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January 1995

US Army Corps
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Waterways Experiment
Station

Kings Bay Coastal and Estuarine Physical Monitoring and Evaluation Program: Coastal Studies

Volume II: Appendices B-G

Edited by *Nicholas C. Kraus, Laurel T. Gorman, Joan Pope*

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Prepared for Office of the Chief of Naval Operations

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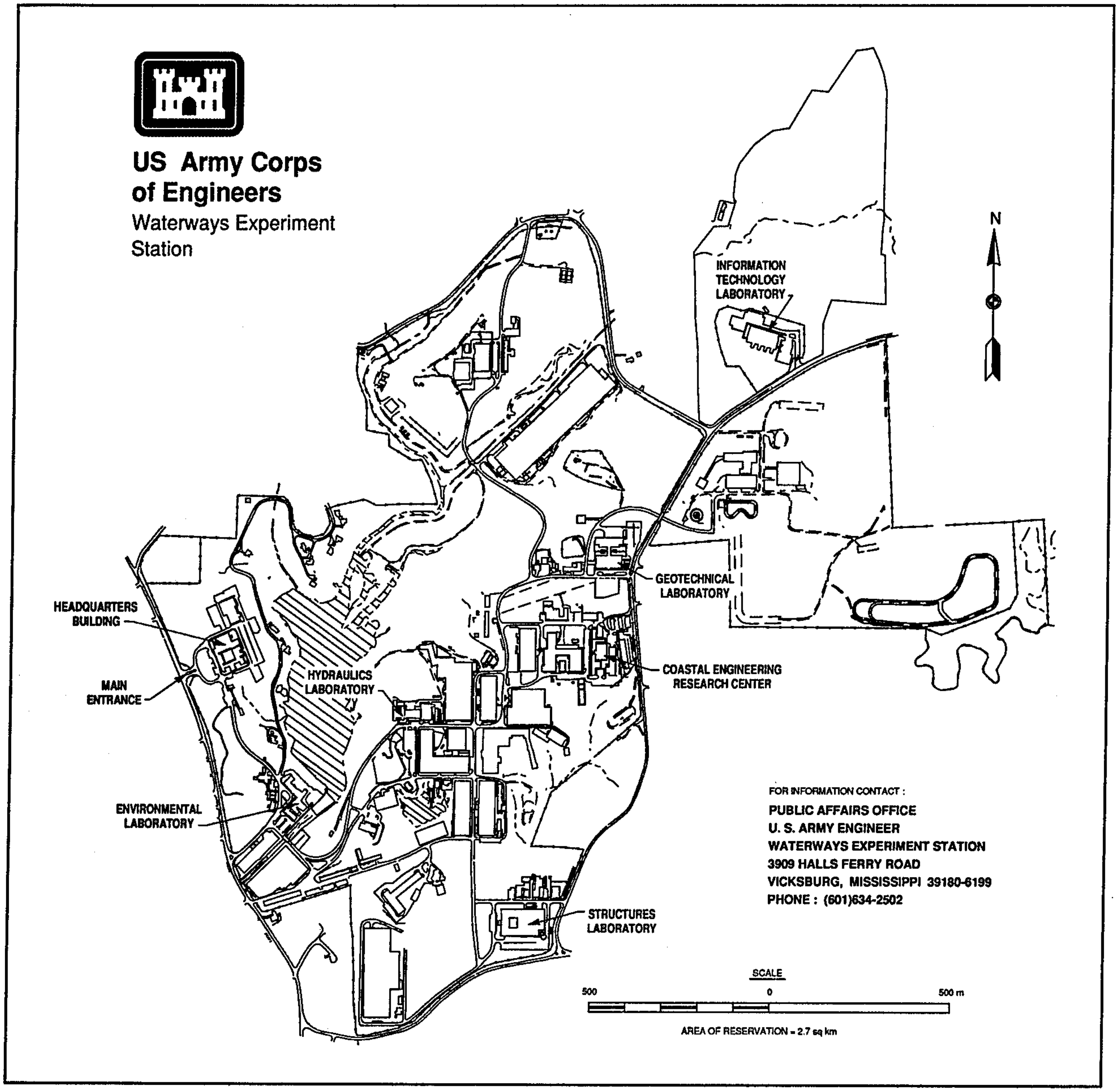

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Preface

The coastal processes physical monitoring and evaluation study described in this report was performed by elements of the U.S. Army Corps of Engineers (USACE) for the Department of the Navy, Office of the Chief of Naval Operations, through the Naval Facilities Engineering Command (NAVFAC). The study was conducted over the 5-year period 1 October 1988 to 30 September 1992. The U.S. Army Engineer Division, South Atlantic (SAD), was the lead Corps element and responsible for overall conduct of the study and coordination with the NAVFAC. The U.S. Army Engineer District (USAED), Jacksonville, and USAED, Savannah, conducted the majority of hydrographic and topographic surveys for the study, and the U.S. Army Engineer Waterways Experiment Station's (WES) Coastal Engineering Research Center (CERC) and Hydraulics Laboratory (HL), respectively, conducted the coastal studies and estuarine studies. In the final 15 months of the project, CERC was assisted through a contract with the Coastal Studies Institute, Louisiana State University (LSU), in analysis of shoreline position and bathymetry change, and in development of a Geographic Information System for the study, and by Offshore Coastal Technology, Inc., - East Coast, (OCTI-EC) in numerical modeling and in a sled hydrographic survey made in April 1992. The study was reviewed by and received guidance from a Technical Review Committee (TRC) reporting to an Interagency Steering Committee (ISC) representing the Department of the Navy and the Department of the Interior (DOI).

This report consists of two volumes. Volume I presents the main narrative, including study objectives, background information, procedures, and principal results. The purpose of Volume I is to present the study results. Volume II describes the historical and field data sets and products generated and analyzed in the study. Each major data set is documented in an appendix in Volume II, in which detailed information is given on data sources and collection methods, properties of the data, data tabulations and plots, and photographs of the study site.

The study was directed by the ISC, whose members were Mr. Thomas J. Peeling, representing the Office of the Chief of Naval Operations as Special Assistant for Environmental Planning, and Drs. Albert G. Green, Jr. (1988-1990) and Dennis Fern (1991-1992) from the DOI. The ISC was responsible for overseeing and reviewing TRC actions and appointment of TRC members. Members of the TRC were: Mr. Darrell Molzan, representing South Division,

NAVFAC, as the U.S. Navy study manager; Dr. Stephen Cofer-Shabica, representing the National Park Service (NPS), DOI as its study manager; Dr. James A. Baillard, formerly of the Naval Civil Engineering Laboratory (1988); Mr. John R. Headland, formerly NAVFAC (1989-1992); the late Dr. William Odum, University of Virginia, NPS representative (1988-1990); Dr. Robert G. Dean, University of Florida, NPS representative; and Dr. Vernon J. Henry, Georgia State University, NPS representative (1991-1992). Mr. Mark Leadon, Florida Department of Natural Resources, represented the State of Florida in TRC study reviews. The USACE study coordinator was Mr. James Robinson, SAD, and USACE District points of contact were Ms. Susan Brinson, USAED, Savannah, and Mr. Thomas Martin, USAED, Jacksonville. Ms. Joan Pope, Chief, Coastal Structures and Evaluation Branch (CSEB), Engineering Development Division (EDD), CERC, was principal WES contact for the study and coordinator of the coastal studies for 1988-1990. Dr. Nicholas C. Kraus, Senior Scientist, CERC, was coordinator of the coastal studies for 1991-1992. Mr. Thomas W. Richardson, Chief, EDD, CERC, participated in preproject planning and assisted throughout the study. Mr. George Fisackerly (HL) was the point of contact for the USACE estuarine studies. Ms. Laurel T. Gorman, CSEB, CERC, coordinated the historical and coastal monitoring substudies (1989-1992).

This report was written over the period October 1991 through March 1993. Chapter 1 was written by Ms. Pope and Mr. Richardson. Chapter 2 was written by Mses. Gorman and Pope. Chapter 3 was written by Dr. Mark R. Byrnes and Mr. Matteson W. Hiland, LSU. Chapter 4 was written by Mr. J. Bailey Smith, CSEB, CERC, and Mses. Pope and Gorman. Chapter 5 was written by Mses. Gorman, Pope, and Karen R. Pitchford, CSEB, CERC. Chapter 6 was written by Messrs. John W. McCormick, CSEB, CERC; William D. Corson, Prototype Measurement and Analysis Branch (PMAB), CERC; and W. Jeff Lillycrop, CSEB, CERC. Chapter 7 was written by Mr. William G. Grosskopf, OCTI-EC, and Dr. Kraus. Chapter 8 was written by Drs. Kraus and Byrnes, with input from all authors. Appendix B was written by Dr. Byrnes and Mr. Hiland. Appendix C was written by Mr. Smith, Mses. Pope and Gorman, Mr. Martin, and Ms. Brinson. Appendix D was written by Mses. Gorman and Pitchford, Dr. Donald K. Stauble, Mr. James T. Langston, and Michelle Kindhart, CSEB, CERC. Appendix E was written by Mr. Corson. Appendix F was written by Ms. Jane McKee Smith, Coastal Processes Branch (CPB), Research Division (RD), CERC. Appendix G was written by Dr. Kraus and Ms. Allison Abbe, CPB, CERC. The reference section was compiled by Ms. J. Holley Messing, CPB, CERC. Dr. Kraus and Mses. Gorman and Pope were technical editors for the report.

Mr. Stephen C. Knowles, formerly CSEB, CERC, and Dr. S. Rao Vemulakonda, CPB, CERC, participated in the early stages of the project. Mr. Randolph A. McBride, LSU, and Mr. Greg Forrester, NPS, assisted with the global positioning system shoreline survey (October 1991). The following individuals assisted in sample and data analysis, file handling, and figure and text preparation: Ms. Mary C. Allison, Mr. Lee A. Cheney, Mses Margaret V. Edris and Jackie J. Johnston, Mr. Corey L. Kindhart, Ms. Michelle K. Kindhart, Mr. M. Danny Marshall, Ms. Yvette L. McGowen, and Mr. Brian N. Williams, all of

CSEB, CERC; Mses Abbe and Messing, CPB, CERC; Ms. Robin Hoban, Coastal Oceanography Branch, RD, CERC; and Ms. Rhonda M. Lofton, PMAB, CERC. Ms. Pitchford contributed substantially in coordinating inter-agency data transfer and in developing final presentations of text and figures for both volumes of this report. Mses. Messing and Kindhart assisted in report formatting and physical production.

This study was performed under the administrative supervision of Dr. James R. Houston, Director, CERC; Mr. Charles C. Calhoun, Jr., Assistant Director, CERC; Mr. Richardson; Mr. H. Lee Butler, Chief, RD, CERC; Mr. Bruce A. Ebersole, Chief, CPB, RD, CERC; Ms. Pope; and Mr. William L. Preslan, Chief, PMAB, EDD, CERC.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048006	meters
inches	25.40005	millimeters
miles (U.S. statute)	1.6093472	kilometers
miles (U.S. nautical)	1.85325	kilometers
yards	0.9144018	meters

Appendix B[1]
Compilation and Analysis of Shoreline and Bathymetry Data

Methods for Compilation and Analysis of Cartographic Data

Various sources of cartographic data were used in the Coastal Monitoring Program to evaluate historical changes in shoreline position and bathymetry. Since the mid-1800s, significant changes in surveying procedures and cartographic representation make it necessary to document changes and adjust historical data for accurate comparison.

Cartographic characteristics and historical survey procedures

The following discussion is an overview of the execution of topographic surveys, the methods of making maps from these surveys, and the accuracy and detail of the surveys and maps. Four time periods are identified with horizontal reference datum changes. They include: (a) pre-North American Datum: 1834 to 1899, (b) North American or U.S. Standard Datum: 1899 to 1927, (c) North American Datum of 1927 (NAD 27): 1927 to 1983, and (d) North American Datum of 1983 (NAD 83): 1983 to present. Surveys involving all four datums were employed to quantify changes in shoreline position for this study, and a summary of data collection procedures and compilation considerations follows. Much of the information summarized below is presented in detail in Byrnes, McBride, and Hiland (1994).[2]

Horizontal control for National Ocean Service (NOS) T- and H-Sheets. In order to utilize maps for quantitative studies of spatial and temporal change, it is necessary to bring all cartographic data to a common system of horizontal control. To do this, geodetic variables must be identified and evaluated for all maps. The basic elements of horizontal control and the drawing of maps are the spheroid of reference (more recently called the ellipsoid), geographic datum, and map projection.

The spheroid of reference is a mathematical representation of the earth's surface or a specific portion of the earth's surface. Variables comprising the spheroid are distance measurements of

[1] Written by Mark R. Byrnes and Matteson W. Hiland.

[2] References cited in this appendix are located at the end of the main text, Volume I.

the semi-major axis and semi-minor axis. Various spheroid calculations are often compared by their values of flattening. If a is the semi-major axis of the earth and b the semi-minor axis, then the flattening f is defined as $(a-b)/a$ (Snyder 1987).[1] There have been many spheroid calculations, the most important of which are the Bessel spheroid of 1841 and the Clarke spheroid of 1866. The Bessel spheroid of 1841 was used for all maps between 1844 and February 1880. The Clarke spheroid of 1866 was adopted at this time and used until 1989, when it was officially replaced by the Geodetic Reference System 1980 (GRS 80) ellipsoid (Wade 1986). It is unclear which spheroid was used for maps before 1844, although reference is made to a value similar to that of the Walbeck 1819 spheroid.

A geographic datum, as defined by Shalowitz (1964), is "the adopted position in latitude and longitude of a single point to which the charted features of a region are referred. More specifically, it consists of five quantities: the latitude and longitude of an initial point, the azimuth of a line from this point to another point to which it is tied by the triangulation, and two constants necessary to define the terrestrial spheroid. It forms the basis for the computation of horizontal control surveys in which the curvature of the earth is considered."

Prior to 1899, there was not a triangulation network that covered the entire country. Instead, there were several detached systems of triangulation based on astronomic readings. Each of these systems represented an independent datum. With the completion of the transcontinental arc of triangulation, it was possible to unite these independent networks into a single datum for the entire country. This datum was named the United States Standard Datum and had its origin at station *Meades Ranch* in Kansas. In 1913, the network was expanded to include both Canada and Mexico and renamed the "North American Datum." However, no changes in the definition of the datum, and therefore no changes in the coordinates of any points, were made.

The practice of the U.S. Coast and Geodetic Survey (USC&GS) has been to update each of the early maps to the current best known coordinate values when there is a need. Updates consisted of drawing a new graticule (coordinate location) on the existing map. This could lead to the presence of several different sets of lines representing the same coordinates. There have been six occasions for updates, although it is often the case that corrections for several or all changes were made at the same time. The majority of the maps used which pre-date the North American Datum have been updated to the North American Datum, and many have been updated to the NAD 27. This is evidenced by the presence of new latitude-longitude lines drawn on the maps. These new lines are drawn and marked with the date of correction, the datum to which the map is corrected, and the initials of the person performing the correction. The procedures for manually performing these corrections are outlined by Shalowitz (1964), but modern computers provide much faster and more accurate methods for datum transformation.

On occasion, there were surveys made before any triangulation stations were established in an area and before astronomic observations were made. In this case, the topographer constructed a rectangular coordinate system and plotted points by their distances from the x- and y-axes (horizontal axes coordinates) and the distance between points. Normally, a 1,000-m grid would then be drawn on the survey sheet to facilitate adding a projection at a later date.

[1] For convenience, symbols are listed in the notation (Appendix A, Volume I).

The last crucial element of cartographic representation is map projection. A map projection is an ordered system of drawing parallels of latitude and meridians of longitude representing a round earth on a flat map. A great number of projections exist, each having its own advantages and disadvantages for varying scales and applications. The Polyconic projection was developed as an improvement on the Bonne projection shortly before 1820, and its use was promoted by Ferdinand Rudolph Hassler, head of the Survey of the Coast (Snyder 1987). The Polyconic projection has been used for all topographic surveys of the USC&GS since the publication of the first polyconic tables in 1853. Prior to this, maps were drawn either on a variation of the Polyconic projection or on the Bonne projection. However, on topographic surveys at scales of 1:10,000 or 1:20,000, the curvature of meridians and parallels is rarely perceptible. Thus, any difference in projection on these early maps makes little quantifiable difference in the positions of points.

Pre-North American Datum Surveys: 1834 to 1899. Nearly all topographic surveys conducted by the USC&GS, prior to the advent of aerial photography, were executed with a planetable. The planetable consisted of a drawing board mounted on a tripod such that the board could be leveled and revolved independently of the tripod. The alidade was a telescope mounted on a ruler such that the line of sight was always parallel to the ruler. The field survey sheet was clamped to the board. A map projection and any available triangulation stations were drawn on the field survey sheet prior to performing the topographic survey. Often, the topographer positioned the planetable over one of these triangulation stations in order to assure the best possible orientation of the instrument. This was accomplished by aligning the alidade and the table with another nearby triangulation station. Then, as the rodman walked to various points along the shoreline, angles to these points could be drawn directly onto the survey sheet. Distances were then measured either by chaining or by telemeter and stadia rod (Shalowitz 1964). Each rodded point was plotted onto the sheet, and the shoreline was sketched between points, allowing a map to be drawn simultaneously with the survey. This enabled the topographer to see and correct errors while still in the field. The planetable survey also eliminated the extra work and additional errors due to plotting the shoreline from field notes.

In the very earliest surveys, before the standardization of procedures, it was possible to have great variations in the amount of detail included on topographic surveys. Certain areas were mapped in greater detail (with more rodded points) while others were more dependent on sketching of the shoreline. This variation in detail depended largely on the topographer's estimation of the importance of the area. It is implied by Shalowitz (1964) that after the first 10 years of surveys, the number of rodded points was significantly increased due to more efficient use of the planetable. Excluding the very first surveys, however, all work conformed to certain standards of accuracy. These were not as high as present-day standards, but the maps produced were undoubtedly the only ones of the time period accurate enough to make quantitative estimates of shoreline position, and their competence has been upheld in court.

The actual accuracy of topographic surveys depends on the date of the survey, the purpose of the survey, the topographer, the methods used, and the amount of triangulation control available in the area. There was likely some variance in the abilities of individuals to sketch accurately, though the topographers generally were professionals who were very careful in their work. All factors taken into account, the interpreted location of the high-water shoreline on these surveys can be assumed to be within 10 m of its actual surveyed position, and it is often much better than this.

North American Datum (U.S. Standard) Surveys: 1899 to 1927. Maps of this period were still created using planetable surveys. Shalowitz (1964) gives no specific reference to the accuracy of these surveys, though one can assume some increased accuracy due to improvement of the triangulation network, advances in optical distance measurements (telemeter), and technological advances in the planetable design. Points on maps on the North American Datum should therefore be located with an error less than ± 10 m.

North American Datum 1927 (NAD 27) Surveys: 1927 to 1983. The constant addition of new surveys and adjustments associated with the existing geodetic network posed serious problems by the 1920s (Bowie 1928, Shalowitz 1964, National Academy of Sciences 1971). As various horizontal control loops were closed, they were adjusted using a least squares fit, introducing distortion in the new arcs instead of readjusting the entire network. As a result, all available primary data were combined in a new system known as the North American Datum 1927 (NAD 27) between 1927 and 1932 (Bowie 1928). The reference ellipsoid for NAD 27 was still Clarke 1866 with *Meades Ranch* as the origin. For the NAD 27 adjustment, latitude and longitude at station *Meades Ranch* on the reference spheroid were held fixed because the figure of the earth investigation in 1909 had shown that its position on which the United States Standard Datum (and North American Datum) depended closely approached the ideal for the country (Church 1920). Therefore, all other stations in the network changed position (USC&GS 1957).

Near-vertical aerial photography was introduced in the 1920s, and by the early 1930s it was used in conjunction with ground surveys (ground truthing) to compile T-sheets (Shalowitz 1964, Ellis 1978). Photogrammetry was in its infancy in the 1930s and did not fully develop until World War II. Therefore, T-sheets compiled in the 1930s and early 1940s are potentially less accurate than those of later years due to improvements in the evolving field of photogrammetry (Ellis 1978). Interpretation of the land-water interface was also problematic at first but recent surveys consistently monitor position of the high-water shoreline (Shalowitz 1964).

North American Datum 1983 (NAD 83): 1983 to Present. The North American Datum 1983 (NAD 83) was officially completed in July 1986 using the reference ellipsoid known as GRS 80 (National Academy of Sciences 1971, Wade 1986, Morgan 1987, Snyder 1987, Doyle and Dewhurst 1989). Eight major geodetic datum blocks exist throughout the world using one of the reference ellipsoids shown in Table B1. NAD 83 is a geocentric datum which means the reference ellipsoid coincides with the origin of the coordinate system -- the earth's center of mass (Morgan 1987). The GRS 80 ellipsoid was accurately determined by numerous earth orbiting satellites.

In 1971, the National Academy of Sciences concluded that the NAD 83 was needed for the following reasons:

a. Since 1927, approximately 99,000 new stations in the United States and several thousand stations in Canada, Mexico, and Central America have been added to the net, and these have been forced to fit into the old adjustment. Inevitably, this resulted in some distortion of previously established positions.

b. The old adjustment did not include the Atlantic Seaboard control.

c. Length control was significantly deficient for the 1927 adjustment.

Table B1
Reference Ellipsoids (from Morgan (1987))

Spheroid	Date	*a* (m)	*1/f*
Everest	1830	6,377,304.063	300.8017
Bessel	1841	6,377,397.155	299.1528128
Airy	1858	6,377,563.396	299.3249646
Clarke	1858	6,378,293.645	294.26
Clarke	1866	6,378,206.4	294.9786982
Clarke	1880	6,378,249.145	293.465
Hayford	1910	6,378,388	297.0
Krassovsky	1938	6,378,245	298.3
Hough	1956	6,378,270	297.0
Fischer	1960	6,378,166	298.3
IUGG	1967	6,378,160	298.25
Fischer	1968	6,378,150	298.3
WGS-72	1972	6,378,135	298.26
IUGG	1975	6,378,140	298.257
IUGG	1979	6,378,137	298.257
GRS 80	1980	6,378,137	298.257222101

d. A number of azimuths used in 1927 have been found to be of inferior accuracy.

e. Horizontal control in Alaska was connected to the datum during World War II by means of a single arc of triangulation along the Alaska Highway.

f. Many engineers who use the control system now have more precise angle and length measuring equipment available and use modern, more precise methods.

g. The National Geodetic Survey (NGS) uses more precise instruments and improved methods capable of increasing the accuracy of the net by approximately an order of magnitude.

h. Many of the original stations have been lost to natural erosion and expanding construction, particularly in urban areas.

i. In some areas of North America, relative horizontal tectonic movements as great as 5 cm/year have been observed.

With the completion of NAD 83, control points (survey monuments) throughout North America have been assigned new coordinates. Physically, the points have not moved, but the reference system has changed.

Data preparation and capture

Once data sources were identified for compiling shoreline position change, a variety of factors related to accurate data capture were considered depending on the vintage of cartographic material. Although difficulties in preparing a shoreline map are numerous, comparing shoreline positions on successive maps and air photos is even more challenging. Shoreline maps should be corrected to reflect a common datum and brought to a common scale, projection, and coordinate system before data from successive maps can accurately be compared (Snyder 1987, McBride 1989). Manual cartographic techniques are very tedious and time consuming. Fortunately, electronic digitizers and computers with a variety of software have greatly facilitated the use of maps for quantifying shoreline change (Byrnes, McBride, and Hiland 1991; McBride et al. 1991). This section discusses the elements of data preparation in terms of transformation variables for ensuring consistent comparison among historical data at a common scale, datum, ellipsoid, and projection. Data-capture procedures are described with reference to standard computer cartographic techniques needed for accurately superimposing metric quality maps.

General considerations. Cartographic parameters, such as map scale, projection, horizontal reference datum, and ellipsoid attributes, are used for representing any portion of the earth's surface (nonlinear and three-dimensional) on linear, two-dimensional media. These parameters were discussed above with reference to updates since the early to middle 1800s. Datum shifts have resulted in the largest amount of change with historical maps, but ellipsoid (or spheroid, as it was originally referenced) parameters used to approximate the earth's shape also have changed. Although NOS T- and H-sheets use a polyconic projection, large-scale planimetric maps produced for localized areas may use state plane coordinates (Transverse Mercator or Lambert Conformal projection). Accurate comparison of temporal changes necessitates data transformation to a common surface of correlation at a common scale (Shalowitz 1964, Ellis 1978).

In addition to considerations associated with coordinate representation, media distortion and incomplete map information present varying degrees of difficulty. Map paper distortion, or shrink and stretch, is recognized as being nonlinear and can represent a 1 percent change with a 60 percent increase in humidity (Snyder 1987). However, at large scale (greater than 1:24,000) and in a controlled laboratory environment, this problem is rather minor. A manual procedure for evaluating and compensating for map distortion is presented in Shalowitz (1964); however, computer cartographic procedures automatically make adjustments to alleviate this problem. Media destruction, such as folds and tears, can cause more serious problems. Each situation is unique and a number of techniques can be used to reduce the impact of potential problems.

A more direct limitation is that associated with restricted horizontal control. The most accurate way to register mapped features to a grid is to use triangulation station positions (Crowell, Leatherman, and Buckley 1991). If these data exist, they are located on maps very accurately (Shalowitz 1964). Newer maps contain many control points, but older maps typically contain very few points. Often, the graticule on a map represents the only level of control. This is especially true for H-sheets where a majority of the data points are offshore. Again, for newer maps this is not a problem; however, older maps may contain misplaced coordinates. If triangulation stations and a graticule do not exist, the map is no longer metric and should not be used for quantitative data comparisons.

Application of computer cartography. In recent years, the development and improvement of hardware and software for computer cartography have greatly reduced the time and effort required to alleviate the above-mentioned problems. Not long ago, accurate comparison of two maps from different years might have involved a trained cartographer to draw new projections at identical scales, a draftsman to redraw both maps, and at least several days for manual drafting of the maps. Now, with the aid of computers, one person can easily perform all of the corrections needed and produce a composite map in 1 day.

When maps are electronically digitized, they are traced into the computer using a high-precision digitizing table and cursor. The computer converts the points on the table to real-world units (meters, feet, latitude-longitude, etc.) in a graphics file using a transformation unique to each map. Consequently, all maps are brought to the same scale (1:1) and actual ground distances and areas can be determined directly. In addition, because all data are in this format, they are easily output to a plotter at any scale desired by defining a simple ratio of plotter units to graphics file units.

Each map may have a different map projection or different parameters for the same projection. Either way, two maps cannot be compared accurately unless they are drawn in the same projection with exactly the same parameters for that projection. Computer cartography software provides a list of several projections which may be used, and it allows the user to define the same set of parameters for a file as it exists on the map. Also included is the ability to convert any file defined with one projection and set of parameters to any other projection or set of parameters. Computer cartography software also provides the capability of defining and converting between a wide range of ellipsoids and datums. This allows all points on a map to be updated to the same horizontal control network and therefore the same coordinate system.

Media distortion can be eliminated by using maps drawn on stable-base materials. However, if paper maps are used, and distortion from shrinking and swelling is significant, the digitizer setup provides some degree of correction by distributing error uniformly across the map. In addition, rubber-sheeting and least-squares fit programs allow the user to define certain control points and correct for distortion errors as much as possible. It is also important to remember that data in digital form acquire no new distortions, whereas even stable-base maps can be torn, wrinkled, and folded, producing distortions on the map. Scale distortion from optical methods of map reproduction are also corrected by bringing all maps to a 1:1 scale.

The final important application of computer cartography is the advantage of saving time. Expert cartographers and draftsmen are trained for years, whereas a person with basic computer skills can be trained to operate a workstation and software in a matter of months. Digitizing maps is faster than manually drafting them, and the time for reproduction, coordinate system conversion, modification, and change of scale is reduced significantly. Also, the time for learning the system is constantly decreasing with improvements in hardware and added software functions. All of the above capabilities are critical for accurately quantifying change, and results obtained without consideration of these points are likely to have serious errors.

Digitizing cartographic data. In the past, map data capture for assessing shoreline change usually meant assembling available analog information and comparing shoreline position relative to a fixed reference point. The method was manual and was used mainly for reconnaissance purposes. Similarly, bathymetric change analysis was time intensive and of varying accuracy. With the advent of electronic digitizers and computer technology, the process of data capture has become much more accurate and less time consuming. The following section describes procedures used in this study to accurately establish a digitizer setup prior to capturing shoreline positions from T- and H-sheets, and the problems encountered with different vintage map sets.

Generally, it can be assumed that the more recent a map, the more accurately it is drawn. This stems from the fact that surveying and map-making technologies have shown a steady improvement over the years, much as technology has improved in other fields. For this reason, more recent maps were digitized first in order to create a better base with which to compare older maps. This method enables users to catch large errors with older maps and can also help improve the control within which they are digitized.

To compile accurate digital shoreline position data, a series of control points is necessary to place the shoreline in a coordinate system. This can be accomplished using triangulation station coordinates or the map graticule. The NGS can compile an alphabetized list of triangulation stations by state or by geographic region. This list gives the name of each station, its latitude and longitude, state plane coordinates, and state plane zone. These represent coordinates that have been updated to the NAD 27. Many of these points can be located on NOS T- and H-sheets, and these generally are considered the most accurate plotted points on the maps. The following is a discussion of digitizer setup methods which were used for compiling shoreline position data from NOS T- and H-sheets. It is important to have a well-outlined and strictly followed procedure for digitizing maps to assure consistency in the quality and reliability of data.

The primary method for linking map data with a defined grid is the use of triangulation station coordinates provided by the NGS. Digitizer setup is performed using at least four well-spaced triangulation stations with known NAD 27 coordinates; generally, the more triangulation stations used, the better the digitizer setup. By well-spaced, it is meant that the points should surround a majority of the area being digitized. This gives the computer a known point in each portion of the map and greatly reduces distortion, which becomes proportionately greater further from the known point. Often, there may be less than four triangulation stations on a particular map, or the stations on the map may be concentrated in one area. In this case, intersections of latitude and longitude lines are used as control points for digitizer setup in addition to triangulation station locations on the map. The graticule points used should complement the triangulation station(s) to provide at least four well-spaced points for digitizer setup.

Occasionally, there are no triangulation stations on a T- or H-sheet. In this case, several graticule points are used for digitizer setup. No noticeable difference has been found in the accuracy of graticule setup versus triangulation setup on recent maps (1932 to present). In other cases, there are triangulation stations drawn on NOS T- and H-sheets that are not included on the list from NGS. Therefore, it may be helpful to review older maps to see if these stations are associated with older shorelines. If a very good digitizer setup is achieved on the newer map, and this is usually the case, the unlisted triangulation stations can be digitized to provide a control point for use on the older map.

In some cases, U.S. Standard Datum maps for the study area contain less than four updated triangulation stations or graticule marks, or control points that are not well spaced. For this circumstance, two options can be pursued. First, the operator can physically measure the magnitude of the datum shift from an existing updated point. This shift can be applied to any other U.S. Standard Datum graticule point on the map (Shalowitz 1964), and the updated point can be drawn. A drawback of this method is that it introduces errors associated with manually measured distances and subsequent drawing of updated lines. As an alternative, the *Datum*

Differences publication should be consulted (USC&GS 1985). If one of the triangulation stations found on the map or an adjacent map is listed in this publication, that shift is applied to the points on the U.S. Standard Datum graticule, and new coordinates are supplied during the digitizer setup. Because the known shift of a point is applicable to any point on a large-scale map (Shalowitz 1964), and a T- or H-sheet at 1:20,000 scale generally covers less than 20 min of longitude or latitude, the known shift of a station is used only if it is located within 10 min of latitude or longitude of the point to be updated. The known shift of the triangulation station that is nearest the desired digitizer setup point is the adjustment applied to that point. This can mean different shifts on the same map, depending on the location of digitizer setup points and the location of the triangulation stations. With this known shift method of digitizer setup, inaccuracies resulting from manual measurement and drawing of lines are eliminated. Good results were achieved using this method.

Most mapping software provides some sort of error calculation as part of digitizer setup. This error represents the difference between points recorded on the digitizer table and their relationship to corresponding points in the graphics file coordinate system. If the coordinate system setup is nearly identical to that represented on the map, this error is normally very small. Large errors can occur due to, for example, uneven shrink and swell of the original map (the older T-sheets on mylar are actually copies of original paper maps onto a stable base), inaccuracies in plotted positions on the map, and misplacement of points by the user.

On the equipment used for this study, the average error and the maximum error of the digitizer setup are expressed as percentages. A transformation matrix is used to convert input digitizer table coordinates to design file coordinates for each point digitized. Input coordinates from the digitizer table are multiplied by the digitizer transformation matrix to calculate the design file coordinates. Digitizer setup points have coordinates for both the digitizer table and the design file. By minimizing the sum of the squares of the distances between the design file coordinates given and the design file coordinates calculated by the transformation, a set of matrix coefficients is calculated which provides the best fit. This matrix is general enough to deal with both rotation and stretching in all directions. The transformation is applied across the entire digitizer surface, making any distortion uniform throughout the map.

A 0.01 percent error corresponds to 1 m of displacement in a distance of 10,000 m on the ground. NOS T- and H-sheets are generally no longer than 1.2 m. At a scale of 1:10,000, this corresponds to a distance of 12,000 m on the ground. Thus, a 0.01-percent digitizer setup error would give a maximum error of 1.2 m for this scale. However, error decreases with proximity to digitizer setup points, thus assuring that errors due to digitizer setup will be considerably less than this maximum. An error of 0.01 percent or less is usually attained for NAD 27 maps. Errors of greater than 0.03 percent are not allowed on NAD 27 maps. This is well within national map accuracy standards (Ellis 1978). For U.S. Standard Datum maps, errors greater than 0.05 percent are not allowed. For pre-North American Datum maps, errors greater than 0.07 percent are not acceptable. The majority of maps used in this study have an average digitizer setup error of 0.03 percent or less (*Cartographic, Aerial Photographic, and Hydrographic Information Sheets* section).

General digitizing guidelines. Shoreline digitizing guidelines developed by the Louisiana State University (LSU) were adopted for reducing errors associated with data capture from cartographic and aerial photographic sources. These include:

a. All shorelines are digitized from stable-base materials. For NOS T- and H-sheets, this means purchasing all maps on mylar, or on bromide if mylar is not available for a particular map. Shorelines mapped from rectified aerial photography are drawn onto, and digitized from, acetate film.

b. Cartographic and photographic source materials are stored flat or vertical if such storage space is available. For mylar and acetate, this is not as essential because the films do not retain curling as badly as bromides. If bromides are shipped in a map tube, they are flattened for several days before digitizing.

c. When attaching a map to a digitizer table, the area being digitized is made as flat as possible. Any wrinkles can cause that portion of the map to move during digitizing, creating positional errors. High-quality drafting tape or masking tape is used to attach the map. One corner is taped first, then the map is smoothed diagonally and the opposite corner is taped securely; this procedure is repeated for the other two corners. Once the corners are secured, the map is smoothed from the center to the edges and taped along each edge.

d. High-precision equipment must be used for accurate shoreline change mapping. Digitizer tables with a precision of 0.1 mm were used. This means that the table can recognize differences in position on the table as small as 1/10 of a millimeter, or 1 m of ground distance at a scale of 1:10,000. The cursor used to trace shorelines from the map also possesses this level of precision. The center bead or crosshair of the cursor ideally should have the dimension of precision. The crosshair must be smaller than the width of the line being digitized; the smallest pen width generally available is 0.13 mm. The width of the crosshair of the high-precision cursor is approximately 0.1 mm.

e. When digitizing, Computer Aided Drafting and Design (CADD) mapping computer software gives the user the choice of manual point input or stream input. Stream input places points at a specified distance as the user traces over the line being digitized. This procedure tends to make a very uniform and smooth line. However, it could miss some crenulations in the line if the specified distance is too large; likewise, it could accept more points than are needed if the specified distance is too small, resulting in extremely large files, as well as storage and display problems. In addition, if the user's hand slips during the digitizing process, stream digitizing will continue to place points in the erroneous locations. These can present problems that are time-consuming to correct. Manual digitizing allows the user to place points at nonuniform distances from each other, and therefore allows the user to represent all variations in the shoreline. Also, a button must be pressed in order to place a point so the user can take care and time in the placement of each individual point. Manual digitizing was used for all aspects of the study.

f. Finally, the seaward edge of the high-water shoreline and the center point of the printed bathymetric sounding are used as the reference positions for data capture.

Potential errors

It is important that all available procedures be used to capture map data as carefully as possible; however, no matter how cautious the approach, a certain measure of error will be retained in all measurements of digitized horizontal position. Potential errors are introduced in two ways. Accuracy refers to the degree to which a recorded value conforms to a known standard. In the case of mapping, this relates to how well a position on a map is represented relative to actual ground location. Precision, on the other hand, refers to how well a measurement taken from a map or an aerial photograph can be reproduced. Table B2 lists the factors impacting the magnitude of error associated with data sources and measurement techniques. Both types of error should be evaluated to gage the significance of calculated changes relative to inherent inaccuracies. The following discussion addresses these factors in terms of data sources, operator procedures, and equipment limitations.

Table B2
Factors Affecting Potential Errors Associated with Cartographic Data Sources (after Anders and Byrnes (1991))

Accuracy		Precision
Maps and Charts	Field Surveys and Aerial Photographs	
Scale Horizontal Datum Shrink/Stretch Line Thickness Projection Ellipsoid Publication Standards	Location, Quality, and Quantity of Control Points Interpretation of High-Water Line Field Surveying Standards Photogrammetric Standards Aircraft Tilt and Pitch Aircraft Altitude Changes Topographic Relief Film Prints Versus Contact Prints	Annotation of High-Water Line Digitizing Equipment Temporal Data Consistency Media Consistency Operator Consistency

Cartographic sources. Shoreline measurements obtained from historical maps can only be as reliable as the original maps themselves. Accuracy depends on the standards to which each original map was made, and on changes which may have occurred to a map since its initial publication. Field and aerial surveys provided the source data used to produce shoreline maps. For T- and H-sheets at a 1:10,000 scale, national standards allow up to 8.5 m of error for a stable point (up to 10.2 m of error at 1:20,000), but the location of these points can be more accurate (Shalowitz 1964; Anders and Byrnes 1991; Crowell, Leatherman, and Buckley 1991). Nonstable points are located with less accuracy; however, features critical to safe marine navigation are mapped to accuracy stricter than national standards (Ellis 1978). The shoreline is mapped to within 0.5 mm (at map scale) of true position, which at 1:10,000 scale is 5.0 m on the ground.

Potential error considerations related to field survey equipment and accurate mapping of high-water shoreline position also were addressed by Shalowitz (1964) as follows:

> "With the methods used, and assuming the normal control, it was possible to measure distances with an accuracy of 1 m (Annual Report, U.S. Coast and Geodetic Survey 192, 1880) while the position of the plane table could be determined within 2 or 3 m of its true position. To this must be added the error due to the identification of the actual mean high water line on the ground, which may approximate 3 to 4 m. This is the accuracy of the actual rodded points along the shore and does not include errors resulting from sketching between points. The latter may, in some cases, amount to as much as 10 m, particularly where small indentations are not visible to the topographer at the plane table."

Measurement accuracy of the high-water shoreline on early surveys is thus dependent on a variety of factors, not the least of which was the ratio of actual rodded points to sketched data used by an individual surveyor. The more sketching used, the lower the overall accuracy. However, by triangulation control, a continuous check was applied to overall exactness of the work so that survey errors were not allowed to accumulate.

In addition to survey limitations listed by Shalowitz (1964), line thickness and cartographic errors (relative location of control points on a map) can be evaluated to provide an estimate of potential inaccuracy for source information. Although it can be argued that surveys conducted after 1900 were of higher quality than original mapping operations in the 1840s, an absolute difference cannot be quantified. Consequently, the parameters outlined above are assumed constant for all field surveys and provide a conservative estimate of potential errors. For the 1857/70 and 1924 T-sheets, digitizer setup recorded an average percent deviation of 0.02, or 4 m ground distance at a 1:20,000 scale. Line thickness, due to original production and photo-reproduction, was no greater than 0.3 mm, or 6 m ground distance for this same scale.

T-sheets for the 1933 (1:10,000) and 1974 (1:20,000) surveys were compiled from rectified aerial photography. Planimetric maps were constructed and field tested for accuracy. Fisher and Simpson (1979) and Everts, Battley, and Gibson (1983) compared well-defined aerial and ground control measurements for the Rhode Island and Florida coastlines and indicated an accuracy of about ± 3 m. For both surveys, average digitizer setup error was about 0.02 percent (2 and 4 m, respectively), whereas line thickness did not exceed 0.25 mm or 2.5 and 5 m ground distance. The 1957 shoreline from U.S. Geological Survey (USGS) 7.5-min topographic maps (1:24,000) was compiled at an earlier phase of the study using procedures inconsistent with detailed methodologies applied for all other phases of cartographic data compilation. As such, it is impossible to accurately quantify digitizer setup error; however, it is doubtful that the value would exceed ± 10 m.

A primary consideration with aerial surveys is the interpreted high-water shoreline position. Because delineation of this feature is done remotely, the potential for error is much greater than field surveys and is a function of geologic control and coastal processes. Dolan et al. (1980) indicated that average high-water line movement over a tidal cycle is about 1 to 2 m along the mid-Atlantic coast; however, accurate delineation of the line is sometimes difficult due to field conditions, knowledge of human impacts, and photographic quality. Although the magnitude of error associated with locating the high-water line is unknown, on gently sloping beaches with moderate tidal ranges (e.g., the area of the present study), significant horizontal displacement (5 to 20 m is not unlikely) can occur with a small increase in elevation.

For H-sheets, a topographical survey of the coast was often conducted before the bathymetric survey. Control points established along the shoreline were then used for positioning of the survey vessel offshore. Due to the nature of triangulating distances and angles from points on land, horizontal positions plotted for the vessel became less accurate as it moved away from shore. When the vessel was out of sight of the triangulation points along the coast, positioning was done by dead reckoning. Therefore, horizontal positions of some offshore soundings on early H-sheets may be suspect. However, with recent developments in positioning technology (Loran C and GPS), offshore positions have become much more reliable. Cumulative errors in bathymetric modeling using H-sheets, including horizontal and depth measurement errors, will be discussed in more detail in the section on bathymetric change.

Digitizer limitations. Another source of error relates to equipment and operator accuracy and precision. As stated earlier, the absolute accuracy (accuracy and precision) of the digitizing tables used for this study is 0.1 mm (0.004 in.). At a scale of 1:10,000, this converts to ± 1 m. Furthermore, the precision with which an operator can visualize and move the cursor along a line can lead to much greater errors (Tanner 1978). Fortunately, improper tracking associated with shoreline digitizing generally is random and may be dampened when averaged over finite distances of shoreline. To evaluate the magnitude of operator error associated with digitizing shoreline position, at least three repetitive measurements should be compared. For this study, the average error incurred using this procedure for a 1:20,000 scale map was about ± 2 m.

Organization of Geographic Data

Reliability of information needed to address the objectives of the coastal monitoring program depends on accurate and consistent data capture, organization, and analysis procedures. Because of the large number of individuals, separate studies, and amount and types of data involved in all components of the coastal monitoring program, and because most of the acquired data are geographic, an organizational strategy was designed to assure quality control standards for development of a coastal database. Over the past few years, significant advances in computer mapping and geographical information survey (GIS) technology have made it possible to capture, store, analyze, and display geo-referenced spatial data with a high degree of accuracy. This section describes the organizational structure of geographic data used in this study.

Geographic data for this project are stored in a GIS format. A GIS is defined as a system for the input, storage, display, analysis, and output of geo-referenced data. A GIS must be able to capture original data from various sources and of various types and store it in an organized manner. The system must then combine these various data, analyze the results of these combinations to produce new information, and produce maps of the original and new information. Although it is not required by definition, a GIS is generally assumed to be a computerized system. Computer graphics and processing provide more efficient means for accomplishing the functions of a GIS than do manual methods. Computers also allow the graphics to be linked with a Relational Database Management System (RDBMS), augmenting the graphics with added information to be used in analysis. In other words, rather than simply analyzing spatial relationships between graphic elements, one can also analyze according to relationships between associated tabular data. The following discussion provides a summary of the data capture and analysis tools used in this study to develop the Kings Bay GIS.

Software

Many combinations of computer hardware and software are commercially available for GIS applications. Most of the work for this project was accomplished using hardware and software from Intergraph Corporation. The basis for all of Intergraph's GIS software is the Modular GIS Environment Single User Nucleus (MGE_SX or MGE). This platform provides the mechanism for input of data and the organizational framework in which it is stored. MGE structures its data into **categories** and **features**. A category is a general type of data, while a feature is a specific element within a category. For example, if the category is coastal engineering structures, there might be several features such as groin, seawall, jetty, or breakwater. Thus, a category may contain several features, but a feature may only belong to one category.

Within MGE, the user creates projects, defines categories and features, and performs several graphics and database utilities. A feature table is built that contains information about each feature to be digitized. This table includes the feature name, its category, type (point, line, area, or area centroid), color, weight, style, level, and placement command. In digitizing, MGE uses this table to automatically place features consistently and correctly. In addition, once a feature has been placed in a file, only features from the same category may be placed in that file. This organization of features assists in preventing accidental erroneous placement of elements. Figure B1 shows the relationships between the various files, categories, and database tables in MGE. The Relational Interface System (RIS) is another integral software module used in the Kings Bay Coastal GIS. RIS works in conjunction with MGE to provide linkages to several commercially available RDBMS's, including Oracle, Informix, and Ingres. RIS provides a single interface to all supported RDBMS's and allows simultaneous access to several different databases. This project is using the Oracle RDBMS. Oracle takes full advantage of networking technology, allowing several different workstations on a network to access the same information.

All attribute information that MGE uses is stored in a database table. A unique set of database tables may be created for each project, or the same set may be used for several different projects if similar data are being processed. Typically, one database table is set up for each category, since all features within the same category will have similar attributes. The categories, features, database tables, and attribute fields comprising each table are all designed and defined prior to data capture.

MicroStation is the CADD software that allows placement of graphic elements in a specific coordinate system, placement of text and labels, and full 3D drawing capabilities. MicroStation provides the base graphics software on which the GIS application software modules are built (Figure B2).

MGE Projection Manager is a software package that is used to set up files with coordinate systems that match those present on the maps to be digitized. After the cartographic data are digitized, Projection Manager provides transformation routines to convert all maps to a common datum and projection, so that they can be correctly compared.

After maps have been digitized, checked for errors, and corrected, MGE Analyst (MGA) is used to build a topological file for performing spatial and relational vector analysis. This means that all spatial relationships between all elements to be analyzed, as well as their textual attributes, are stored in a single file. Then queries are built using a graphical interface. These queries can be combinations of both spatial queries and Structured Query Language (SQL) searches in the database. New files and maps can then be produced from the output of these queries.

MGE Terrain Modeler is the elevation modeling module in the GIS environment. It allows input of point data digitized from maps, contour data digitized from maps, and digital data from magnetic media. A Triangulated Irregular Network (TIN) file is created after elevation definition features are input. Additions and subtractions of surfaces can be performed, as well as interactive editing of the files. Output includes new TIN files, grid files, or design files showing features such as contours and spot elevations.

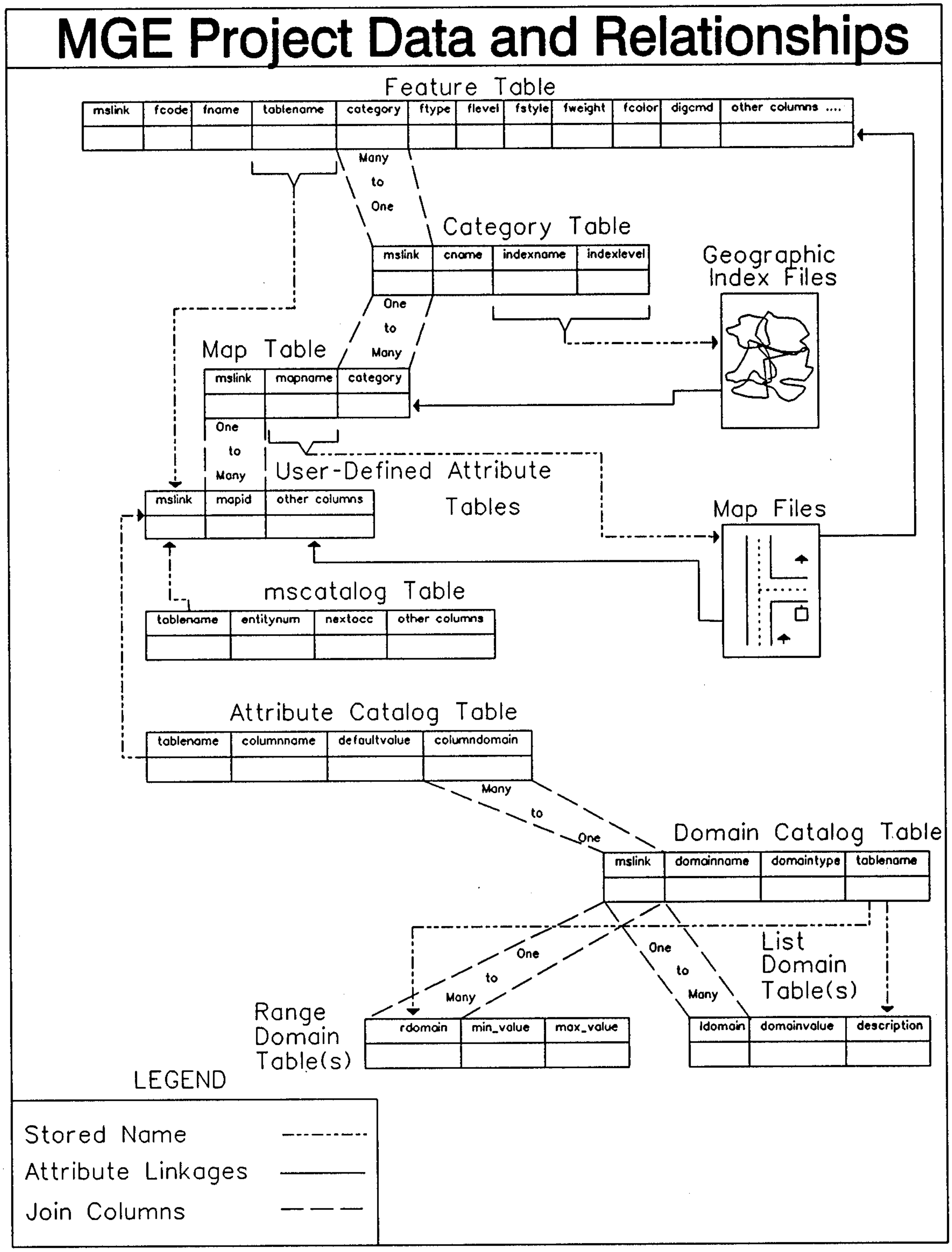


Figure B1. MGE project data and relationships (after Intergraph (1992))

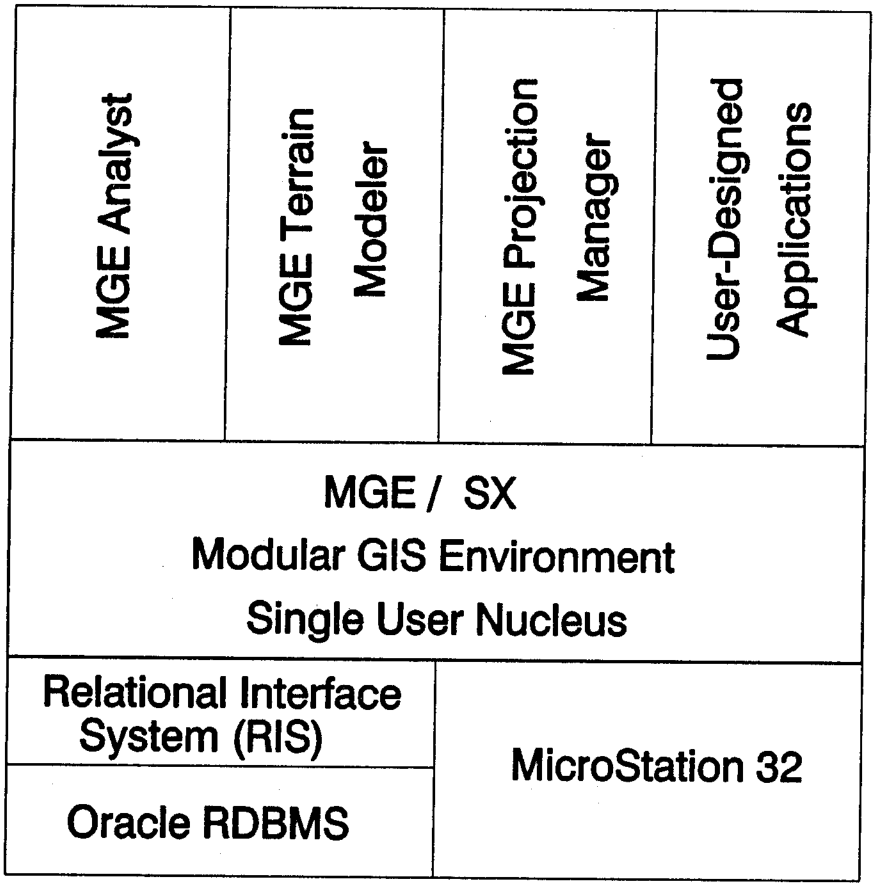


Figure B2. MGE software module relationships (after Intergraph (1992))

Hardware

Four Intergraph Unix-based workstations and one IBM personal computer were used for data capture and analysis. The Intergraph InterView 32C, located at the LSU, is a dual-monitor workstation with a large format digitizing table. GIS software on this platform includes MicroStation, MGE, RIS, Projection Manager, and MGA. Data capture, editing, and analysis are performed on this workstation. Two Intergraph InterPro 2020s with MicroStation, MGE, RIS, MGA, Projection Manager, and Modeler were used to perform bathymetry modeling and change analysis at LSU. Both of these workstations access the Oracle database on an Intergraph InterServe 6105 over an ethernet network. A Corps of Engineers 80386 IBM PC, connected to a large format digitizing table, was used primarily for digitizing in MicroStation PC. Files with the correct coordinate systems were set up on the InterView 32C and then transferred to the PC via serial cable. An Intergraph InterPro 2020, located at the U.S. Army Engineer Waterways Experiment Station's Coastal Engineering Research Center (CERC), is loaded with MGE, RIS, MicroStation, MGA, Projection Manager, Modeler, and Oracle. This machine was used in all phases of the Kings Bay Coastal GIS and contains the final copy of all data. Because LSU and CERC are networked via Internet, project coordination was maintained, quality control standards were checked, and data file transfer was facilitated. This allowed passing of data between LSU and CERC in an interactive and efficient manner.

