

THE AREAL ASSOCIATION
OF TAR-PAMLICO ESTUARINE
SHORELINE TYPES AND SHORELINE LAND USE

A Thesis

Presented to
the Faculty of the Department of Geography
East Carolina University

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts in Geography

by

Gary H. Wilfong

February 1977

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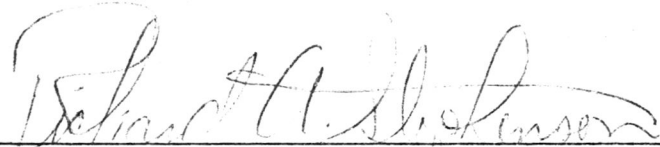
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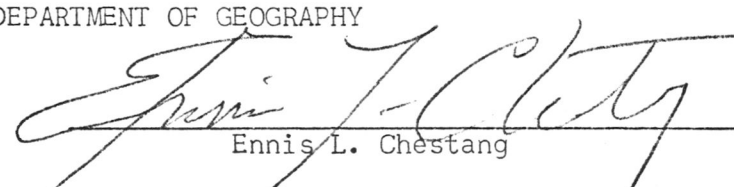
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The purpose of this investigation is to show the areal association between types of shorelines and shoreline land use. Field observations indicated the presence of a variety of shoreline features and land use functions. Measurements were made of randomly sampled shorelines to determine a shoreline classification system. Four distinct types of shorelines were identified using beach profile measurements. The spatial distribution of the various shoreline types showed that the Type I shorelines are more predominant along the north shore and Chocowinity Bay. Type II shorelines are randomly distributed throughout the estuary. The predominance of the Type III and IV shorelines on the south shore can be attributed, at least in part, to the Suffolk Scarp and the regional dip of rock strata.

Observations were also made of the estuarine shoreline land use. Five categories of land use activities were used. Their spatial distribution shows that the north shore is more developed than the south shore. Residential areas are, in most cases, clustered. This clustering tendency is demonstrated by the comparison of the housing density of the entire shoreline with the density of those areas considered as residential. The Texasgulf complex, located on the southern shore, is the only form of industrial land use in the study area. Recreational and farming activity is scattered along both shorelines.

A contingency table was constructed from a sample of the two spatial distributions. A statistical analysis of the data from the contingency table was accomplished using the Chi-square test. The results of this test is significant at the 99 percent confidence level. The null hypothesis that there is no relationship between the distributions was rejected. This suggests that an areal association exists. An interpretation of the test means that the shoreline residents recognize that some shorelines are more favorable for development than others. That can be, at least in part, substantiated by personal interviews. These interviews suggest that most residents were aware of developmental problems. Unfortunately, the awareness of some shoreline residents was not determined until after their property was purchased and most had already suffered property loss due to high water or erosion. Newer residents are benefiting from the experience of others, as homes are either being built on pilings at higher elevations, or are being protected by a variety of shoreline protection devices.

This investigation determined the degree of vulnerability of the nine natural segments using data from the Shoreline Erosion Inventory in conjunction with the housing density and total percentage of Types I and II shorelines. Location is also an important consideration because of storm direction, fetch, wave energy and storm tides.

The combination of these variables will, no doubt, be useful as an aid in determining those areas that will be least effected by storm damage in the future, or those areas where development is more favorable.

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Chapter I

INTRODUCTION

STATEMENT OF PROBLEM

The purpose of this investigation is to determine the areal association between type of shoreline and shoreline land use in the Tar-Pamlico Estuary (Figure 1). Demand for land and water resources seems to increase expotentially with the growth in population thus establishing the rationale for this investigation. At the present time, population pressure in Eastern North Carolina has not reached such proportions that the scarcity of suitable land for settlement has become a problem. Yet, a demand does exist for much of the available shoreline property along the Pamlico River. Several factors are responsible for this demand. The clean, relatively unpolluted waters of the estuary are a vital source of marine life for the commercial and sport fishing industry. Agricultural and commercial forestry activities are taking place on the adjacent shoreline areas as well as the mining of minerals. The most evident demand, however, is for outdoor recreation and its associated activities.

It must be recognized that even though the demand for these estuarine shorelines is increasing, the availability of the shoreline areas are themselves limited. Unlike economic factors, the availability of estuarine shorelines as a resource does not increase with the demand. If the current demand continues to increase, the

LOCATION OF THE TAR-PAMLICO ESTUARY

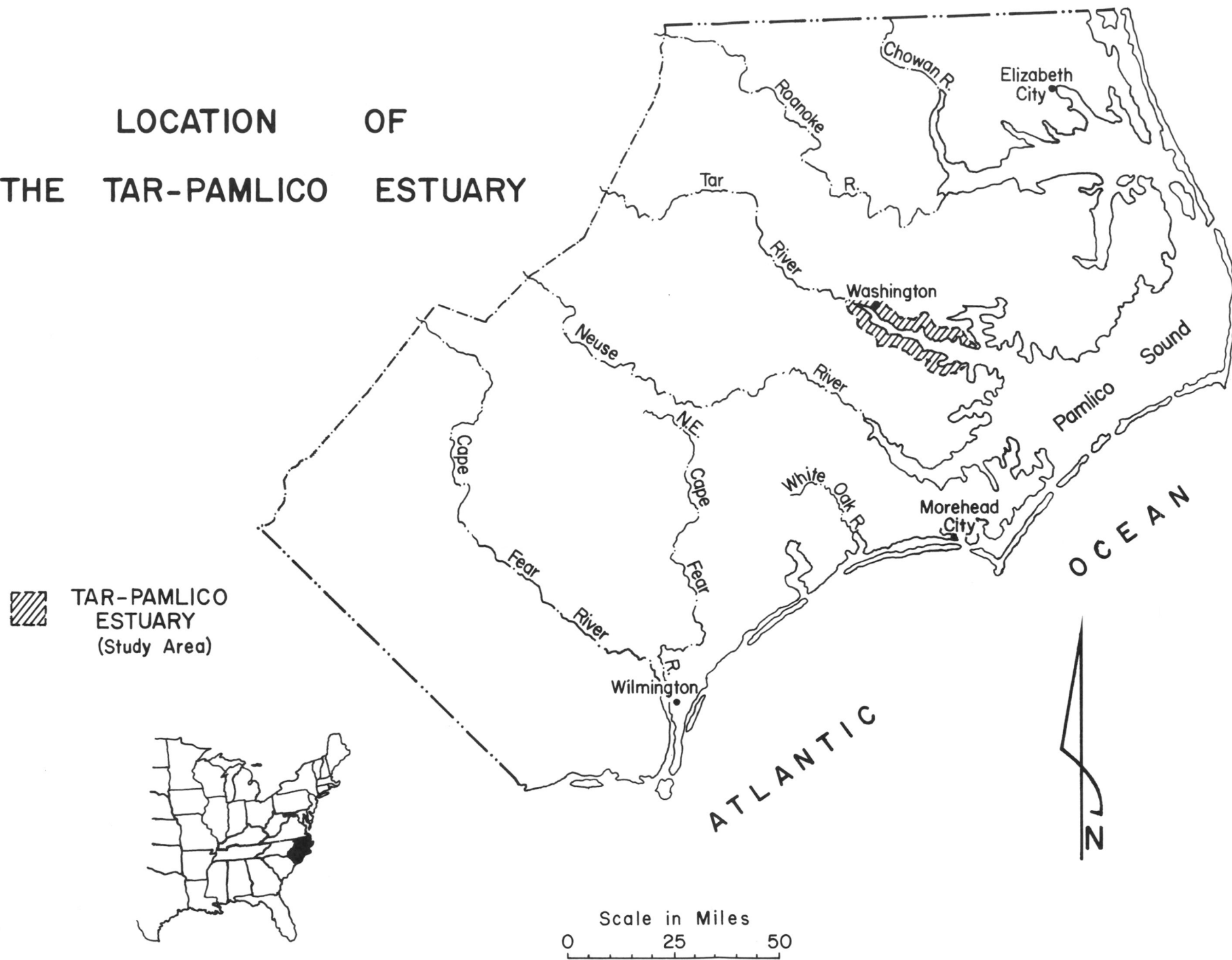


FIGURE 1

availability of land for the purposes originally desired will be almost non-existent.

The demand for the use of estuarine waters will undoubtedly continue to increase. The population pressure upon these estuarine areas, in itself, establishes sufficient rationale for this investigation.

GEOGRAPHICAL SIGNIFICANCE

The relationship between the type of shoreline and shoreline land use in a spatial context is geographically significant because of the linear distribution of the different variables associated with the estuarine shoreline. Since estuarine areas, in most cases, are headed for rapid extinction, it is an excellent time to engage in estuarine research (Russell, 1967). Due to the increasing demand for these resources, research in all areas of the estuarine environment is necessary. Those remaining estuaries which are not yet mutilated are ". . . America's most vulnerable frontiers"(Johns, 1969). To make a complete and comprehensive study of estuaries, it is desirable to trace events as far possible into the past. This would enable the investigator to be familiar with all aspects of the study. Estuarine studies are particularly important today because of how man is manipulating estuaries and their adjacent land areas. Estuaries, along with large lakes and many streams, have become customarily regarded and treated, as virtually limitless reservoirs for dumping industrial and municipal wastes. Since they empty directly into the oceans, estuaries are especially favored as flushing basins by planners and sanitary

engineers. Many estuaries are now no more than urban sewers. In many areas, they are being ringed with concrete seawalls and filled in to either create new land for industrial or commercial development or to attract the affluent looking for "waterfront" homes. Hopefully, a greater understanding of the ecology of estuarine regions will at least slow down the eradication of these unique and important areas (Reid and Wood, 1976).

The significance of estuaries and their related features as a study area can best be substantiated by their vulnerability to human influence. They receive the impact of many human activities and are the brunt of some of the most intense levels of use applied to any marine water area. Man's effect on estuaries, prior to 1850, was probably negligible and limited to the effects of silt erosion from agricultural areas and the disposal of human wastes. A significant increase in agricultural activities, industrial growth, energy production, more transportation routes, and population growth has placed additional pressure on these waters.

New innovations must be utilized to counteract the effects of uncontrolled growth. Basic research is mandatory. Resource management and planning, and the application of sound concepts and techniques must be applied. The results can then be used to prevent certain uses and abuses from degrading these areas. Furthermore, the education of the public is vital to assure the proper use of estuaries. It has even been recommended that selected "typical" estuaries be set aside as undisturbed research centers. It has been proposed that these are to be protected from the exploitation that has destroyed many estuaries in

the past (Cronin, 1967).

Ippen (1967) states:

The ecology of estuaries has very recently moved into the forefront of activities by marine scientists and coastal engineers and intense research studies are underway on computers, in experimental laboratories, and in the field. These have been stimulated by the fact that most of our population centers along the coast have generated increasing demands on the important resource potentials of our estuaries with the respect to use in commerce, industry, urban utilities and public recreation.

We are only now becoming aware that such piece-meal exploitation following the convenience of the movement must receive utmost study and care and that an estuary environment represents a complex system of hydrodynamic components interacting quite delicately with biological, economic and social factors.

By being located along the coastlines of most of the continents, estuaries have served as the main centers of man's development because of their fertile waters, sheltered anchorages, and navigational access (Dyer, 1973). They serve to moderate the weather, provide recreational opportunity of practically all kinds, and perhaps are the most unique and valuable fish and wildlife habitat we possess (Chadbreck, 1973).

North Carolina has more estuarine areas enclosed within its coastline than any other Atlantic or Gulf Coast state. The open water area totals 2,206,000 acres and the coastal marsh include 206,000 acres (U.S. Army, Corps of Engineers, 1970). Increasing demand upon available land and water stresses the importance of ascertaining the future uses of the estuarine system to prevent the destruction of one of North Carolina's most valuable resources. Knowledge of what processes are taking place in an estuary and their relationship to the land area surrounding the estuary is important to industry, land development, and estuarine contamination.

This study will serve as a data base for future investigations. The information will also be of value in fields of study other than geography since it will facilitate projections of future development. As an aid in the prediction of future shoreline land use, the geographical significance of this investigation will continue to increase proportionally with the demand.

SOURCES OF DATA

Since this study is concerned with the physical aspects of geography, the investigation has covered the entire spectrum of research from gathering data from published sources in the library to wading in the water of the Pamlico River to obtain beach measurements.

A comprehensive review of the literature was the initial undertaking to determine that this study does not duplicate any previous investigations of this type and that the required information would be available. Map and aerial photograph comparison was used to determine the degree of development and human interference. The majority of the information, however, was obtained through field investigations, consisting of: (1) personal observations, (2) interviews, and (3) aerial overflights.

Three sources were particularly useful in this research. They include: (1) Estuarine Shoreline Erosion In The Albermarle-Pamlico Region of North Carolina (Bellis, O'Connor, and Riggs, 1975), (2) National Estuary Study (U.S. Army Corps of Engineers, 1970), and (3) Shoreline Erosion Inventory (U.S.D.A.-Soil Conservation Service, 1975). The Shoreline Erosion Inventory accounted for the amount of erosion

along the Pamlico River from 1938 to 1970.

Three modes of transportation were required for the fieldwork: (1) airplane, (2) boat, and (3) automobile. The boat was the most valuable form of transportation. It was used to observe the different sampling locations as well as the land use of the entire shoreline study area.

METHODOLOGY

SHORELINE DESCRIPTION

A sample of shoreline profiles were made, in order to determine the various types of shorelines found in the study area. The area selected for this study has approximately seventy-two miles of shoreline. In 1972, the shoreline was divided into one-mile intervals with each mile constituting a sample point. Thirty of the sampling points were selected for field investigation using a random numbers table. An additional list of alternates were compiled in the event some of the sample sites would be inaccessible.

At each selected site, several observations were needed for the investigation. A beach profile was made to obtain the percentage of shoreline slope. Other observations, such as (1) shoreline features, (2) man-made features, (3) earth material and vegetation, (4) beach trend, and (5) weather conditions were recorded for future use. All of these observations were made from July to November, in order to insure a certain degree of uniformity as far as seasons and weather conditions were concerned. For the purposes of this investigation, the term "shoreline type" refers to a ground slope profile drawn along a line perpendic-

ular to the shoreline. The different variables observed along this line include slope, vegetation, and shoreline features, and were used to classify the shorelines.

