	1,427,485
Charleston Harbor Project	1878 - 1900	21'	2,595,814	524,401	23,836
	1901 - 1910	26'	2,188,536	1,097,589	109,759
	1911 - 1916	28'	4,710,982	329,547	65,910
	1917 - 1940	30'	11,856,913	7,498,350	326,015
	1941 - 1977	35'	16,000,985	138,136,171	3,837,116
Port Royal Harbor Project	1956 - 1977	27'	4,059,825	5,734,793	273,085
Savannah Harbor Project	1873 - 1902	26'	800,864	23,769,880	819,651
	1903 - 1917	28'	20,522,075	11,784,647	841,760
	1918 - 1947	30'	25,213,037	154,496,838	5,327,477
	1948 - 1964	36'	14,520,261	112,170,163	7,010,635
	1965 - 1977	40'	56,408,977	85,890,855	7,157,571
Brunswick Harbor Project	1880 - 1907	21'	1,163,886	344,802	12,770
	1908 - 1959	30'	13,692,652	16,952,929	322,410
	1960 - 1977	32'	3,863,134	23,218,648	1,365,803
St. Marys Entrance Project	1903 - 1925	19'	546,050	924,536	40,197
	1927 - 1954	28'	248,048	498,919	18,480
	1955 - 1979	34'	3,001,108	4,840,529	201,690
	1979	40'	3,089,439	- -	- -
Kings Bay Project	1955 - 1976	32'	10,040,000	4,730,000	225,238
	1977	36'	9,462,000	- -	- -

Table 6-2. Physical description, construction history, dredging data, and disposal easements of the Atlantic Intracoastal Waterway in the Charleston and Savannah Districts, U.S. Army Corps of Engineers.

	Charleston District, U.S. Army Corps of Engineers[a]			Savannah District, U.S. Army Corps of Engineers[b]	
	Little River to Winyah Bay	Winyah Bay to Charleston	Charleston to Port Royal Sound	Port Royal Sound to Savannah River	Savannah River to St. Marys River (Ga./Fla. State line)
Total Channel Length	59.0 miles	53.2 miles	66.7 miles	24.0 miles	161 miles
Dredged distance to obtain 12' MLW x 90' project	35.3 miles	47.3 miles	30.6 miles	4.5 miles	
New Work (in yd^3)[c]	22,634,500 (8'MLW x 75' project 1930[d])	2,554,646 (4'MLW x 60' project 1919[d])	2,774,159 (7'MLW x 75' project, 1925[d])	934,896 (7'MLW project, 1896[d])	1,572,217 (7'MLW project, 1892[d])
	3,984,027 (12'MLW x 90' project, 1937[d])	16,824,270 (10'MLW x 90' project, 1933[d] & 1935[d])	4,878,482 (12'MLW x 90' project, 1937[d])	507,275 (12'MLW x 90' project, 1937[d])	8,075,831 (12'MLW x 90 project, 1938[d])
		4,112,457 (12'MLW x 90' project, 1937[d])			
	26,618,525 TOTAL	23,491,373 TOTAL	7,652,641 TOTAL	1,442,170 TOTAL	9,648,048 TOTAL
Maintenance Dredging[e] for 12'MLW x 90' project (in yd^3) TOTAL	7,431,294 (1941-1970)	29,670,654 (1941-1970)	7,962,197 (1941-1970)	2,150,850 (1941-1977)	59,739,940 (1941-1976)
Average annual maintenance (in yd^3)	247,710 (1941-1970)	989,022 (1941-1970)	265,407 (1941-1970)	58,131 (1941-1977)	1,706,855 (1941-1976)
Distance dredged in maintenance operations	28.3 miles	34.5 miles	14.2 miles	4.5 miles	25.5 miles
Average annual maintenance per maintained mile	8,753	28,667	18,690	12,918	66,935
Disposal Easements (acres)					
Marsh (acres) Unconfined	339	6,093.4	9,135.1	816.6	6,536.2
Diked	42	1,540	628		155.4
High land (acres) Unconfined	1,851				
Diked	2,518				
Forested Flood plain (acres)	762				
TOTAL	5,512	7,633.4	9,763.1	816.6	6,691.1

[a] U.S. Army Corps of Engineers (1976a, c).
[b] U.S. Army Corps of Engineers (1976b), Tinkler (1976).
[c] credited or net yardage.
[d] year authorized.
[e] actual or gross yardage.

Analysis of these data reveals that an average of approximately 375,000 yd^3/yr (287,000 m^3/yr) of maintenance dredging were required to maintain an 18 ft (5.5 m) MLW project depth between 1912 - 1946. Maintenance dredging requirements increased almost fourfold to over 1,400,000 yd^3/yr (1,070,000 m^3/yr) when the project depth was increased to 27 ft (8.2 m) MLW beginning in 1947. Summaries of the historical dredging data, by project depth, are presented in Table 6-1.

Construction of the 27 ft (8.2 m) MLW project dramatically increased maintenance dredging requirements in certain key portions of the project area as compared with those for the 18 ft (5.5 m) MLW project. For example, maintenance dredging requirements for the Sampit River increased 10-fold, while those for the entrance channel increased 9.5-fold.

The 9.5-fold increase in maintenance spoil resulting from dredging the entrance channel is perhaps the easiest to account for since the previous 18 ft (5.5 m) MLW channel was completely within the jetties (see Figs. 6-1 and 6-2) which extend to the 18 ft (5.5 m) MLW isobath, while the existing 27 ft (8.2 m) MLW channel extends out onto the nearshore shelf. This latter channel intercepts sand moving both north and south parallel to the coast as well as any sand swept into the entrance by flooding tidal currents. The north jetty serves to trap littoral drift moving south along the North Island beach as well as material moving into the entrance channel by flooding tidal currents. This has resulted in an average deposition rate of 44,000 m^3/yr (57,548 yd^3/yr) for the southern tip of the island (Figs. 6-1 and 6-2). The original Winyah Bay ebb-tidal delta has been largely destroyed since completion of the south jetty, coincident with the net seaward growth of South Island (Stapor 1980a). Shoreward transport of the ebb-delta's sand by waves and tidal currents probably resulted in the growth of South Island (Figs. 6-1 and 6-2).

The 10-fold maintenance dredging increase for the Sampit River indicates that it has become an even more efficient sediment trap. Deepening of the Sampit River some 10 - 15 ft (3.0 - 4.6 m) below its natural depth with limited, if any, attendant increase in its discharge has resulted in the creation of an efficient sediment trap. Density stratification (the creation of a salt wedge) has probably moved further and further upbay since the original modification to Winyah Bay in the late nineteenth century, adding to the efficiency of the Sampit River as a sediment trap.

c. Charleston Harbor. Major alterations to the physiography of Charleston Harbor are the result of various navigation projects undertaken to improve and maintain port facilities. Naturally occurring depths within this estuary were more than sufficient to accommodate sailing and other vessels of the early nineteenth and twentieth centuries. However, the ebb-tidal delta extending from Sullivans Island southwest and seaward of Morris Island to Lighthouse Inlet had controlling depths of only 12.0 - 13.5 ft (3.7 - 4.1 m) MLW (U.S. Coast and Geodetic Survey 1851).

A jetty project was proposed in the 1870's to secure a 21 ft (6.4 m) MLW channel across this ebb-tidal delta. Construction began in 1878 and was completed in 1896. Since then, deeper and deeper channels have been constructed: 26 ft (7.9 m) MLW in 1901, 28 ft (8.5 m) MLW in 1911, 30 ft (9.1 m) MLW in 1917, and the present 35 ft (10.7 m) MLW in 1941. Maintenance dredging associated with the 30 ft (9.1 m) MLW project between 1917 - 1940 removed an average of 326,000 yd^3/yr (249,260 m^3/yr). Between 1941 - 1977, an average of 3,800,000 yd^3/yr (2,905,480 m^3/yr) has been removed in order to maintain the 35 ft (10.7 m) MLW project depth. This represents a 12-fold increase in maintenance dredging requirements between the two project depths. Historical dredging data for Charleston Harbor are presented in Appendix Table C-2. A summary of these data, by project depth, is presented in Table 6-1.

Sand is swept into Charleston Harbor by currents operating over the submerged portions of both the north and south jetties (Fig. 6-3). These flooding currents, along with wave action, have pushed shoreward the original ebb-tidal delta off Morris Island (Fig. 6-4). The resulting deposition occurring at Morris and Sullivans islands has been measured to be at least 95,000 m^3/yr (124,251 yd^3/yr) and 30,000 m^3/yr (39,237 yd^3/yr), respectively, by Stapor (1977). The fate of sand swept beyond these two islands and their adjacent shallow bottoms into the 35 ft (10.7 m) MLW Charleston Harbor Entrance channel is at present unclear. Nieuwenhuise et al. (1978) have suggested, based on shape analyses of sand grains, that sand is introduced by flood tidal currents into Charleston Harbor proper. Detailed bottom current measurements necessary to test this hypothesis are few (Neiheisel and Weaver 1967) but indicate that this deep channel is dominated by ebb-directed tidal currents.

During maintenance of the 30 ft (9.1 m) MLW as well as during the early periods of the 35 ft (10.7 m) MLW project

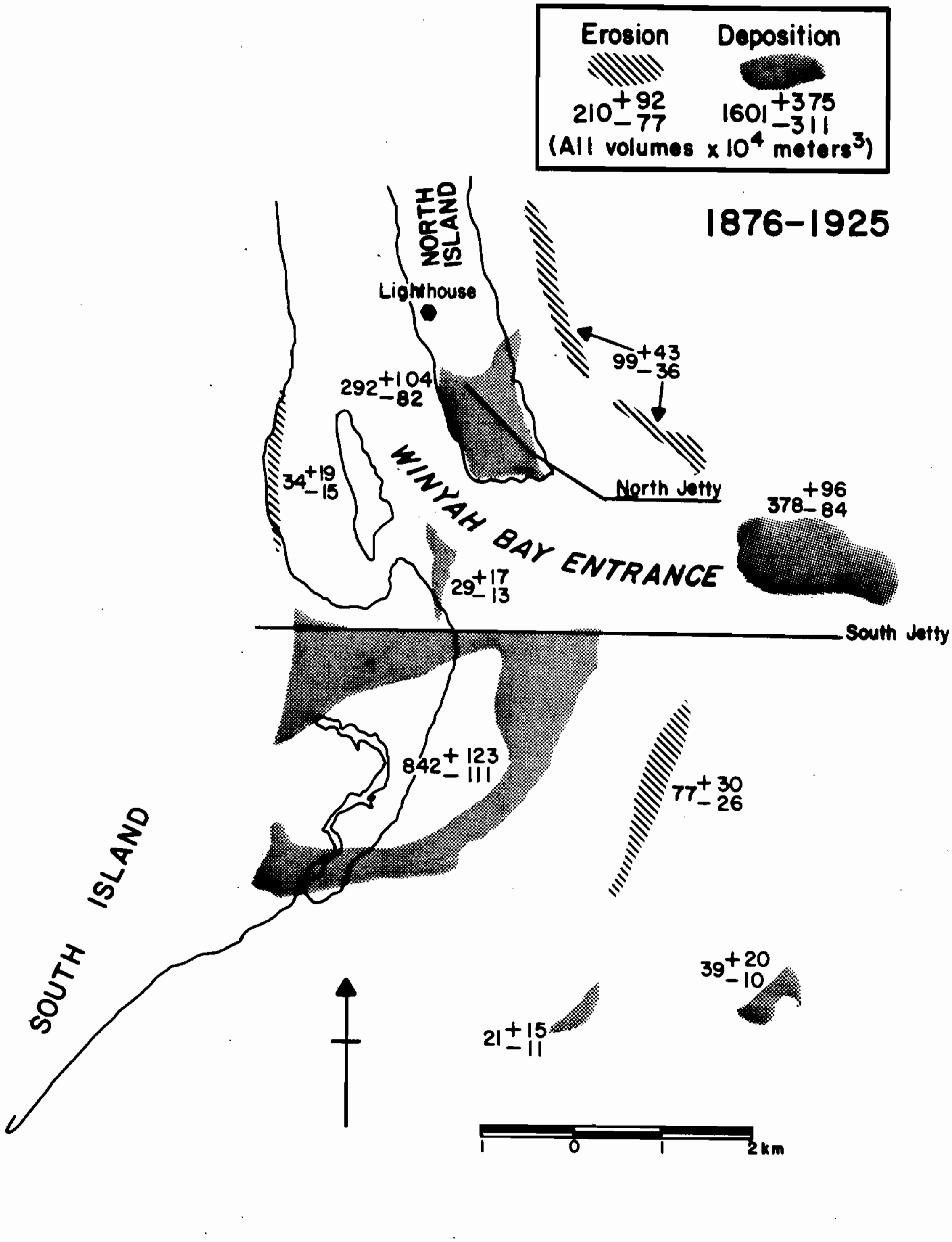


Figure 6-1. Volumes of sediment deposited and eroded at Winyah Bay Entrance between 1876 and 1925 (Stapor 1980a).

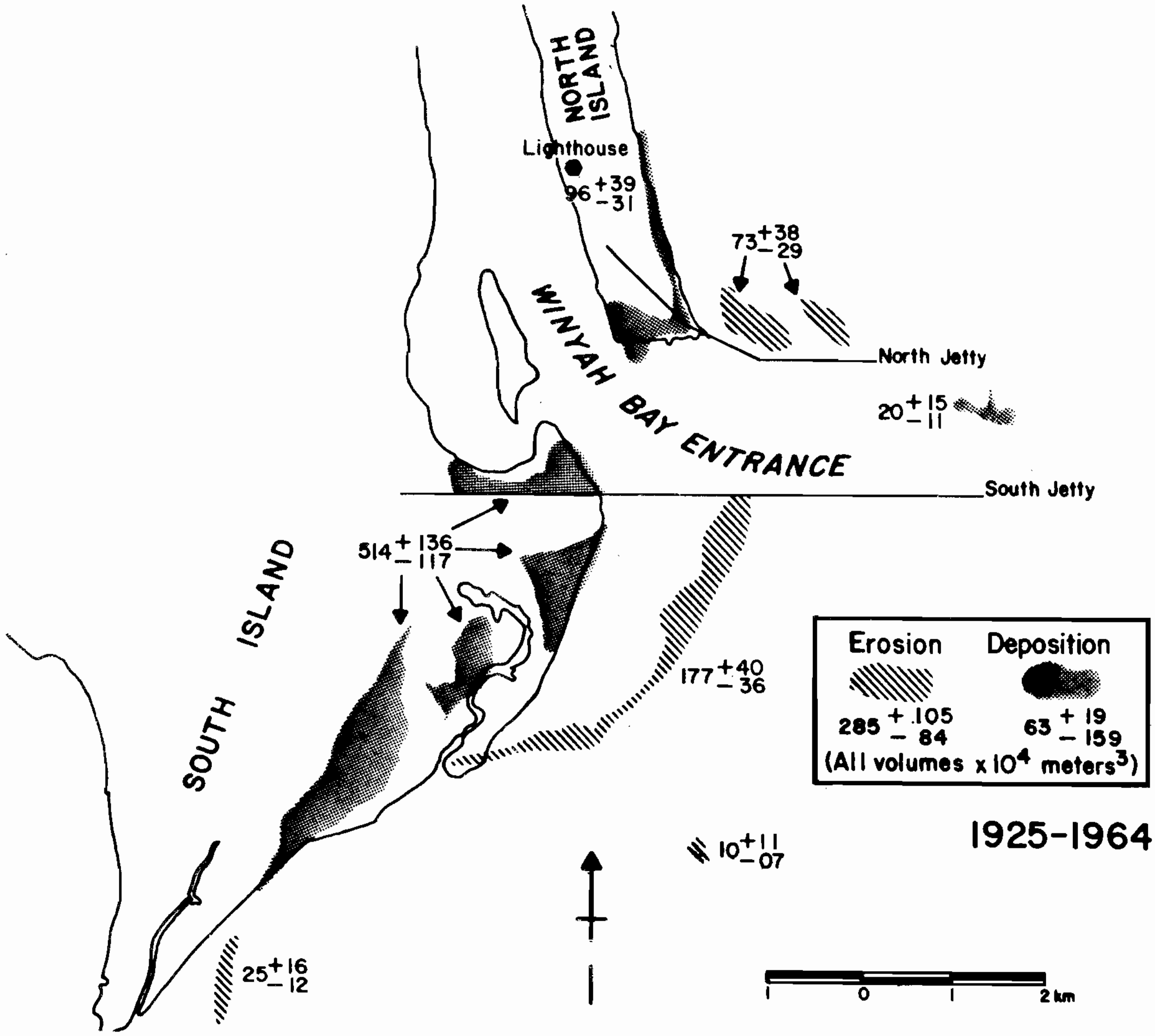


Figure 6-2. Volumes of sediment deposited and eroded at Winyah Bay Entrance between 1925 and and 1964 (Stapor 1980a).

depths, spoil was placed in adjacent marshlands and in various open water areas (see Fig. 6-5 for location of these open water sites). However, with the 12-fold increase in maintenance dredging since 1941, disposal sites in marshlands have had to be diked and open-water disposal terminated. This latter practice in the vicinity of Ft. Sumter (spoil area 11 of Fig. 6-5) had resulted in the construction of considerable acreage above MLW which is, in part, supporting a marsh. Table 6-3 lists the diked sites used for disposal in and about Charleston Harbor, giving their current status and acreages. (See also Atlas plates 35 and 43.)

As this dramatic increase in maintenance dredging was not expected when the 35 ft (10.7 m) MLW project was undertaken, the Charleston District, U.S. Army Corps of Engineers, has conducted studies to identify, evaluate, and correct the shoaling problem in Charleston Harbor (U.S. Army Corps of Engineers 1957, 1966c). Model studies conducted at the U.S. Army Corps of Engineers' Waterways Experiment Station between 1947 and 1964 indicate that deepening the channels from 30 - 35 ft (9.1 - 10.7 m) MLW would increase annual maintenance by approximately 10%, all other factors being equal. Prior to the 1942 diversion of Santee River water, Charleston Harbor received approximately 11 m^3/s (14.4 yd^3/s) of freshwater discharge from its watershed; after diversion, freshwater discharge increased to 451 m^3/s (590 yd^3/s) (U.S. Army Corps of Engineers 1966a). The U.S. Army Corps of Engineers (1966a) identified sediments carried by Santee River water discharging through the Pinopolis Dam, as well as sediments scoured by these waters from the course of the Cooper River immediately below this dam, as the primary (40%) and secondary (33%) sources, respectively, of shoaling material in Charleston Harbor. The remaining 27% came from sources

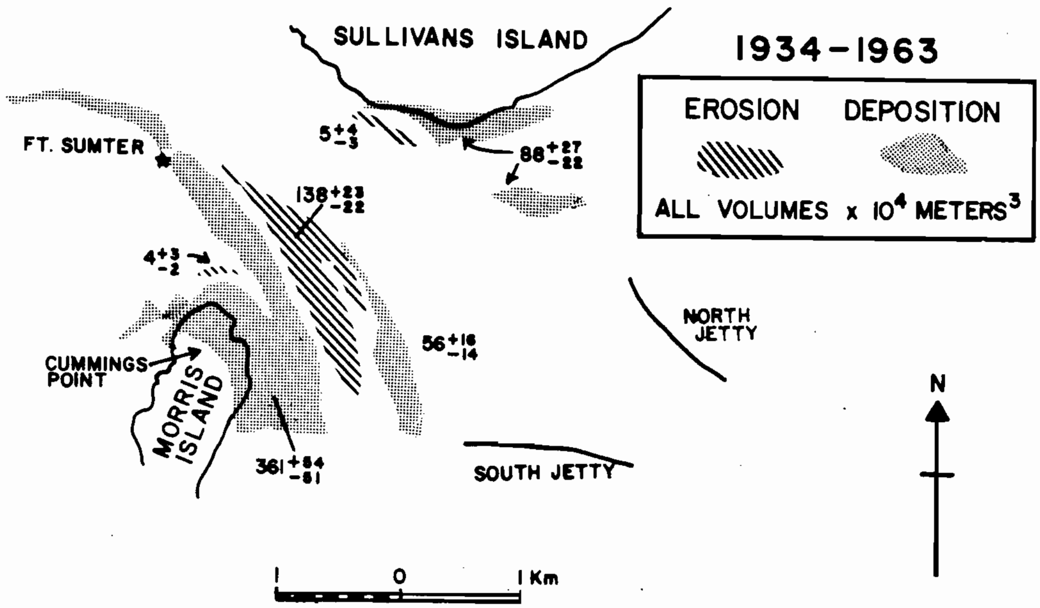


Figure 6-3. Volumes of sediment eroded and deposited on Morris and Sullivans islands and their adjacent shallow bottoms between 1934 and 1963 (adapted from Stapor 1977). Flooding tidal currents sweeping into the harbor over the submerged portions of the jetties are primarily responsible for the deposition at Cummings Point and the southern tip of Sullivans Island.

contributing material to the harbor prior to the 1942 diversion of Santee River water. However, shoaling from this background source has increased by 45% from what it was prior to 1942. Thus, the diversion of Santee River water into Charleston Harbor has not only provided additional sediment for shoaling, but has also made the harbor a more efficient sediment trap. The additional freshwater discharge converted the pre-1942 well-mixed estuary with minimal density stratification into a partially mixed estuary with a definite density stratification or salt wedge. The salt wedge results in flood-dominant bottom currents, which tend to keep sediment within the harbor (Fig. 6-6).

The downstream and upstream flow characteristics of Charleston Harbor after diversion are presented in Figure 6-6. Major shoals, located where net flow is balanced or nearly so, occur at the mouths of the Ashley and Wando rivers (shoals #7, #6, #6A, and #6B of Figs. 6-5 and 6-6). Model studies indicated that a realignment of the navigation channel so as to avoid the mouth of the Ashley River could reduce maintenance dredging in the lower harbor by 85% (U.S. Army Corps of Engineers 1957). This realignment was finished in 1956 and has required no subsequent maintenance dredging (Simmons 1966).

A rediversion project is presently under construction to return 357 m^3/s (467 yd^3/s) discharge back to the Santee River. A canal connecting Lake Moultrie with the Santee is presently under construction to accomplish this task, with the intended result of 1) continuing hydroelectric power generation, 2) significantly reducing the shoaling in Charleston Harbor, and 3) maintaining freshwater discharge sufficient for the industrial concerns located along the Cooper River. (See also Santee-Cooper Diversion and Rediversion section, this chapter.)

d. <u>Port Royal Harbor</u>. In 1954, a navigation project was authorized to provide a 27 ft (8.2 m) MLW channel across the shoals at the mouth of Port Royal Sound and a 24 ft (7.3 m) MLW channel in the Beaufort River and Battery Creek. (See Atlas plate 41C.) Construction began in 1957 and was completed in 1959. Very little dredging had to be done in Port Royal Sound, Beaufort River, and Battery Creek to obtain the necessary project dimensions. However, 3,715,877 yd^3 (2,841,160 m^3) had to be removed to

Table 6-3. Spoil disposal sites in Charleston Harbor (U.S. Army Corps of Engineers 1966d). Numbers designating spoil sites correspond with those in Figure 6-5.

Name	Acreage	Status	Designation Number
Yellow House Creek	608	diked, active[a]	1
Clouter Creek	1,534	diked, active[a]	2
Daniel Island	696	diked, active[a]	3
Drum Island	151	diked, active[a]	4
Morris Island	557	diked, active[a]	5
Patriot's Point	278	diked, inactive	6
Coal Tipple	177	diked, inactive	7
Naval Ammunition Depot B	281	diked, inactive	8
Area D (Shipyard River)	136	diked, inactive	9
Area A (Daniel Island)	515	diked, inactive	10
Harbor Spoil Disposal Site	175	unconfined, inactive	11
Crab Bank	150	unconfined, inactive	12

a. as of fiscal 1979

obtain project dimensions across the shoals at the mouth of Port Royal Sound.

Maintenance dredging of the entrance channel across these shoals annually removes an average of 286,197 yd^3 (218,826 m^3), which is deposited in the open ocean. Maintenance by hopper dredge of the Beaufort River-Battery Creek inner harbor necessitates the annual removal of 15,634 yd^3/yr (11,954 m^3/yr) of clay and silt which is also dumped in the open ocean. Annual dredging data for the Port Royal Harbor Project are presented in Appendix Table C-3. A summary of these data, by project depth, is presented in Table 6-1.

e. Savannah Harbor. Savannah Harbor stretches for 10 mi (16 km) along the Savannah River, starting approximately 10 mi (16 km) upriver from the mouth. Prior to any improvement work, controlling depths on the entrance bar offshore of Tybee Island were 18 - 20 ft (5.5 - 6.1 m) MLW (U.S. Coast and Geodetic Survey 1851). Along the river proper, controlling depths were 9 - 10 ft (2.7 - 3.0 m) MLW. The harbor portion of the Savannah River is actually an estuary occupying a drowned river valley and having a partially mixed, two layer circulation pattern.

Shoaling has historically been a problem throughout the entire project, from the entrance bar off Tybee Island to the head of the maintained channel at Port Wentworth. The present day shoaling patterns are shown in Figure 6-7, along with the location and size of the diked disposal sites. (See Atlas plate 42.) Presently there are 9,052 acres (3,663 ha) of diked and partially diked disposal sites available for use.

Maintenance dredging of the Savannah Harbor Project has removed an annual average of 7,150,000 yd^3 (5,460,000 m^3) since 1965. Annual dredging data for the Savannah Harbor Project are presented in Appendix Table C-4. A summary of these data, by project depth, is presented in Table 6-1. The harbor's variable shoaling rates, reflecting not only the position of the salt wedge, but also the hydrodynamic properties of a curving channel, are

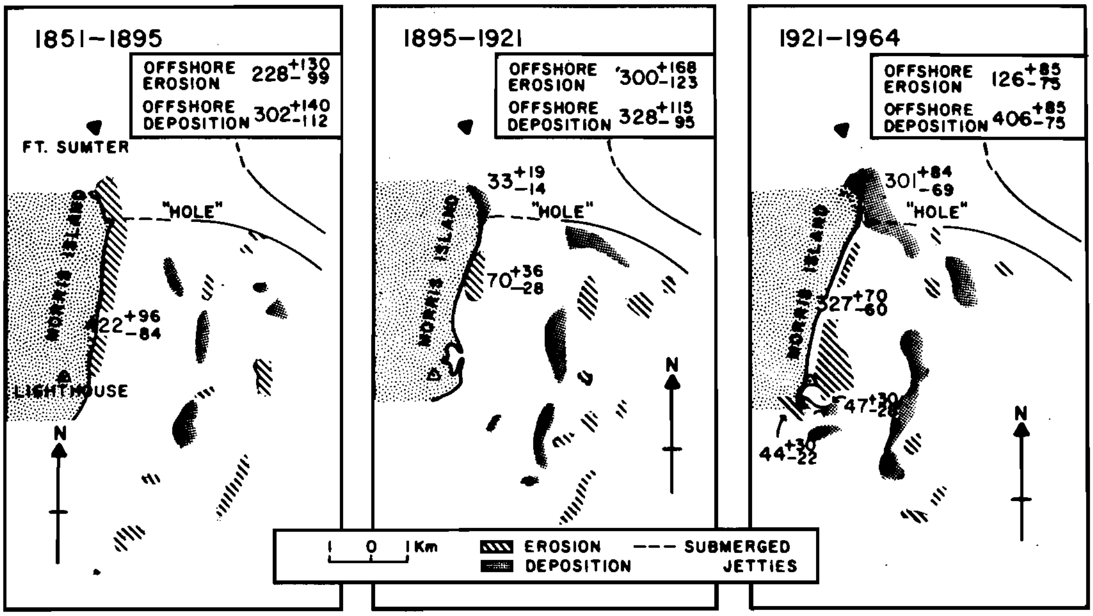


Figure 6-4. Volumes of sediment eroded and deposited on and about Morris Island, Charleston County, South Carolina, between 1851 and 1964 (adapted from Stapor 1977). All volumes are in 10^4 m^3.

presented in Table 6-4. Sands comprise the bulk of the shoaling material north of Kings Island beyond the normal limit of saltwater penetration. Some commercial mining of this material has been done by hydraulic dredge. Mud and sand mixtures comprise the shoaling materials between Kings Island and the river's mouth.

Historically, the locus of maximum shoaling has migrated upriver with successive deepenings of the natural channel (Granger 1968). In the early twentieth century, the stretch between Elba and Long islands was the site of heaviest shoaling, while today it is along Savannah's waterfront. This shift in shoaling with successive channel deepenings is illustrated in Figure 6-8, in which shoaling rates for an upstream and downstream reach are compared for various channel depths.

Model studies conducted for the Savannah District, Corps of Engineers, by the U.S. Army Corps of Engineers Vicksburg Waterways Experiment Station in the 1950's tested the concept of a settling basin to be located in the Back River as a means of alleviating waterfront shoaling (Harris 1965). The model predicted that a decrease in shoaling rates would be obtained with such a basin. This basin was put into full operation in May 1977 and has significantly reduced clay and silt shoaling along the waterfront. However, the increased ebb currents have caused the formation of 5 - 7 m (16 - 23 ft) high sand waves which locally shoal the navigation channel to 34 ft (10.4 m) MLW (W. Clarkson, 1978, Savannah District, U.S. Army Corps of Engineers, Savannah, Georgia, pers. comm).

Tidal currents sweeping into the Savannah River (Oertel 1972) may be largely responsible for shoaling between the river's mouth and Tybee Roads. Wave-induced currents are probably the cause of shoaling in that portion of the channel crossing the ocean bar. Stapor (1980b) presents measurements of long-term, net erosion and deposition volumes for this region.

f. Brunswick Harbor. Brunswick Harbor is located on the East River, with maintained channels extending up the Turtle River, through St. Simons Sound, and across St. Simons Bar to the open Atlantic Ocean (Atlas plate 41B). original depths of the East River were 13 - 17 ft (4 - 5.2 m) MLW (U.S. Coast and Geodetic Survey 1856a). Controlling depths across St. Simons Bar were originally 14 - 16 ft (4.3 - 5.2 m) MLW and through the Sound were 20 - 24 ft (6.1 - 7.3 m) MLW (U.S. Coast and Geodetic Survey 1856b,c, respectively.

The first navigation project constructed in Brunswick Harbor was to secure a 15 ft (4.6 m) MLW channel across the East River entrance bar. Jetty construction and dredging began in FY 1880 and the project was completed in

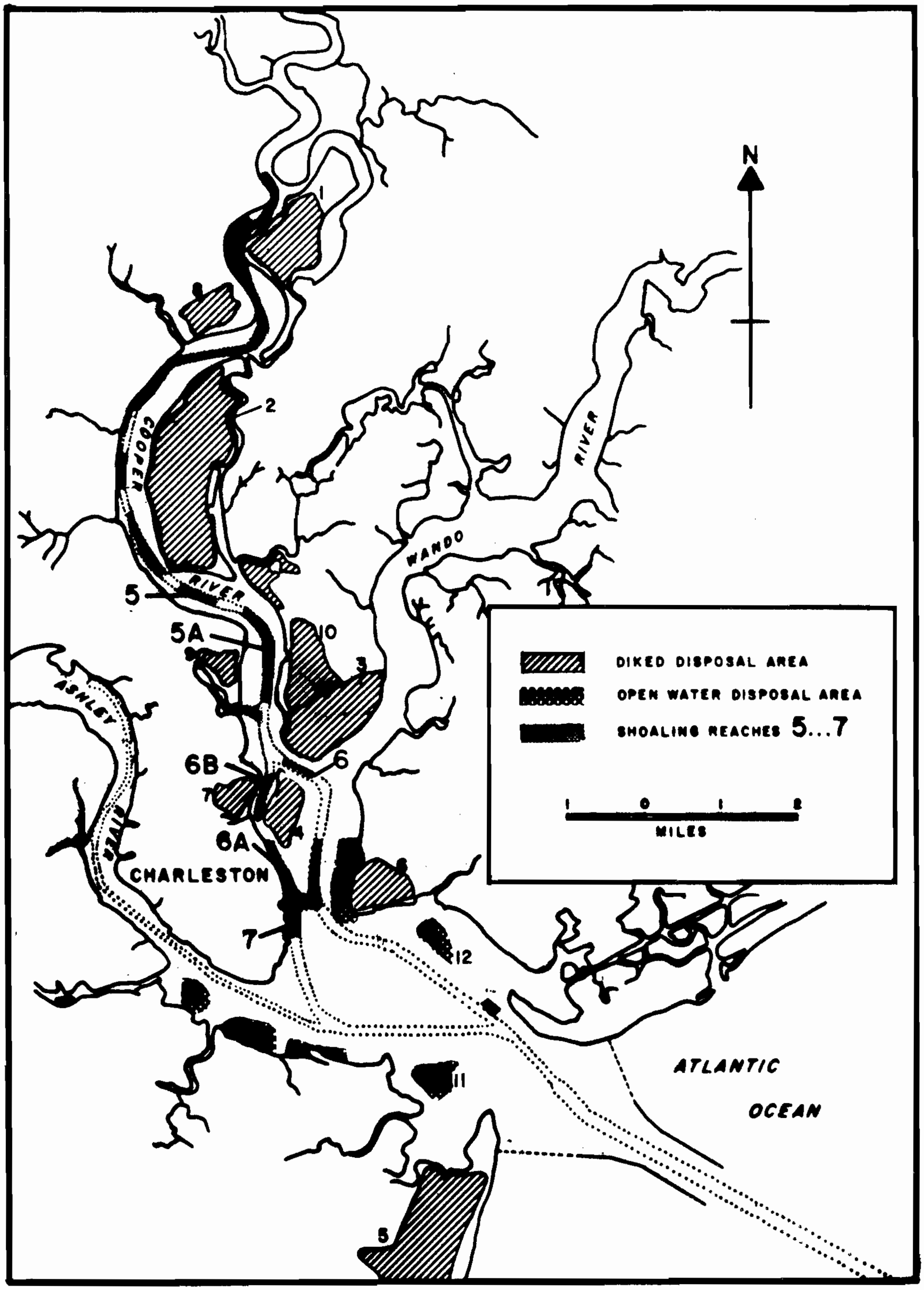


Figure 6-5. The disposal areas and shoaling reaches of the Charleston Harbor navigation project (adapted from U.S. Army Corps of Engineers 1966d). The numbers designating each disposal area correspond with those in Table 6-3. Shoaling reach designations correspond with those in Figure 6-7.