File naming conventions and directory structure

MGE has its own directory structure that is automatically built when a project is created. Within the software, a directory is identified as the *project directory* and is usually named something like */usr/mgeprj*. Under the project directory, MGE creates a new directory for each project, with a % symbol as the first character in the name so the software can identify what projects are available (Figure B3). Under each project, ten directories are created:

/dgn: Contains all design files. These are also referred to as map files, because the data set contained in them is normally a map for GIS work. If a new map file is created while in a particular project, it is placed in this directory.

/grd: Contains grid files. Any raster data or grid surfaces created with MGE Modeler are stored here.

/idx: Contains index files. These are files used in GeoIndex Locate, a utility for locating and displaying maps that cover an area interactively defined on a vicinity map.

/qry: Contains query files. Queries built on topological files can be saved as ASCII text strings for future use, and are placed in this directory.

/rpt: Contains report files. When queries are built, a report of the findings of the queries can be output to an ASCII file, which is stored here.

/seed: Contains seed files. Seed files are empty map files that are set up with specific coordinate systems and other graphics environment settings. These are used to create new map files.

/setup: Contains various files used by the MGE software to control the MGE environment. Also contains cell files that are used to place symbols or groups of elements as a single element.

/topo: Contains *.top* files created by MGA. These files contain topological relationships of all features that have been built. They allow queries on database values and spatial analysis of geographic data.

/ttn: Contains *.ttn* files created by Modeler. These files hold the definitions of triangulated irregular network representations of three-dimensional surfaces, and are loaded into memory when working with Modeler.

/ulf: Contains Universal List Files. These are files containing a list of all elements in a graphics file, their element types, coordinate positions, and other information. These are used by the graphics processing applications such as Line Cleaner.

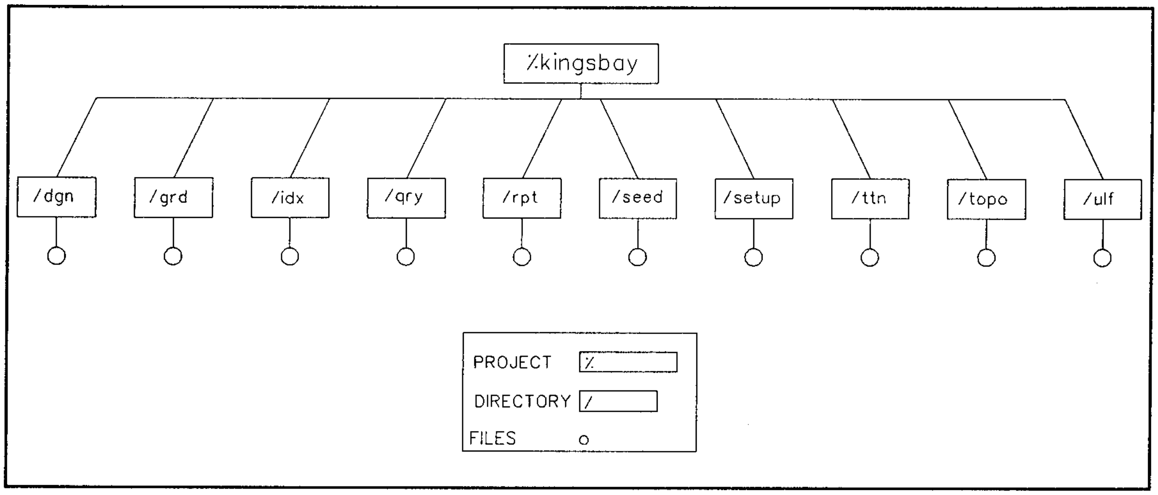


Figure B3. Directory structure of the MGE (Intergraph 1992)

All map files are stored in the */dgn* directory. Each digitized map has two separate files. The files were named so that the first two letters indicate the category of the file contents. Shoreline files begin with *sh* and structure files begin with *st*. Next, the numerical portion of the map name is given. The final two or three letters of the filename are an abbreviation for the projection of the digitized map. All files have a *.dgn* extension, which is the default extension for graphics files. For example, map number T-4068 was surveyed in August-November 1924 and is drawn in the polyconic projection. The shoreline was digitized into *sh4068pc.dgn*, and the structures into *st4068pc.dgn*. There are several different maps from 1924, each in a polyconic projection with slightly different parameters. Each map was digitized into two files matching its coordinate system. Then, all of the 1924 maps were converted to a common datum (NAD 83) and projection (Universal Transverse Mercator [UTM] -zone 17) and combined into two files: *sh1924utm.dgn* and *st1924utm.dgn*. These files can be used to compare shoreline positions of different dates, each having been compiled through a similar process.

Shoreline change data

Historical shoreline positions were digitized from cartographic sources and aerial photographs. A detailed discussion of these methodologies is given in the following section. However, at this point attention is called to the differences in database structure for these two data sources. Also, the two categories of shoreline features identified in this study, shorelines and structures, are described. The shorelines category implies a natural or nonstabilized land-water interface, whereas the structures category includes engineering and cultural objects along the coast.

As an aid in recording the ancestry of the digital shorelines, Cartographic Information Sheets were kept for each map digitized (following section). These record vital information about maps such as date, coordinate system, method of digitizer setup, and digitizer setup error (see the previous section for more detail). The boundaries of each map were entered as features in a category called *cartographic*. Each map date is a feature, similar to the shoreline and structure features. Map outlines were then linked to a database table which contains the information from the Cartographic Information Sheet. This allows future users to call up this information to determine the origin of the shoreline data.

Similarly, approximate centers of interpreted photograph frames are input as features in the *photographic* category. A Photographic Information Sheet was kept with information on each photograph used (following section). This was then stored in a database record for future reference.

Shorelines. As previously described, there is a direct relationship between a category and a database attribute table. The shoreline attribute table includes the following fields:

mslink: MGE software uses this required field as the occurrence number in the feature linkages.

mapid: A required field that identifies the file in which the elements representing a feature are stored. The software uses this field to find features when performing database queries.

map_date: The date of shoreline position digitized from existing maps. For older maps, this attribute represents the date of the field survey, usually given to the nearest month. For maps constructed after approximately 1930, the date of the aerial photography from which the map was produced is provided. This is sometimes only to the nearest month, but usually a specific day is given. For example, 21 October 1956 is the 294th day of the year (all dates are Julian) and would be entered as 1956.81. Maps are grouped into features according to the series to which they belong. In other words, even though two adjoining maps may not have the exact same date (October 1956 vs. November 1956), they will be considered the same feature (1956 shoreline), allowing a complete shoreline of the same feature for analysis purposes.

photo_date: The date of photography for shorelines photo-interpreted by LSU/CERC, also given as a Julian date.

map_num: The register number for historical maps. The maps used for this study were NOS T-sheets. An example of the number is T-615.

photo_num: The frame number of the aerial photography for shorelines photo-interpreted by LSU/CERC.

photoproject: The project code of the aerial photography for shoreline positions photo-interpreted by LSU/CERC.

state: The state in which the shoreline was located.

county: The county in which the shoreline was located.

locale: A local name for the shoreline (e.g. Cumberland Island).

area: The area of a feature defined by a closed polygon. For areas with closed polygons, such as an island, the area of a feature may be calculated and loaded directly into the database table.

perimeter: The perimeter of a feature defined by a closed polygon. Similar to the area, the perimeter may be loaded into the database table.

Database columns particular to cartographic data sources are left blank for shorelines interpreted from aerial photography, and vice versa. Examples of shoreline database records are given in Figures B4 and B5.

Structures. Structures are digitized from the same sources as shorelines. However, because they belong to a different category, they are stored in separate files. The structures category has its own database table with the following fields:

mslink: same as defined for shorelines table

mapid: same as defined for shorelines table

map_num: same as defined for shorelines table

map_date: same as defined for shorelines table

photo_num: same as defined for shorelines table

photo_date: same as defined for shorelines table

photoproject: same as defined for shorelines table

Define Attribution

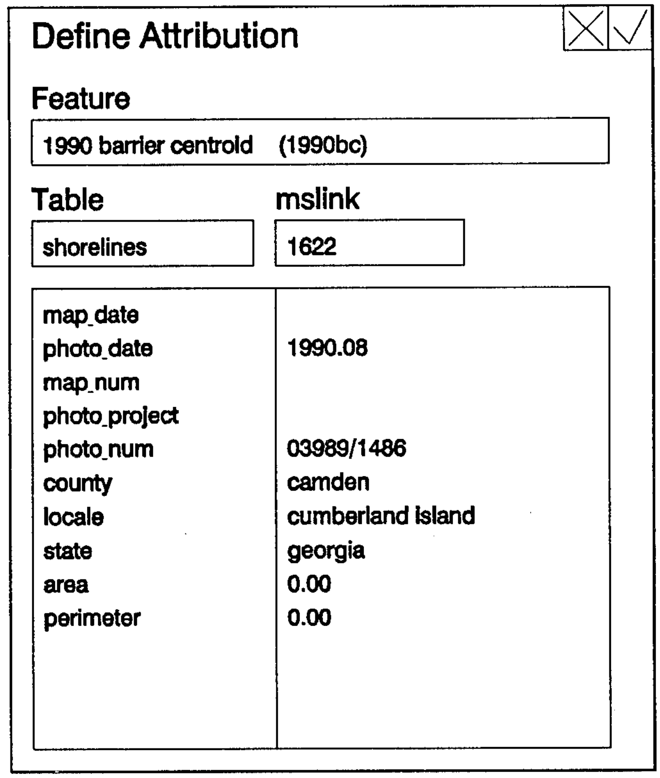
Feature

1924 Shoreline (1924sh)

Table	mslink
shorelines	1550

map_date	1924.72
photo_date	0.00
map_num	t4095
photo_project	
photo_num	
county	camden
locale	cumberland island
state	georgia
area	0.00
perimeter	0.00

Figure B4. Example cartographic shoreline position database record



Define Attribution

Feature

1990 barrier centroid (1990bc)

Table	mslink
shorelines	1622

map_date	
photo_date	1990.08
map_num	
photo_project	
photo_num	03989/1486
county	camden
locale	cumberland island
state	georgia
area	0.00
perimeter	0.00

Figure B5. Example aerial photographic shoreline position database record

state: same as defined for shorelines table

county: same as defined for shorelines table

locale: same as defined for shorelines table

struct_type: A field that defines the type of structure being entered; examples include piers, breakwaters, seawalls, bulkheads, jetties, and groins.

eng_or_cult: A field that specifies whether the structure is an engineering or cultural structure. An engineering structure is one that is built to physically control the coastline or aid navigation, whereas a cultural structure is one that is meant for other purposes. For example, a seawall or a jetty is considered an engineering structure, whereas a pier or drain pipe is considered a cultural structure. An engineering structure will nearly always exert some control on the position of the shoreline. Cultural structures may have some effect on shoreline position, but these effects are incidental and not planned.

Examples of database records for structures are shown in Figures B6 and B7.

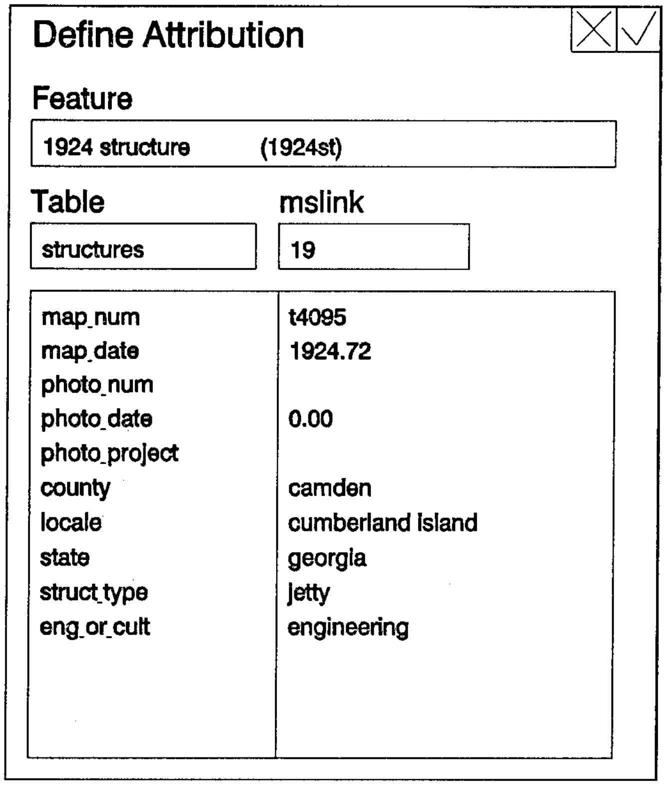


Figure B6. Example database record for engineering structures

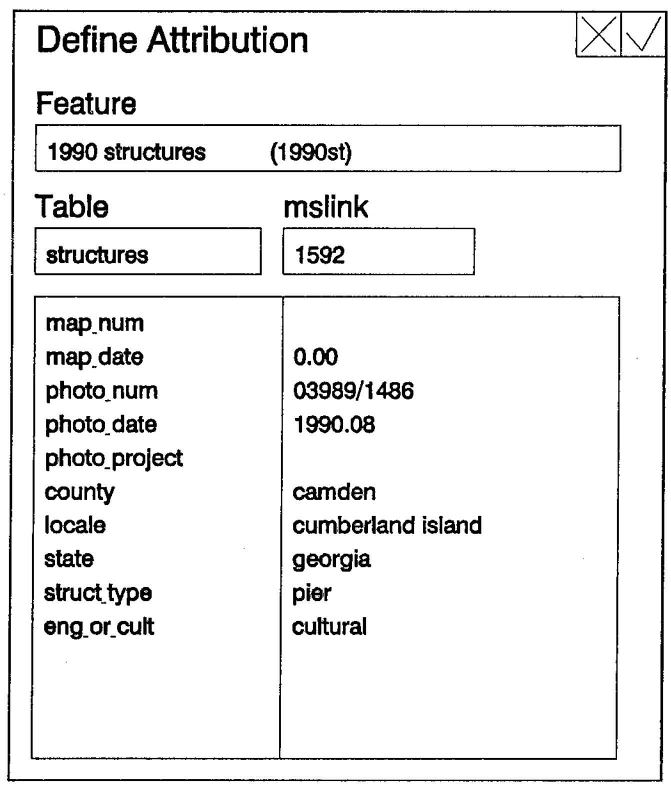


Figure B7. Example database record for cultural structures

Bathymetry change data

Bathymetry data sets were handled differently from shoreline position data due to differences in the software. Bathymetry information was processed using Intergraph's MGE Modeler. Here, the emphasis was not on attribute data attached to the original data, but the model built from these data. Therefore, there are no features and categories as discussed above. Instead, Modeler reads graphic data from a 2D or 3D design file. These graphic elements can be text, lines, points, or polygons. Then, an interactive form is used to read in certain elements from certain files. These elements are designated as different types of terrain features, such as point data, contours, faults, and ridge lines. After the software reads all available elements into memory, a TIN model is created. This model can then be saved to a *.ttn* file for future use. After several models are created, they can be analyzed by comparison with each other.

Cartographic data. Much of the historic bathymetry data used in this project comes from NOS H-charts. These charts are developed from hydrographic surveys that have been conducted at various times since the mid-1800s, focusing on areas of the sea near the United States coast. H-charts used in this study were digitized and processed by LSU and CERC personnel using MGE and Projection Manager software. Digital bathymetric data were then loaded into Modeler for further analysis within a GIS framework. A Hydrographic Information Sheet was kept with information about each map in a format consistent with Cartographic Information Sheets (following section). Map outlines for specific H-charts were created with all available information included in the database table.

Digital data. Digital bathymetric data are now available from the National Geophysical Data Center (NGDC). This information is easily loaded into Modeler for processing. In addition, the format makes it much easier to keep records of the data source. An outline of the location of the data from each source or date was drawn, and information similar to that recorded on the cartographic information sheets (following section) is contained in a database table.

Detailed study areas. Specific areas of interest for sediment budget analysis have been outlined on the regional bathymetry grid. These areas will be stored in a single design file on different levels. Then, when comparing bathymetric models with Modeler, a polygon can be identified by file name and level. The software then compares surfaces only within this area. The capability to operate locally allows for more location-specific change analysis without having to actually subset and store multiple copies of the data.

Beach profile data

In the study monitoring component, beach profile data were collected from July 1988 to May 1992. Details of data collection are discussed in Chapter 3 and in Appendix D. Organization of these data into a GIS and relational database format is presented in this section. As with shorelines and structures, profiles are created as a category. Different dates of profile occupation are defined as features. For example, 1988 and 1989 surveys from the same profile location are stored as separate features. Profile locations were imported to MGE by converting a file of textual coordinates to graphic elements. Profile data are entered in three dimensions by including the elevation values given for each horizontal position along the profile. When available, the following information is entered into the database table.

mslink: same as defined for shorelines table

mapid: same as defined for shorelines table

profile_id: label given to a specific beach profile

profile_date: date of profile survey

monument_x: longitude of profile survey marker

monument_y: latitude of profile survey marker

monument_z: elevation of profile survey marker

endpt_x: longitude of profile end point

endpt_y: latitude of profile end point

endpt_z: elevation of profile end point

azimuth: orientation of profile line relative to true north

technique: method of data collection

survey_party_1: chief of the data collection team

survey_party_2: instrument operator and rodman for data collection team

survey_party_3: additional members of data collection team

vol_above: profile volume above mean low water (MLW)

vol_below: profile volume below MLW

tot_volume: total profile volume

remarks: comments unique to the profile

Sediment sample data

Sediment samples were collected along certain beach profiles in the summers of 1988, 1989, 1990, and 1992 (Appendix D). These samples are represented graphically by a symbol placed at the appropriate horizontal position and elevation along the corresponding profile line. A sediment sample category was created in MGE with the different dates of collection becoming features. The information contained in the database table is described below.

mslink: same as defined for shorelines table

mapid: same as defined for shorelines table

sample_id: sediment sample identifier

sample_date: date sample was collected

profile_id: label given to profile along which sample was taken

environ: position along profile where sample was collected (e.g., berm, MLW, offshore bar)

surf_elev: surface elevation at sample location

depth: sample depth

inc_graph_mean: Folk inclusive graphic mean (include units)

comp_mean: method of moments arithmetic mean (include units)

median: sediment size at midpoint (50 percent) of distribution (include units)

inc_graph_stddev: Folk inclusive graphic standard deviation (include units)

comp_stddev: method of moments arithmetic standard deviation (include units)

inc_graph_skew: Folk inclusive graphic skewness

comp_skew: method of moments arithmetic skewness

inc_graph_kurt: Folk inclusive graphic kurtosis

comp_kurt: method of moments arithmetic kurtosis

pct_gravel: percent gravel

pct_sand: percent sand

pct_silt: percent silt

pct_clay: percent clay

method_collection: method of sample collection

method_analysis: method of sample analysis

date_analysis: date of sample analysis

sampler: person collecting sample

operator: person performing sample analysis

remarks: comments unique to the sediment sample

Cartographic, Aerial Photographic, and Hydrographic Information Sheets

As described above, information concerning the origin of digital shoreline and bathymetry data was recorded during the digitizing process and entered into the digital database. The information collected for the data sources is printed below. Information sheets are given for cartographic, aerial photographic, and hydrographic sources. Preceding each subsection is a legend for each type of information sheet, explaining the terms and information provided.

LEGEND FOR CARTOGRAPHIC INFORMATION SHEETS

Project: The name of the project for which this map was digitized.

Map Number: The number by which this map is indexed. This may be prefixed by a "T-" or an "H-" or it may merely be listed as the "Reference No." on some of the older maps.

Date of Field Survey: The date given for topographic field surveys collected prior to widespread use of aerial photography (if applicable).

Date of Aerial Survey: The date of aerial photography on newer maps (if applicable).

Date Published: The publication date, if different from the survey date.

Map Area: The general area covered by the map, usually the description given on the map itself.

Scale: The scale at which the map is printed.

Projection: The projection in which the map is drawn. This is nearly always printed on newer maps and rarely printed on older ones.

Updated to North American Datum? This refers to the drawing of new graticule points on maps printed prior to 1899 (if applicable). [YES or NO]

Updated to North American Datum 1927? This refers to the drawing of new graticule points on maps printed prior to 1927 (if applicable). [YES or NO]

Triangulation Stations with NAD 27 coordinates: List of all triangulation stations drawn on a map for which the NAD 27 coordinates are given in the list available from the NGS.

Triangulation Stations without NAD 27 coordinates: List of all triangulation stations drawn on a map for which the NAD 27 coordinates are not given in the list available from the NGS.

Method of digitizer setup: This may be one of the following methods, which are described in more detail in the *Digitizing Cartographic Data* section.

1. **Triangulation** - digitizer setup using four or more well-spaced triangulation stations.

2. **Graticule** - digitizer setup using four or more well-spaced points on the latitude-longitude grid drawn on the map.

3. **Digitized Points** - digitizer setup using triangulation stations digitized from more recent and more accurate maps.

4. **Known Shift** - digitizer setup applying the calculated coordinate shifts of nearby triangulation stations to other points throughout the map.

5. **Measured Points** - when only a few points on a map are updated to the North American Datum, the shift in position can be measured from these points and used at other points on the map to manually draw new North American Datum graticule points.

The digitizer setup can also be a combination of these methods. This will be shown by separating the different methods with a slash (for example: Triangulation/Graticule).

Point(s) of known shift: The triangulation station(s) listed in the *Datum Differences* publication that provide(s) shift measurements for the Known Shift digitizer setup method (if applicable).

Points used for digitizer setup (NAD 27): The actual points used for digitizer setup for the map. They may be triangulation station names with NAD 27 latitude-longitude coordinates or latitude-longitude coordinates that were updated to NAD 27.

Digitized by: Person(s) who digitized the map.

Digitizer Setup Error: The maximum and average percentage error calculated by the digitizer setup function in MicroStation. This is explained in greater detail in the *Digitizing Cartographic Data* section.

Remarks: These are comments particular to the map which may include, but are not limited to, lack of or quality of control points, tears, folds, division of maps into two or more sheets, digitizer setup error calculation, etc.

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-613

Date of Field Survey: 1857

Date of Aerial Survey: n.a.

Date Published: not stated

Map Area: St. Marys Entrance, Georgia/Florida

Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? Yes

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: None

Triangulation Stations without NAD 27 coordinates: None

Method of digitizer setup: Known Shift

Point(s) of known shift: Pt. Peter 1855

Points used for digitizer setup (NAD 27):

81°29'59.762",30°44'00.056"   81°26'59.762",30°45'00.056"
81°27'59.762",30°42'00.056"   81°25'59.762",30°41'00.056"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-615

Date of Field Survey: 1857

Date of Aerial Survey: n.a.

Date Published: not stated

Map Area: Amelia Island, Florida

Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? Yes, two points.

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: None

Triangulation Stations without NAD 27 coordinates: None

Method of digitizer setup: Known Shift/Measured Points

Point(s) of known shift: Amelia Island Lighthouse 1905

Points used for digitizer setup (NAD 27):

81°29'59.715",30°40'00.038"	81°26'59.715",30°40'00.038"
81°26'59.715",30°38'00.038"	81°29'59.715",30°38'00.038"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-1145

Date of Field Survey: 1868/1870

Date of Aerial Survey: n.a.

Date Published: not stated

Map Area: St. Andrew Sound, Georgia

Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? Yes

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: None

Triangulation Stations without NAD 27 coordinates: None

Method of digitizer setup: Known Shift

Point(s) of known shift: Bunkley 1913

Points used for digitizer setup (NAD 27):

81°31'59.856",31°05'00.093"	81°23'59.856",31°04'00.093"
81°31'59.856",30°55'00.093"	81°23'59.856",30°55'00.093"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.03%
Average = 0.03%

Remarks:

Two tears at north edge of map.

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-1152

Date of Field Survey: 1870

Date of Aerial Survey: n.a.

Date Published: not stated

Map Area: Cumberland Island, Georgia

Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? Yes

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: Camden 1860

Triangulation Stations without NAD 27 coordinates: None

Method of digitizer setup: Known Shift/Triangulation

Point(s) of known shift: Bat 1860

Points used for digitizer setup (NAD 27):

81°29'59.831",30°56'00.053"	81°23'59.831",30°56'00.053"
81°25'59.831",30°50'00.053"	Camden 1860

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.01%
Average = 0.01%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-1232a

Date of Field Survey: 1871

Date of Aerial Survey: n.a.

Date Published: not stated

Map Area: Nassau Sound, Florida

Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? Yes

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: Braddock, Sterrett, Pine Island

Triangulation Stations without NAD 27 coordinates: None

Method of digitizer setup: Known Shift/Triangulation

Point(s) of known shift: Pine Island

Points used for digitizer setup (NAD 27):

Braddock	81°25'59.755",30°34'00.065"
Sterrett	81°25'59.755",30°37'00.065"
Pine Island	

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.03%
Average = 0.02%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-4106

Date of Field Survey: October 1924

Date of Aerial Survey: n.a.

Date Published: not stated

Map Area: Northern Cumberland Island and St. Andrew Sound, Georgia

Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: Pivot Reference, Bunkley

Triangulation Stations without NAD 27 coordinates: Tilla, Little Cumberland Island L.H., Groves

Method of digitizer setup: Known Shift

Point(s) of known shift: Pivot Reference, Bunkley

Points used for digitizer setup (NAD 27):

81°28'59.915",31°03'00.020"   81°28'59.856",30°55'00.093"
81°23'59.915",31°03'00.020"   81°23'59.856",30°52'00.093"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.03%
Average = 0.02%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-4095

Date of Field Survey: September 1924

Date of Aerial Survey: n.a.

Date Published: not stated

Map Area: Cumberland Island, Georgia, and Northern Amelia Island, Florida

Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: St. Peter

Triangulation Stations without NAD 27 coordinates: Carnegie, Greyfield's Windmill, Dungeness Water Tower, Hammock, Court House, Water Tower, Amelia Light

Method of digitizer setup: Known Shift/Triangulation

Point(s) of known shift: Pt. Peter

Points used for digitizer setup (NAD 27):

81°29'59.762",30°52'00.056"   81°24'59.762",30°52'00.056"
81°24'59.762",30°40'00.056"   81°29'59.762",30°40'00.056"
Point Peter

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-4068

Date of Field Survey: August - November 1924

Date of Aerial Survey: n.a.

Date Published: not stated

Map Area: Amelia Island and Little Talbot Island, Florida

Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: Braddock

Triangulation Stations without NAD 27 coordinates: McRory, Point, South Jetty

Method of digitizer setup: Known Shift/Triangulation

Point(s) of known shift: Braddock

Points used for digitizer setup (NAD 27):

81°22'59.685",30°24'00.030"   81°25'59.685",30°36'00.030"
81°26'59.685",30°24'00.030"   81°29'59.685",30°36'00.030"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.01%
Average = 0.01%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-5228

Date of Field Survey: n.a.

Date of Aerial Survey: November 24-26, 1933; December 16-17, 1933

Date Published: 1938

Map Area: St. Andrew Sound, Georgia

Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°31'00",30°58'00"	81°31'00",31°02'00"
81°25'00",30°58'00"	81°25'00",31°02'00"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-5229

Date of Field Survey: n.a.

Date of Aerial Survey: November 24, 1933; December 16, 1933

Date Published: 1936

Map Area: Northern Cumberland Island, Georgia

Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°28'00",30°52'00"	81°28'00",30°58'00"
81°24'00",30°52'00"	81°24'00",30°58'00"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-5231

Date of Field Survey: n.a.

Date of Aerial Survey: November 24-26, 1933; December 16, 1933

Date Published: April 28, 1937

Map Area: Cumberland Island, Georgia

Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°32'00",30°48'00"	81°32'00",30°51'00"
81°25'00",30°48'00"	81°25'00",30°51'00"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-5232

Date of Field Survey: n.a.

Date of Aerial Survey: November 24-26, 1933

Date Published: not stated

Map Area: Southern Cumberland Island, Georgia

Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°31'00",30°42'00"	81°31'00",30°48'00"
81°27'00",30°42'00"	81°27'00',30°48'00"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-5233

Date of Field Survey: n.a.

Date of Aerial Survey: November 24-26, 1933

Date Published: not stated

Map Area: Northern Amelia Island, Florida

Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°31'00",30°36'00" 81°31'00",30°42'00"
81°26'00",30°36'00" 81°26'00",30°42'00"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.01%
Average = 0.01%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: T-5234

Date of Field Survey: n.a.

Date of Aerial Survey: November 24-26, 1933

Date Published: not stated

Map Area: Southern Amelia Island, Florida

Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°30'00",30°30'00"	81°26'00",30°30'00"
81°26'00",30°36'00"	81°29'00",30°36'00"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.03%
Average = 0.03%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: TP-00497

Date of Field Survey: n.a.

Date of Aerial Survey: September 30 - October 2, 1973

Date Published: October 1975

Map Area: Northern Cumberland Island, Georgia

Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°30'00",30°50'00"	81°20'00",31°00'00"
81°30'00",31°00'00"	81°20'00",30°50'00"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.01%
Average = 0.01%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: TP-00657

Date of Field Survey: n.a.

Date of Aerial Survey: September 30 - October 2, 1973

Date Published: September 1975

Map Area: Southern Cumberland Island, Georgia

Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°30'00",30°40'00"	81°30'00",30°50'00"
81°20'00",30°50'00"	81°20'00",30°40'00"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.03%
Average = 0.03%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: TP-00658

Date of Field Survey: n.a.

Date of Aerial Survey: April 6, 1974

Date Published: September 1975

Map Area: Amelia Island, Florida

Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°30'00",30°30'00"	81°20'00",30°30'00"
81°30'00",30°40'00"	81°20'00",30°40'00"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.03%
Average = 0.03%

Remarks:

CARTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: TP-00659

Date of Field Survey: n.a.

Date of Aerial Survey: April 6, 1974

Date Published: September 1975

Map Area: Nassau Sound and Little Talbot Island, Florida

Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°30'00",30°20'00"	81°30'00",30°30'00"
81°20'00",30°30'00"	81°20'00",30°20'00"

Digitized by: Shirish Morchi (LSU), Prathap Paragi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

LEGEND FOR AERIAL PHOTOGRAPHIC INFORMATION SHEETS

Project: The name of the project for which the photograph was interpreted.

Photo Source: Agency or firm where source data were obtained.

General Location: Geographic description of region covered by the photograph.

USGS Quadrangle: Name and/or number of the 7.5' quadrangle where photo coverage occurs.

Date of Aerial Survey: The date the aerial survey was flown (printed in the upper left corner of the photograph).

Agency Project Code: The project identification code assigned by the flying agency (on the photograph).

Roll Number: The number associated with the roll of film where the photo is recorded (on the photograph).

Flightline Number: The number associated with a specific flightline that is a part of the entire survey (on the photograph).

Frame Number: The number associated with a specific photograph along a flightline (on photo).

Photo Scale: The nominal scale at which the photograph was taken (on photo).

Film Type: The type of film used to record the photograph (Black and White Infrared, Color Infrared, Color, Black and White, Thermal).

Photograph Medium: The type of medium being used for analysis (e.g., positive transparency, contact print).

Photograph Format: The dimensions of the photograph medium (e.g. 9" x 9").

Sensor Class: The type of photography being recorded (vertical cartographic (implies stereo), vertical reconnaissance).

Photo Quality: Characteristics of the photograph that affect analysis (e.g., grainy texture, cloud cover, clarity of wet/dry beach contact for registering the high water line (HWL).

Interpreted by: Person(s) who interpreted the aerial photography and produced a rectified photo map for digitizing.

Digitized by: Person(s) who digitized the rectified photo map.

Digitizer Setup Error: The maximum and average percentage error calculated by the digitizer setup function in MicroStation. This is explained in greater detail in the *Digitizing cartographic data* section.

Remarks: Comments particular to the photograph which may include quality of control for rectifying the photograph to a map, scale and type of cartographic data being used for rectification, morphologic features of interest, etc.

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: West of Cumberland Island, Georgia

USGS 7.5' Quadrangle: Kingsland NE, Georgia

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1490

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Prathap Paragi (LSU), Shirish Morchi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: West of Cumberland Island, Georgia

USGS 7.5' Quadrangle: Kingsland NE, Georgia

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1489

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Prathap Paragi (LSU), Shirish Morchi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: Cumberland Island, Georgia

USGS 7.5' Quadrangle: Cumberland Island North, Georgia

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1487

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Matt Hiland (LSU), Qiang Tao (LSU)

Digitizer Setup Error:

Maximum = 0.03%
Average = 0.03%

Remarks: Ocean-facing shoreline not used for change analysis because of difficulties in interpreting high-water shoreline position due to scale of photography and lack of contrast on beach.

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: Cumberland Island, Georgia

USGS 7.5' Quadrangle: Cumberland Island North, Georgia

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1486

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Matt Hiland (LSU), Qiang Tao (LSU)

Digitizer Setup Error:

Maximum = 0.03%
Average = 0.03%

Remarks: Ocean-facing shoreline not used for change analysis because of difficulties in interpreting high-water shoreline position due to scale of photography and lack of contrast on beach.

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: Kings Bay Submarine Base, Georgia

USGS 7.5' Quadrangle: Harrietts Bluff, Georgia

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1493

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Prathap Paragi (LSU), Shirish Morchi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.01%
Average = 0.01%

Remarks:

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: Kings Bay Submarine Base, Georgia

USGS 7.5' Quadrangle: Harrietts Bluff, Georgia

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1492

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Prathap Paragi (LSU), Shirish Morchi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: Kings Bay Submarine Base, Georgia

USGS 7.5' Quadrangle: Harrietts Bluff, Georgia

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1491

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Prathap Paragi (LSU), Shirish Morchi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: Cumberland Island, Georgia

USGS 7.5' Quadrangle: Cumberland Island South, Georgia

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1484

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Prathap Paragi (LSU), Shirish Morchi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.01%
Average = 0.01%

Remarks: Ocean-facing shoreline not used for change analysis because of difficulties in interpreting high-water shoreline position due to scale of photography and lack of contrast on beach.

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: West of Amelia Island, Florida

USGS 7.5' Quadrangle: St. Marys, Georgia

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1494

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Matt Hiland (LSU), Christina Hebert (LSU), Qiang Tao (LSU)

Digitizer Setup Error:

Maximum = 0.01%
Average = 0.01%

Remarks:

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: Cumberland Island, Georgia and Amelia Island, Florida

USGS 7.5' Quadrangle: Fernandina Beach, Florida

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1482

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Prathap Paragi (LSU), Shirish Morchi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks: Ocean-facing shoreline not used for change analysis because of difficulties in interpreting high-water shoreline position due to scale of photography and lack of contrast on beach.

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: Amelia Island, Florida

USGS 7.5' Quadrangle: Fernandina Beach, Florida

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1481

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU), Karen Westphal (LSU)

Digitized By: Prathap Paragi (LSU), Shirish Morchi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks: Ocean-facing shoreline not used for change analysis because of difficulties in interpreting high-water shoreline position due to scale of photography and lack of contrast on beach.

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: West of Amelia Island, Florida

USGS 7.5' Quadrangle: Hedges, Georgia

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1496

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU)

Digitized By: Qiang Tao (LSU)

Digitizer Setup Error:

Maximum = 0.01%
Average = 0.01%

Remarks:

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: Amelia Island, Florida

USGS 7.5' Quadrangle: Amelia City, Florida

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1480

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU), Karen Westphal (LSU)

Digitized By: Prathap Paragi (LSU), Shirish Morchi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.00%

Remarks: Ocean-facing shoreline not used for change analysis because of difficulties in interpreting high-water shoreline position due to scale of photography and lack of contrast on beach.

AERIAL PHOTOGRAPHIC INFORMATION SHEET

Project: Kings Bay

Photo Source: Waterways Experiment Station, USACE, Vicksburg, MS

General Location: Amelia Island, Florida

USGS 7.5' Quadrangle: Amelia City, Florida

Date of Aerial Survey: January 17, 1990

Agency Project Code: n.a.

Roll Number: 03989

Flightline Number: 90-90-041

Frame Number: 1479

Photo Scale: 1:63,000

Film Type: Color Infrared

Photograph Medium: Contact Print

Photograph Format: 9" x 9"

Sensor Class: n.a.

Photo Quality: Excellent

Interpreted By: Qiang Tao (LSU), Karen Westphal (LSU)

Digitized By: Prathap Paragi (LSU), Shirish Morchi (LSU), Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.00%

Remarks: Ocean-facing shoreline not used for change analysis because of difficulties in interpreting high-water shoreline position due to scale of photography and lack of contrast on beach.

LEGEND FOR HYDROGRAPHIC INFORMATION SHEETS

Project: The name of the project for which this map was digitized.

Map Number: The number by which this map is indexed.

General Location: The area which this map represents.

Date of Bathymetric Survey: The date given for the collection of bathymetry data.

Method of Data Collection: The means by which depth readings were taken (soundings, lead line, pole).

Reference Tidal Station and Epoch: The name of the tide station used for controlling bathymetric surveys and the associated 18-year lunar epoch for the survey.

Reference Vertical Datum: Vertical control under which the bathymetric survey was conducted (e.g., mean low water, mean sea level, National Geodetic Vertical Datum).

Vertical Datum Adjustment: Vertical changes applied to bathymetry data to bring all information to a common datum.

Date Published: The publication date or date of last field inspection, if different from the survey date.

Map Scale: The scale at which the map is printed.

Projection: The projection in which the map is published. This is nearly always printed on newer maps and rarely printed on older ones.

Updated to North American Datum? This refers to the drawing of the new graticule points on maps printed prior to 1899 (n.a. if not applicable).

Updated to North American Datum 1927? This refers to the drawing of new graticule points on maps printed between 1899 and 1927 (n.a. if not applicable).

Triangulation Stations with NAD 27 coordinates: List of all triangulation stations located on a map for which the NAD 27 coordinates are given in the list available from the NGS.

Triangulation Stations without NAD 27 coordinates: List of all triangulation stations drawn on a map for which the NAD 27 coordinates are not given in the list available from the NGS.

Method of digitizer setup: This may be one of the following methods, which are described in more detail in the *Digitizing cartographic data* section.

1. **Triangulation** - digitizer setup using four or more well-spaced triangulation stations.

2. **Graticule** - digitizer setup using four or more well-spaced points on the latitude-longitude grid drawn on the map.

3. **Digitized Points** - digitizer setup using triangulation stations digitized from more recent and more accurate maps.

4. **Known Shift** - digitizer setup applying the coordinate shifts of nearby triangulation stations to other points throughout the map.

5. **Measured Points** - when only a few points on a map are updated to the North American Datum (NAD), the shift in position can be measured from these points and used at other points on the map to manually draw new NAD graticule points.

The digitizer setup can also be a combination of these methods. This will be shown by separating the different methods with a slash (for example: Triangulation/Graticule).

Point(s) of known shift: The triangulation station(s) listed in the *Datum Differences* publication (NGS) that provide(s) shift measurements for the Known Shift digitizer setup method (n.a. if not applicable).

Points used for digitizer setup (NAD 27): The actual points used for digitizer setup for this map. They may be triangulation station names with NAD 27 coordinates or latitude-longitude coordinates with NAD 27 values.

Digitized By: The person(s) who digitized the map.

Digitizer Setup Error: The maximum and average percentage error calculated by the digitizer setup function in MicroStation. This is explained in greater detail in the *Digitizing cartographic data* section.

Remarks: These are comments particular to this map which may include, but are not limited to, lack of or quality of control points, tears, folds, division of maps into two or more sheets, digitizer setup error calculation, etc.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-479

General Location: St. Marys Bar

Date of Bathymetric Survey: 1855

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fernandina (temporary tide station)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -1.1 m

Date Published: Not stated

Map Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? No

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: None

Triangulation Stations without NAD 27 coordinates:

Dungeness North Base Pilot Lookout
McLure's Hill Amelia Light

Method of digitizer setup: Digitized Points

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

Dungeness North Base
Amelia Light McLure's Hill

Digitized by: Prathap Paragi (LSU)

Digitizer Setup Error:

Maximum = 0.18%
Average = 0.09%

Remarks: Triangulation stations used for digitizer setup were digitized from map T-613. This was a very poor digitizer setup, but no other data were available to cover this area.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-1133

General Location: Northern end of Cumberland Island

Date of Bathymetric Survey: April 22-24, 1869; 1872

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fort Pulaski (temporary tide station)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: - 1.4 m

Date Published: Not stated

Map Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? Yes

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Known Shift/Measured Points

Point(s) of known shift: Pivot 1905

Points used for digitizer setup (NAD 27):

81°22'59.915",31°08'00.020" 81°15'59.915",31°05'00.020"
81°24'59.915",30°59'00.020" 81°18'59.915",30°55'00.020"

Digitized by: Shirish Morchi (LSU)

Digitizer Setup Error:

Maximum = 0.04%
Average = 0.04%

Remarks: Several longitude lines were drawn for North American Datum, but new latitude lines were not. Shift in latitude was measured to draw new graticule points.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-1020

General Location: St. Andrew Sound and back-barrier channels behind Cumberland Island

Date of Bathymetric Survey: March 11 - May 18, 1869

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fernandina (temporary tide station)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: - 1.0 m

Date Published: Not stated

Map Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? Yes

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Measured Points/Known Shift

Point(s) of known shift: Pivot 1905

Points used for digitizer setup (NAD 27):

81°29'59.915",30°05'00.020"   81°22'59.915",31°05'00.020"
81°24'59.915",30°57'00.020"   81°28'59.915",30.57'00.020"

Digitized by: Shirish Morchi (LSU)

Digitizer Setup Error:

Maximum = 0.06%
Average = 0.05%

Remarks: Two well-drawn North American Datum points on map. Two new points will be drawn and known shift applied to bring to NAD 27.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-1062

General Location: Cumberland Island and St. Marys Entrance

Date of Bathymetric Survey: January 7 - May 6, 1870

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fernandina (temporary tide station)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: - 1.0 m

Date Published: Not stated

Map Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? Yes

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Known Shift

Point(s) of known shift: Bunkley, Dungeness House Cupola

Points used for digitizer setup (NAD 27):

81°26'59.789",30°45'00.043"	81°23'59.856",30°57'00.093"
81°19'59.856",30°56'00.093"	81°20'59.789",30°43'00.043"

Digitized by: Shirish Morchi (LSU)

Digitizer Setup Error:

Maximum = 0.03%
Average = 0.03%

Remarks:

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-1110

General Location: Amelia Island and Nassau Sound

Date of Bathymetric Survey: January 13 - May 10, 1871

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fernandina (temporary tide station)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: - 1.0 m

Date Published: Not stated

Map Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? Yes

Updated to North American Datum 1927? Yes

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule/Known Shift

Point(s) of known shift: Amelia Island L.H.

Points used for digitizer setup (NAD 27):

81°19'59.715",30°29'00.038"	81°25'00",30°29'00"
81°19'59.715",30°42'00.038"	81°24'59.715",30°42'00.038"

Digitized by: Shirish Morchi (LSU)

Digitizer Setup Error:

Maximum = 0.04%
Average = 0.04%

Remarks: Only one point was updated to NAD 27.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-1113a

General Location: Nassau Sound and Estuaries

Date of Bathymetric Survey: April 11 - May 18, 1871

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Mayport (temporary tide station)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: - 0.8 m

Date Published: Not stated

Map Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? Yes

Updated to North American Datum 1927? Yes

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule/Known Shift/Measured Points

Point(s) of known shift: Nassau 1861

Points used for digitizer setup (NAD 27):

81°27'59.668",30°32'00.049"	81°27'00.000",30°32'00.000"
81°28'00.000",30°31'00.000"	81°27'00.000",30°30'00.000"

Digitized by: Shirish Morchi (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.01%

Remarks: Original graticule is very faint. Known shift applied to North American Datum point. NAD 27 point used to measure two new points.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-1218c

General Location: Entrance to St. Marys River and Fernandina, Florida

Date of Bathymetric Survey: December 1875 - January 1876

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fernandina (temporary tide station)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -1.0 m

Date Published: January 1876

Map Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum?

Updated to North American Datum 1927?

Triangulation Stations with NAD 27 coordinates:

Triangulation Stations without NAD 27 coordinates:

Method of digitizer setup:

Point(s) of known shift:

Points used for digitizer setup (NAD 27):

Digitized by:

Digitizer Setup Error:

Maximum =
Average =

Remarks: No updated graticule points were drawn on this map. The map was overlayed on a light table with T-613 and the North American Datum points were traced. The known shift was then applied to bring the map to NAD 27.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-3555

General Location: Approaches to St. Marys Entrance

Date of Bathymetric Survey: 1910

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fernandina (temporary tide station)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -1.0 m

Date Published: Not stated

Map Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? Yes

Updated to North American Datum 1927? Yes

Triangulation Stations with NAD 27 coordinates: Amelia Island L.H.

Triangulation Stations without NAD 27 coordinates: None

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

Digitized by:

Digitizer Setup Error:

Maximum =
Average =

Remarks:

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-3770

General Location: Offshore St. Simon Sound to St. Johns River

Date of Bathymetric Survey: 1915

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fernandina (1898-1923)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -1.0 m

Date Published: Not stated

Map Scale: 1:80,000

Projection: Polyconic

Updated to North Ameican Datum? n.a.

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Known Shift

Point(s) of known shift: Postell 1913, Mt.Cornelia

Points used for digitizer setup (NAD 27):

81°20'00.079",31°09'59.971"   80°50'00.079",31°09'59.971"
80°54'59.628",30°20'00.002"   81°24'59.628",30°20'00.002"

Digitized by: Prathap Paragi (LSU)

Digitizer Setup Error:

Maximum = 0.04%
Average = 0.04%

Remarks:

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-4444

General Location: St. Andrew Sound and channels behind Cumberland Island

Date of Bathymetric Survey: September - October 1924

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fernandina (1898-1923)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.9 m

Date Published: Not stated

Map Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Known Shift

Point(s) of known shift: Pivot, Bunkley

Points used for digitizer setup (NAD 27):

81°28'59.915",30°03'00.020"	81°18'59.915",30°03'00.020"
81°18'59.856",30°53'00.093"	81°28'59.856",30°53'00.093"

Digitized by: Prathap Paragi (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks: Rips at south end of map.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-4436

General Location: Nearshore Stafford Shoal to Amelia Island, including St. Marys Entrance

Date of Bathymetric Survey: August 1924

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fernandina (1898-1923)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.9 m

Date Published: Not stated

Map Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Known Shift

Point(s) of known shift: Stafford 1860, Amelia Island Light House

Points used for digitizer setup (NAD 27):

81°29'59.803",30°53'00.063"   81°29'59.715",30°40'00.038"
81°19'59.715",30°40'00.038"   81°19'59.803",30°53'00.063"

Digitized by: Prathap Paragi (LSU)

Digitizer Setup Error:

Maximum = 0.03%
Average = 0.03%

Remarks:

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-4376

General Location: Nearshore Amelia Island from Fernandina to Nassau Sound

Date of Bathymetric Survey: July - August 1924

Method of Data Collection: Lead line, Pole

Reference Tidal Station and Epoch: Fernandina (1898-1923)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.9 m

Date Published: Not stated

Map Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? No

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Known Shift

Point(s) of known shift: Nassau, Mt. Cornelia

Points used for digitizer setup (NAD 27):

81°26'59.624",30°24'00.002"	Inset:	81°25'59.715",30°41'00.038"
81°29'59.668",30°37'00.049"		81°22'59.715",30°41'00.038"
81°22'59.624",30°24'00.002"		81°24'59.668",30°36'00.049"
81°22'59.624",30°37'00.049"		81°25'59.668",30°36'00.049"

Digitized by: Prathap Paragi (LSU)

Digitizer Setup Error:

Maximum = 0.05%	Inset:	Maximum	= 0.02%
Minimum = 0.04%		Average	= 0.02%

Remarks: Some points updated to NAD 27, but scale of map makes difference very difficult to see.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-5754

General Location: North River to Jackson Creek, Cumberland Sound

Date of Bathymetric Survey: June 1934 - February 1935

Method of Data Collection: Echo Soundings

Reference Tidal Station and Epoch: Mayport, Florida (1924-1942)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: - 0.7 m

Date Published: Not stated

Map Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

Digitized by:

Digitizer Setup Error:

Maximum =
Average =

Remarks:

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-5690

General Location: St. Marys Entrance

Date of Bathymetric Survey: July - August 1934

Method of Data Collection: Echo Soundings

Reference Tidal Station and Epoch: Mayport, Florida (1924-1942)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.7 m

Date Published: Not stated

Map Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

Digitized by: Jackie J. Johnston (CERC)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-8106

General Location: St. Marys Entrance

Date of Bathymetric Survey: January 1954 - February 1955

Method of Data Collection: Echo Soundings

Reference Tidal Station and Epoch: Fernandina (1924-1942)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.9 m

Date Published: Not stated

Map Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

Left Half:

81°25'00",30°45'00" 81°25'00",30°41'00"
81°28'00",30°41'00" 81°30'00",30°44'00"

Right Half:

81°22'00",30°45'00" 81°22'00",30°41'00"
81°25'00",30°41'00" 81°25'00",30°45'00"

Digitized by: Mary Claire Allison (CERC)

Digitizer Setup Error:

Left Half:
Maximum = 0.01%
Average = 0.01%

Right Half:
Maximum = 0.01%
Average = 0.01%

Remarks:

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-8179

General Location: Fernandina Beach

Date of Bathymetric Survey: February 1955

Method of Data Collection: Echo Soundings

Reference Tidal Station and Epoch: Fernandina (1924-1942)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: - 0.9 m

Date Published: Not stated

Map Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: Amelia Island L.H. 1905,1932

Triangulation Stations without NAD 27 coordinates: Ferna 1954

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°23'00",30°41'00"	81°27'00",30°38'00"
81°23'00",30°38'00"	81°27'00",30°41'00"

Digitized by: Brian Savell (LSU), Shirish Morchi (LSU)

Digitizer Setup Error:

Maximum = 0.00%
Average = 0.00%

Remarks:

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-8108

General Location: Back-barrier channels near Fernandina Beach, Florida

Date of Bathymetric Survey: December 1953 - April 1954

Method of Data Collection: Echo Soundings

Reference Tidal Station and Epoch: Mayport, Florida (1924-1942)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: - 0.7 m

Date Published: 1954

Map Scale: 1:10,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°28'00",30°33'00"   81°24'00",30°33'00"
81°22'00",30°29'00"   81°27'00",30°29'00"

Digitized by: Mary Claire Allison (CERC)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks:

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-9458

General Location: St. Andrew Sound

Date of Bathymetric Survey: August 1974

Method of Data Collection: Digital Fathometer

Reference Tidal Station and Epoch: Ft. Pulaski (1941-1959)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -1.0 m

Date Published: Not stated

Map Scale: 1:20,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°29'00",31°03'00"   81°13'00",31°03'00"
81°29'00",30°54'00"   81°13'00",30°54'00"

Digitized by: Brian Savell (LSU)

Digitizer Setup Error:

Maximum = 0.01%
Average = 0.01%

Remarks: Sounding positions were acquired in digital format from NOS and read directly into map files after making conversions from feet to meters and vertical datum adjustments. The northern limit of the digital data was 31°00'N. Therefore, soundings between 31°00'N and 31°02'N were digitized from maps.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-9678

General Location: Nearshore Cumberland Island and Stafford Shoal

Date of Bathymetric Survey: March - May 1977

Method of Data Collection: Digital Fathometer

Reference Tidal Station and Epoch: Fernandina (1941-1959)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.9 m

Date Published: n.a.