SHORELINE LAND USE

To determine the degree of development that has occurred along the Tar-Pamlico Estuary in the past two decades, map and aerial photograph comparison and personal observations were required. This investigation is concerned with the land use of the study area using all available information. Map series (1:24,000) published in 1951 by the U.S. Geological Survey were used to determine the amount of development at that time. The criteria used to determine the amount of development consisted of: (1) number of buildings, (2) piers, and (3) jetties. The entire shoreline to a depth of 200 feet was observed from a small boat from September to December in 1976, using the same criteria. The information gained from the boat reconnaissance was compiled on a map to use as a comparison with the earlier map and aerial photograph interpretation.

A total of twenty-four personal interviews were conducted along both sides of the estuary. Those interviewed consisted of permanent and seasonal residents, life-long and recent, and young and old with a variety of educational levels. The purpose of these interviews was to gain additional insight into shoreline processes through their personal observations.

CHAPTER II

THE STUDY AREA DEFINED

ESTUARY DEFINED

An estuarine system can be defined as ". . . a semi-enclosed coastal body of water which has a free connection with the open sea and within which seawater is measurably diluted with freshwater derived from land drainage" (Pritchard, 1967). In a geomorphological context an estuary can be defined as a lower part of a river course that is affected by the interface between salt and freshwater (Fairbridge, 1968).

The four universal primary subdivisions of estuaries from the geomorphological standpoint are: (1) drowned river valleys, (2) fjord-type estuaries, (3) bar-built estuaries, and (4) estuaries produced by tectonic processes (Pritchard, 1967). A brief description of a bar-built estuary is as follows:

When offshore barrier islands and sand spits build above sea level and extend between headlands in a chain, broken by one or more inlets, bar-built estuaries are formed. The area enclosed by the barrier beaches is generally elongated parallel to the coastline. Frequently more than one river enters into the estuary, though the total drainage area feeding a bar-built estuary is seldom large. The lower valleys of such rivers have frequently been drowned by the rising sea level, and hence the bar-built estuary might be considered as a composite system, part being an outer embayment partially enclosed by the barrier beaches, and part being a drowned river valley or valleys. Because the inlets connecting the bar-built estuary with the ocean are usually relatively small compared to the dimensions of the sound within the barrier, tidal action is considerably reduced in such estuaries. These systems are usually shallow, and the wind provides the

important mixing mechanism. Albemarle Sound and Pamlico Sound are examples of bar-built estuaries (Pritchard, 1967).

The Tar-Pamlico Estuary is a part of the Albemarle and Pamlico Sound system. This portion stretches from Washington, North Carolina to the confluence of the Pungo River on the north shore and Goose Creek on the south shore (Figure 1, p 2). The Estuary extends some thirty-five miles with the Tar River serving as the primary tributary, and represents but one component in the South Atlantic Estuarine Zone.

SOUTH ATLANTIC ESTUARINE ZONE

This estuarine zone extends from Cape Henry, Virginia, to Fort Lauderdale, Florida (U.S. Army, Corps of Engineers, 1970). The coast is bordered, except in Florida, by a one hundred mile wide Coastal Plain and almost equally broad Continental Shelf. Laterally joined estuaries behind nearly continuous barrier islands are typical of the South Atlantic Coast southward to Cape Fear, North Carolina and from Jacksonville, Florida to Fort Lauderdale. Between Cape Fear and Jacksonville, the estuaries are more open and the barrier islands more fragmented.

Tidal marshes, swamps, and wetlands as well as estuaries are abundant throughout the coastal plain in this region. Wetlands extend inland almost the width of the plains along some streams, and almost continuously along the landward sides of the estuaries. Great swamps such as the Okefenokee in Georgia, Dismal in Virginia and North Carolina, and many smaller ones are located inland from the extensive tidal marshes. This area is also known for its favorable climate, beautiful beaches and numerous historical sites.

THE PAMLICO-ALBEMARLE-CURRITUCK SOUND COMPLEX

The Pamlico-Albemarle-Currituck Sound Complex and associated inshore waters occupy a "drowned" portion of the North Carolina Coastal Plain (U.S. Army, Corps of Engineers, 1970). This complex is the second largest estuarine system on the east coast of the United States, with the sounds extending a length of about 170 miles with a maximum width of 30 miles.

Substrate near mouths of inflowing streams is composed of deposits of mud and organic debris. The deeper, central areas generally contain a more firm bottom of sand and mud.

It is commonly stated that there are no lunar tides in these North Carolina sounds except at the inlets, which implies a general lack of tidal currents. Lunar tides are experienced at the inlets but their effect is dampened with distance from these inlets. The tides vary from a maximum of three feet near the inlets to barely noticeable variations elsewhere within the sounds. The tides created by the wind is the dominant factor in these expansive sounds and adjacent waters. The wind tides are quite important in the mixing of the estuarine waters and in the erosional and depositional processes that are taking place in the estuary.

It is estimated that about sixty percent of all the United States' commercial finfish and shellfish and most marine sport fish inhabit estuaries during all or part of their life cycles. It is also estimated that about ninety percent of the North Carolina commercial finfish and shellfish harvest is dependent upon estuarine environments. This complex contains over two million acres, which represents about

ninety percent of the total estuarine area in North Carolina.

The land areas at higher elevations generally contain pine and hardwoods interspersed with open fields and farmland. Hardwood swamps abound and are characterized by surface water levels that vary seasonally from a few inches to five feet in depth. Extensive salt marshes are interspersed with mud flats, vegetated shallows, and non-vegetated beaches.

The plentiful food supply, diversity of natural habitats, and relative remoteness of the area combine to make the estuary economically attractive for recreational and commercial investments that can possibly be gained from the marine and wildlife found here.

THE TAR-PAMLICO ESTUARY

The Tar-Pamlico Estuary was formed from the submergence of the coastline of North Carolina, and its existence is similar to many other locations along the Eastern Seaboard. Due to the rise in sea level from the melting ice of the last glacial period, many river mouths and valleys opening into the Atlantic Ocean were flooded. The results in many cases was an estuary.

From the origin of the estuary, constant changes take place with every ebb and flow of the tide and variation in wind and fresh water inflow. The influence of man should also be recognized as having a long term effect in estuarine modifications. Because of his dynamic role in environmental reconstruction, it is imperative that man be treated in a context similar to that of the physical processes taking place. While it may take countless number of years for nature to create

a physical form or feature, man may alter and then attempt to rebuild the same feature in a relatively short period of time.

PHYSICAL ASPECTS

The Tar-Pamlico Estuary extends some thirty-five miles from Washington, North Carolina to the Pamlico Sound. It is shallow, from two to six miles wide, and has from 0.5 to 15 or 20 percent salinity. Surface temperatures range from 8°C (46°F) to 29°C (84°F). Vertical variations in temperature and salinity are slight because the estuary is shallow and a high amount of mixing takes place (Stephenson, O'Rear, and Kornegay, 1975). The mixture of freshwater from the rivers and streams reduces the salinity of the inflow from the oceans. Water in the estuary moves very slowly. This is due in part to the slow movement of the river and streams entering the estuary. It is estimated that the outward flow of the water is about 2 or 3 thousand cubic feet per second or a flushing time of about a mile a day (Hobbie, 1971).

Lunar tides are usually less than six inches, and wind tides near three feet. During periods of calm wind conditions and high inflow of freshwater, stratification can occur in the deeper portions of the estuary. Mixing that occurs during the frequent high wind conditions limits these periods of stratification.

The combination of wind tides, shallowness of the estuary, and the high amount of suspended solids in the Tar River, result in a high turbidity rate. It is also speculated, that the inflow of tannin water from swamps add to the turbidity (Harwood, 1975).

BIOLOGICAL ASPECTS

Biologically, the Tar-Pamlico Estuary is a shallow, brackish system. The entire estuarine system encompasses about 4,300 square miles.

The dominant zooplankton is the copepod, Acartia tonsa, which is fed upon by larval fish and by the ctenophore (comb-jellyfish), Mnemiopsis leydii (Hobbie, 1971). There are two ecological categories of fish found in the estuary. The first group is predominantly fresh-water and are considered as permanent residents. They include: Yellow Perch, Pumpkinseed, Largemouth Bass, and Bluespotted Sunfish. The second group consists of migratory species that move into the area primarily during the late spring and move out during the winter and include: Spot, Croaker, Pinfish, American Eel, Atlantic Menhaden, and Striped Mullet (O'Rear, Stephenson, Kornegay, Bailey, and White, 1975).

The benthic animals (bottom dwelling) are dominated in the fresher parts by the clam, Rangia cuneata, and in the saltier parts by the bivalve, Macoma balthica (Hobbie, 1971).

The low tidal marshes are dominated by the smooth cordgrass, Spartina alterniflora. These marshes are usually subject to regular inundation by the more dominant wind tides and by the less effective lunar tides. Marsh areas are soft and muddy and contribute significant amounts of silt and organic material. They serve as a nursery area for young marine life and as a sanctuary for the other forms of wildlife. A secondary form of marsh grass associated with the estuary is the Black Needlerush, Juncus roemarianus. This type of marsh grass is found at higher elevations and does not contribute much organic material

BULLSHIT

to the estuary. Also found adjacent to and sometimes intermingled with the marshes are cypress, various hardwoods and pine (Baker, 1975).

A variety of aquatic macrophytes are found in the Tar-Pamlico Estuary. The different species are as follows: Vallisneria americana, Potamogeton perfoliatus var. bupleuroides, Najas guadalupensis, and Ruppia maritima. Their habitat varies from year to year based upon water depth, turbidity, temperature, and salinity. Although the aquatic macrophytes are an important link in the estuarine food chain, they are also a nuisance element as they foul propellers on boats, make swimming and wading virtually impossible and they wash up on beaches to decay, thereby producing anaerobic conditions and unpleasant odors (Harwood, 1975).

⇒ book on types of plants (swamp, marine, etc)
⇒ basic marine geog-book

CHAPTER III

THE TAR-PAMLICO ESTUARINE SHORELINES

INTRODUCTION

In order to determine whether a relationship between types of shoreline and shoreline land use exists, it was found expedient to classify the various shorelines and shoreline features found in the study area. Field observations, aerial overflights, and topographic map analysis verified the presence of a variety of shoreline forms. Data was assembled into a workable classification system suitable for the purposes of this investigation. The classification system and the spatial distribution of the various types of shoreline will be discussed in this chapter.

GENERAL DESCRIPTION

A wedge of light-colored sand and clay soils covers eastern North Carolina. These soils originate from river and estuarine sediment deposits during several periods when the sea extended much further west of the present coastline. Some 30,000 years ago, during the Pleistocene sea level reached its lowest point, perhaps 400 feet lower than present. During this time period much of the continental shelf lay exposed and was probably covered by cold, low, wetlands and forested uplands. During the warming trend following the last "ice age", birch and maple replaced the fir and spruce forest, and they were in turn

replaced by oak and hickory. Pines occupied both the well drained, higher elevated sandy areas and also vast open spaces within the hardwood forest that had been cleared by frequent fires. The river valleys and swales between relict beach ridges were then sequentially occupied by freshwater marsh, brackish marsh, and finally salt marsh. These marshes will too become a part of relict shoreline forms if sea level continues to rise at the present rate of approximately 0.5 to 1.5 feet per century.

Ancient shorelines and marine sediment deposits reflect the changes in sea level associated with various glacial and interglacial periods. The most noticeable of these features is a prominent ridge or scarp traced throughout northeastern North Carolina known as the Suffolk Scarp or Pamlico Strand. Elevations at the foot of the scarp are 15 to 20 feet while the ridge rises as high as 40 to 50 feet above sea level. The area east of the scarp is known as the Pamlico Terrace and consists of similar fossiliferous marine sands and clays (Bellis, O'Connor, and Riggs, 1975).

These terraces are slowly being inundated by the rising seas, and where streams and their valleys developed they are now becoming embayments. These embayments tend to divide the estuarine shoreline into nine segments. Since drainage patterns are dependent upon the structure of our time, it seems logical to divide these segments for analytical purposes (Figure 2).

*Catherine
Piles*

TYPES OF SHORELINE

Slope and vegetation were used to devise a classification system of shoreline type. As stated in Chapter I, the entire estuarine shoreline system was divided into one mile intervals. Thirty sample locations were randomly selected for the purpose of observation, measurement, and analysis. Several alternates were also selected in the event that some of the points were not accessible or available for observation. Shoreline slope was determined from beach profiles. The beach profiles were made landward from the water's edge for one hundred feet or until there was no appreciable change in the profile. The general description and shoreline vegetation were also recorded.

*Catherine
Piles* Data was compiled and analyzed and four significantly different slopes were observed (Table I). The four types are as follows: (1) a shoreline profile with a slope of less than one percent, (2) a shoreline profile with a slope of 1.1 to 6.9 percent, (3) a shoreline profile with a slope of 7.0 to 19.9 percent, and (4) a shoreline profile with a slope of greater than twenty percent. A brief description of the four types of shoreline follows.