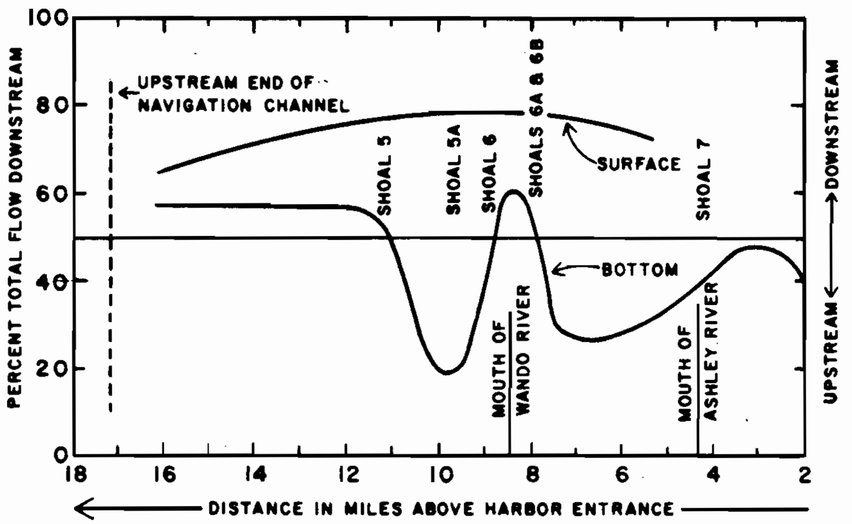


Figure 6-6. Flow characteristics of Charleston Harbor after the 1942 diversion of the Santee River discharge into the Cooper River (adapted from Simmons 1966). Shoaling reaches or shoals commonly occur where upstream and downstream flow is balanced and/or where net flow is upstream.

FY 1884 (Granger 1968). The existing 32 ft (9.8 m) MLW project was begun in 1960 and was completed the following year.

Annual dredging data from 1880 - 1977 are presented in Appendix Table C-5. Analysis of these data reveals that approximately 320,000 yd^3/yr (245,000 m^3/yr) of maintenance dredging were required to maintain a 30 ft (9.1 m) MLW project depth. Maintenance dredging requirements increased four-fold to over 1,350,000 yd^3/yr (1,032,000 m^3/yr) when the project depth was increased to 32 ft (9.8 m) MLW. Summaries of the historical dredging data, by project depth, are presented in Table 6-1.

After deepening the East River to 30 ft (9.1 m) MLW, rapid shoaling began in the channel. Dredging data for the period covering the 24 ft MLW and 27 ft (7.3 m and 8.2 m) MLW channels are not adequate to determine an individual maintenance rate for the East River. However, doubling the depth from 15 ft to 30 ft (4.6 m to 9.1 m) MLW has resulted in a 30-fold increase in maintenance dredging. The East River has progressively become a more and more efficient sediment trap. Neiheisel and Weaver (1967), from an analysis of the clay minerals comprising this shoaling sediment, conclude that the Altamaha River is the major sediment source. This river is connected to the St. Simons Sound region by the Mackay River, a tidal stream traversing a salt marsh. Harris (1963) demonstrated a direct correlation between East River shoaling rates and Altamaha River discharge.

g. Kings Bay-St. Marys Entrance. A navigation project at St. Marys Entrance was proposed in the 1870's to provide a safe and economic route for waterborne commerce using the Port of Fernandina, Florida. The original main channel across the St. Marys Entrance ebb-tidal delta had controlling depths of approximately 12 ft MLW (3.7 m) (Olsen 1977). In order to stabilize the location and depth of the the St. Marys Entrance channel, jetties were contructed from Cumberland and Amelia islands, respectively, in the early 1880's. Maintenance dredging requirements were minimal prior to 1955, when a 34 ft (10.4 m) MLW channel was dredged across the ebb tidal delta for the Department of Defense in order to serve the Kings Bay Ammunition Terminal, located on Cumberland Sound in southern Camden County, Georgia. Unlike previous ones, this channel has needed substantial amounts of maintenance dredging. Over its 23 year history an average of 210,000 yd^3/yr (160,000 m^3/yr) have been removed. The depth of this channel was increased

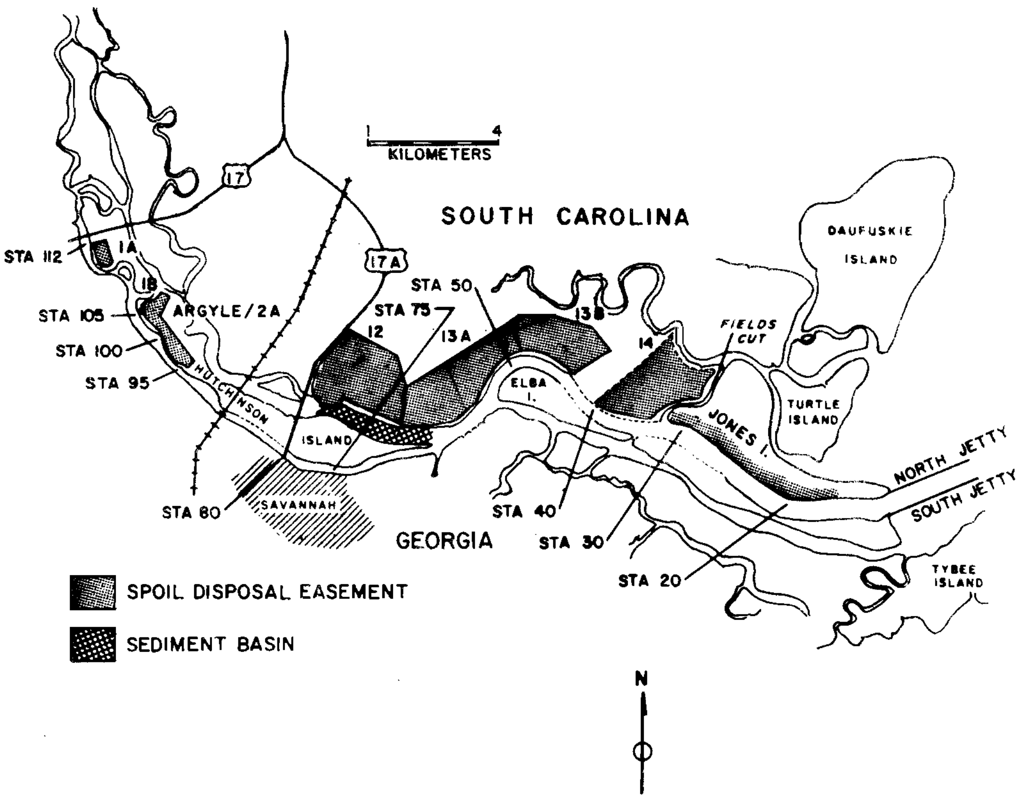


Figure 6-7. The location and size of diked disposal areas for the Savannah Harbor navigation project (adapted from U.S. Army Corps of Engineers 1975a). See Table 6-4 for the projected life span of these disposal areas.

to 40 ft (12.2 m) MLW in FY 1979 to accommodate the East Coast Fleet Ballistic Missile Submarine Refit Site located at Kings Bay. (See Volume Two, Chapter Three, for a discussion of the economic impacts of this facility.) The maintenance dredging volume required to secure the 40 ft (12.2 m) MLW channel across the St. Marys Entrance ebb-tidal delta should be significantly greater than that required for the previous 34 ft (10.4 m) MLW channel.

Annual dredging data for the Kings Bay-St. Marys Entrance Project are presented in Appendix Table C-6. A summary of these data, by project depth, is presented in Table 6-1.

5. Santee-Cooper Diversion and Rediversion

The Santee-Cooper Diversion and Rediversion projects represent a physical alteration of the Sea Island Coastal Region second in magnitude only to the colonial and nineteenth century impoundment of marshes for rice cultivation. The Santee-Cooper Diversion Project was first proposed in 1915 as a means of generating hydroelectric power (U.S. Army Corps of Engineers 1975b). Santee River discharge was to be diverted into the Cooper River so that the topographic scarp at Pinopolis, Berkeley County, South Carolina, could be utilized to provide hydraulic head. Dams were to be constructed to impound each of these rivers, insuring a constant water flow. The South Carolina Public Service Authority began construction in 1938 and electricity generation began in February 1942 (U.S. Army Corps of Engineers 1966e).

Wilson Dam, located 140 km (87 mi) upstream on the Santee River, forms Lake Marion, South Carolina's largest lake, with a 450 km^2 (111,195 acres) area (Kjerfve 1976). Pinopolis Dam forms Lake Moultrie, which has a 245 km^2 (60,540 acres) area (Fig. 6-9). These two lakes are connected by a 12 km (7.5 mi) long diversion canal through which passes, on the average, 88% of the Santee River's annual discharge (Kjerfve 1976). The lower Santee annual mean discharge decreased from 525 to 62 m^3/s (18,532 to 2,189 ft^3/s) and the Cooper River

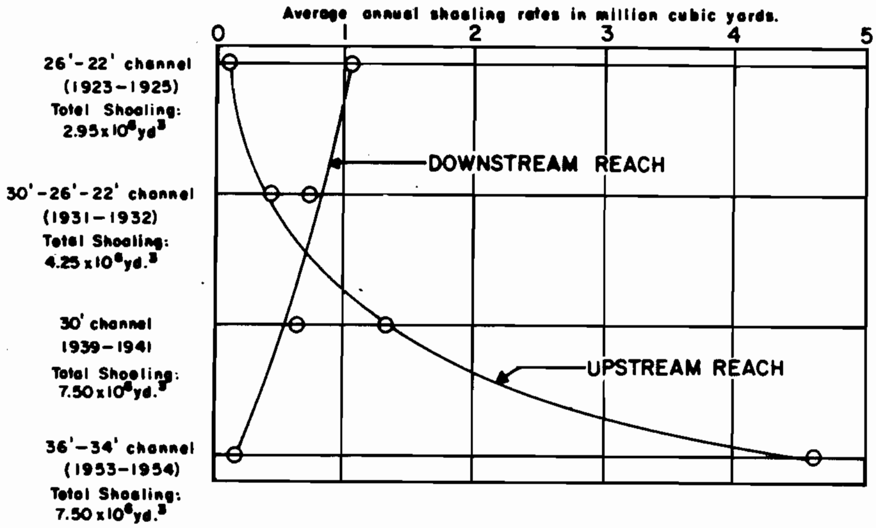


Figure 6-8. Shifts in the location of maximum shoaling between the upstream reach (Hutchinson Island to the City of Savannah waterfront) and the downstream reach (Elba Island to the jetties) with successive channel deepenings (adapted from Simmons 1966).

discharge increased from 2 to 442 m^3/s (71 to 15,602 ft^3/s) (U.S. Army Corps of Engineers 1966a; U.S. Department of Interior, Geological Survey 1976).

When the project was under consideration ". . . it was believed that there would be many incidental benefits, including reduction of shoaling of the navigation channels in the harbor (Charleston Harbor), improvement of water quality (Charleston Harbor) through flushing resulting from the greatly increased freshwater discharge, and of course desalinization of the upper and middle reaches of the Cooper" (U.S. Army Corps of Engineers 1966e). Of these three mentioned incidental benefits, the last two occurred as predicted. Increased discharge aids flushing of Charleston Harbor (Kjerfve 1976) and many large industrial firms have located along the upper and middle Cooper River, attracted by its quantities of fresh water.

However, increased freshwater discharge exacerbated rather than reduced shoaling in Charleston Harbor. Maintenance dredging of navigation channels and auxiliary facilities increased 100-fold from a pre-diversion 110,000 yd^3/yr (84,106 m^3/yr) to a post-diversion 10,000,000 yd^3/yr (7,646,000 m^3/yr) (U.S. Army Corps of Engineers 1966e). (See previous discussion of Charleston Harbor, this chapter.) The U.S. Army Corps of Engineers, Charleston District began investigating this ". . . appalling increase in shoaling. . ." (U.S. Army Corps of Engineers 1966e) in the early 1950's. By the middle 1960's they were able to conclude ". . .beyond any reasonable doubt that the increased freshwater flows into the harbor and the change in the regimen to the harbor from the characteristics of a well-mixed estuary to those of a partly mixed estuary as a result of the diversion of large freshwater flows from the Santee into the Cooper are the principal causes of the present heavy shoaling of the navigation channels" (U.S. Army Corps of Engineers 1966e). Salinities measured at the Custom House Wharf in Charleston declined from an annual mean of 31°/oo prior to diversion to 16°/oo after (Zetler 1953). (See Chapter Five for water circulation patterns of Charleston Harbor.)

The lower Santee River and its delta experienced a significant increase in salinity from a pre-diversion level of 1°/oo or less at the mouths of the North and South Santee rivers (Kjerfve 1976) to a post-diversion level of 20°/oo - 24°/oo at these mouths (Mathews et al. 1980). Commercial oyster and hard clam beds developed in the North and South Santee rivers as a result of this salinity change. Along with the pronounced overall increase, the salinity range remained high, from .02°/oo to 33°/oo, thereby limiting the action of oyster predators in this region (Calder et al. 1977). (See Volume II, Chapter Eight, and also Volume III for more detailed ecological impacts.)

Sediment deposition and erosion also resulted from diversion. The mouth of the North Santee River became filled with marine sands moving into the estuary under the changed tidal circulation pattern (Mullin 1973). Stephens et al.

Table 6-4. Shoaling rates for Savannah Harbor (U.S. Army Corps of Engineers 1975a). These disposal easements and channel lengths covered are located on Figure 6-7.

Shoaling Rate per 1000-feet of channel	Channel Length Covered	Disposal Area Utilized
6,600 yd^3	Sta. 112-105 (7,000 feet)	1A (158 acres)
40,000 yd^3	Sta. 105-100 (5,000 feet)	1B (86 acres)
24,000 yd^3	Sta. 100-95 (5,000 feet)	ARGYLE (298 acres)
35,000 yd^3	Sta. 95-80 (5,000 feet)	2A (350 acres)
77,000 yd^3	Sta. 80-75 (5,000 feet)	12 (1,260 acres)
107,000 yd^3	Sta. 75-50 (125,000 feet)	13A (1,500 acres)
82,000 yd^3	Sta. 50-40 (50,000 feet)	13B (700 acres)
45,000 yd^3	Sta. 40-30 (50,000 feet)	14 (1,800 acres)
9,000 yd^3	Sta. 30-0 (150,000 feet)	Jones Island (2,900 acres)

(1976) have suggested that coastal erosion of the Santee Delta (South, Cedar, and Murphy islands) likewise accelerated after diversion.

In addition to the above-mentioned changes, Czyscinski (1975) proposes that the post-diversion intrusion of marine waters is responsible for sulfide mineral formation in the marsh sediments of the Santee Delta. These sulfide minerals, upon oxidation, cause low soil pH and high acidity which results in cat clay formation. (See Chapter Three for additional discussion of cat clay.) Oxidation is typically caused by drying, e.g., the draining of an impoundment. However, his experiments indicate that oxidation ". . . may be possible from an influx of oxygenated fresh water through the sediment, raising the possibility of wide-spread cat clay development upon redivergence of the Santee River" (Czyscinski 1975).

In order to alleviate the Charleston Harbor shoaling problem, the U.S. Army Corps of Engineers (1966f) considered 10 plans of improvement. These plans took two basic approaches toward solving the shoaling problem: 1) eliminate or greatly restrict the release of water at the Pinopolis Dam or 2) allow the unrestricted release of water at this dam and divert it before reaching the upper Cooper River. Model studies conducted by the U.S. Army Corps of Engineers' Waterways Experiment Station at Vicksburg, Mississippi, indicate that a flow of 85 m^3/s (3,000 ft^3/s) is needed to keep salt water out of the Bushy Park Reservoir (Fig. 6-9), the site of fresh water used by industries located along the upper Cooper River (U.S. Army Corps of Engineers 1966f). This flow rate is high enough to provide cooling for the steam electricity generating plant at Pinopolis without the temperature of its discharge waters exceeding South Carolina legal limits (Kjerfve 1976). The plan ultimately selected was to divert water from Lake Moultrie through a 18.5 km (11.5 mi) long canal to the Santee River (Fig. 6-8). A hydroelectric generating plant will be constructed near St. Stephen, Berkeley County, South Carolina, on this canal, taking advantage of the 15 m (49 ft) hydraulic head.

The Santee Cooper Rediversion Project was authorized by the River and Harbor Act of 1968 (U.S. Army Corps of Engineers 1975b) and construction began in 1977. This project is expected to be completed

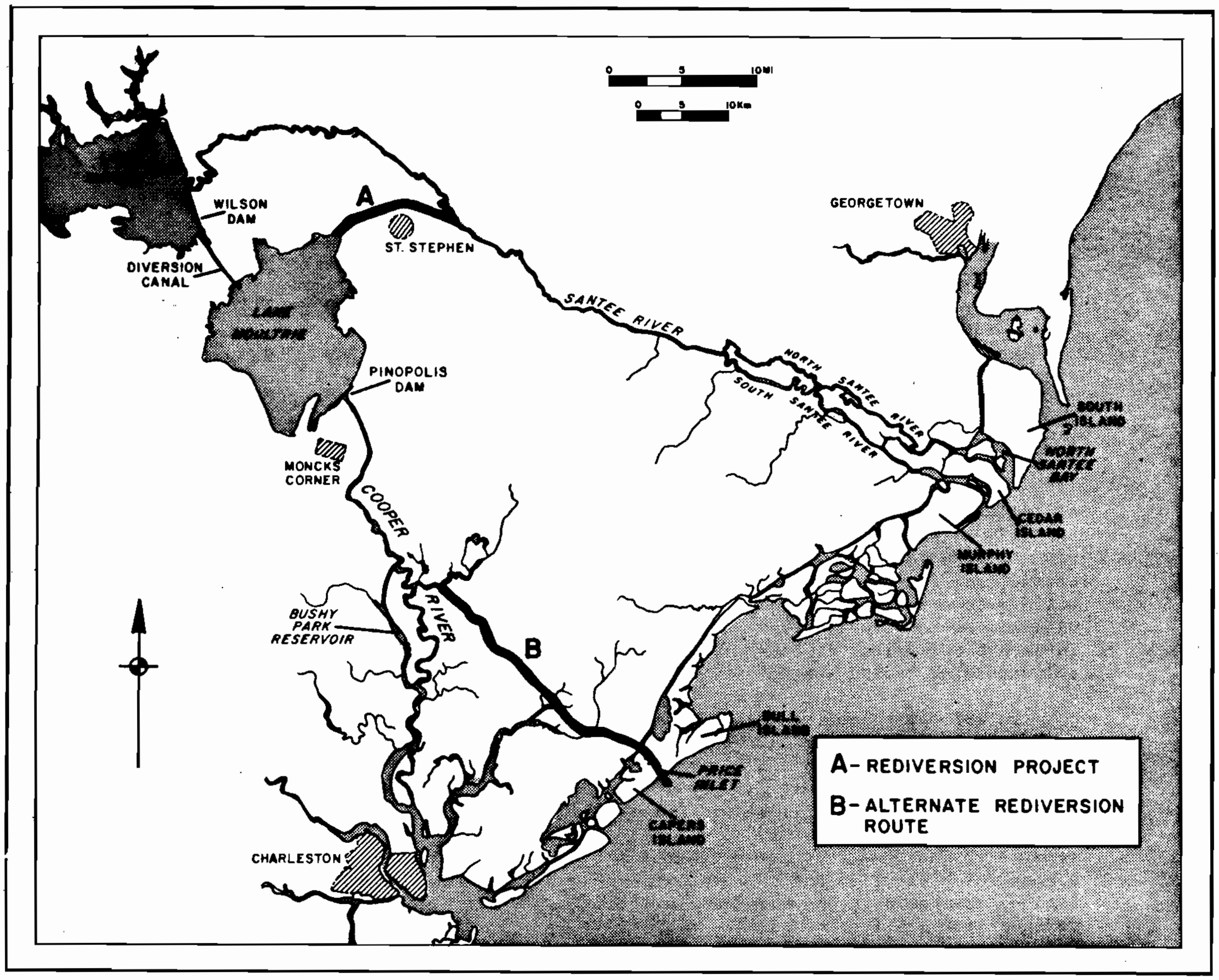


Figure 6-9. Location map of the Santee-Cooper Diversion and Rediversion projects area. Rediversion Project A is the one to be built.

in 1984 at a cost of $139 million (J. L. Coates, 1978, U.S. Army Corps of Engineers, Charleston District, Charleston, South Carolina, pers. comm.).

Shoaling is expected to significantly decrease in Charleston Harbor, thus reducing the cost of annual maintenance and the need to find more and more dredged material disposal sites. Water quality in the harbor may suffer if industrial waste and sewage treatment facilities are not adequate (Kjerfve 1976). Saltwater contamination of the Bushy Park Reservoir is a very real possibility. A study of the Cooper River made during low flow conditions [less than or equal to 85 $m/^3s$ (3,000 ft^3/s)] in 1978 indicates that waters with a significantly higher salinity than that predicted by the Corps of Engineers' model study, or deemed permissible by the industrial water users, penetrated very close to, if not into, the Bushy Park Reservoir (South Carolina Water Resources Commission 1979).

The increased freshwater discharge should cause a return to pre-diversion salinity conditions in the Santee River delta. This has the potential of destroying the commercial oyster and hard clam beds and, perhaps, inducing widespread cat clay formation (Czyscinski 1975) throughout the marshes and impoundments. Silt and clay shoaling, especially in North Santee Bay, should be expected. It is possible that given 1) the steeper gradient of the South Santee and 2) measurements indicating that 27% of the total flood flow goes through it, the South Santee River may become the more important distributary (Kjerfve 1976).

B. EFFECTS

1. Air Quality

Until World War II, our atmosphere had been able to tolerate certain quantities of air contaminants without exhibiting detrimental effects. However, as industrialization developed, large quantities of air contaminants were discharged into the atmosphere, the normal and natural cleaning mechanisms were no longer sufficient and levels of air contaminants built up. As a result, occurrences of air pollution episodes were reported. The static atmospheric conditions during these episodes caused significant increases in human mortality (U.S. Environmental Protection Agency 1976a).

Air pollution is generally thought of as man-induced changes (not necessarily increases) in the atmospheric gas or particle content (Mohnen 1977). These anthropogenic additions to the natural contaminants (e.g., pollen, smoke, dust) alter or overload the natural methods of cleansing the air (e.g., rain, sedimentation, and oxidation) and result in contaminant build-up.

Pollutants exist in a gaseous or particulate state. The five major pollutants are listed in Table 6-5 along with common sources of contamination. Table 6-6 summarizes effects of air pollutants on living and non-living forms.

In 1971, pursuant to the Clean Air Act (Federal Register 1971), the Environmental Protection Agency promulgated national ambient air quality standards for the five pollutants listed in Table 6-5. After promulgation of these standards, each State was required to adopt a plan which provided for the implementation, maintenance, and enforcement of the national air quality standards. Table 6-7 lists the Federal Ambient Air Standards as compared to Georgia and South Carolina air quality standards.

Determination of air quality for this coastal region is similar to that identified by Mohnen (1977) for the New York Bight. His tenets for air quality determination should be applicable for most coastal areas. The three sources that determine air quality are 1) emission of particulate matter and gases from the ocean surface (natural process); 2) emissions of particulate matter and gases from land surfaces, stationary and mobile anthropogenic sources; and 3) particulate and gaseous products resulting from chemical transformation in the atmosphere.

The Sea Island Coastal Region is relatively sensitive to pollution. Recently, there has been increasing evidence that terrestrial systems of the lower coastal plain may be unusually susceptible to air pollution. Jenkins and Fendley (1968) detected disturbingly high concentrations of radioisotopes (Cesium-137) from fallout in game animals and other organisms on the Georgia coast. The causes of such high uptake of radionuclides in this area are not known but may be related to dietary mineral deficiencies associated with some infertile soils in the region (Jenkins and Fendley 1968).

The general air quality for South Carolina and Georgia is good. However, as expected, those regions with major urban and industrial areas have highest concentrations of air pollutants. Table 6-8 presents annual air quality data for all sampling sites in coastal South Carolina. Georgetown has the highest particulate concentrations while North Charleston has the highest sulfur dioxide concentrations and nitrogen dioxide is highest on James Island. These high concentrations correspond to industrial areas in Georgetown and North Charleston, while James Island is indicative of a suburban area with heavy traffic concentrations. Air quality for all sampling sites in coastal Georgia during 1977 were unavailable.

Table 6-9 presents 8-year summaries for particulates, sulfur dioxide, and nitrogen dioxide for coastal Georgia and South Carolina. These data are difficult to analyze since development and construction activities created much variability at each sampling locality. Thus, a knowledge of each sampling area is essential for proper analysis. However, it is obvious for both South Carolina and Georgia that particulate values dropped significantly after 1973. This would correspond to implementation of technologies necessary to meet air quality standards set by each State. It is also obvious that high pollution concentrations are directly related to high population areas (Table 6-9).

2. Water Quality

As might be expected, water pollution in the Sea Island Coastal Region is concentrated in the areas of greatest industrial and urban development. Of the five major river systems in each State, point source pollution is highest in the lower Waccamaw River basin and Winyah Bay near Georgetown and in the lower Ashley and Cooper rivers, including Charleston Harbor, in South Carolina. In Georgia, the majority of point source discharge problems associated with industry are concentrated along the lower Savannah and St. Marys river systems. The two most heavily polluted river systems in the study area are the Savannah River and Cooper River (Georgia Department of Natural Resources 1974, South Carolina Department of Health and Environmental Control 1975b).

Water utilization and discharge practices result in heterogeneous patches of chemicals, eutrophication, oxygen

Table 6-5. Common sources of the major air pollutants (Georgia Department of Natural Resources 1977).

	SOURCE			
Pollutant	Transportation	Fuel Combustion in Stationary Sources	Industrial Process Loss	Miscellaneous
Carbon Monoxide	Gasoline powered motor vehicles			Forest fires, structural fires, etc.
Particulates		Power plants industries space heating	Handling, processing & storage of rock, sand & gravel, iron, steel industries, cement plants	Forest fires agricultural fires agricultural burning
Hydrocarbons	Gasoline powered motor vehicles, gasoline distribution sources			
Nitrogen Oxides	Gasoline powered motor vehicles	Primarily from burning coal: power plants industries space heating		
Sulfur Oxides		Power plants industries space heating	Petroleum refineries smelters sulfuric acid plants steel plants pulp & paper mills	

Table 6-6. Impacts of air pollution on human health, plants, animals, and non-living materials (U.S. Environmental Protection Agency 1976b; Georgia Department of Natural Resources 1977).

HUMAN HEALTH	Emphysema, Bronchitis, Heart disease, Asthma, Bronchial pneumonia: Causes of death during air pollution episodes in Donora, Pennyslvania 1948 and London, England 1952.
	Other symptoms include: headaches, dizziness, coughing, shortness of breath, sore throat, eye irritation, nasal passage irritation, nasal discharge, nausea, and vomiting.
PLANTS	Causes costly damage to row crops, ruins flower gardens, trees, parks, citrus groves, grains, cotton, tobacco, and fruits.
	Sulfur dioxide, hydrogen fluoride, ozone, hydrocarbons, and ethylene have been shown to be direct causative agents in plant death.
ANIMALS	Cattle and sheep have died from eating fluoride absorbed vegetation; fluorosis (fluorine poisoning) affects animals' teeth and bones.
NON-LIVING MATERIALS	Rusts iron; tarnishes silver; makes paint peel and discolor; cracks rubber tires; deteriorates nylon; reduces life of exposed fabrics (cotton, linen, hemp, jute, rayon); fades fabric dyes; corrodes; embrittlement of paper.

Table 6-7. A comparison of South Carolina and Georgia air quality standards with the primary Federal Ambient Air Quality Standards (U.S. Department of Interior, Bureau of Land Management 1977; Howard 1976; South Carolina Department of Health and Environmental Control 1978).

Parameter	FEDERAL		SOUTH CAROLINA		GEORGIA	
	Measuring Interval	Micrograms/m^3 [a]	Measuring Interval	Micrograms/m^3 [a]	Measuring Interval	Micrograms/m^3 [a]
Sulfur Dioxide	3 hours 24 hours Annual	1,300 [b] 365 [b] 80 [b]	3 hours 24 hours Annual	13,000 [b] 365 [b]	1 hour 24 hours Annual	715[c] 229 43
Particulate Matter	24 hours Annual	260 75	24 hours Annual[d]	250 60	24 hours Annual[d]	150 60
Carbon Monoxide	1 hour 8 hour	40,000 10,000	1 hour 8 hour	40,000 10,000	1 hour 8 hour	40,000 10,000
Photochemical Oxidants	1 hour	160	1 hour	160	1 hour	98
Nitrogen Dioxide	Annual	100	Annual	100	24 hours Annual	300 100
Non-methane Hydrocarbons	3 hours	160	3 hours	160	3 hours	98

a. Arithmetic average at 25°C and 760 mm Hg.
b. Not to be exceeded more than once a year.
c. At 0°C and 760 mm Hg.
d. Geometric mean.

Table 6-8. Measurements (micrograms/m^3) of particulates, sulfur dioxide, and nitrogen dioxide for all sampling sites in coastal air quality control regions (AQCR) of South Carolina during 1977 (South Carolina Department of Health and Environmental Control 1977).

Sampling Sites	PARTICULATES			SULFUR DIOXIDE			NITROGEN DIOXIDE		
	Number of Samples	Range	Geometric Mean	Number of Samples	Range	Arithmetic Mean	Number of Samples	Range	Arithmetic Mean
Georgetown AQCR									
Georgetown County Health Department	62	21.0 - 142.0	70.73	55	2.5 - 69.0	7.3	59	2.5 - 76.0	31.0
Georgetown at Howard High School	115	23.0 - 288.0	72.49	-	--	-	-	--	-
Georgetown (Maryville)	53	14.0 - 141.0	44.71	-	--	-	-	--	-
Georgetown Continuous Monitoring Station	112	21.0 - 159.0	71.71	57	2.5 - 57.0	5.9	56	2.5 - 76.0	24.8
Charleston AQCR									
Bushy Park	48	25.0 - 172.0	63.15	57	2.5 - 9.0	2.6	52	2.5 - 77.0	14.0
Charleston County Health Department	63	13.0 - 118.0	47.18	56	2.5 - 77.0	5.0	54	2.5 - 89.0	38.1
Charleston County Hospital	53	14.0 - 98.0	44.20	-	--	-	-	--	-
Goose Creek	-	--	-	48	2.5 - 25.0	3.8	45	2.5 - 63.0	26.2
Harleyville at Jenkins High School	59	10.0 - 137.0	50.09	-	--	-	-	--	-
James Island	57	16.0 - 95.0	53.02	57	2.5 - 14.0	3.0	54	2.5 - 103.0	33.5
Mt. Pleasant	59	10.0 - 86.0	36.21	58	2.5 - 85.0	15.4	50	2.5 - 88.0	20.7
N. Charleston Meeting Street at Pittsburg Avenue	323	24.0 - 203.0	88.28	56	2.5 - 48.0	6.1	53	2.5 - 89.0	36.8
N. Charleston Jenkins Street Fire Station	55	23.0 - 143.0	60.98	55	2.5 - 128.0	10.9	53	2.5 - 64.0	25.0
State Ports Authority	272	13.0 - 252.0	64.14	-	--	-	-	--	-
Savannah-Beaufort AQCR									
Beaufort County Health Department	26	16.0 - 59.0	35.37	33	2.5 - 25.0	3.8	32	2.5 - 70.0	16.5
Hilton Head at Harbor Town	21	5.0 - 44.0	23.41	29	2.5 - 14.0	3.3	30	2.5 - 75.0	16.7
Savannah (Hardeeville)	15	28.0 - 103.0	53.79	27	2.5 - 28.0	5.0	28	2.5 - 124.0	26.9

Table 6-9. Mean annual air quality measurements (micrograms/m^3) for particulates, sulfur dioxide, and nitrogen dioxide for coastal South Carolina and Georgia from 1970 through 1977 (South Carolina Department of Health and Environmental Control, 1977, Columbia, unpubl. data; Georgia Department of Natural Resources, Environmental Protection Division, 1978, Atlanta, unpubl. data). All sampling sites for South Carolina are in coastal air quality control regions (AQCR).