Map Scale: n.a.

Projection: n.a.

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: n.a.

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27): n.a.

Digitized by: n.a.

Digitizer Setup Error:

Maximum = n.a.
Average = n.a.

Remarks: Sounding positions were acquired in digital format from NOS and read directly into map files after making conversions from feet to meters and vertical datum adjustments.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-9449

General Location: Offshore northern Cumberland Island

Date of Bathymetric Survey: June - July 1974

Method of Data Collection: Digital Fathometer

Reference Tidal Station and Epoch: Ft. Pulaski (1941-1959)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -1.0 m

Date Published: Not stated

Map Scale: 1:40,000

Projection: Polyconic

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: Graticule

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27):

81°20'00",31°04'00"	81°00'00",31°04'00"
81°20'00",30°58'00"	81°00'00",30°58'00"

Digitized by: Prathap Paragi (LSU)

Digitizer Setup Error:

Maximum = 0.02%
Average = 0.02%

Remarks: Sounding positions were acquired in digital format from NOS and read directly into map files after making conversions from feet to meters and vertical datum adjustments. The northern limit of the digital data was 31°00'N. Therefore, soundings between 31°00'N and 31°02'N were digitized from maps.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-9675

General Location: Nearshore southern Cumberland Island

Date of Bathymetric Survey: February - April 1977

Method of Data Collection: Digital Fathometer

Reference Tidal Station and Epoch: Fernandina (1941-1959)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.9 m

Date Published: n.a.

Map Scale: n.a.

Projection: n.a.

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: n.a.

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27): n.a.

Digitized by: n.a.

Digitizer Setup Error: n.a.

Maximum = n.a.
Average = n.a.

Remarks: Sounding positions were acquired in digital format from NOS and read directly into map files after making conversions from feet to meters and vertical datum adjustments.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-9428

General Location: Offshore southern Cumberland Island and northern Amelia Island

Date of Bathymetric Survey: June 1974

Method of Data Collection: Digital Fathometer

Reference Tidal Station and Epoch: Fernandina (1941-1959)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.9 m

Date Published: n.a.

Map Scale: n.a.

Projection: n.a.

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: n.a.

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27): n.a.

Digitized by: n.a.

Digitizer Setup Error:

Maximum = n.a.
Average = n.a.

Remarks: Sounding positions were acquired in digital format from NOS and read directly into map files after making conversions from feet to meters and vertical datum adjustments.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-9457

General Location: Nearshore Amelia Island

Date of Bathymetric Survey: July - August 1974

Method of Data Collection: Digital Fathometer

Reference Tidal Station and Epoch: Fernandina (1941-1959)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.9 m

Date Published: n.a.

Map Scale: n.a.

Projection: n.a.

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: n.a.

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27): n.a.

Digitized by: n.a.

Digitizer Setup Error:

Maximum = n.a.
Average = n.a.

Remarks: Sounding positions were acquired in digital format from NOS and read directly into map files after making conversions from feet to meters and vertical datum adjustments.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-9474

General Location: Offshore Nassau Sound

Date of Bathymetric Survey: September - October 1974

Method of Data Collection: Digital Fathometer

Reference Tidal Station and Epoch: Fernandina (1941-1959)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.9 m

Date Published: n.a.

Map Scale: n.a.

Projection: n.a.

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: n.a.

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27): n.a.

Digitized by: n.a.

Digitizer Setup Error:

Maximum = n.a.
Average = n.a.

Remarks: Sounding positions were acquired in digital format from NOS and read directly into map files after making conversions from feet to meters and vertical datum adjustments.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-9800

General Location: Inlet throat at St. Marys Entrance

Date of Bathymetric Survey: 1979

Method of Data Collection: Digital Fathometer

Reference Tidal Station and Epoch: Fernandina (1960-1978)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.8 m

Date Published: n.a.

Map Scale: n.a.

Projection: n.a.

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: n.a.

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27): n.a.

Digitized by: n.a.

Digitizer Setup Error: n.a.

Maximum = n.a.
Average = n.a.

Remarks: Sounding positions were acquired in digital format from NOS and read directly into map files after making conversions from feet to meters and vertical datum adjustments.

HYDROGRAPHIC INFORMATION SHEET

Project: Kings Bay

Map Number: H-9799

General Location: Ebb-tidal delta at St. Marys Entrance

Date of Bathymetric Survey: 1979

Method of Data Collection: Digital Fathometer

Reference Tidal Station and Epoch: Fernandina (1960-1978)

Reference Vertical Datum: Mean Low Water

Vertical Datum Adjustment: -0.8 m

Date Published: n.a.

Map Scale: n.a.

Projection: n.a.

Updated to North American Datum? n.a.

Updated to North American Datum 1927? n.a.

Triangulation Stations with NAD 27 coordinates: n.a.

Triangulation Stations without NAD 27 coordinates: n.a.

Method of digitizer setup: n.a.

Point(s) of known shift: n.a.

Points used for digitizer setup (NAD 27): n.a.

Digitized by: n.a.

Digitizer Setup Error:

Maximum = n.a.
Average = n.a.

Remarks: Sounding positions were acquired in digital format from NOS and read directly into map files after making conversions from feet to meters and vertical datum adjustments.

Appendix C
Dredging and Shoaling Data[1]

Introduction

In this appendix, historical channel maintenance activities, dredging volumes and locations, and shoaling patterns are documented for St. Marys Entrance channel and sections of Cumberland Sound channel. Since 1904, channel deepening and maintenance dredging of the navigation channel have been performed to provide safe passage for various classes of vessels, including submarines, which have required different channel dimensions over the years. Maintenance of the most recent channel dimensions of 150-m width and 15.5-m depth (below MLW) with side slopes of 3H:1V (Figure C1) to accommodate TRIDENT (Ohio-class) submarines has required increased dredging compared to earlier channel usage.

Coastal charts, bathymetric surveys, side-scan sonar records, dredging records, and channel bottom sediment characteristics were utilized in this study to define channel reaches based on shoaling characteristics. Shoal material in the navigation channel is brought there by wave activity, including longshore and storm-induced cross-shore transport, and by ebb- and flood-tidal currents. Seaward of the inlet throat, two areas of significant shoaling are found: (a) in the vicinity of the jetty tips, and (b) at the ebb-tidal delta terminal lobe. Moderate shoaling also occurs in several other areas of St. Marys Entrance channel. Landward of the inlet throat in Cumberland Sound are two areas of moderate shoaling associated with the introduction of littoral sands.

Channel Maintenance

The jetty construction and channel maintenance history discussed herein concern St. Marys Entrance and Cumberland Sound channels (Figure C1). Channel stationing as established by U.S. Army Engineer District (USAED), Jacksonville and USAED, Savannah is presented in units of feet according to customary surveying practice. St. Marys Entrance channel consists of Cut 1N and Cut 2N. Station numbering starts at Station 0+00 of Cut 1N (approximate location

[1] Written by J. Bailey Smith, Joan Pope, Laurel T. Gorman, Thomas Martin, and Susan Brinson.

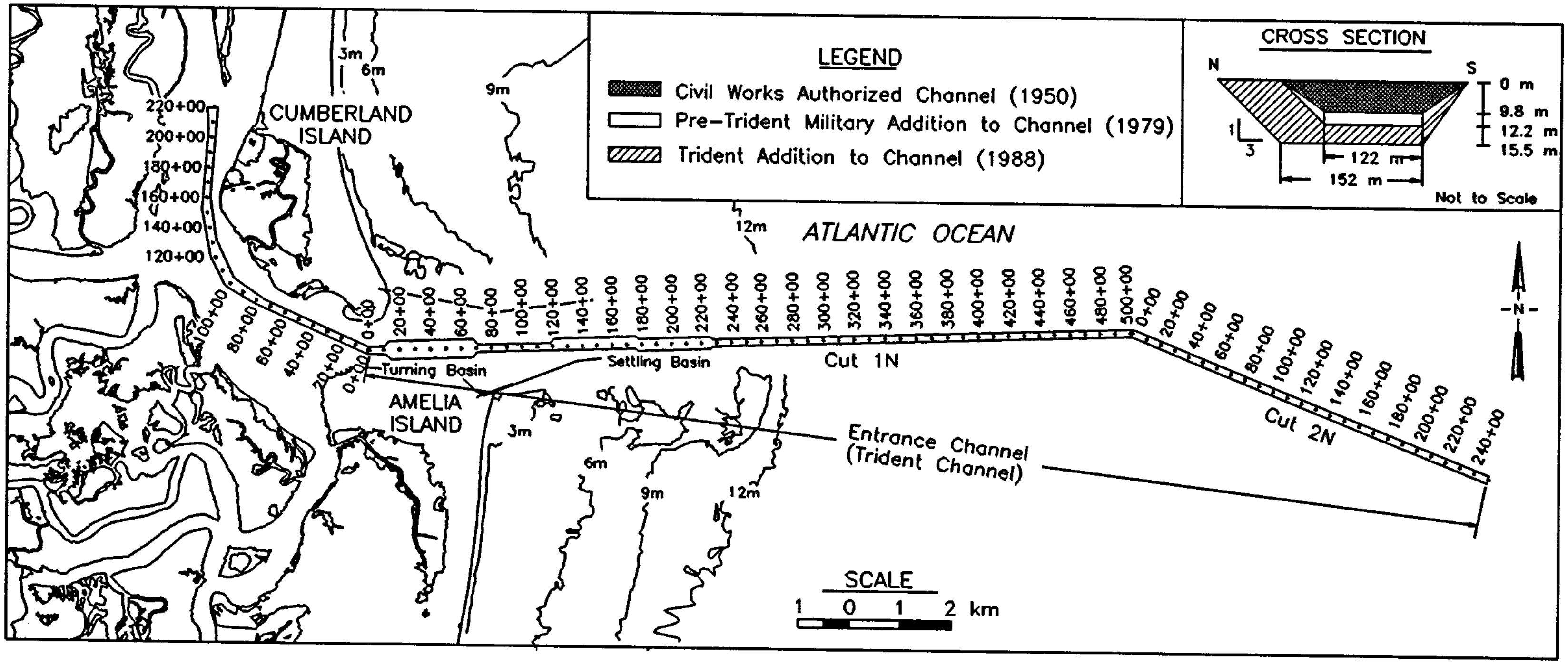


Figure C1. Location of St. Marys Entrance channel with channel cross section at inlet throat) and increases to the east to Station 501+23.68 of Cut 1N. Cut 2N continues seaward from Station 0+00 to Station 250+00. Stationing of Cumberland Sound channel addressed in this appendix commences at Station 0+00 and increases to the west and north to Station 220+00. There is an overlap of 110 ft between Cumberland Sound channel and Cut 1N of St. Marys Entrance channel.

This history has been separated into seven epochs (Table C1). The epochs represent periods of jetty construction (1881 to 1904) and heightening (1924 to 1953) and numerous channel deepening, widening, and lengthening construction activities. The natural channel depth in 1934, prior to authorized channel deepening, included a depth of 5.8 m at the inlet throat and a depth of 5.0 m in the vicinity of the jetty tips. The St. Marys Entrance channel was deepened to 8.5 m below MLW in 1940, 10.4 m below MLW from 1955 to 1956, and 12.2 m (122-m width, 8.3-km length) below MLW from 1978 to 1979. Each channel deepening event extended the channel length to that particular bathymetric depth contour. Channel deepening to 12.2 m for the Cumberland Sound channel from Station 155+00 to 212+25 was performed in 1979. Maintenance dredging from Station 0+00 to 155+00 of the Cumberland Sound portion of the channel prior to 1979 eliminated the need for new work dredging and associated channel-deepening.

The most recent epoch of construction and maintenance from 1988 to 1992 (Epoch 7) included channel deepening to 15.5 m (14.0 m authorized channel depth, 0.9 m advance maintenance, and 0.6 m to allow for dredging inaccuracies), widening to 152 m at the bottom of the channel, and

Table C1
Epochs of Construction and Maintenance of St. Marys Entrance Channel and Cumberland Sound Channel

Epoch	Period	Event
1	Pre-1880	Natural inlet; bifurcated channel.
2	1881-1904	Jetty construction. New work dredging to reduce shoals for jetty construction.
3	1905-1923	Natural width and length of channel. Channel deepened to 5.8 m MLW and realigned. Maintenance dredging to contain shoals during jetty modification.
4	1924-1953	Channel deepened to 8.5 m MLW. North jetty-crest elevation increased to 2.1 m MLW. South jetty-crest elevation increased to 1.8 m MLW.
5	1954-1973	Channel realigment. Channel deepened to 10.4 m MLW.
6	1974-1987[1] 1979-1987[2] 1979-1985[3]	Channel deepened to 12.2 m MLW, widened to 122 m, and lengthened to 8.3 km.
7	1988-1992[1] 1987-1992[2] 1985-1992[3]	Construction and maintenance of TRIDENT channel. Channel deepened to 15.5 m MLW, widened to 152 m, and lengthened to 19.8 km. Sand-tightening of landward 460 m south of jetty.

[1] Dates for St. Marys Entrance channel dredging.
[2] Dates for Cumberland Sound channel dredging from Station 0+00 to 155+00.
[3] Dates for Cumberland Sound channel dredging from Station 155+00 to 220+00.

seaward lengthening to 19.8 km to the 15.5-m depth contour. Dredging included channel widening to create a sediment settling basin 240 m wide and a turning basin 360 m wide. Epoch 7 modifications for the Cumberland Sound channel commenced in 1987 for the channel from Station 0+00 to 155+00, and in 1985 for the channel from Station 155+00 to 220+00. The landwardmost 460-m-long section of the south jetty was sand-tightened between 1986 and 1988. The actual construction started in the summer of 1987 and continued intermittently until October 1988.

Dredging History

The dredging history of St. Marys Entrance and Cumberland Sound channels was determined from records of dredging location and volume summaries from miscellaneous unpublished and individual dredging activity reports maintained by the USAED, Jacksonville, and USAED, Savannah. For St. Marys Entrance channel, dredging activities during and after the 1987-1988 TRIDENT channel expansion (Epoch 7) are well documented. However, analysis and comparison of dredging events prior to the TRIDENT channel expansion (Epochs 1-6) are restricted due to limited records which do not distinguish between dredging estimates and actual dredged volumes. Dredging records for the Cumberland Sound channel are complete for both pre- and post-TRIDENT dredging, allowing the volume of dredged material to be compared through time.

Dredging at St. Marys Entrance channel for the period 1955 to 1983 was performed by U.S. Government hopper dredges on all but two occasions when U.S. Government cutterhead pipeline and clamshell dredges were used. From 1984 to the present, dredging was performed by the U.S. Government and private companies utilizing hopper, clamshell, and cutterhead pipeline dredges. The Cumberland Sound channel has been and is presently dredged using cutterhead pipeline dredges operated by private companies.

The dredging histories for St. Marys Entrance and Cumberland Sound channels are summarized in Tables C2 and C3, respectively. Each table is divided into the defined epochs, with total dredged material volume listed for each epoch. The locations of dredging events are noted by either formal names of the channel or by station numbers and have been identified as either new work or maintenance dredging. New work dredging indicates deepening/widening of the channel, and maintenance dredging includes all dredging conducted to maintain the channel at a given depth.

Table C2 illustrates that for St. Marys Entrance channel, as channel dimension parameters including depth, width, and length increased, maintenance dredged volumes also increased (Figure C2). (Authorized and natural channel depths of Figure C2 are placed at actual dates of channel deepening events. Maintenance dredged volumes are placed in the center of the epochs as maintenance dredging occurs not during one event but over a period of time.) The largest annual channel maintenance dredged volume of 616,200 cu m/year occurs during the most recent epoch from 1988 to 1992, which is associated with the lengthening and deepening of the channel to 15.5 m below MLW. However, a direct comparison of dredged volume over time is complicated by the increase in channel length. The U.S. involvement in World War II (1941-1945) and the Korean War (1950-1953) may have affected national prioritization toward civil work channel maintenance, thus yielding the relatively low dredged volume during Epoch 4 (1924-1953).

Table C2
Dredging History at St. Marys Entrance Channel

Event Number	Year	Location	Amount of Dredged Material cu yd	Amount of Dredged Material cu m
Epoch 2 1881-1904[1] (24 Years)				
1	1903	Entrance Channel - New Work[2]	379,600	290,200
2	1904	Entrance Channel - New Work	166,500	127,300
Total[3] (1881-1904)			546,100	417,500
Total Maintenance Dredged Volume per Year[4] (1881-1904)			0	0
Epoch 3 1905-1923[1] (19 Years)				
3	1905	Entrance Channel - Maintenance	59,400	45,400
4	1908	Entrance Channel - Maintenance	187,000	143,000
5	1911	Entrance Channel - Maintenance	121,200	92,700
6	1912	Entrance Channel - Maintenance	47,300	36,100
Total[3] (1905-1923)			414,900	317,200
Total Maintenance Dredged Volume per Year[4] (1905-1923)			21,800	16,700
Epoch 4 1924-1953 (30 Years)				
7	1937	Entrance Channel - Maintenance	302,600	231,300
8	1940	Entrance Channel - New Work	248,000	189,600
9	1945	Entrance Channel - Maintenance	196,400	150,100
Total[3] (1924-1953)			747,000	571,000
Total Maintenance Dredged Volume per Year[4] (1924-1953)			16,600	12,700
Epoch 5 1954-1973 (20 Years)				
10	1955-56	Entrance Channel - Sta 109+20 to 266+60 - New Work	2,616,700	2,000,600
11	1963	Entrance Channel - Maintenance	319,800	244,500
12	1964	Entrance Channel - Maintenance	364,800	278,900

(Sheet 1 of 4)

[1] New work and maintenance dredging between 1903 and 1923 (Epochs 1 and 2) performed during jetty construction and maintenance.
[2] New work indicates deepening of channel to new depths. Other dredging events indicate maintenance dredging to maintain the channel at a given depth.
[3] Total includes both maintenance dredging and new work.
[4] Total maintenance dredged volume per year includes <u>only</u> maintenance dredging.

Table C2 (Continued)				
Event Number	Year	Location	Amount of Dredged Material	
			cu yd	cu m
13	1966	Entrance Channel - Maintenance	231,500	177,000
14	1967	Entrance Channel - Maintenance	201,000	153,700
15	1968	Entrance Channel - Maintenance	179,400	137,200
16	1969	Entrance Channel - Maintenance	340,000	260,000
17	1973	Entrance Channel - Maintenance	476,800	364,500
Total[3] (1954-1973)			4,730,000	3,616,400
Total Maintenance Dredged Volume per Year[4,5] (1954-1973)			105,700	80,800
Epoch 6 1974-1987 (14 years)				
18	1974	Entrance Channel - Maintenance	35,700	27,300
19	1975	Entrance Channel - Maintenance	75,900	58,000
20	1976	Entrance Channel - Maintenance	108,600	83,000
21	1978	Entrance Channel - Sta -85+00[6] to 165+00 - Maintenance	268,700	205,400
22	1978	Entrance Channel - Sta -68+00 to 168+00 Maintenance	245,600	187,800
23	1978	Entrance Channel - Sta -61+00 to 166+50 Maintenance	373,700	285,700
24	1979	Entrance Channel - Sta -68+00 to 165+00 Maintenance	270,300	206,700
25	1979	Entrance Channel - Sta -60+00 to -50+00, -15+00 to -8+00, 5+00 to 16+00 - Maintenance	71,100	54,400
26	1978-79	Entrance Channel - New Work	1,910,300	1,460,500
27	1978-79	Entrance Channel - Maintenance	1,550,600	1,185,500
28	1982	Entrance Channel - Maintenance	798,000	610,100
29	1983	Entrance Channel Sta 40+00 to 420+00 - Maintenance	78,900	60,300
30	1983	Entrance Channel - Maintenance	621,800	475,400
31	1984	Entrance Channel Sta 125+00 to 215+00 - Maintenance	160,900	123,000

(Sheet 2 of 4)

[5] Total maintenance dredged volume per year would be 161,300 cu m for the period 1963 to 1973.
[6] Negative station values indicate channel locations landward of Station 0+00 in Cumberland Sound.

Table C2 (Continued)				
Event Number	Year	Location	Amount of Dredged Material	
			cu yd	cu m
32	1987-88	Entrance Channel - Maintenance[7]	321,000	245,500
Total[3] (1974-1987)			6,891,100	5,268,600
Total Maintenance Dredged Volume per Year[4] (1974-1987)			355,800	272,000
Epoch 7 1988-1992 (4 Years)[8,9]				
33	1987-88	Entrance Channel - New Work	906,800	693,300
34	1987-88	Entrance Channel - New Work	1,618,200	1,237,200
35	1988	Entrance Channel - New Work	5,456,000	4,171,400
36	1988	Entrance Channel - New Work	530,000	405,200
37	1988	Cut 1N - Sta 240+00 to 320+00 - Maintenance	720,000	550,500
38	1989	Cut 1N - Maintenance	152,000	116,200
39	1989	Cut 1N - Sta 135+00 to 145+00 - Maintenance	330,000	252,300
40	1989	Cut 1N - Sta 220+00 to 323+00 - Maintenance	424,100	324,300
41	1990-91	Cut 1N - Sta 210+00 to 340+50 - Maintenance	506,000	386,900
42	1990-91	Cut 1N - Sta 114+50 to 154+50 - Maintenance	147,700	112,900
43	1990-91	Cut 2N - Sta 67+00 to 69+00, 78+00 to 88+00, 142+00 to 148+00 - Maintenance	17,400	13,300
44	1990-91	Cut 1N - Sta 164+00 to 177+00 - Maintenance	6,700	5,100
45	1990-91	Cut 1N - Sta 183+00 to 189+00 - Maintenance	3,700	2,800
46	1990-91	Cut 1N - Sta 200+00 to 210+00 - Maintenance	46,400	35,500
47	1992	Cut 1N - Sta 115+00 to 200+00 - Maintenance	193,300	147,800

(Sheet 3 of 4)

[7] This dredging event represents material shoaled during Epoch 6, but removed during Epoch 7 New Work excavations.
[8] Epoch 7 dredging activity (1988-1992) removed shoaled material in the channel during 1988-1991 (4 years).
[9] Epoch 7 includes some work prior to 1988 (Event Numbers 33 and 34). Epoch 6 (1974-1987) includes some post Trident-deepening channel maintenance (Event Number 32).

Table C2 (Concluded)				
Event Number	Year	Location	Amount of Dredged Material	
			cu yd	cu m
48	1992	Cut 1N - Sta 230+00 to 310+00 - Maintenance	640,200	489,500
49	1992	Cut 1N - Sta 210+00 to 230+00 - Maintenance	36,000	27,500
Total[3] (1988-1992)			11,734,500	8,971,700
Total Maintenance Dredged Volume per Year[4] (1988-1992)			805,900	616,200
(Sheet 4 of 4)				

A relationship also exists between channel dimensions and new work and total dredged volumes (Figure C3). This relationship is a function of channel expansion rather than littoral processes. The greatest new work and total dredged volumes during Epoch 7 (1988-1992) are 6,507,100 and 8,971,600 cu m, respectively.

In Cumberland Sound channel, no relationship is apparent between maintenance dredged volume and channel dimensions (Table C3). Total maintenance dredged volume decreased from 17,200 cu m/year during the period 1979 to 1984 (prior to the TRIDENT channel deepening to 15.5 m below MLW Epoch 6), to 3,700 cu m/year during the period 1985 to 1992 after the TRIDENT channel deepening (Epoch 7) (Cumberland Sound Epoch 7 deepening commenced in 1985). This decrease may have resulted from the increase in new work dredging performed between 1985 to 1992 which incorporated overdredging. From 1979 to 1984, the new work dredged volume in Cumberland Sound channel was 466,200 cu m, which compares to 3,132,600 cu m from 1985 to 1992.

Disposal operations may represent a recycling of material within the system. Therefore, documentation of their location may help to provide an understanding of this possible contribution to sediment transport patterns. The disposal locations of dredged material from the St. Marys Entrance and Cumberland Sound channels are presented in Figures C4 and C5 and Tables C4 and C5.

Channel Sediment Characteristics

Analysis of channel bottom sediment characteristics provides insight into material sources and transport mechanisms which influence shoaling patterns. Information on sediments found in St. Marys Entrance channel is based on maintenance dredging core borings from 1989 to 1991 (Tables C6-C8), new work core borings obtained prior to the TRIDENT channel deepening (1985-1986) (USAED, Jacksonville, Geotechnical Branch),[1] and geological cross section as presented in Chapter 2. Bottom sediment characterization of Cumberland Sound channel was based on new work core borings performed prior to the TRIDENT channel deepening (1983 to

[1] Unpublished report, 1981. "Kings Bay Geological Cross Sections," USAED, Jacksonville, Florida.

Table C3
Dredging History of Cumberland Sound Channel from Station 0 + 00 to 220 + 00

Event Number	Year	Location	Amount of Dredged Material	
			cu yd	cu m
1979-1984 (6 years)[1]				
1	1979	Sta 174 + 00 to 212 + 25 - New Work[2]	526,100	402,200
2	1979	Sta 150 + 00 to 174 + 00 - New Work	83,700	64,000
3	1981	Sta 20 + 00 to 60 + 00 - Maintenance	-3,900	-3,000
4	1981	Sta 100 + 00 to 150 + 00 - Maintenance	14,800	11,300
5	1981	Sta 60 + 00 to 100 + 00 - Maintenance	4,000	3,100
6	1982	Sta 60 + 00 to 100 + 00 - Maintenance	120,100	91,800
Total (1979-1984)[3,4]			744,800	569,400
Total Maintenance Dredged Volume per Year (1979-1984)[5]			22,500	17,200
1985-1992 (8 years)[6]				
7	1986	Sta 172 + 50 to 200 + 00 - New Work	977,600	747,400
8	1986	Sta 152 + 50 to 172 + 50 - New Work	346,600	265,000
9	1987	Sta 145 + 00 to 155 + 00 - New Work	228,300	174,600
10	1987	Sta 140 + 00 to 145 + 00 - New Work	151,000	115,400
11	1987	Sta 130 + 00 to 140 + 00 - New Work	258,200	197,400
12	1987	Sta 120 + 00 to 130 + 00 - New Work	309,400	236,600
13	1988	Sta 95 + 00 to 105 + 00 - New Work	232,200	177,500
14	1988	Sta 90 + 00 to 95 + 00 - New Work	117,500	89,800
15	1988	Sta 115 + 00 to 120 + 00 - New Work	146,200	111,800
16	1988	Sta 105 + 00 to 115 + 00 - New Work	261,000	199,600
17	1988	Sta 80 + 00 to 90 + 00 - New Work	227,300	173,800
18	1988	Sta 65 + 00 to 80 + 00 - New Work	305,000	233,200
19	1988	Sta 0 + 00 to 40 + 00 - New Work	267,500	204,500

(Continued)

[1] Dredging prior to 1979 from Station 00 + 00 to 150 + 00 are included in Table C2 as negative stations. No dredging conducted from 1983-1985.
[2] New work indicates initial deepening of channel. Other dredging events are maintenance dredging.
[3] Total includes both maintenance dredging and new work.
[4] An estimated 327,000 cu yd (250,000 cu m) of dredged material would be added to this volume if the negative station values of St. Marys Entrance channel were included.
[5] Total maintenance dredged volume per year would be 67,500 cu yd (51,600 cu m) for the period 1981-1982.
[6] No dredging conducted during 1985.

Table C3 (Concluded)				
Event Number	Year	Location	Amount of Dredged Material	
			cu yd	cu m
20	1988	Sta 40+00 to 65+00 - New Work	269,400	206,000
21	1991	Sta 0+00 to 200+00 - Maintenance	37,600	28,700
22	1991	Sta 0+00 to 200+00 - Maintenance	800	600
Total (1985-1991)[3]			4,135,600	3,161,900
Total Maintenance Dredged Volume per Year (1985-1992)[7]			4,800	3,700
Total (1979-1991)[4]			4,880,500	3,731,300

[7] Total maintenance dredged volume per year would be 19,200 cu yd (14,700 cu m) for the period 1991-1992.

1985) and an evaluation of the geological cross sections information as presented in Chapter 2 (USAED, Jacksonville).[1] The channel can be divided into five reaches based on the dominant bottom sediment type (Figure C6):

a. Type 1 (Station 0+00 to 225+00 of Cumberland Sound channel) is characterized by moderately to poorly sorted, fine- to medium-grained sand with silt, shell matter, and limestone fragments. Limestone bedrock occurs intermittently at depth.

b. Type 2 (Station 0+00 to 50+00 of St. Marys Entrance channel, Cut 1N) is characterized by moderately sorted, fine- to medium-grained sand and limestone bedrock. Maintenance core borings indicate that calcareous sandstone bedrock is present rather than limestone bedrock in this reach.

c. Type 3 (Station 50+00 to 225+00 of St. Marys Entrance channel, Cut 1N) is characterized by moderately to poorly sorted, fine- to medium-grained sand with significant amounts of shell matter.

d. Type 4 (Station 225+00 to 355+00 of St. Marys Entrance channel, Cut 1N) is dominated by inorganic silt and soft clay with traces of sand and shell matter. Bedrock was located from Station 234+00 to 260+00 at depths of 12.2 m to 16.5 m below MLW as demonstrated in geological cross sections in Chapter 2 (USAED, Jacksonville).[1]

e. Type 5 (seaward of Station 250+00 of St. Marys Entrance channel, Cut 1N) is dominated by moderately to poorly sorted, fine- to medium-grained sand, and shell.

[1] Unpublished report, 1981. "Kings Bay Geological Cross Sections," USAED, Jacksonville, Florida.

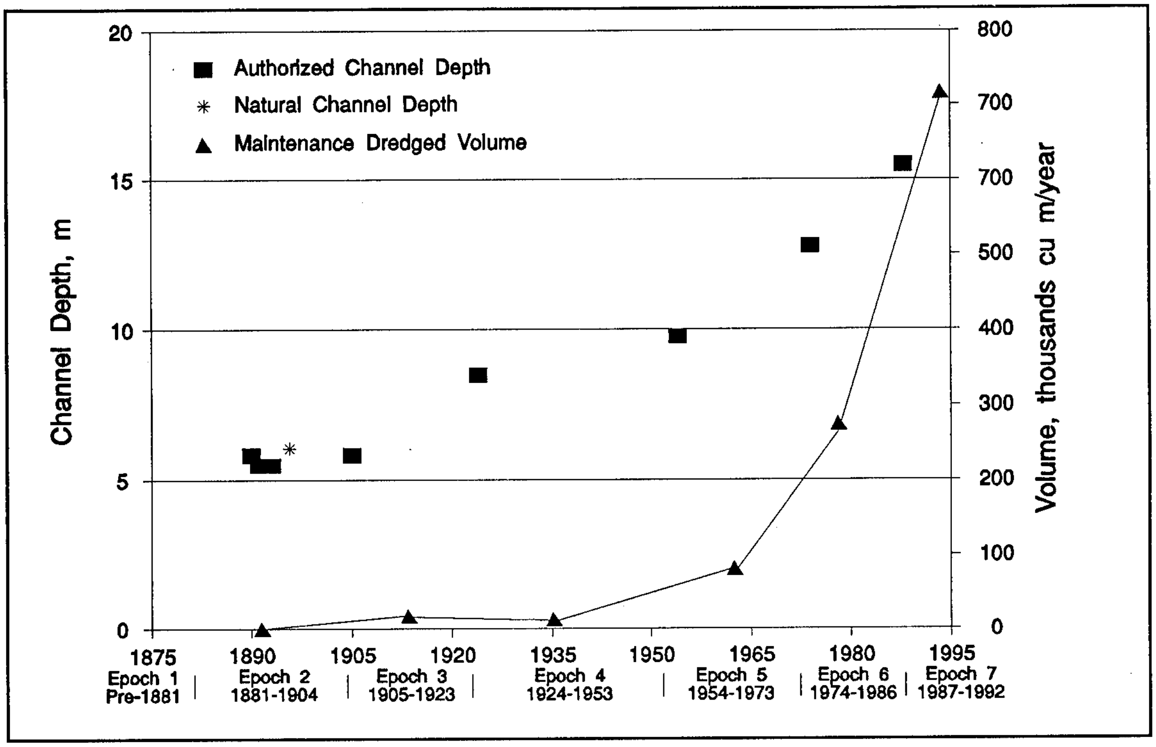


Figure C2. Channel depth and average annual maintenance dredged volumes for St. Marys Entrance channel for the period 1870-1992

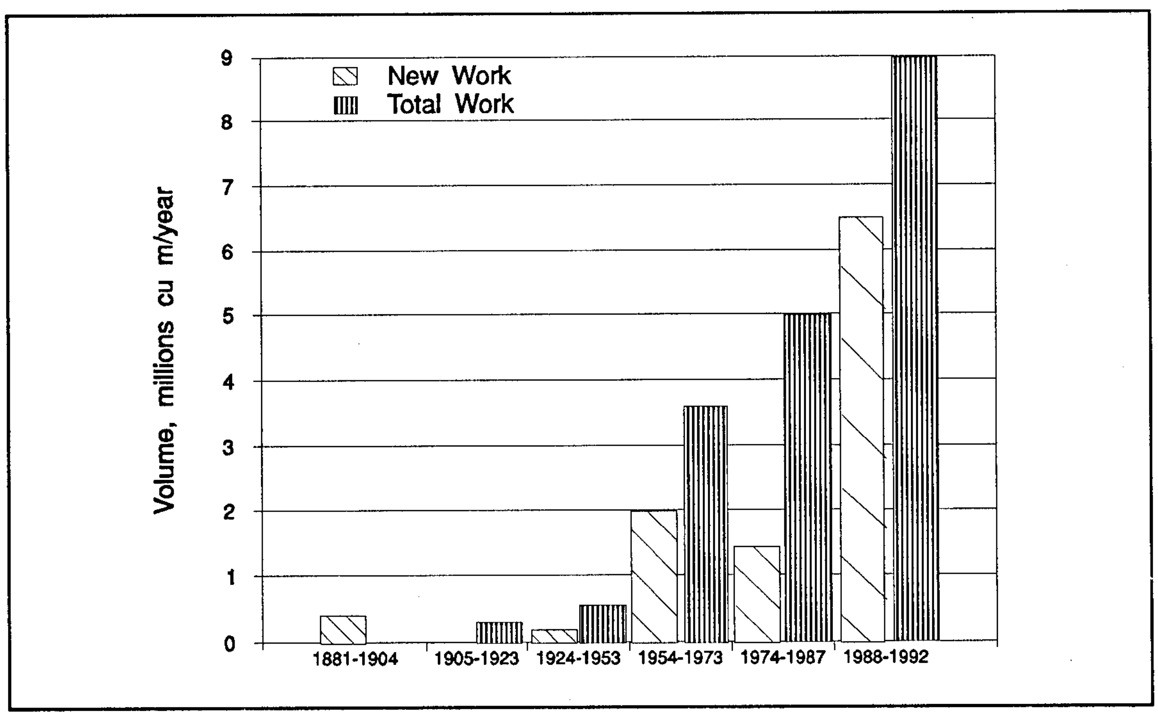


Figure C3. New work and total dredged volume at St. Marys Entrance channel by epoch

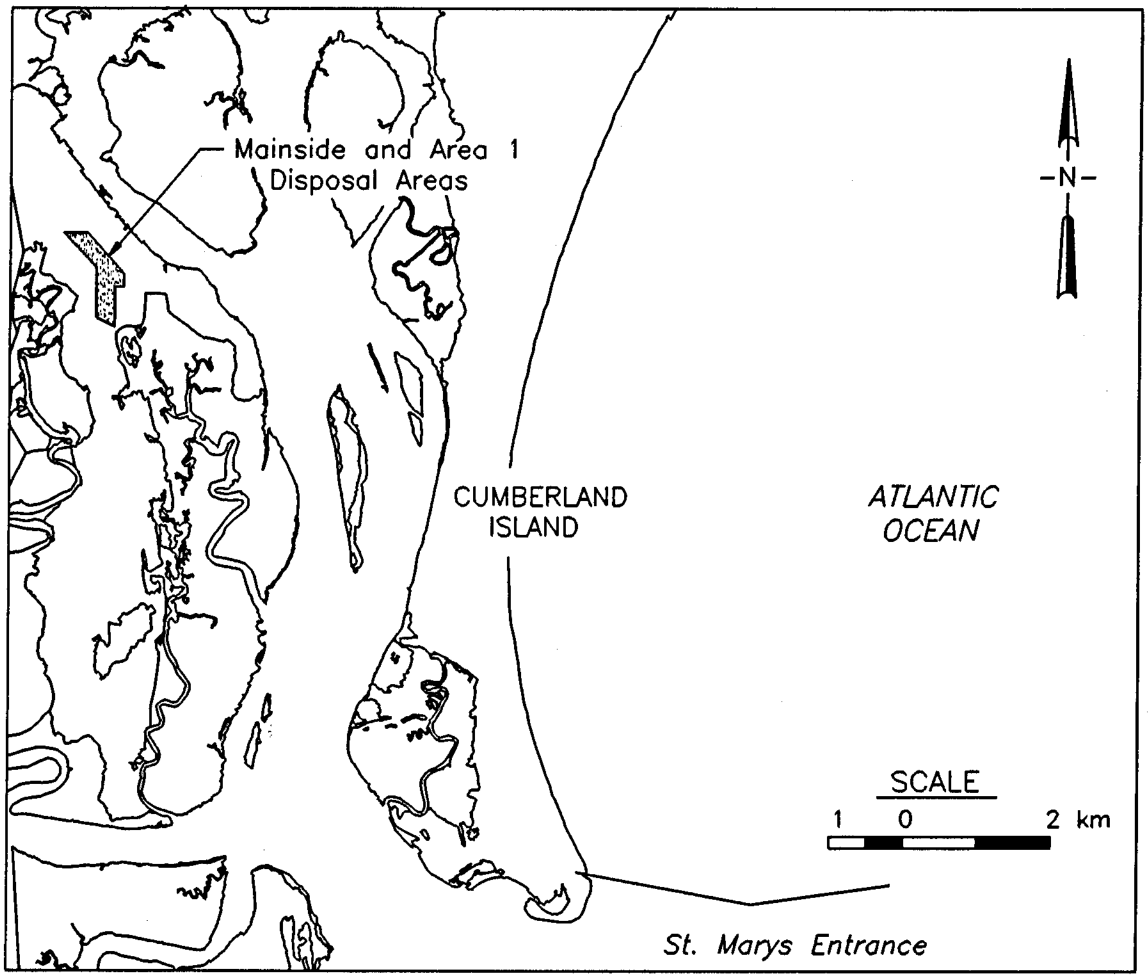


Figure C4. Location of dredged-material disposal areas in the vicinity of Cumberland Island

Bed Form and Shoal Distribution

Shoals and bed forms occur both north and south of St. Marys Entrance channel. Significant shoaling to the north of the channel is produced by waves from the northeast which occur primarily during the winter months. Discussion of hindcast wave climatology for the study site is contained in Chapters 2 and 4. Shoaling to the south of the channel is caused by waves arriving from the southeast and localized transport reversal downdrift of the inlet due to the refraction of waves around the ebb-tidal delta. For the period 1988 to 1992, the National Data Buoy Center (NDBC) buoy located in 18 m of water indicated average H_{m0} wave heights[1] of 1.2 and 0.9 m, and maximum H_{m0} wave heights of 4.0 and 4.6 m, for waves from the northeast and southeast directions, respectively (Appendix E).

[1] See list of notations in Appendix A.

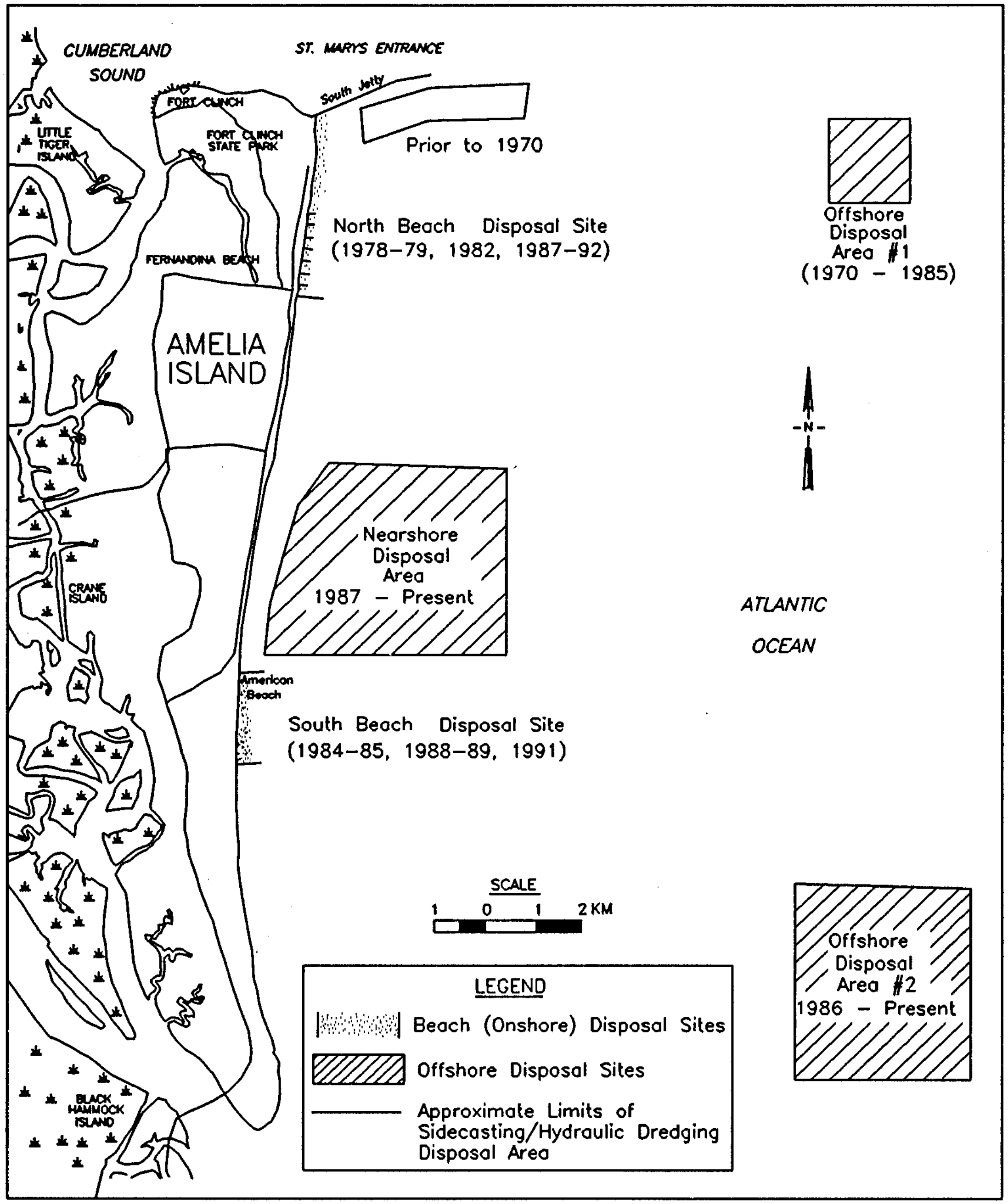


Figure C5. Location of dredged-material disposal areas in the vicinity of Amelia Island

As discussed by Aubrey, McSherry, and Spencer (1990),[1] Hurricane Hugo, in September 1989, resulted in shoaling of 0.3 to 0.8 m throughout the channel for a total of 382,000 cu m of sediment deposited in the channel. The NDBC buoy measured a maximum wave height of 3.1 m

[1] References cited in this appendix are located at the end of the main text, Volume I.

Table C4
Disposal History for St. Marys Entrance and Cumberland Sound Channels

Dredging Event No.[1]	Year	Disposal Location	Amount of Disposed Material cu yd	Amount of Disposed Material cu m
---[2]	1955-87	Sidecast and Offshore Disposal Area	19,650,700	15,024,100
---[3,4]	1979-88	Kings Bay	3,560,300	2,722,100
27[5]	1979	Amelia Island - North Beach	1,003,300	767,100
28	1982	Amelia Island - North Beach	359,900	275,200
28	1982	Offshore Disposal Area	438,100	335,000
29	1983	Offshore Disposal Area	78,900	60,300
30	1983	Offshore Disposal Area	621,800	475,400
31	1984	Offshore Disposal Area	160,900	123,000
---[6]	1984	Amelia Island - South Beach	75,000	57,300
---[6]	1985	Amelia Island - South Beach	5,500	4,200
32[7]	1987-88	Offshore Disposal Area	321,100	245,500
33	1987-88	Amelia Island - North Beach	906,800	693,300
34[8]	1987-88	Nearshore Disposal Area	1,618,200	1,237,200
35[7]	1988	Offshore Disposal Area	5,456,000	4,171,400
36	1988	Amelia Island - South Beach	530,000	405,200
19[3]	1988	Offshore Disposal Area	267,500	204,500
20[3]	1988	Offshore Disposal Area	269,400	206,000

(Continued)

[1] Dredging Event No. refers to Dredging Event No. as listed in Tables C2 and C3 for St. Marys Entrance channel and Cumberland Sound channel, respectively. Relationships between dredging and disposal volumes as presented are difficult to establish prior to Epoch 7 as both dredging and disposal histories are incomplete. Ambiguous dredging and disposal events during Epoch 7 are described separately in Footnotes 3, 8, and 9.

[2] Dredged material prior to 1970 was sidecast to the south of the south jetty. Dredged material disposed at ocean locations between 1970-1985 was at Offshore Disposal Area #1 as illustrated in Figure C5. Differentiation between disposed volumes at these two areas cannot be made.

[3] Material dredged from Cumberland Sound. Otherwise, material dredged from St. Marys Entrance channel.

[4] Cumberland Sound dredged material during this period was disposed at the Mainside and Area 1 Disposal Areas in Kings Bay as illustrated in Figure C4.

[5] Only 767,100 cu m of disposed material for 1979 St. Marys Entrance channel dredging events totaling 1,460,500 cu m have been accounted for.

[6] Privately funded beach fills. Sediment was transported from upland sources. Therefore, no channel dredging event correlates with these beach fill events.

[7] Dredged material disposed at ocean locations from 1986 to the present was at Offshore Disposal Area #2 as designated by EPA and illustrated in Figure C5.

[8] Of the 1,237,200 cu m of material moved to the Nearshore Disposal Area from 1987-88, a total of 825,700 cu m (Footnote #9) of this amount was placed at the Amelia Island - South Beach Disposal Site.

Table C4 (Concluded)				
Dredging Event No.[1]	Year	Disposal Location	Disposed Material cu yd	Disposed Material cu m
---[9]	1988-89	Amelia Island South Beach	1,080,000	825,700
37	1988	Offshore Disposal Area	720,000	550,500
38	1989	Offshore Disposal Area	152,000	116,200
39	1989	Offshore Disposal Area	330,000	252,300
40	1989	Offshore Disposal Area	424,100	324,300
41	1990-91	Offshore Disposal Area	506,000	386,900
---[6]	1989	Amelia Island - South Beach	50,000	38,200
42	1990	Amelia Island - North Beach	147,700	112,900
43	1990-91	Offshore Disposal Area	17,400	13,300
44	1990-91	Nearshore Disposal Area	6,700	5,100
45	1990-91	Nearshore Disposal Area	3,700	2,800
46	1990-91	Offshore Disposal Area	46,400	35,500
21[3]	1991	Offshore Disposal Area	37,600	28,700
22[3]	1991	Nearshore Disposal Area	800	600
---[6]	1991	Amelia Island - South Beach	13,000	9,900
47	1992	Amelia Island - North Beach	193,300	147,800
48	1992	Offshore Disposal Area	640,200	489,500
49	1992	Offshore Disposal Area	36,000	27,500

[9] Material was removed from the Nearshore Disposal Area and disposed at the Amelia Island-South Beach Disposal Site.

Table C5
Total Disposal Amounts with Respect to Disposal Area, 1979-1992[1]

Disposal Area	cu yd	cu m
Offshore Disposal Area #2	9,223,700	7,052,100
Kings Bay - Mainside and Areal Disposal Areas	3,560,400	2,722,100
Amelia Island - North Beach Disposal Site	2,611,000	1,996,300
Amelia Island - South Beach Disposal Site	1,753,500	1,340,700
Offshore Disposal Area #1	1,299,700	993,700
Nearshore Disposal Area[2]	549,300	420,000
Total[3]	18,997,600	14,524,800

[1] Amounts do not include sidecast and ocean disposed material of 1955-84 as indicated in Table C4.
[2] Amount does not include 825,700 cu m moved to Amelia Island - South Beach Disposal Site from 1987-88.
[3] Total reported amount of disposed material is slightly less than total reported amount of dredged material over similar time periods. This may be a result of losses during dredging operations and reporting inaccuracies.

Table C6
Maintenance Dredging Core Borings of St. Marys Entrance Channel (1989)

Core Number	Depth[1] m MLW	Sediment Characteristics[2]	Florida State Plane Coordinates X(ft)	Florida State Plane Coordinates Y(ft)	Approximate Channel Station[3]
KB-89-1	15.3 to 16.8	Sand, medium to coarse grained, shelly	738,434	258,955	138+57, 29m L
KB-89-2	15.8 to 17.0	Sand, medium to coarse grained	738,795	259,285	142+33, 125m L
KB-89-3	15.4 to 16.2	Sand, medium to coarse grained, shelly	739,083	259,008	145+08, 36m L
KB-89-4	15.3 to 15.7	Sand, medium to coarse grained, trace shell	740,024	259,363	154+64, 131m L
KB-89-5	15.5 to 16.7	Sand, medium to coarse grained, shelly	739,788	258,722	151+99, 61m R
KB-89-5A	15.1 to 16.4	Sand, medium to coarse grained, shelly	739,747	258,743	151+59, 54m R
KB-89-6	15.5 to 15.7	Sand, medium to coarse grained	740,715	259,165	161+46, 61m L
KB-89-7	15.1 to 16.4	Sand, medium to coarse grained	740,814	258,783	162+27, 56m R
KB-89-8	15.3 to 16.8	Sand, trace silt	747,004	259,458	224+41, 63m L
KB-89-9	15.6 to 16.2	Clay, very soft, trace sand	747,155	259,031	225+73, 69m R
KB-89-10	14.6 to 16.3	Clay, very soft, trace sand	748,067	259,429	235+02, 40m L
KB-89-11	14.8 to 16.4	Clay, very soft, trace sand	748,121	259,100	235+41, 61m R
KB-89-12	14.6 to 15.8	Clay, very soft, trace sand	757,032	259,925	324+80, 66m L
KB-89-13	15.0 to 16.1	Clay, trace sand, trace shell	756,949	259,498	323+78, 63m R
KB-89-14	16.0 to 17.4	Clay, trace sand	757,638	259,888	330+84, 46m L

[1] Only upper portion of core inclusive of TRIDENT channel deepening (15.5 m below MLW) is described.
[2] Sediment characteristics of each core are representative of entire described portion of core.
[3] Stations are relative to centerline of navigation channel: L indicates to the left of the centerline oriented in a seaward direction, R to the right.

Table C7
Maintenance Dredging Core Borings of St. Marys Entrance Channel, Post-TRIDENT Channel Deepening (1990)

Core Number	Depth[1] m MLW	Sediment Characteristics[2]	Florida State Plane Coordinates		Approximate Channel Station3
			X(ft)	Y(ft)	
KB-90-1	14.5 to 15.7	Sand, shelly, trace silt	727,049	257,784	24+31, 169m R
KB-90-2	11.2 to 15.4	Sand, shelly, trace silt	736,847	259,232	122+85, 136m L
KB-90-3	14.9 to 16.5	Sand, shelly	737,518	258,775	129+34, 13m R
KB-90-4	14.7 to 16.3	Sand, shelly	738,726	258,935	141+48, 19m L
KB-90-5	15.9 to 17.4	Sand, shelly	742,005	259,523	174+51, 153m L
KB-90-6	13.3 to 16.4	Sand, shelly	743,102	259,384	185+40, 95m L
KB-90-7	15.5 to 17.0	Sand, silty	745,779	258,855	211+90, 103m R
KB-90-8	15.3 to 16.8	Sand, little silt, seams of sand, trace shell, little clay, clay	746,068	259,522	215+09, 96m L
KB-90-9	14.6 to 14.9	Sand, little silt, trace shell	746,537	259,613	219+82, 117m L
KB-90-10	14.8 to 16.0	Clay, slightly plastic, trace shell	747,860	259,522	232+99, 71m L
KB-90-11	14.9 to 15.7	Clay, plastic, trace sand, isolated seams, clayey sand	752,560	259,592	279+98, 27m L
KB-90-12	14.3 to 15.9	Clay, plastic, organic stains, isolated seams of clayey sand, trace to little sand	753,150	259,739	285+94, 63m L
KB-90-13	15.2 to 15.5	Clay, plastic, organic stains	754,255	259,652	296+94, 21m L
KB-90-14	15.6 to 17.4	Clay, plastic, organic stains	757,952	259,890	333+98, 43m L

[1] Only upper portion of core inclusive of TRIDENT channel deepening (15.5 m below MLW) is described.
[2] Sediment characteristics of each core are representative of entire described portion of core.
[3] Stations are relative to centerline of navigation channel: L indicates to the left of the centerline oriented in a seaward direction, R to the right.

with a peak wave period of 16.7 sec associated with this event. Significant shoaling in southern portions of the channel was also attributed to Hurricane David (4 September 1979) as determined by analysis of bathymetric surveys taken from July 1979 and October 1979.[1]

Reaches of bed forms (defined as sand bodies with relief of less than 1.5 m above the bottom), and shoals (sand bodies with relief of 1.5 m or greater above the bottom) north and south of St. Marys Entrance channel occur from Station 80+00 to 450+00 as identified by analysis of bathymetric and side-scan sonar surveys (Aubrey, McSherry, and Spencer 1990) (Figure C7).