** Type I Marshes*

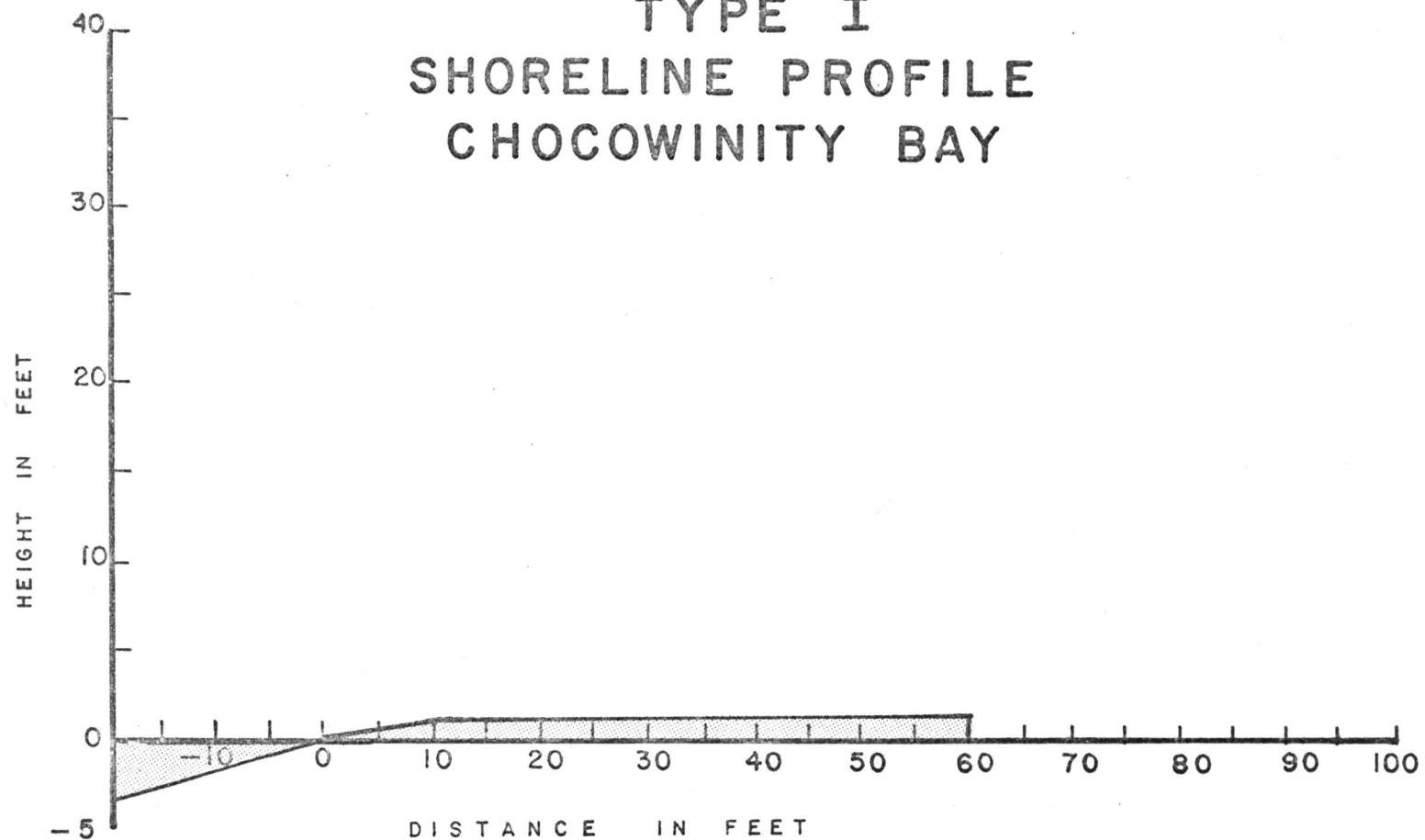
Those shorelines defined as Type I found in the Tar-Pamlico Estuary are limited to a maximum slope of one percent (Figure 3a). The actual slope is almost negligible, and two vegetative forms are generally associated with this type of shoreline. Marsh grass species vary with water depth and salinity. A species of marsh grass that is underwater during periods of high tide is the Spartina alterniflora. Juncus

TABLE I
SELECTED DATA FROM SHORELINE MEASUREMENTS
ALONG THE TAR-PAMLICO ESTUARY

Sample Shore	Description	Slope (%)	Type
South	Marsh	0.1	I
South	Marsh	0.1	I
South	Marsh	0.1	I
North	Marsh	0.1	I
North	Marsh	0.1	I
North	Swamp Forest	0.1	I
North	Beach	0.9	I
South	Beach	1.1	II
South	Beach	1.4	II
North	Beach	1.8	II
North	Beach	1.8	II
South	Beach	2.8	II
South	Marsh & Cypress	3.0	II
North	Beach	3.0	II
North	Cypress Swamp	3.3	II
North	Beach	4.0	II
North	Beach	4.8	II
North	Beach	5.0	II
South	Beach	6.6	II
North	Beach	8.0	III
North	Beach	8.0	III
North	Moderate Bluff	8.3	III
South	Moderate Bluff	11.8	III
South	Steep Bank	18.3	III
South	Steep Bank	22.6	IV
North	Steep Bank	34.0	IV
South	Steep Bank	37.8	IV
South	Steep Bank	42.4	IV
South	Steep Bank	43.9	IV
North	Steep Bank	58.0	IV

Source: Derived from data collected by the author during field observations in the fall of 1972.

TYPE I SHORELINE PROFILE CHOCOWINITY BAY



1972

FIGURE 3a

roemarianus is found at slightly higher elevations and is normally not under water.

Marshes are characterized by oxygen deficient, water-saturated peat soils subject to periodic flooding by fresh to brackish water. Marsh grasses respond rapidly to slight changes in water level. Low water levels promote evaporation and oxidation while high water retards these processes. Salt and brackish marsh grasses are very productive of organic material, some of which remains in the marsh to form new layers of peat.

Wave action is eroding away those portions of the marsh adjoining the estuary. The wave action undercuts the peat layer, creating a cavity beneath the grass. This leaves the shoreline increasingly more vulnerable to extensive wave action or energy. Water adjacent to the marsh is often very turbid due to the presence of colloidal or suspended peat that has been deposited from the marsh. A benefit to be gained from marshy areas is that they serve as a buffer to disperse the energy of wave action; thus protecting sandy shorelines (Bellis, O'Connor, and Riggs, 1975).

~~HOW~~ Also included within this classification are swamp forests. This vegetation is generally at a somewhat higher elevation than marshes or in areas of minor water level fluctuation and consists of cypress and other hardwoods occasionally intermingled with pine. Low gradient, combined with low relief increases their susceptibility to flooding and retention of standing water during wet seasons of the year (Bellis, O'Connor, and Riggs, 1975). Offshore water depth is generally shallow with remnants of tree stumps and cypress knees indicating erosional

activity. Swamp forests, however, are areally insignificant in comparison to the marsh areas. A combination of marsh and forest is quite common, with the hardwoods grading into pine towards the mouth of the estuary.

TYPE II

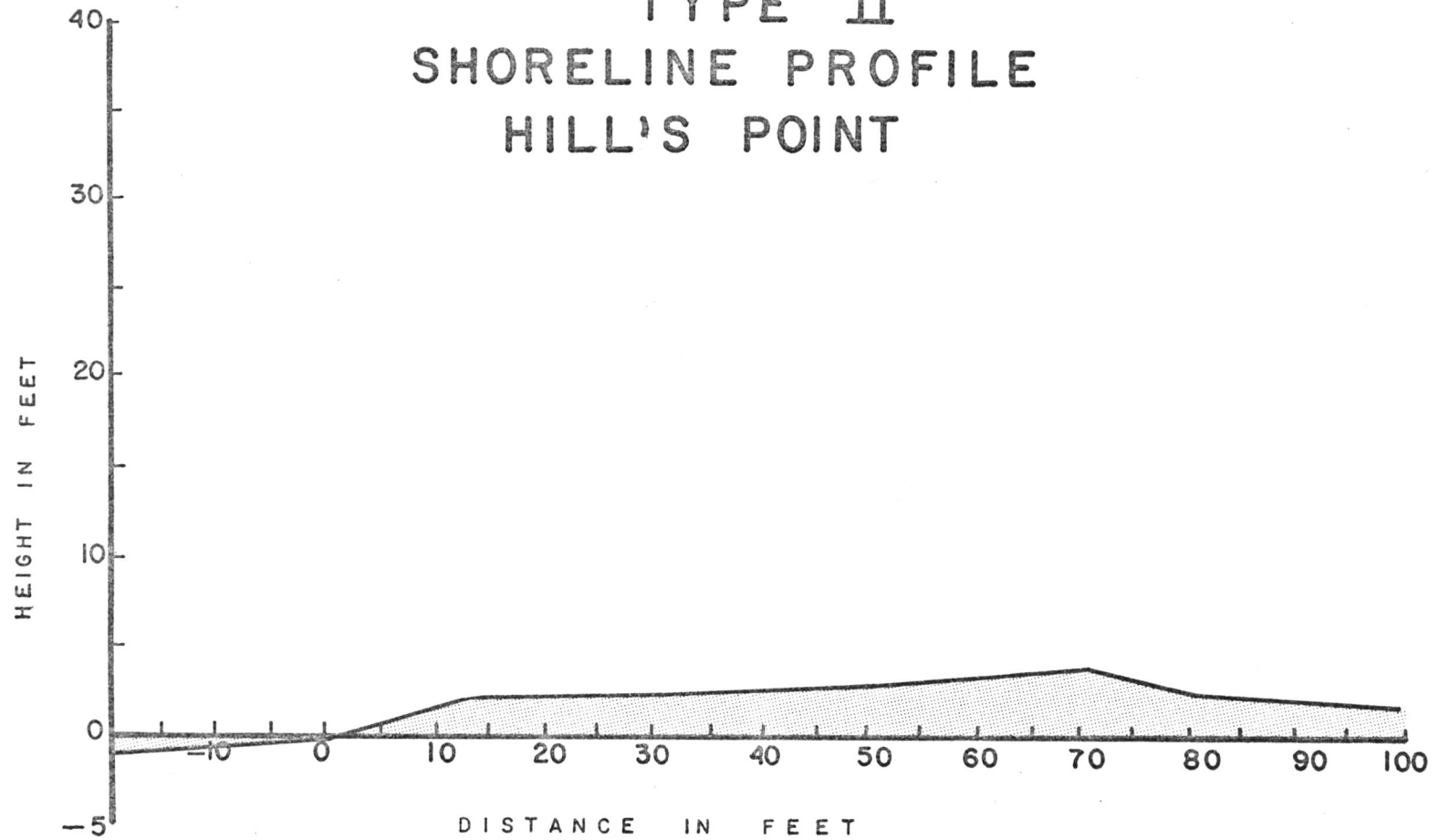
Those shorelines defined as Type II profiles are limited to a slope of 1.1 to 6.9 percent. This form is associated with bar-built formations along the estuarine shoreline. In some cases, these beaches are the remains of relict bars. Some of the beach features resemble, on a miniature scale, those forms associated with ocean beaches. Examples include a bay-mouth bar, with marsh grass growing in the area beyond the beach, and spit formations attempting to close off the mouths of small streams. Other indications of depositional activity are the presence of sandy beaches of varying width (Figure 3b).

Shoreline beaches generally consist of a moderately cohesive mixture of medium sand, silt and clay, and quite commonly have a clay-rich layer which occurs at or just below the water level (Bellis, O'Connor, and Riggs, 1975).

Vegetation varies from marsh grass to cypress and pine forest, depending upon the elevation. The vegetation also varies in an easterly direction as pine forests become more dominant approaching the mouth of the estuary.

These shorelines experience both erosional and depositional activity, however, erosional activity appears to be the more dominant. Aerial photographs of the area indicate that the erosional activity

TYPE II
SHORELINE PROFILE
HILL'S POINT



1972

FIGURE 3b

tends to reduce the size of the depositional formations.

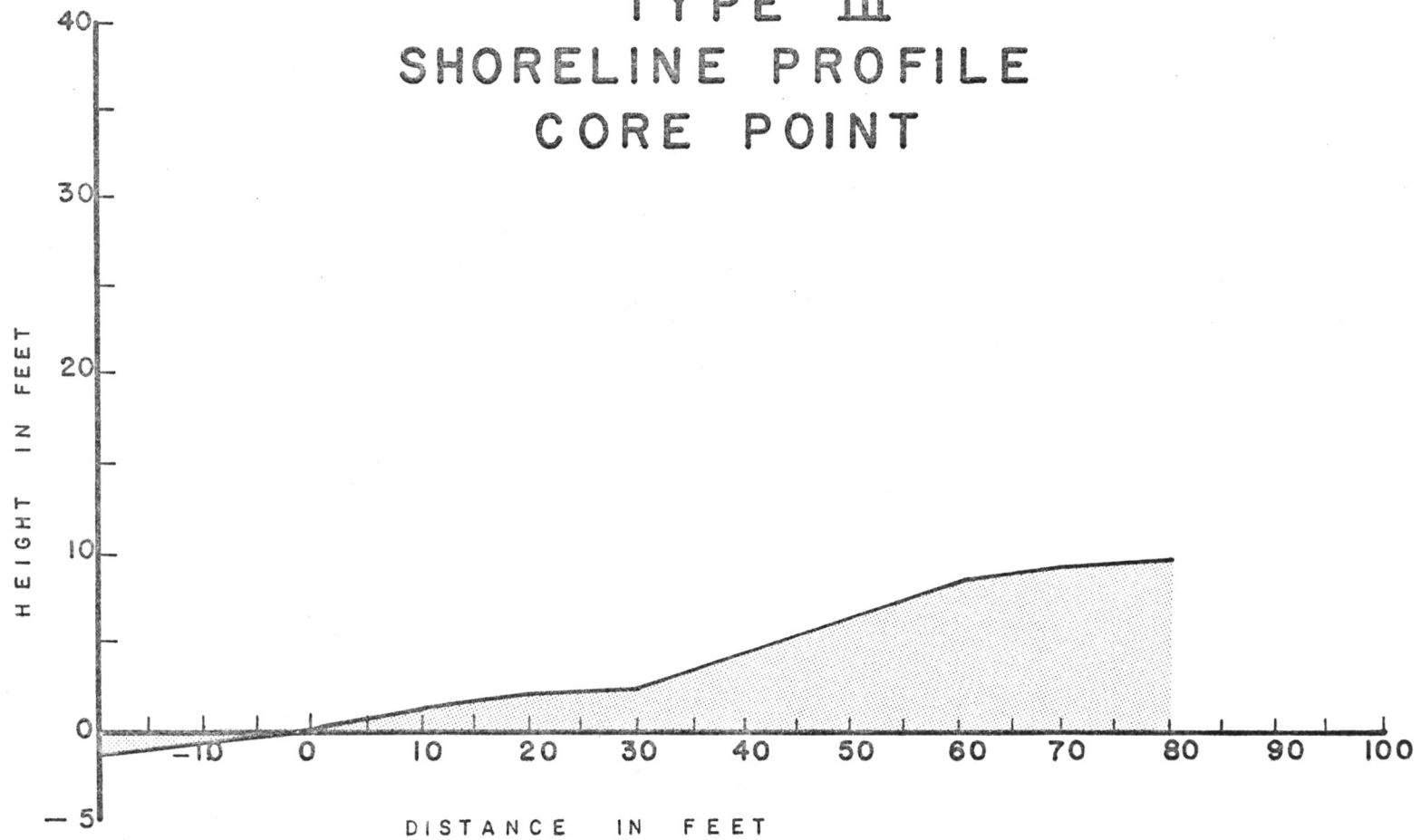
TYPE III

A beach profile with a slope of 7.0 to 19.9 percent defines a Type III shoreline (Figure 3c). The shorelines generally consisted of a sandy beach rising upward to its maximum elevation after passing through several terrace-like levels. These beaches, like the Type II, are bar-built formations, sloping upward through several older, larger terraces. In addition, this category includes a narrow beach, often covered with fallen trees and debris sloping upward to its maximum elevation.