SAMPLING SITES	PARTICULATES[a]								SULFUR DIOXIDE[b]							
	1970	1971	1972	1973	1974	1975	1976	1977	1970	1971	1972	1973	1974	1975	1976	1977
Georgetown AQCR																
Georgetown County Health Department	75	61	62	67	72	73	72	71	-	-	6	6	9	6	8	7
Georgetown at Howard High School	-	77	84	93	80	70	73	72	-	-	-	-	-	-	-	-
Georgetown (Maryville)	-	-	-	-	-	-	-	45	-	-	-	-	-	-	-	-
Georgetown Continuous Monitoring Station	-	-	-	104	76	77	73	72	-	-	-	-	12	3	5	6
Charleston AQCR																
Bushy Park	-	-	36	49	35	43	40	63	-	-	-	5	9	3	3	3
Charleston County Health Department	52	38	48	33	42	55	51	47	-	-	4	5	3	4	5	5
Goose Creek	-	-	-	-	-	57	68	-	-	-	-	-	-	5	5	4
Harleyville at Jenkins High School	-	-	52	42	39	45	43	50	-	-	-	-	-	-	-	-
James Island	-	-	61	46	44	51	50	53	-	-	3	5	6	4	3	3
Mt. Pleasant	-	-	40	38	43	31	36	36	-	-	-	7	10	6	4	5
N. Charleston Meeting Street at Pittsburg Avenue	174	145	133	137	97	82	80	88	-	-	10	5	5	5	8	6
N. Charleston Jenkins Street Fire Station	-	-	-	-	-	56	58	61	-	-	-	-	9	4	12	11
States Ports Authority	-	-	111	91	92	72	75	64	-	-	-	-	-	-	-	-
Savannah - Beaufort AQCR																
Beaufort County Health Department	43	36	37	33	34	37	38	35	-	-	3	4	4	4	5	4
Hilton Head at Harbor Town	-	-	-	-	-	28	32	23	-	-	-	-	-	3	3	3
Savannah (Hardeeville)	-	-	-	32	36	51	61	54	-	-	-	5	7	6	10	5

Table 6-9. Continued

SAMPLING SITES	PARTICULATES[a] 1970	1971	1972	1973	1974	1975	1976	1977	SULFUR DIOXIDE[b] 1970	1971	1972	1973	1974	1975	1976	1977
Savannah - Beaufort																
Savannah - Abercorn and Columbus	65	55	60	-	38	43	45	56	-	-	-	-	-	-	-	-
Savannah - Fire Station #2	-	-	-	68	67	58	59	62	-	-	-	5	5	2	2	2
Savannah - Fire Station #4	-	-	-	95	103[c]	97[c]	82[c]	-	-	-	-	34	32	30	30	36
Savannah - Lathrop and Augusta	156	114	121	104	89	78	68	99	-	-	-	10	15	5	13	16
Savannah - Savannah Electric	-	-	-	61	53	50	48	54	-	-	-	8	8	4	3	3
Savannah - Windsor Forest	37	36	36	33	28	37	34	38	-	-	-	-	-	-	-	-
Rincon - 9th Street Pump Station	-	-	-	-	-	-	38	51	-	-	-	-	-	-	2	5
Garden City - Mercer Junior High	-	-	-	-	-	-	45	63	-	-	-	-	-	-	11	5
Savannah - State Patrol Post	-	-	-	-	-	-	40	43	-	-	-	-	-	-	-	-
Port Wentworth - Strong Elementary	-	-	-	-	-	-	41	54	-	-	-	-	-	-	9	10
Savannah - Fort Jackson	-	-	-	-	-	-	-	-	-	-	-	8	10	4	8	3
Jacksonville - Brunswick																
Brunswick - Glendale	-	-	-	-	37	35	36	36	-	-	-	-	3	2	2	3
Brunswick - Health Department	76	69	64	77	46	45	38	42	Trace	3	10	8	5	2	2	3
Brunswick - Townsend	-	-	-	-	52	48	45	56	-	-	-	-	-	-	-	2
Jesup	-	-	-	-	50	53	47	-	-	-	-	-	-	-	-	-

NITROGEN DIOXIDE[b]

SAMPLING SITES	1970	1971	1972	1973	1974	1975	1976	1977
Savannah - Beaufort								
Savannah - Abercorn and Columbus	-	-	-	-	-	-	-	-
Savannah - Fire Station #2	-	-	-	45	34	31	36	37
Savannah - Fire Station #4	-	-	-	-	-	-	-	-
Savannah - Lathrop and Augusta	-	-	-	54	42	37	41	38
Savannah - Savannah Electric	-	-	-	13	29	21	30	28
Savannah - Windsor Forest	-	-	-	-	-	-	-	-
Rincon - 9th Street Pump Station	-	-	-	-	-	-	19	17
Garden City - Mercer Junior High	-	-	-	-	-	-	28	33
Savannah - State Patrol Post	-	-	-	-	-	-	-	-
Port Wentworth - Strong Elementary	-	-	-	-	-	-	28	30
Savannah - Fort Jackson	-	-	-	19	18	20	26	13
Jacksonville - Brunswick								
Brunswick - Glendale	-	-	-	-	22	29	40	20
Brunswick - Health Department	8	28	36	15	22	16	19	20
Brunswick - Townsend	-	-	-	-	-	-	-	-
Jesup	-	-	-	-	-	-	-	-

Table 6-9. Concluded

SAMPLING SITES	NITROGEN DIOXIDE[b]							
	1970	1971	1972	1973	1974	1975	1976	1977
Georgetown AQCR								
Georgetown County Health Department	-	-	40	40	17	22	33	31
Georgetown at Howard High School	-	-	-	-	-	-	-	-
Georgetown (Maryville)	-	-	-	-	-	-	-	-
Georgetown Continuous Monitoring Station	-	-	-	-	22	22	27	25
Charleston AQCR								
Bushy Park	-	-	-	30	12	14	15	14
Charleston County Health Department	-	-	20	54	45	45	44	38
Goose Creek	-	-	-	-	-	22	29	26
Harleyville at Jenkins High School	-	-	-	-	-	-	-	-
James Island	-	-	51	47	33	20	32	34
Mt. Pleasant	-	-	-	41	39	12	21	21
N. Charleston Meeting Street at Pittsburg Avenue	-	-	37	54	45	42	46	37
N. Charleston Jenkins Street Fire Station	-	-	-	-	25	30	35	25
State Ports Authority	-	-	-	-	-	-	-	-
Savannah - Beaufort AQCR								
Beaufort County Health Department	-	-	39	25	16	18	11	16
Hilton Head at Harbor Town	-	-	-	-	-	14	15	17
Savannah (Hardeeville)	-	-	-	34	31	24	34	27

a. Geometric mean
b. Arithmetic mean
c. Heavy construction activities adjacent to sampling site.

depletion, turbidity, and other conditions pernicious to life in marine ecosystems. Environmental impacts from pollutants vary with the type of pollutant and biota. The unique characteristics of estuaries, however, may increase the potential for certain types of impacts. Some toxic metals are greatly reduced during or subsequent to the flocculation of dissolved organic or inorganic matter when fresh water mixes with salt water. Often a single type of chemical or pollutant may come from several sources, and consequently its origin is difficult to detect. The most prevalent sources of pollution from water discharge in coastal areas are domestic sewage, pulp mill waste, urban runoff, industrial effluent, and thermal effluent.

In general, discharge of domestic sewage enriches the water's nutrient load not unlike fertilization from agricultural runoff. Domestic sewage consists of dissolved and suspended materials, and because these materials were originally plant and animal material, they contain high levels of nitrogen, potassium, and phosphorus (the three most important ingredients of commercial fertilizers). Whereas agricultural runoff is predominant only during rainy periods, domestic sewage discharge is relatively constant (or increasing) regardless of water conditions. Urbanization of coastal areas results in greater discharge rates, and the estuary and nearshore waters may continue to be the ultimate sump of sewage and sludge discharges in the foreseeable future. These discharges contain not only nutrients which encourage eutrophication, but also coliform bacteria and pathogenic viruses. Pathogenic organisms disperse outward from the point of waste discharge and either die or are consumed by filter feeding animals such as oysters and clams. Many productive oyster and clam beds are closed to harvesting because of domestic pollution. Extensive areas closed to shellfish harvesting exist around Murrells Inlet, Charleston, Beaufort, Savannah, and Brunswick. (See Atlas plates 31,41,42,43.)

Urban runoff is also a source of water pollution. Drainage from streets, service stations, and residential areas contains many organic and inorganic compounds toxic to marine life. Fallout from industrial airborne emissions, automobile exhaust, tire particles on highways, and leached materials from solid waste disposal sites are a few of the sources of water pollution from urban runoff.

Effluents from heavy industry result in acute as well as chronic sources of pollution. Such effluents often contain complex metallic and organic compounds which resist biodegradation and are toxic to marine life. These compounds may be discharged in dilute concentrations but, because of their nature, they may be assimilated into the food chain and undergo biological amplification as they pass through increasingly higher consumer levels (see Volume III).

Among the more dangerous industrial pollutants discharged into the estuaries are the heavy metals (mercury, cadmium, zinc, lead, etc.). In the summer of 1970, the Savannah River below Augusta was closed to fishing due to methyl mercury pollution from the Olin Mathieson Company at Augusta, Georgia. Fish and seafood approximately 180 mi (288 km) downstream from the pollution source were declared unsafe for human consumption. A similar case involving mercury pollution from Allied Chemical Company also occurred in Brunswick Harbor during the early 1970's (Johnson et al. 1974).

Paper mills have been a primary source of industrial pollution in coastal areas, primarily in Georgetown, Charleston, Chatham, Liberty, Glynn, and Camden counties (see Volume II, Chapter Six). Effluents from pulp mills can drastically alter the pH, dissolved oxygen, and turbidity of receiving waters, and thus affect aquatic life directly and indirectly. Characteristically, pulp mill effluent exerts high chemical (oxidation of SO_2) and biological (oxidation of sugars) demands on dissolved oxygen, and suspended materials reduce light, which inhibits photosynthetic processes. Suspended materials may also settle out, forming sludge banks and thus rendering the bottom substrate unsuitable for benthic organisms. Also, pulp-mill wastes have direct toxic effects upon the biota, especially the alkaline effluent which contains hydrogen sulfide, mercaptans, resin acids, and soaps. These effluents may reduce surface tension of receiving waters and cause increased foaming, which makes waters aesthetically unattractive. Many of these adverse effects have been alleviated by settling ponds and aeration prior to discharge.

The use of coastal waters for cooling by industry and power-generating plants results in thermal pollution (see Volume II, Chapter Four). Fossil and nuclear-fueled steam generating electrical plants are capable of elevating estuary temperatures via the discharge of cooling waters. Temperature increases can result in substantial alterations in the biology of affected biota because water temperature may be a cue to migrate or reproduce. Elevated water temperatures are known to cause developmental abnormalities in larval fish and to stress adult populations (Krenkel and Parker 1969). Also, oxygen solubility decreases with increasing water temperature. In addition to physiological stresses, fish may be killed directly by impingement on intake screens or suffer mortality through drastic pressure changes subsequent to entrainment into the power plant's cooling system (Krenkel and Parker 1969).

Thermal pollution is not now a serious threat to estuaries in the Sea Island Coastal Region. However, with development of nuclear-powered electric-generating plants, the situation could change. According to Johnson et al. (1974), Georgia Power Company is developing such a plant about 70 mi 112 km) above Altamaha Sound on the Altamaha River. Water demands upon the river will be approximately 25,000 gallons per minute, of which 12,000 will be returned to the river as cooling tower effluent. The temperature of the effluent will vary from 78° to 90°F (24.5°C to 32.2°C).

Classifications for major coastal river systems and locations of point-source discharges are available through the Georgia Department of Natural Resources and South Carolina Department of Health and Environmental Control. (See Directory of Information Sources for addresses and types of data.)

a. <u>South Carolina River Basins</u>. The following section identifies major coastal problem areas and describes the general water quality problems for the South Carolina portion of the study area (see Atlas plates 31 - 40).

The Georgetown and Charleston areas in South Carolina and the Savannah and Brunswick areas in Georgia are the most extensively developed areas of the Sea Island Coastal Region. These areas grew with little overall planning and contain many inadequate sewer systems and septic tanks. The small, isolated estuaries near these metropolitan centers are subject to both point source and non-point source pollution. Many of the shellfish grounds are opened and closed frequently during the year on the basis of water quality.

Winyah Bay has been closed to shellfishing since 1964 (Atlas plate 31). The bay receives pollution from runoff of the Pee Dee, Waccamaw, Black, and Sampit rivers. The Sampit is heavily polluted, receiving discharges from both domestic and industrial sources. The Pee Dee, Waccamaw, and Black are dominated by agricultural runoff from upstate and combine to concentrate pollution levels in Winyah Bay. Improving water quality in the bay will be a difficult task. The more stringent 1980 EPA regulations will help, but a full scale effort must be made to improve all industrial treatment facilities and sewage systems.

The North and South Santee rivers receive most of their toxic materials from agricultural runoff. This condition could worsen after completion of the Santee-Cooper Rediversion Project, which is discussed earlier in this chapter. The area seaward from the Atlantic Intracoastal Waterway is now open for shellfishing but could be shifted further toward the ocean after rediversion. Both rivers have rich hard clam beds and are an important part of South Carolina's clam fishery (see Volume II, Chapter Seven).

Water quality from Cape Romain to the Isle of Palms is generally excellent, with one exception. Jeremy Creek near McClellanville receives the domestic effluent from McClellanville and is closed to shellfishing. The other small creeks of this area are located in largely undeveloped areas, and contain large areas of prime shellfish grounds. Development of Dewees Island and the Isle of Palms may threaten this classification in the future.

The tidal creeks and inlets of this area have been recently reopened to shellfishing. Much of this area was closed due to the influence of Charleston Harbor. Improved water quality in Charleston Harbor and improved domestic sewage treatment is responsible for the re-opening of the area.

Charleston Harbor receives water from the Ashley, Cooper, and Wando rivers. The Ashley and Cooper rivers have heavy industry located along the river banks. The Wando River is less developed and contains valuable subtidal "seed" oyster beds. Although these areas are closed to commercial harvesting due to nearby point source discharges, oysters from those beds are dredged and moved to non-polluted areas for later harvesting (Volume II, Chapter Seven). A proposed port facility and future industrial development could add to harbor water quality problems. The addition of sewage treatment facilities and improved industrial waste treatment have improved the water quality of Charleston Harbor. Clarke Sound, which is adjacent to Charleston Harbor, may be opened to shellfishing in the near future if sewage treatment facilities in the surrounding residential areas are improved.

The Stono River receives some exchange of water from Charleston Harbor through Elliots Cut (AIWW). Portions of the river under influence of this exchange are closed to shellfish harvesting. The lower reaches of the river are open to shellfishing because of the tidal influence of Stono Inlet. Water quality of much of the river is dependent on the water quality of Charleston Harbor. Abbapoola Creek, a small creek that empties into the Stono, is polluted by agricultural runoff and livestock operations which drain into the creek.

The area between the Edisto River and Brickyard Creek (Coosaw River) has high water quality due to lack of development. Recent residential development of adjacent barrier islands may change water quality of this area in the near future. Church Creek on Wadmalaw Island and Fishing Creek on Edisto Island are the only small creeks in the area closed to shellfishing. Both are closed because of domestic pollution.

The Beaufort River-Port Royal Sound-Savannah River shellfish area is under heavy pressure from development in the area. A majority of the closed areas are due to domestic sewage treatment facilities. The Beaufort area is one of the fastest growing areas in South Carolina because of military installations, port facilities, and recreational areas. Proper management of this area is necessary since many of the shellfish grounds are near impacted areas. The area from the Cooper River south is closed due to the influence of the Savannah River.

b. Georgia River Basins. Although a comprehensive monitoring program for Georgia coastal waters was established in 1973-74, there have not been enough samples to provide detailed water quality information. The large areas of water that have been approved for oyster growing and harvesting, however, reflect the excellent overall quality of Georgia's coastal waters. Additional areas may be approved when additional sanitary surveys are completed.

On Georgia's coast, six areas totalling an estimated 125,528 acres (50,211 ha) have been approved for shellfish harvesting. Approved oyster growing areas are located west of Wassaw Island, west of Little Tybee Island, west of Sapelo Island, south of Sapelo Island, west of Jekyll Island, and west of Cumberland Island. These areas are marshlands and tidal creeks, distant from the mainland shore and ship channel (Atlas plates 8,9, and 10).

As mentioned previously, the Savannah River has been heavily polluted over the years. However, during the 1970's, water quality in the lower reach of the Savannah - including the industrialized section of the river and harbor - has improved. This improvement has been largely due to steps taken by individual industries. Municipal waste discharge and discharge from several non-complying industries remain serious problems.

The Turtle River, the Brunswick River, and East River form the major areas of the Port of Brunswick. Industrial and municipal wastewater discharge is also the main source of pollution in these areas. Industrial pollution in Brunswick Harbor has been of special concern because of the persistent mercury contamination upstream from Brunswick. Although the polluting industries have substantially reduced discharges, some long-term effects are being experienced.

Generally, good water quality is found in the Altamaha, Satilla, Ogeechee, and St. Marys rivers. In the Altamaha, the area downstream from pulp and paper mills near Jesup has caused problems in the past. However, the water quality in the lower reaches of the Altamaha is in good condition. The Ogeechee River is one of the most primitive and unspoiled streams in Georgia. The North Newport River in Liberty County has been found to have extremely high sulfate levels caused by papermill discharges. The Satilla River receives significant waste discharges from a textile mill and a meat-packing plant. The major sources of waste on the St. Marys River are a mining company at Folkston and a paper company in St. Marys. The overall good water quality of the St. Marys reflects the natural influence of the Okefenokee Swamp.

Due to stringent Federal and State standards, it is likely that water quality problems in Georgia's coastal counties in the next 10 years will be minimal, with the exception of those locations where industries and municipal waste treatment facilities have not met State and Federal standards. However, any material that is placed in the water will have some effect, even if water quality standards are met.

It is virtually impossible to project the potential water quality problems that may arise from non-point sources. Although it is expected that the urban centers in the coastal counties (especially the Savannah and Brunswick areas) will increase in population, it is unknown whether coastal communities, in cooperation with State offices, will plan in advance for orderly growth to reduce problems of erosion and runoff, and utilize storm water systems.

3. Solid Wastes

The amounts of solid wastes generated in the Sea Island Coastal Region are rising each year. For the most part, they are disposed of on land. The rising volume of waste generation has a magnifying influence on problems related to solid wastes, especially the costs of waste management, the shortage of disposal sites in urban areas, and the potential environmental and health effects of disposal.

Virtually all types of wastes have potential for causing environmental problems. Some of these, particularly certain types of industrial solid wastes, pose special hazards to public health and the environment unless they are properly handled, transported, treated, stored, and disposed of. Hazardous wastes may contain toxic chemicals; pesticides; acids; caustics; infectious, radioactive, or explosive substances; or other materials in sufficient amount to cause acute or chronic health effects or severe damage to the environment. Damage from land disposal of hazardous wastes can occur in several ways: groundwater contamination through leaching; surface water contamination via runoff; air pollution by open burning, evaporation, sublimation, and wind erosion; poisoning through direct contact; poisoning via the food chain; and fire and explosion (Council on Environmental Quality 1979).

Concurrent with population growth, solid waste generation and disposal problems are increasing in the Sea Island Coastal Region. However, specific data relating to solid waste management problems in coastal South Carolina and Georgia are not readily available at this time.

APPENDIX A

COUNTY DESCRIPTIONS

I. INTRODUCTION

Appendix A contains a brief description of each county in the Sea Island Coastal Region from Georgetown County, South Carolina, to Camden County, Georgia (Preface Fig. 2). Each county description is limited to basic information on certain physiographic and cultural aspects of the county and generally includes data on its size, bounds, elevations, drainage, wetland areas, developed areas, economic base, and population. Tabular summaries of data for the counties can be found in Tables 5-2 and 5-3.

II. SOUTH CAROLINA COUNTIES

A. GEORGETOWN

Georgetown County is located in the lower Atlantic Coastal Plain of South Carolina. Occupying 813 mi^2 (2,106 km^2) (South Carolina State Soil and Water Conservation Needs Committee 1970), it is bounded on the east by approximately 37 mi (60 km) of irregular Atlantic Ocean shoreline (U.S. Army Corps of Engineers 1972a). A series of marsh and barrier islands forms the coast. These include Pawleys and North islands, which are barrier islands, and South and Cedar islands, which are marsh islands. All four islands are Holocene beach ridge plain islands, separated from one another and the mainland by tidal streams and inlets draining an extensive system of drowned river valleys and shallow, marsh-filled coastal lagoons. The profile of the mainland topography consists of subtle undulations in the landscape characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 75 ft (23 m).

The county is drained by five significant river systems: the Waccamaw, Black, Sampit, Pee Dee, and Santee. Of these, the Sampit River is a coastal river (coastal plain stream), i.e., it originates in the coastal plain and its flow is dominated by tidal action. Salinities range from $0^{o}/oo$ to $20^{o}/oo$ throughout the year. The other rivers have significant freshwater discharge. The South Santee forms the southwestern boundary, the Black bisects the county, and the Pee Dee forms part of the northern boundary. The inland boundary of the county borders Horry, Marion, Williamsburg, Charleston, and Berkeley counties. Because of the low topography, many broad, low-gradient drains are present as either extensions of tidal streams and rivers or flooded bays and swales.

The many diverse wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 11% of the county. Of this, 20,540 acres (8,313 ha) consist of salt and brackish water marshes, 23,764 acres (9,617 ha) consist of freshwater marshes, and 11,940 acres (4,832 ha) consist of coastal impoundments (Tiner 1977).

In 1967, the urbanized area of Georgetown County consisted of 21,800 acres (8,823 ha), while agricultural land and pasture occupied 34,953 acres (14,146 ha) (South Carolina State Soil and Water Conservation Needs Committee 1970). Welch (1968) reported that 391,300 acres (158,359 ha) were forested. Although agriculture and timber production constitute the bulk of rural land use, the main economic base of the county consists of an interrelationship of industrial and transportational components tied to the Port of Georgetown. As of 1970, Georgetown County had a total population of 33,500 people (South Carolina Budget and Control Board 1977), the majority of whom were centered around the county seat of Georgetown.

B. BERKELEY

Berkeley County is located in the lower Atlantic Coastal Plain of South Carolina. The county occupies 1,100 mi^2 (2,849 km^2) (South Carolina State Soil and Water Conservation Needs Committee 1970) and is adjacent to the coastal counties of Georgetown, Charleston, and Colleton. Berkeley County has access to the Atlantic Ocean via the Wando and Cooper rivers, but has no beach front. The profile of the mainland topography consists of subtle undulations in the landscape characteristic of beach ridge plains. Elevations in the county range from sea level to approximately 105 ft (32 m). Berkeley County is drained by three significant river systems: the Santee, Wando, and Cooper rivers. The Santee has a large freshwater discharge and forms the northern boundary with neighboring Georgetown County. The remaining two rivers were originally coastal river systems, i.e., their flow was dominated by tidal action, but the Cooper was modified by a large volume of fresh water diverted from the Santee. Because of the low topography of the county, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales.

The many diverse emergent wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 4% of the county's total area. Of this, 7,252 acres (2,935 ha) are brackish and saltwater marshes, 17,511 acres (7,087 ha) are freshwater marsh, and 4,294 acres (1,738 ha) are impounded marshes (Tiner 1977).

In 1967, the developed area in Berkeley County consisted of 29,546 acres (11,957 ha) of urbanized land while agricultural and pasture land occupied 63,617 acres (25,746 ha) (South Carolina State Soil and Water Conservation Needs Committee 1970). Welch (1968) reported that 583,300 acres (236,062 ha) were forested.

Although agriculture and timber production constitute the bulk of rural land use, the principal economic base of the county consists of an interrelationship of industrial and military components tied to the Port of Charleston in Charleston County.

As of 1970, Berkeley County had a total population of 56,199 people (South Carolina Budget and Control Board 1977), the majority of whom were centered in Moncks Corner, the county seat.

C. DORCHESTER

Dorchester County occupies 569 mi^2 (1,474 km^2) within the lower Atlantic Coastal Plain of South Carolina (South Carolina State Soil and Water Conservation Needs Committee 1970). The county has no ocean shoreline, but has water access to the Atlantic via the Ashley and Edisto rivers. The profile of the mainland topography consists of subtle undulations in the landscape characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 130 ft (40 m).

The county is drained by two significant river systems, the Ashley and the Edisto. The Ashley River is a coastal plain stream with salinities ranging from 0^o/oo to 30^o/oo throughout the year, whereas the Edisto River has a significant freshwater discharge throughout the year. The Edisto River forms the southwest boundary of Dorchester County. Colleton, Berkeley, Charleston, and Orangeburg counties share the remaining inland political boundaries. Because of the low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales.

The many diverse wetland communities occurring within the areas influenced by tidal inundation and river flow occupy less than 1% of the county. Of this, 439 acres (178 ha) consist of brackish water marshes, 862 acres (349 ha) consist of freshwater marshes, and 45 acres (18 ha) consist of coastal impoundments (Tiner 1977).

In 1967, the urbanized area of Dorchester County consisted of 5,041 acres (2,040 ha) while agricultural land and pasture occupied 64,716 acres (26,191 ha) (South Carolina State Soil and Water Conservation Needs Committee 1970). Cost (1968) reported that 263,200 acres (106,517 ha) were forested. Agriculture and timber production constitute the bulk of rural land use. St. George, the county seat, serves the rural interests of the northern portions of the county, whereas Summerville to the south has evolved from a similar rural situation into a fast-growing residential community serving metropolitan Charleston (Berkeley-Charleston-Dorchester Regional Planning Council 1976). The county had a population of 32,276 people in 1970 (South Carolina Budget and Control Board 1977), centered around St. George and Summerville.

D. CHARLESTON

Charleston County is located in the lower Atlantic Coastal Plain of South Carolina and occupies 940 mi^2 (2,435 km^2) (South Carolina State Soil and Water Conservation Needs Committee 1970). It is bounded on the east by approximately 75 mi (121 km) (U.S. Army Corps of Engineers 1972a) of irregular Atlantic Ocean shoreline. Several marsh, barrier, and sea islands combine to form the coastal fringe. The barrier islands, which are typically Holocene beach ridge plain islands, include Cape, Bull, Capers, Dewees, Isle of Palms, Sullivans, Folly, Kiawah, Seabrook, and Botany Bay. The marsh islands, also Holocene beach ridge plain islands in origin but lacking high energy beaches, are Murphy, Lighthouse, Raccoon Key, and Morris. The sea islands, which include James, Johns, Wadmalaw, and Edisto, are Pleistocene in origin. The coastal islands are separated from one another and the mainland by tidal creeks and inlets draining an extensive system of drowned river valleys and shallow, marsh-filled coastal lagoons. The profile of the mainland topography consists of subtle undulations in the landscape characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 70 ft (21 m).

The county is drained by seven river systems: the Santee, Wando, Cooper, Ashley, Stono, and the North and South Edisto. Of these, all but three are coastal, i.e., flow dominated by tidal action with salinities ranging from 0^o/oo to 30^o/oo throughout the year. The three rivers with significant freshwater discharges are the Santee, forming the northern boundary for the county, the Cooper, which bisects the county, and the South Edisto, forming the southwestern boundary. The inland boundary of the county borders parts of Colleton, Dorchester, Berkeley, and Georgetown counties. Because of the low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales.

The many diverse wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 28% of the county. Proportionately, 142,401 acres (57,630 ha) consist of salt and brackish water marshes, 5,000 acres (2,024 ha) consist of freshwater marshes, and 22,999 acres (9,308 ha) consist of coastal impoundments (Tiner 1977).

In 1967, the urbanized area of Charleston County consisted of 45,416 acres (18,380 ha) (South Carolina State Soil and Water Conservation Needs Committee 1970). The amount of urbanized land in the county, however, has undoubtedly increased significantly since then. Agricultural land presently occupies approximately 29,390 acres (11,893 ha) and is decreasing slightly each year (U.S. Department of Agriculture Extension Service, 1978, Clemson, S.C., pers. comm.). Welch (1968) has reported that 391,300 acres (158,359 ha) of Charleston County are forested. Although agriculture and timber production constitute the bulk of rural land use, the main economic base of the county consists of an interrelationship of industrial, transportation, and military components associated with the Port of Charleston. As of 1970, Charleston County had a total population of 250,000 (South Carolina Budget and Control Board 1977), the major portion of which is centered around the cities of Charleston and North Charleston, the town of Mount Pleasant, and several unincorporated public service districts.

E. COLLETON

Colleton County is located in the lower Atlantic Coastal Plain of South Carolina and occupies 1,048 mi^2 (2,714 km^2) (South Carolina State Soil and Water Conservation Needs Committee 1970). It is bounded on the south and east by approximately 4 mi (6.4 km) (U.S. Army Corps of Engineers 1972a) of irregular Atlantic Ocean shoreline. Edisto Beach, a barrier island, and Pine and Otter islands, which are marsh islands, form the coast. The islands are Holocene beach ridge plain islands separated from the mainland by tidal creeks and inlets draining an extensive system of drowned river valleys and shallow, marsh-filled coastal lagoons. The gradient of the mainland topography consists of subtle undulations in the landscape, characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 125 ft (38.1 m).

The county is drained by three significant river systems: the Edisto, Ashepoo, and Combahee-Salkehatchie. All three river systems have significant freshwater discharges, with the Combahee forming the southwestern boundary, the Ashepoo bisecting the county, and the Edisto forming part of the northern boundary of the county.

The inland boundary of the county borders Charleston, Dorchester, Orangeburg, Bamberg, Allendale, and Hampton counties. Because of the low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales.

The diverse emergent wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 9% of the county. Of this, 30,641 acres (12,400 ha) consist of salt and brackish water marshes, 8,608 acres (3,484 ha) consist of freshwater marshes, and 20,596 acres (8,335 ha) consist of coastal impoundments (Tiner 1977).

In 1967, the urbanized area of Colleton County consisted of 26,885 acres (10,880 ha), while agricultural land and pasture occupied 131,300 acres (53,137 ha) (South Carolina State Soil and Water Conservation Needs Committee 1970). Cost (1968) reported that 484,500 acres (196,077 ha) were forested. Agriculture and timber production constitute the bulk of the economic base of the county and are tied to the county seat of Walterboro. As of 1970, Colleton County had a total population of 27,622 people (South Carolina Budget and Control Board 1977), the majority of whom were centered around the county seat of Walterboro.

F. BEAUFORT

Beaufort County is located in the lower Atlantic Coastal Plain of South Carolina. Occupying 581 mi^2 (1,505 km^2) (South Carolina State Soil and Water Conservation Needs Committee 1970), it is bounded on the south and east by approximately 36 mi (58 km) (U.S. Army Corps of Engineers 1972a) of irregular Atlantic Ocean shoreline. A series of marsh, barrier, and sea islands forms the coast. The marsh islands, which are typically Holocene beach ridge plain islands, include Little Capers, St. Phillips, and Bay Point. The barrier islands, also Holocene, include Hunting, Fripp, and Pritchards islands. The sea islands, which are Pleistocene beach ridge plain islands with or without a Holocene fringe, include Coosaw, Morgan, Ladies, St. Helena, Pinckney, Hilton Head, Daufuskie, Port Royal, and Parris

Island. They are separated from one another and the mainland by tidal creeks and inlets draining an extensive system of drowned river valleys and shallow, marsh-filled coastal lagoons. The gradient of the mainland topography consists of subtle undulations in the landscape characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 40 ft (12 m).

The county is drained by five significant river systems: the May, Combahee, New, Broad-Pocotaligo-Coosawhatchie, and the Colleton. The May, New, Broad-Pocotaligo-Coosawhatchie, and Colleton rivers are coastal, i.e., flow dominated by tidal action with salinities ranging from $0^{o}/oo$ to $30^{o}/oo$ present the entire year. The Combahee River, however, has a sizable freshwater discharge throughout the year. Part of the New River forms the southwestern boundary and the Combahee River forms the northeastern boundary of the county. The inland boundary of the county borders Colleton, Hampton, and Jasper counties. Because of the low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales.

The diverse emergent wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 37% of the county. Of this, 130,015 acres (52,617 ha) consist of salt and brackish water marshes, 1,523 acres (616 ha) consist of freshwater marshes, and 4,278 acres (1,731 ha) consist of coastal impoundments (Tiner 1977).

In 1967, the urbanized area of Beaufort County consisted of 18,543 acres (7,504 ha), while agricultural land and pasture occupied 54,381 acres (22,008 ha) (South Carolina State Soil and Water Conservation Needs Committee 1970). Cost (1968) reported that 157,000 acres (63,538 ha) were forested. Although agriculture and timber production constitute the bulk of rural land use, the principal economy of the county consists of an interrelationship of military, light industrial, and tourism components. As of 1970, Beaufort County had a total population of 51,136 people (South Carolina Budget and Control Board 1977), the majority of whom were centered around the county seat of Beaufort.

G. JASPER

Jasper County is located in the lower Atlantic Coastal Plain of South Carolina. Occupying 661 mi^2 (1,712 km^2) (South Carolina State Soil and Water Conservation Needs Committee 1970), it is bounded on the south by approximately 2.8 mi (4.5 km) (U.S. Army Corps of Engineers 1972a) of irregular Atlantic Ocean shoreline. Turtle Island, a marsh island, forms the coast. The island is a Holocene beach ridge plain island separated from the mainland by tidal creeks and inlets draining a system of drowned river valleys. The profile of the mainland topography consists of subtle undulations in the landscape, characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 105 ft (32 m).

The county is drained by two significant river systems: the Savannah River and the New River. The Savannah, forming the southwestern boundary of the county, has a sizable freshwater discharge (see Table 5-4). The New River, forming part of the northern boundary, has a much smaller rate of flow. The inland boundary of the county borders Beaufort, Hampton, Effingham, and Chatham counties. Because of the low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales.

The diverse emergent wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 11.5% of the county. Of this, 36,014 acres (14,575 ha) consist of salt and brackish water marshes, 6,536 acres (2,645 ha) consist of freshwater marshes, and 6,224 acres (2,519 ha) consist of coastal impoundments (Tiner 1977).

In 1967, the urbanized area of Jasper County consisted of 10,600 acres (4,290 ha), while agricultural land and pasture occupied 48,215 acres (19,513 ha) (South Carolina State Soil and Water Conservation Needs Committee 1970). Cost (1968) reported that 312,900 acres (126,613 ha) were forested. Agriculture and timber production constitute the bulk of rural land use, and provide the economic base of the county. As of 1970, Jasper County had a total population of 11,885 people (South Carolina Budget and Control Board 1977), the majority of whom were centered around the county seat of Ridgeland.