[1] Unpublished report, 1980. "U.S. Navy Kings Bay Shoaling Study," USAED, Jacksonville, Florida.

Table C8
Maintenance Dredging Core Borings of St. Marys Entrance Channel (1991)

Core Number	Depth[1] m MLW	Sediment Characteristics[2]	Florida State Plane Coordinates X(ft)	Florida State Plane Coordinates Y(ft)	Approximate Channel Station[3]
KB-91-1	15.0 to 16.2	Sand, fine to medium grained, shelly, trace silt and clay	742,052	259,508	174+97, 147m L
KB-91-2	12.9 to 15.9	Sand, fine to medium grained, shelly, trace silt	743,017	259,419	184+57, 107m L
KB-91-3	14.8 to 16.3	Sand, fine to medium grained, some shell, trace silt and clay	744,070	259,470	195+11, 108m L
KB-91-4	15.4 to 16.2	Sand, fine to medium grained, silty, trace shell and clay	745,247	259,524	206+89, 108m L
KB-91-5	13.2 to 16.2	Sand, medium to coarse grained, shelly, trace silt, some shell	743,595	258,720	190+02, 114m R
KB-91-6	13.9 to 16.2	Sand, fine to medium grained, trace silt	743,361	259,419	188+00, 102m L
KB-91-7	15.5 to 16.2	Sand, fine to medium grained, trace shell, trace clay	744,656	259,492	200+97, 106m L
KB-91-8	13.8 to 16.2	Sand, fine to medium grained, clayey, shelly	745,243	258,794	206+52, 114m R
KB-91-9	14.3 to 16.2	Sand, fine to medium grained, some shell, trace silt	742,402	258,691	178+09, 106m R
KB-91-10	13.1 to 16.9	Sand, fine to coarse grained, shelly, shell fragments, trace silt	736,599	259,106	120+31, 101m L
KB-91-11	14.1 to 17.1	Sand, fine to coarse grained, shelly with fragments, trace silt	742,111	259,512	175+56, 148m L
KB-91-12	14.7 to 16.3	Sand, fine to medium grained, some coarse shell fragments, scattered thin clay layers	742,390	258,713	177+98, 99m R
KB-91-13	10.8 to 13.9	Sand, fine to coarse grained, shelly, trace silt	743,218	259,415	186+57, 103m L

(Continued)

[1] Only upper portion of core inclusive of TRIDENT channel deepening (15.5 m below MLW) is described.
[2] Sediment characteristics of each core are representative of entire described portion of core.
[3] Stations are relative to centerline of navigation channel: L indicates to the left of the centerline oriented in a seaward direction, R to the right.

Table C8 (Concluded)					
Core Number	Depth m MLW	Sediment Characteristics	Florida State Plane Coordinates		Approximate Channel Station
			X(ft)	Y(ft)	
KB-91-14	14.3 to 16.1	Sand, fine to medium grained, shelly, scattered thin lenses of clayey sand, clay	743,634	258,766	190+43, 101m R
KB-91-15	12.5 to 14.2	Sand, fine to coarse grained, shelly, trace clay, trace silt	743, 854	259,461	192+95, 108m L
KB-91-16	15.9 to 16.6	Clay, very soft, low to medium plasticity, little fine sand	750,832	259,234	262+55, 58m R
KB-91-17	15.6 to 16.5	Clay, very soft, low plasticity, some fine sand	751,350	259,490	267+84, 13m L
KB-91-18	15.5 to 17.5	Clay, very soft, low to medium plasticity, little fine sand	751,612	259,289	270+37, 52m R
KB-91-19	15.7 to 17.2	Clay, soft, low to medium plasticity, little fine sand, some silt	752,792	259,702	282+34, 57m L
KB-91-20	15.0 to 17.1	Clay, medium plasticity, little very fine sand, trace shell	754,448	259,780	298+92, 58m L

Significant shoaling north of the channel occurs relative to the following channel stationing:

a. Shoaling from Station 80+00 of Cumberland Sound to 25+00 of St. Marys Entrance channel, Cut 1N, results from movement of littoral material through the permeable north jetty near Cumberland Island and spit accretion on the downdrift end of Cumberland Island. This shoaling may also be a result of movement of the flood-tidal delta deposits.

b. Shoaling from Station 120+00 to 286+00 of St. Marys Entrance channel, Cut 1N, results from both shoal and bed form formation and movement. Significant shoaling occurs inside of the north jetty (Station 120+00 to 150+00), just seaward of the jetty tips (Station 160+00 to 190+00), and at ebb-tidal delta locations (Station 240+00 to 260+00). Bed forms with 0.3- to 1.0-m wavelengths exist between Station 160+00 and 260+00.

c. Shoaling occurs from Station 440+00 to 450+00 of St. Marys Entrance channel, Cut 1N. This reach, which is located seaward of the ebb-tidal delta terminal lobe, shoals on an episodic basis as associated with storm activity.

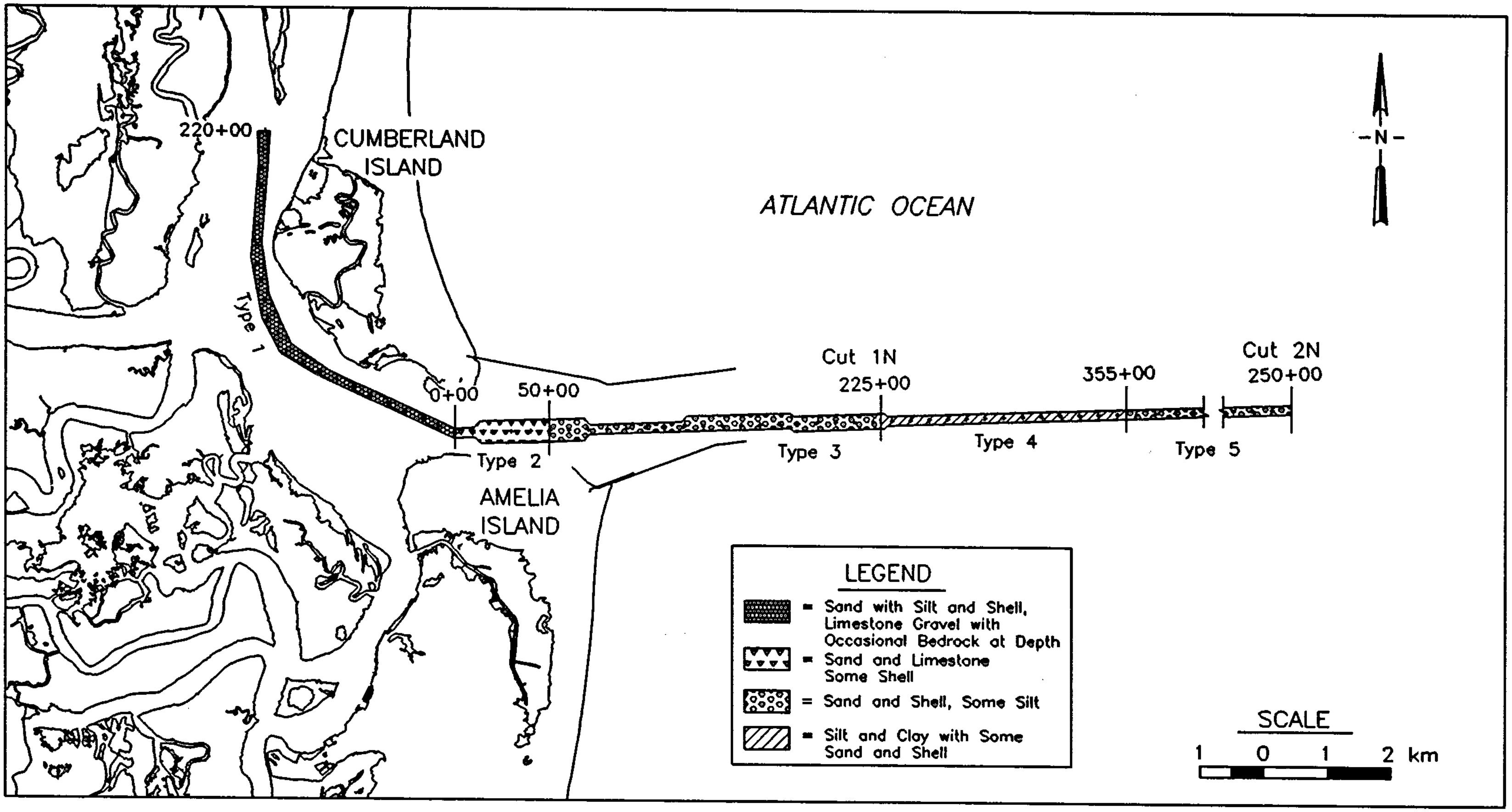


Figure C6. Channel reaches based on channel bottom sediment type

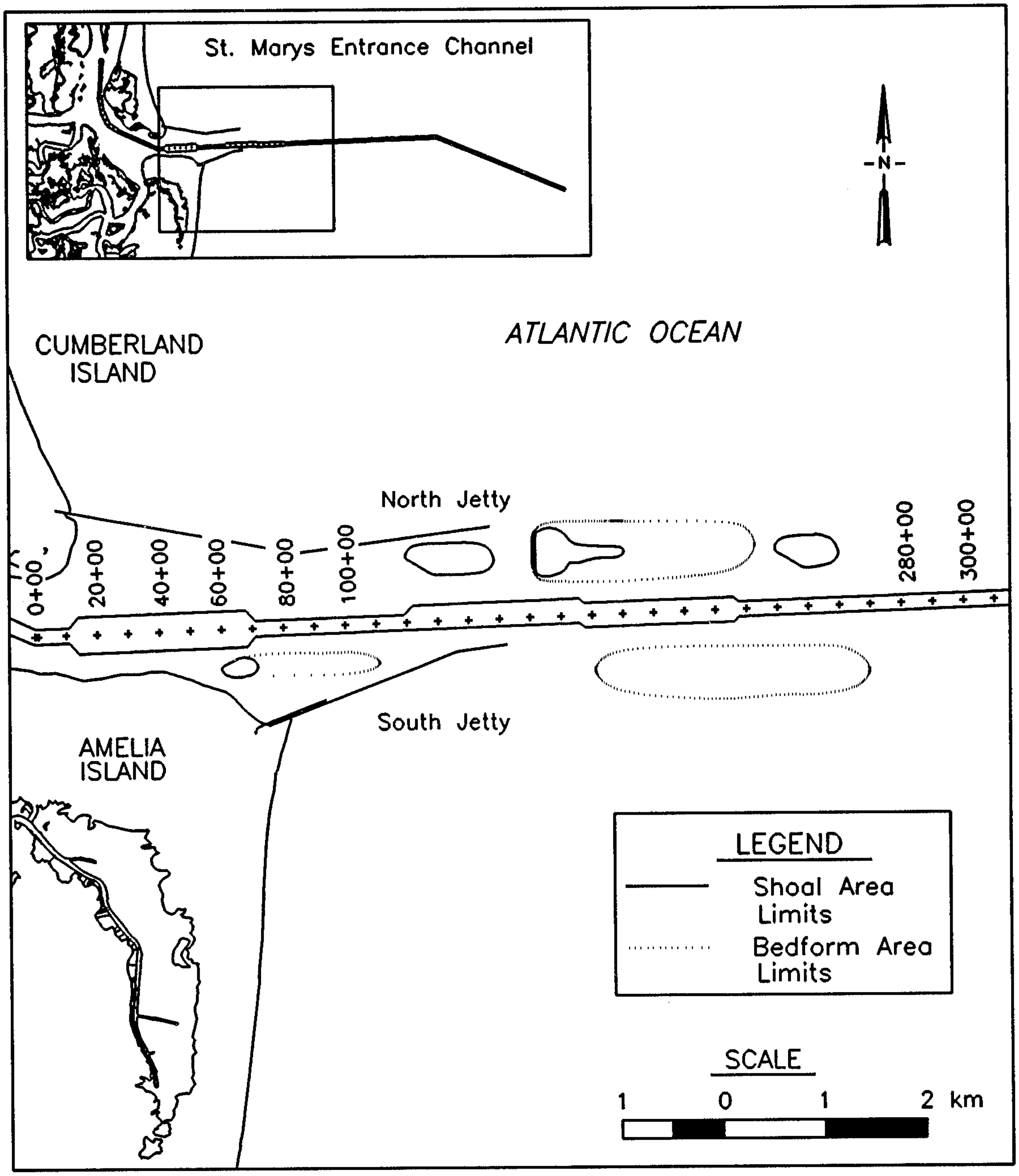


Figure C7. Areas of bed form and shoaling adjacent to channel between Station 00+00 and 315+00 during 1988-1990 (after Aubrey, McSherry, and Spencer (1990))

Significant shoaling south of the channel occurs within the following channel reaches:

a. Shoaling occurs from Station 50+00 of Cumberland Sound channel to 0+00 of St. Marys Entrance channel, Cut 1N. This shoaling is most likely associated with migration of flood-tidal delta shoals.

b. Shoals and bed forms with wavelengths greater than 3.6 m occur between Stations 72+00 and 110+00 of St. Marys Entrance channel, Cut 1N. An area of frequent shoaling is located in the vicinity of Station 72+00.

c. An area of shoaling occurs between Stations 180+00 and 270+00 of St. Marys Entrance channel, Cut 1N, and extends 450 m south of the southern channel margin. This area has bed forms with wavelengths greater than 3.6 m. Some bed forms with wavelengths of 1 to 2 m also occur in this area. Shoal formation in this reach is dependent upon the strength and frequency of storms with waves from the southeast.

Shoaling in the navigation channel proper is produced by the introduction of longshore transported sediment from the sides of the channel through side-slope adjustment. Shoaling also occurs in the navigation channel from migration of bed forms within the channel. Bed forms exist between Station 0+00 and 72+00 of St. Marys Entrance channel, Cut 1N, due to the narrow width and constriction of the channel and the resultant strong tidal currents. However, these tidal currents appear to have enough scouring capability to inhibit deposition in this area, resulting in little need for maintenance dredging between Stations 00+00 and 110+00, Cut 1N. Seaward of the inlet throat, increased channel width and depth and energy dissipation over the ebb-tidal delta surface weaken the ebb-tidal current velocity. Sediments can be deposited, thus producing both bed forms and significant shoaling seaward of Station 230+00, Cut 1N. Aubrey, McSherry, and Spencer (1990) documented bed forms inside the channel with wavelengths between 1.0 and 3.6 m between Stations 72+00 and 220+00. Seaward of Station 220+00, both bed form size and frequency decrease.

Channel Shoaling Characteristics

Shoaling locations and rates have been determined for both St. Marys Entrance channel and Cumberland Sound channel. Channel reaches were distinguished based on significant shoaling (rates above 30,000 cu m/year/1,000-m section of channel), moderate shoaling (15,000-30,000 cu m/year/1,000-m section of channel), and minor shoaling rates (0-15,000 cu m/year/1,000-m section of channel).

St. Marys Entrance channel

Shoaling database. Characterization of shoaling rates and patterns at St. Marys Entrance channel is based on an extensive database including:

a. Dredging records, including dates, volumes, locations, and sediment type of both maintenance and new work dredging events from both the USAED, Jacksonville and USAED, Savannah.

b. Comparison of condition surveys (bathymetric surveys conducted to determine the need for channel maintenance) and associated volumetric sediment difference analysis from both the USAED, Jacksonville and USAED, Savannah.

c. Pre- and post-maintenance dredging core borings and related channel bottom sediment classification.

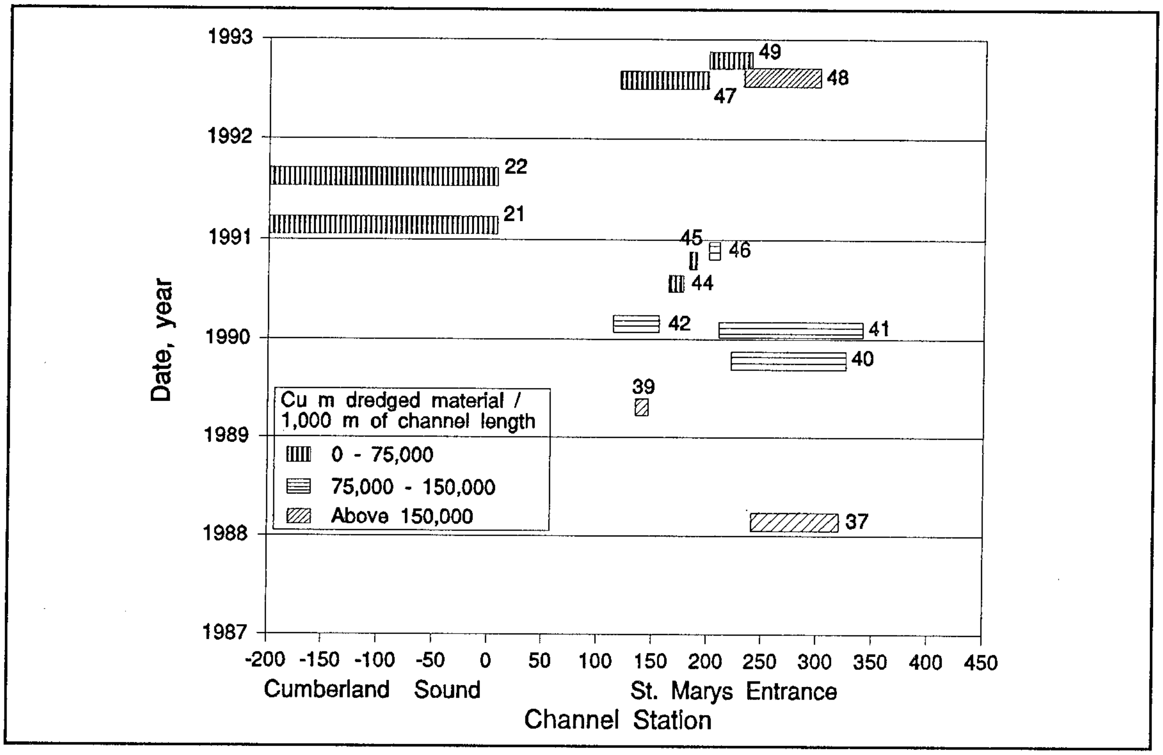
d. Field analysis of sediments of dredged material associated with maintenance dredging events.

Comparison of shoaling rates between epochs of channel maintenance is difficult for several reasons. First, quantitative comparison of shoaling rates between Epochs 6 and 7 is hampered by limited dredging records prior to the 1987 channel deepening. Estimation of shoaling rates becomes ambiguous due to the expansion of channel dimensions, particularly channel length between Epochs 6 and 7. Second, comparison of surveys over time is limited to one occasion due to occurrence of maintenance dredging between surveys, insufficient time interval between surveys, and lack of survey coverage of the entire channel length. Third, side-slope adjustment of the channel after dredging may be interpreted as shoaling from littoral processes, thus overestimating actual littoral shoaling rates. Last, dredging practices over time have been inconsistent in that amounts of overdepth dredging were not always reported.

Shoaling patterns and sources. Maintenance dredging in St. Marys Entrance channel during Epoch 7, indicative of shoaling, was performed between Stations 115+00 and 435+00, Cut 1N (Figure C8). Dredging during Epoch 7 focused on the channel reach between Stations 120+00 and 350+00, Cut 1N. Shoaling locations can be better classified by defining two shoaling processes. First, the introduction of littoral sands into the system produces shoals and bed forms on both sides of the channel from Station 0+00 to 230+00, Cut 1N. These sand bodies subsequently migrate into the channel, creating shoals within the channel. An area of significant shoaling occurs in the vicinity of the jetty tips from Station 110+00 to 180+00, Cut 1N. However, shoaling to the north and south of the channel does not necessarily indicate shoaling within the navigation channel. For instance, shoaling occurs north of the channel from Station 80+00 of Cumberland Sound channel to 25+00, Cut 1N, due to sediment moving through the permeable north jetty and growth on the southern end of Cumberland Island. However, shoaling does not occur within the channel between these two stations, probably because of scouring by the tidal current. The second shoaling process results from the introduction of clay and silt into the channel between Stations 230+00 and 340+00, Cut 1N, in the vicinity of the ebb-tidal delta terminal lobe. These sources of clay and silt include estuarine clays and silts carried offshore during ebb-tidal discharge and mobilization of clay and silt in deeper water by waves and currents.

Vemulakonda et al. (1988) predicted shoaling patterns utilizing a system of hydrodynamic and sediment transport numerical simulation models. Their results, calculated for noncohesive sediments (sand), indicated that shoaling would occur approximately between Stations 110+00 and 310+00 with maximum shoaling rates located between Stations 130+00 and 230+00. The required maintenance dredging of sand during Epoch 7 has been concentrated between Stations 110+00 and 210+00, supporting the shoaling location predictions of Vemulakonda et al. (1988).

Figure C8 illustrates that Dredging Events 37, 39, and 48 are the most significant for Epoch 7 with volumes of 226,000, 827,000, and 200,000 cu m dredged material/1,000-m channel length, respectively. Two of these events (Events 37 and 48), as well as two others with volumes greater than 90,000 cu m dredged material/1,000-m channel length (Events 40 and 41), took place between Station 240+00 and 300+00, Cut 1N. Another area of frequent dredging during Epoch 7 was located between Station 115+00 and 210+00, Cut 1N. Nine dredging events, three



Dredging Event No.[1]	Total Dredged Amount cu m	Cu m Dredged Material/1,000 m of Channel Length	Dredging Event No.	Total Dredged Amount cu m	Cu m Dredged Material/1000 m of Channel Length
37	550,500	226,000	45	2,800	16,000
38	116,200	NA[2]	46	35,500	116,000
39	252,300	827,000	21[4]	28,700	5,000
40	324,300	101,000	22[4]	600	100
41	386,900	98,000	47	147,800	57,000
42	112,900	93,000	48	489,500	200,000
43[3]	13,300	24,000	49	27,500	45,000
44	5,100	13,000			

[1] Same Dredging Event Number as in Table C2 - Dredging History at St. Marys Entrance channel.
[2] Cu m dredged material/1,000 m of channel length cannot be determined as channel reach of dredging event not available.
[3] Dredging event was not included in the graph above as dredging was performed at three sections of channel, each of which varied from 60-300 m in length, between Stations 67+00 and 148+00.
[4] Same Dredging Event Number as in Table C3 - Dredging History of Cumberland Sound from Station 0+00 to 220+00.

Figure C8. Maintenance dredging location for Epoch 7 (1988-1992) of which had volumes greater than 90,000 cu m dredged material/1,000-m channel length (Events 39, 42, and 46), occurred there. Note that Figure C8 does not include new work (6,495,700 cu m), and Cut 2N (13,300 cu m) dredging events. No trend in dredging location could be determined for the period 1974 to 1986.

Shoaling rates. Shoaling rates for the entire length of St. Marys Entrance channel during Epoch 7 (1988-1992) were calculated at 616,200 cu m/year for both cohesive and noncohesive sediments. However, because 99 percent of the maintenance dredging took place in Cut 1N, this rate is indicative of dredging (and shoaling rate) only for Cut 1N (a length of 15,300 m). This rate is close in magnitude to a rate of 602,500 cu m/year for noncohesive sediments only as predicted numerically by Vemulakonda et al. (1988) for a 12,300-m length of Cut 1N from Station 77+00 to 481+00. These shoaling rates are lower than a maximum potential shoaling rate of 1,032,100 cu m/year determined from the cumulative maximum rates of several channel reaches as presented in the Kings Bay Environmental Impact Statement (EIS) (1986).[1]

The USAED, Jacksonville (1993) utilized volume differences as determined from June 1988, December 1989, and June 1990 condition surveys to compute shoaling rates for portions of the channel from Station 226+00 to 331+00, Cut 1N (shoaling resulting from the introduction of clay and silt), and from Station 345+00 to 375+00, Cut 1N (Figure C9). Shoaling volumes from Station 226+00 to 331+00 were calculated for the 6-month period of December 1989 to June 1990. Shoaling volumes between Stations 345+00 and 375+00 were calculated for the 2-year period of June 1988 to June 1990. No dredging was performed during this period, suggesting that the documented volumetric changes represent true shoaling rates.

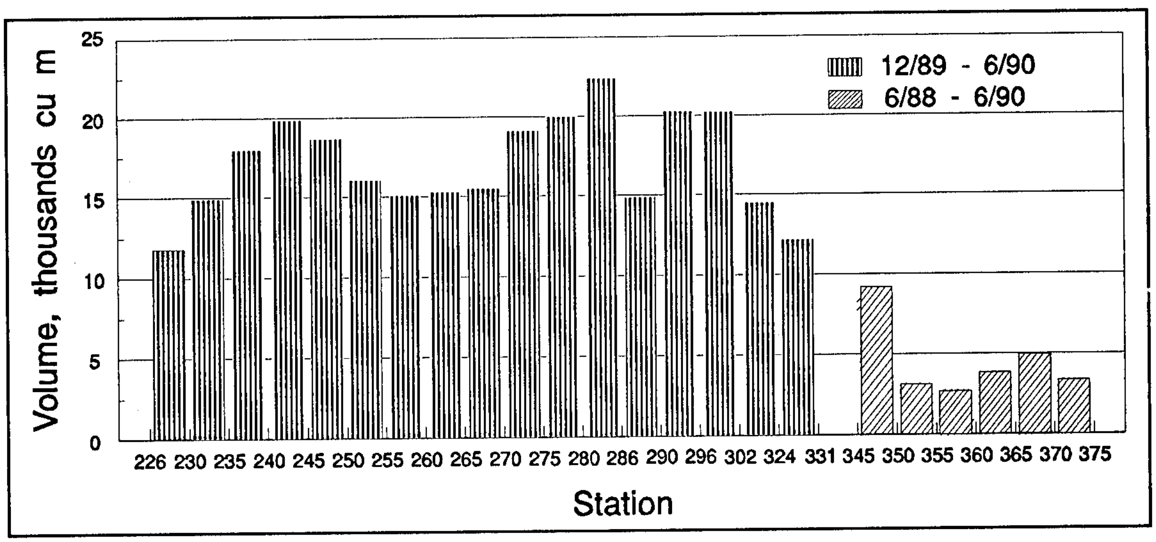


Figure C9. Comparison of shoaling volumes (USAED, Jacksonville 1993)

[1] Kings Bay Environmental Impact Statement (EIS). 1986. "Final Third Supplement to the Environmental Impact Statement for Preferred Alternative Location for a Fleet Ballistic Missile Submarine Support Base, Kings Bay, Georgia (St. Marys Entrance Channel)," unpublished report, Department of the Navy, Officer in Charge of Construction, Trident, St. Marys, Georgia.

Shoaling volumes between Station 226+00 and 331+00, Cut 1N, are on the order of 336,600 cu m for the 6-month period, or a shoaling rate of 210,300 cu m/year/1,000-m section of channel. Reaches of high shoaling rates of 250,800 and 214,300 cu m/year/1,000-m section of channel were recorded from Station 275+00 to 286+00 and from Station 290+00 to 302+00, respectively (after USAED, Jacksonville[1]) (Figure C9). In contrast, shoaling volumes from Station 345+00 to 375+00 was 27,100 cu m for the 2-year period, or a shoaling rate of 14,800 cu m/year/1,000-m section of channel. Reaches of low shoaling rates of 9,400 cu m/year/1,000-m section of channel were located from Station 350+00 to 360+00.

Shoaling through channel-bottom accretion of sediment at ebb-tidal delta locations is demonstrated in a cross section of the channel at Station 280+00 obtained from USAED, Jacksonville[1] (Figure C10). Shoaling over the 6-month period from December 1989 to June 1990 indicates channel bottom accretion of between 0.4 and 1.2 m. Note also the bank accretion on both sides of the channel which is a result of side slope adjustment and infilling from outside sediment sources.

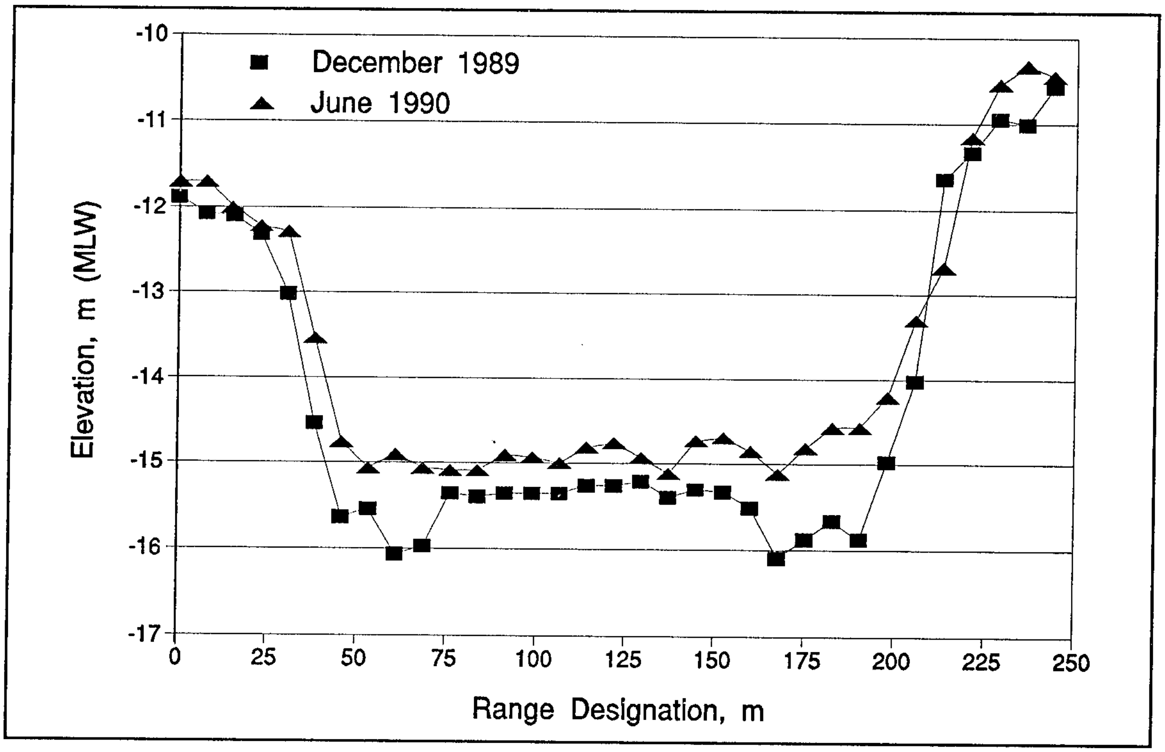


Figure C10. Typical channel cross-sectional profile (Station 280) (USAED, Jacksonville 1990)

Another area of significant shoaling at the St. Marys Entrance TRIDENT channel occurred between Station 110+00 and 180+00, Cut 1N. Volume of shoaled material in this portion of the channel was estimated at 31,000 cu m/year/1,000-m section of channel as determined from volume differences between the February 1988 (121,600 cu m) dredging event from

[1] Unpublished report, 1990. "Kings Bay Entrance Channel Shoaling Analysis," USAED, Jacksonville, Florida.

Station 130+00 to 180+00 and the March 1991 (112,900 cu m) dredging event from Station 114+00 to 154+00 (Table C2).

Shoaling rates - material. Shoaling rates of sediments were calculated for Epoch 7 to determine the relative importance of different sources of these materials in channel shoaling. The shoaling rates of fine-grained material (clay and silt) versus sand are distinguished by ascertaining the approximate proportion of material introduced into St. Marys Entrance channel by three mechanisms: (a) littorally introduced sand, (b) estuarine silts and clays carried offshore during ebb-tidal discharge, and (c) mobilization of deeper water silts and clays.

Two methods were employed to determine shoaling rates of different materials. The first method compared maintenance dredging events with channel-bottom sediment type (based on the Unified Soil Classification Method) (Figure C6) of pre-dredging core borings (1989-1991) (Tables C6-C8). Archived samples were inspected during this study to verify core boring descriptions and the quantity of sand found in different sections of the channel. Based on this analysis, Epoch 7 maintenance dredging performed between Stations 50+00 and 225+00, Cut 1N, tends to remove littoral sands trapped in the channel, whereas maintenance dredging performed between Stations 225+00 and 355+00, Cut 1N, tends to remove silt and clay. Of the 13 total maintenance dredging events performed at St. Marys Entrance channel during Epoch 7, four are judged to have removed silt and clay from the channel for a total of 1,751,200 cu m, whereas eight events removed 597,200 cu m of sand (Table C9). Average channel maintenance dredged volumes for Epoch 7 based on channel bottom sediment type (indicative of shoaling rate) were 437,800 cu m/year for silt and clay and 149,300 cu m/year for littorally introduced sand into the channel. These volumes represent low estimates, as 116,200 cu m of material (29,100 cu m/year) associated with three maintenance dredging events could not be classified with respect to sediment type because the dredging event channel reach was not specified.

Figure C11 illustrates the dredging event channel reach, volume and sediment type with respect to reaches of channel shoaling material type (sand shoaling from Stations 125+00 to 225+00, Cut 1N, and silt and clay shoaling seaward of Station 225+00), and channel configuration (depth and length). Note that Figure C11 does not include Dredging Event Nos. 38, 43, 44, or 45 as channel reach was not specified or was insignificant.

The second method used to distinguish between shoaling rates of clay/silt and sandy material employed the field classification of sediments estimated during maintenance dredging activities. Field classification of sand was based on suitability of sediment for beach disposal. If the silt content was greater than 10 to 15 percent, then the dredged material was classified as "silt" and placed at the Offshore Disposal Area (Figure C5). If the silt content was less than 10 to 15 percent, the dredged material was classified as "sand" and placed at the Amelia Island North and South Beach Disposal Sites (Figure C5). This sediment classification method indicates that four of the dredging events (Events 42, 43, 47, and 49) removed silt instead of sand as based on channel bottom sediment type of pre-dredging core borings. This field classification of channel sediments suggests shoaling rates of 549,000 cu m/year and 67,200 cu m/year, for clay and silt, and sand, respectively.

Final shoaling rates with respect to type of material were determined by averaging the rates calculated in the previously mentioned two methods (channel-bottom sediment type from cores, and field classification of dredged material) and presenting their difference as a margin of error.

Table C9
Estimated Shoaling Rates of Dredged Silt and Clay and Sand at St. Marys Entrance Channel During Epoch 7 (1988-1992)

Event No.[1]	Year	Location	Volume Silt and Clay cu m	Volume Sand cu m	Insufficient Information[2]
37	1988	Cut 1N - Sta 240+00 to 320+00 - Maintenance	550,500		
38	1989	Cut 1N - Maintenance			116,200
39	1990-91	Cut 1N - Sta 135+00 to 145+00 - Maintenance		252,300	
40	1990-91	Cut 1N - Sta 220+00 to 323+00 - Maintenance	324,300		
41	1990-91	Cut 1N - Sta 210+00 to 340+50 - Maintenance	386,900		
42	1990-91	Cut 1N - Sta 114+50 to 154+50 - Maintenance		112,900	
43	1990-91	Cut 2N - Sta 67+00 to 69+00, 78+00 to 88+00, 142+00 to 148+00 - Maintenance		13,300	
44	1990-91	Cut 1N - Sta 164+00 to 177+00 - Maintenance		5,100	
45	1990-91	Cut 1N - Sta 183+00 to 189+00 - Maintenance		2,800	
46	1990-91	Cut 1N - Sta 200+00 to 210+00 - Maintenance		35,500	
47	1992	Cut 1N - Sta 115+00 to 200+00 - Maintenance		147,800	
48	1992	Cut 1N - Sta 230+00 to 310+00 - Maintenance	489,500		
49	1992	Cut 1N - Sta 210+00 to 230+00 - Maintenance		27,500	
Total Maintenance Dredged Volume per Year[3]			437,800	149,300	29,100
Total Maintenance Dredged Volume per Year[4]			549,000	67,200	
Total Maintenance Dredged Volume per Year[5]			493,400 ±55,600	108,300 ±41,100	

[1] Event numbers refer to dredging events at St. Marys Entrance channel as listed in Table C2.
[2] Maintenance dredged material cannot be determined because dredging event channel reach is not defined.
[3] Shoaling rates determined considering location of maintenance dredging event with respect to channel bottom sediment type (except where noted by Footnote 4).
[4] Shoaling rates determined considering field evaluation of sediment type during maintenance dredging events.
[5] Shoaling rates were determined by considering both location of maintenance dredging event with respect to channel bottom sediment type as determined by analysis of cores and field evaluation of sediment type during maintenance dredging events.

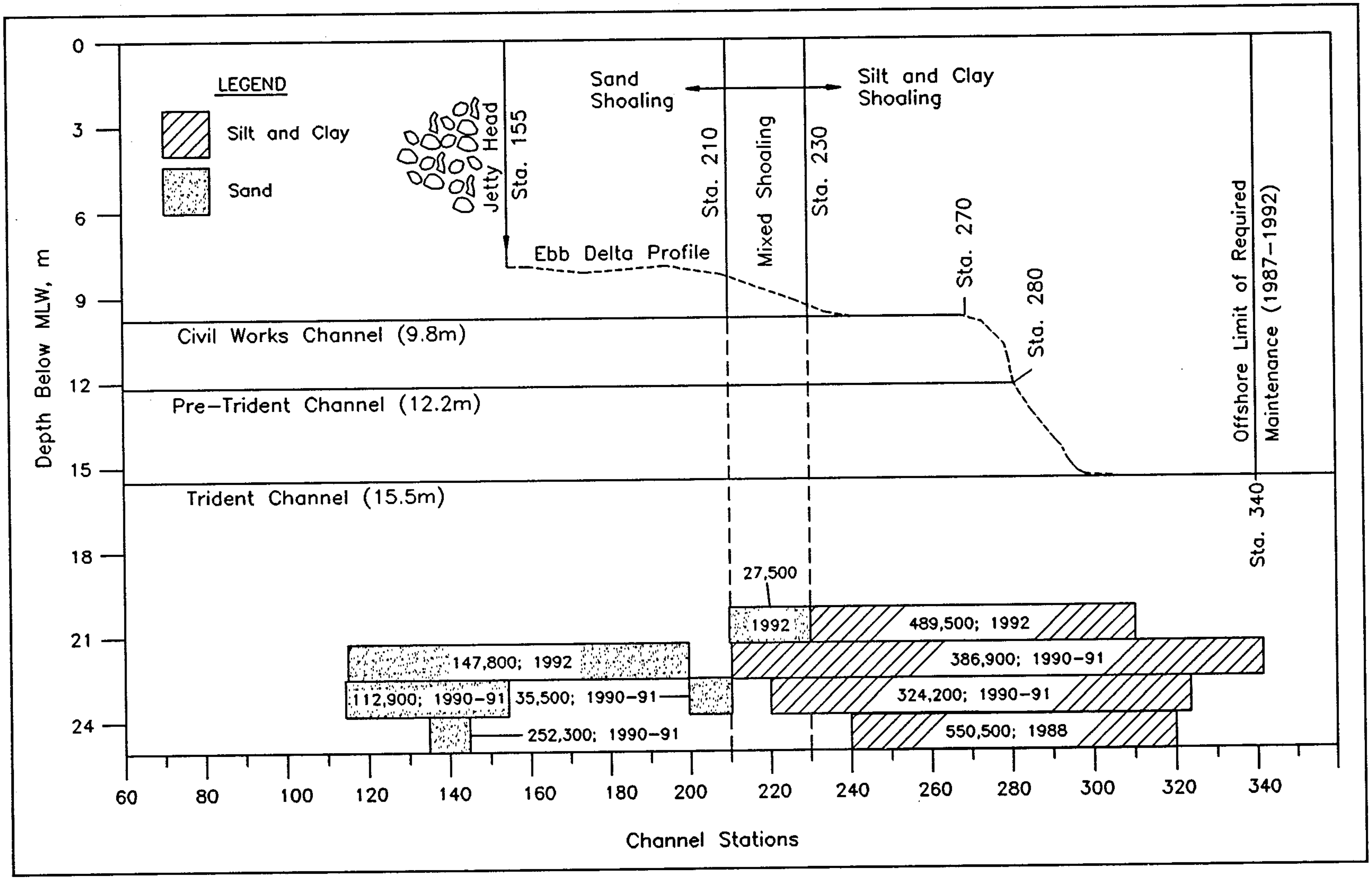


Figure C11. Maintenance dredging event channel reach, volume, and sediment type with respect to channel configuration and ebb-tidal delta profile (1988-1992)

Shoaling rates for St. Marys Entrance channel during Epoch 7 were 493,500 ± 55,600 cu m/year for clay and silt, and 108,300 ± 41,100 cu m/year for sand introduced by littoral processes.

Of the total 616,200 cu m/year of shoaling during Epoch 7 (1988-1992), 71 percent (437,800 cu m/year) (Table C9) of the dredged material consisted of fine-grained silt and clay material, of estuarine or offshore origin, dredged between Stations 210+00 and 340+00 inclusive of the ebb-tidal delta terminal lobe. Littorally introduced sand constituted 24 percent (149,300 cu m/year) of Epoch 7 maintenance dredging. Dredging of littoral sands occurred in the vicinity of the ends of the jetties between Stations 67+00 and 230+00, Cut 1N, with predominate dredging performed between Stations 110+00 and 180+00. The remaining 5 percent of the 616,200 cu m/year of Epoch 7 maintenance dredging (29,100 cu m/year) was unclassified with respect to sediment type.

Cumberland Sound channel

Shoaling rates and patterns in Cumberland Sound from Station 0+00 to 220+00 were based on the dredging history (Table C3) and comparison of channel cross sections from condition survey data which show sediment volume differences between survey dates and average annual volume differences for both pre- and post-TRIDENT channel conditions (Table C10). Dredging was not performed within the three survey comparison windows.

The entire Cumberland Sound portion of the channel from Station 0+00 to 220+00 is generally scoured (indicated by negative numbers). It is unclear if this scouring is a response associated with long-term geological trends or is due to channel deepening elsewhere. This scouring is supported by average volume differences of 378,800 cu m/year of scour and 31,200 cu m/year of scour between pre- (September 1983 - January 1985) and post- (January 1989 - August 1990 and April 1991 - October 1991) TRIDENT channel condition surveys, respectively. These values suggest scouring rates of 56,500 and 4,700 cu m/year/1,000-m section of channel for pre- and post-TRIDENT channel conditions, respectively. Average post-TRIDENT channel deepening scour rates from Station 0+00 to 50+00 and from Station 100+00 to 150+00 are 74,200 cu m/year (48,700 cu m/year/1,000-m section of channel), and 30,400 cu m/year (19,900 cu m/year/1,000-m section of channel), respectively. However, two reaches of shoaling associated with littoral sands transported to the backbarrier channels occur from Station 50+00 to 100+00 and from Station 150+00 to 200+00. The annual shoaling rates for post-TRIDENT channel conditions for each of these 1,500-m-long reaches were 26,000 cu m (or 17,100 cu m/year/1,000-m section of channel) and 35,800 cu m (or 23,500 cu m/year/1,000-m section of channel), respectively.

Comparisons for Cumberland Sound channel indicate that for Station 50+00 to 100+00 and Station 150+00 to 200+00, the channel scoured during pre-TRIDENT channel conditions, but shoaled during post-TRIDENT channel conditions. Average volume differences for this combined 3,000-m section of channel are 140,900 cu m/year of scour (or 46,200 cu m of scour/year/1,000-m section of channel) for pre-TRIDENT channel conditions and 61,800 cu m (or 20,300 cu m of shoaling/year/1,000-m section of channel) for post-TRIDENT channel conditions.

Channel shoaling reaches

For the present analysis, the navigation channel was divided into six reaches of shoaling patterns based on analysis of coastal charts, bathymetric data, location of dredging operations,

Table C10
Cumberland Sound (Station 0+00 to 220+00) Pre- and Post-TRIDENT Channel Deepening Condition Survey Volume Analysis

Station Section	Pre-TRIDENT Channel	Post-TRIDENT Channel		Average Annual Volume Difference, cu m	
	September 1983-January 1985 Volume Difference (cu m)	January 1989-August 1990 Volume Difference (cu m)	April 1991-October 1991 Volume Difference (cu m)	Pre-TRIDENT Channel[1]	Post-TRIDENT Channel[2]
0+00-10+00	-30,800[3]	-32,000	-15,300	-23,800	-22,600
10+00-20+00	-20,900	-23,700	-37,100	-16,100	-29,000
20+00-30+00	-36,200	-46,800	22,500	-27,900	-11,600
30+00-40+00	-27,400	-4,000	-900	-21,100	-2,300
40+00-50+00	-19,100	-17,500	-700	-14,700	-8,700
50+00-60+00	-8,100	-14,200	10,100	-6,300	-2,000
60+00-70+00	-17,700	-8,100	900	-13,700	-3,400
70+00-80+00	-19,900	-17,900	4,300	-15,400	-6,500
80+00-90+00	-21,600	10,000	13,800	-16,700	11,800
90+00-100+00	-29,400	20,000	34,600	-22,700	26,100
100+00-110+00	-32,800	-15,900	-31,100	-25,300	-22,400
110+00-120+00	-23,500	6,200	22,900	-18,100	13,900
120+00-130+00	-29,800	14,700	-34,700	-23,000	-9,500
130+00-140+00	-33,400	25,100	-21,100	-25,800	1,900
140+00-150+00	-27,700	35,200	-47,400	-21,400	-5,800
150+00-160+00	-21,200	13,800	7,300	-16,400	10,100
160+00-170+00	-15,900	2,300	12,700	-12,300	7,200
170+00-180+00	-9,400	4,700	11,600	-7,300	7,800
180+00-190+00	-25,000	-4,400	18,900	-19,300	6,900
190+00-200+00	-17,500	3,800	4,200	-13,500	3,800
200+00-210+00	-15,000	15,100	1,500	-11,600	7,900
210+00-220+00	-8,300	11,000	-900	-6,400	-4,800
Total	-490,600	-19,100	-24,900	-378,800	-31,200

[1] Average annual volume difference was calculated over the 473-day period between the 22-23 September 1983 and 8-9, 15 January 1985 condition surveys.
[2] Average annual volume difference was calculated over the 564-day period between the 24-26 January 1989 and 8-14 August 1990 condition surveys and the 201-day period between the 2 April 1991 and 22-25 October 1991 condition surveys.
[3] Positive values indicate sediment shoaling; while negative values indicate scouring.

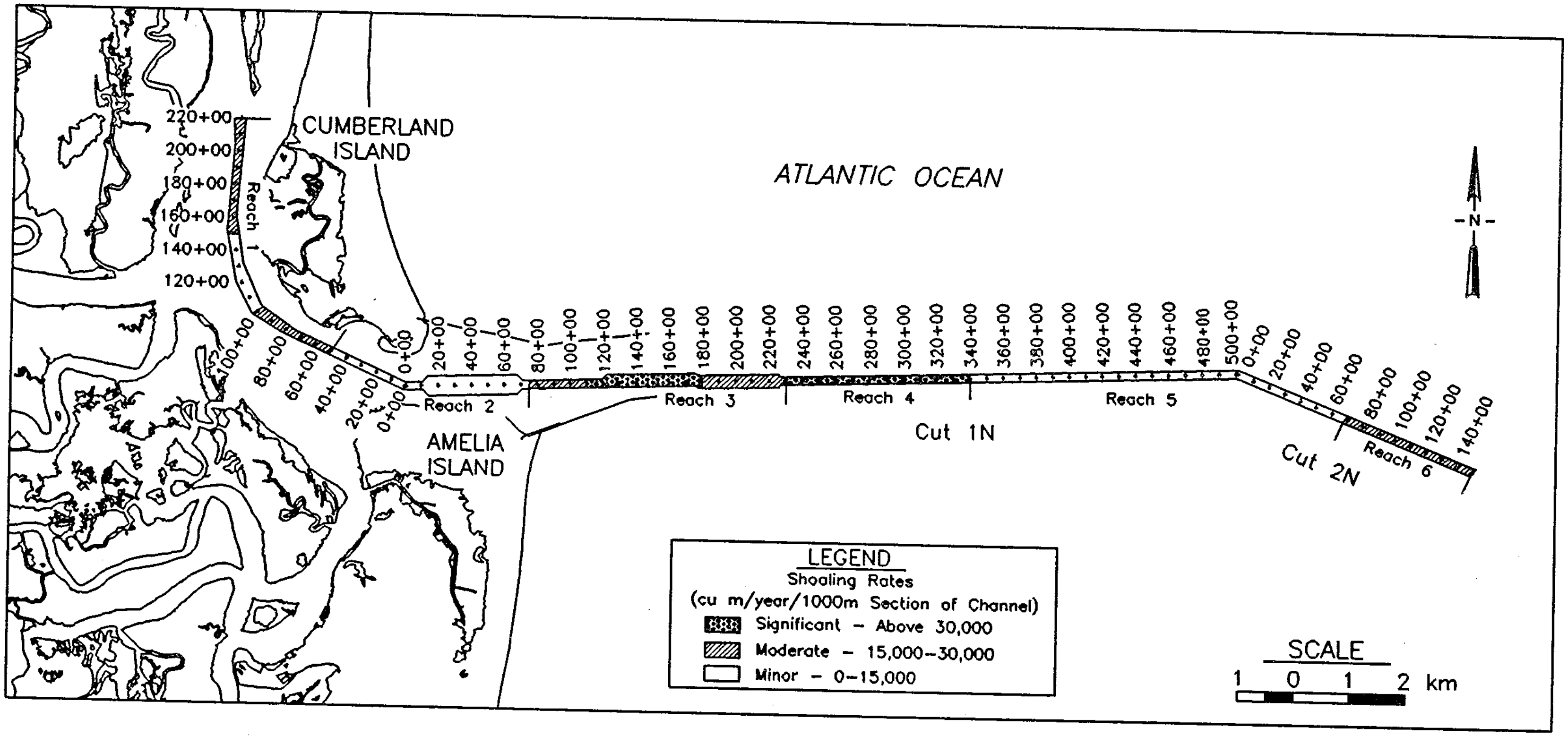


Figure C12. Channel reaches based on shoaling characteristics after the 1987 channel deepening side-scan sonar survey data, geological cross sections, and channel bottom sediment characteristics as determined from maintenance dredging core borings performed from 1989 to 1991 and new work core borings obtained prior to the TRIDENT channel deepening from 1985-1986 (Figure C12). Three basic types of shoaling patterns are classified into reaches of significant shoaling (above 30,000 cu m/year/1,000-m section of channel), moderate shoaling (15,000-30,000 cu m/year/1,000-m section of channel), and minor shoaling (0-15,000 cu m/year/1,000-m section of channel) rates. These reaches are defined below, with significant shoaling rates found in Reaches 3 and 4:

a. Reach 1 (Station 220+00 to 50+00 of Cumberland Sound channel) is generally devoid of significant shoaling. An area of moderate shoaling associated with the transport of littoral sands into the backbarrier channels does exist from Station 50+00 to 100+00 and from Station 150+00 to 200+00. Sediment type in this reach is moderately to poorly sorted fine- to medium-grained sand.

b. Reach 2 (Station 50+00 of Cumberland Sound channel to Station 75+00 of St. Marys Entrance channel, Cut 1N), located in the vicinity of the inlet throat, experiences little or no shoaling because strong currents tend to keep the channel scoured. Sediment type in this reach seaward of Station 0+00 is fine- to medium-grained sand with some silt and shell matter.

c. Reach 3 (Station 75+00 to 230+00 of St. Marys Entrance channel, Cut 1N) includes significant shoaling rates from Station 110+00 to 180+00 of St. Marys Entrance channel, Cut 1N, associated with the migration of shoals and bed forms at the tips and slightly landward of the jetties into the navigation channel. Sediment type in this reach is also moderately to poorly sorted fine- to medium-grained sand with some silt and shell matter.

d. Reach 4 (Station 230+00 to 340+00 of St. Marys Entrance channel, Cut 1N) has the most significant shoaling rates, particularly in the vicinity of the ebb-tidal delta. Sediment type in this portion of the channel is primarily silt and clay with traces of sand and shell matter.

e. Reach 5 (Station 340+00 of St. Marys Entrance channel, Cut 1N, to Station 65+00 of St. Marys Entrance channel, Cut 2N) experiences little to no shoaling. Silt and clay (from Station 340+00 to 355+00 of St. Marys Entrance channel, Cut 1N) and moderately to poorly sorted fine- to medium-grained sand and shell (from Station 355+00 of St. Marys Entrance channel, Cut 1N, to Station 65+00 of St. Marys Entrance channel, Cut 2N) are the dominant sediment types.

f. Reach 6 (Station 65+00 to 150+00 of St. Marys Entrance channel, Cut 2N) has a moderate amount of shoaling associated with significant storm events. Sediment type is moderately to poorly sorted fine- to medium-grained sand and shell.