These beach forms consist of moderately to occasionally well hardened mixtures of sand, silt, and clay. In some areas west of the Suffolk Scarp, more resistant bluffs of varying degrees of hardness of sand and clay, make up the base. The majority of these materials are the uppermost units of the Yorktown Formation of Miocene Age, with some being younger Pleistocene deposits. Erosional activity is slower in those areas consisting of the more resistant materials than the moderate to severe erosion rate of those shorelines consisting primarily of sand. When the overlying soils are water bearing, this often leads to slumping of the overlying layers (Bellis, O'Connor, and Riggs, 1975).

Vegetation varies with elevation and distance relative to the mouth of the estuary. Some marsh area is still evident at the confluence of streams and occasionally at the bases of the larger bars and narrow beaches.

TYPE III SHORELINE PROFILE CORE POINT



1972

FIGURE 3c.

TYPE IV

Steep cut banks with a slope of greater than twenty percent define the Type IV shorelines (Figure 3d). Erosion is more severe at these locations than any other observed in the study area. Extensive slumping is evident, with the earth material accumulating at the base of the bank. This accumulation serves as a source of material for future erosion. In some cases, fallen trees indicate undercutting by wave action and erosion. Undercutting, results in a loosening of the bank, which would eventually lead to further slumping. Intermittent beaches frequently exist at the foot of the steep cut banks. These narrow beaches are normally formed during interstorm periods.

These steep banks consist of the same material found in the Type II shorelines, except that the bases are much more likely to consist of the more resistant Miocene clays and sands. Most occur within the Suffolk Scarp, but some are found in the Talbot Terrace farther to the west (Bellis, O'Connor, and Riggs, 1975). The frequent slumping of the steep banks discourages any permanent vegetative cover. Thick hardwood and pine forests grow at the top of these high steep banks and those nearer to the edge fall as the result of erosion.

SPATIAL DISTRIBUTION OF TYPES OF SHORELINE

The spatial distribution of the four shoreline types found in the estuary is the result of several variables including: (1) elevation, (2) vegetation, and (3) beach profiles. Since only thirty sampling points were selected for field measurement, the remaining data was obtained from the 1951 U.S. Geological Survey (1:24,000) topographic

map series. Although shoreline alteration could have possibly occurred since the maps were published, field observations of the entire shoreline indicated that such was not the case. The description of the spatial distribution of the types of shorelines will be made according to the nine natural segments of the estuary (Table II).

WASHINGTON, NORTH CAROLINA TO BROAD CREEK

Type II shorelines dominant this segment of the study area (Figure 4). Here, elevation is the primary controlling factor. There is a slight variation in elevation with the highest locations being considered as Type III. The majority of the shorelines in this area have a slope of less than four percent, with the Type III shorelines being located in the center.

In those areas where natural shorelines exist, erosion is evident. Very few areas remain in their natural state due to man's alteration of the shoreline. A large portion of the shoreline is protected by bulkheads, groins and jetties, those areas unprotected are receiving the brunt of the erosion (Figure 5). Recession of these shorelines under the impact of this high wave energy is evident by the large number of tree roots and stumps offshore. While the profile gradient is low, there is an abrupt change in slope near the water's edge. This abrupt change can be attributed to slumping at the plunge point with the increase in wind tides and wave height.

The shoreline crenulates with small bays and points. The resistance to erosion can be seen where root system of trees hold the earth material together. It is sometimes difficult to observe these

TABLE II

LENGTH OF SHORELINE AND SHORELINE TYPE ACCORDING TO
SHORELINE SEGMENTS ALONG THE TAR-PAMLICO ESTUARY

NORTH SHORE LOCATION	Length (Miles)	Type I (%)	Type II (%)	Type III (%)	Type IV (%)
Washington-Broad Creek	7.2	0.0	94.4	5.6	0.0
Broad Creek-Bath Creek	9.0	50.0	40.0	4.4	5.6
Bath Creek-North Creek	10.1	35.6	51.5	12.9	0.0
North Creek-Pungo River	5.8	5.2	43.1	37.9	13.8
Totals	32.1	26.2	56.4	13.4	4.0
SOUTH SHORE LOCATION					
Whichard Beach Peninsula	7.2	90.3	9.7	0.0	0.0
Chocowinity Bay-Blounts Creek	9.2	27.2	10.9	15.2	46.7
Blounts Creek-Durham Creek	11.1	16.2	22.5	22.5	38.8
Durham Creek-South Creek	8.8	9.1	28.4	62.5	0.0
South Creek-Goose Creek	4.0	35.0	65.0	0.0	0.0
Totals	40.3	32.3	23.1	23.3	21.3
Total Shoreline	72.4	I 29.5	II 37.8	III 18.9	IV 13.8

Source: Derived from data collected by the author during field observations in the fall of 1976.

processes here because of man's alteration of the shoreline. One may surmise, however, that vegetation and elevation tend to reduce the magnitude of the rate of erosion.

BROAD CREEK TO BATH CREEK

Low shoreline elevation and the large amount of marshy areas accounts for the predominance of Type I shorelines in this segment of the study area (Figure 6). The higher elevations associated with the Suffolk Scarp are reflected in the beach profiles and indicate a transition from Type I to Type IV shorelines in an easterly direction.

The majority of the area has a slope of less than one percent and is associated with the marshy areas (Figure 7). These areas are located in the westerly portions of the shoreline near the Broad Creek embayment.

An area of deposition is evident at the sampling point considered as Type II. It is a bar-built beach, which resembles a bay-mouth bar because of the marshy areas behind the beach. This may be the result of depositional activity closing off the mouth of a small stream that is creating the marshy area.

The elevation of the Type IV shoreline observed was more akin to a Type III. This bluff was almost perpendicular to the water, which can be attributed to the extreme erosional activity in this segment of the shoreline.

A large portion of the area remains in its natural state and is generally under the influence of erosional processes. This is evident in such situations as the Type IV shoreline mentioned above. A shoreline



Fig. 7. Type I shoreline on northern shore at Ragged Point. Erosional activity is evident by the remnants of tree stumps offshore.

erosion survey was conducted to determine the amount of erosion from 1928-1970. The report divided this shoreline into three sections. In these three segments the reported amount of shoreline eroded away was 53.8, 23.5, and 59.8 feet, respectively, while the length of shoreline accreted was zero (U.S.D.A.-Soil Conservation Service, 1975).

Depositional activity is visible along certain areas of the shoreline. The mouth of Duck Creek is being closed off by a spit. This spit has been forming for a long time, as evidenced by trees growing on the spit. Water levels are becoming increasingly shallow and boat passage into Duck Creek is becoming restricted because of sediment accretion.

Crenulation is evident, especially in those areas where jetties and groins are being built to encourage deposition. It is also visible in undeveloped areas where the remains of fallen trees on beaches perform a similar function.

It is possible to observe the larger portions of this area in its natural state. In some of these areas, the effects of erosion and deposition are quite visible. It is possible that the focal point of the wave energy shifts from those areas of shoreline protection to those left in a relatively natural state. Unlike the forested areas where tree stumps and cypress knees are the remnants of the past shoreline, it is difficult to determine the extent of erosion in marsh areas. Therefore, the evidence of depositional activity is much more noticeable along this segment of the shoreline.

BATH CREEK TO NORTH CREEK

The ten mile segment from Bath Creek to North Creek consists primarily of Type II shorelines (Figure 8). As in the other areas investigated, the low elevation was the controlling factor. All the sampling points measured had slopes of less than one percent. The vegetation consisted of a combination of marsh grass and mixed forest. With the elevation being somewhat higher, the forest begins grading into a mixture of hardwood and pine.

In this area it appears that the local inhabitants are either not concerned with erosion or that erosional activity is not as high. This assumption is based upon the fact that only approximately one-third of the residential area is bulkheaded (Table III).

According to the shoreline survey, this segment of the shoreline was divided into two sections with 59.7 and 42.6 feet of shoreline being eroded away and the length of shoreline accreting still zero (U.S.D.A.-Soil Conservation Service, 1975). However, during the field observations, some areas observed reflected depositional activity, especially those areas using groins and jetties to aid the process.

Crenulation is developing in those areas of extensive groins and jetties. These areas are very evident on the aerial photographs, but according to waterside residents, these change with every storm or period of high wave energy.

This segment continued with the elevation trend of the other areas discussed. Overall elevations are higher in relation to those areas to the west; however, with the marsh areas being located in the center of this segment it was unlike the other areas observed. The

TABLE III

MAGNITUDE OF BULKHEADS, PIERS AND JETTIES
ALONG THE TAR-PAMLICO ESTUARY*

NORTH SHORE LOCATION	Mileage	Bulkheads Per Mile	Bulkheads Per Devel- oped Mile	Percent of Shore Bulkheaded	Piers & Jetties Per Mile	Piers & Jetties Per Devel- oped Mile
Washington-Broad Creek	7.2	19.3	20.2	18.3	38.8	40.6
Broad Creek-Bath Creek	9.0	13.0	53.2	12.3	3.4	14.1
Bath Creek-North Creek	10.1	21.2	34.5	20.1	22.3	36.2
North Creek-Pungo River	5.8	31.7	44.6	29.7	28.4	39.95
Totals	32.1	20.4	33.7	19.3	21.8	36.1
SOUTH SHORE LOCATION						
Whichard Beach Peninsula	7.2	4.3	9.7	4.0	15.4	34.7
Chocowinity Bay-Blounts Creek	9.2	3.5	8.9	3.3	7.8	20.0
Blounts Creek-Durham Creek	11.1	1.3	2.9	1.2	5.2	12.1
Durham Creek-South Creek	8.8	17.5	29.1	16.6	5.1	8.5
South Creek-Goose Creek	4.0	10.3	51.2	9.7	6.5	32.5
Totals	40.3	6.7	6.75	6.4	7.7	17.6

* Data collected November, 1976

Suffolk Scarp in this area, is not as noticeable as the steep banks on the southern shore.

NORTH CREEK TO THE PUNGO RIVER

The final segment on the northern shore consists primarily of Type II shorelines (Figure 9). Only five percent of the shorelines are considered as Type I which depicts a gradual rise in elevation towards another relict shoreline or scarp (Table II, p 30). Several factors might be responsible for this occurrence. This area is located on the remains of an ancient shoreline which would account for higher elevations. It is also possible that the rise in sea level as covered the low marshy areas located closer to the mouth of the estuary.

Shorelines in this segment have the highest percentage of slope of any points sampled. The one Type IV shoreline observed had a slope of fifty-eight percent. This shoreline had a steep cut bank with evidence of active erosion. At some time in the past, a groin had been built to encourage deposition. When the shoreline was observed, the bank had completely eroded away from the groins. There was also a narrow beach covered with fallen trees and debris (Figure 10).

This segment had a sufficient range in elevation to support all four types of shoreline. Marsh grass is evident, but the vegetation consists primarily of pine with some hardwoods.

Approximately two-thirds of the area is developed. Local residents are apparently cognizant of the effects of erosion since almost half of the residential area is bulkheaded (Table III, p 39). Extensive use of piers, groins and jetties has done much to alter the effect of

wave energy. These protective measures are located primarily in the eastern portions of the area, leaving the remaining undeveloped areas susceptible to the effects of erosion. The natural shorelines are more eroded, with the beaches being narrow, and in most cases, only temporary. The wide, sandy beaches, located around Wades Point, have the most noticeable accretion features along this segment of the shoreline.

The erosion survey was again in agreement about the domination of erosional activity with 78 feet of shoreline being eroded away. They also observed that the length of shoreline accreting was zero (U.S.D.A.-Soil Conservation Service, 1975).

Crenulation was evident along those areas considered as residential. This is due in part to the shoreline structures enhancing deposition.

The highest elevation found in this segment is located near a high sandy formation at its western end. This formation is relict sand dunes from a period when sea level was higher than present. The elevation decreases to form a Type II shoreline at the Pungo River embayment.

WHICHARD BEACH PENINSULA

The shoreline from Washington, North Carolina to Chocowinity Bay, for the purposes of this paper, has been designated as Whichard Beach Peninsula (Figure 11). This entire area resembles a deltaic formation and is part of a lowland area extending westward between Chocowinity Bay and the Tar River. Type I shorelines dominate this segment of the study area. Elevation is the controlling factor due to the fact that the shoreline is so low. Marsh and swamp forest are the primary

forms of vegetation depending upon the elevation.

Five points were sampled in this segment. Three of these were Type II with the remaining being Type I. Two of the Type II shorelines consisted of swamp forest. The first one sampled had a slope of approximately three percent and is an area of active erosion as is evident by the numerous tree stumps and cypress knees. At the time of the observation, the trees were standing in pools of stagnant water. The second Type II shoreline had a slope of 1.1 percent and consisted of a narrow beach with a swamp forest in the background. Remains of tree stumps in the water reflected the effects of erosional activity as well as the temporary beach formation. Vegetation consisted of a mixture of cypress and other hardwoods. The final Type II shoreline had a slope of 5.0 percent and consisted of a bar-built beach. As a result of high wave energy, the beach was notched and being eroded away. The sample point was the front yard of a waterfront home and had grass planted to stop erosion.

Two Type I shorelines with a slope of less than one percent were observed (Figure 12). Both of these were marshy areas located in Chocowinity Bay. Offshore water depth was deep and along with irregular shoreline caused by the undercutting of wave action reflected the effects of erosion.

More than half of the area is in a relatively natural state. Residents of the area are apparently not too concerned as only ten percent of the residential area is protected by bulkheads. Other shoreline protection devices are being used, however. This may be due to the expense involved or because of the recommendations of other residents.



Fig. 12. Type I shoreline on south shore in Chocowinity Bay. This photograph shows a good example of irregularly flooded marsh.

It is possible to observe the effects of erosion under both situations with so little of the residential shoreline areas being protected.

Both erosional and depositional processes are visible. One shoreline under observation had the remains of tree stumps and cypress knees indicating the presence of active erosion. Offshore water depth of the marshy areas was considerably deeper than the other areas which also leads to the conclusion that active erosion is present. On the other hand, bar-built beaches are also present. These type of beaches are few in number and are generally associated with man-made structures. Deposition of sediment encouraged by these shoreline structures results in crenulation at the tip of the peninsula. Beach nourishment is taking place at Whichard's Beach as sand has been brought in to enhance the appearance of the recreational area and to replace the sand that has been carried away. There is additional spoil from the extensive dredge and fill operations that have taken place in the past. This spoil area is an additional source of sediment for possible deposition along the estuarine shoreline.