III. GEORGIA COUNTIES

A. EFFINGHAM

Effingham County is located in the lower Atlantic Coastal Plain of Georgia, and occupies some 480 mi^2 (1,243 km^2) (Coastal Area Planning and Development Commission 1975b). The county is located inland and has no Atlantic Ocean shoreline, but is located on the Savannah River and has potential as a future port site. The gradient of the mainland topography consists of subtle undulations in the landscape characteristic of the ridge and bay topography of Pleistocene age beach ridge plains. Elevations in the county range from sea level to approximately 135 ft (41 m).

The county is drained by two significant river systems: the Savannah and Ogeechee. The two rivers have significant freshwater discharge. The Savannah forms the northeast boundary and the Ogeechee forms part of the southwest boundary. The political boundaries of the county border Chatham, Bryan, Bulloch, and Screven counties in Georgia, and Hampton and Jasper counties in South Carolina.

Because of the low topography, broad, low-gradient interior drains are present as streams and rivers. No recent quantitative data on wetland communities occurring within the area influenced by tidal inundation and river flow are available. There are 455 acres (184 ha) of open water in the county (Wilkes 1978).

In 1978, the urbanized area of Effingham County consisted of 7,294 acres (2,952 ha), while agriculture consisted of 126,975 acres (51,387 ha), and forested areas totalled 247,811 acres (100,289 ha) (Coastal Area Planning and Development Commission 1975b). Although agriculture and timber production constitute the bulk of rural land use, the main economic base of the county consists of an interrelationship of industrial and transportational components tied to the Port of Savannah. As of 1970, Effingham County had a total population of 13,632 people (Coastal Area Planning and Development Commission 1973), the majority of whom were centered around the county seat of Springfield.

B. CHATHAM

Chatham County is located in the lower Atlantic Coastal Plain of Georgia. Occupying 441 mi^2 (1,142 km^2) (Wilkes et al. 1974), it is bounded on the south and east by approximately 23 mi (37 km) of irregular Atlantic Ocean shoreline. A series of marsh, barrier, and sea islands forms the coast. Chatham County's marsh islands, Little Tybee and Williamson islands are Holocene beach ridge plain islands. The barrier islands, also Holocene, include Tybee and Wassaw. The sea islands, which are Pleistocene beach ridge plain islands, include Wilmington and Skidaway. Ossabaw, also a Pleistocene beach ridge plain island, has a Holocene fringe along the ocean shoreline. The coastal islands are separated from one another and the mainland by tidal creeks and inlets draining an extensive system of drowned river valleys and shallow, marsh-filled coastal lagoons. The gradient of the mainland topography consists of subtle undulations in the landscape characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 70 ft (21 m).

The county is drained by four significant river systems: the Savannah, Wilmington, Little Ogeechee, and Ogeechee-Canoochee. Of these, the Wilmington and Little Ogeechee rivers are coastal, i.e., flow dominated by tidal action with salinities ranging from 10^o/oo to 34^o/oo throughout the year. The remaining two rivers have sizable freshwater discharges. The Savannah forms the northeast boundary and the Ogeechee forms part of the southwest boundary of the county. The inland boundary of the county borders Jasper County, South Carolina, and Effingham and Bryan counties, Georgia.

Because of low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales. The many diverse wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 38% of the county. Proportionately, 91,965 acres (37,218 ha) consist of saltwater and brackish marshes, 12,180 acres (4,929 ha) consist of freshwater marshes, and 2,000 acres (809 ha) consist of tidal swamps (Wilkes 1976). There are also 48,955 acres (19,812 ha) of open water in the county (Wilkes 1978).

In 1978, the urbanized area of Chatham County consisted of 61,074 acres (24,717 ha), while agriculture consisted of 21,197 acres (8,578 ha), and forest consisted of 109,779 acres (44,428 ha) (Wilkes 1978). As of 1970, Chatham County had a total population of 187,767 people (Coastal Area Planning and Development Commission 1973), the majority of whom were centered around metropolitan Savannah, the county seat.

C. BRYAN

Bryan County occupies 443 mi^2 (1,147 km^2) (Coastal Area Planning and Development Commission 1975a) of the lower Atlantic Coastal Plain of Georgia. The county has no ocean shoreline but has water access to the Atlantic via St. Catherines Sound. The gradient of the mainland topography consists of subtle undulations in the landscape characteristic of the ridge and bay topography of Pleistocene beach ridge plains. Elevations in the county range from sea level to approximately 150 ft (46 m).

The county is drained by two significant river systems: the Medway-Jericho and Canoochee-Ogeechee. The Medway-Jericho, which forms a part of the southwestern boundary of the county, is a coastal river, i.e., flow dominated by tidal action with salinities ranging from $0^{o}/oo$ to $30^{o}/oo$ present throughout the year. The Canoochee River forms the upper portion of the southwestern boundary of the county; it then crosses the county and joins the Ogeechee River, which forms the northeastern boundary of the county. This river system has a predominately freshwater discharge the entire year. The inland boundaries border Chatham, Effingham, Bulloch, Evans, and Liberty counties.

Because of the low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales. The diverse wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 9% of the county. Proportionately, 20,495 acres (8,294 ha) consist of brackish and saltwater marshes, 2,020 acres (818 ha) consist of freshwater marshes, and 3,685 acres (1,491 ha) consist of tidal swamps (Wilkes 1976). There are also 8,520 acres (3,448 ha) of open water in the county (Wilkes 1978).

In 1974, the urbanized area of Bryan County consisted of 7,840 acres (3,173 ha), while agriculture and forest lands totalled 161,310 acres (65,282 ha) (Coastal Area Planning and Development Commission 1975a). Although agriculture and timber production constitute the bulk of the rural land use, the principal economy of the county consists of an interrelationship of pulp and paper and military components. As of 1970, Bryan County had a population of 6,539 people (Coastal Area Planning and Development Commission 1973), the majority of whom were centered around Pembroke, the county seat, and Richmond Hill.

D. LIBERTY

Liberty County is located in the lower Atlantic Coastal Plain of Georgia. Occupying 514 mi^2 (1,331 km^2) (Coastal Area Planning and Development Commission 1975b), the county is bounded on the east by approximately 11 mi (18 km) of irregular Atlantic Ocean shoreline. The coast of Liberty County is bounded by St. Catherines Island which is a sea island. Colonels Island, also a sea island, is located inland of St. Catherines. Colonels and St. Catherines are Pleistocene beach ridge plain islands, with St. Catherines having a Holocene fringe along the ocean shoreline. They are separated from one another and the mainland by tidal creeks and inlets draining an extensive system of drowned river valleys and shallow, marsh-filled coastal lagoons. The profile of the mainland topography consists of subtle undulations in the landscape, characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 70 ft (21 m).

The county is drained by four significant river systems: the Medway-Jericho, Canoochee, North Newport, and South Newport. All except the Canoochee are coastal rivers, i.e., flow dominated by tidal action with salinities ranging from $0^{o}/oo$ to $30^{o}/oo$ present throughout the year. The Canoochee River, however, drains the northwestern portion of the county and has a predominantly freshwater discharge. Part of the Medway River forms the northwestern boundary of the county and a part of the South Newport River forms the southwestern boundary. The inland boundaries border Bryan, Evans, Tattnall, Long, and McIntosh counties.

Because of the low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales. The many diverse wetland communities occuring within the areas influenced by tidal inundation and river flow occupy approximately 13% of the county. Proportionately, 39,761 acres (16,091 ha) consist of saltwater and brackish marshes, 1,500 acres (607 ha) consist of freshwater marshes, and 1,000 acres (405 ha) consist of tidal swamps (Wilkes 1976). There are also 16,981 acres (6,872 ha) of open water in the county (Wilkes 1978).

In 1976, the urbanized area of Liberty County consisted of 7,946 acres (3,216 ha), while agriculture and forest lands totalled 278,753 acres (112,811 ha) (Coastal Area Planning and Development Commission 1978). Although agriculture and timber production constitute the bulk of rural land use, the economy of the county consists of an interrelationship of pulp and paper, textiles, and military components. As of 1970, Liberty County had a population of 17,569 people (Coastal Area Planning and Development Commission 1973), the majority of whom were centered around the Hinesville-Fort Stewart complex. Hinesville is the county seat.

E. MCINTOSH

McIntosh County is located in the lower Atlantic Coastal Plain of Georgia. Occupying 426 mi^2 (1,103 km^2) (Coastal Area Planning and Development Commission 1975b), the county is bounded on the east by approximately 14 m (23 km) of irregular Atlantic Ocean shoreline. A series of low, sandy marsh, barrier, and sea islands forms the coast. There is one marsh island, Wolf, which is a Holocene beach ridge plain island. Blackbeard, a Holocene barrier island, is of the same origin. The sea island, Sapelo, is a Pleistocene beach ridge plain island with a Holocene fringe along the ocean shoreline consisting of Nanny Goat Beach and Cabretta Island. The islands are separated from one another and the mainland by tidal creeks and inlets draining an extensive system of drowned river valleys and shallow, marsh-filled lagoons. The gradient of the mainland topography consists of subtle undulations in the landscape, characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 80 ft (24 m).

The county is drained by three significant river systems: the South Newport, Sapelo, and Altamaha. The South Newport, forming part of the northeastern boundary, and the Sapelo, bisecting the county, are coastal rivers, i.e., flow dominated by tidal action with salinities ranging from $0^{o}/oo$ to $30^{o}/oo$ present throughout the year. The Altamaha, which forms the southern boundary, has a predominantly freshwater discharge the entire year. The inland boundary of the county borders Liberty, Long, Wayne, and Glynn counties.

Because of the low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales. The diverse wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 36% of the county. Proportionately, 77,485 acres (31,358 ha) consist of saltwater and brackish marshes, 5,647 acres (2,285 ha) consist of freshwater marshes, and 14,033 acres (5,679 ha) consist of tidal swamps (Wilkes 1976). There are also 35,503 acres (14,368 ha) of open water in the county (Wilkes 1978).

In 1976, the urbanized area of McIntosh County consisted of 3,760 acres (1,522 ha), while agriculture and forest lands totalled 171,715 acres (69,493 ha) (Coastal Area Planning and Development Commission 1978). Agriculture and timber production constitute the bulk of rural land use and also provide the county with its economic base. As of 1970, McIntosh County had a population of 7,371 people (Coastal Area Planning and Development Commission 1973), the majority of whom were centered around Darien, the county seat.

F. GLYNN

Glynn County is located in the lower Atlantic Coastal Plain of Georgia. Occupying 491 mi^2 (1,272 km^2) (Coastal Area Planning and Development Commission 1975b), the county is bounded on the south and east by approximately 21 mi (34 km) of irregular Atlantic Ocean shoreline. A series of marsh, barrier, and sea islands borders the coast. Little St. Simons is a marsh island; Sea Island is a barrier island; and St. Simons and Jekyll are sea islands. The islands are separated from one another and the mainland by tidal creeks and inlets draining an extensive system of drowned river valleys and shallow, marsh-filled coastal lagoons. The gradient of the mainland topography consists of subtle undulations in the landscape characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 50 ft (15 m).

The county is drained by three significant river systems: The Altamaha, Turtle-Brunswick, and Little Satilla. The Turtle-Brunswick, which almost bisects the county, and the Little Satilla, which forms a portion of the southern boundary of the county, are coastal rivers, i.e., flow dominated by tidal action with salinities ranging from $5^{o}/oo$ to $30^{o}/oo$ present throughout the year. The Altamaha, which forms the northern boundary of the county, is dominated by freshwater discharge the entire year. The inland boundaries border McIntosh, Wayne, Brantley, and Camden counties.

Because of the low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales. The diverse wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 37% of the county. Proportionately, 74,236 acres (30,043 ha) consist of saltwater and brackish marshes, 4,700 acres (1,902 ha) consist of freshwater marshes, and 4,700 acres (1,902 ha) consist of tidal swamps (Wilkes 1976). There are also 29,474 acres (11,928 ha) of open water in the county (Wilkes 1978).

In 1976, the urbanized area of Glynn County consisted of 24,935 acres (10,091 ha), while agriculture and forest lands totalled 155,109 acres (62,773 ha) (Coastal Area Planning and Development Commission 1978). Although agriculture and timber production constitute the bulk of rural land use, the main economy of the county consists of an interrelationship of transportation, military, industrial, and tourism components. As of 1970, Glynn County had a population of 50,528 people (Coastal Area Planning and Development Commission 1973), the majority of whom were centered around Brunswick, the county seat.

G. CAMDEN

Camden County is located in the lower Atlantic Coastal Plain of Georgia. Occupying 653 mi^2 (1,691 km^2) (Coastal Area Planning and Development Commission 1975b), the county is bounded on the east by approximately 18 mi (29 km) of irregular Atlantic Ocean shoreline. Little Cumberland and Cumberland are sea islands which form the coast of Camden County. They are separated from one another and the mainland by tidal creeks and inlets draining an extensive system of drowned river valleys and shallow, marsh-filled coastal lagoons. The gradient of the mainland topography consists of subtle undulations in the landscape, characteristic of the ridge and bay topography of beach ridge plains. Elevations in the county range from sea level to approximately 80 ft (24 m).

The county is drained by four significant river systems: the Little Satilla, Satilla, Crooked, and St. Marys. The Little Satilla, forming a portion of the northern boundary, and the Crooked are coastal rivers, i.e., flow dominated by tidal action with salinities ranging from $0^o/oo$ to $30^o/oo$ present throughout the year. The Satilla, which almost bisects the county, and the St. Marys, which forms the southern boundary of the county, have a predominantly freshwater discharge during most of the year. The inland boundaries border Glynn, Brantley, and Charlton counties, Georgia, and Nassau County, Florida. Because of the low topography, many broad, low-gradient interior drains are present as either extensions of tidal streams and rivers or flooded bays and swales. The diverse wetland communities occurring within the areas influenced by tidal inundation and river flow occupy approximately 29% of the county. Proportionately, 78,275 acres (31,678 ha) consist of brackish and saltwater marshes, and 21,000 acres (8,499 ha) consist of freshwater marshes (Wilkes 1976). There are also 35,602 acres (14,408 ha) of open water in the county (Wilkes 1978).

In 1976, the urbanized area of Camden County consisted of 5,392 acres (2,182 ha), while agriculture and forest lands totalled 292,253 acres (118,275 ha) (Coastal Area Planning and Development Commission 1978). Agriculture and timber production constitute the bulk of rural land use, and the economy of the county consists of an interrelationship of these elements plus light industry and a growing military component at the U.S. Navy's Kings Bay Fleet Ballistic Missile Submarine Refit Site. As of 1970, Camden County had a population of 11,334 people (Coastal Area Planning and Development Commission 1978), the majority of whom were centered around Kingsland and St. Marys. Woodbine is the county seat.

APPENDIX B

ISLAND DESCRIPTIONS

I. INTRODUCTION

Appendix B contains brief descriptions of the major islands in the Sea Island Coastal Region from Pawleys Island, South Carolina, to Cumberland Island, Georgia (Preface Fig. 2). Each description is comprised of physiographic data, dominant vegetative types, rates of erosion and/or deposition, and miscellaneous data, such as real estate prices and development plans. The descriptions have been written to provide a brief sketch of each island for quick reference. Tabular summaries of island data are shown in Table 5-1. Physiographic, biological, and cultural resources of these islands are presented in graphic format in the various map series found in the Characterization Atlas.

James Island, South Carolina, and Sapelo Island, Georgia were chosen as examples of developed and undeveloped sea islands, respectively. While James Island still has agricultural zones, it is mainly an area of housing developments and, to a lesser extent, shopping areas. Sapelo Island is predominantly undeveloped except for agricultural areas. The other islands described in this appendix, except St. Helena, have an ocean front and were not selected as specific examples of developmental state.

II. SOUTH CAROLINA ISLANDS

A. PAWLEYS ISLAND

Pawleys Island is a barrier island located in Georgetown County, South Carolina, between Litchfield Beach to the north and Debidue Island to the south. The island is separated from Litchfield Beach by Midway Inlet and Pawleys Island Creek and from Debidue Island by Pawleys Inlet. A narrow band of salt marsh and tidal creeks separates the island from the mainland. The island has a sandy beachfront along its entire length of 3.5 mi (5.6 km), and a maximum width of 0.5 mi (0.8 km), including both high ground and marsh. In 1975, there were 162 acres (65.6 ha) of totally developed high land, 8 acres (3.2 ha) of undeveloped high land, and 640 acres (259 ha) of salt marsh (Warner and Strouss 1976).

Pawleys Island is a Holocene beach ridge island with a remnant maritime forest community in the undisturbed natural dune areas. Elevations on the island range from sea level to 13 ft (4 m) at the top of the beach ridges. The remnant maritime forest consists of live oak, loblolly pine, wax myrtle, cabbage palmetto, southern red cedar, and hollies. The typically polyhaline salt marsh is dominated by smooth cordgrass, with less abundant species such as black needlerush, sea ox-eye, salt-meadow cordgrass, glassworts, and salt grass also occurring.

The ocean front beach on Pawleys Island is experiencing erosion. To help remedy this condition, the South Carolina Highway Department constructed a groin field. This construction began in the late 1940's and has continued to date. Measured rates of shore retreat for the bulk of the island average 2 ft/yr (0.6 m/yr) for the period 1872 - 1966 (U.S. Army Corps of Engineers 1972b).

Shore-parallel sand transport along this island is perhaps best indicated by the continual southward migration of Pawleys Inlet. However, Midway Inlet has exhibited no long-term, net migration. Computer modeling of shore-parallel sand transport indicates the existence of several very short transport cells moving material northward (Stapor and Murali 1978). The magnitude of this transport is less than 10,000 m^3/yr (13,079 yd^3/yr).

Pawleys Island was used by wealthy plantation owners during the nineteenth century as a resort and refuge from the diseases of the swamp. Twentieth century residential resort development has enveloped all but 8 acres (3.2 ha) of high land on the island. Real estate prices on the island have soared: lots 100 ft by 150 ft (30.5 m by 45.7 m) begin at $40,000 on the ocean, $30,000 on the sound front, and $20,000 in the interior of the island (Warner and Strouss 1976). Scarcity of remaining high land acreage should limit further development. The entire island is privately owned.

B. NORTH ISLAND

North Island is a barrier island located in Georgetown County, South Carolina, between Debidue Island to the north and South Island to the south. The island is separated from Debidue Island by North Inlet and from South Island by Winyah Bay. The island has a sandy beachfront that is 8.0 mi (12.9 km) long, a length of 8.3 mi (13.4 km), and a maximum width of 2.0 mi (3.2 km), including both high ground and marsh. There is 1 acre (0.4 ha) of developed high land supporting a U.S. Coast Guard Station. The remaining 6,029 acres (2,440 ha), including 700 acres (283 ha) of high land and 5,329 acres (2,157 ha) of marsh, remain in an undeveloped state (South Carolina Wildlife and Marine Resources Department 1975a).

North Island is a Holocene beach ridge island with a maritime forest community on the beach ridge areas. Elevations on the island range from sea level to 42 ft (12.8 m) at the top of the highest ridge. The major components of the maritime forest community are live oak, loblolly pine, southern red cedar, wax myrtle, cabbage palmetto, and hollies. The typically polyhaline salt marsh is dominated by smooth cordgrass, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glass-worts, and salt grass also occurring.

Sequential aerial photographs and historical charts indicate that the central portion of North Island's sandy beach displays the most consistent stability, whereas extreme variability is evident at either end of the beach (Hubbard et al. 1977). This is generally thought to be the result of the effects of adjacent tidal inlets on both ends of the island. Individual littoral sand transport cells carry sand for short distances in one of several directions, resulting in net erosion of the north end of the the island and net deposition at the south end of the island. Computer modeling of shore-parallel sand transport under free waves (deep-ocean generated) predicts a net erosion of 42,000 m^3/yr (54,932 yd^3/yr) at the northern third of the island and a net deposition of 10,000 m^3/yr (13,079 yd^3/yr) at the southern tip of the island (Stapor and Murali 1978). Finley (1978) studied in detail the North Inlet ebb- and flood-tidal deltas, littoral transport, and resulting sediment deposition. He concluded that the deltas grew at a rate of 433,000 m^3/yr (566,000 yd^3/yr) between 1925 and 1964 and that this material was removed from the littoral drift. Inlet-directed littoral drift (from both north and south) is estimated to be 353,000 m^3/yr (460,000 yd^3/yr) based on field observations made during 1974-75. Nummedal and Humphries (1978) concluded that net littoral drift is southerly, towards North Island, at this inlet and was 87,000 m^3 (114,000 yd^3) and 390,000 m^3 (510,000 yd^3) during 1974-75 and 1975-76, respectively. Gross littoral drift (the combination of material moving north and south) was estimated to be 800,000 m^3 (1,047,200 yd^3) for each of the 2 years during which field observations were made.

C. SOUTH ISLAND

South Island is a marsh island located in Georgetown County, South Carolina, between North Island to the north and Cedar Island to the south. The island is separated from North Island by Winyah Bay and from Cedar Island by North Santee Bay. A wide band of marsh, tidal creeks, and impoundments separate the island from Cat Island to the west. There are 870 acres (352 ha) of undeveloped high land, 2,355 acres (953 ha) of impoundments, and 3,450 acres (1,396 ha) of salt and brackish water marsh on the island. The island has a sandy beachfront that is 5.5 mi (8.9 km) long, a length of 5.5 mi (8.9 km), and a maximum width of 2.0 mi (3.2 km), including both high ground and marsh.

South Island is a Holocene marsh island with a maritime forest community. Elevations on the island range from sea level to 21 ft (6.4 m) at the top of the beach ridges. The maritime forest consists of live oak, loblolly pine, southern red cedar, wax myrtle, cabbage palmetto, and hollies.

Vegetation within impounded areas consists of a variety of fresh and brackish water species, including cat-tails, bulrushes, widgeon grass, giant cordgrass, smooth cordgrass, and others. Unimpounded areas contain typical salt-marsh species such as smooth cordgrass, glassworts, and salt grass. The northern end of the island, which borders Winyah Bay, is closed to shellfishing due to the influence of residential and industrial development in Georgetown. The southern end of the island, which borders on the North Santee River, has high water quality and is open for shellfishing.

Comparison of shoreline maps of the South Island region over the interval 1876 to 1964 indicates that between 1925 and 1964 South Island experienced a net deposition rate of 70,000 m^3/yr (91,553 yd^3/yr). This sand moved on-shore under the influence of waves and tidal currents rather than by shore-parallel sand transport (Stapor and Murali 1978). Nineteenth- and twentieth-century shorelines from topographic maps prepared by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey for South Island are presented on Atlas plate 24.

D. CEDAR ISLAND

Cedar Island is a marsh island located in Georgetown County, South Carolina, between South Island to the north and Murphy Island to the south. The island is separated from South Island by North Santee Bay and from Murphy Island by the South Santee River. Broad expanses of unmodified marshlands and impounded marshlands, along with Four Mile Creek Canal (a portion of the AIWW), separate the western portion of the island from the mainland. The island has a sandy beachfront 3.0 mi (4.8 km) long, a total length of 4.8 mi (7.7 km), and a maximum width of 4.1 mi (6.6 km) including both high ground and marsh. There are 280 acres (113 ha) of high land, 2,700 acres (1,093 ha) of impoundments, and 1,070 acres (433 ha) of unmodified salt marsh (Warner and Strouss 1976).

Cedar Island is a Holocene marsh island with a maritime forest community in the undisturbed natural beach ridge areas. Coring by Aburawi (1972) indicates that structurally the island is a chenier underlain by deltaic deposits rather than sand. Elevations on the island range from sea level to 16 ft (4.9 m). The major components of the remnant maritime forest are live oak, loblolly pine, wax myrtle, southern red cedar, cabbage palmetto, and hollies.

Vegetation within the impoundments consists of a variety of salt and brackish water species including widgeon grass, dwarf spikerush, smooth cordgrass, salt grass, and sea ox-eye. The typically polyhaline saltmarsh areas are dominated by smooth cordgrass, with less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, sea ox-eye, and marsh elder also occurring.

Cedar Island is currently subjected to shoreline changes that are the result of the interaction between river discharge, tidal currents, and wave action. The northern portion of the island appears to be an area of net deposition, whereas the southern face of the island appears to be experiencing significant erosion (Stephen et al. 1975).

Cedar Island was used by rice planters in the early 1800's as a retreat from the diseases of the swamp that reportedly infested the nearby plantations. Planters from Santee Delta and lower Winyah Bay came to Cedar Island to enjoy a kind of marooning while away from the plantation (Doar 1908). Since the early 1900's, Cedar Island was managed as a waterfowl hunting reserve by the Santee Gun Club. In 1974, the State of South Carolina acquired the island as a part of the Santee Coastal Reserve through the Nature Conservancy. Management plans are currently being formulated that will provide limited natural resource recreation while maintaining the majority of the island as a wildlife reserve (Warner and Strouss 1976).

E. MURPHY ISLAND

Murphy Island is a marsh island located in Charleston County, South Carolina, between Cedar Island to the north and Cape Island to the south. The island is separated from Cedar Island by the South Santee River and from Cape Island by Cape Romain Harbor. A broad expanse of impounded marsh separates the island from the mainland. The island has a sandy beachfront that is 4.1 mi (6.6 km) long, a total length of 6.0 mi (9.7 km), and a maximum width of 3.3 mi (4.9 km), including both high ground and marsh. There are 690 acres (279 ha) of high land and 7,340 acres (2,971 ha) of marsh including 5,500 acres (2,226 ha) of impoundments (Warner and Strouss 1976).

Murphy Island is a Holocene island with a maritime forest community. Coring by Aburawi (1972) indicates that the island is underlain by deltaic deposits. Elevations on the island range from sea level to 16 ft (4.9 m). The forest cover consists of live oak, loblolly pine, southern red cedar, wax myrtle, cabbage palmetto, and hollies.

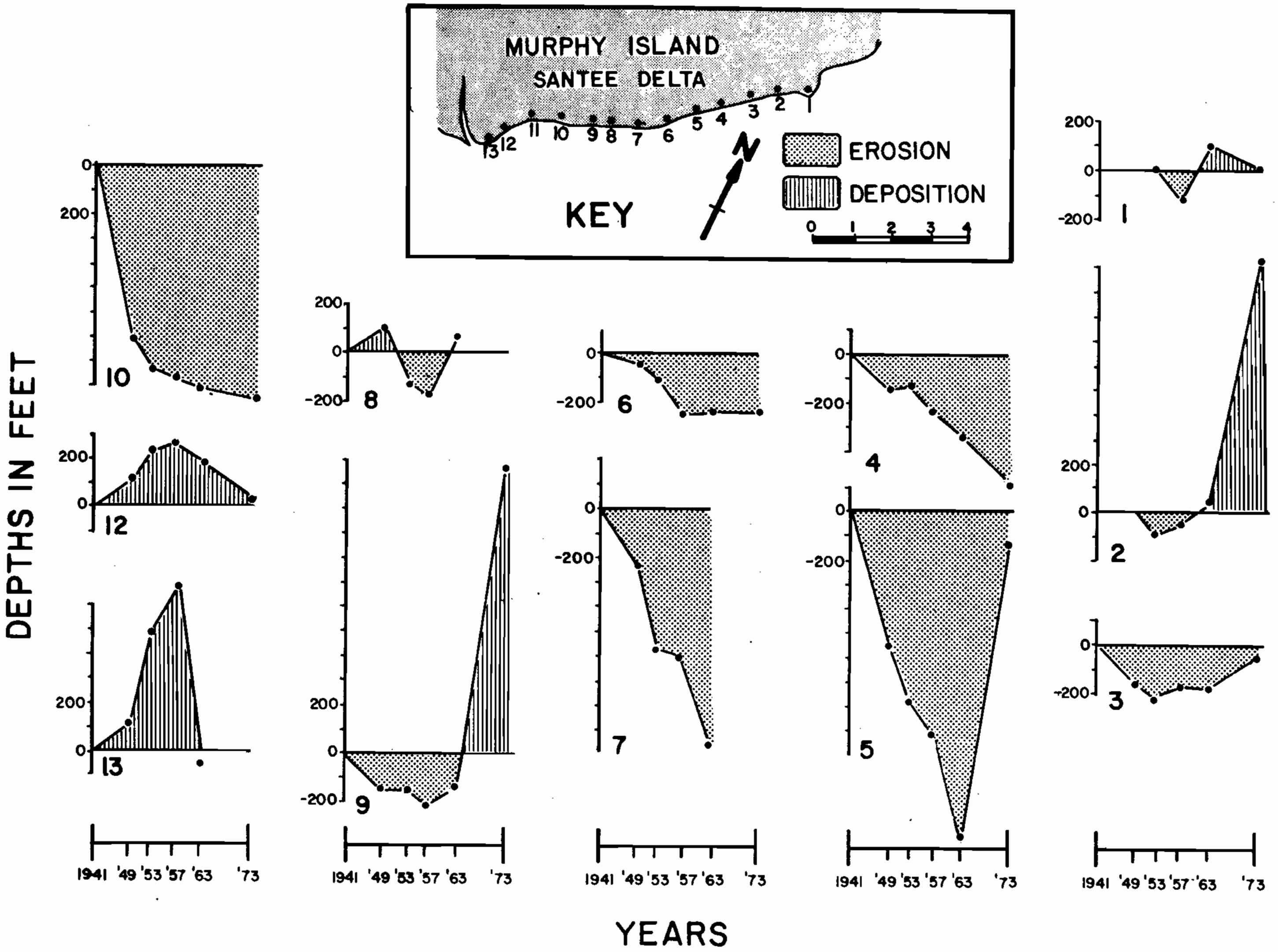
Vegetation within impounded areas consists of a variety of fresh and brackish water species, including cat-tails, bulrushes, widgeon grass, giant cordgrass, smooth cordgrass, and others. Unimpounded areas contain typical saltmarsh species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass.

Murphy Island has prograded seaward since 1873-74 between 800 and 500 m (2,625 and 1,640 ft) and southward some 240 m (787 ft). The northern portion facing the South Santee River has undergone net erosion as the main channel migrates southward, a local loss of some 650 m (2,133 ft) (Stapor and Murali 1978). Shoreline changes recorded by aerial photography are presented in Appendix Figure B-1 and cover the interval 1941 - 1973.

Murphy Island was part of the Harry Plantation, an early nineteenth-century rice plantation which, in 1836, was converted to cotton growing. The impounded rice fields were maintained by the Santee Gun Club until 1974, when the area was turned over to the State of South Carolina through the Nature Conservancy. The State will continue to manage the area for waterfowl habitat, but will permit limited recreation in the area. Murphy Island will be maintained in its natural state.

F. CAPE ISLAND

Cape Island is a barrier island located in Charleston County, South Carolina, between Murphy Island to the north and Lighthouse Island to the southwest. The island is separated from Murphy Island by Cape Romain Harbor and from Lighthouse Island by Key Inlet. A broad expanse of salt marsh separates the island from the mainland. The island has a sandy beachfront along its entire length of 5.3 mi (8.5 km), and a maximum width, including both high ground and marsh, of 1.3 mi (2.1 km). Of the 1,500 total acres (607 ha) of Cape Island, 875 acres



Appendix Figure B-1. Shoreline erosion and deposition on Murphy Island between 1941 and 1973, as measured from aerial photography.

(354 ha) are composed of high land and 625 acres (253 ha) are composed of marsh and impoundments (Warner and Strouss 1976).

Vegetative cover on Cape Island consists of a scrub shrub and immature maritime forest community surrounded by a high salinity salt marsh. Elevations on the island range from sea level to 10 ft (3.0 m) at the top of the higher beach ridges. The major components of the scrub shrub community are wax myrtle, southern red cedar, and hollies. The only large trees on the island are loblolly pines. The typically polyhaline salt marsh is dominated by smooth cordgrass in the low marsh areas, with less abundant species such as saltmeadow cordgrass, sea ox-eye, glassworts, salt grass, and black needlerush also occurring.

Cape Island has undergone long-term erosion along most of its shoreline. Sediments eroded from the apex of Cape Island move away in two directions forming recurved spits to the north and to the west. The northernmost portion of the northern spit has accreted more than 2,000 ft (610 m) since 1941. The western spit is over 4,000 ft (1,219 m) long and was accumulated between 1941 and 1968 at an average rate of 145 ft/yr (44.2 m/yr) (Stephen et al. 1975). All other localities along the front beach of Cape Island show net erosion. Nineteenth- and twentieth-century shorelines from topographic maps prepared by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey for Cape Island are presented on Atlas plate 25.

Cape Island, owned by the U.S. Fish and Wildlife Service, is one of four islands which make up Cape Romain National Wildlife Refuge. The area provides valuable habitat for colonial-nesting shorebirds and over-wintering migratory waterfowl. The area is also recognized as one of the major nesting beaches for the endangered loggerhead sea turtle. The island is undeveloped and has restricted public access (Warner and Strouss 1976).

G. LIGHTHOUSE ISLAND

Lighthouse Island is a low marsh island located in Charleston County, South Carolina, between Cape Island to the northeast and Raccoon Key to the southwest. The island is separated from Cape Island by Cape Romain Harbor and from Raccoon Key by Key Inlet. The island is separated from the mainland by a broad expanse of tidal creeks and salt marsh which are part of the Cape Romain National Wildlife Refuge. There are 943 total acres (382 ha) of land on Lighthouse Island of which 37 acres (15 ha) are high land and 906 acres (367 ha) are marsh (Warner and Strouss 1976). The island has a sandy beachfront that is 2.0 mi (3.2 km) long, a total length of 2.4 mi (3.9 km), and a maximum width, including both high ground and marsh, of 0.9 mi (1.4 km).

The island is a Holocene marsh island surrounded by a high salinity salt marsh. Elevations on the island range from sea level to 10 ft (3.0 m) at the top of the dunes. A scrub shrub community consisting of wax myrtle, cabbage palmetto, southern red cedar, and hollies is present. The typically polyhaline salt marsh is dominated by smooth cordgrass, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occurring.