Conclusions

St. Marys Entrance channel

St. Marys Entrance channel shoaling rates for the period 1988-1992 (Epoch 7 TRIDENT Military channel, authorized depth of 15.5 m (MLW)) were 616,200 cu m/year. Prior to Epoch 7, shoaling rates were significantly less; e.g., 81,000 cu m/year for the period 1954-1973 (Epoch 5 Civil Works channel, authorized channel depth of 10.4 m MLW), and 272,000 cu m/year for the period 1974-1987 (Epoch 6 Pre-TRIDENT Military channel, authorized channel depth of 12.2 m (MLW)).

Further comparison of the different channel configurations indicates that the seaward end of the 10.4-m-deep (MLW) Epoch 5 channel was positioned at the crest of the ebb-tidal delta terminal lobe (approximately at Station 270+00, Cut 1N) (Figure C11). The 12.2-m-deep (MLW) Epoch 6 channel had a maximum seaward extent near the base of the ebb-tidal delta terminal lobe (approximately at Station 280+00, Cut 1N). The 15.5-m-deep (MLW) Epoch 7 channel had a maximum seaward extent at approximately Station 300+00, Cut 1N, 600 m seaward of the base of the ebb-tidal delta terminal lobe. Thus, both the Epoch 5 and Epoch 6 channels are expected to have similar shoaling rates associated with the introduction of silt and clay into the channel in the vicinity of the ebb-tidal delta (Station 225+00 to 280+00). (Comparison between silt and clay shoaling rates for Epochs 5 and 6 cannot be made due to limited dredging records for Epoch 5.) However, the Epoch 7 channel is expected to trap more silt and clay because of the increased channel length.

During Epoch 6, the majority of dredging locations (as indicated by six of the seven stationed maintenance dredging events) were landward of Station 215+00 in areas expected to trap littoral sand. Only one identified Epoch-6 dredging event occurred seaward of Station 225+00.

During Epoch 7, of the total 616,200 cu m/year of shoaling, 71 percent (437,800 cu m/year) (Table C9) of the dredged material consisted of silt and clay material of estuarine or offshore origin, dredged between Station 210+00 and 340+00 inclusive of the ebb-tidal delta terminal lobe. The increased dredging of silt and clay seaward of Station 225+00 in the vicinity of the ebb-tidal delta lobe during Epoch 7 is the major reason for the increased shoaling rate of 616,200 cu m/year. Littorally introduced sand constituted 24 percent (149,300 cu m/year) of Epoch-7 maintenance dredging. This dredging of littoral sands occurred in the vicinity of the ends of the jetties between Stations 67+00 and 230+00, Cut 1N, with predominant dredging performed between Stations 110+00 and 180+00. (The portion of the channel from Station 210+00 to 230+00, Cut 1N, undergoes shoaling of both silt and clay, and sand.) Five percent of the 616,200 cu m/year of Epoch-7 maintenance dredging (29,100 cu m/year) was unclassified with respect to sediment type. Increases in shoaling rates which occurred during both Epoch 6 (272,000 cu m/year) and Epoch 7 (616,200 cu m/year) resulted primarily from the dredged channel extensions and associated additional dredging of silt and clay.

Eventually, the side slopes of the recently widened and deepened channel will adjust to a stable angle of repose. As this occurs, the contribution of shoal material from the channel walls should be reduced. Thus, the average annual shoaling rate at St. Marys Entrance channel for Epoch 7 of 616,200 cu m/year represents a realistic, but probably high, estimate of the future average annual dredging requirement. Future annual variability of maintenance dredging quantities will primarily be related to the occurrence of storms and to dredging operation schedules.

Cumberland Sound channel

Shoaling landward of the jetties in the Cumberland Sound portion of the channel is limited to the introduction of sands associated with flood-tidal delta deposits. Although the pre-TRIDENT channel (1974-1986) experienced only minor shoaling, the TRIDENT channel has had two areas of moderate shoaling, from Station 50+00 to 100+00, and from Station 150+00 to 200+00. Shoaling rates for these portions of the channel were 26,000 cu m/year and 35,800 cu m/year, respectively.

Appendix D
Survey and Sediment Grain-Size Data[1]

Introduction

Appendix D provides detailed information pertaining to the survey and sediment data collected during the project monitoring period, July 1988 - April/May 1992. These data were obtained as part of the coastal monitoring task to assist in determining impacts of the TRIDENT channel modifications as discussed in Chapter 1 of the main report. Specifically, the data include annual and seasonal profile surveys and sediment samples taken along the beach and nearshore zone of Cumberland and Amelia Islands, annual profile surveys of the subaerial marsh to the inner channel along Cumberland Sound, and hydrographic surveys of St. Marys ebb-tidal delta. Prior to this project, only a limited amount of data was collected outside the immediate vicinity of St. Marys Entrance. As part of this study, regional data were collected covering 50 km alongshore and 5 km offshore. Hence, the Kings Bay monitoring data set provides a unique, comprehensive record of the regional geomorphology and sediment characteristics within the study area, between St. Andrew Sound, Georgia, and Nassau Sound, Florida (Figure D1).

This appendix is organized into two main sections (*Profile Surveys* and *Sediment Grain Size*). Within each section, the following topics are covered: background and previous work, survey and sampling plan, field data collection, data processing, analysis methods, results, and summary. Results are presented in the context of morphologic compartments, as discussed below and illustrated in Figure D1. These compartments were established (Gorman 1991)[2] and later modified for this project based on local processes and related morphologic characteristics of the nearshore zone. In order to describe the beach and nearshore zone extending out to the 12-m depth contour, the following compartment names were designated from north to south within the study limits: St. Andrew Tidal Inlet Complex, Stafford Shoal, Cumberland Embayment, St. Marys Tidal Inlet Complex, North Amelia Platform, Amelia Embayment, and Nassau Sound Tidal Inlet Complex. Profile and sediment data were not collected north of the Stafford Shoal compartment in the St. Andrew Tidal Inlet Complex, since the focus of the study was on St. Marys Entrance channel and vicinity. However, this compartment is an important sediment source to the study area and is discussed and analyzed in Chapter 3 (*Nearshore Bathymetric Change* section). The Stafford Shoal compartment is dominated by its namesake, the large,

[1] Written by Laurel T. Gorman, Karen R. Pitchford, Donald K. Stauble, James T. Langston, and Michelle Kindhart.

[2] References cited in this appendix are located at the end of the main text, Volume I.

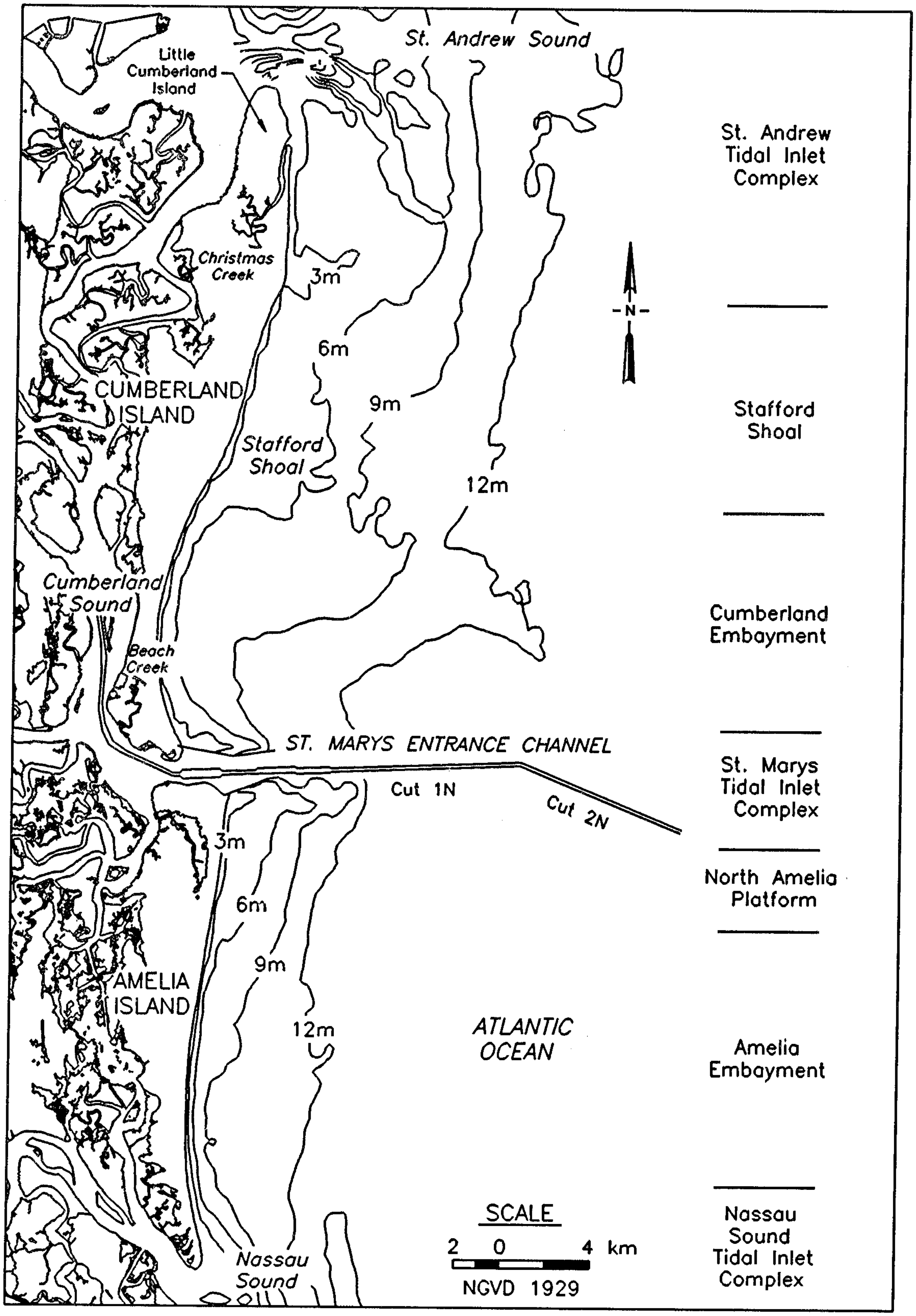


Figure D1. Location of the morphologic compartments out to the 12-m (NGVD) depth contour within the study area dynamic shoal seaward of central Cumberland Island. Cumberland Embayment is distinctive because of the arc-shaped shoreline and adjacent nearshore contours. This area has a relatively featureless seafloor due to the sheltering effects of Stafford Shoal. St. Marys Entrance channel from the inlet throat out to Cut 2N, the fillet areas adjacent to the jetties, and the ebb-tidal delta constitute the St. Marys Tidal Inlet Complex. This compartment is primarily influenced by inlet processes and the associated disruption of longshore drift near the jetties. The North Amelia Platform refers to the remnant historic ebb delta platform as evidenced by the 6-m contour, and is modified by downdrift effects of the St. Marys Tidal Inlet Complex. South of the St. Marys Tidal Inlet Complex is the Amelia Embayment where the beach and nearshore features become slightly arc-shaped. The Amelia Embayment compartment extends over the geographic central portion of the island. At the southern limit of the study area is the Nassau Sound Tidal Inlet Complex consisting of a shallow, wave-dominated ebb-tidal delta. The monitoring period data collection and analysis are limited to the north bank of the natural inlet channel and updrift portion of the Nassau Sound ebb-tidal delta.

Profile Surveys

Background and previous work

A review of previous studies which relate specifically to profile surveys is presented below. Most of the available historic land-based profiles were surveyed using the rod and level method, unless otherwise specified. For further information covering other aspects of previous work within the study area refer to Chapter 2 (*Coastal Response to Inlet Stabilization* section). In addition, a chronology of engineering modifications is presented in Chapter 2 (*Engineering History of St. Marys Entrance* section) and in Appendix C.

Cumberland Island. Along Cumberland Island, available survey data are limited to several minor field data collection efforts conducted by USAED, Savannah (USACE 1961) and two unpublished theses by Roberts (1975) and Nash (1977). Because the Cumberland shoreline has historically been undeveloped and more recently been designated as the Cumberland Island National Seashore, there is limited survey data coverage. The USAED, Savannah surveyed the southern end of Cumberland Island to assess the beach and nearshore topography associated with the north jetty. From the base of the dunes seaward to about the 10-m depth contour, two profile lines north of the north jetty were surveyed in 1957 (see the *Sediment Grain Size* section for a location map). Roberts (1975) surveyed seven beach profiles along Cumberland Island using a line of sight method (Emery 1961). These surveys were used to identify the barrier island geomorphology and describe the relative erosional and depositional trends along the shoreline and nearshore bar system (Figure D2). Because the profiles surveyed by Roberts did not reference a control baseline, they cannot be directly compared to the monitoring period survey data. Nash (1977) also presented profile comparisons using hydrographic surveys and MHW shoreline change maps from the USC&GS to delineate morphology and general volumetric change trends out to the 6-m depth contour along selected transects for Cumberland Island. The time period of the bathymetric maps used on Nash's study included 1869-1871 to the 1970s. Further discussion of Nash's work and findings can be found in Chapter 2 (*Coastal Response to Inlet Stabilization* section).

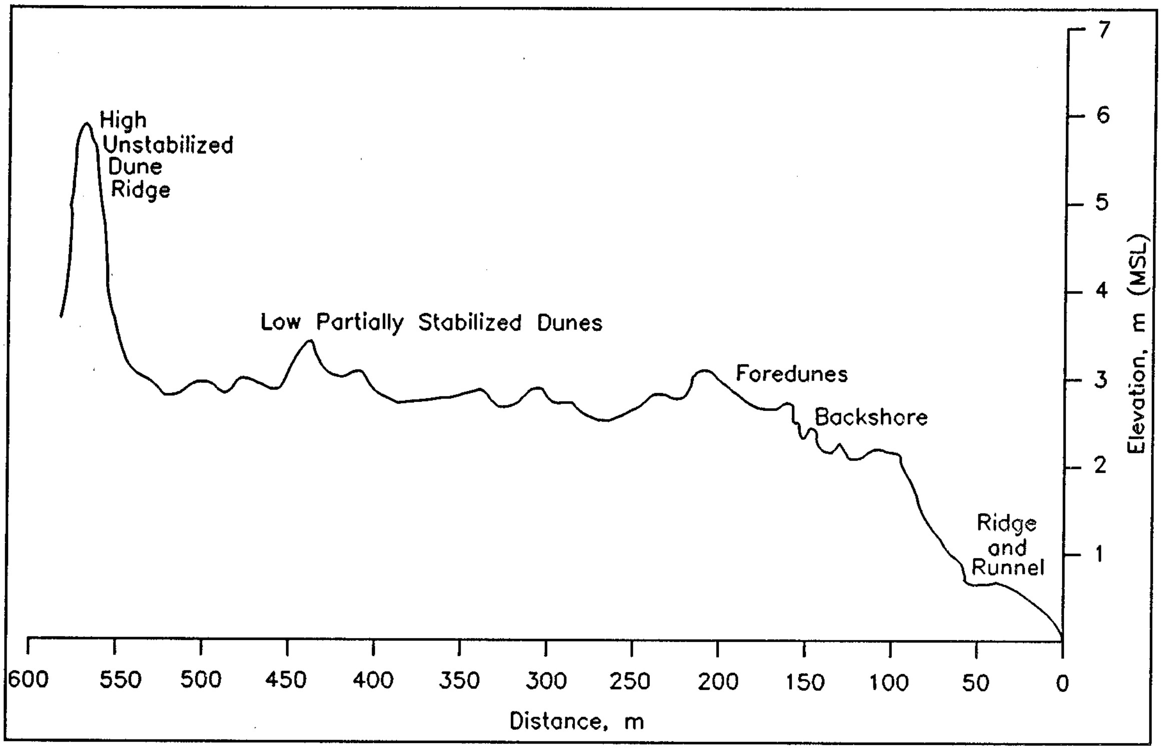


Figure D2. Typical profile along southern Cumberland Island (after Roberts (1975))

Amelia Island. The earliest reported beach and nearshore profile surveys along northern and central Amelia Island were conducted in response to proposed modifications to the existing Federal project for Fernandina Harbor, Florida (USACE 1948). In 1945, USAED, Savannah surveyed 21 profile lines from the high-water line out to a depth of approximately 8 m (MLW) to determine shoreline position and bathymetric topography. These profile lines were resurveyed in 1957 to evaluate shore protection methods in reducing shoreline losses along northern Amelia Island (USACE 1961). Volumetric changes were computed for the beach and nearshore zone. From the south jetty to 1.2 km south of the south jetty the beach accreted, and from 1.2 to 7.6 km south of the south jetty it eroded. In October 1975 and February 1981, surveys were taken by USAED, Jacksonville (1984a) to quantify beach changes along northern Amelia Island (south jetty to 6.4 km south of the jetty). As discussed for Cumberland Island, Nash (1977) also evaluated several bathymetric profiles along Amelia Island (Chapter 2, *Coastal Response to Inlet Stabilization* section).

Since this time, more complete survey data have been collected due to Federally authorized beach fill and storm protection projects, and the State of Florida's coastal monitoring program. A permanent baseline following Florida State Highway A1A was established by the Florida Department of Natural Resources (DNR) in February 1974 for Amelia Island. The baseline included the shoreline adjacent to Fort Clinch and continued around to the south jetty and southward to Nassau Sound inlet. A total of 82 profile monuments are maintained and surveyed periodically by the DNR as part of the State's coastal monitoring program (Figure D3). Surveys are generally conducted after a major storm or before a beach fill placement. Since their original placement, several of the Florida DNR monuments have been reset when disturbed by either storm damage or beachfront development. The DNR coastal profile database is maintained by Florida DNR, Division of Beaches and Shores in Tallahassee, Florida, and contains wading depth

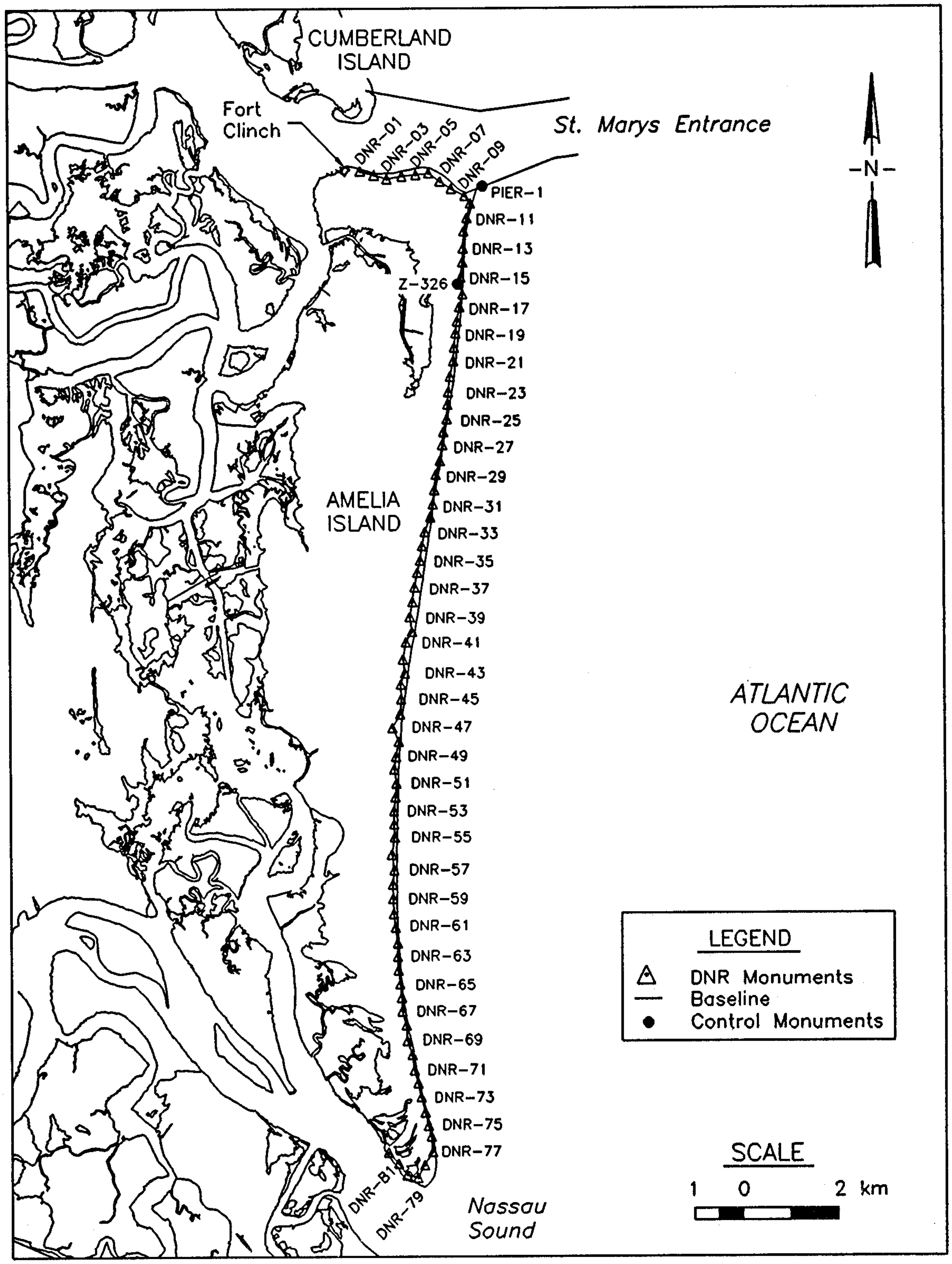


Figure D3. Location of Florida DNR monuments and baseline established in February 1974 (only odd-numbered monument labels shown) surveys conducted since February 1974. Table D1 lists the available surveys for the period February 1974 - August/September 1991. Prior to the coastal monitoring period, the most complete DNR data sets were the surveys conducted in February 1974, April/May 1977, and September/November 1981. Other data sets within this time period, particularly September 1982 (25 profile lines), November 1984 (22 profile lines), February/March 1987 (32 profile lines), and February 1988 (40 profile lines), contained a limited number of profiles taken after a storm event or associated with beach fill placement. During the monitoring period (July 1988 - April/May 1992), DNR beach profiles and the coastal monitoring survey by USAED, Jacksonville were conducted concurrently. The DNR surveys during this time period included a partial set taken in October/December 1990 (eight profile lines) and a complete set (82 profile lines) taken in August/September 1991.

In order to establish pre-project conditions, previous studies were examined and used to identify topographic changes. An effort was made to correlate previous data sets with the coastal monitoring profile surveys. The majority of previous profile data sets could not be utilized due to differences in either baseline location or lack of sufficient baseline documentation. The DNR surveys, however, correspond to the same profile lines used for this project. The February 1974 and September/November 1981 DNR surveys were consequently selected to evaluate the pre-channel deepening conditions. The February 1974 survey was selected because it was the earliest complete survey and the September/November 1981 survey was selected because it was the most complete data set prior to the 1987-1988 TRIDENT channel modification. Analysis of these profile data sets was limited to shoreline position change.

Representative beach profiles from the DNR survey set along Amelia Island for February 1974 and September/November 1981 are shown in Figures D4-D13. Because the Amelia Island shoreline has not been mapped since the 1973-1974 period by the United States Geologic Survey, the DNR profile set and the coastal monitoring profile data depict the modern, short-term response along the coastal geomorphic zones. In general, the suite of profile plots indicate topographic features that vary slightly from north to south along the dune and beach system. Significant changes occur at the northern and southern ends where inlet processes have modified the shoreline and adjacent nearshore zone. At the northern limits of Amelia Island, well-developed dunes recurving to the east are the dominant features. Within the fillet area, a typical profile shows the high primary dune adjacent to a wide, accretionary beach (Figure D4). Fill material placed in November 1978 - June 1979 was transported from beaches to the south (Lines A12-A22) and entrained next to the jetty. In the vicinity of Fernandina Beach (North Amelia Platform compartment), smaller dunes (averaging 3-4 m NGVD) are located next to a steep, erosional beach face (Figures D5-D7). The first DNR survey (February 1974) indicates accretion along the North Amelia Platform compartment as a result of the November 1978 - June 1979 beach fill (Figures D5-D6). Dunes gradually become wider toward the south (Figure D8) with the profile gradually changing from net erosion to a stable, slightly accretional profile toward the center of the island (Figures D8-D12). Since the profile surveys were taken during the winter (February 1974) and fall (September/November 1981) months, a distinctive berm is not usually present. However, a few profiles show the natural berm between elevation 2.5 m (NGVD) in Figure D8 and 2.0 m (NGVD) in Figure D10. The southern portion of the island is dominated by scarped dunes and a steep, recessional beach as shown by the representative Line DNR-70 (Figure D13).

Engineering-related activities prior to this project included disposal of dredged material on the beach and construction of storm protection structures, as also described in Chapter 2 (*Engineering*

Table D1
Amelia Island DNR Survey Dates

Survey Line	Feb 1974	Apr/ May 1977	Jan 1979	Mar/ Apr 1981	Jun 1981	Sep/ Nov 1981	Sep 1982	Mar/ Apr 1983	Nov 1984	Jun 1985	Jan 1987	Feb/ Mar 1987	Feb 1988	Oct/ Dec 1990	Aug/ Sep 1991
DNR-01	X[1]	X				X	X		X			X	X		X
DNR-02	X	X		X		X									X
DNR-03	X	X				X						X	X		X
DNR-04	X	X		X		X									X
DNR-05	X	X				X	X		X					X	X
DNR-06	X	X				X						X	X		X
DNR-07	X	X				X									X
DNR-08	X	X				X									X
DNR-09	X	X				X						X	X		X
DNR-10[2]	X	X				X	X		X						X
DNR-11	X	X				X									X
DNR-12	X	X		X		X						X	X		X
DNR-13[2]	X	X		X		X							X		X
DNR-14	X	X				X							X		X
DNR-15	X	X				X[3]	X					X	X		X
DNR-16[2]	X	X				X	X		X				X		X
DNR-17	X	X				X	X						X		X

(Sheet 1 of 5)

[1] Profile line surveyed.
[2] Profile survey line corresponds to monitoring survey line as discussed later in this section.
[3] Surveyed in both Oct 1981 and Nov 1981.

Table D1 (Continued)

Survey Line	Feb 1974	Apr/ May 1977	Jan 1979	Mar/ Apr 1981	Jun 1981	Sep/ Nov 1981	Sep 1982	Mar/ Apr 1983	Nov 1984	Jun 1985	Jan 1987	Feb/ Mar 1987	Feb 1988	Oct/ Dec 1990	Aug/ Sep 1991
DNR-18	X	X				X[3]	X					X	X		X
DNR-19[2]	X	X		X		X	X						X		X
DNR-20	X	X				X	X						X		X
DNR-21	X	X		X[4]		X[3]	X		X			X	X		X
DNR-22[2]	X	X				X	X						X		X
DNR-23	X	X		X[4]		X	X		X				X		X
DNR-24	X	X		X		X[3]	X			X		X	X[5]		X
DNR-25[2]	X	X				X	X						X	X	X
DNR-26	X	X				X							X		X
DNR-27	X	X				X[3]						X	X		X
DNR-28[2]	X	X				X							X		X
DNR-29	X	X				X							X		X
DNR-30	X	X				X[3]		X				X	X		X
DNR-31[2]	X	X				X	X		X				X		X
DNR-32	X	X				X							X		X
DNR-33	X	X				X[3]				X		X	X		X

(Sheet 2 of 5)

[4] Profile line surveyed again within days of the previous survey.
[5] Also surveyed in Dec 1988.

Table D1 (Continued)

Survey Line	Feb 1974	Apr/ May 1977	Jan 1979	Mar/ Apr 1981	Jun 1981	Sep/ Nov 1981	Sep 1982	Mar/ Apr 1983	Nov 1984	Jun 1985	Jan 1987	Feb/ Mar 1987	Feb 1988	Oct/ Dec 1990	Aug/ Sep 1991
DNR-34[2]	X	X				X							X		X
DNR-35	X	X				X	X		X				X		X
DNR-36	X	X				X[3]		X				X	X		X
DNR-37[2]	X	X				X									X
DNR-38	X	X		X[4]		X									X
DNR-39	X	X				X[3]						X	X		X
DNR-40[2]	X[4,6]	X				X	X		X						X
DNR-41	X	X		X		X								X	X
DNR-42	X	X		X[4]	X[4]	X[3]						X	X		X
DNR-43[2]	X	X		X		X									X
DNR-44	X	X				X									X
DNR-45	X	X				X[3]	X		X			X	X		X
DNR-46[2]	X	X				X									X
DNR-47	X	X		X[4]		X									X
DNR-48	X	X		X		X[3]					X	X	X		X
DNR-49[2]	X	X				X						X[7]	X		X

(Sheet 3 of 5)

[6] Also surveyed in Jan 1974.
[7] Also surveyed in Apr 1987.

Table D1 (Continued)

Survey Line	Feb 1974	Apr/ May 1977	Jan 1979	Mar/ Apr 1981	Jun 1981	Sep/ Nov 1981	Sep 1982	Mar/ Apr 1983	Nov 1984	Jun 1985	Jan 1987	Feb/ Mar 1987	Feb 1988	Oct/ Dec 1990	Aug/ Sep 1991
DNR-50	X	X				X	X		X				X		X
DNR-51	X	X				X					X	X			X
DNR-52[2]	X	X		X[4]		X								X	X[4]
DNR-53	X	X				X						X[4]	X		X
DNR-54	X	X				X					X	X	X		X
DNR-55[2]	X	X				X						X[4]	X		X
DNR-56	X	X		X		X								X	X
DNR-57	X	X				X[3]	X		X			X	X		X
DNR-58[2]	X	X			X	X			X						X
DNR-59	X	X				X			X						X
DNR-60	X	X				X						X	X		X
DNR-61[2]	X	X				X	X		X						X
DNR-62	X	X				X								[8]	X
DNR-63	X	X				X						X			X
DNR-64[2]	X	X				X									X
DNR-65	X	X				X	X		X						X

(Sheet 4 of 5)

[8] Also surveyed in Dec 1989.

Table D1 (Concluded)

Survey Line	Feb 1974	Apr/ May 1977	Jan 1979	Mar/ Apr 1981	Jun 1981	Sep/ Nov 1981	Sep 1982	Mar/ Apr 1983	Nov 1984	Jun 1985	Jan 1987	Feb/ Mar 1987	Feb 1988	Oct/ Dec 1990	Aug/ Sep 1991
DNR-66	X	X	X			X						X			X
DNR-67[2]	X	X				X									X
DNR-68	X	X				X	X		X						X
DNR-69	X	X	X			X						X[9]			X
DNR-70[2]	X	X				X									X
DNR-71	X	X		X		X									X
DNR-72	X	X	X			X						X[9]			X
DNR-73[2]	X	X	X			X									X
DNR-74	X	X	X			X	X		X			X[4]			X
DNR-75	X	X	X			X			X			X			X
DNR-76[2]	X	X	X			X								X	X
DNR-77	X	X	X			X			X						X
DNR-78	X	X				X			X			X			X
DNR-79[2]	X	X				X	X		X						X
DNR-80	X	X		X		X								X	X
DNR-81	X	X		X		X						X			X
DNR-82	X	X				X								X	X

(Sheet 5 of 5)

[9] Surveyed in both Feb 1987 and Mar 1987.

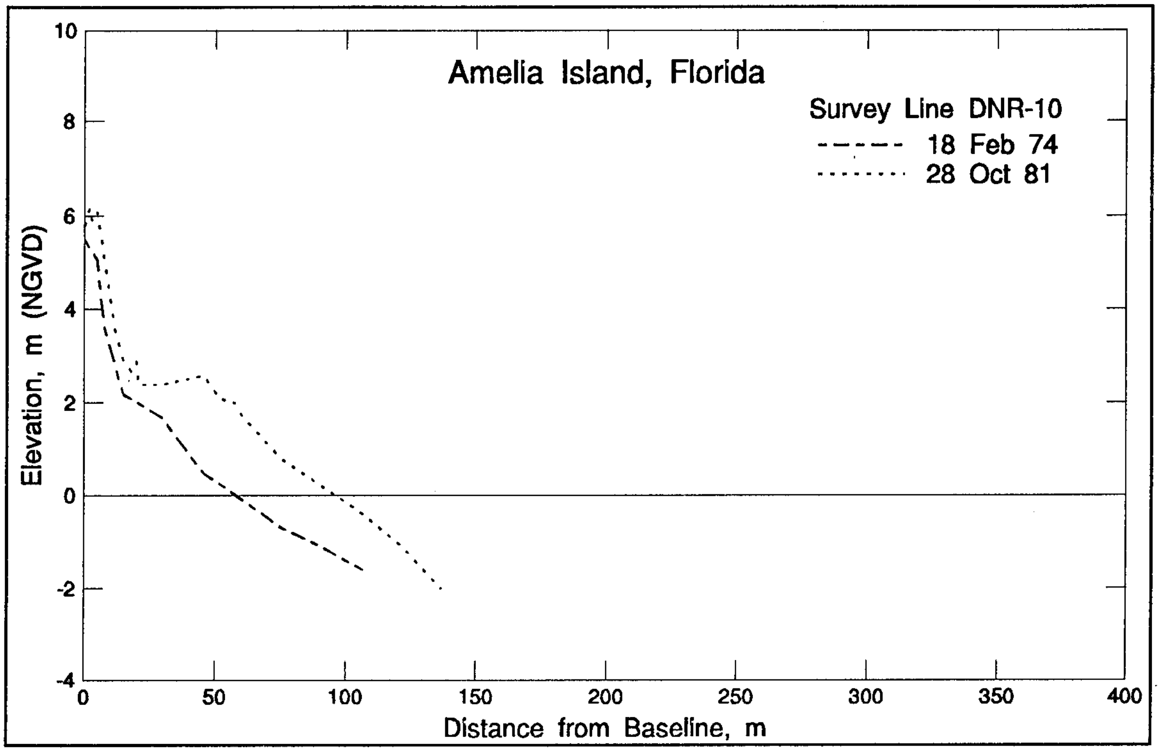


Figure D4. Beach profiles, Line DNR-10, St. Marys Tidal Inlet Complex compartment

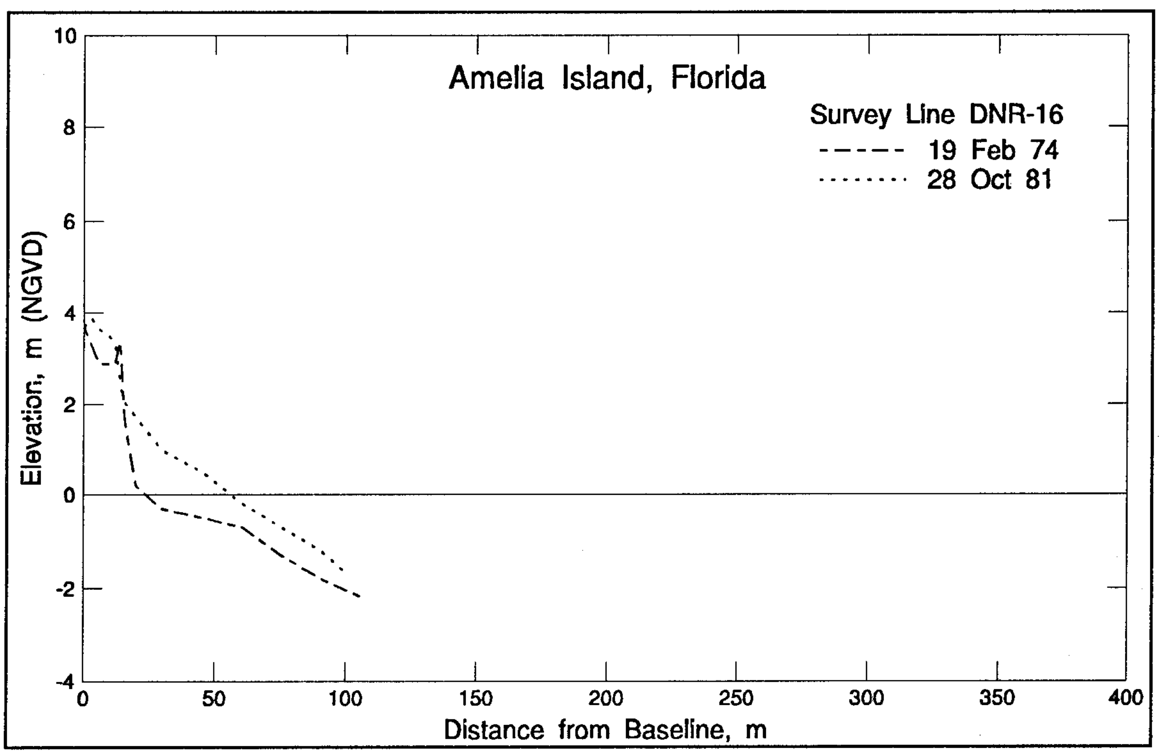


Figure D5. Beach profiles, Line DNR-16, North Amelia Platform compartment

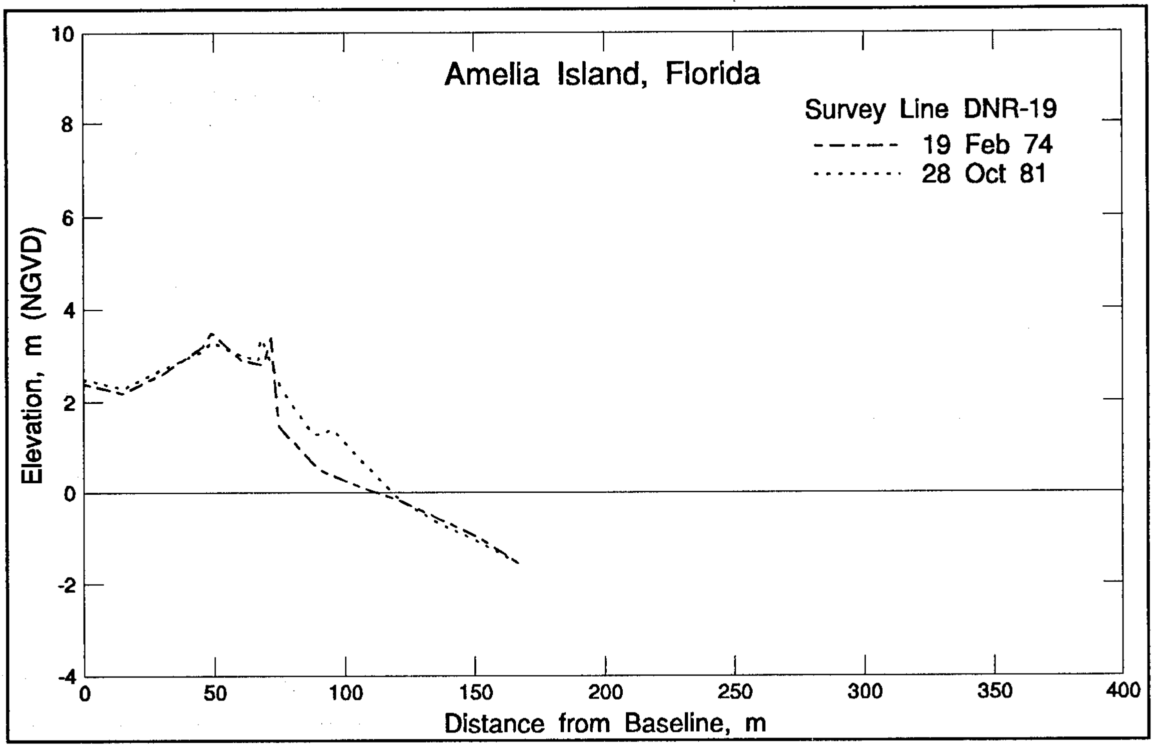


Figure D6. Beach profiles, Line DNR-19, North Amelia Platform compartment

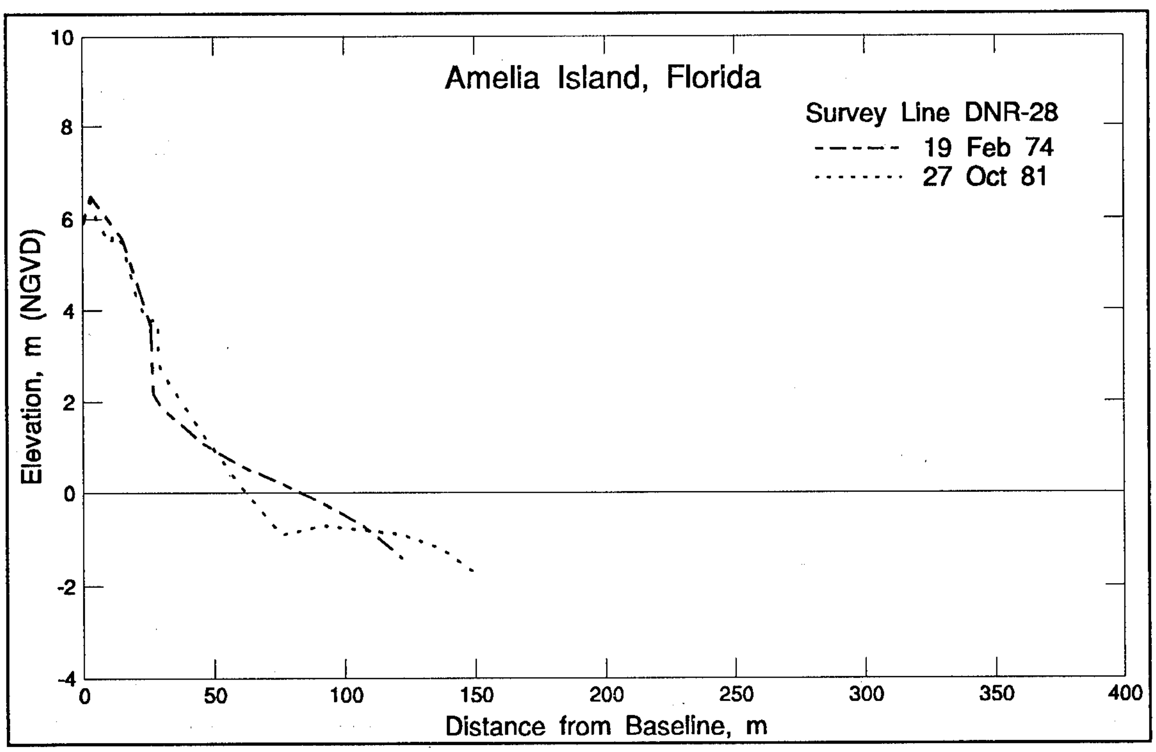


Figure D7. Beach profiles, Line DNR-28, North Amelia Platform compartment

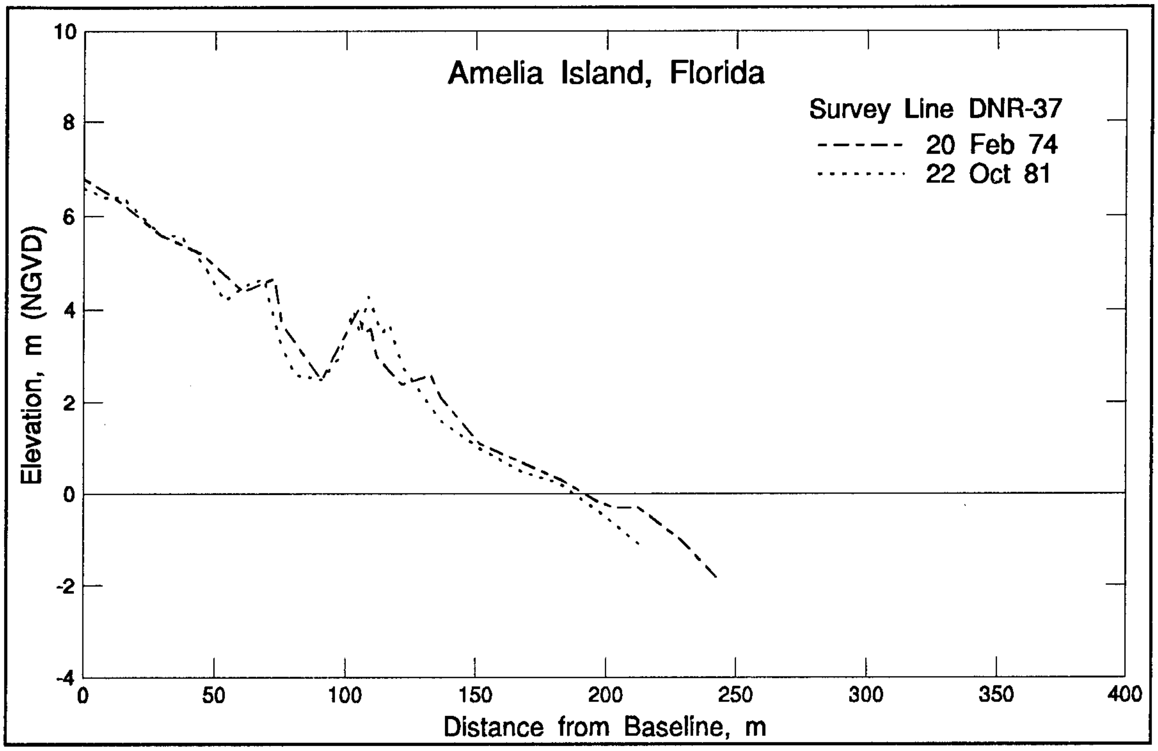


Figure D8. Beach profiles, Line DNR-37, Amelia Embayment compartment

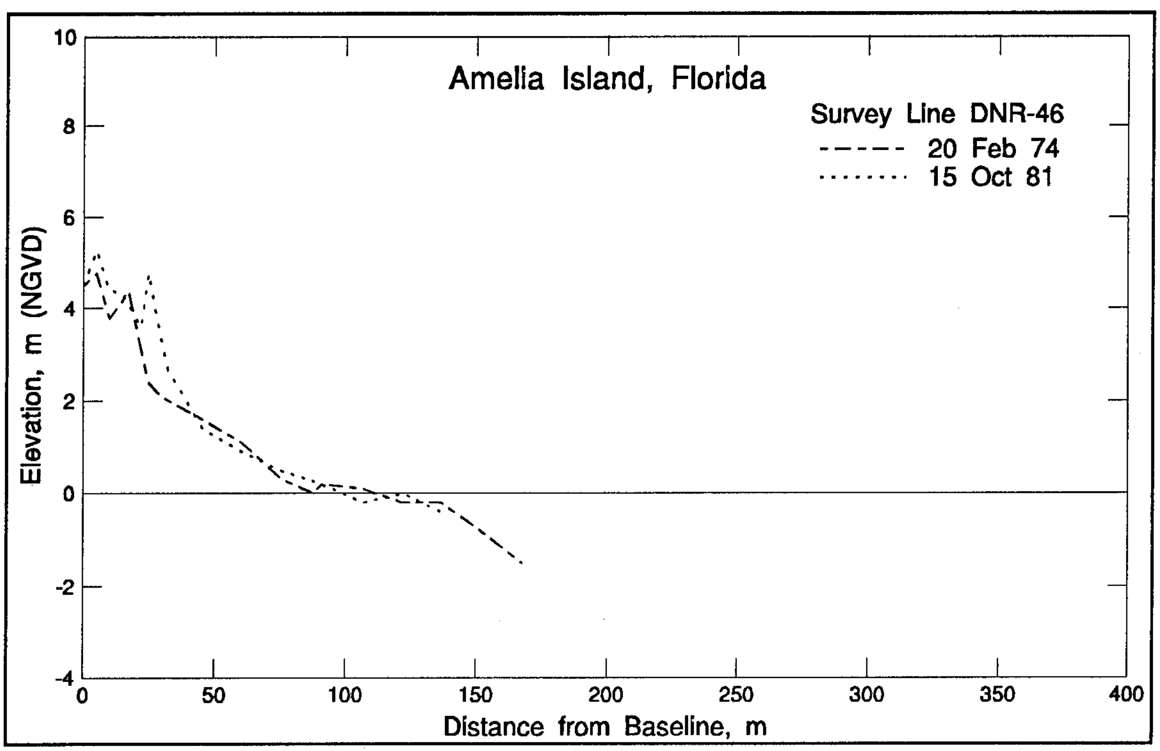


Figure D9. Beach profiles, Line DNR-46, Amelia Embayment compartment

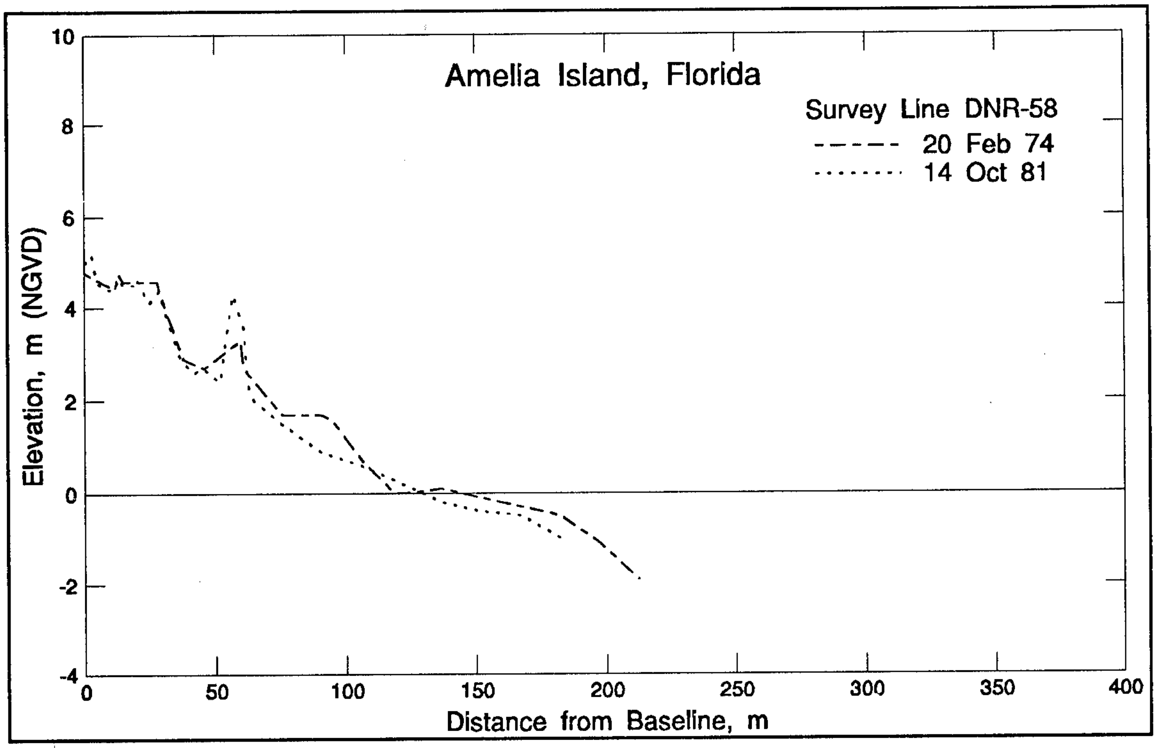


Figure D10. Beach profiles, Line DNR-58, Amelia Embayment compartment

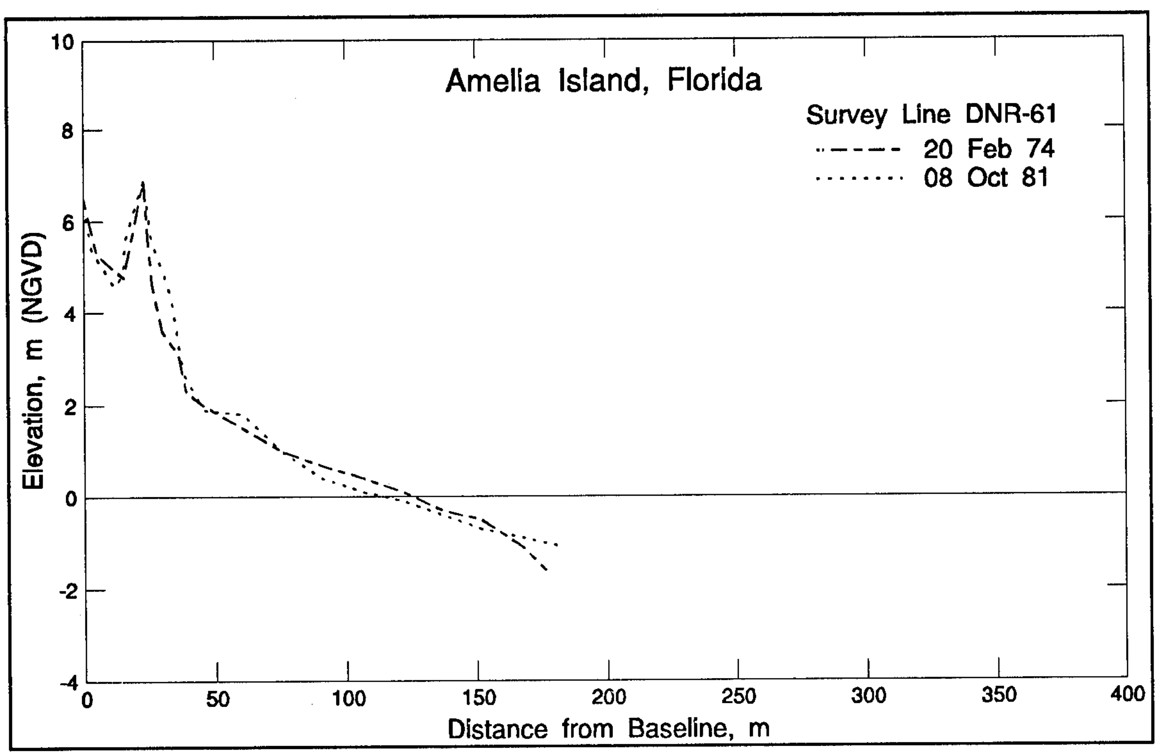


Figure D11. Beach profiles, Line DNR-61, Amelia Embayment compartment

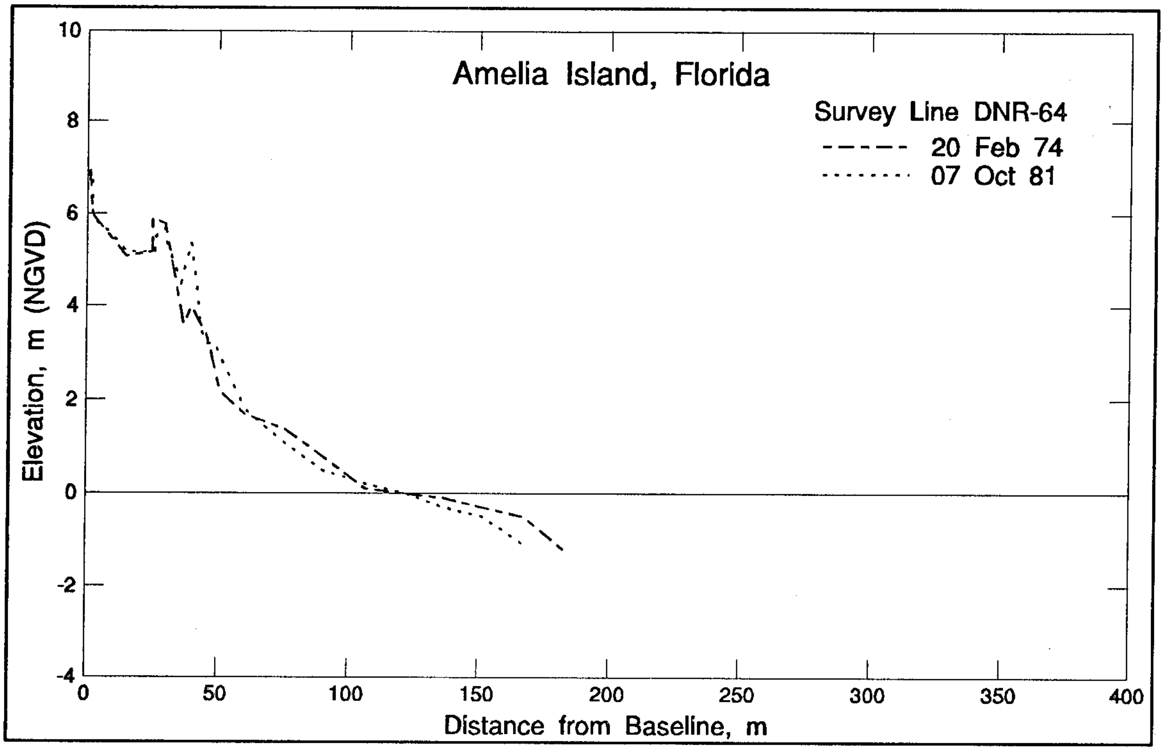


Figure D12. Beach profiles, Line DNR-64, Amelia Embayment compartment

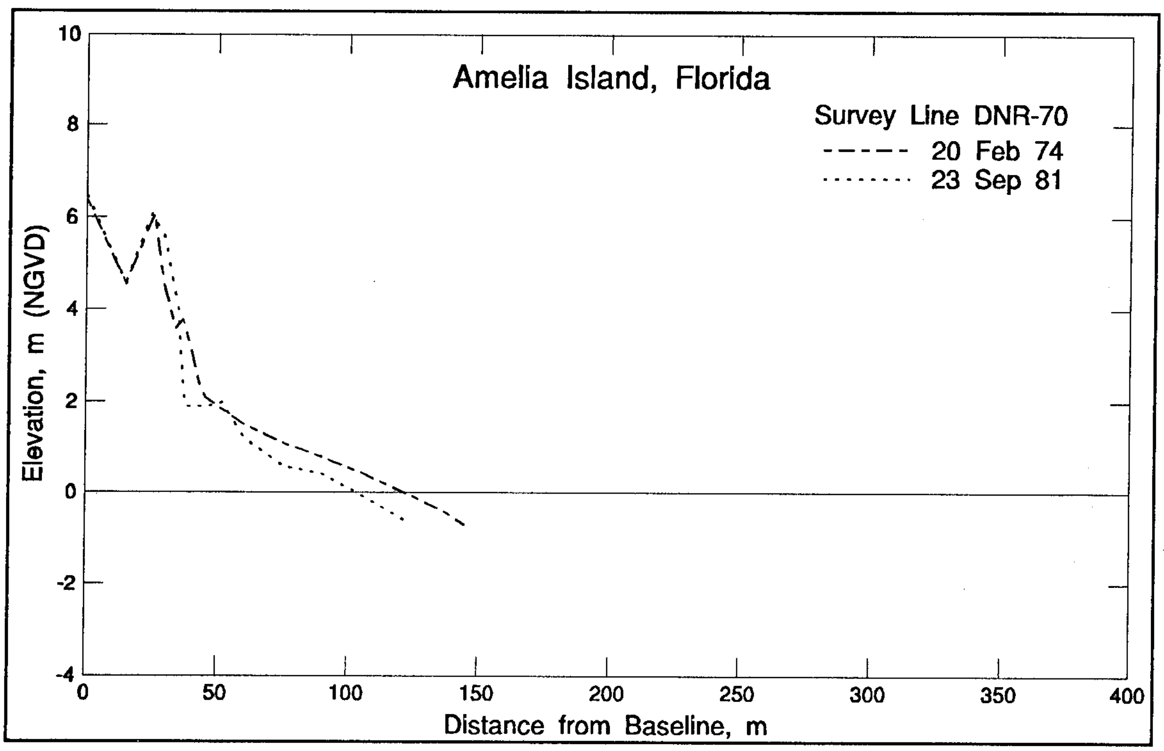


Figure D13. Beach profiles, Line DNR-70, Nassau Sound Tidal Inlet Complex compartment