CHOCOWINITY BAY TO BLOUNTS CREEK

The predominance of Type IV shorelines in this segment is indicative of the increase in elevation (Figure 13). Vegetation as a classifying factor becomes less important with increased variation in elevation. Marshy areas and swamp forest are still evident as they are more dominant at the lower elevations in Chocowinity Bay. Even with the general elevation being higher, the marshy areas are located at the confluence of the small streams entering the estuary.

Waterfront residents are either not concerned with or financially able to deter erosion. This is evident by only ten percent of the residential area being bulkheaded. The use of other shoreline protection devices is also uncommon. It is apparent that some residents are aware of the extent of erosion on the steep banks associated with the Type IV, by the variety of methods of erosional control being used. Such devices are eight foot high bulkheads and bulkheads built in terraces on steep banks.

Although there is evidence of both erosional and depositional activity, erosion appears to be the more dominant. Some depositional activity is visible along the Type II and III shorelines. These areas are generally bar-built formations, and in this case, are located at the eastern end of the segment. The erosion survey divided this area into two sections with the shoreline erosion being 57.8 and 52.5 feet, respectively. The length of shoreline accreting was zero (U.S.D.A.-Soil Conservation Service, 1975).

There was very little crenulation along the shoreline. This can be attributed to the lack of shoreline structures encouraging deposition. Other possibilities might be high wave energy or the lack of available sediment in this area to be deposited. The primary depositional activity observed was in the form of small beaches not appearing as crenulation on the aerial photographs.

This segment still reflects the gradual rise in elevation in an eastward direction. The high percentage of steep banks located in this and the other areas on the southern shoreline are the resulting formations of earlier sea levels and the southeasterly dip of the strata.

This relict shoreline was mentioned earlier as the Suffolk Scarp.

BLOUNTS CREEK TO DURHAM CREEK

Blounts Creek to Durham Creek is the longest shoreline under investigation and consists primarily of Type IV beach profiles (Figure 14). Certain areas of the shoreline are some of the most impressive and highest elevations in the study area (Figure 15). Beach profiles in this segment consisted of slopes as high as forty-four percent. The percentage of shoreline considered as Type I is smaller, indicating the trend towards increasing elevation approaching the mouth of the estuary (Table II, p 30).

As on the northern shore, the vegetation grades from the mixture of hardwood to pine forest with increase in elevation. There are small areas of marsh which are usually associated with the embayments and confluence of small streams.

The Type II shoreline observed consisted of a combination of swamp forest and marsh. Accumulating sediment around the cypress roots is gradually building up this swampy area. A Type III shoreline, consisting of a sandy beach, was observed. It is a bar-built formation sloping upward through several older, larger bars. Offshore water depth is shallow, which is another indication of deposition (Figure 16).

There were two Type IV shorelines sampled in this segment. Both were receiving the brunt of erosional activity. One of the points, located in an undeveloped area, consisted of a narrow beach covered with fallen trees and debris. The other point was located in an residential area, where a variety of methods were being used to stop erosion. Some



Fig. 15. Type IV shoreline located on south shore at Tripp Point. It is an area of active erosion. Residents have attempted to deter erosion by the use of bulkheads, tires, and assorted debris.

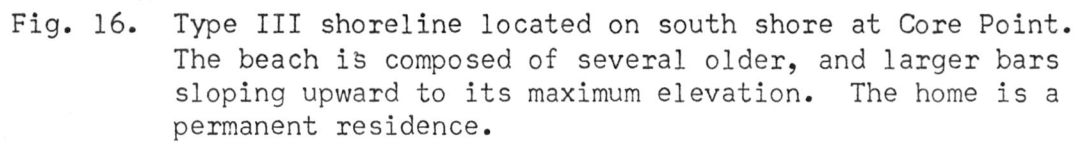


Fig. 16. Type III shoreline located on south shore at Core Point. The beach is composed of several older, and larger bars sloping upward to its maximum elevation. The home is a permanent residence.

of these included old tires, discarded refrigerators, garbage, and trees thrown over the side of the bank (Figure 17). Along some of the Type IV shorelines located in the undeveloped areas, such as those along Blounts Bay, the steep banks have eroded away at such a rapid rate that the stream beds resemble "hanging valleys". This resulting phenomenon is quite visible along certain sections of the shoreline.

Shoreline structures used to deter erosion are both expensive and difficult to maintain, when used along the steep banked shorelines. This can possibly explain the lack of bulkheads, with only three percent of the residential area being bulkheaded. Other shoreline protection devices used in this segment is also limited (Table III, p 39). The expense involved is the primary reason. Wide, sandy beaches are the most noticeable indication of depositional activity with their absence indicating the dominance of erosional activity. Narrow, temporary beaches are present, but they are few in number. The shoreline erosion survey divided this area into two sections and indicated that 55.1 and 31.9 feet of shoreline material had eroded away with the length of shoreline accreting being zero (U.S.D.A.-Soil Conservation Service, 1975).

There was very little crenulation of the shoreline. Aerial photographs indicate a high degree of sediment in the water around Maul's Point, giving the shoreline a crenulating effect.

Shorelines of the higher elevations are located at the western end of the area near Blounts Creek. They can be attributed to the Suffolk Scarp. As stated earlier, the presence of this relict shoreline is much more noticeable on the southern shore than on the north. There is a gradual decrease in elevation approaching Durham Creek which



Fig. 17. The use of tires to deter erosion at the base of a Type IV shoreline located on the south shore at Tripp Point.

is associated with the marshy areas of the embayment.

DURHAM CREEK TO SOUTH CREEK

Certain portions of this segment of the study area has been extremely altered by man (Figure 18). The Texasgulf complex has done much filling and dredging to make the shoreline more compatible for its industrial requirements. This alteration has been recognized by the investigator, and the measured beach profiles are being used to support the data gathered from the topographic maps.

Type III shorelines are dominant in this segment (Table II, p 30). Increasing elevation in an easterly direction is evident with the low percentage of Type I shorelines (Table II, p 30). These marsh areas are associated with the confluence of small streams and embayments. Vegetation remains the same, but with the pine forest becoming more dominant and is still dependent upon elevation. The amount of marsh grass is inversely proportional to the elevation.

There were only two shorelines sampled in this section, both of which were considered as Type II. Like certain other points observed in the study area, this first shoreline, because of the depositional activity, had closed off the mouth of a small stream which resulted in a wide beach. The other Type II shoreline is an area of erosional activity located in the yard of a deserted waterfront home. Past erosional activity was great enough that the home, raised on stilts, had waves breaking under the house (Figure 19).

Both erosional and depositional activity was visible at the two points sampled, but according to the erosion survey, 55.5 feet of



Fig. 19. Deserted house on pilings on southern shore at Hickory Point. Area of very active erosion. Waves are breaking under the house. Attempts have been made to inhibit the erosion by the use of bricks and concrete.

material had eroded away (Figure 20). There was still negative shoreline accretion (U.S.D.A.-Soil Conservation Service, 1975). Waterfront residents are acutely aware of the effects of erosion. This is demonstrated by almost two-thirds of the residential area being bulkheaded (Table III, p 39). Local inhabitants apparently feel that the use of bulkheads is more beneficial than the other protection devices because of the small amount of them observed (Table III, p 39).

The small amount of jetties and groins accounts for the lack of crenulation. Formation of wide beaches in the future will lead to further crenulation.

This shoreline is still consistent with the other areas as the elevation continues to rise in a seaward direction. Texasgulf has had an effect on the shoreline processes because of the large amount of dredge and fill. Also the shoreline alteration required for the ferry dock was responsible for increased sediment through erosion of the spoil areas. Water runoff from the gypsum being stockpiled is also responsible for additional sediment being added to the estuary. A sediment plume is commonly visible at the Lee's Creek outfall adjacent to the complex. All of this combines to have an effect on this segment of the shoreline and possibly on the entire estuary.

SOUTH CREEK TO GOOSE CREEK

Type II beach profiles are predominant in this final segment of shoreline investigation (Figure 21). This area does not follow the trend set by the other areas. The highest elevation recorded was only seven feet, which is lower than the other shorelines observed this far



Fig. 20. Type II shoreline located on south shore near Hickory Point. Area of active erosion is indicated by the remnants of tree stumps in the water.

from the head of the estuary.

Most of the lower elevations are located at the confluence of small streams, with the exception of Reed Hammock. Reed Hammock, a small island, is entirely marsh with a few scattered shrubs.

Those shorelines with the higher percentage of slope are located in the center portion of the area with the lower marshy areas being adjacent to the stream embayments.

Due to the lower elevations, the vegetation has more similarity to the shorelines closer to Washington. Vegetation consists more of hardwoods than the thick pine forests observed across the river on the northern shore.

Erosion appears to be the more dominant of the shoreline processes. There are very few beaches or depositional areas. Eighty percent of the area is undeveloped and in those sections where beaches exist, they are narrow, usually covered with fallen trees, and a variety of trash that has washed ashore.

Residents of this section are knowledgeable of the effects of erosional activity which is demonstrated by almost half of the residential area being bulkheaded (Table III, p 39). There is, in addition, extensive use of other shoreline structures to encourage deposition. This area was divided into three sections by the erosion survey and they determined that 76.6, 116.5, and 82.5 feet of shoreline had eroded away, respectively. These figures demonstrate the extensive amount of erosion occurring, while there is zero length of shoreline accreting (U.S.D.A.-Soil Conservation Service, 1975).

Because of the high amount of erosional activity, deposition required for crenulation was not observed during field observations or from aerial photograph analysis.

This final segment has been left in its relatively natural state with only twenty percent being developed. So much shoreline has been left unprotected that nature has been free to complete its natural processes which is again reflected by the high erosion rate.

SUMMARY

A summation of the shoreline description of the Tar-Pamlico Estuary will be accomplished by comparing the north and south shores. Various percentages will be used to discuss the entire estuarine shoreline to complete this segment of the investigation (Table II, p 30).

More shorelines considered as Type I were found on the southern shore than the north. This can be attributed to the large percentage of marshy areas in Chocowinity Bay.

Shorelines considered as Type II on the northern shore is almost double that of the south. The large amount of shoreline frontage considered as Type III and IV on the southern shore would account for this difference.

The exact opposite occurs regarding the Type III shorelines with twenty-three and thirteen percent for the south and north shore, respectively. Higher elevation on the southern shore due to the Suffolk Scarp and the regional dip of the strata accounts for the increased presence of Type III and IV shorelines.

There are more than five times the percentage of Type IV shorelines on the southern shore than on the north. This great difference again can be related to the Suffolk Scarp and the regional dip.

Thirty percent of the entire estuarine shoreline studied was considered as Type I. Type II shorelines account for thirty-eight percent of the area. When considering the entire area, the Type III and IV shorelines are not as common. They only account for twenty and fourteen percent, respectively.

A comparison was made between three maps published in 1874, 1914, and 1974, to determine if the shoreline had been eroding away over a period of time. The width of the Pamlico River was measured along $76^{\circ} 45' 00''$ longitude on all three maps to determine the change. From 1874 to 1914, the river width increased 182 feet. An additional increase of 183 feet was recorded from 1914 to 1974. Total river width increased 365 feet in 100 years. Measurements were also made of the distance from Hickory Point to Indian Island. It is assumed that any increase in distance between the two points would indicate a loss of shoreline. There was no appreciable change from 1874 to 1914. From 1914 to 1974, the increase in distance was 790 feet. A combination of factors is responsible for the increase in river width and the linear distance between the two points. Rise in sea level over this period would account for some increase in both width and distance, and the shoreline loss can be attributed to the associated erosion. This can be substantiated by the shoreline erosion survey. Using aerial photography, the survey has estimated that an average of 1.7 feet per year of shoreline is lost because of erosion. It is recognized that there

might be some inaccuracy in the data because of the surveying methods used one hundred years ago, but the resulting figures are still in agreement that the shoreline is being eroded away. Also for the entire study area, the erosion survey reports that the length of shoreline accreting is zero (U.S.D.A.-Soil Conservation Service, 1975).

Both erosional and depositional activity was observed throughout the entire study area. It is not possible to determine the actual percentage of shoreline that is effected by either process, but the field observations are in agreement with all of the other data compiled concerning the predominance of erosional activity.

It should once again be mentioned that the spatial distribution of the various shoreline types is based primarily upon the data obtained from the U.S.G.S. topographic maps published in 1951. As stated earlier, this investigation recognizes the fact that shorelines have been altered over a twenty-five year period. The entire shoreline was observed and compared with the data gathered from the thirty locations sampled to insure accuracy.

CHAPTER IV

THE TAR-PAMLICO ESTUARINE SHORELINE LAND USE

INTRODUCTION

Man has had and will continue to have an effect on the character of the estuary and its adjacent land areas. Land use patterns serve as a visible element of mankind's cultural and technological impact upon the environment.

Data encompassing a twenty-five year period was analyzed, to determine the intensity of land use adjacent to the Tar-Pamlico Estuary. Field observations completed in the fall of 1976 were compared with data obtained from map series (1:24,000) published in 1951. Buildings, piers, groins, and jetties were counted and used because they could be identified through time with any increase in the number of these landscape elements being considered as an indication of development (Tables IV, V, VI, and VII). The extent of development is proportionally related to the percentage increase in any of the four structure variables used. Degree of development varied from forty-seven percent to over fifteen thousand percent. These increases suggest that the area is still in a state of development. This chapter will specifically identify the various land use functions found throughout the study area and their spatial distribution.

TABLE IV
DENSITY OF PIERS AND JETTIES ALONG THE
TAR-PAMLICO ESTUARY, 1951 AND 1976

NORTH SHORE LOCATION	Number of Devices 1951	Number of Devices 1976	Percent Increase	Devices Per Mile 1951	Devices Per Mile 1976	Percent Increase
Washington-Broad Creek	56	279	398	7.7	38.8	404
Broad Creek-Bath Creek	8	31	288	0.9	3.4	278
Bath Creek-North Creek	35	225	543	3.5	22.3	537
North Creek-Pungo River	22	165	650	3.8	28.4	647
Totals	121	700	479	3.8	21.8	474
SOUTH SHORE LOCATION						
Whichard Beach Peninsula	1	111	11000	0.1	15.4	15300
Chocowinity Bay-Blounts Creek	2	72	3500	0.2	7.8	3800
Blounts Creek-Durham Creek	10	58	480	0.9	5.2	478
Durham Creek-South Creek	2	45	2150	0.2	5.1	2450
South Creek-Goose Creek	5	26	420	1.3	6.5	400
Totals	20	311	1455	0.5	7.7	1440

Source: Derived from data collected by the author from USGS Topographic maps and field observations during the Fall of 1976.