Lighthouse Island, owned by the U.S. Fish and Wildlife Service, is one of four islands which make up the Cape Romain National Wildlife Refuge. The area is important because it provides valuable nesting habitat for various species of birds as well as for loggerhead turtles. The area also provides important habitat for migrating waterfowl. Parts of the refuge have been recently designated as wilderness areas. The refuge is totally undeveloped, but some 15,000 to 20,000 people tour the area each year (Warner and Strouss 1976). Nineteenth- and twentieth-century shorelines from topographic maps prepared by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey for Lighthouse Island are presented on Atlas plate 25.

H. RACCOON KEY

Raccoon Key is a low marsh island located in Charleston County, South Carolina, between Lighthouse Island to the east and Bull Island to the southwest. The island is separated from Lighthouse Island by Key Inlet and from Bull Island by Bulls Bay. Raccoon Key is separated from the mainland by a broad expanse of salt marsh and tidal creeks. There are 165 acres (67 ha) of land on Raccoon Key of which 25 acres (10 ha) are high land and 140 acres (57 ha) are salt marsh (Warner and Strouss 1976). The island has a sandy beachfront that is 5.4 mi (8.7 km) long, a length of 5.5 mi (8.9 km), and a maximum width, including both high ground and marsh, of 1.4 mi (2.2 km).

Raccoon Key consists of a washover beach backed by a high salinity salt marsh. Elevations on the island range from sea level to less than 5 ft (1.5 m). The adjacent salt marsh is dominated by smooth cordgrass in the low marsh areas, with less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, sea ox-eye, and salt grass in the high marsh areas.

Raccoon Key has a transgressive shoreline whose beaches consist of eroding marsh mud, a low sand and shell berm, and washover terraces. Measured erosion rates range from 600 to 1,500 ft/yr (183 to 457 m/yr). A long-term erosional trend is indicated for Raccoon Key (Stephen et al. 1975).

Raccoon Key, owned by the U.S. Fish and Wildlife Service, is one of four islands which make up the Cape Romain National Wildlife Refuge. The area is valued as prime nesting habitat for many species of shorebirds and the endangered loggerhead turtle. The area is also popular for recreational surf fishing and beachcombing. Raccoon Key is part of the Wilderness Area of the Cape Romain National Wildlife Refuge which is totally undeveloped (Warner and Strouss 1976). Nineteenth- and twentieth-century shorelines from topographic maps prepared by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey for Raccoon Key are presented on Atlas plate 25.

I. BULL ISLAND

Bull Island is a barrier island located in Charleston County, South Carolina, between Raccoon Key to the north and Capers Island to the south. The island is separated from Raccoon Key by Bulls Bay and from Capers Island by Price Inlet. A maze of tidal creeks and small marsh islands separates the island from the mainland. There are some 4,500 acres (1,821 ha) on Bull Island of which 1,980 acres (801 ha) are high land and 2,520 acres (1,020 ha) are salt marsh. The island has a sandy beachfront along its entire length of 6.8 mi (10.9 km), and a maximum width, including both high ground and marsh, of 1.9 mi (3.1 km).

Bull Island is a Holocene beach ridge island backed by a high salinity salt marsh. Elevations on the island range from sea level to 27 ft (8.2 m) at the top of the beach ridges. The maritime forest consists of live oak, loblolly pine, wax myrtle, cabbage palmetto, southern red cedar, and hollies. The typically polyhaline salt marsh is dominated by smooth cordgrass, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occurring.

Comparison of shoreline maps of Bulls Bay over the interval 1859 to 1963 indicates erosion of $5.37 \pm 1.55 \times 10^6$ m^3 ($7.03 \pm 2.03 \times 10^6$ yd^3) and deposition of $5.82 \pm 1.55 \times 10^6 m^3$ ($7.6 \pm 2.03 \times 10^6$ yd^3) occurring on or near the northern Bull Island shore (Stapor and Murali 1978). This averages out to a transport of 73,000 m^3/yr (95,477 yd^3/yr), with material being eroded from this northern Bull Island shore and deposited immediately adjacent to the island up against the Bull Creek tidal channel. The remainder of Bull Island shows minimal transport.

Bull Island is the largest of four islands which make up the Cape Romain National Wildlife Refuge. The impounded areas on the island are managed for waterfowl and provide excellent brackish water habitat for migrating waterfowl. Managed archery hunts to control the deer population are allowed in the fall. Nature trails crisscross the island. The area provides valuable nesting habitat for several species of birds as well as loggerhead turtles. The island is undeveloped, but some 15,000 to 20,000 people tour the island each year (Warner and Strouss 1976).

J. CAPERS ISLAND

Capers Island is a barrier island located in Charleston County, South Carolina, between Bull Island to the north and Dewees Island to the south. The island is separated from Bull Island by Price Inlet and from Dewees Island by Capers Inlet. A broad expanse of salt marsh isolates the island from the mainland. The island has a sandy beachfront that is 3.3 mi (5.3 km) long, a length of 3.4 mi (5.5 km), and a maximum width, including both high ground and marsh, of 1.5 mi (2.4 km). Capers Island has 850 acres (344 ha) of high ground, 1,090 acres (441 ha) of unmodified salt marsh, 50 acres (20 ha) of tidal creeks, and 110 acres (45 ha) of fresh and brackish water impoundments (South Carolina Wildlife and Marine Resources Department 1975b).

Capers Island is a Holocene barrier island with a maritime forest community. The island consists of an open sandy beach zone facing the Atlantic Ocean to the east and a series of parallel maritime forest beach ridges separated by low areas of brackish water marsh, ponds, and tidal creeks. Elevations on the island range from sea level to 15 ft (4.6 m) at the top of the natural beach ridges. The major components of the maritime forest are live oak, loblolly pine, wax myrtle, cabbage palmetto, southern red cedar, and hollies. Extensive areas of salt marsh are present on the western side of the island. The typically polyhaline saltmarsh areas are dominated by smooth cordgrass in the low marsh areas, with less abundant species such as saltmeadow cordgrass, glassworts, sea ox-eye, black needlerush, and marsh elder occurring in the high marsh areas. These marshlands are unpolluted, highly productive, relatively isolated, and unaltered by man.

Capers Island is currently eroding along most of its front beach. Erosion is particularly severe at the southeast end of the island, where the forest cover has been undermined and a low bluff exists. There is evidence that erosion has been occurring since 1875. Interpretation of scales, sequential aerial photography, and historic coastal charts indicates an approximate erosion rate of 15 ft/yr (4.6 m/yr) over the past 107 years. During the period from 1963 to 1973, there was an encroachment of approximately 200 ft (61 m) by the sea on the front beach. The only period of significant deposition occurred between 1956 and 1975. The bulk of this deposition was located at the northeast end of Capers Island adjacent to Price Inlet (South Carolina Wildlife and Marine Resources Department 1975b). Nineteenth- and twentieth-century shorelines from topographic maps prepared by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey for Capers Island are presented on Atlas plate 25.

The exact history of Capers Island has been lost, but it was one of several sea islands given as grants by the King of England to the colonists. Traditionally, the island was under cultivation in the eighteenth century when sea island cotton and indigo were the major crops. The island was operated as a farming entity until the boll weevil killed the sea island cotton industry, prior to World War I. The island was named in honor of the Capers family, an early colonial family that played a significant role in the development of the State and the nation.

Capers Island was purchased by the State of South Carolina in 1974 as a natural area and wildlife refuge. The island is unusual because of its diverse flora and fauna. The South Carolina Wildlife and Marine Resources Department is directly responsible for the management of this island. Current usage and management are directed towards maintaining a natural habitat for marine life, waterfowl, shorebirds, and other native vertebrates including sea turtles. To perpetuate the natural character of the island, Capers Island has been approved for inclusion into the South Carolina Heritage Trust as a Heritage Preserve.

K. DEWEES ISLAND

Dewees Island is a barrier island located in Charleston County, South Carolina, between Capers Island to the northeast and the Isle of Palms to the southwest. The island is separated from Capers Island by Capers Inlet and from the Isle of Palms by Dewees Inlet. It is separated from the mainland by a broad expanse of salt marsh and Bullyard Sound. The island has a sandy beachfront along its entire length of 2.2 mi (3.5 km), and a maximum width, including both high ground and marsh, of 1.4 mi (2.3 km). Dewees Island contains 940 acres (380 ha), of which 290 acres (117 ha) are high land and 650 acres (263 ha) are marsh.

Dewees Island is a Holocene beach ridge island with a maritime forest community in undisturbed areas. Elevations on the island range from sea level to 25 ft (7.6 m) at the top of the beach ridges. The maritime forest consists of live oak, loblolly pine, wax myrtle, cabbage palmetto, southern red cedar, and hollies. The polyhaline salt marsh is dominated by smooth cordgrass, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occurring.

Dewees Island is a relatively stable island with an accreting beach (Warner and Strouss 1976). The northern portion of Dewees Island is suffering from erosion (Stapor and Murali 1978). Littoral transport predictions by Stapor and Murali (1978) show littoral drift at a rate of 10,000 to 20,000 m^3/yr (13,079 to 26,158 yd^3/yr) to the northwest.

Dewees Island is owned by the Citizens and Southern National Bank of South Carolina. Plans to develop the island have been made and some preliminary work has been started on the island. To date, this island has been slightly altered with some 5 acres (2 ha) of land being developed and some 296 acres (120 ha) of marsh impounded. Development of Dewees Island may be slowed by a lack of access to the island since there is no bridge across Dewees Inlet. The State's purchase of Capers included an easement preventing development of the northern side of Dewees and limiting construction to 125 single family units (Warner and Strouss 1976). The island was appraised at $1,860,000 as of November 1974 (Warner and Strouss 1976).

L. ISLE OF PALMS

Isle of Palms is a barrier island located in Charleston County, South Carolina, between Dewees Island to the north and Sullivans Island to the south. The island is separated from Dewees Island by Dewees Inlet and from Sullivans Island by Breach Inlet. A broad expanse of saltmarsh separates the island from the mainland. The island has a sandy beachfront that is

6.2 mi (10 km) long, a length of 6.3 mi (10.1 km), and a maximum width, including both high ground and marsh, of 0.9 mi (1.4 km). There are 1,700 acres (688 ha) of high land on the island of which nearly 1,300 acres (526 ha) are developed. Approximately 520 acres (210 ha) of marsh are located on the back side of the island.

The Isle of Palms is a Holocene beach ridge island with a remnant maritime forest community. Elevations on the island range from sea level to 45 ft (14 m) at the top of the natural beach ridges. The maritime forest community consists of live oak, loblolly pine, wax myrtle, cabbage palmetto, and hollies. The typically polyhaline salt marsh is dominated by smooth cordgrass, with less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, sea ox-eye, and salt grass also occurring.

The northern half of the Isle of Palms is very unstable with some areas having 500 to 600 ft (152 to 183 m) of erosion between 1958 and 1968. Groins which were placed in the 1960's have had somewhat of a stabilizing effect. The southern end of the island has shown long-term deposition and has formed a "large accretional recurved spit" (Stephen et al. 1975).

Two-thirds of the Isle of Palms is fully developed, while the final one-third of the island is presently undergoing development as the Isle of Palms Beach and Racquet Club. As of 1975, there were 4,000 permanent residents and approximately 10,000 visitors annually (Warner and Strouss 1976). The Isle of Palms acts as a suburb of Charleston and is a tourist attraction. Limited parking and beach access for Charleston residents and tourists are major issues on the island. In 1975, lots 95 ft by 175 ft (29 m by 53 m) were $65,000 on the ocean front, $33,000 on the sound front, and $12,000 in the interior of the island (Warner and Strouss 1976).

M. SULLIVANS ISLAND

Sullivans Island is a barrier island located in Charleston County, South Carolina, between the Isle of Palms to the north and Morris Island to the South. The island is separated from the Isle of Palms by Breach Inlet and from Morris Island by the Charleston Harbor Entrance. A broad expanse of marsh separates the island from the mainland. The island has a sandy beachfront that is 3.0 mi (4.8 km) long, a length of 3.5 mi (5.6 km), and a maximum width, including both high ground and marsh, of 1.0 mi (1.6 km). There are 830 acres (336 ha) of high land on the island of which 809 acres (327 ha) are totally developed. Approximately 480 acres (194 ha) of marsh are located on the landward side of the island.

Sullivans Island is a Holocene beach ridge island with a remnant maritime forest community. Elevations on the island range from sea level to 15 ft (4.6 m) at the top of the natural beach ridges. The remnant maritime forest consists of live oak, loblolly pine, wax myrtle, cabbage palmetto, southern red cedar, and hollies. The typically polyhaline salt marsh is dominated by smooth cordgrass, with less abundant species such as black needlerush, saltmeadow cordgrass, glassworts, and salt grass also occurring. The water quality in the surrounding creeks is suitable for crabbing and commercial fishing. Shellfish grounds that are adjacent to Charleston Harbor are closed due to the degraded water quality.

Sullivans Island has experienced net deposition since 1849, except for 1,500 ft (0.5 km) of beach immediately east of Ft. Moultrie, which has been the site of long-term erosion. Stapor and Murali (1978) demonstrated that the area inside or west of the submerged north jetty off Sullivans Island experiences a net deposition rate of approximately 30,000 m^3/yr (39,237 yd^3/yr). Flood tidal currents sweeping west into Charleston Harbor are responsible for this deposition (Stapor and Murali 1978).

Sullivans Island is heavily developed as a suburb of Charleston. Ft. Moultrie, a portion of Ft. Sumter National Monument, has been restored and is a major tourist attraction. Lack of parking areas and limited access to the beach are current issues on the island. Land assessments are not readily available.

N. MORRIS ISLAND

Morris Island is a marsh island located in Charleston County, South Carolina, between Sullivans Island to the northeast and Folly Island to the southwest. The island is separated from Sullivans Island by the Charleston Harbor Entrance and from Folly Island by Lighthouse Creek and Lighthouse Inlet. A broad expanse of marsh separates Morris Island from James Island. The island has a sandy beachfront that is 3.5 mi (6.5 km) long, a length of 3.4 mi (5.5 km), and a maximum width of 1.6 mi (2.6 km), including both high ground and marsh. There are 120 acres (49 ha) of high land and 1,390 acres (563 ha) of salt marsh. Approximately 640 acres (259 ha) are used by the Corps of Engineers as a dredge spoil area for Charleston Harbor (Warner and Strouss 1976).

Morris Island is a Holocene marsh island with a maritime scrub shrub thicket in the beach ridge areas. Elevations on the island range from sea level to 10 ft (3.0 m) at the top of the highest ridge. The major components of the maritime scrub shrub thicket are live oak, loblolly pine, wax myrtle, and several types of holly. The surrounding salt marsh is of varying salinity, with smooth cordgrass dominating in the low marsh areas. Less abundant species such as saltmeadow cordgrass, glassworts, sea ox-eye, black needlerush, and salt grass occur in the high marsh areas.

Erosion of the front beach is severe. Since 1939, over 1,600 ft (488 m) of shoreline at the southern end of the island have been lost, averaging over 45 ft/yr (13.7 m/yr) (Stephen et al. 1975). Nineteenth- and twentieth-century shorelines from topographic maps prepared by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey for Morris Island are presented on Atlas plate 25.

The State of South Carolina owns all of Morris Island except for 111 acres (45 ha) of high land. The latter are privately held; there are no plans for development at this time.

Morris Island is the site of one of the oldest lighthouses in South Carolina. The existing tower was built in 1876 to replace the damaged Morris Island or Charleston Lighthouse. Through the years, severe erosion has isolated the tower about 440 yd (400 m) offshore (Griffin 1977).

O. JAMES ISLAND

James Island is a sea island located in Charleston County, South Carolina, between Charleston, South Carolina, to the north and Johns Island to the south. The island is separated from Folly Island by the Folly River and from the mainland by Wappoo Creek (AIWW). It is separated from Charleston by Charleston Harbor and from Johns Island by the Stono River. The island is 7 mi (11.3 km) long and has a maximum width of 7 mi (11.3 km). There are 11,000 acres (4,452 ha) of high land and some 4,800 acres (1,943 ha) of marsh on the island.

James Island is a Pleistocene island with a remnant coastal pine-mixed hardwood forest. The major components of the coastal pine-mixed hardwood forest are live oak, water oak, laurel oak, loblolly pine, wax myrtle, hollies, hackberry, sweet gum, hickories, southern magnolia, pecan, black cherry, and cherry laurel.

The areas of salt marsh in the vicinity of James Island are typically polyhaline. The marsh is dominated by smooth cordgrass in the low marsh areas, with less abundant species such as salt-meadow cordgrass, glassworts, black needlerush, sea ox-eye, and marsh elder occurring in the high marsh areas.

Since James Island has no beachfront, erosion is a relatively minor problem; however, some localized erosion is occurring along creek banks and adjacent to Charleston Harbor and the Atlantic Intracoastal Waterway.

Parts of James Island are now in the City of Charleston and are rapidly developing. The island was a rural farming area until about 10 years ago, when an influx of new residents moved to the island. The trend can be directly attributed to expanded port facilities and military bases in Charleston.

Development of James Island has been largely unplanned; subsequently, water and sewer problems exist. Some subdivisions on the island have individual sewage treatment facilities (oxidation ponds) and many homes are still using septic tanks. Traffic problems also exist on the island and a new bridge is proposed into downtown Charleston. The bridge, however, has been a source of controversy and has had to be replanned several times. James Island has a public service district form of government at the present time, except for those areas that have been annexed into the City of Charleston.

P. FOLLY ISLAND

Folly Island is a barrier island located in Charleston County, South Carolina, between Morris Island to the north and Kiawah Island to the south. The island is separated from Morris Island by Lighthouse Inlet and from Kiawah by Stono Inlet. A band of salt marsh and the Folly River separate the island from James Island and the mainland. The island has a sandy beachfront along its entire length of 6.0 mi (9.7 km), and a maximum width of 0.5 mi (0.8 km), including both high ground and marsh. There are 710 acres (287 ha) of high land on the island and 690 acres (279 ha) of salt marsh. Five hundred acres (202 ha) of land are developed on the island (Warner and Strouss 1976).

Folly Island is a Holocene island with a series of parallel dune ridges. Elevations on the island range from sea level to 20 ft (6.1 m) at the top of the natural dune ridge. The remnant maritime forest consists of live oak, slash pine, wax myrtle, cabbage palmetto, southern red cedar, and hollies. The typically polyhaline salt marsh is dominated by smooth cordgrass, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occurring.

Folly Beach is experiencing erosion along its entire length. Groins have been constructed in an effort to stabilize the shoreline; however, success has been limited. Since Morris Island to the north is undergoing extreme erosion, especially on its southern tip, the sand leaving the northern end of Folly Island probably is deposited on the Lighthouse Inlet shoal rather than Morris Island (Stapor and Murali 1978).

Folly Island is almost completely developed. Present zoning regulations limit further large scale commercial development of the island, but allow the construction of single family residential neighborhoods. Restricted parking areas limit public access to the beach. Local residents have asked for Federal aid to fight the severe erosion on the beach, but have met with opposition due to limited public access and parking areas on the beach. Sample lots in 1975 on the ocean front were valued at $14,000 to $22,000, on the island side at $19,000 to $20,000, and on the interior at $5,000 to $12,000 (Warner and Strouss 1976).

Q. KIAWAH ISLAND

Kiawah Island is a barrier island located in Charleston County, South Carolina, between Folly Island to the northeast and Seabrook Island to the southwest. The island is separated from Folly Island by Stono Inlet and from Seabrook Island by the Kiawah River. It is separated from Johns Island to the north by an expanse of marsh and the Kiawah River. The island has a sandy beachfront that is 9.0 mi (14.5 km) long, a length of 9.1 mi (14.7 km), and a maximum width of 2.0 mi (3.2 km), including both high ground and marsh. There are 3,300 acres (1,336 ha) of high land and 3,730 acres (1,510 ha) of salt marsh, of which 50 high land acres (20 ha) are developed. The remainder of the area is in an undeveloped state (Warner and Strouss 1976).

Kiawah Island is a Holocene beach ridge island with a maritime forest modified by agricultural activities and residential development. There are several fresh and brackish water impoundments which were constructed by isolating saltmarsh sloughs with earthen dikes. Elevations on the island range from sea level to 25 ft (7.6 m). The major components of the maritime forest are live oak, loblolly pine, wax myrtle, cabbage palmetto, and hollies. Vegetation within the impoundments consists of a variety of fresh and brackish water species including widgeon grass, duckweed, cattails, saw grass, bulrushes, giant cordgrass, smooth cordgrass, sea ox-eye, and black needlerush. The surrounding salt marsh is of varying salinity. The marsh is dominated by smooth cordgrass in the low marsh areas, with less abundant species such as saltmeadow cordgrass, glassworts, sea ox-eye, black needlerush, and salt grass occurring in the high marsh areas.

Kiawah Island, unlike most barrier islands in South Carolina, is prograding with a gradual seaward growth. The island has a relatively stable shoreline and is generally free of erosion with the exception of one or two areas (Hayes 1977). The northeastern end of Kiawah accreted approximately 4,000 ft (1,219 m) during the period from 1890 to 1940 (Stephen et al. 1975). This accretion is thought to be the product of sediments derived from Morris Island and Folly Beach. Beginning in the 1930's, the beach adjacent to Stono Inlet began to erode and has continued to erode at an average rate of 55 ft/yr (16.8 m/yr). Approximately 1900 ft (579 m) of sediment have eroded in this area, causing a general straightening of the beach face (Stephen et al. 1975). The rest of Kiawah Island is relatively stable with accretion rates of 400 to 2,000 ft (122 to 610 m) between 1890 and 1940 (Stephen et al. 1975).

Kiawah Island is owned by Kiawah Island Company, a subsidiary of Kiawah Investment Company. A large resort area is being developed which will have up to 7,000 residential units. The first phase of this development, a 150-unit hotel-resort complex, opened in the summer of 1976. High land acreage on Kiawah Island was assessed at $1,686/acre and marshlands at $20/acre in 1970. The entire island was assessed at $5,742,720 in 1970 (Warner and Strouss 1976).

R. SEABROOK ISLAND

Seabrook Island is a barrier island located in Charleston County, South Carolina, between Kiawah Island to the north and Botany Bay Island to the south. The island is separated from Kiawah Island by Captain Sams Inlet and the Kiawah River, and from Botany Island by the North Edisto River. A broad expanse of marsh and Bohicket Creek separate the island from Johns Island. There are 2,610 acres (1,056 ha) of high land and 2,710 acres (1,097 ha) of marsh on Seabrook Island. About 1,000 acres (405 ha) of land have been developed on Seabrook Island. The island has a sandy beachfront that is 2.5 mi (4.0 km) long, a length of 3.5 mi (5.6 km), and a maximum width of 2.8 mi (4.8 km), including both high ground and marsh.

Seabrook Island is a Holocene beach ridge island, with a maritime forest community in undisturbed areas. Elevations on the island range from sea level to 27 ft (8.2 m) at the top of the natural beach ridges. The maritime forest community consists of live oak, slash pine, loblolly pine, wax myrtle, cabbage palmetto, southern red cedar, and hollies. The surrounding salt marsh is typically polyhaline with smooth cordgrass dominating. Less abundant species such as black needlerush, sea ox-eye, glassworts, and salt grass also occur.

Historically, the Seabrook Island shoreline has been accreting while that portion of Kiawah Island to the north predicted to furnish sand deposited on Seabrook has not eroded (Stapor and Murali 1978). Tidal currents active adjacent to the North Edisto Inlet may be complicating the situation. The presence of extensive parallel beach dunes in this stretch of the coast may suggest "extra" sand coming ashore (Stapor and Murali 1978). Sand transport toward Seabrook is well documented by southwest migration of the spit attached to Kiawah Island, which separates the Kiawah River from the Atlantic Ocean (Stapor and Murali 1978).

Seabrook Island is owned by three groups: the Episcopal Church, the Seabrook Island Development Company, and the private landowners who purchased their land from the development company. Seabrook was originally totally owned by the Episcopal Church, which maintained Camp St. Christopher as a summer camp. Taxes and a desire to upgrade the camp forced the Church to sell a large portion of the island to the Seabrook Island Development Company. The development company has plans to completely develop their portion of the island. The camp's land will remain in its near natural condition. One-half acre (0.2 ha) lots in the development sold for $60,000 on the ocean front, $30,000 on the sound, and $12,500 in the interior in 1975 (Warner and Strouss 1976).

S. DEVEAUX BANK

Deveaux Bank is a low-lying sand bar island located in Charleston County, South Carolina, between Seabrook Island to the north and Botany Bay Island to the south. It is located at the mouth of the North Edisto River, which separates it from both Seabrook Island and Botany Bay Island. As of March 1978, the island was 3,200 ft (975 m) long by 1,100 ft (335 m) wide (Stark 1978).

Deveaux Bank is a Holocene sand bar island with a patchy distribution of salt marsh and scrub shrub vegetation. The major components of the vegetative community are panic grass, dropseed, saltmeadow cordgrass, dog fennel, golden aster, beach elder, sea myrtle, glassworts, smooth cordgrass, and sea purslane.

Deveaux Bank is currently undergoing tremendous erosion. During the period from March to May 1978, Deveaux Bank lost 350 ft (107 m) from the southeast end of the island (Stark 1978). Nineteenth- and twentieth-century shorelines from topographic maps prepared by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey for Deveaux Bank and Botany Bay Island are presented on Atlas plate 25.

Deveaux Bank, also known as the Alexander Sprunt Jr. Wildlife Refuge and Sanctuary, is managed by the National Audubon Society under direction and supervision of the South Carolina Wildlife and Marine Resources Department. The area is extremely important as a rookery for the endangered brown pelican, as well as numerous other species of shorebirds.

T. BOTANY BAY ISLAND

Botany Bay Island is a barrier island located in Charleston County, South Carolina, between Seabrook Island to the north and Edingsville Beach to the south. The island is separated from Seabrook Island by the North Edisto River and from Edingsville Beach by South Creek. A narrow band of marsh and South Creek separate the island from Edisto Island. Seaward of Botany Bay Island is a low sandbar, Deveaux Bank. There are 260 acres (105 ha) of high land and 212 acres (86 ha) of marsh on the island (Warner and Strouss 1976). The island has a sandy beachfront that is 1.0 mi (1.6 km) long, a length of 1.2 mi (1.9 km), and a maximum width, including both high ground and marsh, of 0.7 mi (1.1 km).

Botany Bay Island is a Holocene beach ridge island with a maritime forest community in undisturbed areas. Elevations on the island range from sea level to 5 ft (1.5 m) at the top of the natural beach ridges. The maritime forest consists of live oak, slash pine, loblolly pine, wax myrtle, cabbage palmetto, southern red cedar, and hollies. The typically polyhaline salt marsh is dominated by smooth cordgrass, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occurring.

The overall character of this section of shoreline has been one of continued erosion (Stephen et al. 1975). The beaches consist of sand and reworked shell material eroded from oyster shell beds exposed on the beach face as the shoreline transgresses over tidal marsh. Storm waves over the low berm produced a 20 - 50 m (66 - 164 ft) wide washover terrace. Marsh clays outcrop along the beach face (Stephen et al. 1975).

Botany Bay Island is a small island with an extremely high rate of erosion. It is owned by Botany Bay Investors, Atlanta, Georgia, and individual lot owners. The investment group originally planned a 75 unit retreat, with emphasis on protection of the natural system. Tight money and a depression in building construction has brought on financial difficulties within the investment group. One house was built and a small marina was completed before development was stopped by the owners. At the present time, there is no development being carried out on the island. In 1974, 2-acre lots sold for $100,000 on the ocean front, $80,000 on the sound front, and $30,000 on the interior. The only access to the island is by an unscheduled ferry or by small boat (Warner and Strouss 1976).

U. EDISTO BEACH

Edisto Beach is the barrier island portion of Edisto Island located in Colleton County, South Carolina. Edisto Island proper is a sea island located immediately shoreward of Edisto Beach and is in Charleston County. The barrier island is separated from the main body of Edisto Island by Big Bay Creek, Scott Creek, Jeremy Creek, and associated salt marsh. Edisto Beach has a sandy beachfront that is 4.0 mi (6.4 km) long, a length of 4.4 mi (7.1 km), and a maximum width, including both high ground and marsh, of 1.5 mi (2.4 km). There are 920 acres (372 ha) of high land and 464 acres (188 ha) of salt marsh.

Edisto Beach is a Holocene island with a maritime forest and scrub shrub community. Elevations on the island range from sea level to 30 ft (9.1 m). The major components of the maritime forest are live oak, slash pine, loblolly pine, wax myrtle, cabbage palmetto, southern red cedar, and hollies. The surrounding salt marsh is of varying salinity and is dominated by smooth cordgrass in the low marsh areas. Less abundant species such as saltmeadow cordgrass, glassworts, sea ox-eye, black needlerush, and salt grass occur in the high marsh areas.

Edisto Beach is currently undergoing erosion at its northern and southern ends. Minor erosion has taken place on the northern end of the beach next to Jeremy Inlet, and significant erosion is in progress at the southern tip of the beach (Stephen et al. 1975). The remainder of the beach appears to have been undergoing accretion for the past 120 years (Stapor and Murali 1978).

Edisto Beach State Park occupies approximately one-third of Edisto Beach at the northern end. The west end of the island is currently being developed as a resort area by the Oristo Development Corporation. The rest of the island is privately owned by small landowners. The number of permanent residents is small (approximately 100); however, over 189,000 people visit the beach each year (Warner and Strouss 1976).

V. PINE ISLAND

Pine Island is a marsh island located in Colleton County, South Carolina, between Edisto Island to the north and Otter Island to the south. The island is separated from Edisto Island by the South Edisto River and from Otter Island by Fish Creek. A broad expanse of marsh and Pine Creek separate the island from the mainland. The island has a sandy beachfront that is 1.6 mi (2.6 km) long, a length of 1.7 mi (2.7 km), and a maximum width, including both high ground and marsh, of 1.0 mi (1.6 km). There are 250 acres (101 ha) of high land on the island and 690 acres (279 ha) of marsh (Warner and Strouss 1976).

Pine Island is a Holocene marsh island with a maritime forest and scrub shrub community surrounded by extensive tidal salt marsh. Elevations on the island range from sea level to 10 ft (3.0 m) at the top of the beach ridges. The major components of the maritime forest are live oak, loblolly pine, dwarf palmetto, wax myrtle, cabbage palmetto, and hollies. Dominant vegetation in the scrub shrub community consists of wax myrtle, cabbage palmetto, saw palmetto, southern red cedar, and hollies. The surrounding salt marsh is typically polyhaline, dominated by smooth cordgrass. Less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occur. Sand transport data on Pine Island are not available.

Pine Island is presently owned by four persons who have no plans to develop the area (Warner and Strouss 1976).

W. OTTER ISLAND

Otter Island is a marsh island located in Colleton County, South Carolina, between Pine Island to the northeast and St. Helena Sound to the southwest. The island is separated from Pine Island by Fish Creek and Jefford Creek. Otter Island has a sandy beachfront that is 1.8 mi (2.9 km) long, a length of 2.0 mi (3.2 km), and a maximum width of 1.2 mi (1.9 km), including both high ground and marsh. There are 40 acres (16.2 ha) of high land and 2,210 acres (895 ha) of salt marsh (Warner and Strouss 1976).

Otter Island is a Holocene marsh island with a maritime forest and scrub shrub community in the beach ridge areas. Elevations on the island range from sea level to 10 ft (3.0 m). The maritime forest consists of live oak, loblolly pine, wax myrtle, cabbage palmetto, saw palmetto, and hollies. The dominant vegetation in the scrub shrub community consists of wax myrtle, cabbage palmetto, yaupon holly, and southern red cedar. The surrounding salt marsh is of varying salinity with smooth cordgrass dominating in the low marsh areas. Less abundant species such as saltmeadow cordgrass, glassworts, salt grass, sea ox-eye, and black needlerush occur in the high marsh areas.

The island is privately owned and there are no plans for development at this time (Warner and Strouss 1976).

X. ST. HELENA ISLAND

St. Helena Island is a sea island located in Beaufort County, South Carolina, between Ladies Island to the north and Hunting Island, Fripp Island, Pritchards Island, Little Capers Island, St. Phillips Island, and Bay Point Island to the east. The island is bounded by the Morgan River and St. Helena Sound to the north and the Beaufort River to the west. Many tidal creeks and small marsh islands separate St. Helena Island from the surrounding islands.

The island is 13 mi (21 km) long by 2.0 mi (3.2 km) wide. There are 21,053 acres (8,520 ha) of high land and 13,125 acres (5,312 ha) of marsh on the island. St. Helena Island is a Pleistocene island with a remnant coastal pine-mixed hardwood forest. The major components of the coastal pine-mixed hardwood forest are live oak, water oak, laurel oak, loblolly pine, wax myrtle, hollies, hackberry, sweet gum, hickories, southern magnolia, pecan, black cherry, and cherry laurel.

The areas of salt marsh in the vicinity of St. Helena Island are typically polyhaline. The salt marsh is dominated by smooth cordgrass in the low marsh areas, with less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, sea ox-eye, and marsh elder occurring in the high marsh areas.

Since St. Helena Island has no beachfront, erosion is a relatively minor problem; however, some localized erosion is occurring along creekbanks.

St. Helena Island is located near the City of Beaufort, but has remained a rural farming area. Beaufort's expansion has been mainly around the U.S. Marine Corps Air Station in Beaufort and near the U.S. Marine Recruit Training Base at Parris Island. St. Helena Island has escaped development thus far, but expansion from the City of Beaufort has spread to Ladies Island and will probably extend to St. Helena Island in the near future. Water quality in the creeks surrounding St. Helena Island is excellent and supports much of Beaufort's oyster fishery.