History of St. Marys Entrance section). Several of the DNR surveys were taken prior to beach disposal of dredged material, particularly in April/May 1977 and February/March 1987, but there is limited coverage (Table D1). Two specific areas, the northern disposal site located between Lines DNR-12 and DNR-25 and the southern disposal site located between Lines DNR-48 and DNR-59.8, have had five and two beach fill placements, respectively (Table D2, Figure D14). In addition, small truck-hauled fills were also placed between DNR-60 and DNR-71 by private interests in March 1984, November 1984, December 1989, and December 1991. An idealized beach placement template was used that varied in berm width and elevation according to the existing conditions at the time of disposal. Fill material was generally placed along the natural slope or at about 1V on 20H until the fill met the existing bottom (Figure D15). The distinctive berm and fill profile envelope are evident on DNR surveys taken since April/May 1977.

St. Marys ebb-tidal delta. The earliest hydrographic surveys of the ebb-tidal delta were conducted by USC&GS for regional mapping purposes, as further discussed in Chapter 3 (*Nearshore Bathymetric Change* section). Other historic surveys were associated with inlet stabilization or harbor improvement projects. Many of these were conducted between 1881 and 1924 when most of the inlet stabilization work was performed by USAED, Savannah and

Table D2
Beach Fill Placements on Amelia Island[1]

Year	Authority	Profile Number	Quantity,[2] cu m
Nov 1978 to Jun 1979	Federal	DNR-12 to DNR-22	765,000
Jun 1982 to Sep 1982	Federal	DNR-19 to DNR-25	302,000
Mar 1984	Private	DNR-60 to DNR-71	57,340
Nov 1984	Private	DNR-60 to DNR-71	4,200
Jun 1987 to Feb 1988[3]	Federal	DNR-13 to DNR-22	693,370
Sep 1987 to May 1988[3]	Federal	DNR-48 to DNR-53.7	405,240
Total Federal fill, prior to Kings Bay monitoring period			**2,165,610**
Total private fill, prior to Kings Bay monitoring period			**61,540**
Jul 1988 to Jul 1989	Federal	DNR-53.7 to DNR-59.8	825,770
Dec 1989	Private	DNR-60 to DNR-71	38,230
Oct 1990 to Mar 1991	Federal	DNR-13 to DNR-16	112,930
Dec 1991	Private	DNR-60 to DNR-71	9,940
Feb 1992 to Mar 1992	Federal	DNR-13 to DNR-16	147,820
Total Federal fill, during Kings Bay monitoring period			**1,086,520**
Total private fill, during Kings Bay monitoring period			**48,170**

[1] Source: USAED, Jacksonville (1993).
[2] Quantity represents volume dredged from the channel which was designated for beach disposal. The actual volume placed on the beach will be less due to losses during the dredging and disposal operations.
[3] Fill placement occurred as part of the TRIDENT channel deepening, before the monitoring period (Jul 1988 to Apr/May 1992) of this study.

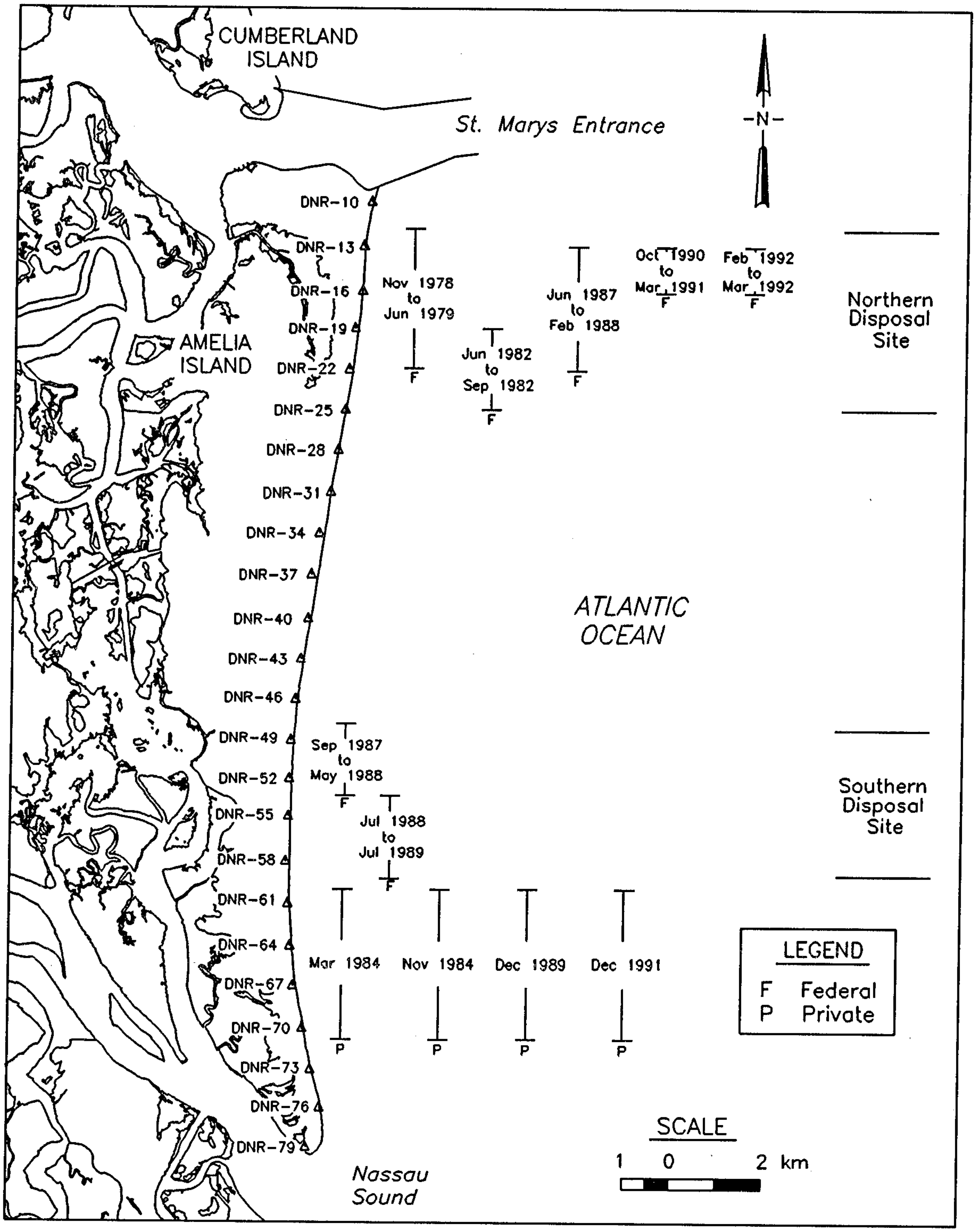


Figure D14. Location of beach fill placements along Amelia Island

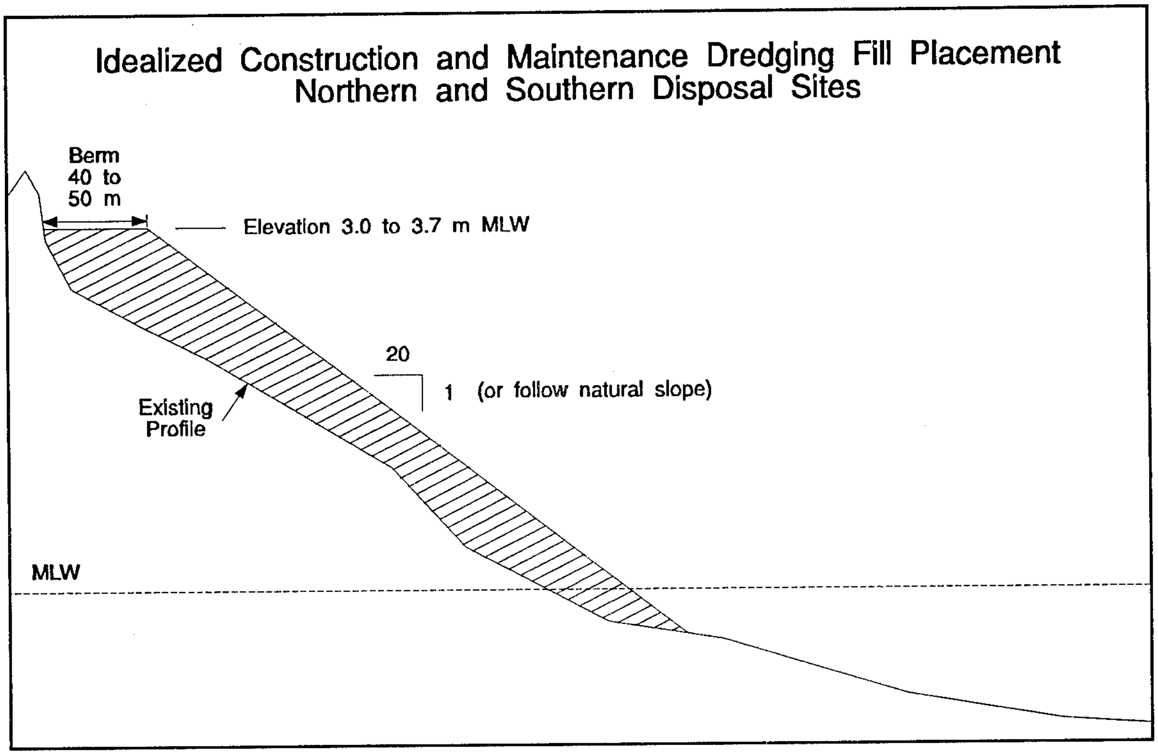


Figure D15. Idealized construction and maintenance fill placement for the TRIDENT navigation project (modified after USAED, Jacksonville (1984a))

USAED, Jacksonville. Historic bathymetry was usually taken concurrently with major channel surveys and was confined to the inlet channel, ebb shoals, and fillet area next to the south jetty. Detailed field maps of specific inlet areas were drafted by USAED, Savannah and USAED, Jacksonville to monitor channel migration, location of shoal bars within the navigation channel, and the outer bar across the historic ebb delta. Another set of detailed survey data was taken as a result of channel realignment toward the south jetty in 1955. Often, the survey plan maps of specific channel sections were submitted with the annual reports of the river and harbor improvements to the U.S. Congress. Many of these early surveys could not be used for the project analysis because of lack of accurate tidal datum control and mappable coordinates. Historic ebb-delta and channel survey data taken prior to the 1930s used a lead-line technique. These early surveys may result in deeper than actual depth readings due to bowing of the line with increased depth. Further discussion of engineering activities is presented in Chapter 2 (*Engineering History of St. Marys Entrance* section).

Profile survey plan

A primary focus of the coastal monitoring program was the collection of beach and nearshore profile survey data to assess the morphology and potential impacts of the TRIDENT channel modifications within the study area. These surveys included annual and seasonal profiles taken during the monitoring period, July 1988 - April/May 1992. The survey plan included 28 profile lines along the ocean shoreline of Cumberland Island (Figure D16), 27 lines along the inlet throat (north bank) and marsh shoreline of Cumberland Sound (Figure D16), and 27 lines along the inlet throat (south bank) and ocean shoreline of Amelia Island (Figure D17). Profile lines are numbered in consecutive order from north to south, and are prefaced in the text for clarification

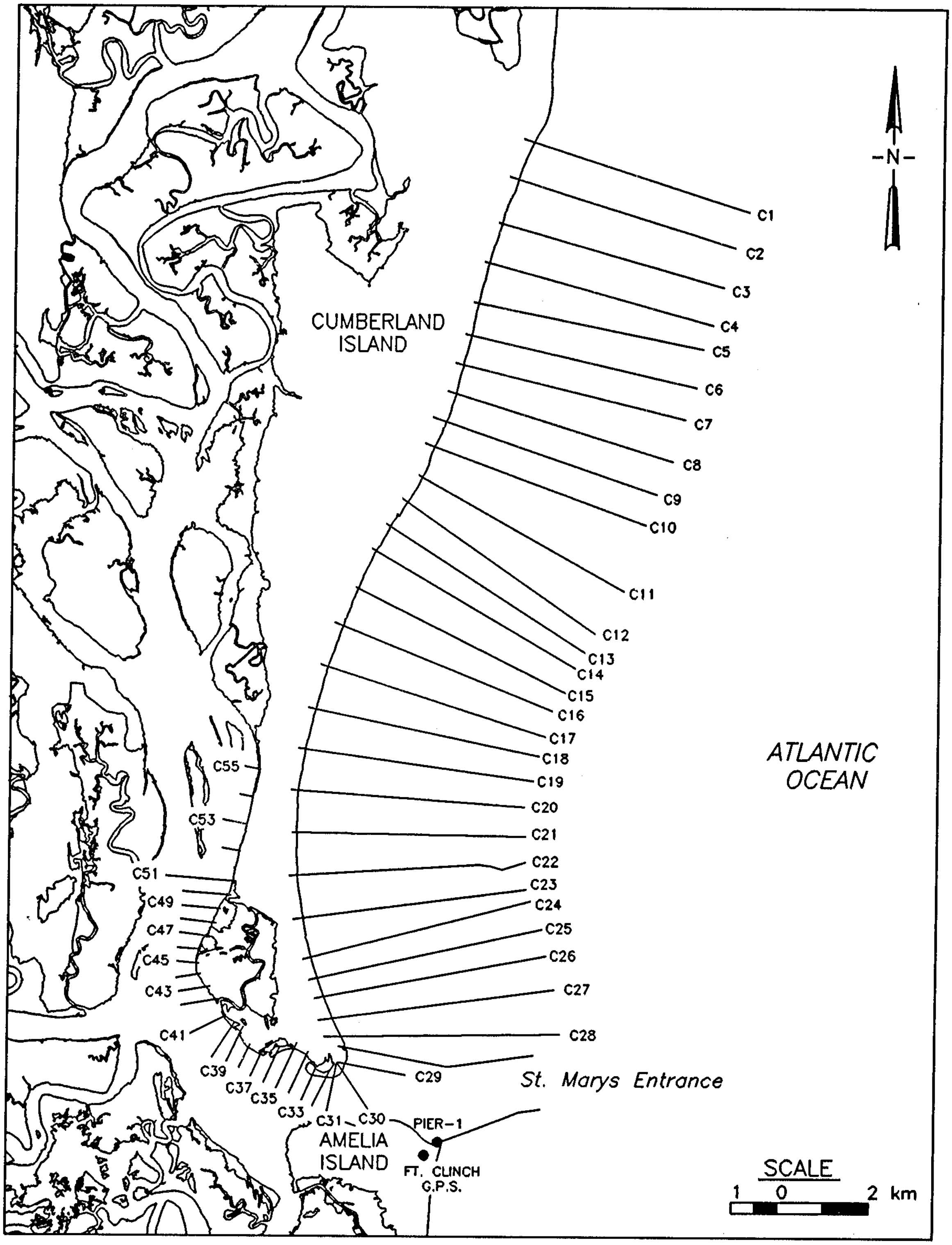


Figure D16. Survey plan of Kings Bay monitoring profile lines along Cumberland Island and Cumberland Sound

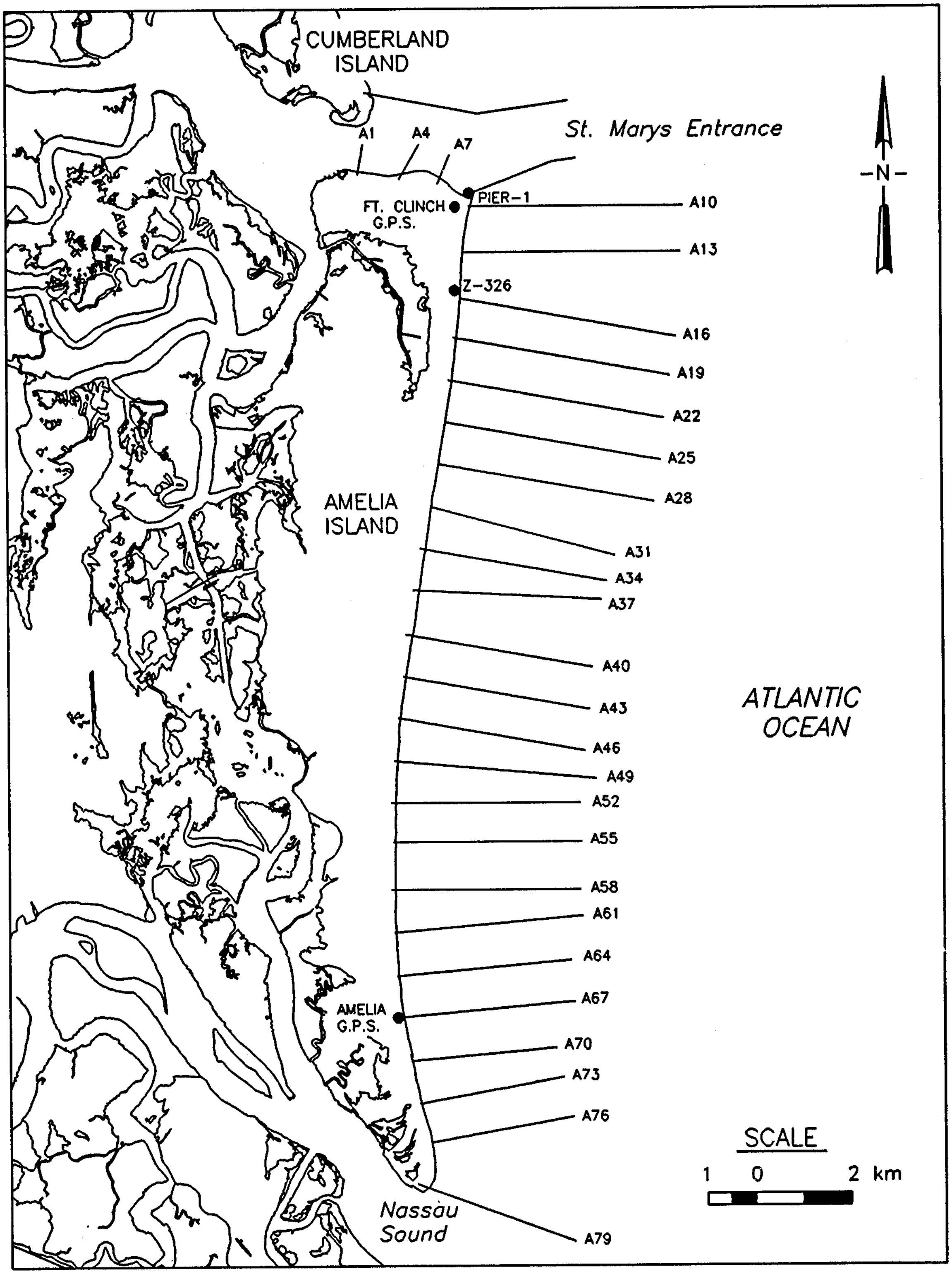


Figure D17. Survey plan of Kings Bay monitoring profile lines along Amelia Island by a C or an A denoting whether the line pertains to Cumberland or Amelia Island, respectively. The Amelia Island survey lines presented below are coincident with the DNR survey lines discussed in the previous section. Survey dates are listed in Tables D3-D5 for Cumberland Island, Cumberland Sound, and Amelia Island, respectively. Dates listed represent when the land portions of the surveys were conducted. Also included within the coastal monitoring program were two hydrographic surveys of the ebb-tidal delta, one taken at the beginning and one at the end of the monitoring period. The ebb delta surveys were conducted as a series of 22 lines which formed an approximate grid pattern (Figure D18).

Cumberland Island. Because a permanent baseline was not available for Cumberland Island, one was established in 1988 for the Kings Bay project. This baseline extends from north-central Cumberland Island and follows the shoreline southward to the north jetty. Spacing between successive profiles along this baseline was approximately 0.9 km with slight variations in spacing caused by local topographic irregularities. For each profile, USACE monuments of standard bronze disks set in concrete were positioned behind the dune ridge, approximately parallel to the shoreline and referenced to the first-order NGS vertical control monument located at Station Pier-1 (Figure D16). Then, at the base of the dune, USACE survey markers consisting of 2.5-cm brass plugs set in iron pipes embedded in concrete were located as secondary markers. The monuments and secondary markers are used in tandem to orient each profile line. Survey data for Cumberland Island were reported in State Plane, Georgia, East Zone coordinates and were derived from a second-order control monument (Fort Clinch GPS station) established using the NAVSTAR GPS.

Along the ocean shoreline of Cumberland Island (Lines C1-C28), the profile lines were surveyed offshore to about 5 km (Figure D16). Profile Lines C1-C14, along north-central Cumberland Island, occur within the influence of Stafford Shoal (Table D6). The next 11 profiles (Lines C15-C26) comprise the Cumberland Embayment compartment. Finally, the two southernmost profiles (Lines C27-C28) were surveyed across the fillet associated with the north jetty.

The July 1988 survey included all 28 profile lines along Cumberland Island. A seasonal profile survey was conducted in May 1989 on a subset of four lines (Lines C2, C11, C20, and C27). From August 1989 - August 1991, surveys along nine lines (Lines C3, C5, C13, C14, C16, C17, C19, C22, and C23) were eliminated to reduce overall survey costs without affecting profile characterization within the morphologic compartments. Another profile (Line C25) was surveyed intermittently within this time period (Table D3). The final profile survey, April/May 1992, again included the full set of 28 lines along Cumberland Island. Some of the profiles mentioned above were later omitted from the analysis due to horizontal or vertical control problems (*Data processing* section).

Cumberland Sound. As described in the DOS (Chapter 1), Cumberland Sound profiles were surveyed during the coastal monitoring study fieldwork for logistical convenience associated with other Navy-sponsored dredging and maintenance contract work. The purpose of these surveys was to document any changes to the Cumberland Island shoreline on the sound side which is close to the modified TRIDENT navigation channel. These data were collected and reduced and are presented in graphical format along with the coastal monitoring data sets. However, no quantitative analysis of these profiles was required or performed as part of this coastal monitoring study which was charged with assessing any potential impacts of the TRIDENT channel modifications to the ocean shoreline of Cumberland or Amelia Islands.

Table D3
Cumberland Island Survey Dates

Survey Line	Annual	Seasonal	Annual	Annual	Annual	Annual
	Jul 1988	May 1989	Aug/ Sep 1989	Jul 1990	Aug 1991	Apr/ May 1992
C1	X[1]		X	X	X	*[2]
C2	X	X	X	X	X	X
C3	X					X
C4	X		X	X	X	X
C5	X					X
C6	X		*	X	X	X
C7	X		X	X	X	X
C8	X		X	X	X	X
C9	*		X	X	X	X
C10	X		*	X	X	X
C11	X	X	X	X	X	X
C12	X		*	X	X	X
C13	X					X
C14	X					X
C15	X		X	X	X	X
C16	X					X
C17	X					X
C18	X		X	X	X	X
C19	X					X
C20	X	X	X	X	X	X
C21	X		X	X	X	X
C22	X					X
C23	X					X
C24	X		X	X	X	X
C25	X				X	X
C26	X		X	X	X	X
C27	X	X	X	X	*	X
C28	X		X	X	X	X

[1] Profile line surveyed.
[2] Profile line surveyed, but dropped for the analysis due to survey error and/or control problems.

Table D4
Cumberland Sound Survey Dates

Survey Line	Annual Jul 1988	Annual Aug 1989	Annual Jul 1990	Annual Sep 1991
C29	X[1]	X	X	X
C30	X	X	X	X
C31	X			X
C32	X	X	X	X
C33	X	X	X	X
C34	X			X
C35	X	X	X	X
C36	X	X	X	X
C37	X	X	X	X
C38	X	X	X	X
C39	X	X	X	X
C40	X	X	X	X
C41	X	X	X	X
C42	X	X	X	X
C43	X	X	X	X
C44	X	X	X	X
C45	X	X	X	X
C46	X	X	X	X
C47	X	X	X	X
C48	X	X	X	X
C49	X	X	X	X
C50	X			
C51	X	X	X	X
C52	X	X	X	X
C53	X	X	X	X
C54	X	X	X	X
C55	X	X	X	X

[1] Profile line surveyed.

Table D5
Amelia Island Survey Dates

Survey Line	Annual Jul 1988	Seasonal Mar 1989	Annual Oct 1989	Annual Aug 1990	Annual Sep/ Nov 1991	Annual Apr/ May 1992
A1	*[1]		*	X[2]	X	
A4	*		*	X		
A7	*		*	X	X	
A10	X		X	X	X	*
A13	X	X	X	X		*
A16	X			X		X
A19	X	X		X		X
A22	X		X	X		X
A25	X			X		*
A28	X			X		X
A31	X		X	X		X
A34	X	X		*		X
A37	X		X	X	*	X
A40	X			X		*
A43	X	X	X	X	X	X
A46	X			X		X
A49	X		X	X		X
A52	X			X		*
A55	X		X	X		X
A58	X		X	X		X
A61	X		X	X		X
A64	X	X	X	X		X
A67	X		X	X		X
A70	X		X	X	X	X
A73	X		X	X	X	X
A76	X	X	X	X	*	*
A79	*		X	X	X	X

[1] Profile line surveyed, but dropped for the analysis due to survey error and/or control problems.
[2] Profile line surveyed.

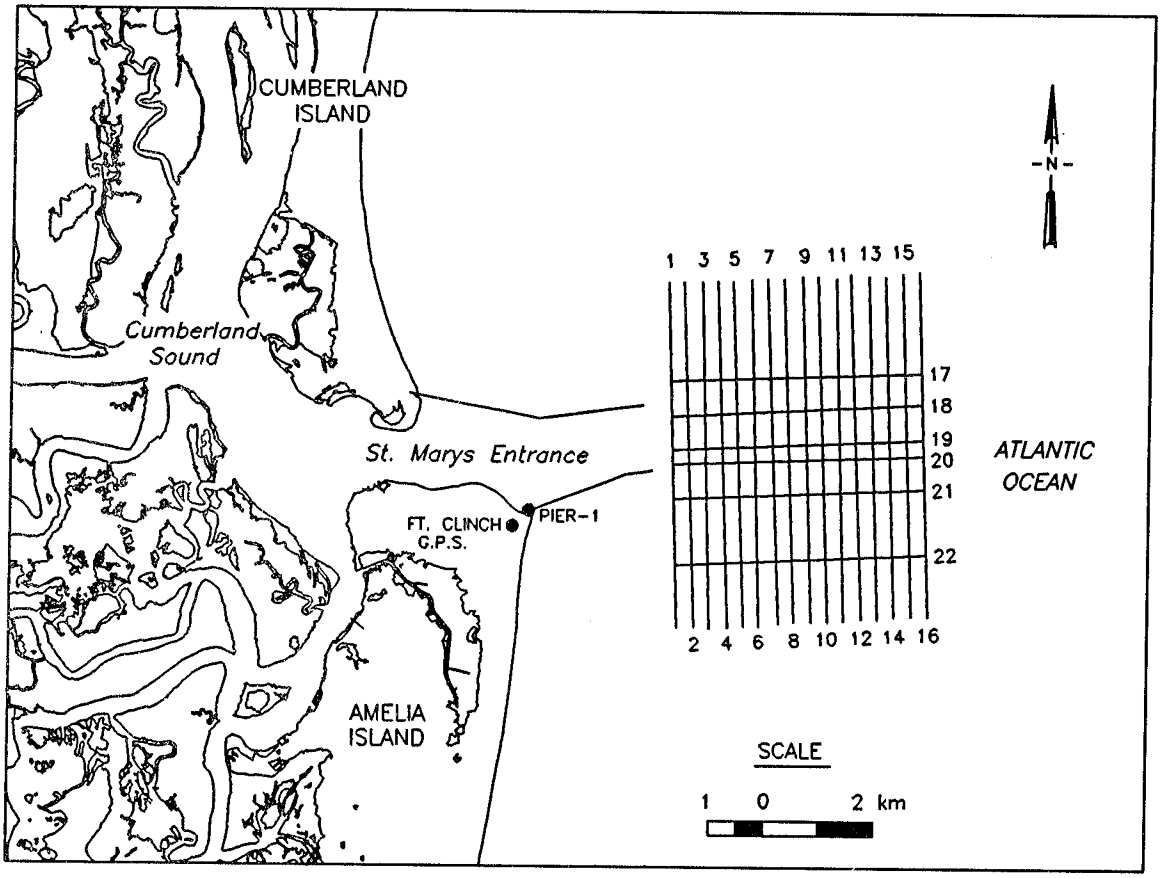


Figure D18. Survey plan of the profile lines for the St. Marys ebb-tidal delta

The Cumberland Island baseline established in 1988 also included Cumberland Sound. This portion of the baseline began on the inlet side of the north jetty and curved westward along the inlet throat and then northward along the marsh coastline (Figure D16). Average spacing between profiles for Cumberland Sound (Lines C29-C55) was approximately 0.7 km and the profiles extended seaward a distance of 50-150 m to the navigation channel. Monuments were

Table D6
Categorization of Survey Lines within Morphologic Compartments

Morphologic Compartment	Survey Line
Stafford Shoal	C1 to C14
Cumberland Embayment	C15 to C26
St. Marys Tidal Inlet Complex	C27 to C28 ; A10 to A13
North Amelia Platform	A16 to A28
Amelia Embayment	A31 to A67
Nassau Sound Tidal Inlet Complex	A70 to A79

positioned in fixed upland deposits and secondary markers were located along the marsh mud flat or bank. Control stations and coordinates were the same as for the ocean coastline of Cumberland Island.

The July 1988 profile survey included all 27 lines along Cumberland Sound. Lines C31, C34, and C50 were eliminated from the August 1989 and July 1990 surveys to reduce overall survey costs (Table D4). The September 1991 profiles also excluded Line C50. No Cumberland Sound profiles were surveyed as part of the April/May 1992 data set.

Amelia Island. A permanent baseline had previously been established by Florida DNR along Amelia Island. The monitoring period surveys utilized this existing baseline. Every third DNR monument along the baseline was surveyed as part of the Kings Bay monitoring program. Similar to Cumberland Island, monuments and survey markers were used along the baseline and dune line, respectively. Vertical baseline control for Amelia Island referenced Station Z-326 (Figure D17) which is located between Lines A15 and A18. Survey data for Amelia Island were reported in State Plane, Florida, East Zone coordinates which were derived from the USAED, Jacksonville, Fort Clinch, and Amelia GPS horizontal control monuments.

Along Amelia Island (Lines A1-A79), profiles were spaced approximately 0.9 km apart (Figure D17). Lines A1-A7 were located along the south bank of the inlet throat and extended seaward to the navigation channel. Along the ocean shoreline (Lines A10-A79), the surveys extended offshore about 4 km. Within the south fillet, two profiles (Lines A10-A13) occurred in the St. Marys Tidal Inlet Complex (Table D6). Further south, Lines A16-A28 comprise the North Amelia Platform compartment. Along central Amelia Island (Lines A31-A67), Amelia Embayment is represented by 13 profile lines. Finally, again within the influence of inlet processes, Lines A70-A79 define the Nassau Sound Tidal Inlet Complex.

The first monitoring survey, July 1988, included all 27 profile lines (Table D5) along both the inlet throat and ocean shoreline of Amelia Island. In addition, a limited data set of six lines (Lines A13, A19, A34, A43, A64, and A76) was collected in March 1989 to document seasonal variations in profile shape. During the period October 1989 - November 1991, selected profile lines were intermittently eliminated to reduce overall costs without significantly impacting data coverage within the morphologic compartments. The April/May 1992 survey included all profile lines along Amelia Island except the three lines located along the inlet throat. As with Cumberland Island, some lines were later omitted from the analysis due to horizontal or vertical control problems (*Data processing* section).

St. Marys ebb-tidal delta. Hydrographic surveys of the ebb-tidal delta were conducted during the first and last years of the monitoring period, June/July 1988 and April 1992. The purpose of conducting these surveys was to generate bathymetric grids and then compare them to the historical ebb delta morphology as discussed in Chapter 3. The data included 16 survey lines oriented approximately north-south with a spacing of 0.3 km and six lines approximately east-west with a spacing of 0.3 to 1.2 km (Figure D18). The survey covered a 27-sq-km area just seaward of the jetties and extended offshore well beyond the terminal lobe of the ebb-tidal delta (about 10-m depth). Survey control was referenced to Station Pier-1 (vertical) and Fort Clinch GPS (horizontal), which are located on northern Amelia Island adjacent to the south jetty (Figure D18).

Field data collection

The USAED, Savannah and USAED, Jacksonville conducted the profile surveys of Cumberland and Amelia Islands, respectively, for the period July 1988 - November 1991. The April/May 1992 profiles of both islands were surveyed by Offshore & Coastal Technologies, Inc. East Coast (OCTI-EC). The USAED, Jacksonville also conducted the June/July 1988 and April 1992 ebb delta hydrographic surveys. Field procedures and quality control standards for such surveys are described in USACE (1991) for hydrographic surveying and U.S. Department of the Army (1970) for geodetic and topographic surveying.

The July 1988 - November 1991 profile surveys were conducted by District personnel using conventional survey equipment and techniques (Table D7). The profile lines were surveyed in three sections: (a) beach (baseline monument to wading depth); (b) nearshore (wading depth to about 3-m depth); and (c) offshore (3-m depth to the seaward end of the survey or approximately 10-m depth). For the beach surveys, a rod and level were used to record elevations starting from the monument and extending seaward along the beach to wading depth (see *Profile survey plan* section for monument locations). The data were surveyed at approximately low tide and manually entered into the survey field log. The interval between readings along the beach section of the profile lines was approximately 7.6 m. The nearshore and offshore surveys employed a fathometer mounted on either a small boat for shallow water (up to 3-m depth) or a large vessel for depths greater than 3 m. The boat position relative to shore was maintained with a Del Norte electronic microwave positioning system. This system operates in the Ultra High Frequency L-Band (UHF) at a frequency range of 30 to 300 MHz, and provides accurate horizontal position measurements. Bar checks of the fathometer were performed twice daily to evaluate and, if necessary, modify the calibration of the system. The data from these fathometer surveys were usually recorded automatically in digital format at an approximate interval of 1 sec (approximately 3 m) between readings.

The three sections (beach, nearshore, and offshore) of the profile line are not necessarily taken contiguously due to time and weather limitations. In some instances, adjoining segments may not be taken on the same day. In that case, the listed profile date (Tables D3-D5) denotes the beach portion of the survey. Also, differences in atmospheric and sea conditions may affect the amount of overlap (if any) between adjacent profile segments. Both Districts employed Class 2 survey standards (USACE 1991) which are specified for condition surveys of navigation channels and nearshore areas, including conditions of beach nourishment and/or storm protection projects. A

Table D7
District Survey Equipment

Type of Equipment	USAED, Savannah	USAED, Jacksonville
Beach equipment	Survey rod and level	Survey rod and level
Small boats	8-m work boat	6-m work boat
Large vessels	S/S Halcyon	S/S Florida
Fathometers	Ross fathometer	Raytheon fathometer and Raytheon depth sounder
Positioning system	Del Norte	Del Norte

summary of estimated accuracies for land and hydrographic Class 2 surveys is listed in Table D8. These accuracies are based on assumed calm sea conditions.

The April/May 1992 beach and nearshore profiles were surveyed using a survey sled system, which provides continuous coverage through the surf zone (Clausner, Birkemeier, and Clark 1986). The data interval between readings for this survey was about 6 m from the dune to the bar and 12 m from the bar seaward to the end of the profile or at a lesser interval if the vertical elevation changed by ±0.3 m. Shore-based instrumentation included a laser-based measurement system consisting of a Leitz Set2 total station and a Sokkisha SDR33 data collector. This data collector recorded measurements digitally during the survey. The maximum range of this equipment was a distance of approximately 2,350 m. The profiles were obtained in two segments, beach and offshore. The beach segment was surveyed from the dune to wading depth with a hand-held survey rod equipped with a reflector assembly and a 0.3-m square baseplate to prevent penetration of the sediment surface. The offshore segment was taken with the survey sled which consisted of steel runners and an aluminum mast with upper glass survey reflectors (prisms) and a lower single reflector. While surveying, the sled was towed by a 6-m-long boat and intermittently stopped between elevations 1.2 and 10 m (NGVD). Properly conducted sled surveys are accurate to ±0.02 m in both distance and elevation, and remain within ±3 m of the profile line (Clausner, Birkemeier, and Clark 1986).

Data processing

During the period July 1988 through October 1989, the Districts were responsible for data reduction of the three profile segments (beach, nearshore, and offshore) into one contiguous survey line. The beach portion was computed using standard methodology to reference profile measurements to the monument. Corrections using local tidal records were applied to adjust the nearshore and offshore fathometer surveys to MLW. The USAED, Savannah referenced a tide staff located on southern Cumberland Island, while USAED, Jacksonville accessed the ARTTES tide gage adjacent to the south jetty (Figure D19). The Districts eliminated vertical spikes in the fathometer data caused by electronic noise. USAED, Savannah also smoothed the fathometer portion of the Cumberland Island profile surveys. The data were then routed to CERC in a digital XYZ coordinate format. The data were in feet with the XY coordinates referenced to the State Plane system (Georgia, East Zone for Cumberland Island and Florida, East Zone for Amelia

Table D8
Summary of Class 2 Project Condition Survey Accuracy[1]

Survey Criteria	Estimated Positional Accuracy, ± m
Horizontal positional accuracy	1.0
Vertical accuracy - fathometer	0.3
Visual range intersection	1.0 to 6.1
Transit/theodolite angle intersection	0.3 to 1.5
Range-azimuth intersection	0.1 to 1.0
Tag line (baseline boat)	1.5 to 15.0+

[1] Source: USACE (1991).

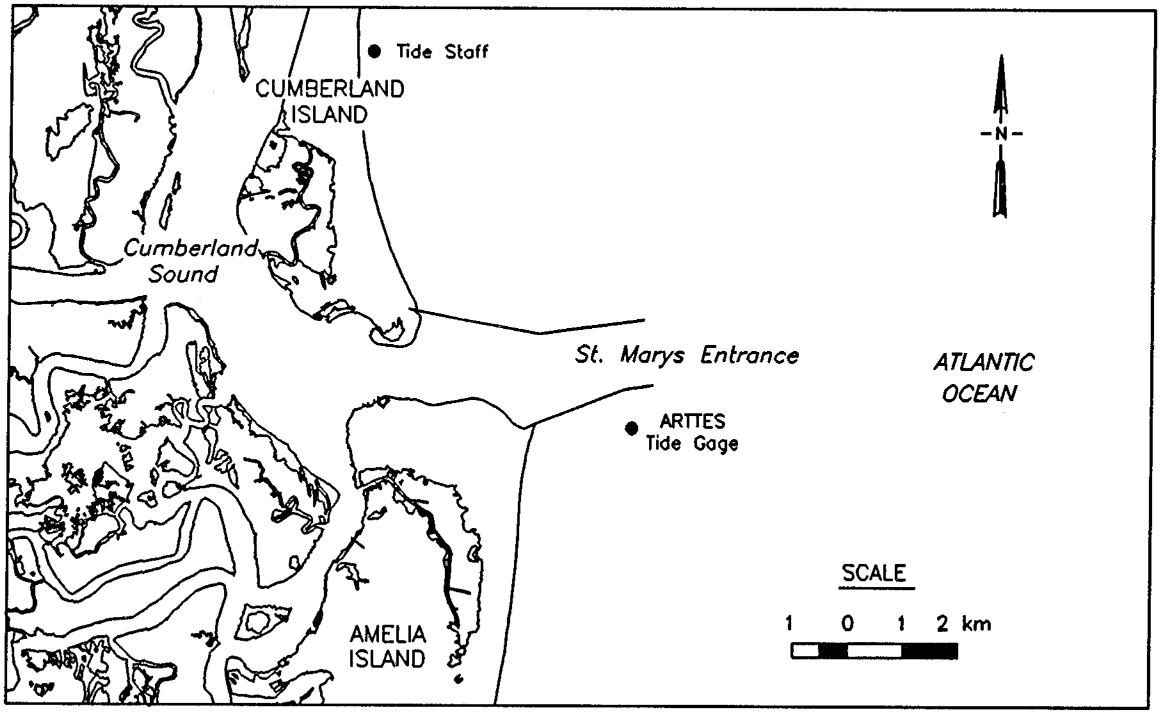


Figure D19. Locations of tidal instrumentation used to correct the July 1988 - October 1989 profile surveys

Island) and the Z coordinate referenced to MLW. Personnel from CERC then scanned the survey data for erroneous points and verified monument positions. The profile surveys were converted to metric units and adjusted to NGVD (by the addition of -0.81 m for ocean profiles and -0.84 m for sound profiles). Finally, the data were converted to distance and elevation and formatted for entry into the Interactive Survey Reduction Program (ISRP) (Birkemeier 1984).

For July 1990 - November 1991, the Districts processed the three profile segments individually and then transferred these to CERC for processing. The fathometer portions of the survey data were corrected by applying the ARTTES system as discussed in Chapter 6 (*Tides and Waves* section). The fathometer sections of the profile were then smoothed using a moving average algorithm. Smoothing was required to reduce fathometer noise and limit the number of points to a total of 400 or less for use with ISRP. The number of points which were averaged varied between seven and ten depending on the original data density. Due to the gradual nearshore slope, the elevation differences between the data points smoothed were commonly on the order of 0.03 m. Tests were made of the smoothing routine to ensure that small-scale features were adequately represented. Volumetric differences between the original and smoothed data were negligible. Following the fathometer corrections, the three segments of the profile were combined into one file and any overlapping data were merged. Finally, the data were converted into final ISRP format as discussed in the preceding paragraph.

The April/May 1992 survey set was processed by OCTI-EC. The digital data were extracted from the field data collector and referenced to the baseline monument. The short overlap which occurred between the beach and offshore segments was analyzed to determine if there was any significant bottom penetration by the sled runners that could affect reported elevations in the hydrographic portion of the profile. No discrepancies were found between the rod and sled data in the overlap region through the surf zone, and the rod data seaward of 0.0 m (NGVD) were edited from the final data set. Survey data were converted from XYZ coordinates into ISRP format and forwarded to CERC. CERC then converted the profiles to metric units and adjusted the datum from MLW to NGVD.

After the profile survey data were processed and plotted, two types of survey problems were evident: monument control problems and vertical offsets throughout the offshore portion of the fathometer surveys. If a profile could not be properly referenced to the monument because of undocumented horizontal or vertical offsets, the survey line was eliminated. Monument resets were necessary due to both natural and man-made modifications. In unstable areas, some monuments were damaged by storms, particularly those monuments located in high dunes at the distal ends of both islands, such as Lines C1, C2, A1, A4, A7, and A79. Other monuments along central Amelia Island, such as Line A52, required a reset as a result of new construction and commercial development. Figure D20 is an example of a profile line surveyed at a monument that was reset but in a different location.

In addition, vertical offsets of up to 2 m were observed along the fathometer portions of the nearshore profiles, which indicated that some source of survey error exceeded tolerable limits and was masking the annual and seasonal profile variations. Vertical offsets between surveys varied at the seaward limit of the profile lines (-6.1 m NGVD) at a depth which is considered one of relative topographic stability (i.e. profile closure depth). Logistically, the fathometer surveys through the surf zone were hazardous to obtain because of the wave action and large tidal range in the region. This resulted in minimal or no overlap between the beach and nearshore segments

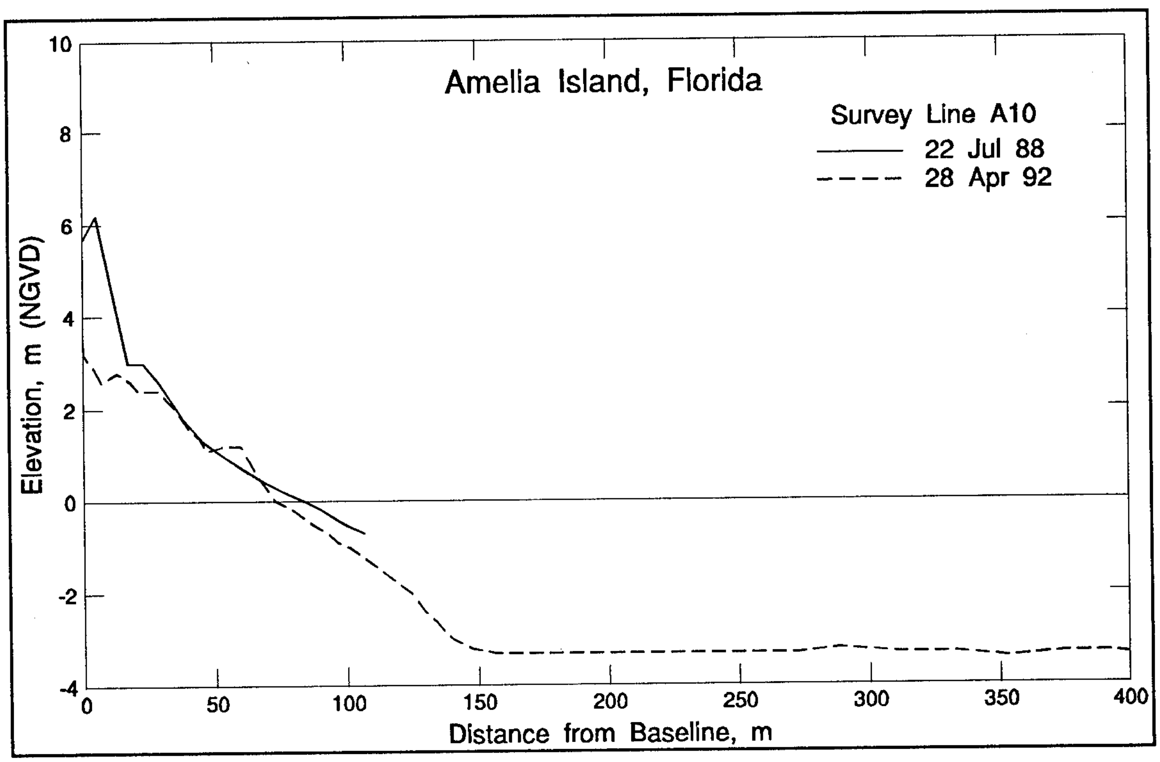


Figure D20. Example of profile with undocumented offset at the monument for most surveys. Hence, consistent vertical and horizontal control could not be attained for all profiles. Assuming all standard operational procedures as defined by USACE (1991) were followed, another probable source of this offset was difficulty in attaining consistent tidal datum control over such a large region. Examples are shown in Figures D21 and D22. Because the vertical error associated with the fathometer surveys in many cases exceeded the expected natural variability of the offshore portions of these profiles, only the beach portion of the survey was used for quantitative analysis. In some cases, there was no vertical displacement and these profiles were used to qualitatively describe the bathymetric topography and identify dynamic features in the offshore.