TABLE V
BUILDINGS AND PIERS AND JETTIES
ALONG THE TAR-PAMLICO ESTUARY, 1951

NORTH SHORE LOCATION	Mileage	Number of Buildings	Buildings Per Mile	Number of Piers & Jetties	Piers & Jetties Per Mile
Washington-Broad Creek	7.2	134	18.6	56	7.7
Broad Creek-Bath Creek	9.0	30	3.3	8	0.9
Bath Creek-North Creek	10.1	89	8.8	35	3.5
North Creek-Pungo River	5.8	101	17.4	22	3.8
Totals	32.1	354	11.0	121	3.8
SOUTH SHORE LOCATION					
Whichard Beach Peninsula	7.2	3	0.4	1	0.1
Chocowinity Bay-Blounts Creek	9.2	19	2.1	2	0.2
Blounts Creek-Durham Creek	11.1	41	3.7	10	0.9
Durham Creek-South Creek	8.8	18	2.0	2	0.2
South Creek-Goose Creek	4.0	9	2.3	5	1.3
Totals	40.3	90	2.2	20	0.5

Source: Derived from data collected by the author from USGS Topographic maps in the fall of 1976.

TABLE VI
NUMBER OF BUILDINGS
ALONG THE TAR-PAMLICO ESTUARY, 1976

NORTH SHORE LOCATION	Mileage	Number of Buildings	Buildings Per Mile	Buildings Per Devel- oped Mile
Washington-Broad Creek	7.2	257.0	35.7	37.4
Broad Creek-Bath Creek	9.0	44.0	4.9	20.0
Bath Creek-North Creek	10.1	286.0	28.3	46.1
North Creek-Pungo River	5.8	201.0	34.7	48.7
Totals	32.1	788.0	24.5	40.6
SOUTH SHORE LOCATION				
Whichard Beach Peninsula	7.2	133.0	18.5	41.6
Chocowinity Bay-Blounts Creek	9.2	126.0	13.7	35.0
Blounts Creek-Durham Creek	11.1	131.0	11.8	27.3
Durham Creek-South Creek	8.8	76.0	8.6	14.3
South Creek-Goose Creek	4.0	50.0	12.5	62.5
Totals	40.3	516.0	12.8	29.2

Source: Derived from data collected by the author during field observations in the fall of 1976.

TABLE VII

DENSITY OF BUILDINGS ALONG THE
TAR-PAMLICO ESTUARY, 1951 AND 1976

NORTH SHORE LOCATION	Number of Buildings 1951	Number of Buildings 1976	Percent Increase	Buildings Per Mile 1951	Buildings Per Mile 1976	Percent Increase
Washington-Broad Creek	134	257	92	19	36	92
Broad Creek-Bath Creek	30	44	47	3	5	49
Bath Creek-North Creek	89	286	221	9	28	222
North Creek-Pungo River	101	201	99	17	35	99
Totals	354	788	123	11	25	123
SOUTH SHORE LOCATION						
Whichard Beach Peninsula	3	133	433	0.4	19	4525
Chocowinity Bay-Blounts Creek	19	126	563	2.0	14	552
Blounts Creek-Durham Creek	41	131	220	4.0	12	219
Durham Creek-South Creek	18	76	322	2.0	9	330
South Creek-Goose Creek	9	50	456	2.0	13	443
Totals	90	516	473	2.0	13	482

Source: Derived from data collected by the author from USGS Topographic maps and field observations during the Fall of 1976.

CLASSIFICATION

A land use classification system:

"... should systematically arrange land uses into groups by means of their characteristics according to a definite set of ideas or principles reflecting the purposes for which the system will be used (Voorhees, 1959).

The methodology for this study is based upon a general category of functions and forms recorded during field observations. General topics were categorized into more descriptive divisions in order to prevent vagueness and the over use of generalities. The accompanying map will illustrate distributional aspects of the general classifications, with the discussion explaining in greater detail their subdivisions (Figure 2, p 18).

The land use classification system of the Tar-Pamlico Estuary is as follows: (1) Residential, (2) Recreational, (3) Industrial, (4) Farmland, and (5) Undeveloped marsh and forest areas.

RESIDENTIAL

Those areas considered as residential consist of the shoreline developed primarily for the purpose of habitation. This category does not differentiate between permanent or seasonal shoreline buildings. It is assumed that the more impressive homes are occupied throughout the year, but the smaller, in some cases, "unkept" homes are primarily of a seasonal nature. Reference is made to the predominance of one type or the other in the different areas observed. A house-to-house survey would be required to determine the actual percentage, and it is not included in this investigation. This type of survey would also be beneficial in determining whether some of the residents are using their homes

for some form of commercial activity. Also included in the residential areas are mobile homes. Mobile home parks are depicted on the land use map and designated as a separate subdivision of the residential classification.

RECREATIONAL

Areas designated as recreational are further subdivided into several categories: These subdivisions are as follows: (1) Public, (2) Private, (3) Commercial, and (4) Institutional.

Public recreation areas are those maintained by local, state or federal governments. One example would be Haven's Garden, located on the Pamlico River within the city limits of Washington, North Carolina. The areas are open to all interested persons with most having no admission charge.

Private recreation facilities are operated and maintained for private use. Texasgulf's recreation area and Washington Park are examples of this subdivision.

Commercial recreation facilities are operated for the public and are intended as a source of monetary gain for the owner. Campgrounds, swimming areas, and boat ramps are included in this category.

The final recreational subdivision are those areas owned or operated by institutional organizations. Such organizations as churches, Boy Scouts, and Girl Scouts are included. These areas are generally camps which are primarily used during the summer months. Most of these camps are located in the more isolated areas of the shoreline.

INDUSTRIAL

Of the entire study area investigated, only one location was found to be used for industrial purposes. That area was the phosphate mining operation of Texasgulf.

Small commercial establishments such as convenience stores, and gas stations, are found at various locations throughout the entire estuarine shoreline. These areas are very small on the basis of linear shoreline footage, therefore, they will not be depicted on the land use map, but will be explained in the text.

FARMLAND

Farmland includes all cultivated and fallow land. Fields under cultivation were well differentiated from undeveloped areas. It should be noted that tree farms located along the shoreline are considered as undeveloped, unless otherwise designated. It is also possible that areas under cultivation may be located behind forested areas adjacent to the shoreline, but are not considered because they were not immediately adjacent to the shoreline.

UNDEVELOPED MARSH AND FOREST

The final segment of the land use classification is concerned with those areas defined as undeveloped marsh or forest. These undeveloped areas have been left in a seemingly natural state. They may consist of marsh, swamp, forest, or a combination of all three. These areas are located throughout the entire estuarine shoreline. They may be long stretches, several miles in length, or several hundred yards intermingled with residential areas. As stated earlier, some of these

areas may be commercial ventures, but unless so specified are considered as undeveloped.

GENERAL DESCRIPTION

Again it seems best to use the natural divisions of the Pamlico River, to evaluate the shoreline land use (Figure 2, p 18). These areas are divided into northern and southern shorelines, so as to make comparisons relating to rates of development. Opinions vary as to why the northern shore has developed at a faster rate. One individual felt that better access and the more favorable southwest winds inhibiting the mosquitos in summer has led to a faster rate of development of the northern shore (Shore, 1976). The different areas will be discussed and evaluated in further detail in the following sections.

SPATIAL DISTRIBUTION

WASHINGTON, NORTH CAROLINA TO BROAD CREEK

The first area to be evaluated encompasses about 7.2 miles of shoreline (Figure 4, p 31). Portions of this section are in the city of Washington which contributes to a high percentage of residential land use (Figure 22). The residential areas have a density of about 37 houses per mile (Table VI, p 69). Some homes are the older, more impressive ones of early Washington inhabitants. Seasonal homes are more predominant in those areas farther from Washington.

Farmland constitutes about seven percent of the shoreline (Table VIII). One farm, in this case, makes up the farmland for the entire section. A residential area surrounds this farm, and it is surprising that the farm has not been subdivided into lots and sold

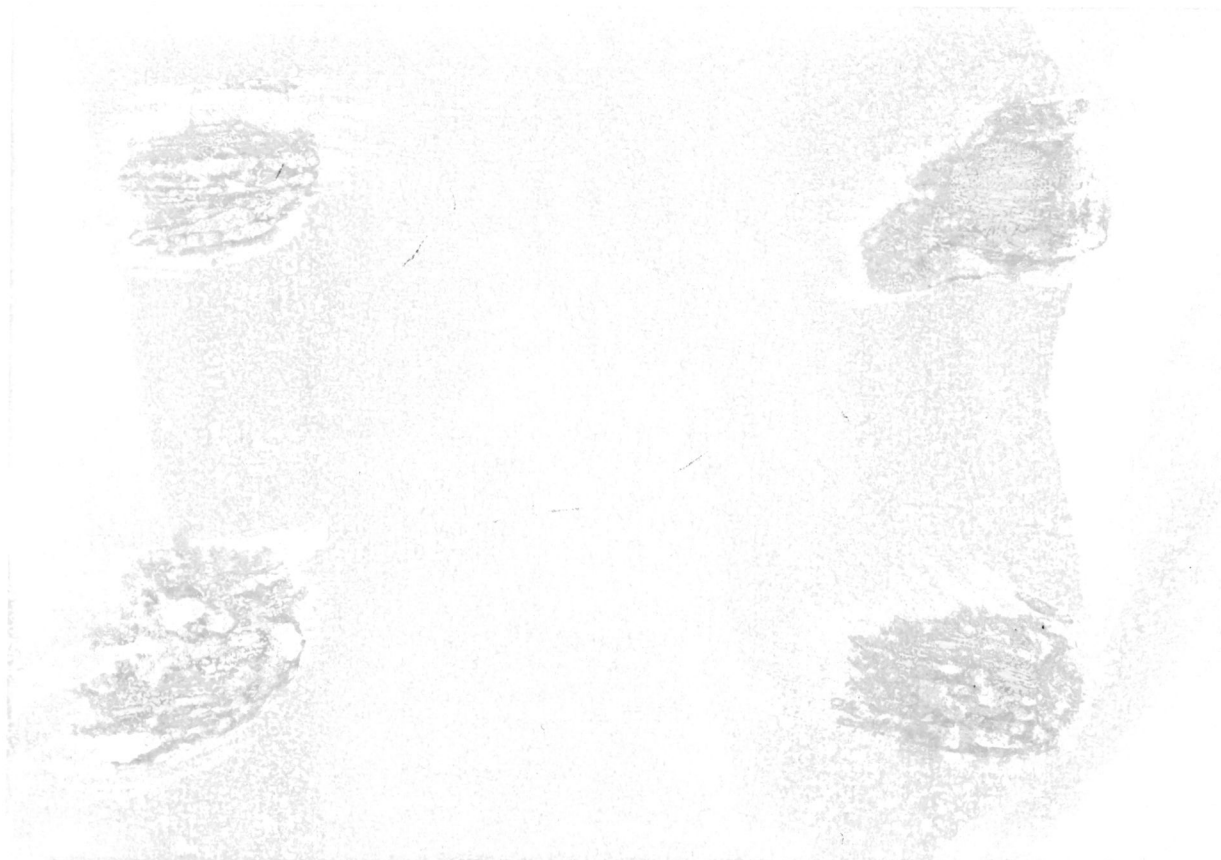


Fig. 22. Type III shoreline located on northern shore near Broad Creek.
Note the variety of methods used to deter erosion.

TABLE VIII

SHORELINE LAND USE ALONG THE
TAR-PAMLICO ESTUARY, 1976

NORTH SHORE LOCATION	Percent Residential	Percent Farmland	Percent Recreation	Percent Industrial	Percent Undeveloped
Washington-Broad Creek	79.6	6.9	9.0	0.0	4.5
Broad Creek-Bath Creek	10.1	11.1	3.3	0.0	75.5
Bath Creek-North Creek	59.4	2.0	0.0	0.0	38.6
North Creek-Pungo River	71.2	0.0	0.0	0.0	28.8
Totals	52.4	5.2	3.0	0.0	39.5
SOUTH SHORE LOCATION					
Whichard Beach Peninsula	40.3	0.0	4.2	0.0	55.5
Chocowinity Bay-Blounts Creek	39.2	0.0	0.1	0.0	60.8
Blounts Creek-Durham Creek	36.0	4.5	2.7	0.0	56.8
Durham Creek-South Creek	26.1	0.1	2.2	34.1	37.5
South Creek-Goose Creek	20.0	0.0	0.0	0.0	80.0
Totals	33.7	1.4	2.2	6.9	56.0

Source: Derived from data collected by the author during field observations in the Fall of 1976.

because of the large demand for waterfront home sites.

Approximately nine percent of this section is considered recreational land use (Table VIII, p 76). Various recreational activities found in the area encompass the entire spectrum of the overall classification. Haven's Garden, built by the City of Washington, is located on the banks of the Pamlico River (Figure 23). Residents of Washington Park, have an open area solely for their benefit and is not for public use. Also observed was Griffin's Beach, a commercial recreation area consisting of a dancehall and picnic facilities (Figure 24). A camp, sponsored by the First Church of Christ, which falls under the institutional classification is located on this segment of the shoreline (Figure 25).

There is no industrial land use. The undeveloped portions account for only five percent of the total land use (Table VIII, p 76). These areas are still in their natural state. It is only speculation, but the land could be held for a future real estate venture. These undeveloped areas will be at a premium in the near future, because of the adjacent areas being so intensely developed.

BROAD CREEK TO BATH CREEK

The shoreline from Broad Creek to Bath Creek is approximately nine miles in length (Figure 6, p 34). Unlike the first segment it is primarily undeveloped. This area is mostly marsh, occasionally interspersed with forest. In most cases, it is poorly suited for development because of the wet conditions. Government regulations and the expense involved in such a venture limits the development.



Fig. 23. Haven's Garden, public recreation land use on northern shore. It is a Type II shoreline with concrete rip-rap used to deter erosion.



Fig. 24. Griffin's Beach, a Black commercial recreation area located on northern shore. It is a Type II shoreline experiencing some erosional activity as evidenced by the tree stumps offshore.



Fig. 25. Christian Service Camp, an example of institutional recreation located on the northern shore. Note the use of a groin to encourage deposition.

Farmland constitutes the next largest percentage of land use (Table VIII, p 76). This large percentage can be attributed to the large horse farm owned by Texasgulf. This farm accounts for approximately one mile of shoreline.