Y. HUNTING ISLAND

Hunting Island is a barrier island located in Beaufort County, South Carolina, between Harbor Island to the north and Fripp Island to the south. The island is separated from Harbor Island by Johnson Creek and from Fripp Island by Fripp Inlet. A narrow band of marsh and the Harbor River separate the island from St. Helena Island. There are 1,420 acres (575 ha) of high land on the island and 270 acres (109 ha) of marsh. The island has a sandy beachfront that is 4.0 mi (6.4 km) long, a length of 4.1 mi (6.6 km), and a maximum width of 1.1 mi (1.8 km), including both high ground and marsh.

Hunting Island is a Holocene beach ridge island with a maritime forest community in undisturbed areas. Elevations on the island range from sea level to 20 ft (6.1 m) at the top of the natural beach ridges. The maritime forest consists of live oak, loblolly pine, wax myrtle, cabbage palmetto, saw palmetto, southern red cedar, and hollies. The surrounding salt marsh is typically polyhaline with smooth cordgrass dominating. Less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occur.

Hunting Island has been the site of severe long-term erosion. The northerly portion of the island and nearshore bottoms are building, while the southerly 60% of the island is undergoing active erosion (Berg and Essick 1972). The Army Corps of Engineers has initiated a beach nourishment project to maintain the eroding portion of the beach for recreational purposes. After the first nourishment, it was found that the erosion was much more severe than the original 250,000 yd^3/yr (191,150 m^3/yr) prediction. It was also found that particle size of the sand on the beach was very small and thus the beach was very unstable. Analysis of the data has shown that the sediment characteristics of the beach and nearshore underwater bottom have changed little with the beach restoration and first nourishment from those that existed prior to the project. The data accumulated to date indicate that the annual nourishment needs for Hunting Island is 470,000 yd^3 (359,362 m^3) of sand (Berg and Essick 1972).

Hunting Island is owned by the State of South Carolina and is used for medium to high density recreation. Management of the island is by the South Carolina Department of Parks, Recreation and Tourism. Development includes camping sites, beach houses, and nature trails. Osprey, alligators, and possibly bald eagles are found on the island (Warner and Strouss 1976).

Z. FRIPP ISLAND

Fripp Island is a barrier island located in Beaufort County, South Carolina, between Hunting Island to the northeast and Pritchards Island to the southwest. The island is separated from Hunting Island by Fripp Inlet and from Pritchards Island by Skull Inlet. A broad expanse of water and salt marsh separates Fripp Island from St. Helena Island. There are 1,030 acres (417 ha) of high land and 840 acres (340 ha) of salt marsh. The island has a sandy beachfront that is 3.0 mi (4.8 km) long, a length of 3.3 mi (5.3 km), and a maximum width, including both high ground and marsh, of 1.4 mi (2.2 km).

Fripp Island is a Holocene barrier island with a maritime forest community which has been modified by commercial and residential development. Elevations on the island range from sea level to 25 ft (7.6 m) at the top of the highest beach ridge. Major components of the maritime forest are live oak, loblolly pine, wax myrtle, cabbage palmetto, saw palmetto, southern red cedar, and hollies. The surrounding salt marsh is of high salinity, with smooth cordgrass predominating in the low marsh areas and less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, salt grass, and sea ox-eye occurring in the high marsh areas.

Extensive shoaling in the area of Fripp Inlet on the northeastern end of Fripp Island causes a reversal in wave approach direction for the northeastern one-third of the island. This condition results in long-term accretion intermixed with periods of rapid short-term erosion (Hubbard et al. 1977).

Between 1939 and 1951, the headland of Fripp Inlet was eroded by approximately 600 yd (548 m) and a hooked spit grew from the south side in a northeasterly direction. By 1953, the northern end of the hooked spit merged with the northeastern end of Fripp Island and enclosed a lagoon behind it. By 1955, and after hurricane Hazel of October 1954, the ocean side of the new barrier was eroded and the material was washed over to fill the lagoon behind it (El-Ashry 1966). Erosion at the headland by concentrated wave action was accompanied by 120 yd (110 m) of accretion along the southeastern side of Fripp Island from 1951 to 1955 (El-Ashry 1966).

Fripp Island is owned by Fripp Island Development Company. The island is currently being developed as a second home and retirement resort area. There are 300 people who live year around on the island and approximately 900 seasonal residents. As of 1975, a lot 100 ft by 200 ft (31 m by 61 m) was valued at $55,000 on the ocean front, $25,000 on the backside, and $10,000 to $20,000 in the interior (Warner and Strouss 1976).

AA. PRITCHARDS ISLAND

Pritchards Island is a barrier island located in Beaufort County, South Carolina, between Fripp Island to the northeast and Little Capers Island to the southwest. The island is separated from Fripp Island by Skull Inlet and Skull Creek and from Little Capers Island by Pritchards Inlet. A broad expanse of salt marsh separates the island from St. Helena Island. There are 370 acres (150 ha) of high land and 1,150 acres (465 ha) of marsh on Pritchards Island. The island has a sandy beachfront along its entire length of 2.5 mi (4.0 km), and a maximum width, including both high ground and marsh, of 1.6 mi (2.6 km).

Pritchards Island is a Holocene beach ridge island with a maritime forest community surrounded by a broad expanse of salt marsh. Elevations on the island range from sea level to 10 ft (3.0 m) at the top of the beach ridges. The remnant maritime forest consists of live oak, loblolly pine, wax myrtle, cabbage palmetto, saw palmetto, southern red cedar, and hollies. The surrounding salt marsh is typically polyhaline. The marsh is dominated by smooth cordgrass, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occurring.

Pritchards Island suffered considerable erosion between 1859 and 1920 with a shoreline retreat of approximately 100 m (328 ft), but has not undergone significant erosion since 1920 (Hubbard et al. 1977).

Pritchards Island is almost totally undeveloped. To date, there are three houses on the island. The island was slated for development as a religious retreat for the leaders of the Protestant Churches of America, but financial problems caused these plans to be scrapped and the island's future remains in doubt. In 1974, the island was sold to Eugene Holly for $1,400,000, which averages $400 an acre for high land and marsh (Warner and Strouss 1976).

BB. LITTLE CAPERS ISLAND

Little Capers Island is a marsh island located in Beaufort County, South Carolina, between Pritchards Island to the northeast and Trenchards Inlet to the west. The island is separated from Pritchards Island by Pritchards Inlet. The island has a sandy beachfront along its entire length of 2.5 mi (4.0 km), and a maximum width, including both high ground and marsh, of 1.2 mi (1.9 km). There are 120 acres (49 ha) of high land and 680 acres (271 ha) of salt marsh. Ten acres (4.1 ha) of high land are developed, while the remaining 790 acres (320 ha) on the island are in an undeveloped state (Warner and Strouss 1976).

Little Capers Island is a Holocene marsh island consisting of a series of washover dunes and isolated beach ridges surrounded by a large expanse of salt marsh. Dominant vegetation is a maritime scrub shrub community interspersed with a remnant maritime forest. Elevations on the island range from sea level to less than 10 ft (3.0 m) at the top of the beach ridges. The major components of the remnant maritime forest and scrub shrub communities of the beach ridge areas are live oak, loblolly pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and yaupon holly. The surrounding salt marsh is typically polyhaline. Smooth cordgrass dominates in the low marsh areas, while less abundant species such as saltmeadow cordgrass, glassworts, salt grass, sea ox-eye, and black needlerush occur in the high marsh areas.

Due to the location of Fripp Island, St. Helena Sound, and Port Royal Sound, a complex pattern of wave refraction exists, which causes great variability in the sediment transport of the area. Little Capers Island is characterized by severe washover and extremely high erosion rates in excess of 29 m/yr (95 ft/yr) (Hubbard et al. 1977).

Little Capers Island has approximately 20 small lots on isolated high ground areas where summer cottages can be built. Only two or three small houses have been built, and they do not appear to be threatening the natural system (Warner and Strouss 1976).

CC. ST. PHILLIPS ISLAND

St. Phillips Island is a marsh island in Beaufort County, South Carolina, located between Trenchards Inlet to the northeast and Bay Point Island to the southwest. The island is separated from Bay Point Island by Morse Island Creek. A broad expanse of marsh separates the island from St. Helena Island. There are 1,230 acres (498 ha) of high land and 4,180 acres (1,692 ha) of marsh on the island. The island has a sandy beachfront that is 1.0 mi (1.6 km) long, a length of 6.0 mi (9.7 km), and a maximum width of 1.6 mi (2.6 km), including both high ground and marsh.

St. Phillips Island is a Holocene marsh island consisting of a beach ridge and dune system backed by a maritime forest community. Elevations on the island range from sea level to 15 ft (4.6 m) at the top of the natural beach ridges. The major components of the remnant maritime forest are live oak, loblolly pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is typically polyhaline. Smooth cordgrass dominates in the low marsh areas, while less abundant species such as saltmeadow cordgrass, sea ox-eye, glassworts, salt grass, and black needlerush occur in the high marsh areas.

In 1910 and earlier, St. Phillips and Bay Point islands were connected together as one island and known as Phillips Island. Morse Island Creek did not have an outlet to the Atlantic Ocean and was known then as Horse Island Creek (El-Ashry 1966). By 1919, erosion of the beach of St. Phillips Island facing the channel of Morse Island Creek resulted in the opening of the creek outlet, thus connecting Port Royal Sound with Trenchards Inlet and dividing the island in two (El-Ashry 1966).

St. Phillips' southern shoreline has undergone much change since 1939, with periods of accretion followed by periods of erosion. The beach is presently undergoing heavy erosion on the southern portion. The narrow dune system on St. Phillips Island plus the near sea-level elevation of the beach ridges makes the island highly susceptible to flooding, especially during storm tides.

Of all the islands described in this report, St. Phillips has had less modification by man than the others. The ecosystem of the island remains pristine. Many various habitats are present on the island, from high salinity marshes to natural freshwater impoundments. The maritime forest has escaped lumbering and there are no cleared areas for agriculture. The ecotonal "edge effect" is evident on St. Phillips and probably is responsible for the abundance of plant and animal species on the island.

Mr. Ted Turner bought the island for $2 million in 1979. At present, there are no plans to develop the island.

DD. BAY POINT ISLAND

Bay Point Island is a marsh island located in Beaufort County, South Carolina, between St. Phillips Island to the north and Port Royal Sound to the southwest. The island is separated from St. Phillips Island by Morse Island Creek. The island has a sandy beachfront that is 2.5 mi (4.0 km) long, a length of 2.6 mi (4.2 km), and a maximum width, including both high ground and marsh, of 0.5 mi (0.8 km). There are 450 acres (182 ha) of undeveloped land, of which 235 acres (95 ha) are high land and 215 acres (87 ha) are marsh (Warner and Strouss 1976).

Bay Point Island is a Holocene marsh island consisting of a beach ridge and dune system backed by a maritime forest community. Elevations on the island range from sea level to 10 ft (3.0 m) at the top of the natural dune ridges. The major components of the remnant maritime forest are live oak, loblolly pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is typically polyhaline. Smooth cordgrass dominates in the low marsh areas, while less abundant species such as saltmeadow cordgrass, sea ox-eye, glassworts, salt grass, and black needlerush occur in the high marsh areas.

Due to the location of Fripp Island, St. Helena Sound, and Port Royal Sound, a complex pattern of wave refraction exists which causes great variability in the sediment transport of the area. The overall trend for Bay Point Island is one of severe erosion, losing as much as 10 m/yr (33 ft/yr) since 1951 (Hubbard et al. 1977).

Bay Point Island is privately owned by the Anne McLeod Poulnot family, and there are no plans for development at this time (Warner and Strouss 1976).

The southern tip of Bay Point was once the site of Fort Beauregard, an earthwork fort occupied by the Confederate forces during the Civil War. Fort Beauregard was attacked by Federal forces on 7 November 1861, captured, and occupied until the end of the Civil War. Preliminary studies indicate that the site of the fort has succumbed to erosion and is now under water (W. J. Keith, 1979, South Carolina Marine Resources Division, Charleston, pers. comm.).

EE. HILTON HEAD ISLAND

Hilton Head Island is a sea island located in Beaufort County, South Carolina, between Port Royal Sound to the north and Daufuskie Island to the south. The island is separated from Daufuskie Island by Calibogue Sound. A narrow band of marsh and Skull Creek separate the island from the mainland. The island has a sandy beachfront along its entire length of 11.5 mi (18.5 km), and a maximum width, including both high ground and marsh, of 6.8 mi (10.9 km). There are 19,460 acres (7,876 ha) of high land and 2,400 acres (971 ha) of marsh on the island.

Hilton Head Island has a Pleistocene core with a Holocene beach ridge fringe. A maritime forest community modified by development is present on the island, along with many small freshwater depressions and bays located between remnant beach or dune ridges. Elevations on the island range from sea level to 21 ft (6.4 m) at the top of the highest natural beach ridges. The major components of the maritime forest community are live oak, loblolly pine, slash pine, wax myrtle, cabbage palmetto, saw palmetto, southern red cedar, and hollies. The forested freshwater depressions or bays are characterized by a predominance of red maple, swamp tupelo, sweet gum, red bay, sweet bay, cypresses, and various hollies. Emergent vegetation includes maidencanes, Virginia chain fern, sedges, and smartweeds. The areas of salt marsh in the vicinity of Hilton Head are typically polyhaline. Smooth cordgrass dominates in the low marsh areas, while less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, sea ox-eye, salt grass, and marsh elder occur in the high marsh areas.

Between 1860 and 1970, a high rate of erosion, about 6 ft/yr (1.8 m/yr), was found to have occurred along the central portion of the shoreline (U.S. Army Corps of Engineers 1971). During the period from 1952 to 1970, the most serious problem areas were at the ends of the island, with the highest rate experienced at the north end of about 17 ft/yr (5.2 m/yr). The annual rate of erosion for all eroding beaches on Hilton Head Island was estimated at 6.2 ft (1.9 m) (U.S. Army Corps of Engineers 1971).

Development of Hilton Head in 1956 started the resort boom in coastal real estate, with hundreds of imitations along the coast today (Warner and Strouss 1976). A large portion of the maritime forest, dune system, and freshwater depressions has been altered and in some cases destroyed. The island has been extensively developed, with only some 6,000 undeveloped acres (2,428 ha) remaining (Warner and Strouss 1976).

Land along the ocean front is completely developed and none is available for sale. Lots of 2,000 ft^2 (186 m^2) on the mainland side are selling for \$50,000 to \$70,000; in the interior, for

\$15,000 to \$30,000; and on golf courses, for \$35,000 to \$50,000 (Warner and Strouss 1976).

FF. DAUFUSKIE ISLAND

Daufuskie Island is a sea island located in Beaufort County, South Carolina, between Hilton Head Island to the northeast and Turtle Island to the southwest. The island is separated from Hilton Head Island by Calibogue Sound and from Turtle Island by the New River. The Cooper River, Ramshorn Creek, and a broad expanse of salt marsh separate Daufuskie Island from the mainland. The island has a sandy beachfront that is 3.0 mi (4.8 km) long, a length of 5.0 mi (8.1 km), and a maximum width, including both high ground and marsh, of 2.7 mi (4.3 km). There are 5,200 acres (2,104 ha) of high land and 950 acres (385 ha) of salt marsh. A total of approximately 160 acres (65 ha) of high land is developed (Warner and Strouss 1976).

Daufuskie Island is a Pleistocene island with a maritime forest community modified by agriculture. Several forested freshwater swales and bays are located between beach ridges. Elevations on the island range from sea level to 30 ft (9.1 m) at the top of the highest natural beach ridges. The major components of the remnant maritime forest are live oak, laurel oak, loblolly pine, slash pine, wax myrtle, cabbage palmetto, saw palmetto, southern red cedar, and hollies. The forested freshwater swales or bays are characterized by a predominance of red maple, swamp tupelo, sweet gum, red bay, sweet bay, cypresses, and various hollies.

The extensive areas of salt marsh in the vicinity of Daufuskie Island are typically polyhaline. Smooth cordgrass dominates in the low marsh areas, while less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, sea ox-eye, salt grass, and marsh elder occur in the high marsh areas.

Water quality in the area surrounding Daufuskie Island is variable. Waters at the northern end of the island are of high quality, being suitable for the survival, propagation, and harvesting of shellfish. Waters at the southern end of the island, however, are of low quality, suitable only for recreational fishing and uses requiring waters of lesser quality. The slightly degraded water quality at the southern end of the island is believed to be attributable to pollution by the nearby Savannah River.

The shoreline of Daufuskie Island exhibits relative stability compared to other shorelines in Beaufort County. The island's beach has undergone gradual retreat during the period 1942 - 1973, with the sand being removed by the actions of waves and tidal currents. Daufuskie's relative position in Calibogue Sound permits gradual removal of beach sand with no apparent accretion (Hubbard et al. 1977).

At the peak of its prosperity during the early 1900's, the population of Daufuskie numbered greater than 700 persons. During this time farming, logging, and the oyster industry were the primary areas of endeavor. Current population fluctuates between 100 and 200 persons, with average incomes of a little more than \$1,000 per year (Dickey 1974). These permanent residents of Daufuskie Island are descendants of slaves of the early plantation era and have recently been portrayed in the movie "Conrack." They own approximately 1,000 acres (405 ha) of land in small tracts in the interior of the island. Approximately 870 acres (352 ha) of ocean front property and almost all of the 2,700 acres (1,093 ha) fronting on Calibogue Sound are owned by land development companies (Warner and Strouss 1976).

GG. TURTLE ISLAND

Turtle Island is a marsh island located in Jasper County, South Carolina, between Daufuskie Island to the north and Oyster Bed Island and the Savannah River to the south. The island is separated from Daufuskie by the New River and from Oyster Bed Island by the Wright River. A broad expanse of marsh and tidal creeks separates the island from the mainland. There are 120 acres (49 ha) of high land and 1,600 acres (648 ha) of marsh on the island. The island has a sandy beachfront along its entire length of 2.5 mi (4.0 km), and a total width, including both high ground and marsh, of 1.9 mi (3.1 km).

Turtle Island consists of a maritime forest and scrub shrub community on a narrow series of beach ridges surrounded by a high salinity salt marsh. Elevations on the island range from sea level to 10 ft (3.0 m) at the top of the higher beach ridges. The maritime forest community consists of live oak, slash pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The major components of the scrub shrub community are wax myrtle, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is dominated by smooth cordgrass, and less abundant species such as saltmeadow cordgrass, sea ox-eye, glassworts, salt grass, and black needlerush also occur.

From 1919 to 1939, about 400 yd (366 m) of beach were eroded from Turtle Island along the northern end, while the southern end prograded by about 200 yd (183 m). Between 1941 and 1955, the southern part of Turtle Island prograded by 150 yd (137 m). The main source of beach sediment was that which was eroded from the north end and carried southward by littoral currents (El-Ashry 1966).

Turtle Island was donated to the State of South Carolina in December 1975 by Union Camp Corporation. The State is now managing the island as a wildlife refuge. The area was donated to the State because it is low, isolated, and not worth developing (Warner and Strouss 1976). Union Camp claimed a gift of $400,000 when the island was turned over to the State (Warner and Strouss 1976).

III. GEORGIA ISLANDS

A. TYBEE ISLAND

Tybee Island is a barrier island located in Chatham County, Georgia between the Savannah River to the north and Little Tybee Island to the south. The island is separated from Little Tybee Island by Little Tybee Creek. The island has a sandy beachfront that is 3.4 mi (5.5 km) long, a length of 4.0 mi (6.4 km), and a maximum width, including both high ground and marsh, of 3.4 mi (5.5 km). There are 1,000 acres (405 ha) of developed high land of which the City of Savannah Beach occupies the major portion. The remaining 2,430 acres (983 ha), including 1,930 acres (781 ha) of marsh and 500 acres (202 ha) of high land, remain in an undeveloped state (Warner and Strouss 1976).

Tybee Island is a Holocene barrier island consisting of a beach ridge and dune system backed by a large expanse of salt marsh containing isolated high ground beach ridges. The dune system, along with the remnant maritime forest community associated with the beach ridge areas, has been considerably altered by development. Elevations on the island range from sea level to 18 ft (5.5 m) at the top of the high beach ridges. The major components of the remnant maritime forest are live oak, slash pine, wax myrtle, cabbage palmetto, saw palmetto, southern red cedar, and yaupon holly. The surrounding salt marsh is typically polyhaline. Smooth cordgrass dominates the low marsh areas, while less abundant species such as black needlerush, salt-meadow cordgrass, sea ox-eye, glassworts, and salt grass occur in the high marsh areas.

The north end of Tybee Island has been eroding at an average rate of 3.3 m/yr (10.8 ft/yr) since 1897, with a maximum erosion of 11.6 m/yr (38.1 ft/yr) during the 1939 - 1952 interval. A maximum shoreline retreat of 425 m (1,394 ft) was measured for this area between the years of 1897 and 1965 (Oertel and Chamberlain 1975). The Corps of Engineers has conducted a $4 million beach restoration project that included a groin at the northern end of the beach. The southern end of Tybee Island appears to have advanced 503 m (1,650 ft) between 1897 and 1971, and has undergone alternate intervals of advance and retreat (Oertel and Chamberlain 1975).

Most of Tybee Island is owned by small landowners and is completely developed. Current zoning regulations permit high density development and it is predicted that the island will have a year-round population of 2,500 by 1985. Savannah Beach represents the only accessible beach for the residents of Savannah. During the summer season, the population of Tybee Island is about 10,000. In conjunction with the beach restoration project, the Corps of Engineers is requiring that the City of Savannah Beach provide improved parking and public access and a sand dune ordinance. It is hoped that the beach restoration project and associated improvements will boost the economy of the island (Warner and Strouss 1976).

B. LITTLE TYBEE ISLAND

Little Tybee Island is a marsh island in Chatham County, Georgia, between Tybee Island to the north and Wassaw Island to the south. The island is separated from Tybee Island by Tybee Creek and from Wassaw Island by Wassaw Sound. The interior side of the island is separated from Wilmington Island by a broad marsh and the Tybee River. The island has a sandy beachfront that is 5.0 mi (8.1 km) long, a length of 5.6 mi (9.0 km), and a maximum width, including both high ground and marsh, of 4.0 mi (6.4 km).

Little Tybee consists of a narrow washover beach backed by a large marsh that contains isolated high ground islands (beach ridges). There are 6,780 acres (2,744 ha) of land on Little Tybee, of which 600 acres (243 ha) are high land and 6,180 acres (2,501 ha) are marsh (Warner and Strouss 1976).

Little Tybee Island consists of a group of Holocene beach ridges surrounded by a broad expanse of marsh. Elevations on the island range from sea level to 10 ft (3.0 m) at the top of the beach ridges. The maritime forest consists of live oak, southern red cedar, slash pine, wax myrtle, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is typically polyhaline. Smooth cordgrass dominates the low marsh, while less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass occur in the high marsh areas.

Little Tybee Island has had an unstable shoreline since 1897. Using both maps and aerial photography, Oertel and Chamberlain (1975) found that during the interval from 1897 to 1975, Little Tybee Island had an average rate of retreat of 0.7 m/yr (2.3 ft/yr). The zone of maximum retreat from 1897 to 1975 is a 375 m (1,230 ft) stretch just south of the inlet to Tybee Creek. The area to the south of this shows the greatest variability, with a maximum advance of 375 m (1,230 ft) and a maximum retreat of 220 m (722 ft). Periodic advances and retreats have also occurred at the southern end of the island. Between 1897 and 1975, the southern end of the island had a net growth of 96 m (315 ft), an average of 1.2 m/yr (3.9 ft/yr). However, more recent history (1965 - 1975) revealed retreats up to 12 m/yr (39.4 ft/yr) (Oertel and Chamberlain 1975). Williamson Island, the newly formed island at the mouth of Little Tybee Creek, apparently formed between 1957 and 1960 and has doubled in acreage in the past 5 years (Warner and Strouss 1976). Nineteenth- and twentieth-century shorelines from topographic maps prepared by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey for Williamson Island and Little Tybee Island are presented on Atlas plate 24.

Little Tybee Island is owned by Kerr-McGee Corporation of Oklahoma. In 1968, Kerr-McGee applied for a permit to strip mine phosphate deposits from the marshes surrounding the island. The permit was stopped by environmental protests and the island has remained largely undamaged. The future of the island depends on Kerr-McGee's ability to obtain a permit to strip mine the area (Warner and Strouss 1976).

C. WILLIAMSON ISLAND

Williamson Island is located south of Little Tybee Island along the Atlantic Ocean adjacent to Wassaw Sound. It is little more than an accreting sand spit (an extension of Little Tybee's ocean shoreline) that has become isolated by the formation of an inlet at its northern end. The island is 1.7 mi (2.7 km) long by 0.2 mi (0.3 km) wide. The major components of the vegetative community are panic grass, dropseed, saltmeadow cordgrass, dog fennel, golden aster, beach elder, sea myrtles, glassworts, smooth cordgrass, and sea purslane.

D. WASSAW ISLAND

Wassaw Island is a barrier island located in Chatham County, Georgia, between Little Tybee Island to the north and Ossabaw Island to the south. The island is separated from Little Tybee Island by Wassaw Sound and from Ossabaw Island by Ossabaw Sound. A broad expanse of marsh and tidal creeks separates the island from the mainland. The island has a sandy beachfront along its entire length of 6.0 mi (9.7 km), and a maximum width, including both high ground and marsh, of 2.0 mi (3.2 km). There are 2,358 acres (954 ha) of high land and 7,692 acres (3,113 ha) of marsh. There are 5 acres (2 ha) of developed land on the island (Warner and Strouss 1976).

Wassaw Island is a Holocene beach ridge island with a maritime forest community. Elevations on the island range from sea level to 15 ft (4.6 m) at the top of the beach ridges. The maritime forest consists of live oak, slash pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is polyhaline. Smooth cordgrass dominates the marsh, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occurring.

Wassaw Island illustrates erosional and depositional trends similar to Tybee Island. The northeast portion has a history of erosion while the northwest and southern portions have accreted. Since 1897, the northwest and northeast beaches have advanced and retreated alternately. On the northeast end of the island, the maximum distance of advance was 100 m (328 ft). Using both maps and aerial photography, Oertel and Chamberlain (1975) found that the maximum rate of erosion was 10.0 m/yr (33.1 ft/yr) during the interval 1939 to 1965. These rates were verified by field surveys which revealed a shoreline advance rate of 33.0 m/yr (108 ft/yr) during the period October 1973 to November 1974 (Oertel and Chamberlain 1975).

Wassaw was bought by the Nature Conservancy and turned over to the U.S. Fish and Wildlife Service in 1969, and is now managed as a National Wildlife Refuge (Warner and Strouss 1976). Before the island was turned over to the Federal Government, restrictions were agreed upon to include no bridge access and no camping. The previous owners retain 290 acres (117 ha) in private holdings through the Wassaw Island Trust (Warner and Strouss 1976).

E. OSSABAW ISLAND

Ossabaw Island is a sea island located in Chatham County, Georgia, between Wassaw Island to the northeast and St. Catherines Island to the southwest. The island is separated from Wassaw Island by Ossabaw Sound and from St. Catherines Island by St. Catherines Sound. A broad expanse of marsh and open water separates the island from the mainland. The island has a sandy beachfront along its entire length of 9.5 mi (15.3 km), and a maximum width, including both high ground and marsh, of 4.0 mi (6.4 km). There are 8,700 acres (3,521 ha) of high land and 12,350 acres (4,988 ha) of marsh. Between 50 to 100 acres (20 to 40 ha) are developed with remaining acreage existing in a natural state (Warner and Strouss 1976).

Ossabaw Island has a Pleistocene core with a Holocene beach ridge fringe. Elevations on the island range from sea level to 25 ft (7.6 m). The high land acreage supports a maritime forest consisting of live oak, slash pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is of varying salinity. Smooth cordgrass dominates in the low marsh areas, with less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, salt grass, and sea ox-eye occurring in the high marsh areas.

Using both maps and aerial photographs, Oertel and Chamberlain (1975) found that since 1897, the shoreline of Ossabaw Island has generally advanced. The largest advances have occurred along the capes on the northeast and central parts of the island. From 1897 to 1975, the cape on the northeast corner has advanced 350 m (1,148 ft) at rates between 2 and 20 m/yr (6.6 and 66 ft/yr). The shoreline along the north-central portion of the island has advanced a maximum of 1,033 m (3,389 ft) and the resulting cape produced approximately 845 acres (342 ha) of new land since 1897. South of the cape, approximately 2 mi (3.2 km) of shoreline were continuously eroded from 1897 to 1975. The net retreat (1897 - 1975) in this area was 448 m (1,470 ft). The southern end of the island had a relatively continuous accretionary history, with the shoreline advancing 485 m (1,591 ft) between 1897 and 1971. The mean rate of advance from 1897 to 1975 was approximately 5.4 m/yr (17.7 ft/yr), with maximum rates of 20 m/yr (65.6 ft/yr) during several of the time measurement intervals (Oertel and Chamberlain 1975).

This island was purchased by the Georgia Department of Natural Resources in May 1978 as a Heritage Preserve. The island will remain a wildlife area under the management of the Georgia Department of Natural Resources.

F. ST. CATHERINES ISLAND

St. Catherines Island is a sea island located in Liberty County, Georgia, between Ossabaw Island to the north and Blackbeard Island to the south. The island is separated from Ossabaw Island by St. Catherines Sound and from Blackbeard Island by Sapelo Sound. A wide band of marsh and tidal creeks separates the island from the mainland. The island has a sandy beachfront along its entire length of 11.0 mi (17.7 km), and a maximum width, including both high ground and marsh, of 3.3 mi (5.2 km). There are 14,642 acres (5,924 ha) of land on the island of which 6,870 acres (2,780 ha) are high land and 7,772 acres (3,145 ha) are marsh. One hundred acres (40 ha) of high ground are developed (Warner and Strouss 1976).

St. Catherines Island has a Pleistocene core with a Holocene beach ridge fringe. Elevations on the island range from sea level to 23 ft (7 m). The highland acreage supports a maritime forest community consisting of live oak, slash pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is typically polyhaline. Smooth cordgrass is dominant in the marsh, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occurring.

St. Catherines Island is bordered on the north and south by tidal inlets that head in the marshes and have no river sources. According to Oertel and Chamberlain (1975), the island had the most ubiquitous erosion history of all Georgia islands with an average shoreline retreat of 4 m/yr (13 ft/yr). Only two areas on the island are not experiencing erosion. The northeast corner of the island advanced 385 m (1,263 ft) from 1897 to 1971 while the shoreline on the southern side of a small inlet in the central portion of the island (McQueens Inlet) advanced 128 m (420 ft). The remaining shoreline (except the southern end) exhibits intervals of erosion, stability, and accretion (Oertel and Chamberlain 1975). Rates of retreat varied from a maximum of 24.8 m/yr (81.4 ft/yr) (1897 to 1916) to a minimum of 0.7 m/yr (2.3 ft/yr) (1952 to 1965) (Oertel and Chamberlain 1975). Nineteenth- and twentieth-century shorelines from topographic maps prepared by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey for St. Catherines Island are presented on Atlas plate 24.

St. Catherines Island is owned by the John Nobel Foundation. Research projects in archaeology, terrestrial animal populations, and breeding of rare and endangered species have been underway for several years by the New York Museum of Natural History and the New York Zoological Society and are funded by the Foundation. Access to the island is restricted. The Foundation is presently trying to get a tax exempt status since taxes have risen astronomically in recent years (Warner and Strouss 1976).

G. BLACKBEARD ISLAND

Blackbeard Island is a barrier island located in McIntosh County, Georgia, between St. Catherines Island to the northeast and Sapelo Island to the west and southwest. The island is separated from St. Catherines Island by Sapelo Sound and from Sapelo Island by Blackbeard Creek and Cabretta Inlet. The island has a sandy beachfront that is 6.3 mi (10.0 km) long, a length of 6.4 mi (10.3 km), and a maximum width, including both high ground and marsh, of 2.6 mi (4.2 km). There are approximately 3,620 acres (1,465 ha) of high land and 2,000 acres (809 ha) of marsh. All of Blackbeard Island is in an undeveloped state (Warner and Strouss 1976).

Blackbeard Island is a Holocene beach ridge island with a maritime forest community on the beach ridges. Elevations on the island range from sea level to 30 ft (9.2 m). Major components of the remnant maritime forest are live oak, slash pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The high land acreage on Blackbeard Island is interwoven with fresh and brackish water ponds. Vegetation within these ponds consists of cattails, bulrushes, widgeon grass, duckweed, saw grass, giant cordgrass, smooth cordgrass, sea ox-eye, black needlerush, water-shield, white water-lily, and arrow-arum. Smooth cordgrass dominates in the low marsh areas, while less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, sea ox-eye, and salt grass occur in the higher marsh areas.

Sequential aerial photography over a 10-year period indicates that Blackbeard Island is continuously eroding on the northern end. Further information is unavailable.

Parts of Blackbeard Island have been in Federal ownership since 1800. R. J. Reynolds owned a large part of the island until the late 1940's when it was traded to the Federal Government for Federal land on Sapelo Island. It is currently owned and managed by the U.S. Fish and Wildlife Service as a National Wildlife Refuge. Much of the island is classified as wilderness, which limits the intensity and nature of utilization (Warner and Strouss 1976).

H. CABRETTA ISLAND

Cabretta Island is a barrier island located in McIntosh County, Georgia, between Blackbeard Island to the northeast and Wolf Island to the southwest. The island is separated from Blackbeard Island by Cabretta Inlet and from Sapelo Island by Big Hole Inlet. Although Cabretta Island and Nanny Goat Beach are geologically the same island, they are being treated as separate islands since Nanny Goat Beach is considered part of Sapelo Island. There are 899 total acres (364 ha) on Cabretta Island of which 688 acres (278 ha) are high land and 201 acres (81 ha) are marsh. The island is in an undeveloped state. A sandy beachfront of 2.5 mi (4.0 km) extends the entire length of the island and the average width is 0.5 mi (0.8 km).