Profile survey data

Plots of profiles in this report utilize consistent line styles to represent the same survey dates. The complete data set of beach and nearshore profiles for the study area is plotted in Figures D23-D104. Only representative offshore portions of profile lines are included in this appendix. Examples of typical profile shape and volume changes for the monitoring period within major morphologic compartments are organized in the following sets of figures:

a. Figures D23-D50: Graphical presentation of beach and nearshore survey lines, July 1988 - April/May 1992, for Cumberland Island.

b. Figures D51-D77: Graphical presentation of Cumberland Sound survey lines, July 1988 - September 1991.

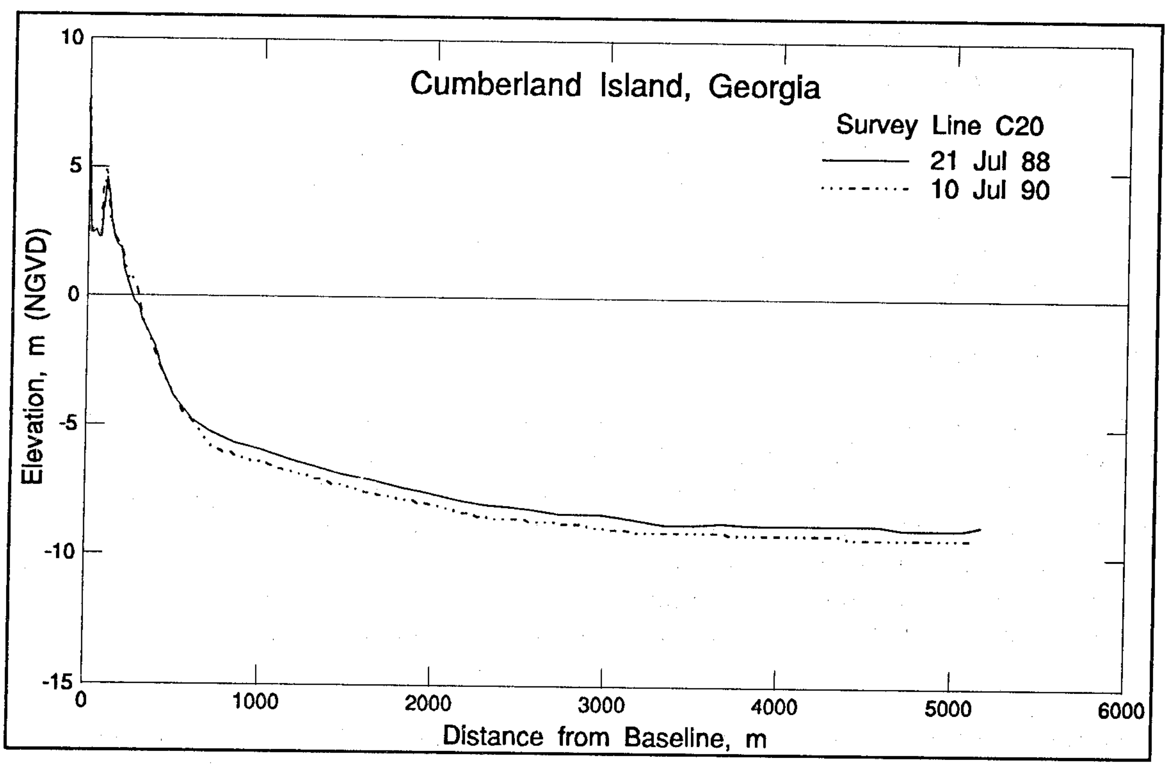


Figure D21. Example of vertical datum error, Cumberland Island

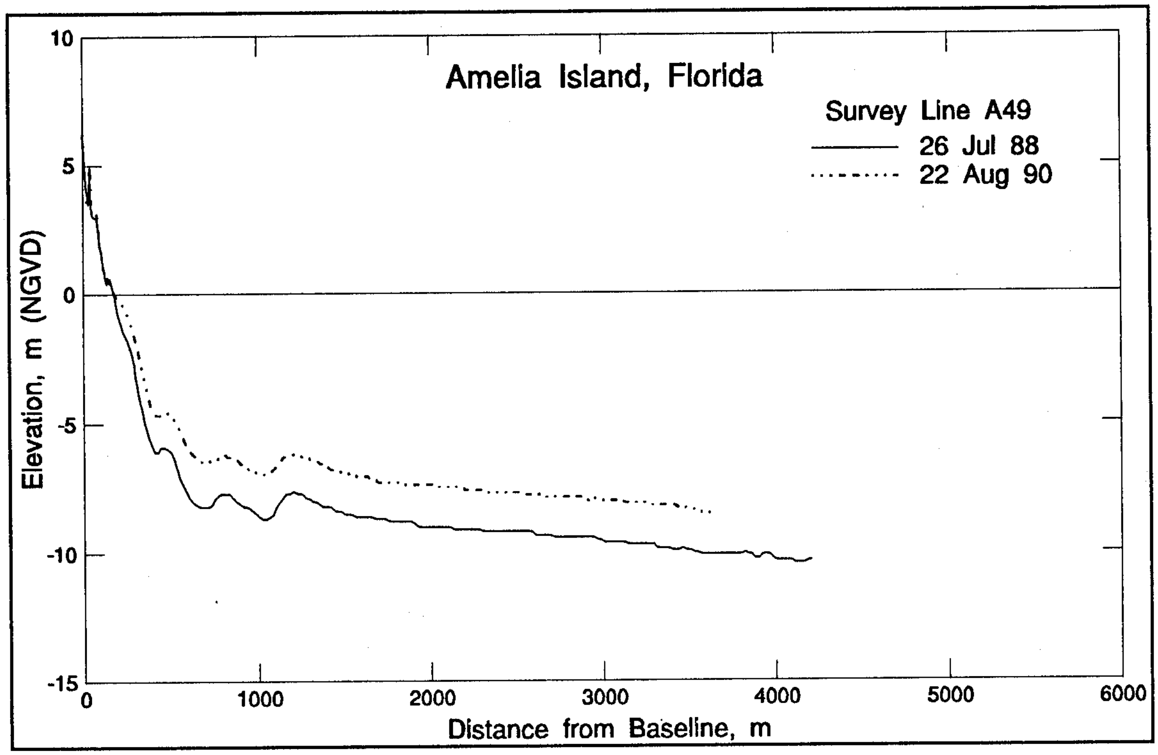


Figure D22. Example of vertical datum error, Amelia Island

c. Figures D78-D104: Graphical presentation of beach and nearshore survey lines, July 1988 - April/May 1992, for Amelia Island.

d. Figures D105-D111: Selected graphical presentations of beach, nearshore, and offshore survey lines, July 1988 - August 1990, for both Cumberland and Amelia Islands.

e. Figures D112-D115: Selected graphical presentations of hydrographic survey lines, June/July 1988 and April 1992, for St. Marys ebb-tidal delta.

Analysis methods

Several types of beach parameters can be measured from profile data including the width of the subaerial beach, location and depth of the inner bar, and beach and nearshore profile slope. Comparisons between successive profiles can be used to quantify shoreline position change, volumetric change, and seasonal profile response. Several studies (Hands 1976, Wright and Short 1983, and Short 1991) have documented the cyclic nature of beach topography in response to seasonal shifts in the local wind and wave climate. In addition to normal effects, profile surveys can also be used to measure change caused by short-term episodic events (Savage and Birkemeier 1987).

Profile survey analysis for open-coast beaches has typically been based on distances specified from a survey baseline. Previous work utilizing profile measurements for shoreline position change and volume computations in particular was accomplished primarily along wave-dominated coastlines with moderate to steep slopes (Bruun 1954; Dean 1977; Hands 1980; Kraus et. al