About ten percent is considered residential (Table VIII, p 76). Homes are not as impressive as those found closer to Washington, but are more closely related to a seasonal type of residence. Housing density is almost half that of the first area (Table VI, p 69). The houses are clustered in two separate locations at the eastern end of the section.

Recreation plays a small part in the overall land use pattern. There are two areas of recreation: (1) a small picnic area for the use of boating enthusiast, and (2) two adjacent church camps. Both of these are located in the relatively undeveloped area, which is ideally suited for this form of recreation.

Commercial endeavors are considered as a subdivision of the industrial classification. A small convenience store and boat dock are located in this area. These occupy such a small portion that it is not possible to be depicted on the land use map.

BATH CREEK TO NORTH CREEK

The shoreline from Bath Creek to North Creek, is one of the longer segments under investigation (Figure 8, p 38). This section of shoreline is approximately ten miles long. Fifty-nine percent of this segment is residential. Homes are of a more seasonal nature, with residents being either permanent or "seasonal". Houses are clustered in highly dense areas, with the density being as high as 46 houses per

developed mile. When the total shoreline of this area is considered, the density decreases to 28 per mile (Table VI, p 69). This decrease reflects the clustering tendency of the shoreline residents in this particular segment.

Marsh and forest comprise approximately thirty-nine percent of the area (Table VIII, p 76). Like other areas, it still remains in its present state. The marshy areas would again require extensive dredge and fill operations, which for the most part are being prevented by government regulations. Portions of these areas have limited highway access, which may have some bearing on their lack of development. The foundation of a waterfront building was observed, indicating that at one time there was occupancy in this undeveloped area.

Farmland constituted the remainder of the shoreline land use (Table VIII, p 76). Two farms were under cultivation, both of which were located in the densely settled residential areas. Their location leads to the assumption that they are owned by long time residents.

NORTH CREEK TO THE PUNGO RIVER

The easternmost segment of the northern shore consists of the shoreline from North Creek to the Pungo River. It is a short segment with only 5.8 miles of shoreline (Figure 9, p 41). It has the second highest percentage of residential development, with seventy-one percent being classified as such. This segment is also second highest in housing density per developed mile (Table VIII, p 76). Like the majority of the other areas, the homes are a mixture of permanent and seasonal. Being located at the farthest point along the northern shore, the

residents are equidistant from Washington and Belhaven. An added advantage of two shopping areas and better highways would explain the demand for waterfront sites.

Undeveloped areas, consisting of approximately twenty-nine percent of the land use, are found at the western end of the section (Table VIII, p 76). Vegetation is a mixture of marsh and forest. There are no roads leading into this area, which would inhibit future development. This segment of the shoreline has no evidence of farmland, recreation, or industrial activity.

WHICHARD BEACH PENINSULA

Whichard Beach Peninsula has 7.2 miles of shoreline (Figure 11, p 44). Fifty-six percent of the shoreline is marsh, hardwood forest and swamp forest. Portions of these areas are favorable for development, while certain segments will for the foreseeable future remain in their present state. Attempts have been made to develop certain areas, but these have been curtailed because of environmental concern. Some of the marshy areas were altered prior to the passage of federal regulations and are now being developed for residential purposes.

Forty percent of the shoreline is now residential (Table VIII, p 76). Mobile homes play an important role in the residential development of the area. In addition to double-wide mobile homes, some mobile homes mounted on large pilings are becoming a part of the landscape (Figure 26). This new type of residence reflects the attitude of the residents. Because of the lower shorelines, the residents have become more cognizant of the effects of erosion, inundation, and high wave



Fig. 26. Mobile home mounted on pilings, located on south shore near Whichard's Beach. It is along a former Type I shoreline, which has been altered through dredge and fill operations.

energy during storms.

The beach around Whichard Beach consists of approximately four percent of the segment. It is considered as commercial recreation, because of the dancehall, swimming area, and overnight camping facilities. This area was once farmland, but commercial recreation apparently is more profitable. Another developer is in the planning process of building a campground adjacent to Whichard's Beach.

The marina at Whichard's Beach is considered as commercial activity (Figure 27). It does not qualify as industrial, but it is worth noting as a business enterprise generated by the estuarine environment.

There is no land use considered as farmland in this segment. It is recognized that farmland is located in the inner portions of the peninsula, but is outside the study area.

CHOCOWINITY BAY TO BLOUNTS CREEK

This segment of the shoreline is on the south side of the Pamlico River (Figure 13, p 48). Data, from both 1951 and 1976, indicates that the southern shore is less developed than the northern shore. This segment reflects this observation, with sixty-one percent being undeveloped. These undeveloped areas consist of marsh, swamp forest, and hardwood forest. It is not known why those areas favorable for development remain in their natural state. It is known, however, that the Weyerhaeuser Corporation owns large tracts of land adjacent to the river and this could be the reason. It is also possible that the limited highway access may have some bearing.



Fig. 27. Whichard's Beach Marina, located on southern shore. The land use is a combination of commercial and recreational activity.

Thirty-one percent of the shoreline land use is residential (Table VIII, p 76). Residential areas are fairly dense with 35 houses per developed mile as opposed to 14 per mile total. This density is partially influenced by the presence of mobile homes. The mobile homes, in this case, are congregated in relatively large numbers in a small area. Like the areas already investigated, there exists a combination of both permanent and seasonal residents. It was also observed that a developer has built a subdivision of waterfront homes of the same type and design (Figure 28). Some of the homes, perched on the high steep banks, are quite impressive as far as a good view is concerned, however, the use of a variety of methods to deter erosion distracts from their overall appearance.

There are no areas of industrial activity or farmland in this area and institutional forms of recreation accounts for only one percent of the land use. Camp Hardee is located along the water's edge in a relatively remote area. A nice swimming area and long pier are ideally suited for the Girl Scouts from the surrounding areas.

BLOUNTS CREEK TO DURHAM CREEK

The area from Blounts Creek to Durham Creek is the longest shoreline under investigation (Figure 14, p 51). Fifty-seven percent of the area is considered undeveloped. Marshy areas are generally found at the mouths of small streams and adjacent to the larger streams which define this segment, and are not as dominant when compared to other segments. The forested areas are located on top of high steep banks and are quite striking throughout this segment.



Fig. 28. A subdivision of homes built on the south shore along Chocowinity Bay. The Type IV shoreline has been graded, leaving the area vulnerable to erosion.

Residential land use comprises about thirty-six percent of the area and the houses are generally clustered. A housing density of 27 per developed mile is more than twice the density of the total area (Table VI, p 69). Residences of this area consists primarily of permanent homes, with some residents having spent their entire lives along the river. The largest assembly of homes is found at Core Point, where the population is approximately one hundred. A large number of fishing nets, boats and crab and eel pots, gives the impression of a small fishing village.

Three farms constitute about five percent of the land use. It is not possible to indicate the size of the farms, but the presence of tobacco barns tends to indicate certain types of cultivation.

Approximately three percent of the land use is recreational. Commercial recreation is represented by the Billy K Campground. Camp Bonner, the Boy Scout camp, is located in a remote area of Blount's Bay. It is located in the center of a large undeveloped area, which is excellent for the type of training desired by the Boy Scouts. A wide, sandy beach and swimming area has been provided for the residents of the Crystal Beach subdivision.

A small marina and motel at Core Point, are the only forms of commercial activity in this section. They are not large enough to be presented on the map.

DURHAM CREEK TO SOUTH CREEK

This shoreline, 8.8 miles in length, extends from Durham Creek to South Creek (Figure 18, p 57). About thirty-eight percent is

considered undeveloped. This figure is small compared to the other areas of the southern shoreline. A large amount of shoreline incorporated into the Texasgulf complex is the primary reason. Marshy areas are still visible along the shoreline, but the thick pine forests are becoming more dominant.

Texasgulf accounts for thirty-four percent of the land use. This huge complex is a phosphate mining operation, and is the only actual form of industrial activity found in the entire study area (Figure 29). Its facilities include a loading area for barges and railroad cars, a laboratory, and a runway used for executive air transportation. The company is involved in a land reclamation project, which recycles the mined areas into pasture land for cattle. The plant site is constantly being monitored for water and air pollution. Local inhabitants are concerned that their large consumption of water may lead to an influx of brackish water into the groundwater supply. Another mining operation, North Carolina Phosphate Corporation, will be constructing facilities on the southern shore as soon as they have final approval of state and federal officials.

Twenty-six percent of the shoreline is considered residential. These areas are not densely settled with only about 14 houses per developed mile. The majority of the homes are seasonal and found at the eastern most portion of the area. There is limited access to shopping areas, but good highways are available. The ferry, which supplies the only method of crossing the river by car, may have an added bearing on the clustering of homes in this area.



Fig. 29. Texasgulf phosphate mining operation located along the southern shore. It is a multi-million dollar complex built on a Type III shoreline.

Commercial and private recreation accounts for two percent of the land use. Texasgulf has a recreation area with picnic and boating facilities for its employees. EASNOCA, a Black recreation area consisting of small cottages, boat docks and swimming area is found in this segment of the study area.

Farmland consists of less than one percent of the area. Only one farm was observed along this portion of the shoreline. According to the cleared area on the topographic map, the farm is rather large.

SOUTH CREEK TO GOOSE CREEK

The final area of study is the shoreline from South Creek to Goose Creek (Figure 21, p 61). This segment is only four miles in length, but eighty percent is undeveloped. Forest and marsh make up the undeveloped portions. Reed Hammock, is entirely marsh with the exception of a few scattered shrubs. A majority of the area is favorable for development, but is limited by highway access.

Remaining portions of the area are considered as residential, and has the highest housing density of anywhere in the study area. This density amounts to 63 houses per mile (Table VI, p 69). The homes are clustered in one area in the center of the section. This residential area is somewhat protected by being in a bay between two points of land.

There are no areas devoted to farmland, recreation or industrial land use in this area.

SUMMARY

Spatial distribution of land use can be summarized through a comparison of the northern and southern shorelines. The entire estuarine shoreline will be discussed using the percentages of land use.

In 1976, there were 272 more buildings on the northern shore. This resulted in a nineteen percent difference in residential land use. When comparing the houses per developed mile, the northern shore had the higher density which amounted to 11 houses per mile. The northern shoreline's density per mile total was almost double that of the southern shore.

There was only a slight difference in recreational land use. It is not possible to speculate as to whether one shoreline is more conducive to recreation than the other with there being less than one percent difference.

Southern shorelines had approximately seventeen percent more undeveloped area than the northern shore. This difference in percentage is not unrealistic, with the majority of the southern shoreline study areas having more than fifty percent undeveloped land use.

There was almost four times more shoreline under cultivation on the northern shore. The large Texasgulf horse farm would account for a large portion of this percentage, and it is also possible that some farms on the southern shore have become tree farms and were recorded as being undeveloped (Table VIII, p 76).

The impact of man, through his use of the land in the Tar-Pamlico Estuary, can be indicated through the analysis of the data gathered during the field observations. Various land use activities

throughout the entire study area, will on a percentage basis, present man's impact on the estuary.

Forty-two percent of the entire shoreline area investigated was considered as residential. Housing density of the residential areas was 43 houses per mile as compared to the density of the total area of 18 per mile (Table VI, p 69). This substantiates the earlier findings that clustering of homes occurs throughout the entire study area. It is not the scope of this investigation to show what factors cause such an occurrence.

Farmland amounts to three percent of the entire shoreline area. As explained earlier, the spatial distribution shows about three times as much on the northern shore.

Recreational land use accounts for approximately three percent of the shoreline. The distribution is about equally divided between the two shorelines (Table VIII, p 76).

Texasgulf accounts for four percent of the shoreline in the industrial classification. This percentage would be a little higher if all the various commercial activities could be determined.

Remaining portions of the shoreline are considered as undeveloped. These areas of marsh and forest amount to forty-nine percent. It is not possible through the data available to determine what percentage of these areas are available or favorable for development.

As population pressure increases, the estuarine shoreline land use will be at a premium. It is possible to predict that there will be confrontations between environmentalists and developers. Presently, government regulations prevent the altering of the undeveloped marsh

areas, however, when only those areas are left, the regulations will undoubtedly be challenged.

CHAPTER V

THE AREAL ASSOCIATION OF TAR-PAMLICO ESTUARINE SHORELINE TYPES AND SHORELINE LAND USE

INTRODUCTION

The purpose of this chapter is to determine the areal association between shoreline types and shoreline land use. A contingency table was constructed using a total of 274 points at quarter-mile intervals along the estuarine shoreline to examine this relationship. Additional information obtained through personal interviews will be used as an aid in combination with the other data to more thoroughly understand the meaning of the contingency analysis.

HYPOTHETICAL RELATIONSHIP OF SHORELINE TYPES AND SHORELINE LAND USE

While observing the various shorelines along the Tar-Pamlico Estuary, several hypotheses were posed. These hypotheses will be presented and discussed in this chapter.

Beginning with the lower shorelines, which were considered Type I, it has been suggested that the lower shorelines were highly vulnerable to the effects of wave energy. Also the combination of expense involved to make these areas less vulnerable and federal dredge and fill regulations would inhibit if not prevent the development of these areas. It was hypothesized that all of the shorelines considered as Type I,

whether they be swamp forest or marsh, would be left in their present state.

Type II shorelines, having a higher elevation and a greater amount of shoreline slope, are still vulnerable to erosion but more conducive to shoreline development than the Type I. Erosional activity is more dominant along these shorelines thus adding to their vulnerability. It was assumed that these areas would be developed, but restricted to less expensive, more mobile type of structures such as mobile home parks, campgrounds, or small, overnight cottages. Periods of high winds, tides or storms are quite devastating to these areas because of their lower elevations. Prior notification of pending storms or hurricanes would enable the owners of mobile homes and campers to have them towed to higher ground and safety. Overnight cottages would not suffer as great a loss because of their small investment. Another reason for investing smaller amounts in the structures built on this type of shoreline would be the difficulty and expense of obtaining insurance.

Type III shorelines would be the most desirable for development. A combination of higher elevations, still greater shoreline slope, and the predominance of depositional activity accounts for their desirability. These areas would be more naturally suited for those structures of a permanent nature and greater investment. This would include such features as larger, permanently occupied residences, industrial sites and commercial recreational facilities. These shorelines are less vulnerable to wave energy, but yet offer easy access to the water for recreational or commercial activities.