Cabretta Island is a Holocene island. Elevations on the island range from sea level to 14 ft (4.2 m) at the top of the beach ridges. The high land acreage supports a maritime scrub shrub community and a smaller maritime forest community consisting of live oak, slash pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is polyhaline. Smooth cordgrass is dominant in the marsh, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts and salt grass also occurring.

The dune ridges are sharply truncated on the north side of Cabretta Island. The sand from these dunes is transported along the front of the island and deposited on Nanny Goat Beach at the south end of Sapelo Island (Hoyt and Henry 1967). Through time, this island complex is moving south. This migration has been taking place for the last 1000 to 2000 years (Maney et al. 1968).

The State of Georgia currently owns all of Cabretta Island. This island is part of the Sapelo Island National Estuarine Sanctuary. For further details on the sanctuary refer to Volume II, Chapter Nine.

I. SAPELO ISLAND

Sapelo Island is a sea island located in McIntosh County, Georgia, between Blackbeard Island to the northeast and Wolf Island to the southwest. The island is separated from Blackbeard Island by Blackbeard Creek and from Wolf Island by Doboy Sound. The Duplin River and a broad expanse of marsh separate the island from the mainland. There are 17,950 total acres (7,264 ha) on Sapelo Island, of which 10,900 acres (4,411 ha) are high land and 7,050 acres (2,853 ha) are marsh (Warner and Strouss 1976). Some 200 - 300 acres (81 -121 ha) are developed. The island has a sandy beachfront that is 3.0 mi (4.8 km) long, a length of 8.6 mi (13.8 km), and a maximum width, including both high ground and marsh, of 3.0 mi (4.8 km).

Sapelo Island has a Pleistocene core with a Holocene beach ridge at the southern end. Elevations on the island range from sea level to 27 ft (8.2 m) at the top of the beach ridge. The high land acreage supports a maritime forest community consisting of live oak, slash pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is polyhaline. Smooth cordgrass is dominant in the marsh, with less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occurring.

The dune ridges are sharply truncated on the north side of the island. The sand from these dunes is transported along the front of the island and deposited at the south end of Sapelo Island (Hoyt and Henry 1967). Through time, this island complex is moving south. This migration has been taking place for the last 1000 - 2000 years (Maney et al. 1968).

The State of Georgia currently owns all of Sapelo Island and it is now part of the Sapelo Island National Estuarine Sanctuary. The University of Georgia's Sapelo Island Marine Research Station is located on the southern tip of the island, adjacent to the Duplin River and Doboy Sound. For further details on the sanctuary, refer to Volume II, Chapter Nine.

J. WOLF ISLAND

Wolf Island is a marsh island located in McIntosh County, Georgia, between Sapelo Island to the northeast and Little St. Simons Island to the south. The island is separated from Sapelo Island by Doboy Sound and from Little St. Simons Island by Altamaha Sound. A wide band of marsh and tidal creeks separates Wolf Island from the mainland. The island's 250 acres (101 ha) of high land and 4,876 acres (1,973 ha) of marsh exist in an undeveloped state. The island is 3.5 mi (4.8 km) long and 3.0 mi (4.8 km) wide through an interspersion of marsh and high land. A sandy beach extends the entire length of the island.

Wolf Island is a Holocene marsh island with a successional shrub community on the high land areas that have been formed by dredged materials removed from the Atlantic Intracoastal Waterway (AIWW). Elevations on the island range from sea level to 10 ft (3.0 m) at the top of the upland areas. The successional shrub community consists of yaupon holly, slash pine, southern red cedar, saw palmetto, and wax myrtle. The surrounding salt marsh is of varying salinity. Smooth cordgrass dominates in the low marsh areas, with less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, salt grass, sea myrtle, and sea ox-eye occurring in the high marsh areas.

Wolf Island experiences continual erosion. Recession has been greatest at the northern end of the island and lessens to the south. The northern portion of the island has eroded about 2,300 ft (701 m) while the southern end has experienced approximately 500 ft (152 m) of erosion between 1867 - 1952 (U.S. Army Corps of Engineers 1971).

Wolf Island has been federally owned since 1828 (Warner and Strouss 1976). Acquired through the Nature Conservancy, the U.S. Fish and Wildlife Service manages the island as a National Wildlife Refuge. Congress has designated Wolf Island as a wilderness area, which severely limits use. It is a major nesting area for loggerhead turtles (Warner and Strouss 1976).

K. LITTLE ST. SIMONS ISLAND

Little St. Simons Island is a marsh island located in Glynn County, Georgia. The island is separated from Wolf Island by Altamaha Sound and from Sea Island by the Hampton River. A broad expanse of marsh and the Hampton River separate the island from St. Simons Island. The island has a sandy beachfront that is 5.4 mi (8.7 km) long, a length of 10.5 mi (16.9 km), and a maximum width, including both high ground and marsh, of 3.0 mi (4.8 km). There are 8,800 acres (3,578 ha) of land on Little St. Simons Island of which 2,300 acres (931 ha) are high ground and approximately 6,500 acres (2,631 ha) are marsh (Warner and Strouss 1976).

Little St. Simons Island is a Holocene marsh island with a maritime forest community. Elevations on the island range from sea level to 28 ft (8.5 m) at the top of the dune ridge. The maritime forest consists of live oak, slash pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. Logging and feral animals introduced by man have altered historic vegetation patterns. The surrounding salt marsh is dominated by smooth cordgrass, and less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occur. Nineteenth- and twentieth-century shorelines from topographic maps prepared by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey for Little St. Simons Island are presented on Atlas plate 24.

Little St. Simons Island is owned by the Berolzhimer family, who presently use the island as a hunting preserve (Warner and Strouss 1976). Taxes on the island are increasing and may force the present owners to sell to developers. The natural system has been altered by man and cannot be considered virgin or unique. The only development on the island is one building (Warner and Strouss 1976).

L. ST. SIMONS ISLAND

St. Simons Island is a sea island located in Glynn County, Georgia, between Sea Island to the north and Jekyll Island to the south. The island is separated from Sea Island by Goulds Inlet, Blackbank River, and Village Creek and from Jekyll Island by St. Simons Sound. The island is separated from the mainland by the Back River, Mackay River, and the AIWW. The island has a sandy beachfront that is 3.0 mi (4.8 km) long, a length of 11.0 mi (17.7 km), and a maximum width, including both high ground and marsh, of 3.0 mi (4.8 km). There are 12,300 acres (4,978 ha) of high land and 13,329 acres (5,394 ha) of marsh. Approximately 2,500 acres (1,012 ha) of high land are developed (Warner and Strouss 1976).

St. Simons Island has a Pleistocene core with a Holocene beach ridge fringe. Elevations on the island range from sea level to 25 ft (7.6 m) at the top of the natural beach ridges. The maritime forest consists of live oak, slash pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is dominated by smooth cordgrass, and less abundant species such as black needlerush, sea ox-eye, saltmeadow cordgrass, glassworts, and salt grass also occur. Sand transport data for St. Simons Island are not available.

The beach front at St. Simons Island is almost totally developed and two development companies own most of the remaining land (Warner and Strouss 1976). The north end behind Sea Island is undeveloped and is owned by the Sea Island Company and the St. Simons Company which plan to build as the economy improves (Warner and Strouss 1976). Half-acre lots were assessed at $60,000 on the ocean front, $35,000 on the waterfront, and $20,000 on the marsh front in 1975 (Warner and Strouss 1976).

M. SEA ISLAND

Sea Island is a barrier island located in Glynn County, Georgia. The island is located between Little St. Simons Island to the northeast and St. Simons Island to the west. The island is separated from Little St. Simons Island by the Hampton River and from St. Simons Island by Village Creek, Blackbank River, and Goulds Inlet. There are 1,100 acres (445 ha) of high land and 800+ acres (324+ ha) of marsh. Sea Island has 736 acres (298 ha) of developed high land and 364 acres (147 ha) of undeveloped high land (Warner and Strouss 1976). The island has a sandy beachfront that is 4.5 mi (7.2 km) long, a length of 4.6 mi (7.4 km), and a maximum width, including both high ground and marsh, of 2.0 mi (3.2 km).

Sea Island is a Holocene barrier island with a maritime forest community on the beach ridges. Elevations on the island range from sea level to 22 ft (6.7 m). The major components of the remnant maritime forest are live oak, slash pine, wax myrtle, southern red cedar, cabbage palmetto, saw palmetto, and hollies. The surrounding salt marsh is of varying salinity. Smooth cordgrass dominates in the low marsh areas, with less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, salt grass, and sea ox-eye occurring in the high marsh areas.

Sea Island has experienced a gradual recession with a variably stable shoreline over most of its length since 1870. A spit at the southern end of Sea Island extended to the south some 2,000 ft (610 m) between 1867 - 1870, and again in 1951 - 1952. Both the accretion and erosion along Sea Island have been generally less than 200 ft/yr (61 m/yr) (U.S. Army Corps of Engineers 1971).

Sea Island is owned by the Sea Island Company. It is approximately two-thirds developed, with the remaining land to be developed as it is sold. In 1975, a lot 150 ft by 160 ft (46 m by 49 m) was valued at $200,000 for ocean front, $70,000 - $80,000 for water front, and $40,000 - $50,000 in the interior. The island is an exclusive private resort with no public access to the beach.

N. JEKYLL ISLAND

Jekyll Island is a sea island located in Glynn County, Georgia, between St. Simons Island to the northeast and Little Cumberland Island to the south. The island is separated from St. Simons Island by St. Simons Sound and from Little Cumberland Island by St. Andrews Sound. A broad expanse of marsh and open water separates the island from the mainland. The island has a sandy beachfront along its entire length of 8.0 mi (12.9 km), and a maximum width, including both high ground and marsh, of 1.5 mi (2.4 km). There are 4,300 acres (1,740 ha) of high land and 1,400 acres (567 ha) of marsh. Of the total 5,700 acres (2,307 ha) of land on Jekyll Island, 3,700 acres (1,497 ha) are developed, with the balance in an undeveloped state (Warner and Strouss 1976).

Jekyll Island has a Pleistocene core with a Holocene beach ridge fringe along the ocean shoreline. Elevations on the island range from sea level to 35 ft (10.7 m). The high land acreage supports a remnant maritime forest which has been substantially altered by commercial and residential development. The maritime forest community consists primarily of live oak, cabbage palmetto, saw palmetto, southern red cedar, wax myrtle, and slash pine. The surrounding salt marsh is of varying salinity. Smooth cordgrass dominates in the low marsh areas, with less abundant species such as saltmeadow cordgrass, glassworts, black needlerush, salt grass, and sea ox-eye occurring in the high marsh areas.

Since 1856, about 900 ft (274 m) have been eroded from the northern tip of Jekyll Island. The northern 2,700 ft (823 m) of the island are receding at an average rate of 4.2 ft/yr (1.3 m/yr), while the southern shore is accreting. In addition, the 37,700 ft (11,491 m) along the northern tip of the island are receding at an average rate of 8 ft/yr (2.4 m/yr) (U.S. Army Corps of Engineers 1975c).

In 1947, Jekyll Island was purchased by the State of Georgia to be operated by the Jekyll Island Authority as a State park. A bridge and causeway costing about $5 million were built in 1954 to link the island with the mainland. Since that time, rapid development on the island has taken place. Six hundred private dwellings were built on land leased from the Authority and the area now supports numerous tourist accommodations including motels, golf courses, the "Aquarama" (a convention hall and group activity center), a half million dollar fishing pier, a campground, picnic sites, and modern bathhouses. The island is served with complete water and sewer systems, fire department, shopping center, and postal and police services (U.S. Army Corps of Engineers 1975c).

O. LITTLE CUMBERLAND ISLAND

Little Cumberland Island is a sea island located in Camden County, Georgia, between Jekyll Island to the north and Cumberland Island to the south. It is separated from Jekyll Island by St. Andrews Sound and from Cumberland Island by Christmas Creek. A broad expanse of marsh and tidal creeks separates the island from the mainland. The island has 2.4 mi (3.9 km) of sandy beachfront, a length of 3.5 mi (5.6 km), and a maximum width of 1.4 mi (1.7 km), including both high land and marsh. There are 1,000 acres (405 ha) of salt marsh, 1,410 acres (571 ha) of high land, and 200 acres (81 ha) of developed high land on the island, with the remaining high land acreage in an undeveloped state (Warner and Strouss 1976).

Little Cumberland Island has a Pleistocene core with a Holocene beach ridge fringe along the ocean shoreline. The high land acreage supports a maritime forest community with several freshwater lakes, ponds, and sloughs. Elevations on the island range from sea level to 55 ft (16.8 m). Major components of the remnant maritime forest are live oak, slash pine, wax myrtle, southern red cedar, saw palmetto, and hollies.

Net erosion on the beaches of Little Cumberland Island is typically low, due mainly to the immediate redeposition of sand downdrift from the sector of erosion, as well as the trapping effect of the inlet shoals, which may serve as a reservoir of sand for subsequent resupply to the beach (Hillestad et al. 1975). (See Atlas plate 24).

Little Cumberland Island is privately owned by a group of conservationists collectively designated as the Little Cumberland Island Association. Little Cumberland Island is included as part of the Cumberland Island National Seashore, operated by the National Park Service. The Association is permanently preserving approximately three-quarters of the island as virtual wilderness. Development of the remainder is limited by covenants and deed restrictions mutually agreed upon by the Park Service and the Association (Warner and Strouss 1976).

P. CUMBERLAND ISLAND

Cumberland Island is a sea island located in Camden County, Georgia, between Little Cumberland Island to the north and Amelia Island, Florida, to the south. It is separated from Little Cumberland Island by Christmas Creek and from Amelia Island by Cumberland Sound. A broad expanse of marsh and tidal creeks separates the island from the mainland. Cumberland Island has a sandy beachfront along its entire length of 17.0 mi (27.4 km), and a maximum width of 4.0 mi (6.4 km), including both high land and marsh. There are 15,150 acres (6,131 ha) of high land on Cumberland Island and 8,050 acres (3,258 ha) of salt marsh. The majority of the high land exists in an undeveloped state (Warner and Strouss 1976).

The island has a Pleistocene core with a Holocene beach ridge fringe along the ocean shoreline. The high land acreage supports a maritime forest community with several freshwater lakes, ponds, and sloughs. Elevations range from sea level to 55 ft (16.8 m). Net erosion on the beach of Cumberland Island is similar to that of Little Cumberland (see Atlas plate 24). It is typically low due to the immediate redeposition of sand downdrift from the sector of erosion, as well as the trapping effect of the inlet shoals (Hillestad et al. 1975).

Cumberland Island has had a long history of human occupation and stewardship. It exists today in a semi-wild state, although greatly modified by the land uses and management practices of earlier inhabitants. Cumberland Island has served as a hunting area since aboriginal times and as an intermittent source of timber. Its militarily strategic location was recognized during the Spanish occupation, and forts were erected by several armies over a period of 180 years. Cumberland produced high quality sea island cotton during the plantation era and has been the site of various attempts at animal husbandry. Feral swine and other residual livestock still roam the island (Bullard 1975).

Starting in 1962, the National Park Foundation began acquiring land on Cumberland Island totaling 15,554 acres (6,295 ha) by 1972. In 1972 the 15,554 acres (6,295 ha) became part of the National Park System managed by the U.S. Department of the Interior (Bullard 1975). It is now a national seashore. (See Volume II, Chapter Nine for additional information on this national seashore.) The area included in the National Park System comprises approximately 80% of Cumberland Island, with the remaining 20% (6,450 acres) (2,610 ha) being privately owned (Warner and Strouss 1976).

APPENDIX C

DREDGING DATA

Appendix C is a summary of dredging data for Georgetown Harbor-Winyah Bay, Charleston Harbor, Port Royal Harbor, Savannah Harbor, Brunswick Harbor, and St. Marys Entrance Channel and Kings Bay. These data are from the annual reports of the U.S. Army Corps of Engineers, Charleston, Savannah, and Jacksonville Districts, dating from 1878.

Appendix Table C-1. Summary of Georgetown Harbor-Winyah Bay dredging data (U.S. Army Corps of Engineers 1872 - 1977). All volumes are in net cubic yards. New Work refers to material removed during initial construction and/or enlargement of a channel. Maintenance refers to material removed to keep or maintain the dimensions of the authorized channel. Net volumes refer to those volumes a dredging contractor was paid for removing - these are the amounts specified to be removed in the work contract. Gross values refer to those volumes actually removed by a dredging contractor as determined by channel surveys. To assure meeting contract depth requirements, over-dredging is almost always done and hence gross values always exceed net values. The $\bar{x}$ values refer to annual averages for the respective intervals. All depths are mean low water (MLW) unless otherwise designated.

	ENTIRE PROJECT		ENTRANCE CHANNEL			INNER HARBOR WINYAH BAY TO SAMPIT RIVER		
FISCAL YEAR	New Work	Maintenance	New Work	Maintenance	Depth	New Work	Maintenance	Depth
1885	20,924					20,924		
1886	2,684					2,684		
1887	7,614		Construction began on North Jetty			7,614		
1888	No Work Done							
1889	15,563					15,563		
1890	No Work Done							
1891	" " "							
1892	" " "							
1893	31,856					31,856		
1894	No Work Done							
1895	" " "							
1896	" " "		Construction began on South Jetty					
1897	" " "							
1898	" " "							
1899	172,977		172,977		15'			
1900	337,218		337,218		15'			
1901	351,094	7,509	327,391		15'	23,703	7,509	
1902	165,376		165,376		15'			
1903	78,919	17,549	78,919		15' completed			
1904	188,432			17,549		188,432		
1905	125,896					125,896		
1906	461,209	133,239		133,239		461,209		
1907	249,761	253,991		253,991		249,761		
1908	149,130	163,061		42,903		149,130	120,158	
1909	139,130	172,493		306		139,130	172,187	
1910		90,615					90,615	15'
1911	No Work Done							
1912	2,014,191	236,725				2,014,191	236,725	18'
1913	261,385	196,375				261,385	196,375	18'
1914	1,117,409	288,610				1,117,409	288,610	18'
1915	92,917	629,700	31,787			61,130	629,700	18'
1916	86,212	267,594		59,955		86,212	207,639	18'
1917	8,525	539,850				8,525	539,850	18'
1918		360,000					360,000	18'
1919		395,890					395,890	18'
1920		255,192					255,192	18'
1921	No Work Done							
1922	" " "							
1923		275,015					275,015	18'
1924		945,956					945,956	18'
1925		343,358					343,358	18'
1926								
1927		40,648					40,648	18'
1928		1,420,252					1,420,252	18'
1929	No Work Done							18'
1930		190,701		126,273	18'		64,428	18'
1931		405,055					405,055	18'

Entrance Channel Maintenance, 1901–1911: 40,726 $\bar{x}$ for 11 years

Entrance Channel Maintenance, 1915–1931: 24,606 $\bar{x}$ for 33 years

Inner Harbor Maintenance, 1907–1931: 340,077 $\bar{x}$ for 35 years (gross - 1.22 x net)

Appendix Table C-1. Continued

FISCAL YEAR	SAMPIT RIVER New Work	SAMPIT RIVER Maintenance	SAMPIT RIVER Depth	UPPER WINYAH BAY New Work	UPPER WINYAH BAY Maintenance	UPPER WINYAH BAY Depth
1885	20,924		12'			
1886	2,684		12'			
1887	7,614		12'			
1888						
1889	15,563		12'			
1890						
1891						
1892						
1893	31,856		12' completed			
1894						
1895						
1896						
1897						
1898						
1899						
1900						
1901		7,509	12'			
1902						
1903						
1904						
1905	27,593		18'			
1906	87,137		18'			
1907	91,949		18'			
1908	149,130		18'			
1909	139,130		18'			
1910						
1911						
1912		88,920	18'			
1913	47,405		18'			
1914	308,277		18'			
1915	61,130		18'			
1916	86,212	115,320	18'			
1917	8,525	86,850	18' completed			
1918		140,000	18'			
1919		190,720	18'			
1920	(gross = 1.13 x net) 89,898 x for 29 years	103,747	18'			
1921						
1922						
1923						
1924						
1925		87,031	18'			
1926						
1927		40,648	18'			
1928		218,292	18'			
1929						
1930						
1931		63,072	18'			

Appendix Table C-1. Continued

FISCAL YEAR	EASTERN CHANNEL New Work	EASTERN CHANNEL Maintenance	EASTERN CHANNEL Depth	WESTERN CHANNEL New Work	WESTERN CHANNEL Maintenance	WESTERN CHANNEL Depth
1885						
1886						
1887						
1888						
1889						
1890						
1891						
1892						
1893						
1894						
1895						
1896						
1897						
1898						
1899						
1900						
1901	23,703		15'			
1902			15'			
1903			15'			
1904	188,432		15'			
1905	98,303		15'			
1906	374,072		15'			
1907	157,812		15'			
1908		120,158	15'			
1909		172,187	15' completed			
1910		80,615	15'			
1911			15'			
1912		147,805	15'	2,014,191		18'
1913				213,890	196,375	18'
1914				809,132	288,610	18'
1915					629,700	18'
1916					72,319	18'
1917					453,000	18'
1918					220,000	18'
1919					205,170	18'
1920					151,445	18'
1921						
1922						
1923					275,015	18'
1924					945,956	18'
1925					256,327	18'
1926						
1927						
1928					1,201,960	18'
1929						
1930					64,428	
1931					341,983	18'

106,153 $\bar{x}$ for 5 years

(gross - 1.25 x net)
331,148 $\bar{x}$ for 23 years

Appendix Table C-1. Continued

FISCAL YEAR	ENTIRE PROJECT New Work	ENTIRE PROJECT Maintenance	ENTRANCE CHANNEL New Work	ENTRANCE CHANNEL Maintenance	ENTRANCE CHANNEL Depth	INNER HARBOR WINYAH BAY TO SAMPIT RIVER New Work	INNER HARBOR WINYAH BAY TO SAMPIT RIVER Maintenance	INNER HARBOR WINYAH BAY TO SAMPIT RIVER Depth
1932		240,721		12,118	18'		228,603	18'
1933		1,198,083		85,910	18'		1,112,173	18'
1934		1,164,180					1,164,180	18'
1935		398,192					398,192	18'
1936	No Work Done							
1937	6,846,972	163,912				6,846,972	163,912	18'
1938		1,297,703		294,072	18'		1,003,631	18'
1939		447,162		233,680	18'		213,482	18'
1940		323,798					323,798	18'
1941		141,216					141,216	18'
1942		38,179					38,179	18'
1943	No Work Done							
1944		16,485					16,485	18'
1945	No Work Done							
1946		494,650					494,650	18'
1947	13,160					13,160		27'
1948	5,024,974					5,024,974		27'
1949	5,965,225		1,142,390		27'	4,822,835		27'
1950	2,544,950	2,023,224	55,163	556,836	27'	2,489,787	1,866,388	27'
1951	1,055,654	2,523,483	1,055,654				2,523,483	27'
1952		1,295,869					1,295,869	27'
1953		1,554,377					1,554,377	27'
1954		1,099,435					1,099,435	27'
1955		1,288,284		118,157	27'		1,170,127	27'
1956		851,678					851,678	27'
1957		878,949					878,949	27'
1958		1,738,160					1,738,160	27'
1959		733,433		512,466	27'		220,967	
1960		1,540,595					1,540,595	27'
1961		1,578,597		424,861	27'		1,153,736	27'
1962		728,231					728,231	27'
1963		1,841,482		461,458	27'		1,380,024	27'
1964		618,284		155,284	27'		463,000	27'
1965		1,391,980		582,147	27'		809,833	
1966		1,488,482		361,904	27'		1,126,578	27'
1967		1,511,848		432,551	27'		1,079,297	27'
1968		1,601,147		312,753	27'		1,288,394	27'
1969		1,889,597		277,629	27'		1,611,968	27'
1970		1,850,987		307,128	27'		1,543,859	27'
1971		1,762,670		212,530	27'		1,550,140	27'
1972		2,161,917		156,289	27'		2,005,628	27'
1973		2,047,856		360,836	27'		1,687,020	27'
1974		1,004,257					1,004,257	27'
1975		1,327,731		96,571	27'		1,231,160	27'
1976		2,467,012		487,189	27'		1,979,823	27'
1977		1,624,995		181,489	27'		1,443,506	27'

Entrance Channel Maintenance, 1932–1949: 24,606 $\bar{x}$ for 33 years

Entrance Channel Maintenance, 1950–1977: 214,217 $\bar{x}$ for 28 years

Inner Harbor Maintenance, 1932–1946: 340,077 $\bar{x}$ for 35 years (gross - 1.22 x net)

Inner Harbor Maintenance, 1949–1977: 1,315,231 $\bar{x}$ for 28 years (gross 1.48 x net)

Appendix Table C-1. Continued

FISCAL YEAR	SAMPIT RIVER New Work	SAMPIT RIVER Maintenance	SAMPIT RIVER Depth	UPPER WINYAH BAY New Work	UPPER WINYAH BAY Maintenance	UPPER WINYAH BAY Depth
1932		37,913	18'			
1933		141,343	18'			
1934		316,356	18'			
1935		113,422	18'			
1936						
1937		163,912	18'			18'
1938		328,058	18'			
1939		213,482	18'			
1940		51,000	18'		272,798	18'
1941		141,216	18'			
1942		38,179	18'			
1943						
1944		16,485	18'			
1945						
1946						
1947	13,160		27'			27'
1948	1,968,291		27'	3,056,683		27'
1949	4,822,835		27'			27'
1950			27'			27'
1951			27'			27'
1952			27'			27'
1953			27'			27'
1954			27'			27'
1955			27'			27'
1956		851,678	27'			27'
1957		878,949	27'			27'
1958		685,000	27'			27'
1959		220,967	27'			27'
1960			27'			27'
1961			27'			27'
1962			27'			27'
1963			27'			27'
1964			27'			27'
1965		644,833	27'			27'
1966		853,316	27'		273,262	27'
1967		723,414	27'		355,883	27'
1968		980,394	27'		308,000	27'
1969		1,168,941	27'		443,027	27'
1970		998,106	27'		545,753	27'
1971			27'			27'
1972			27'			27'
1973			27'			27'
1974		839,233	27'		165,024	27'
1975		791,723	27'		439,437	27'
1976			27'			27'
1977			27'			27'

Sampit River maintenance 1932–1946: (gross - 1.13 x net) 89,898 $\bar{x}$ for 29 years

Sampit River maintenance 1948–1977: (Gross - 1.49 x net) (Using ratio of 68% dredging done in Sampit River) 894,357 $\bar{x}$ for 28 years

Appendix Table C-1. Concluded

FISCAL YEAR	EASTERN CHANNEL New Work	EASTERN CHANNEL Maintenance	EASTERN CHANNEL Depth	WESTERN CHANNEL New Work	WESTERN CHANNEL Maintenance	WESTERN CHANNEL Depth
1932					(gross - 1.25 x net) 331,148 x for 23 years 190,690	18'
1933					970,830	18'
1934					847,824	18'
1935					284,770	18'
1936						
1937			27'			
1938		675,573				
1939						
1940						
1941						
1942						
1943						
1944						
1945						
1946						
1947			27'			
1948						
1949						
1950	2,489,787		27'			
1951			27'			
1952			27'			
1953			27'			
1954			27'			
1955			27'			
1956			27'			
1957			27'			
1958			27'			
1959			27'			
1960			27'			
1961			27'			
1962			27'			
1963			27'			
1964			27'			
1965		165,000	27'			
1966			27'			
1967			27'			
1968			27'			
1969			27'			
1970			27'			
1971			27'			
1972			27'			
1973			27'			
1974			27'			
1975			27'			
1976			27'			
1977			27'			

Appendix Table C-2. Summary of Charleston Harbor dredging data (U.S. Army Corps of Engineers 1872 - 1977). The values are net cubic yards or those volumes that the dredging contractor was paid for. Actual or gross amounts removed can be estimated by multiplying net values by 1.36 (U.S. Army Corps of Engineers 1966a). The $\bar{x}$ values refer to annual averages for the respective intervals. As hopper dredges are used in the entrance channel, net values essentially become gross values as the volume of material removed is actually measured. All depths are mean low water (MLW) unless designated otherwise.

	ENTIRE PROJECT		ENTRANCE			COOPER RIVER			ASHLEY RIVER		
FISCAL YEAR	New Work	Maint.	New Work	Maint.	Depth	New Work	Maint.	Depth	New Work	Maint.	Depth
1878			Work began on jetties								
1879											
1880											
1881											
1882											
1883											
1884				Dredging began							
1885											
1886											
1887											
1888											
1889											
1890											
1891											
1892											
1893											
1894											
1895											
1896	2,205,544		2,205,544		21'						
1897	Costs only, no yardages										
1898	390,270		390,270		21'						
1899		271,000		271,000	21'						
1900		253,401		253,401	21'						
1901	287,206		287,206		26'						
1902	174,968	19,958	174,968	19,958	26'						
1903	288,965		288,965		26'						
1904	517,429		517,429		26'						
1905	919,968		919,968		26'						
1906		678,155		678,155	26'						
1907		143,411		143,411	26'						
1908		148,280		148,280	26'						
1909		85,591		85,591	26'						
1910		22,194		22,194	26'						
1911	1,212,722		1,212,722		28'						
1912	1,461,204		1,326,335		28'	97,000			37,869		
1913	1,254,319		964,434		28'				289,885		20'
1914	736,967	253,077	666,016	253,077	28'				70,951		20'
1915	45,770	22,500							45,770	22,500	20'
1916		53,970								53,970	20'
1917	1,039,000	126,820	300,000	126,820	30'	739,000					
1918	401,095	61,891	401,095	61,891	30'						
1919	1,446,109	13,845	1,446,109	13,845	30'						
1920	1,013,001	18,666	171,172		30'	841,829			18,666		20'
1921	1,124,157					1,124,157					
1922	No Work Done										
1923	" " "										
1924		735,248		735,248	30'						
1925	31,744					31,744					

381,331 $\bar{x}'$ for 20 years

14,775 $\bar{x}$ for 24 years

Appendix Table C-2. Concluded

FISCAL YEAR	ENTIRE PROJECT New Work	ENTIRE PROJECT Maint.	ENTRANCE New Work	ENTRANCE Maint.	ENTRANCE Depth	COOPER RIVER New Work	COOPER RIVER Maint.	COOPER RIVER Depth	ASHLEY RIVER New Work	ASHLEY RIVER Maint.	ASHLEY RIVER Depth
1926	127,891	584,872		584,872	30'	127,891					
1927		23,483		23,483	30'						
1928	10,666	625,027		586,088	30'	10,666	2,819			36,120	20'
1929	595,960	820				595,960	820				20'
1930	1,058,045	949,321	882,845	765,595	30'	175,200	160,241	30'		23,485	20'
1931	75,900	113,143				75,900	113,143	30'			
1932	228,075	162,285	228,075	150,350	30'		11,935	30'			
1933		10,035					10,035	30'			
1934		721,147		441,878	30'		279,269	30'			
1935		438,158		336,150	30'		102,008	30'			
1936	318,932	723,886				318,932	572,662	30'		151,224	20'
1937		184,295					166,977	30'		17,318	20'
1938	48,625	944,194	48,625	571,447	30'		341,432	30'		31,315	
1939	2,042,625	635,876		431,500	30'	554,658	159,325	30'	1,487,967	45,051	
1940	2,295,088	425,338					392,682	30'	2,295,088	32,656	30'
1941	1,138,695	399,271	504,560		35'	634,135	190,980	35'		20,829	30'
1942	4,680,770	686,826	3,122,813		35'	1,557,957	650,160	35'		36,666	30'
1943	1,252,900	428,047				1,252,800	396,906	35'		31,141	30'
1944		2,246,575		803,850	35'		1,442,725	35'			
1945		5,065,818		1,359,100	35'		3,288,894	35'		417,824	30'
1946		3,022,828		98,150	35'		2,343,320	35'		581,358	30'
1947		3,394,160					3,394,160	35'			
1948	1,221,850	2,642,466	1,221,850	286,000	35'		2,302,542	35'		53,924	30'
1949	1,065,453	2,323,997	1,065,453		35'		2,283,361	35'		40,636	30'
1950		4,519,586					4,474,759	35'		44,827	30'
1951	1,842,272	3,594,209		1,000,000	35'	1,842,272	1,957,731	35'		636,478	30'
1952		4,743,482		400,000	35'		4,343,482	35'			
1953		4,206,302		400,000	35'		3,806,302	35'			
1954		4,865,975		600,000	35'		4,113,905	35'		152,070	30'
1955		2,138,359					1,786,385	35'		351,974	30'
1956	1,110,880	7,098,601		1,137,168	35'	1,110,880	5,961,433	35'			
1957		2,722,246					2,722,246	35'			
1958		2,921,520		573,200	35'		2,348,320	35'			
1959		2,116,165					2,116,165	35'			
1960		4,683,938					4,683,938	35'			
1961	331,813	8,000,616		1,672,900	35'	331,813	6,327,716	35'			
1962	894,647	5,234,336		500,000	35'	894,647	4,734,336	35'			
1963	2,461,705	4,942,677				2,461,705	4,942,677	35'			
1964		6,302,209		1,135,456	35'		5,166,753	35'			
1965		7,443,019		1,053,486	35'		6,409,533	35'			
1966		3,433,469		1,316,324	35'		2,117,145	35'			
1967		3,321,764		1,655,557	35'		1,666,207	35'			
1968		2,803,910		275,000	35'		2,528,910	35'			
1969		2,671,267		1,408,427	35'		1,262,840	35'			
1970		3,710,007		200,000	35'		3,510,007	35'			
1971		3,899,674		262,532	35'		3,637,142	35'			
1972		2,785,992		949,922	35'		1,836,070	35'			
1973		3,336,402		1,158,962	35'		2,177,440	35'			
1974		4,975,550		369,073	35'		4,606,477	35'			
1975		2,552,229		334,696	35'		2,217,533	35'			
1976		5,806,453		1,618,770	35'		4,187,683	35'			
1977		3,096,226		878,662	35'		2,217,564	35'			

381,331 $\bar{x}$ for 20 years

651,729 $\bar{x}$ for 29 years

242,373 $\bar{x}$ for 13 years

3,237,503 $\bar{x}$ for 35 years

161,740 $\bar{x}$ for 16 years

14,775 $\bar{x}$ for 24 years

No longer maintained

Appendix Table C-3. Summary of Port Royal Harbor dredging data (U.S. Army Corps of Engineers 1872 - 1977). Values are in cubic yards and indicate net or paid volumes removed. The Inner Harbor as well as the Entrance Channel is maintained by hopper dredges. These net values are essentially the actual volumes removed. All depths are mean low water (MLW) unless designated otherwise.

Fiscal Year	Inner Harbor New Work	Inner Harbor Maintenance	Inner Harbor Depth	Entrance Channel New Work	Entrance Channel Maintenance	Entrance Channel Depth	Comments
1956							
1957				425,625		27'	Project begun
1958				1,715,099		27'	
1959				1,575,153	229,710	27'	Project completed
1960							
1961					287,023	27'	
1962							
1963		121,164			358,200	27'	
1964		58,196	27'		448,372	27'	
1965			27'		444,675	27'	
1966			27'		430,929	27'	
1967			27'		218,966	27'	
1968	15,634/year		27'		305,550	27'	
1969			27'		515,947	27'	
1970		53,578	27'	286,197/year	274,902	27'	
1971			27'		324,482	27'	
1972			27'		291,005	27'	
1973			27'		82,205	27'	
1974			27'		101,408	27'	
1975			27'		607,938	27'	
1976			27'		283,542	27'	
1977		112,304	27'		232,897	27'	
TOTAL	343,948	297,042		3,715,877	5,437,751		

Appendix Table C-4. Summary of Savannah Harbor dredging data (U.S. Army Corps of Engineers 1872 - 1977). Values are in cubic yards and represent net or paid volumes removed. Actual or gross volumes removed are greater than net values by an unknown amount. As hopper dredges are used in the entrance channel, net values essentially become gross values as the volume of material removed is actually measured.

	ENTIRE PROJECT			ENTRANCE (Tybee Knoll to Bar)			RIVER		
FISCAL YEAR	New Work	Maint.	Depth	New Work	Maint.	Depth	New Work	Maint.	Depth
1872	NO	WORK	DONE						
1873	51,005		22'MHW	671			50,334		
1874	115,763		22'MHW	55,639			60,124		
1875	207,783		22'MHW	99,992			107,791		
1876	225,542		22'MHW	18,349			207,193		
1877	158,643		22'MHW	18,407			140,236		
1878		28,419	22'MHW						
1879	27,131		22'MHW				27,131		
1880	15,000	155,359	22'MHW	113,387			15,000	41,972	
1881		268,220	22'MHW						
1882		1,241,500	22'MHW						
1883		112,221	22'MHW						
1884		1,509,894	22'MHW						
1885		1,569,119	22'MHW						
1886		1,667,233	22'MHW						
1887		1,736,542	22'MHW						
1888		11,208	22'MHW					11,207	
1889		187,671	26'MHW						
1890		31,551	26'MHW						
1891		176,922	26'MHW						
1892		36,170	26'MHW						
1893		488,518	26'MHW						
1894		978,096	26'MHW						
1895		1,866,723	26'MHW						
1896		3,765,654	26'MHW		2,128,067			1,637,587	26'MHW
1897		6,037,363	26'MHW						26'MHW
1898		108,434	26'MHW					108,434	26'MHW
1899		427,749	26'MHW					427,749	26'MHW
1900		890,000	26'MHW						26'MHW
1901		276,933	26'MHW						26'MHW
1902		198,381						198,381	26'MHW
1903	1,048,614	241,238					1,048,614	241,238	28'MHW
1904	2,658,377						2,658,377		28'MHW
1905	1,735,981						1,735,981		28'MHW
1906	528,384	258,584		528,384				258,584	28'MHW
1907	636,074	344,161		636,074				344,161	28'MHW
1908	773,049	370,762		773,049				370,762	28'MHW
1909	877,794	691,203		877,794				691,203	28'MHW
1910	1,248,017	688,896		1,248,017		26'MLW		668,896	28'MHW
1911	2,949,572	275,801		1,112,972		26'MLW	1,836,600	275,801	
1912	2,718,074	721,500		1,572,517		26'MLW	1,145,557	721,500	

Appendix Table C-4. Continued

	ENTIRE PROJECT			ENTRANCE (Tybee Knoll to Bar			RIVER		
FISCAL YEAR	New Work	Maint.	Depth	New Work	Maint.	Depth	New Work	Maint.	Depth
1913	3,573,736	302,860		1,186,272		26'MLW	2,387,464	302,860	
1914	1,563,527	1,373,000				26'MLW			
1915	210,876	2,121,072				26'MLW		407,177	
1916		2,200,357			1,016,564	26'MLW		1,183,793	
1917		2,215,213			1,215,984	26'MLW		999,229	
1918	159,336	1,517,894				30'MLW		219,190	
1919		2,333,491						94,604	
1920	188,018	2,917,655					188,018		
1921	582,877	2,249,428		565,000			17,877		
1922		3,073,688			156,690			2,916,998	
1923	270,200	5,167,509		270,200					
1924	1,142,197	5,214,877		1,142,197					
1925	458,141	7,604,346		322,794			135,347		
1926	5,282,759			502,244			4,780,515		
1927	1,068,277	6,258,828		217,000			851,277		
1928	1,562,917	5,806,092		716,727			846,190		
1929	375,976	5,811,748					375,976		
1930	4,398,556	5,025,335							
1931	649,196	7,579,814							
1932	964,669	2,044,833							
1933		5,412,441							
1934		4,002,820							
1935		6,408,433							
1936		3,684,630							
1937	5,870,580	3,754,432							
1938	1,567,988	6,029,151							
1939		5,947,901							
1940		5,700,944							
1941		4,974,138							
1942		6,098,844							
1943		7,061,273							
1944		7,976,738							
1945		8,710,449							
1946		10,526,221							
1947	671,350	5,602,845		671,350					
1948	6,455,380	7,010,234		546,183	4,977,452	30'MLW	5,909,197	2,032,782	26'MLW
1949		8,569,427			2,830,694	34'MLW		5,738,733	33'MLW
1950	3,197,961	7,388,426		3,197,961		36'MLW		7,388,426	
1951	2,864,502	4,765,362		2,864,502				4,765,362	
1952	973,707	5,737,050					973,707	5,737,050	
1953	10,521	5,392,527			916,454		10,521	4,476,073	
1954		6,971,225			504,022			6,467,203	
1955		9,360,937						9,360,937	

Appendix Table C-4. Concluded

FISCAL YEAR	ENTIRE PROJECT New Work	ENTIRE PROJECT Maint.	ENTIRE PROJECT Depth	ENTRANCE (Tybee Knoll to Bar) New Work	ENTRANCE (Tybee Knoll to Bar) Maint.	ENTRANCE (Tybee Knoll to Bar) Depth	RIVER New Work	RIVER Maint.	RIVER Depth
1956		8,296,181			450,636			7,845,545	
1957		9,190,217			3,316,709			5,873,508	
1958	221,044	3,925,395			95,382		221,044	3,830,013	
1959	797,146	7,675,971					797,146	7,675,971	
1960		4,931,199						4,931,199	
1961		6,035,393			1,368,231			4,667,162	
1962		5,805,445			1,231,648			4,573,797	
1963		5,994,902			1,017,490			4,977,412	
1964		5,120,272			645,095			4,475,177	
1965	796,746	4,809,193			504,254	40'MLW	796,746	4,304,939	38'MLW
1966		5,479,717			711,046	40'MLW		4,768,671	38'MLW
1967		4,476,001				40'MLW		4,476,001	38'MLW
1968		3,605,263			431,046	40'MLW		3,174,217	38'MLW
1969	5,505,442	6,705,889			375,872	40'MLW	5,505,442	6,330,017	38'MLW
1970		5,183,526			565,329	40'MLW		4,618,197	38'MLW
1971	9,403,768	6,874,110			582,442	40'MLW		6,291,668	38'MLW
1972	7,395,510	5,865,724		2,667,987	304,405	40'MLW	4,727,523	5,561,319	38'MLW
1973	30,005,116	7,293,316		2,151,664	648,144	40'MLW	853,452	6,645,172	38'MLW
1974	1,146,262	5,639,910		1,146,262		40'MLW		5,639,910	38'MLW
1975	441,340	7,600,407			96,503	40'MLW	441,340	7,503,904	38'MLW
1976	738,632	9,191,646		738,632	1,306,627	40'MLW		7,885,019	38'MLW
1977	976,161	13,166,153		976,161	494,324	40'MLW		12,671,829	38'MLW

463,078 x̄

6,143,913

Appendix Table C-5. Summary of Brunswick Harbor dredging data (U.S. Army Corps of Engineers 1872 - 1977). All values are in cubic yards and represent net volumes or those that the dredging contractor was paid to remove. Actual or gross volumes removed are higher by some unknown amount. New Work refers to material removed during initial construction and/or enlargement of a channel. Maintenance (Maint.) refers to material removed to maintain the dimensions of the authorized channel. The $\bar{x}$ values refer to annual averages for the respective intervals. All depths are mean low water (MLW) unless otherwise designated.

	ENTIRE PROJECT		EAST RIVER			ACADEMY CREEK			BRUNSWICK PORT			TURTLE RIVER		
FISCAL YEAR	New Work	Maintenance	New Work	Maint.	Depth	New Work	Maint.	Depth	New Work	Maint.	Depth	New Work	Maint.	Depth
1880	1,842		1,842		15'									
1881	34,160		34,160		15'									
1882	16,016		16,016		15'									
1883	8,484		28,484		15'									
1884	No Work Done													
1885	" " "													
1886	" " "													
1887		40,000		40,000	15'									
1888	No Work Done													
1889		50,797		50,797	15'									
1890		29,097		29,097	15'									
1891	No Work Done													
1892		49,324		49,324	15'									
1893		29,933		29,933	15'									
1894	No Work Done		18,621 $\bar{x}$ for 15 years											
1895		36,079		36,079	15'									
1896	No Work Done													
1897	45,112	14,571		14,571	15'	45,112		12'						
1898	No Work Done													
1899		11,357		3,106	15'		8,251	12'						
1900	No Work Done													
1901		63,644		63,644	15'									
1902	No Work Done													
1903	113,783		90,000		21'	23,783		18'						
1904	384,761		243,289		21'									
1905	520,383		126,901		21'									
1906	19,345	20,000					20,000	18'						
1907	No Work Done													
1908	653,183		1,784		30'MHW	157,886		30'MHW	10,153		30'MHW	26,505		30'MHW
1909	1,176,638	79,000	303,941	79,000					114,267		30'MHW	45,219		30'MHW
1910	270,872								60,119		30'MHW			
1911	13,728	91,304	3,509	52,925	30'MHW		38,379	30'MHW				10,219		30'MHW
1912	14,158	391,714										14,158		30'MHW
1913	No Work Done													
1914		464,892		224,312	30'MHW		37,331	30'MHW		23,821	30'MHW		3,965	30'MHW
1915		398,866								146,323	30'MHW		28,411	30'MHW
1916	20,125	294,080	20,125		30'MHW		57,406	30'MHW						
1917		278,030		75,000										
1918		36,000		15,000			21,000	30'MHW						
1919		354,136		4,500										
1920		374,192		20,000										
1921	771,600	816,376			24'			24'						
1922	90,710	191,957										35,898		24'
1923	284,885	807,956					3,600	24'	19,834		24'	5,051		24'

Appendix Table C-5. Continued

FISCAL YEAR	ENTIRE PROJECT New Work	ENTIRE PROJECT Maintenance	BACK RIVER New Work	BACK RIVER Maint.	BACK RIVER Depth	TERRY CREEK New Work	TERRY CREEK Maint.	TERRY CREEK Depth	ST. SIMONS SOUND New Work	ST. SIMONS SOUND Maint.	ST. SIMONS SOUND Depth	ENTRANCE CHANNEL New Work	ENTRANCE CHANNEL Maint.	ENTRANCE CHANNEL Depth
1880	1,842													
1881	34,160													
1882	16,016													
1883	28,484													
1884	No Work Done													
1885	" " "													
1886	" " "													
1887		40,000												
1888	No Work Done													
1889		50,797												
1890		29,097												
1891	No Work Done													
1892		49,324												
1893		29,933												
1894	No Work Done													
1895		36,079												
1896	No Work Done													
1897	45,112	14,571												
1898	No Work Done													
1899		11,357												
1900	No Work Done													
1901		63,644												
1902	No Work Done													
1903	113,783													
1904	384,761											141,472		
1905	520,383											393,482		
1906	19,345	20,000										19,345		
1907	No Work Done													
1908	653,183											456,855		30'MHW
1909	1,176,638	79,000										713,211		30'MHW
1910	270,872											210,753		30'MHW
1911	13,728	91,304												
1912	14,158	391,714											391,714	30'MHW
1913	No Work Done													
1914		464,892											175,463	30'MHW
1915		398,866											224,132	30'MHW
1916	20,125	294,080												30'MHW
1917		278,030											88,222	
1918		36,000												
1919		354,136												
1920		374,192												
1921	771,600	816,376												
1922	90,710	191,957												
1923	284,885	807,956												

Appendix Table C-5. Continued

	ENTIRE PROJECT		BACK RIVER			TERRY CREEK			ST. SIMONS SOUND			ENTRANCE CHANNEL		
FISCAL YEAR	New Work	Maintenance	New Work	Maint.	Depth	New Work	Maint.	Depth	New Work	Maint.	Depth	New Work	Maint.	Depth
1924	1,459,382	725,743												
1925	450,231	670,585												
1926	687,654	227,298												
1927	288,463	289,750												
1928	145,000	952,212												
1929	345,333	1,082,474												
1930		1,151,034												
1931	1,619,340	448,625												
1932	938,176													
1933	Costs Only,	No Yardages												
1934	" "	" "												
1935	" "	" "												
1936	1,490,037 Combined													
1937	277,526	86,370											86,370	30'
1938	491,232	555,711											555,711	30'
1939	228,563	800,584											800,584	30'
1940	383,945	537,562				218,148		10'					537,562	30'
1941	182,529	519,302					86,437						432,865	30'
1942		13,655					13,655	10'						
1943	No Work Done													
1944	" " "													
1945	" " "													
1946		518,827					194,170	10'					274,359	30'
1947	570,082	783,689											728,579	30'
1948	No Work Done													
1949	" " "													
1950	" " "													
1951	" " "													
1952	" " "													
1953	463,991													
1954		921,525											921,525	30'
1955	No Work Done													
1956	" " "													
1957	" " "													
1958		1,622,239											1,622,239	
1959	375,269	915,866											592,228	
1960	3,015,562	405,891							102,286			2,104,629		32'
1961	847,572	668,980							150,658			696,914		
1962		1,217,442								21,359			588,951	32'
1963		1,312,557								75,209			597,636	32'
1964		1,058,759								36,749			423,093	32'
1965		1,391,051								2,703			554,221	32'
1966		921,930								64,188			438,397	32'
1967		775,570								30,352			161,150	32'

284,871 $\bar{x}$ for 23 years

729,135 $\bar{x}$ for 16 years

Appendix Table C-5. Continued

FISCAL YEAR	ENTIRE PROJECT New Work	ENTIRE PROJECT Maintenance	EAST RIVER New Work	EAST RIVER Maint.	EAST RIVER Depth	ACADEMY CREEK New Work	ACADEMY CREEK Maint.	ACADEMY CREEK Depth	BRUNSWICK PORT New Work	BRUNSWICK PORT Maint.	BRUNSWICK PORT Depth	TURTLE RIVER New Work	TURTLE RIVER Maint.	TURTLE RIVER Depth
1924	1,459,382	725,743	27,720	5,000	24'									
1925	450,231	670,585												
1926	687,654	227,298												
1927	288,463	289,750												
1928	145,000	952,212												
1929	345,333	1,082,474												
1930		1,151,034												
1931	1,619,340	448,625												
1932	938,176		938,176		24'									
1933	Costs Only,	No Yardages												
1934	" "	" "												
1935	" "	" "												
1936	1,490,037	Combined												
1937	277,526	86,370	277,526											
1938	491,232	555,711	491,232											
1939	228,563	800,584	228,563											
1940	383,945	537,562	165,797											
1941	182,529	519,302	182,592											
1942		13,655												
1943	No Work Done													
1944	" " "													
1945	" " "													
1946		518,827											50,298	27'
1947	570,082	783,689	570,082										55,110	27'
1948	No Work Done													
1949	" " "													
1950	" " "													
1951	" " "													
1952	" " "													
1953	463,991		463,991											
1954		921,525												
1955	No Work Done													
1956	" " "													
1957	" " "													
1958		1,622,239												
1959	375,269	915,866	375,269	323,638										
1960	3,015,562	405,891	808,647	405,891										
1961	847,572	668,980		668,890										
1962		1,217,442		607,132										
1963		1,312,557		639,712	559,052 x̄ for 19 years									
1964		1,058,759		598,917										
1965		1,391,051		834,127										
1966		921,930		419,345										
1967		775,570		584,068										

Appendix Table C-5. Continued

FISCAL YEAR	ENTIRE PROJECT		EAST RIVER			ACADEMY CREEK			BRUNSWICK PORT			TURTLE RIVER		
	New Work	Maintenance	New Work	Maint.	Depth	New Work	Maint.	Depth	New Work	Maint.	Depth	New Work	Maint.	Depth
1968		1,202,380		482,562										
1969		1,806,619		307,689										
1970		710,791		295,068										
1971		1,596,262		673,748										
1972		1,088,175		471,338										
1973		1,527,133		475,574										
1974		1,683,592		1,143,840										
1975		554,949		315,000										
1976		2,583,229		490,808										
1977		2,713,338		884,584			282,499							

559,052 $\bar{x}$ for 19 years

Appendix Table C-5. Concluded

FISCAL YEAR	ENTIRE PROJECT New Work	ENTIRE PROJECT Maintenance	BACK RIVER New Work	BACK RIVER Maint.	BACK RIVER Depth	TERRY CREEK New Work	TERRY CREEK Maint.	TERRY CREEK Depth	ST. SIMONS SOUND New Work	ST. SIMONS SOUND Maint.	ST. SIMONS SOUND Depth	ENTRANCE CHANNEL New Work	ENTRANCE CHANNEL Maint.	ENTRANCE CHANNEL Depth
1968		1,202,380								27,848			691,970	32'
1969		1,806,619								150,178			1,348,725	32'
1970		710,791											415,723	32'
1971		1,596,262					57,000						865,514	32'
1972		1,088,175											616,837	32'
1973		1,527,133					506,063						545,496	32'
1974		1,683,592											539,752	32'
1975		554,949										729,135 $\bar{x}$ for 16 years	239,949	32'
1976		2,583,229											2,092,421	32'
1977		2,713,338											1,546,291	32'

Appendix Table C-6. Summary of St. Marys Entrance Channel and Kings Bay dredging data (U.S. Army Corps of Engineers 1872 - 1977, J. Wilson, 1979, U.S. Army Corps of Engineers, Savannah, Georgia, pers. comm.; B. Lancaster, 1979, U.S. Army Corps of Engineers, Jacksonville, Florida, pers. comm.). All values are in cubic yards and are gross or those volumes actually removed. The depth column refers to the authorized project depth.

	ST. MARYS ENTRANCE CHANNEL			KINGS BAY		
Fiscal Year	New Work (Gross)	Maintenance (Gross)	Depth	New Work (Gross)	Maintenance (Gross)	Depth
1903	379,571		19' MLW			
1904	166,479					
1905		59,412				
1906		153,491				
1907						
1908		186,981				
1909						
1910						
1911		121,214				
1912		47,262				
1913						
1914		356,176				
1915						
1916						
1917						
1918						
1919						
1920						
1921						
1922						
1923						
1924						
1925						
1926						
1927			26' MLW			
1928						
1929						
1930						
1931						
1932						
1933						
1934						
1935						
1936						
1937		302,569				
1938						
1939						
1940	248,048		28' MLW			
1941						
1942						
1943						

Appendix Table C-6. Concluded

	ST. MARYS ENTRANCE CHANNEL			KINGS BAY		
Fiscal Year	New Work (Gross)	Maintenance (Gross)	Depth	New Work (Gross)	Maintenance (Gross)	Depth
1944			28' MLW			
1945		196,350				
1946						
1947						
1948						
1949						
1950						
1951						
1952						
1953						
1954						
1955				10,040,000		32' MLW
1956	3,001,108					
1957			34' MLW			
1958						
1959						
1960						
1961						
1962						
1963						
1964		835,837				
1965		305,780			1,500,000	32' MLW
1966		343,217				
1967		114,800				
1968		221,728				
1969		292,127			1,530,000	32' MLW
1970		262,625				
1971						
1972						
1973		525,238				
1974		42,693				
1975		81,476				
1976		155,397			1,700,000	32' MLW
1977				9,462,000		32' MLW
1978		989,447				36' MLW
1979	3,089,439	670,164	40' MLW			

St. Marys Entrance Channel maintenance, 1956–1979: $\bar{x}$ = 210,000/year for 23 years

Kings Bay maintenance, 1955–1978: $\bar{x}$ = 215,000/year for 22 years

APPENDIX D

PRIORITY RANKING OF AREAS IN SOUTH CAROLINA AND GEORGIA IDENTIFIED BY THE U.S. FISH AND WILDLIFE SERVICE AS BEING IN NEED OF PRESERVATION.

The U.S. Fish and Wildlife Service has, as a high priority national mission, the task of identifying, evaluating, and seeking measures to assure the protection and perpetuation of unique or nationally significant wildlife ecosystems. Through close cooperation with other Federal agencies, State and local governments, and private concerns, the Service's Southeastern Regional Office personnel have identified unique or nationally significant wildlife areas in the States of South Carolina and Georgia.

The goals of this effort are to 1) identify the wildlife ecosystems within these States that are unique, with the intent of positively influencing the protection and preservation of these areas; 2) determine the nature and imminence of threat to each area; and 3) provide information needed to make sound judgements as to the most feasible means of preserving these unique areas.

This information became available after the final report for the Sea Island Ecological Characterization had been completed. Because of the potential significance of this information, the following summary tables have been included as an appendix to this report.

The following tables, prepared by the U.S. Fish and Wildlife Service, list by priority ranking the unique or nationally significant wildlife areas in South Carolina and Georgia that are not under public ownership or control, and briefly describe the significance of each area and the nature of threats to their continued functioning as natural ecosystems. Additional information can be obtained from the Regional Director, U.S. Fish and Wildlife Service, Richard B. Russell Federal Building, 75 Spring Street SW, Atlanta, Georgia 30303.

Appendix Table D-1. Summary of areas in South Carolina identified as being in need of preservation, by priority ranking.

NO.	NAME OF AREA	ACREAGE APPROXIMATE	SIGNIFICANCE OF AREA	THREAT
1	St. Phillips Island (Beaufort County)	5,000	Coastal barrier island with unique dune ridge formation. Great diversity of wildlife supported by unusual overlapping of maritime and marine habitats. Extensive salt marsh system. Atlantic loggerhead sea turtle nesting area. Few areas remain on the Atlantic coast in the pristine condition this island is presently in.	Resort Development
2	Cape Romain Moores Landing (Charleston County)	6,000 962	Valuable area of habitat essential to preservation of integrity of existing refuge holdings. Great diversity, particularly of avifauna. Important area for 6 endangered and threatened species, 251 species of birds, and 42 species of mammals.	Residential Development Logging
3	Upper Santee Swamp Area (Sumter and Clarendon counties)[a]	17,000	One of the finest remaining examples of bottomland hardwood swamp in the State.	Logging
4	(Ashepoo, Combahee, Edisto (ACE) River Basin (Colleton County)	90,000	Exceptional area of bottomland hardwood, brackish and freshwater impoundments along 3 estuarine rivers. Largest concentration of nesting bald eagles in S.C. Includes 2 small barrier islands with high intensity of nesting loggerhead sea turtles. Used by 4 endangered species.	Residential and Industrial Development
5	Mayrant's Reserve - Fairlawn Plantation (Charleston County)	300	One of the largest white ibis rookeries in the State. Part of last known nesting area in North America for the endangered Bachman's Warbler.	Logging
6	Drum Island (Charleston County)	285	Largest wading bird rookery on the Atlantic Coast. Hosts 25 - 30,000 prs. of nesting birds annually.	Disposal of Dredged Material Threatens to Eliminate Rookery
7	Mountain Bridge (Greenville and Pickens counties)[a]	47,000	Exceptionally diverse area, containing examples of every type of mountain habitat found in the State.	Resort Development
8	Lower Santee Swamp (Georgetown County)	34,000	One of the least developed large areas of cypress-hardwood bottomland in the State.	Logging Santee Rediversion Project
9	Ocatee Club (Jasper County)	52,000	Complex of fire-maintained savannahs; supports an extremely diverse herpetofauna, many species of rare plants.	None Imminent

Appendix Table D-1. Concluded.

NO.	NAME OF AREA	ACREAGE APPROXIMATE	SIGNIFICANCE OF AREA	THREAT
10	Kinloch Plantation (Georgetown County)	6,000	Large wintering population of waterfowl, nesting bald eagles.	Santee Rediversion Project
11	Bay Point Island (Beaufort County)	500	One of the few remaining, relatively undisturbed barrier islands on the South Carolina coast. Very close proximity to St. Phillips Island.	None Imminent
12	Dewees Island (Charleston County)	1,800	One of the few large undeveloped coastal barrier islands along the South Carolina coast.	Development
13	Black River (Georgetown and Williamsburg counties)	35,000	Predominantly undeveloped area of black water river bordered by cypress-gum swamps. Recommended for status as State Wild and Scenic River.	Draining and Clearing for Agriculture
14	Four Holes Swamp Area (Dorchester County)	1,145	Areas of bottomland hardwood whose preservation is vital to integrity of largest virgin stand of tupelo-cypress remaining in U.S.	Logging

a. Outside of Sea Island Coastal Region.

Appendix Table D-2. Summary of areas in Georgia identified as being in need of preservation, by priority ranking.

NO.	NAME OF AREA	ACREAGE APPROXIMATE	SIGNIFICANCE OF AREA	THREAT
1	Bears Island (Effingham County)	5,890	Best unprotected virgin hardwood bottomland community in Georgia. Three endangered species with unique association of bottomland forest fauna.	Logging
2	Lower Altamaha River (Glynn, McIntosh, Long and Wayne counties)	69,800	Largest hardwood river-swamp ecosystem in Southeast. Primeval area with diverse aquatic and terrestial habitats. Five endangered species.	Clearcutting and secondary development in the flood plain.
2a	Boyles Island (Wayne County) [a]	7,000	Priority #1 lands included in Lower Altamaha River description.	Logging (approximately 600 acres have been recently cut).
3	Satilla River (Camden County)	30,000	Diverse freshwater and marine ecosystem supporting 9 endangered species. Area of significant importance to a larger coastal ecosystem.	Subdivision and industrial development along river bluffs.
4	Little Ohoopee River (Johnson and Emanuel counties)[a]	20,000	Five endangered species and two threatened vegetative communities. Best indigo snake habitat in Georgia.	Pine plantation conversion and housing development.
5	Flint River (Upson and Meriwether counties) [a]	32,000	Diverse ecosystem exerting significant biological influence on other habitats downstream of site. Diversity of terrestrial and aquatic flora and fauna.	Dam construction, housing development, poor timber management.
6	Little St. Simons Island (Glynn County)	8,095	Five endangered species and diversity of freshwater, marine, and terrestrial species. An endangered habitat.	Housing and industrial development potential.
7	Barbour/Oldnor Islands (McIntosh County)	5,000	Undisturbed tidal marsh and sea island habitat of importance to endangered species, mammals, and migratory and resident birds.	Subdivision developments adjacent to Harris Neck NWR. Important habitat will be destroyed by development.
8	Ogeechee River (Effingham and Bryan counties)	2,600	Best floodplain forest community along the Ogeechee River, with 4 endangered species. Blackwater river system.	Poor timber management for wildlife and recreational development in floodplain.
9	Grand Bay (Lanier and Lowndes counties) [a]	15,000	Diversity of habitats, 5 endangered species, and largest natural lake in Georgia. One of the largest Carolina Bay swamps known.	Recreational and housing development.
10	Ebenezer Creek (Effingham County)	1,350	Best remaining cypress-gum forest community in the Savannah River Basin, with a unique stunted virgin cypress forest. Two endangered species.	Recreational development along creek and under-story clearing in flood plain.

Appendix Table D-2. Concluded.

NO.	NAME OF AREA	ACREAGE APPROXIMATE	SIGNIFICANCE OF AREA	THREAT
11	Evelyn Grantly Tract (Glynn County)	565	Four endangered species. Site adjacent to Altamaha River near Georgia coast. Industrial development of area could have tremendous impact on the biological productivity of the Altamaha River and coastal ecosystems.	Area is adjacent to U.S. 17 and the Altamaha River waterway. A prime site for industrial development.
12	Chickasawahattchee Area (Dougherty County)[a]	900	Four endangered species and diversity of other aquatic and terrestrial species. Most extensive lime sink area in Georgia.	Drainage and poor timber management.
13	Amicolola Creek (Dawson County)[a]		Pristine mountain stream with redeye bass and trout fisheries. Diversity of flora and fauna.	Plans are being developed for subdivision housing of area.
14	Savannah River Swamp (Richmond County)[a]	7,700	Diverse aquatic and upland environment supporting an abundance of wildlife. Site of biological importance to the Savannah River ecosystem.	Clearcutting and drainage.
15	Alapaha River and Sand Ridge (Irwin County)[a]	1,100	Site contains sand ridge habitat which is threatened in Georgia. Unique flora and fauna, including gopher tortoise-indigo snake association.	Conversion to pine plantation.
16	Oconee River (Wilkinson County)[a]	7,180	Excellent bottomland hardwood habitat supporting a faunal diversity of terrestrial and aquatic species.	Clearcutting and development in flood plain.
17	Rabun Bald (Rabun County)[a]	72	Area of importance in controlling the land stability and management of a larger ecological zone.	Recreational and second home development.
18	Southern Nantanalas (Towns County)[a]	1,000	Area of importance in controlling the land stability and management of a larger ecological zone.	Second home development and poor timber management.
19	Towaliga River (Monroe County)[a]	36,000	Productive bottomland community providing important wildlife habitat in the Piedmont Region.	Poor timber management for wildlife, and recreational development.
20	Williamson Creek Swamp (Washington County)[a]	20,500	Extensive floodplain swamp supporting about the only remaining wildlife in an intensively managed agricultural area.	Poor timber management for wildlife, drainage for agriculture.

a. Outside of Sea Island Coastal Region.

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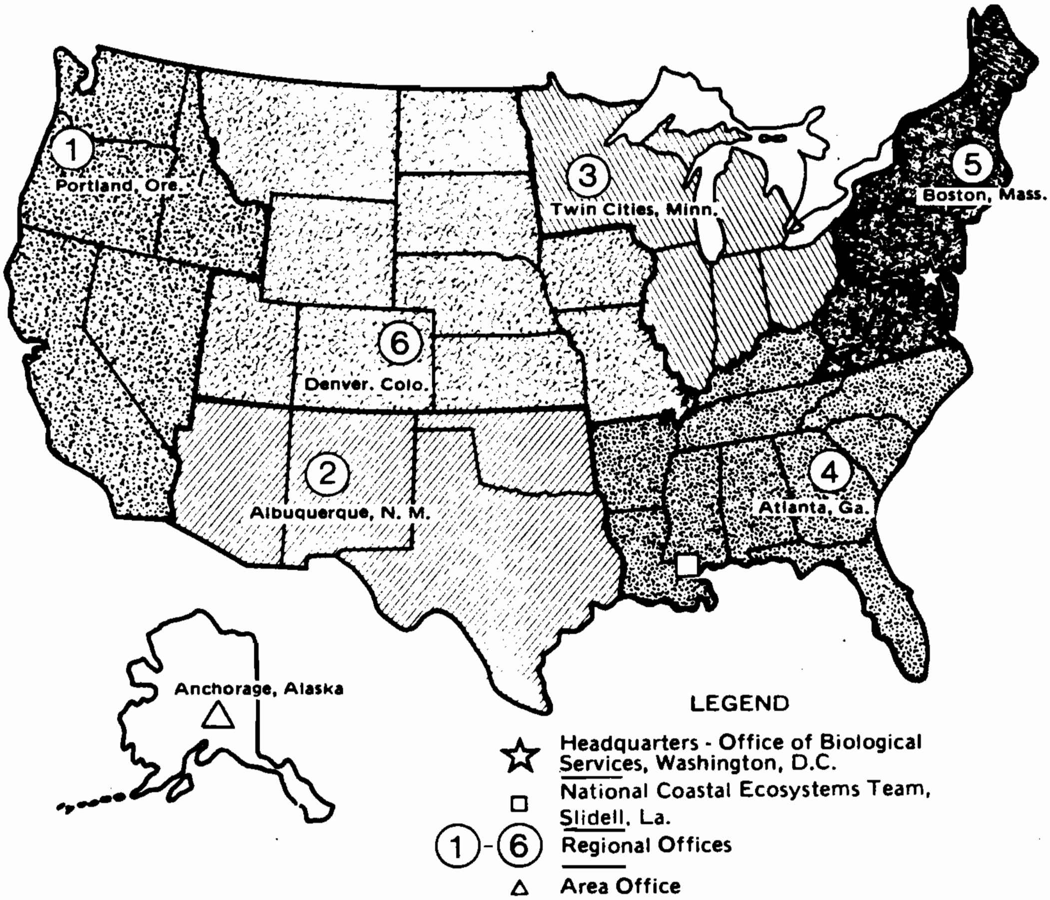

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