Those shorelines associated with the Type IV classification, with their higher elevations, are the least effected by high water. They are, however, highly susceptible to erosion. This can be attributed to the greater expense involved in constructing the shoreline protection devices. Because of this lack of devices along most of these shorelines extreme erosion is quite evident. Type IV shorelines, like the Type III, are excellent for the more permanent structures. They should be built either away from the eroding shoreline or at least construct protection devices. The high banks offer an excellent view of the river which would be desired by waterfront residents or even commercial eating establishments. There are two disadvantages with these shorelines. First, there would be the high amount of erosional activity and secondly, there would be poor access for water related activities.

This portion of the chapter has been devoted to the hypothetical situations that the investigator expected to find along the Tar-Pamlico estuarine shorelines. The results obtained from the contingency table in comparison with the other data assembled will be discussed in the remaining portions of this chapter.

THE CONTINGENCY OF TAR-PAMLICO ESTUARINE SHORELINE TYPES AND SHORELINE LAND USE

The actual relationship, if any, will be determined in this section. Data from the contingency table will be explained and related to information obtained from field observations and personal interviews. Using the data from the contingency table, a relationship seems to exist (Tables IX, X, XI). The relationships in comparison to the hypotheses

TABLE IX
 PERCENT OF TAR-PAMLICO ESTUARINE SHORELINE
 LAND USE BY SHORELINE TYPE

	Type I	Type II	Type III	Type IV
Residential	24.4	51.9	41.5	40.0
Farmland	0.0	2.9	13.2	5.7
Recreational	1.2	2.9	0.0	2.9
Industrial	0.0	0.9	20.8	0.0
Undeveloped	74.4	41.3	24.5	51.4
Totals	100.0	100.0	100.0	100.0

Source: Derived from data collected by the author during field observations in the fall of 1976.

TABLE X
PERCENT OF TAR-PAMLICO ESTUARINE SHORELINE TYPE
BY SHORELINE LAND USE

	Type I	Type II	Type III	Type IV	Totals
Residential	18.2	49.1	20.0	12.7	100.0
Farmland	0.0	25.0	58.3	16.7	100.0
Recreational	20.0	60.0	0.0	20.0	100.0
Industrial	0.0	8.3	91.7	0.0	100.0
Undeveloped	45.2	31.9	9.6	13.3	100.0

Source: Derived from data collected by the author during field observations in the fall of 1976.

TABLE XI
CONTINGENCY OF SHORELINE TYPE
AND LAND USE ALONG THE TAR-PAMLICO ESTUARY

	Type I	Type II	Type III	Type IV	Totals
Residential	7.3	19.7	8.0	5.1	40.1
Farmland	0.0	1.1	2.6	0.7	4.4
Recreational	0.4	1.1	0.0	0.4	1.8
Industrial	0.0	0.4	4.0	0.0	4.4
Undeveloped	22.3	15.7	4.7	6.6	49.3
Totals	29.9	37.9	19.3	12.8	100.0

Source: Derived from data collected by the author during field observations in the fall of 1976.

will be presented in greater detail in the following text.

Percentages of residential land use show an uneven distribution. It was surprising to see that the percentages were not in complete agreement with the hypothetical situations. The dredge and fill operations prior to the passage of relatively new federal regulations and the newer methods of having mobile homes mounted on large stilts would account for the higher percentages of residential land use than anticipated along the Type I shorelines. Residential land use percentages of the Type II shorelines were also higher than anticipated. This can be attributed to the greater amount of Type II shorelines. Also, those homes built on shorelines at the upper limits of the Type II classification would benefit of the advantages associated with the Type III shorelines. This would also account for the lower percentage of Type III shorelines than anticipated. Type IV percentages were not unrealistic because of the disadvantages associated with these shorelines as mentioned earlier.

The relationship between farmland and shoreline type was as expected. Farmers are usually long-time residents of the areas where they reside. Higher percentages of farmland on the Type III and IV shorelines would substantiate this hypothesis. They would have had a better selection of farmland years ago, and would certainly choose the higher, less vulnerable shorelines. This is even more apparent when observing that there was a zero percentage of farmland on the Type I shorelines.

According to the contingency table, the distribution of the recreational land use was as expected. The high percentage of recreational land use on the Type II shorelines was in agreement with the

hypothetical relationship. Recreational facilities located on the Type I shorelines which had been improved through dredge and fill operations would account for the higher than expected percentages. It was surprising that there was not any points sampled for recreational purposes along the Type III shorelines.

Industrial land use was associated with the Type II and III shorelines. This relationship is not considered valid for this classification since there was only one activity considered as industrial and it was located primarily on a Type III shoreline. This would tend to bias the relationship. The multi-million dollar Texasgulf complex is located on a Type III shoreline with extensive bulkheading to insure its investment.

The relationship of the undeveloped areas was in complete agreement with the hypothetical relationship. It was expected that the percentages would be higher for the Type I undeveloped areas. Desirability of the Type III shorelines was demonstrated by having the lowest percentage of undeveloped areas. Their value is apparently based upon monetary gains such as farmland and industrial productivity instead of residential occupancy. This assumption is based upon the higher percentages of both of these categories.

Data from the contingency table indicates that the Type II shorelines are the most versatile. This is demonstrated by the representation of all the different categories of land use. There are several reasons that account for this situation. There is a greater percentage of Type II shorelines, and secondly as mentioned earlier, those Type II shorelines bordering on the margins of the Type III would

have approximately the same advantages. This does not necessarily mean that they are the best suited for development. There are several other variables that are related to development other than shoreline type. Some of these variables include the location of highways, zoning laws, the size of municipalities, and the extensive tracts of land owned by large corporations, all of which would tend to control shoreline development. These factors have influenced development in the past and will continue to do so in the future.

Information gathered in Chapter III concerning shoreline type was converted to percentage of shoreline type of the entire shoreline (Table II, p 30). The sample points from the contingency table were also converted to percentages (Table X, p 100). When these were compared, it was interesting to note that only minor differences existed. When compared to the land use percentages, the results were similar, but the differences were greater (Table VIII, p 76). This reflects the accuracy of the map interpretation, field observations, and contingency analysis.

CHI-SQUARE TEST

Several other methods were used to show this relationship. First, is the statistical analysis. The method used is the testing of independence through contingency tables and the Chi-square test. This, method, according to Walker and Lev (1953), uses the approach of having more than two classes for each variable. Using the original contingency table, the results proved significant, however, due to the large number of cells with less than five expectations per cell, the results could

not be used. Several classes were combined to reduce the number of cells with less than five expectations in order to satisfy statistical restraints. Industrial, recreational, and farmland were combined for this purpose. Though combined for the purposes of this table, these three classes are considered as separate entities for the remaining portion of the paper. The resulting value of the Chi-square test was 62.8. This value exceeded the Chi-square tabled value of 16.8 at the 99 percent level of confidence thus rejecting the null hypothesis that there was no relationship. It means that shoreline land use and shoreline type are dependent and that to a certain extent residents and users are aware of environmental constraints.

PERSONAL INTERVIEWS

The opinions and observations of shoreline residents concerning the relationship should give additional support to the hypotheses. A total of 24 shoreline residents of various ages were interviewed and included: (1) Life-time residents, and (2) Seasonal residents. Their response, in most cases, indicated an awareness of the shoreline processes and its effects. Of the twenty-four persons interviewed in the fall of 1976, seventy-one percent were aware of this relationship and had made efforts to deter erosion or encourage deposition. When the property was purchased, twenty percent were not aware of this relationship, but had since made efforts to deal with the erosional activity. The remaining eight percent was not aware of the problems associated with living along the Pamlico River at the time of purchase and are still not concerned. It seems that only the more recent residents have

any choice of where to build or develop. The residents, who have lived for a long time along the river are usually residing on property passed down for several generations. They had no part in the selection or location of the property and now can either sell the property and then move to another location rather than maintain the present one. They are usually fortunate that when the property was purchased, the more favorable areas were still available. Even these people who had no real choice of location, seemed to be more concerned with the various processes taking place along the shoreline. According to Taylor Koonce (1976), he and his father were very aware and concerned over the effects and the other shoreline processes. He felt that some of the newer waterfront home owners were not concerned. He spoke favorably of the concern of his father about erosion and deposition. His father used a variety of methods to encourage deposition. Such methods include the sinking of tires, weighted V-shaped wooden structures sunken perpendicular to the shoreline, sinking of abandoned barges, and finally the building of groins. His methods proved effective as deposition was increased resulting in shoreline accretion. Taylor Koonce, is currently building several homes along the Pamlico River. The homes are on a Type II shoreline, and to allow for periods of high water, the floor level is being built above the highest recorded point. This occurred in 1913 when the water was 9.25 feet deep in Washington.

Another long-time resident, Edwin R. Tripp (1976), whose home is located high above the water on a Type IV shoreline, recommended building back away from the water and also letting the shrubs and other forms of vegetation to continue growing in its natural state. Some of the more

recent residents cut down the trees and remove the other vegetation to improve their view, thus aiding the erosion process.

H. J. Smithwick (1976), has lived on the Pamlico River for seventy years. He has experienced the various weather phenomena and their resulting effects, because of this he recommends living on the higher elevations in more protected areas such as where the larger streams enter into the estuary.

In contrast, several people interviewed, were not aware of the effects of the various processes or the relationship. These people only wanted a place for water oriented recreational activities. For example, Jay M. Hodges (1976), a Beaufort county auditor, only wanted a place for him and his family to go swimming. The original building was a cottage for overnight visits, but now a new residence has been built, but for full time occupancy. He has now become aware of the associated processes on his Type II shoreline since he has lost about twenty feet of shoreline. He used beach nourishment until federal regulations prevented this method of protection. He has since built a bulkhead to deter erosion. Another example would be some shoreline property purchased from the father of Taylor Koonce. His father had sunk an abandoned wooden barge to encourage deposition. This method was effective, resulting in a bar being formed then later, grass began to grow. All of this created a new portion of shoreline. The new property owners did not like the old wooden barge, and had it removed and the grass cut down. The bar was soon eroded away along with some of their property. He also cited one other example of people not being aware of or understanding the relationship of shoreline type and land use. A developer built a number

of expensive homes on a Type I shoreline built up through dredge and fill operations. After the passage of Hurricane Hazel, all that remained was the foundations. Hurricane Hazel in 1954, did much to educate shoreline residents. They began building bulkheads, groins and jetties. Those persons who had built homes on the lower, more vulnerable shorelines, were faced with several choices. Some were forced to rebuild, some as in the case of Mrs. Robert Tyndall (1976) had their home raised 2.5 feet.

It is evident that there is varying degrees of awareness of the relationship of shoreline type and shoreline land use. Fortunately, people are becoming more cognizant of this relationship and the associated shoreline processes. They are exhibiting newer approaches to construction. Henry Moore (1976), constructed his home after the passage of Hurricane Hazel. His home, a permanent residence, to be built on a lower elevation required a modification of the shoreline. Sand was pumped in to increase the elevation and pilings were driven down about 15 or 20 feet to form a support for the concrete footings. Also groins were constructed. Mobile home parks, which are generally located on the lower shorelines, are using the double-wide mobile homes resting on the top of large stilts for added protection.

PROSPECTS FOR THE FUTURE

Contingency analysis substantiates the earlier hypothesis that a relationship exists between shoreline type and shoreline land use. It is possible to use the contingency table to foster some thoughts regarding future development of the shoreline. Further, if the shoreline

structures were ever destroyed by hurricanes or storms, this study can help determine the areas that would be the least effected by erosion and damage.

The Shoreline Erosion Inventory was used to determine the location of those areas most effected by erosion. This information was not available for the shorelines from Washington, N.C., to Broad Creek and Whichard Beach Peninsula. Both of these areas are predominantly Type I and II shorelines, thus being very susceptible to erosion and periods of high water associated with storms. The remaining seven shorelines will be ranked based upon the amount of shoreline eroded from 1938 to 1970. These segments are as follows: (1) South Creek to Goose Creek, (2) North Creek to the Pungo River, (3) Durham Creek to South Creek, (4) Chocowinity Bay to Blounts Creek, (5) Bath Creek to North Creek, (6) Broad Creek to Bath Creek, and (7) Blounts Creek to Durham Creek.

The shorelines are also ranked according to the total percentage of Type I and II shorelines, both of which are highly vulnerable to erosion and periods of high water and wave energy associated with storms. These are ranked as follows: (1) Whichard Beach Peninsula, (2) Washington, N.C., to Broad Creek, (3) South Creek to Goose Creek, (4) Broad Creek to Bath Creek, (5) Bath Creek to North Creek, (6) North Creek to the Pungo River, (7) Blounts Creek to Durham Creek, (8) Chocowinity Bay to Blounts Creek, and (9) Durham Creek to South Creek.

Finally, the shorelines are ranked according to housing density and are as follows: (1) South Creek to Goose Creek, (2) North Creek to the Pungo River, (3) Bath Creek to North Creek, (4) Whichard Beach Peninsula, (5) Washington, N.C., to Broad Creek, (6) Chocowinity Bay to

Blounts Creek, (7) Blounts Creek to Durham Creek, (8) Broad Creek to Bath Creek, and (9) Durham Creek to South Creek.

A rank ordering of the nine shoreline segments based upon percentage of Type I and II shorelines, rate of erosion, and housing density would determine which areas are more vulnerable to the effects of shoreline processes, thus suffering the greater amount of damage during those periods of high water and wave energy. Two segments, Washington, N.C., to Broad Creek, and Whichard Beach Peninsula, did not have available data for all three categories; therefore, could not be ranked. These two areas have high percentages of Type I and II shorelines and housing density, making them quite vulnerable. The rank ordering of the remaining segments is as follows: (1) South Creek to Goose Creek, (2) North Creek to the Pungo River, (3) Bath Creek to North Creek, (4) Chocowinity Bay to Blounts Creek, (5) Blounts Creek to Durham Creek, (6) Broad Creek to Bath Creek, and (7) Durham Creek to South Creek.

Location becomes very important when determining the vulnerability of the various shoreline areas, especially concerning Nor'easters and hurricanes. They have an additional impact on these vulnerable areas because of storm direction, fetch, wave energy and tides. So, if the situation should ever arise, location, in conjunction with the information contained within this investigation would be useful in determining those areas that are least effected by storm damage, or those areas where development is more favorable.

Most shoreline structures will be demolished by a storm such as Hazel in 1954. Property damage by a similar storm will probably be in the tens of millions of dollars for the Tar-Pamlico Estuary alone. This

study should aid in decreasing the impact of such storms. If not, it will provide baseline data for studying the effects of future storms and the resultant damage.

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