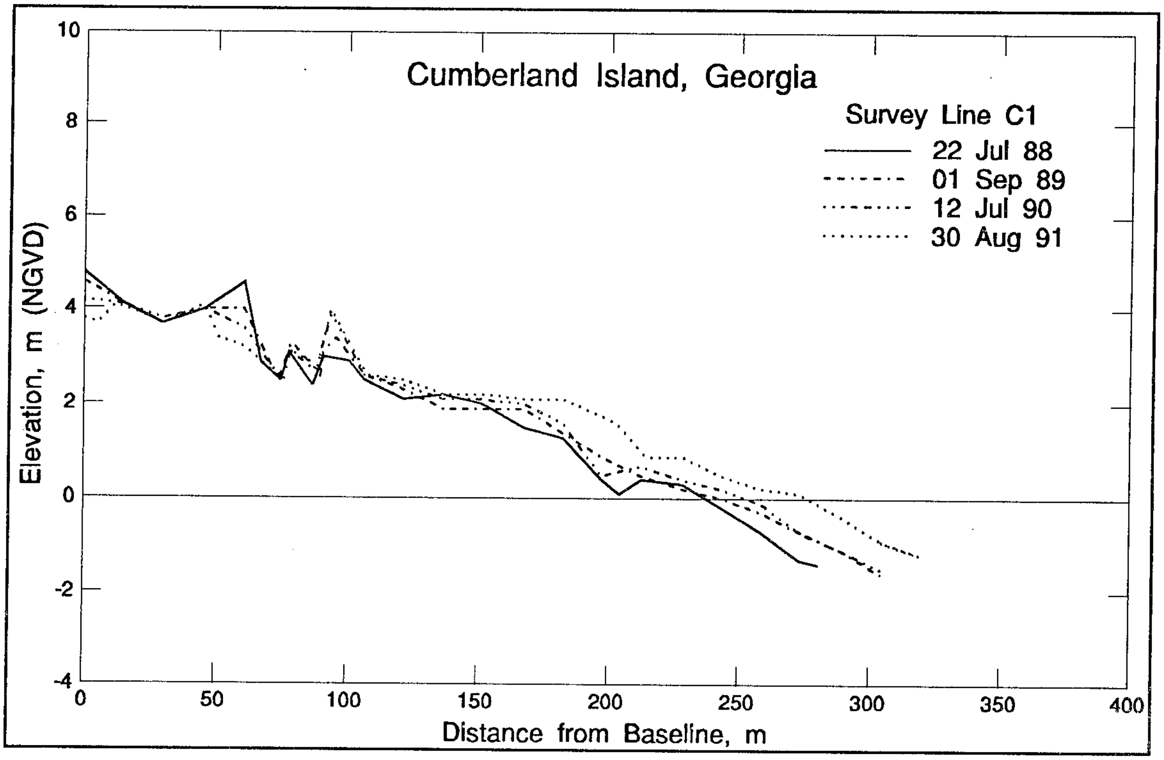


Figure D23. Beach and nearshore profiles, 1988-1991, Line C1

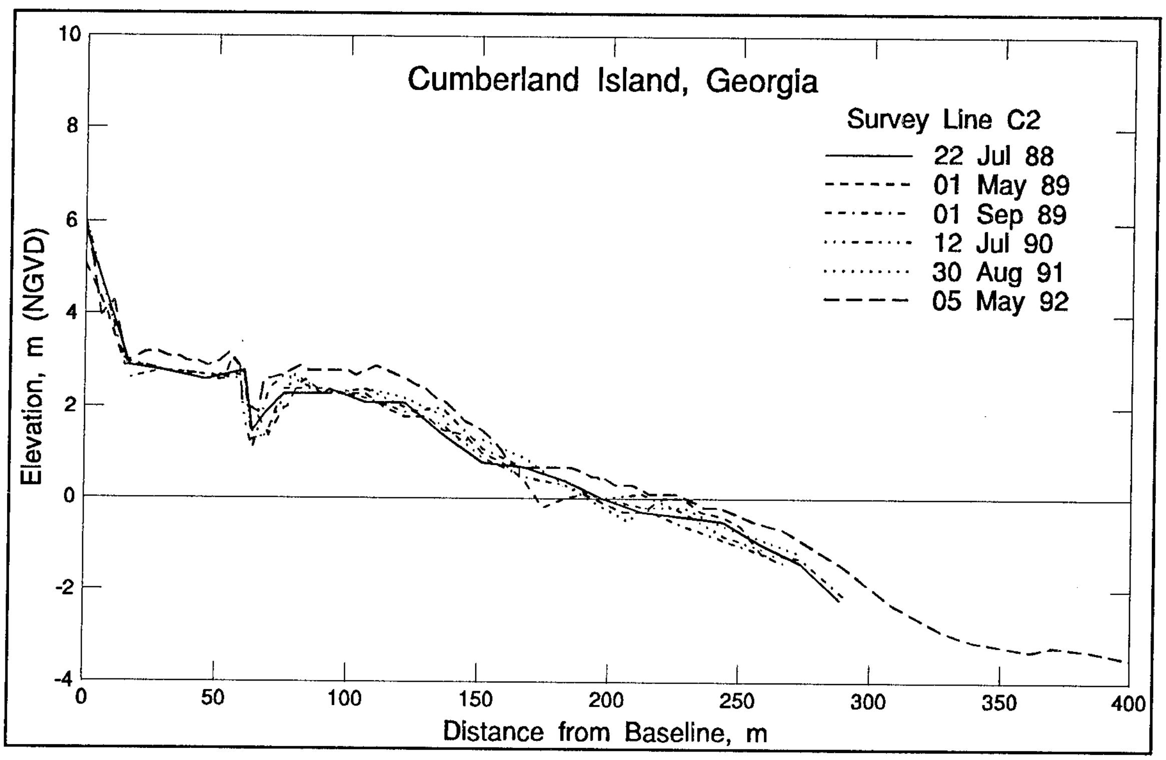


Figure D24. Beach and nearshore profiles, 1988-1992, Line C2

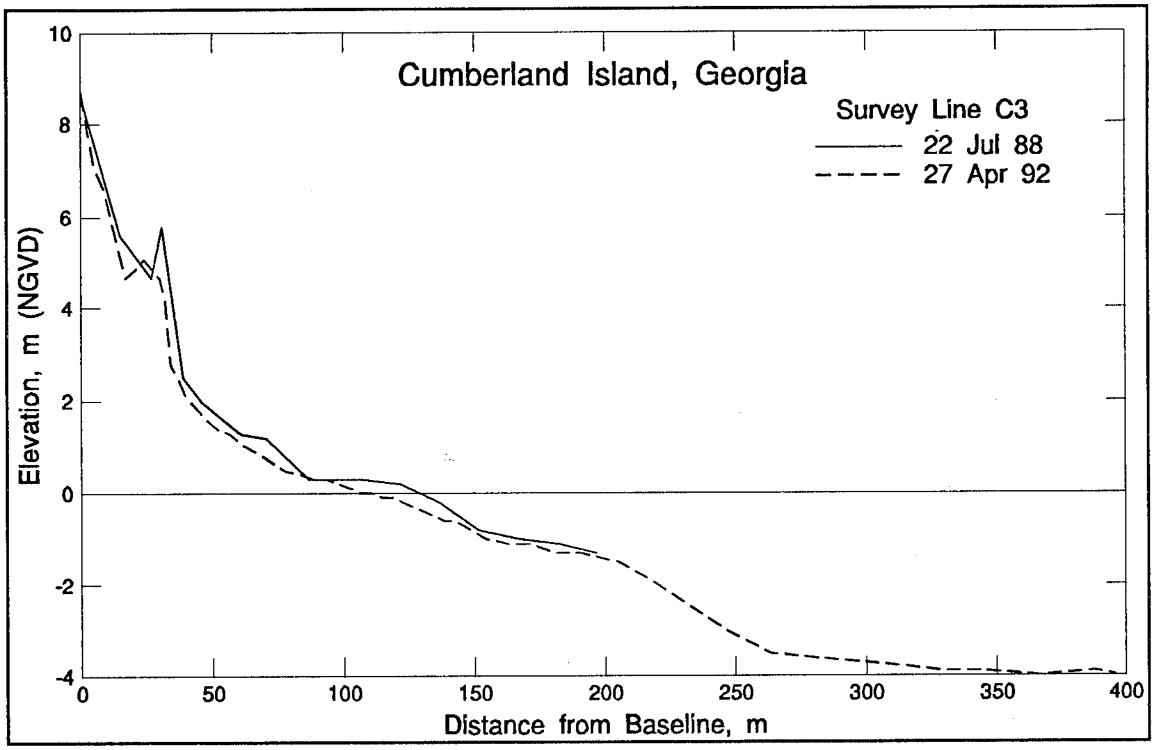


Figure D25. Beach and nearshore profiles, 1988 and 1992, Line C3

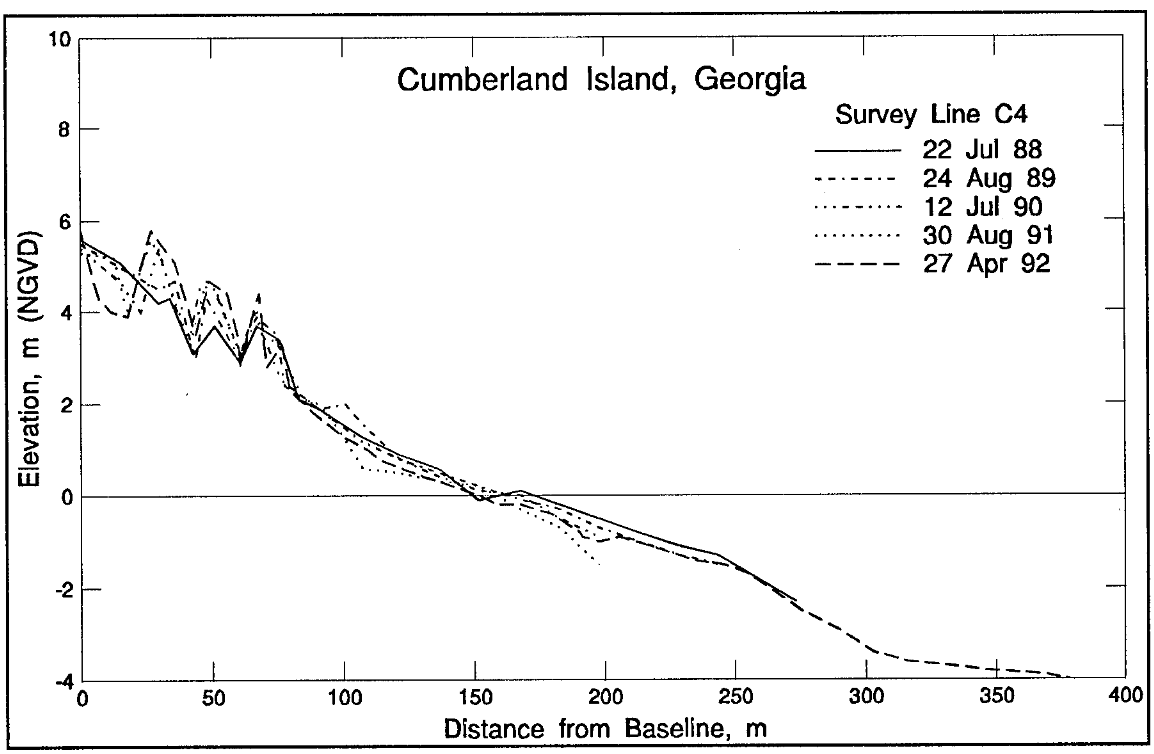


Figure D26. Beach and nearshore profiles, 1988-1992, Line C4

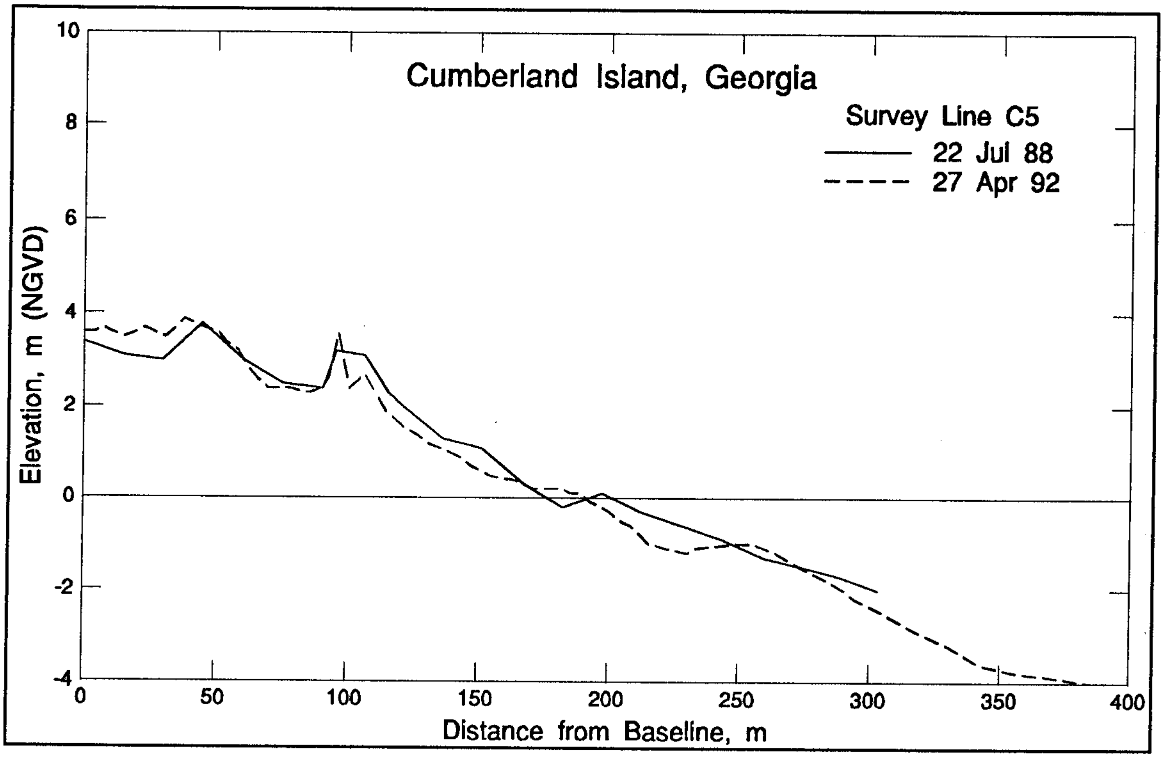


Figure D27. Beach and nearshore profiles, 1988 and 1992, Line C5

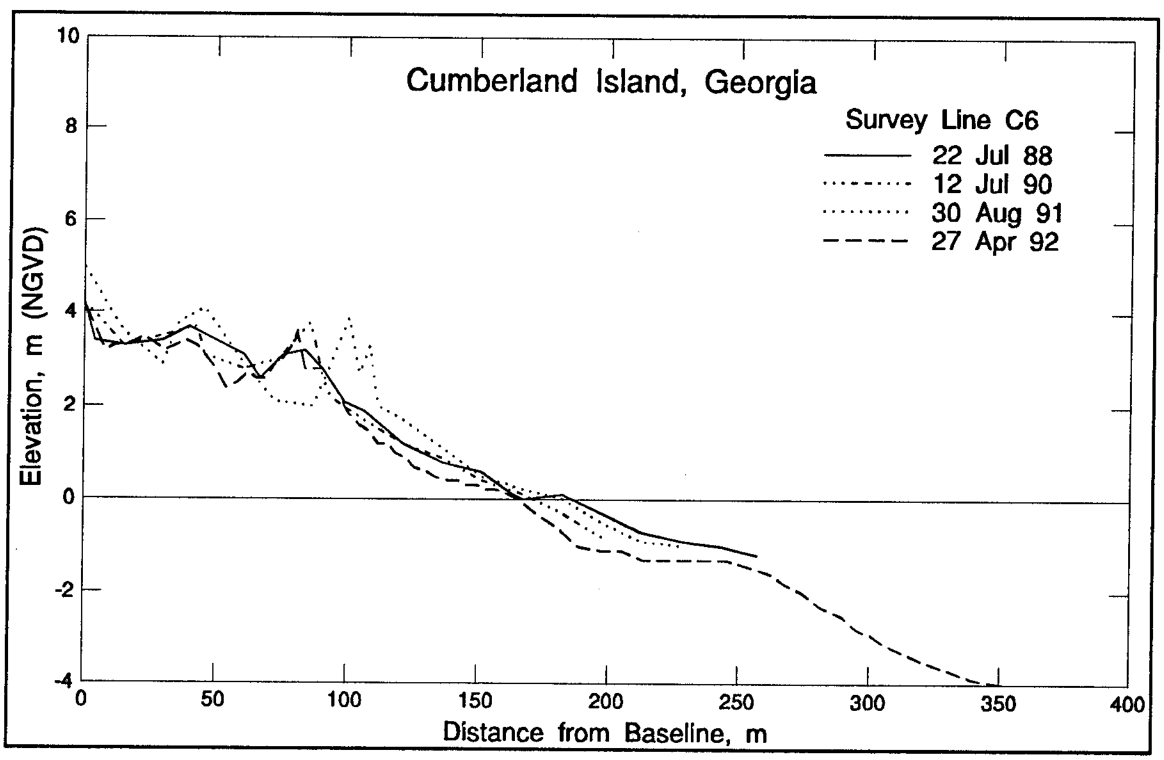


Figure D28. Beach and nearshore profiles, 1988-1992, Line C6

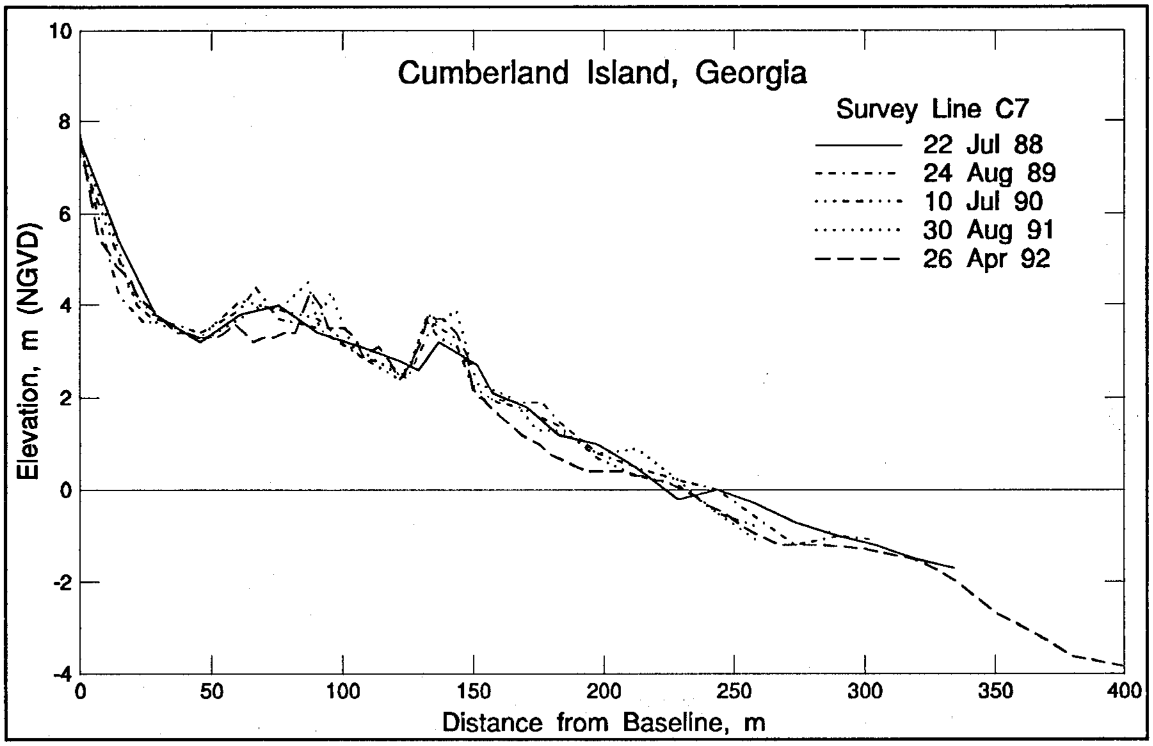


Figure D29. Beach and nearshore profiles, 1988-1992, Line C7

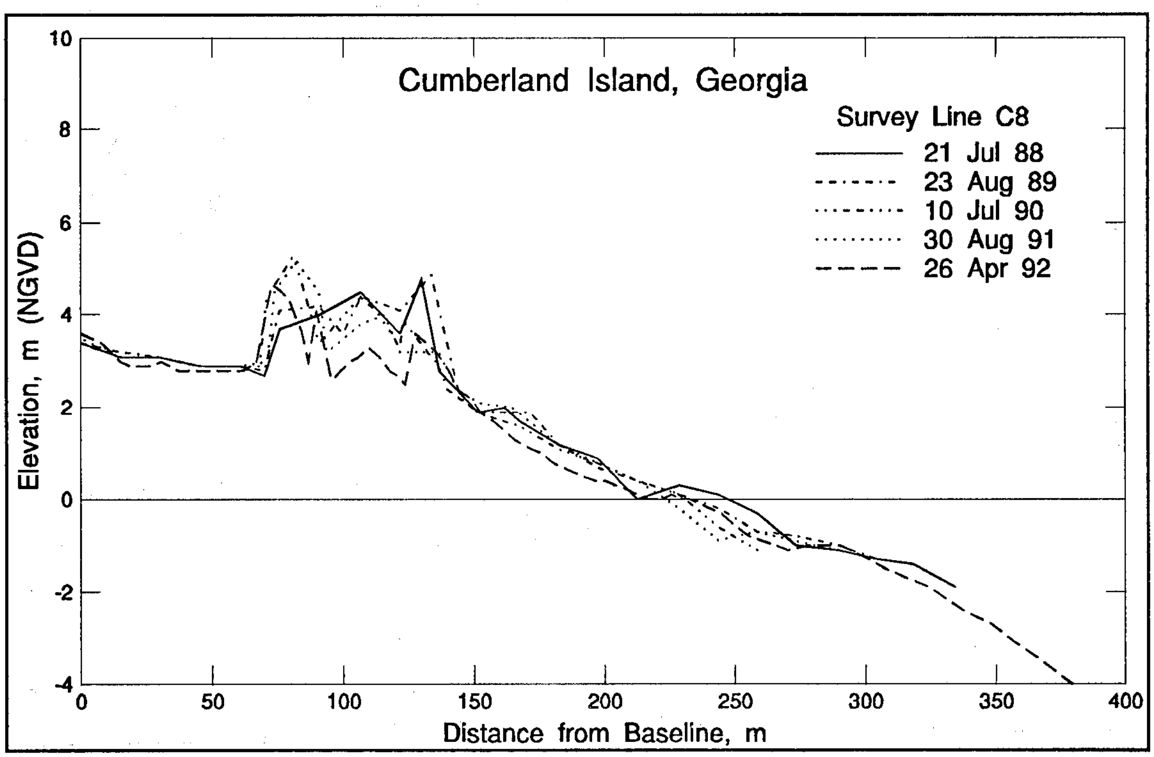


Figure D30. Beach and nearshore profiles, 1988-1992, Line C8

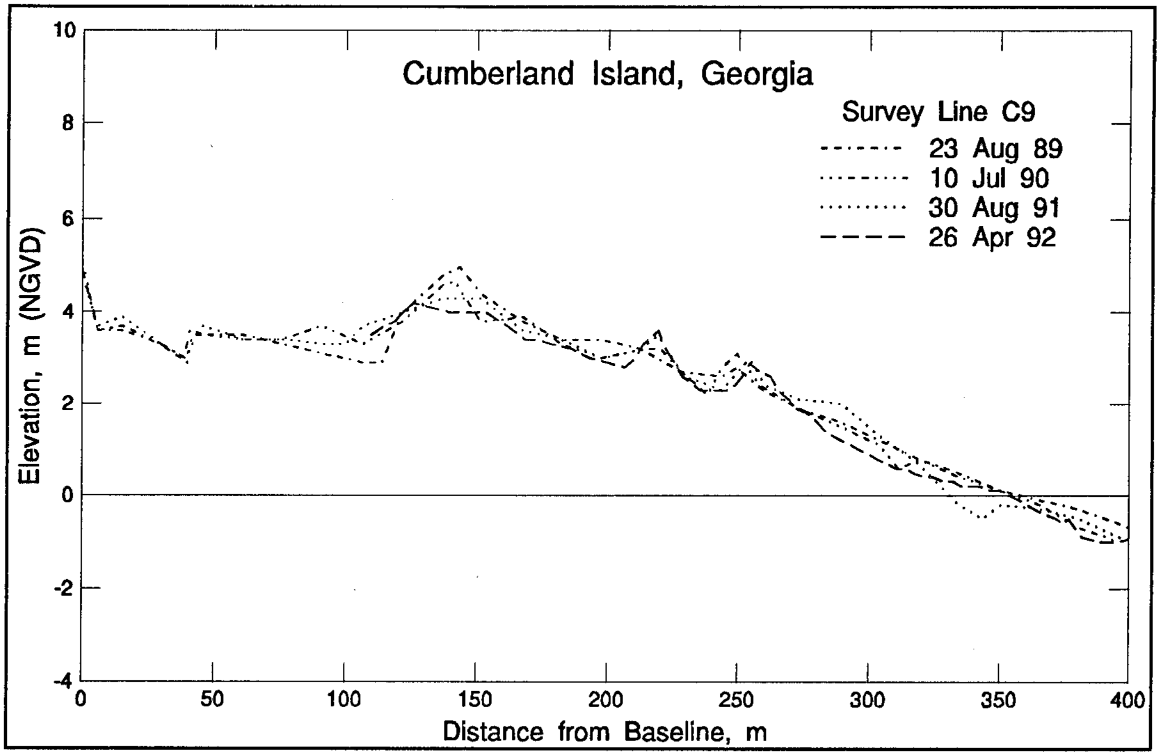


Figure D31. Beach and nearshore profiles, 1989-1992, Line C9

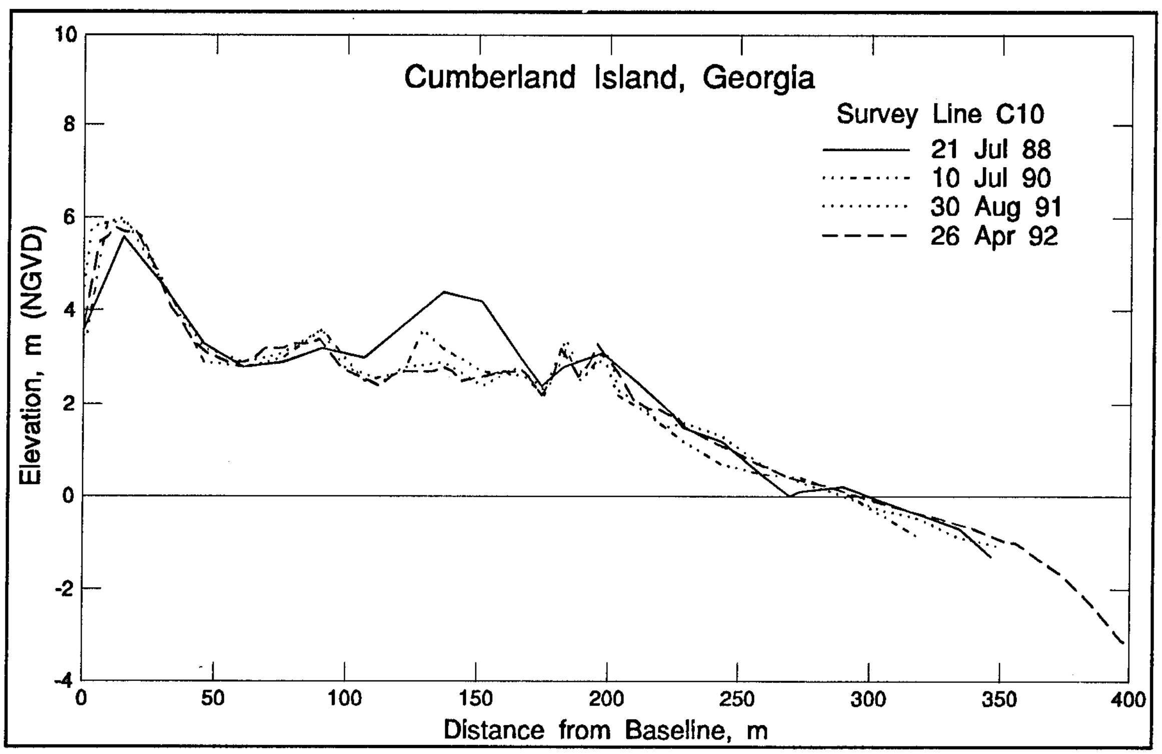


Figure D32. Beach and nearshore profiles, 1988-1992, Line C10

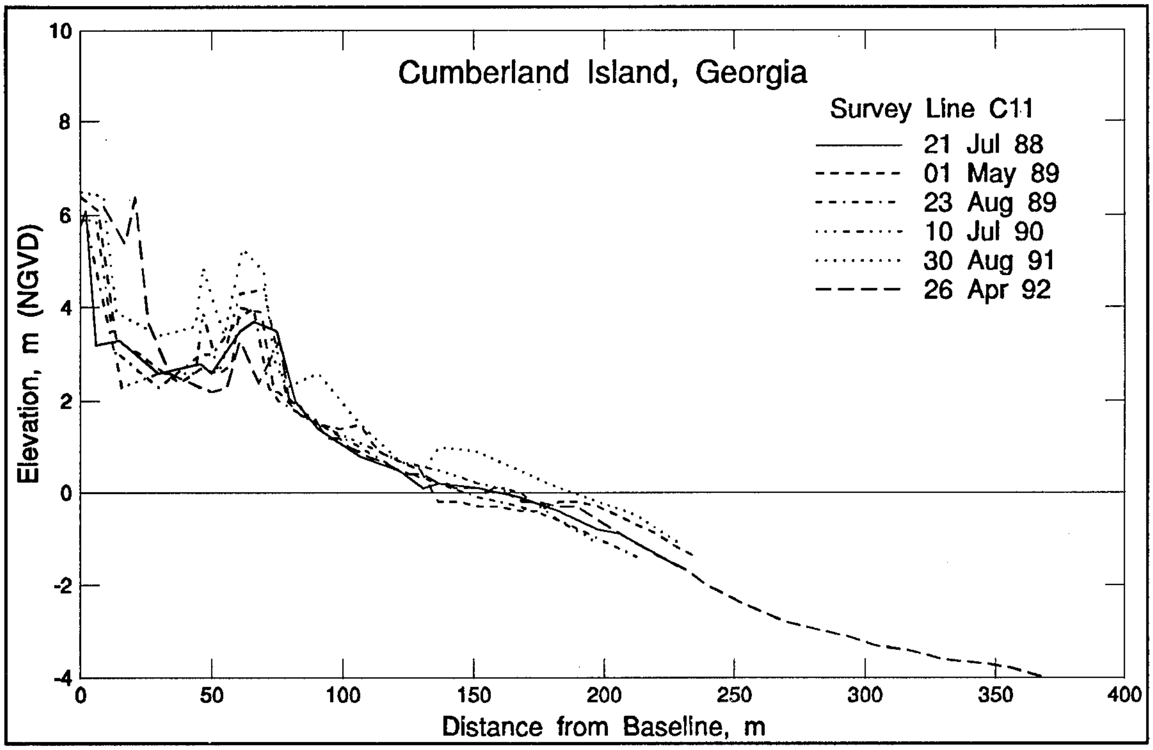


Figure D33. Beach and nearshore profiles, 1988-1992, Line C11

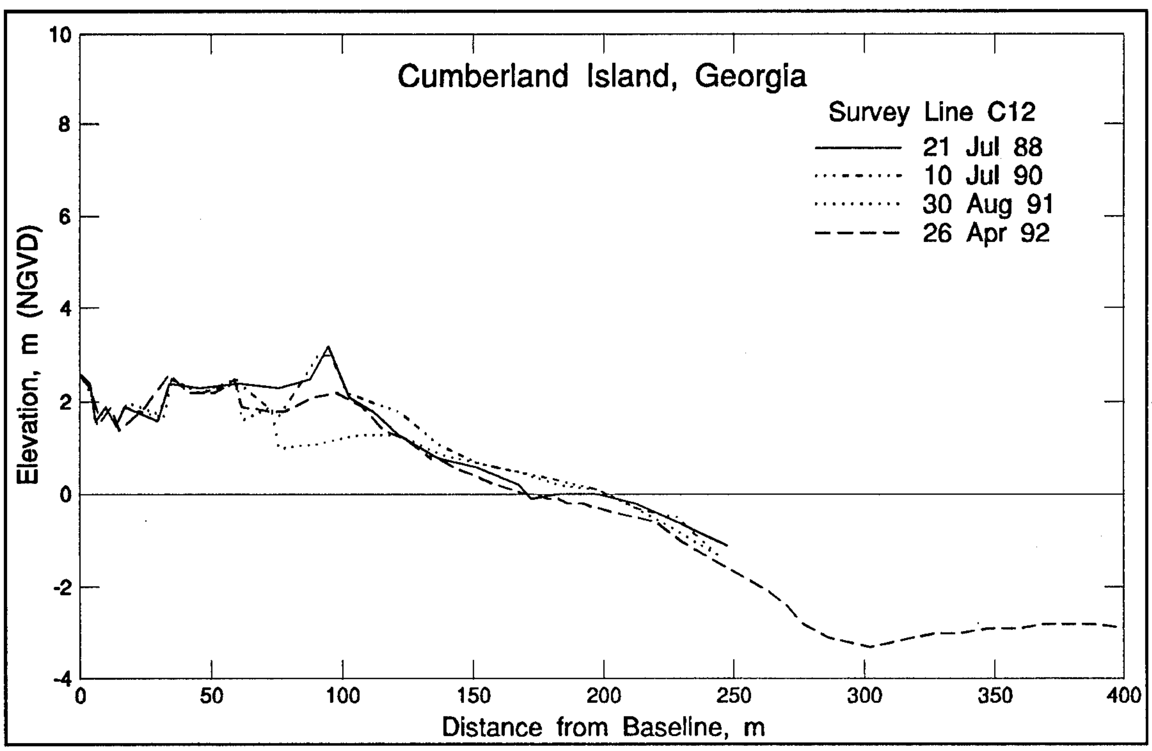


Figure D34. Beach and nearshore profiles, 1988-1992, Line C12

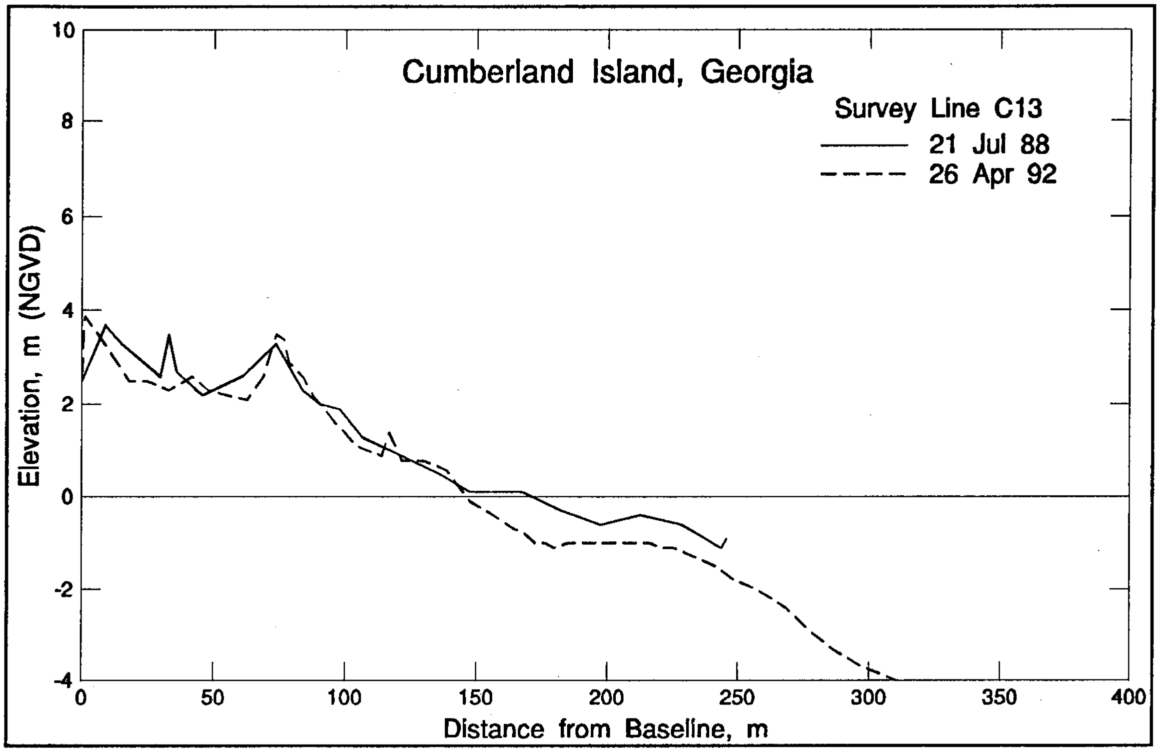


Figure D35. Beach and nearshore profiles, 1988 and 1992, Line C13

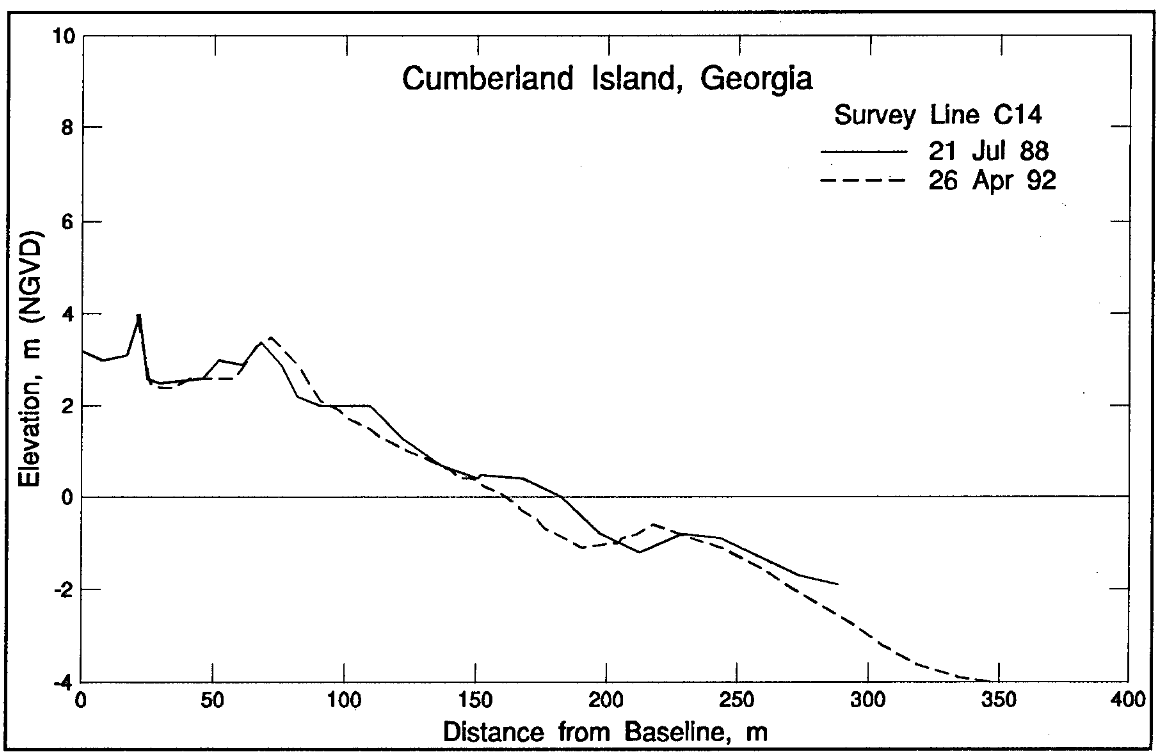


Figure D36. Beach and nearshore profiles, 1988 and 1992, Line C14

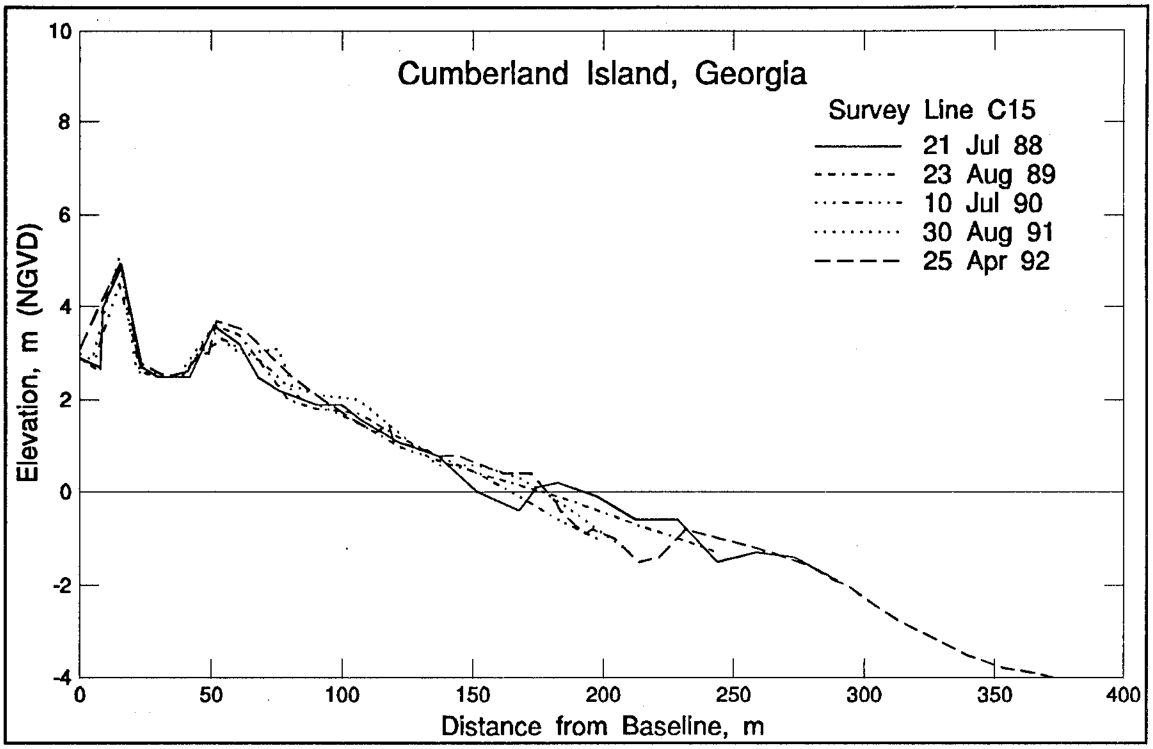


Figure D37. Beach and nearshore profiles, 1988-1992, Line C15

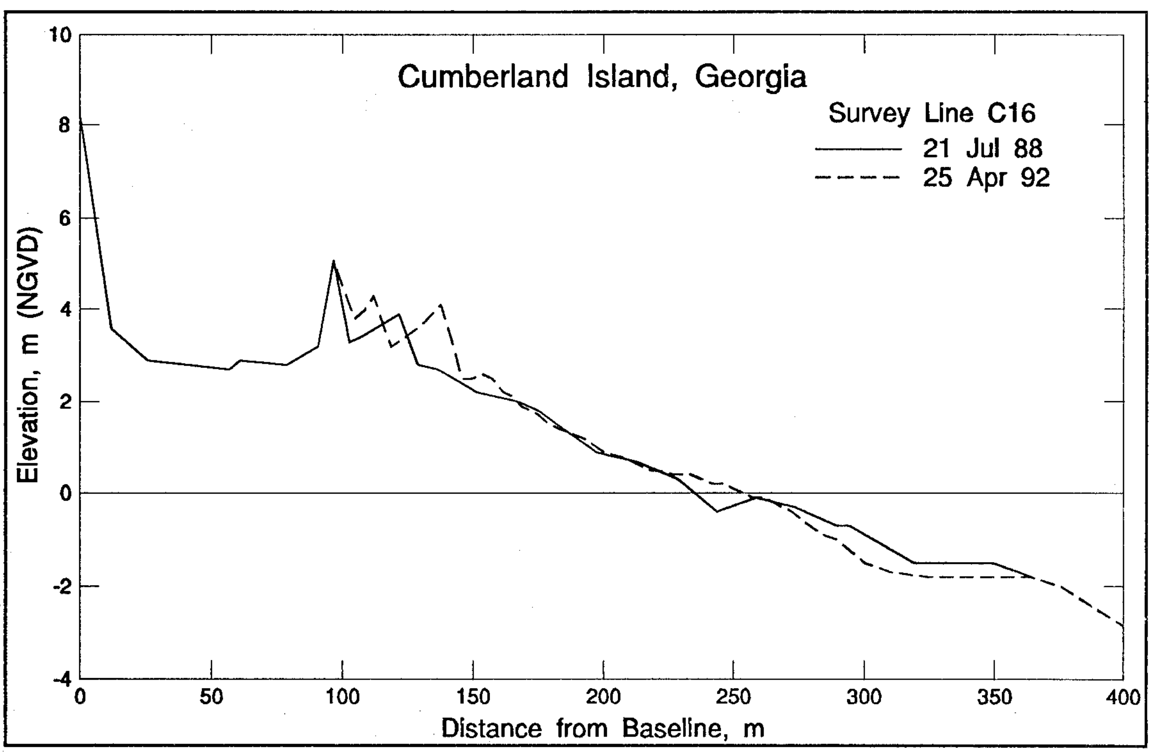


Figure D38. Beach and nearshore profiles, 1988 and 1992, Line C16

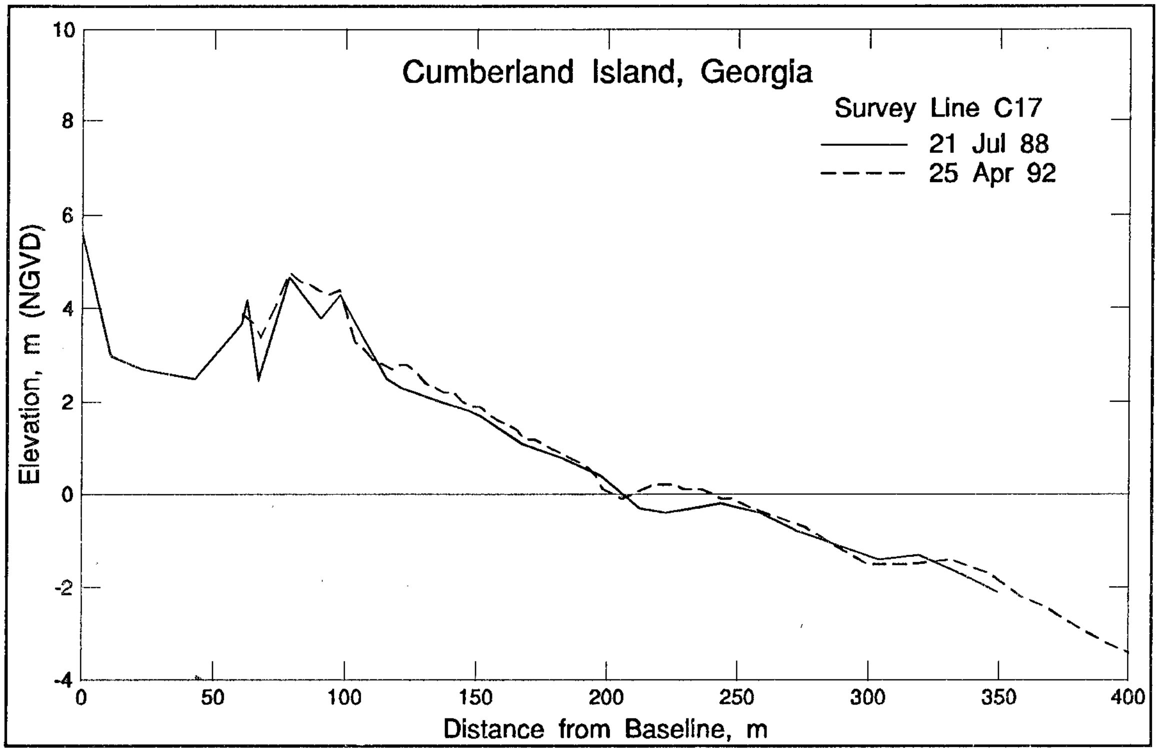


Figure D39. Beach and nearshore profiles, 1988 and 1992, Line C17

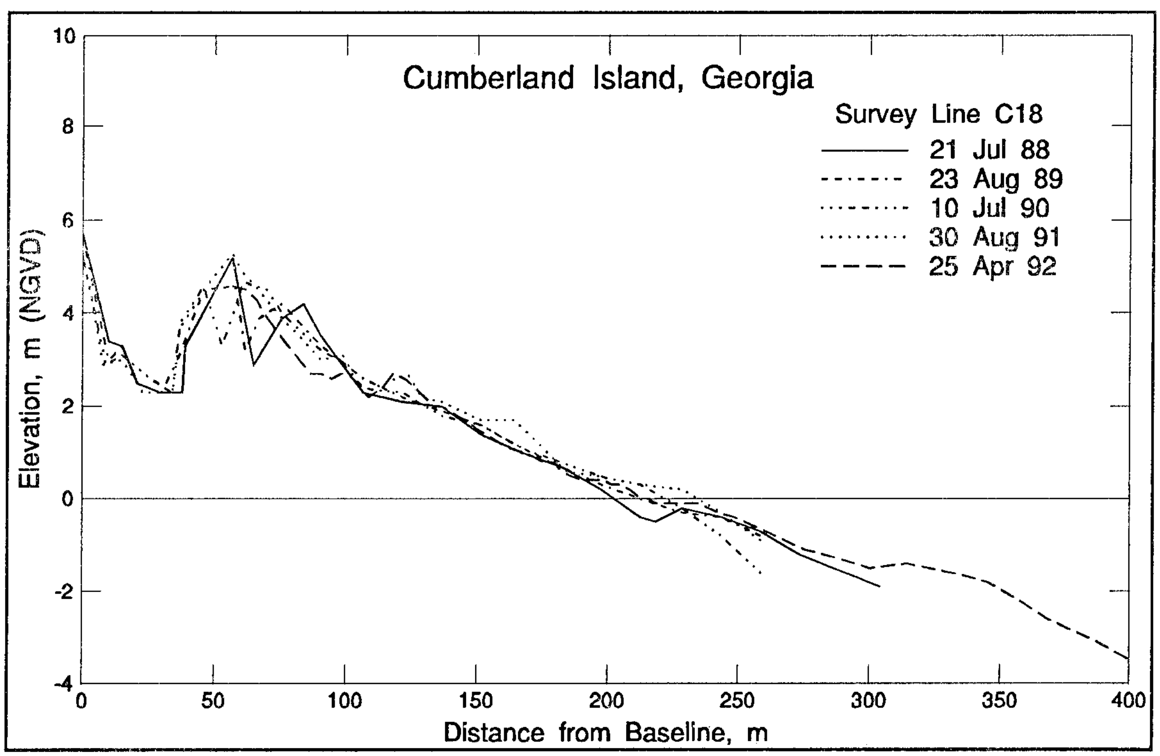


Figure D40. Beach and nearshore profiles, 1988-1992, Line C18

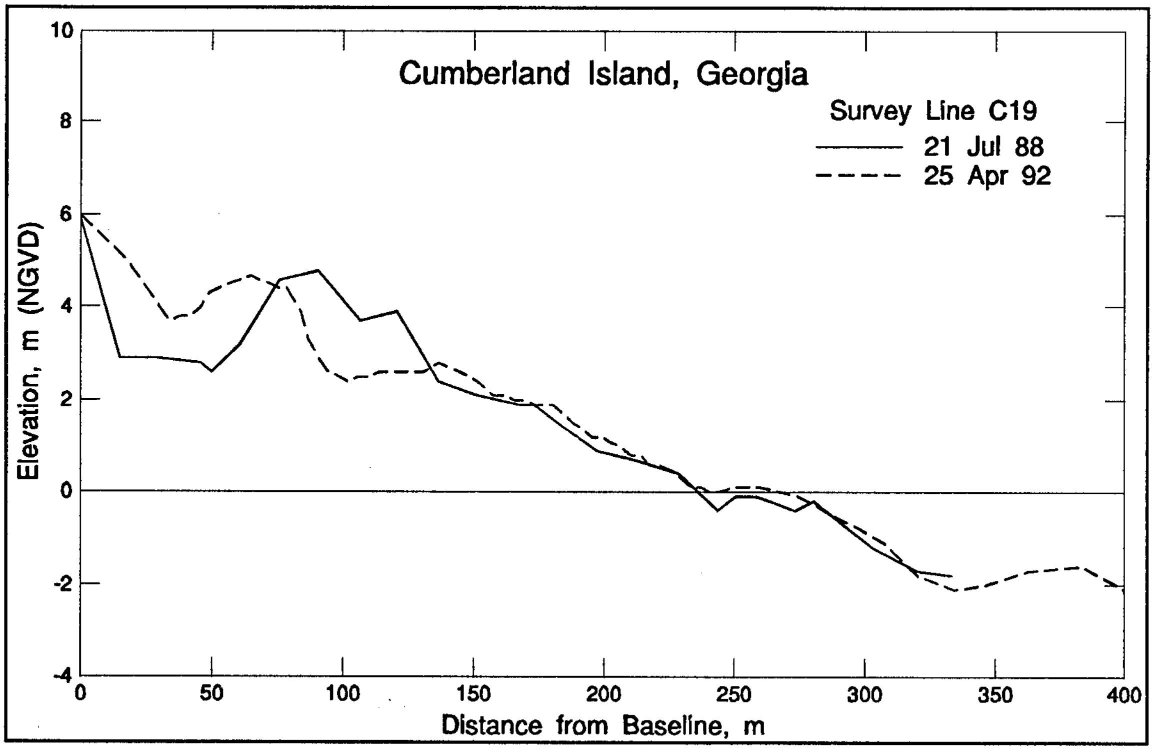


Figure D41. Beach and nearshore profiles, 1988 and 1992, Line C19

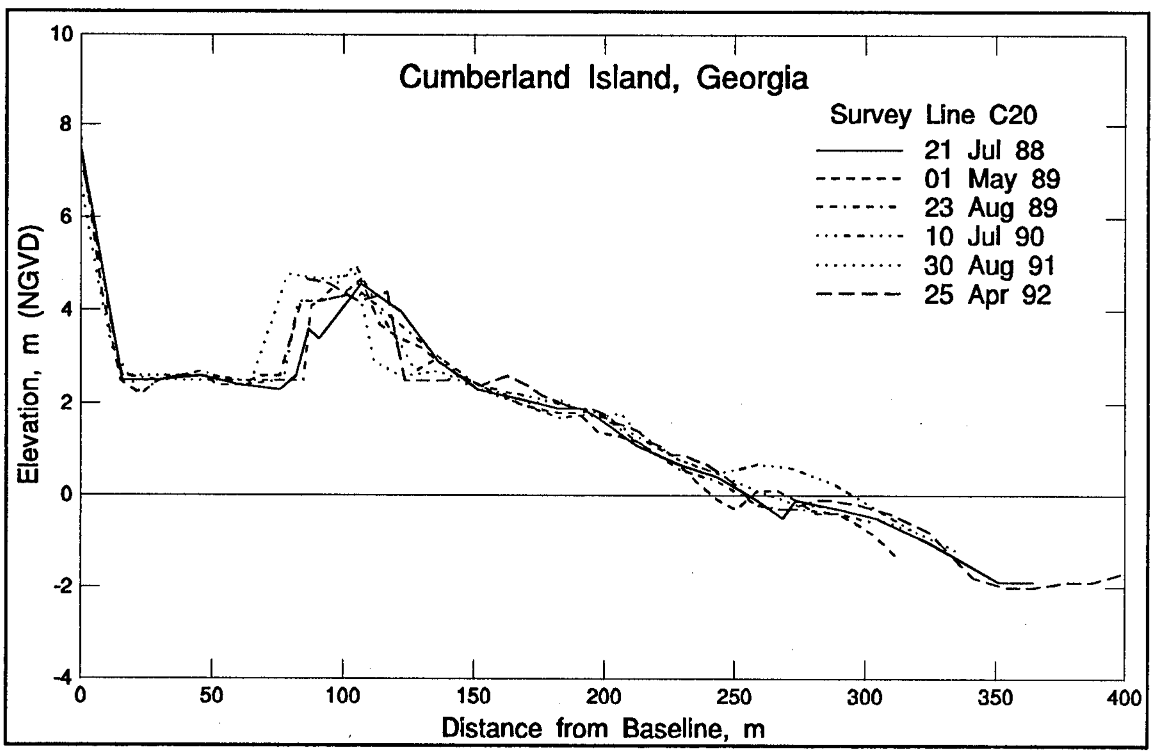


Figure D42. Beach and nearshore profiles, 1988-1992, Line C20

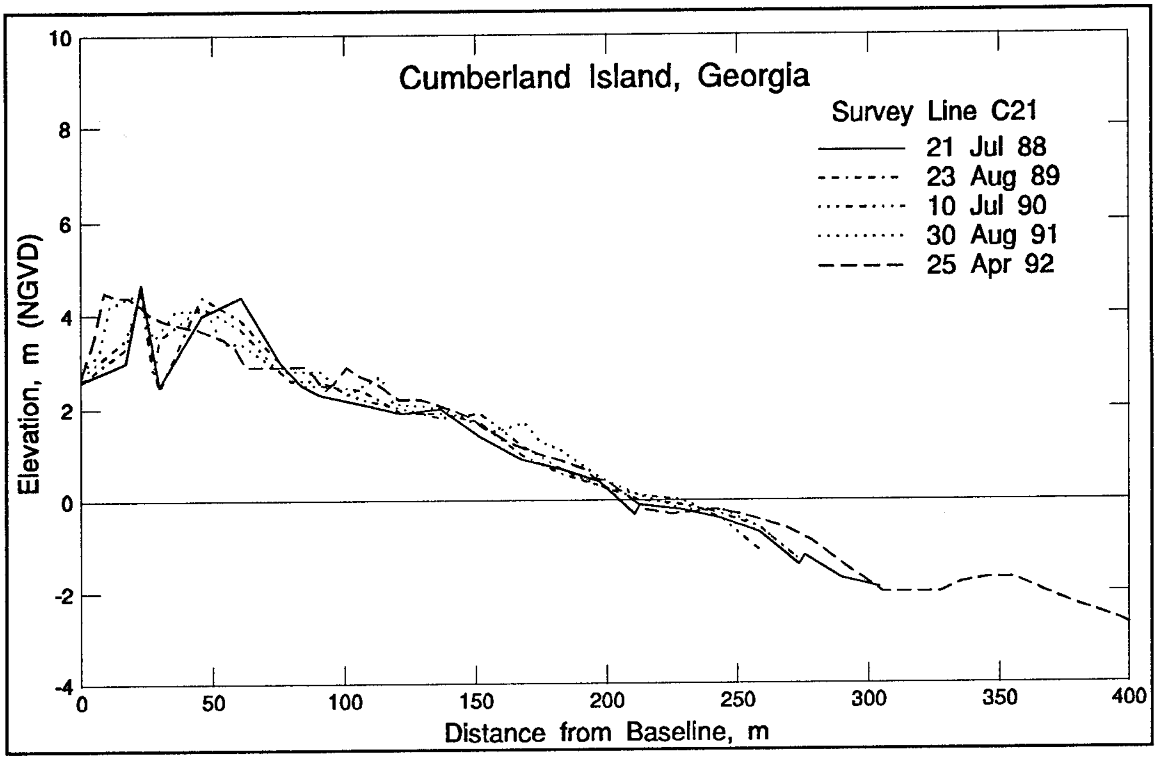


Figure D43. Beach and nearshore profiles, 1988-1992, Line C21

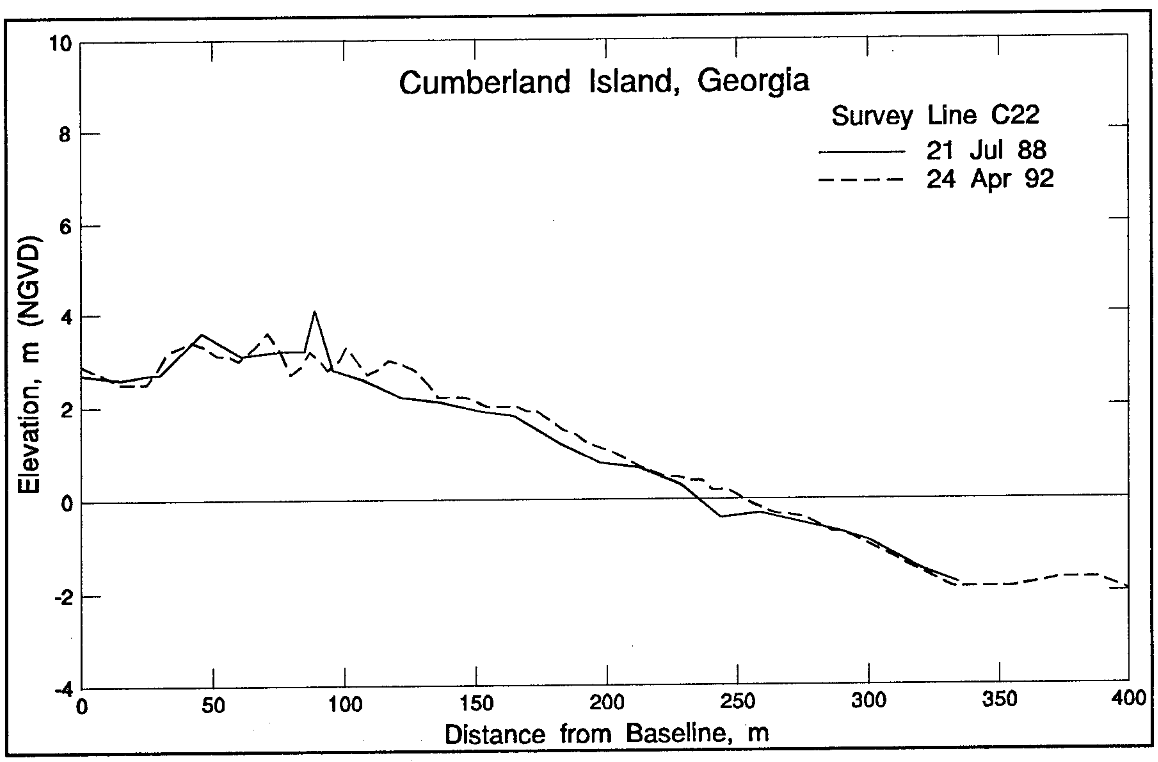


Figure D44. Beach and nearshore profiles, 1988 and 1992, Line C22

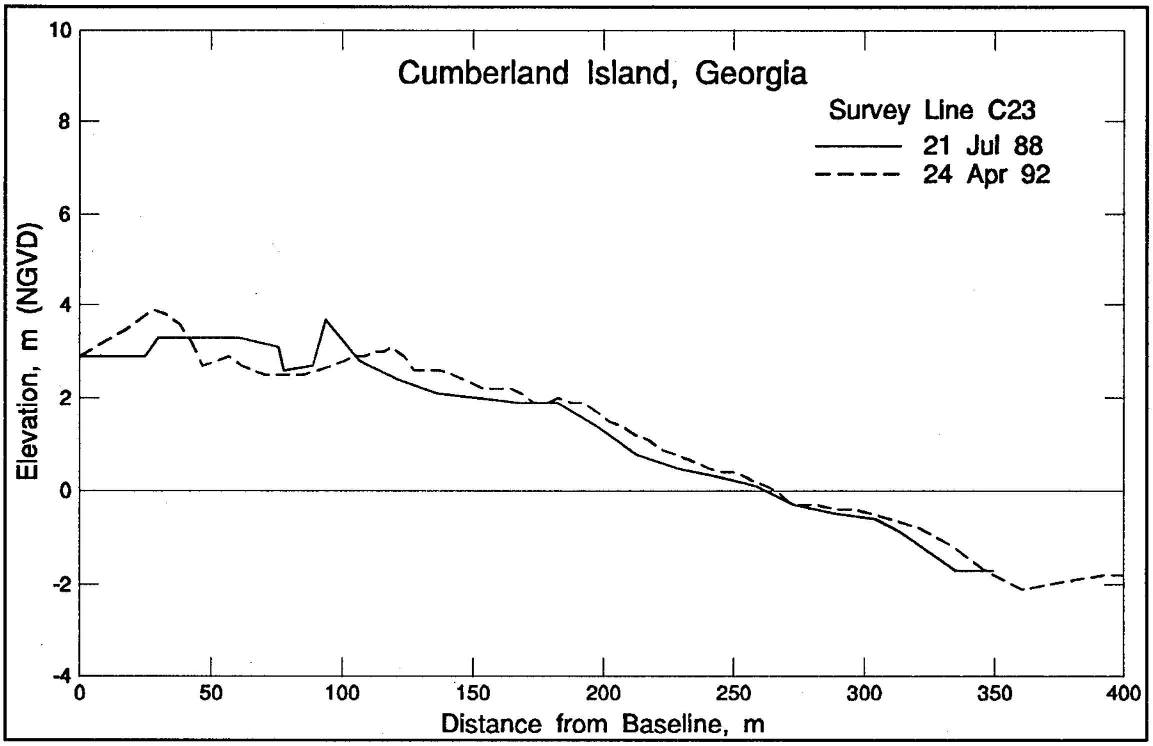


Figure D45. Beach and nearshore profiles, 1988 and 1992, Line C23

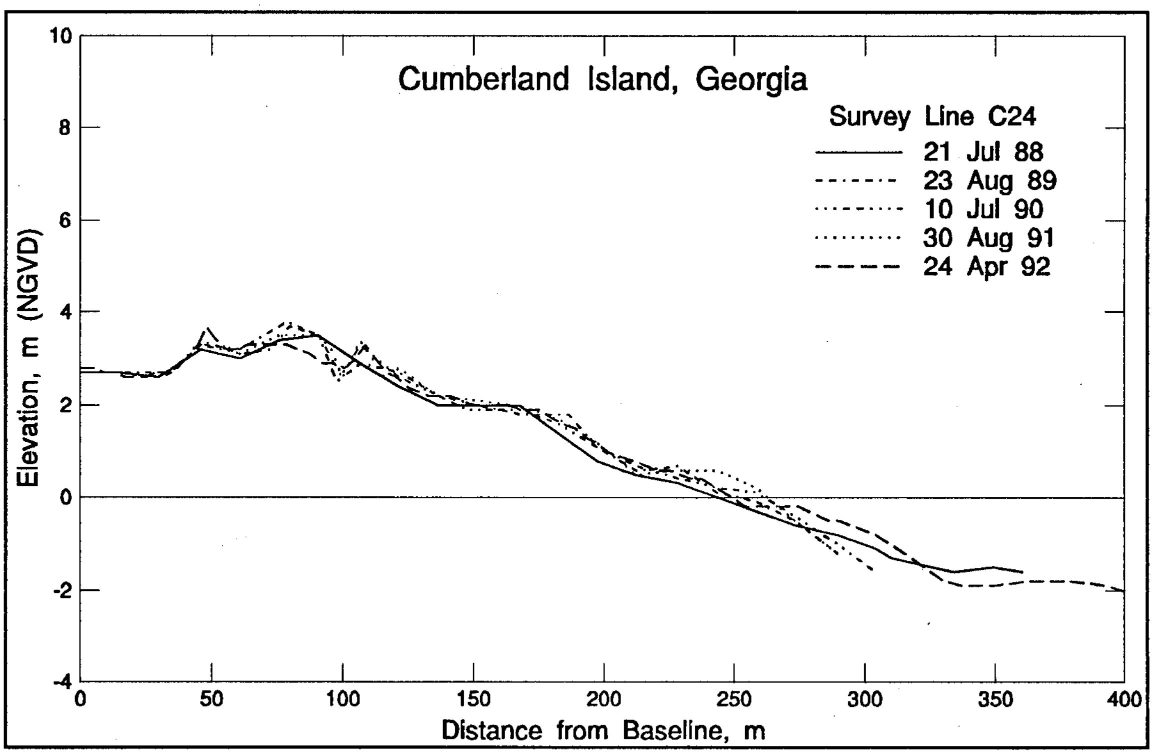


Figure D46. Beach and nearshore profiles, 1988-1992, Line C24

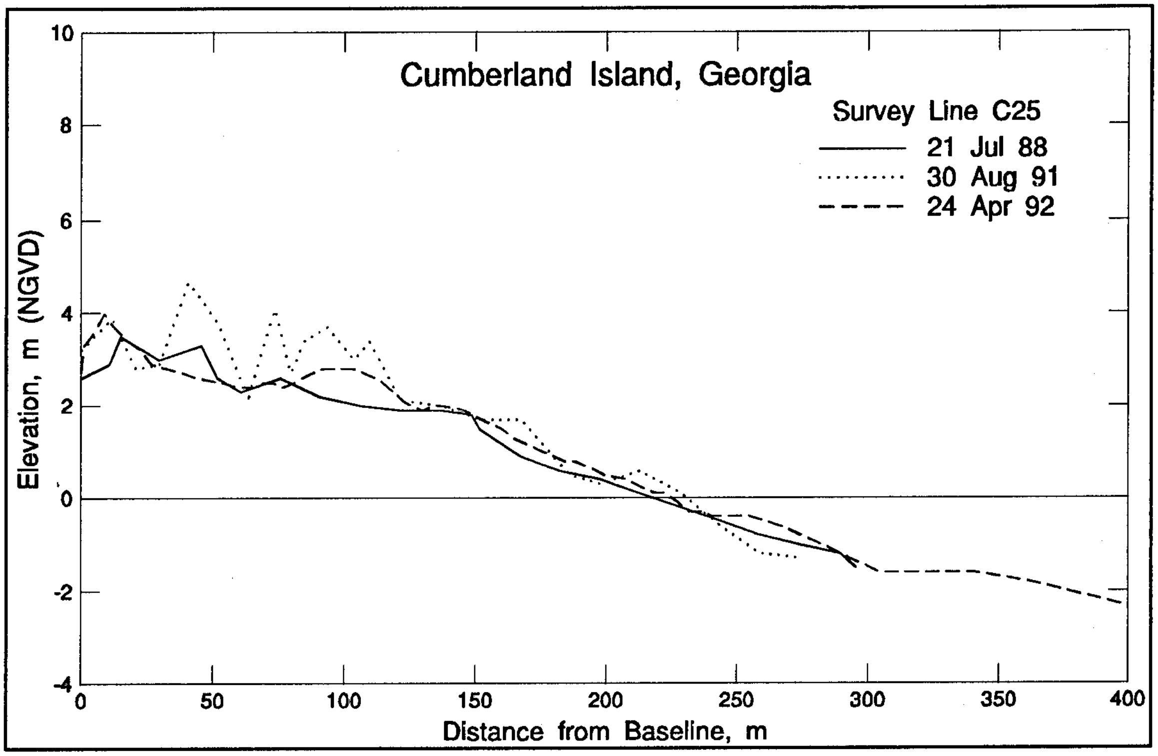


Figure D47. Beach and nearshore profiles, 1988-1992, Line C25

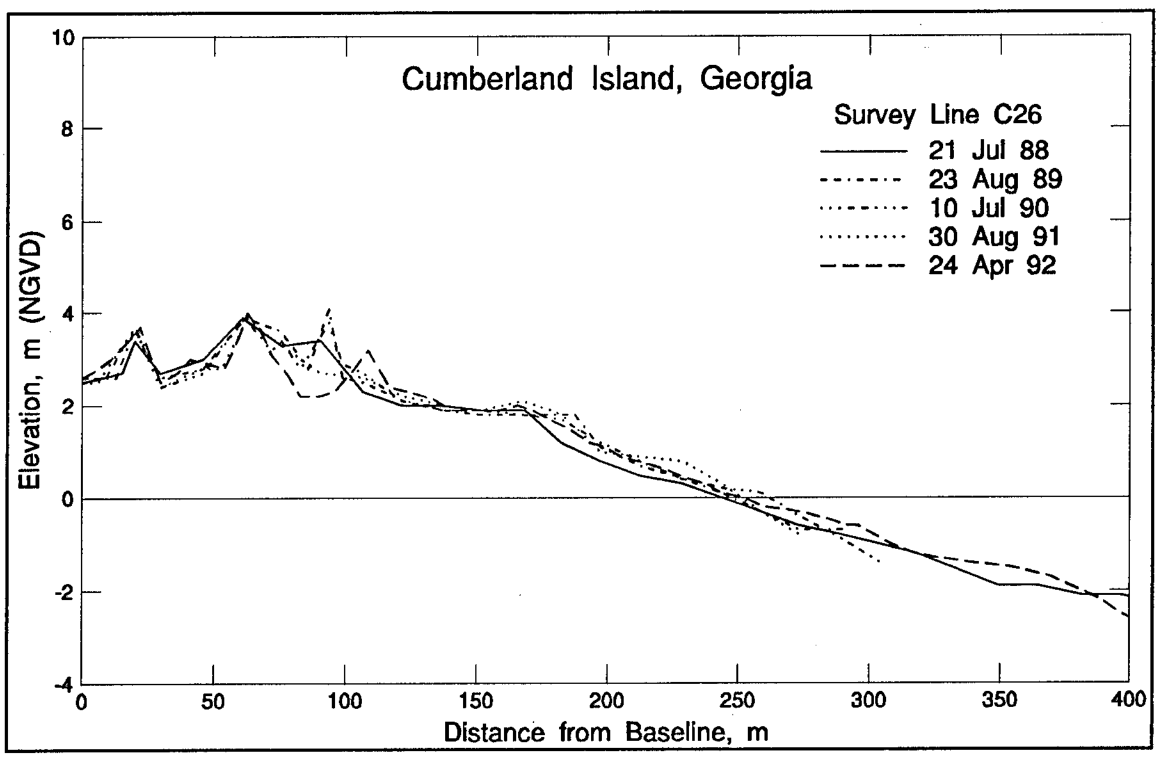


Figure D48. Beach and nearshore profiles, 1988-1992, Line C26

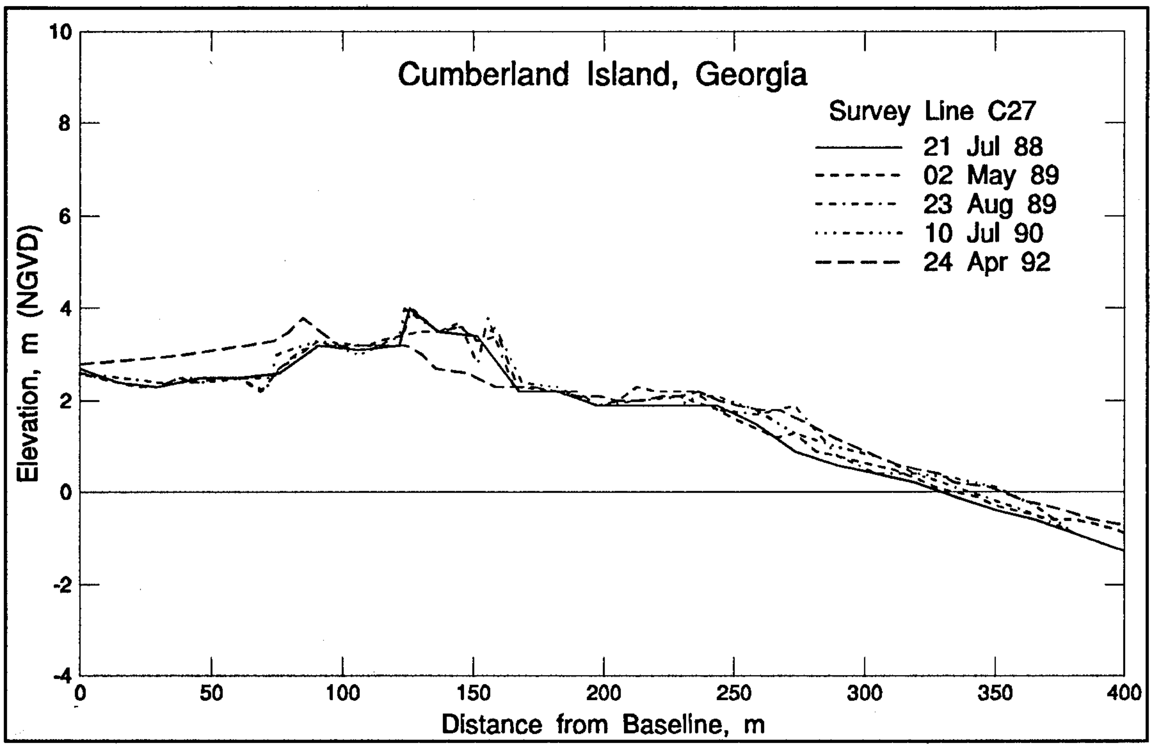


Figure D49. Beach and nearshore profiles, 1988-1992, Line C27

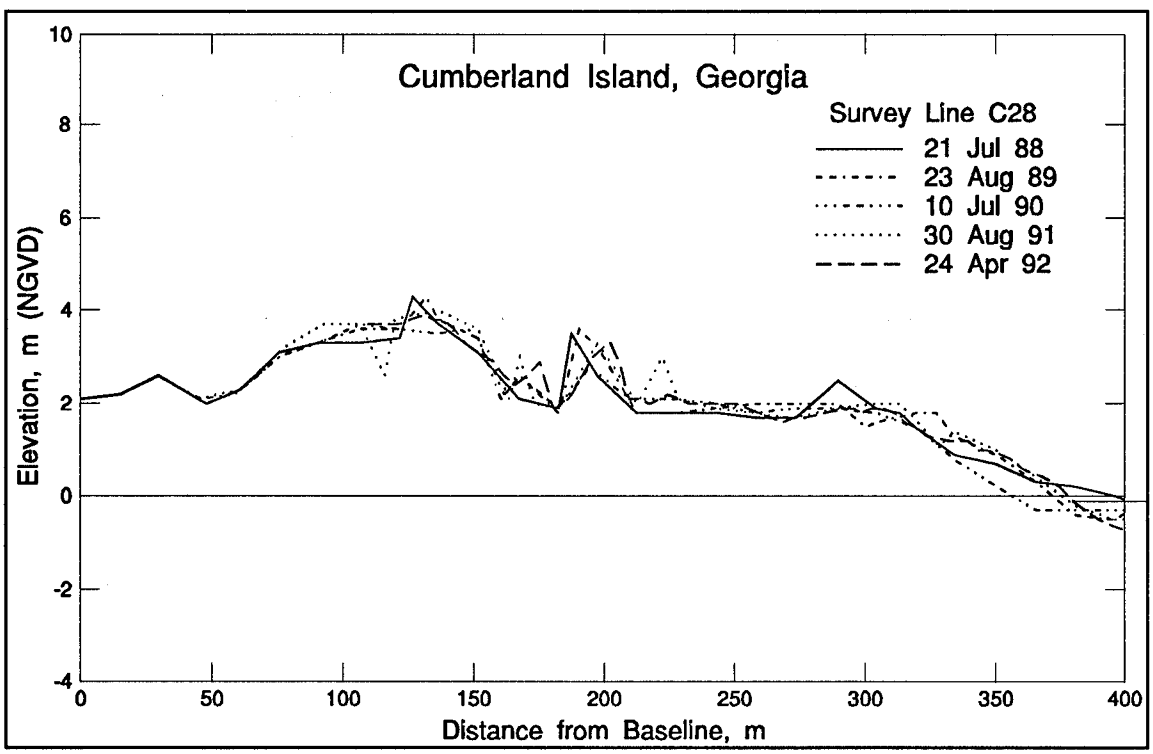


Figure D50. Beach and nearshore profiles, 1988-1992, Line C28

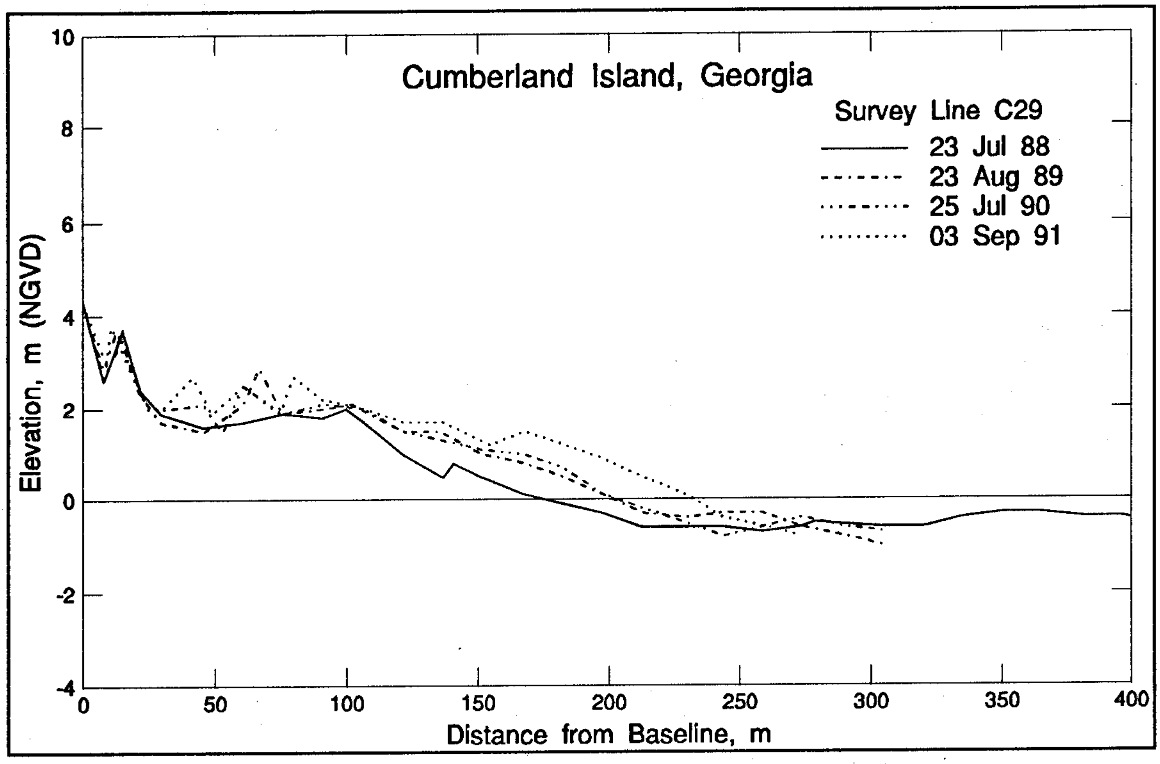


Figure D51. Cumberland Sound profiles, 1988-1991, Line C29

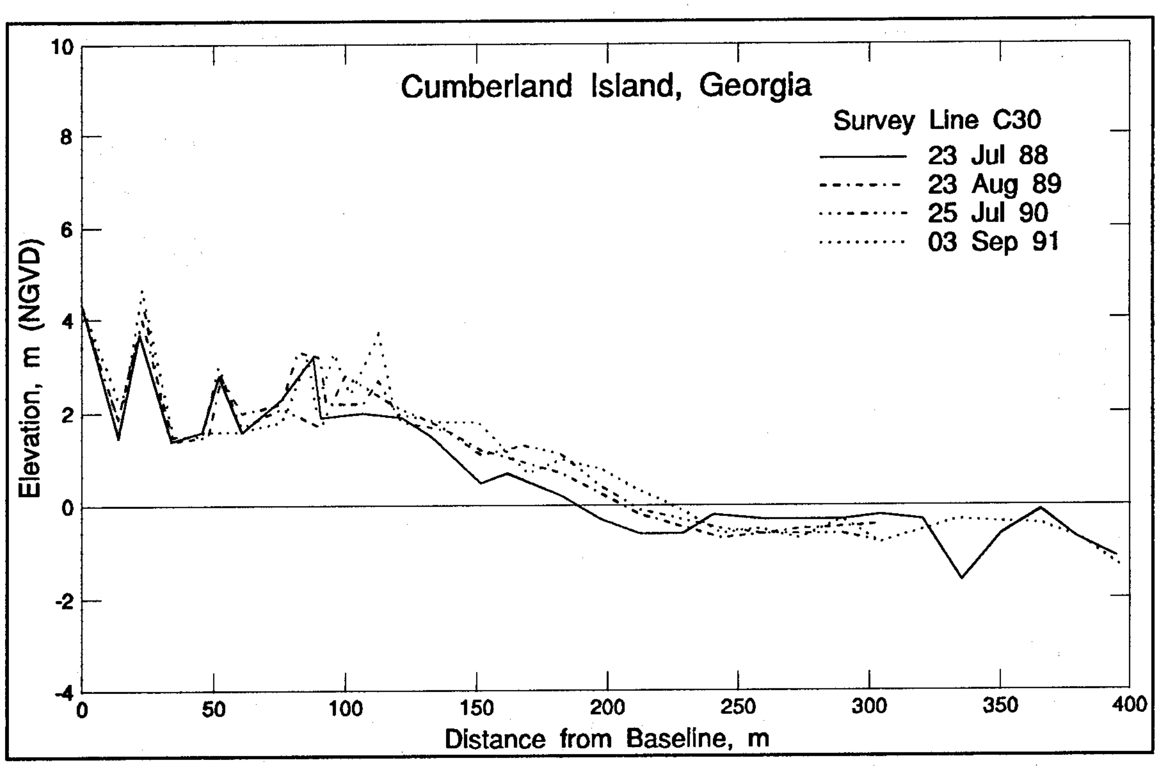


Figure D52. Cumberland Sound profiles, 1988-1991, Line C30

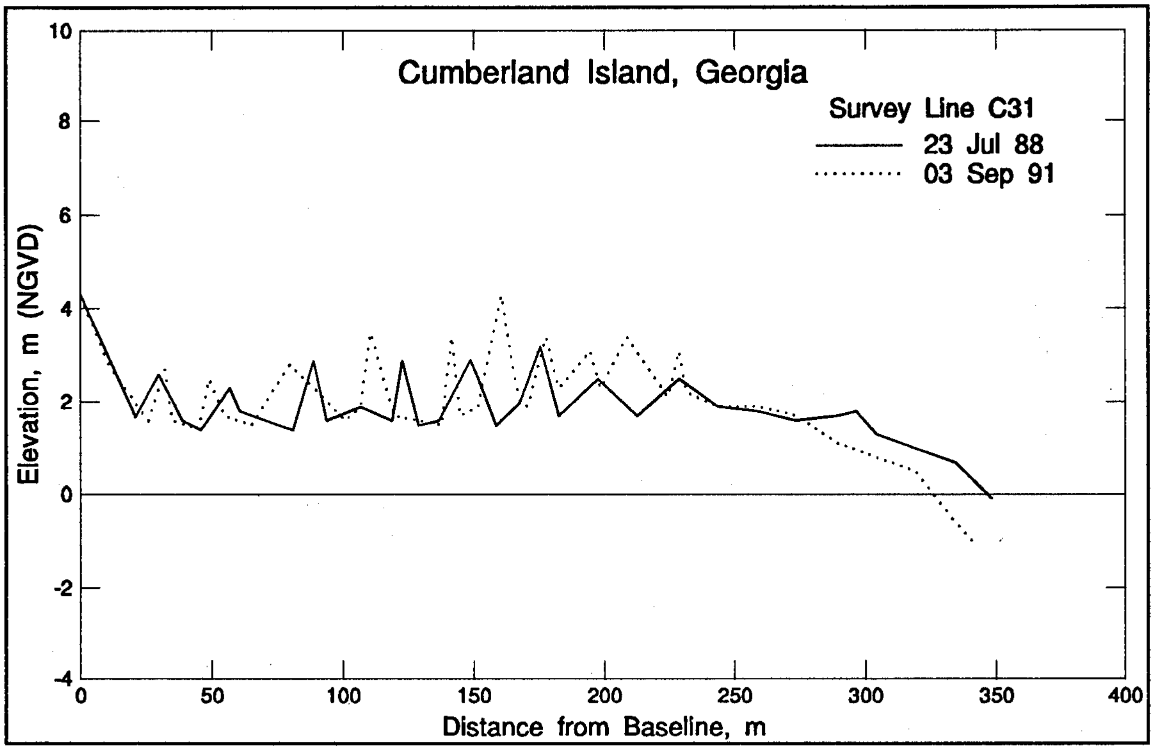


Figure D53. Cumberland Sound profiles, 1988 and 1991, Line C31

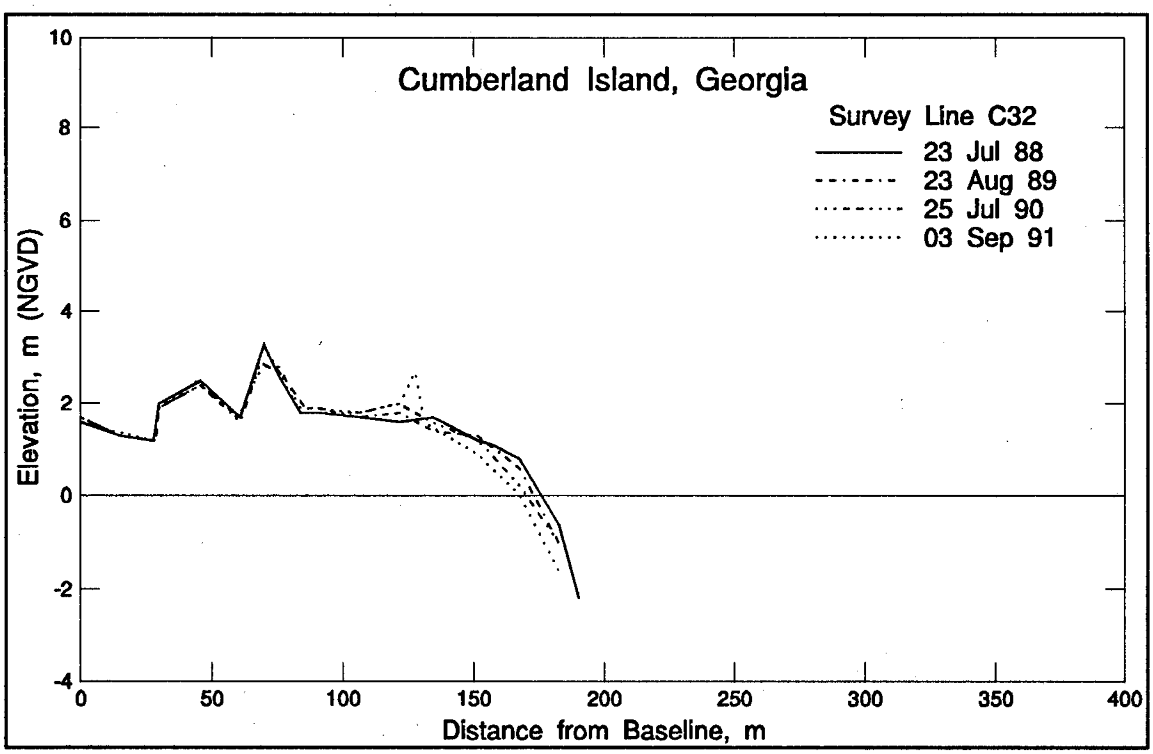


Figure D54. Cumberland Sound profiles, 1988-1991, Line C32

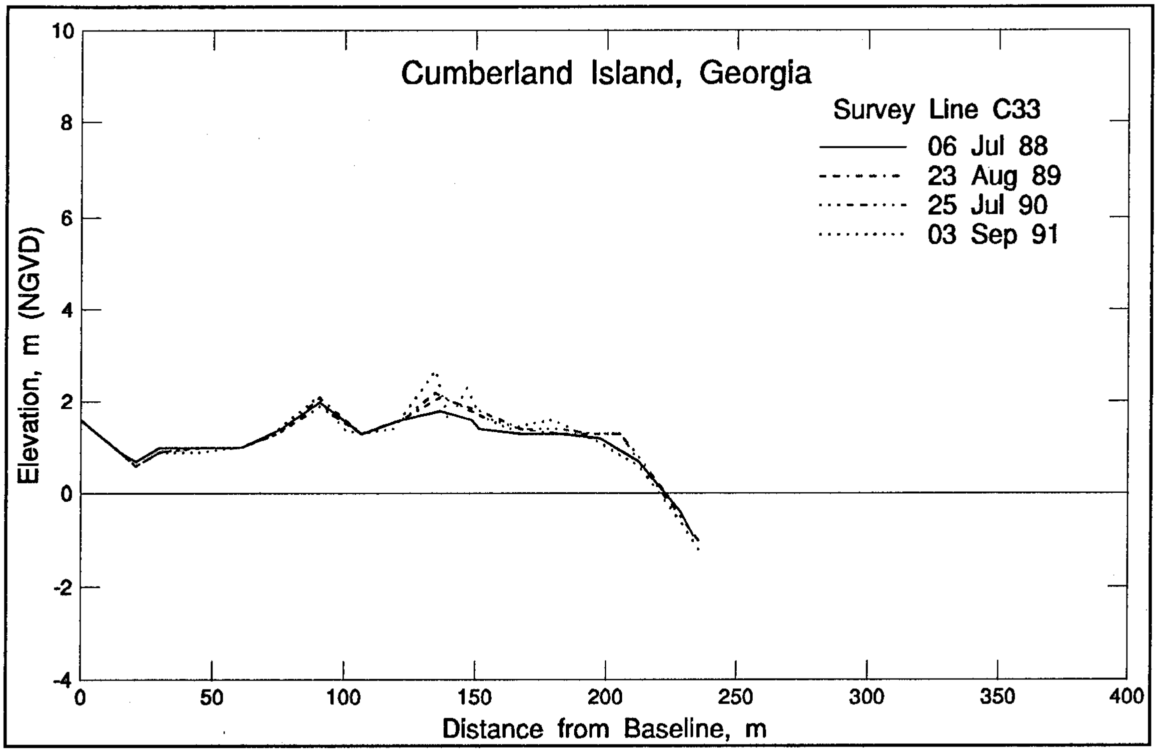


Figure D55. Cumberland Sound profiles, 1988-1991, Line C33

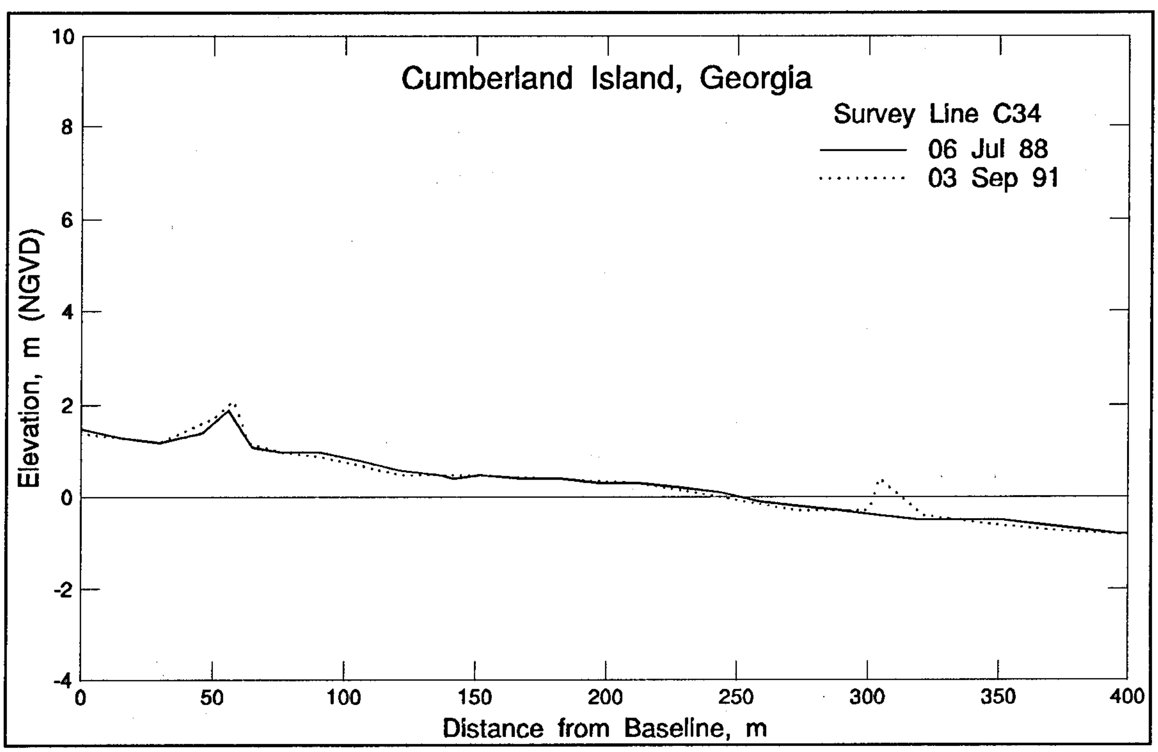


Figure D56. Cumberland Sound profiles, 1988 and 1991, Line C34

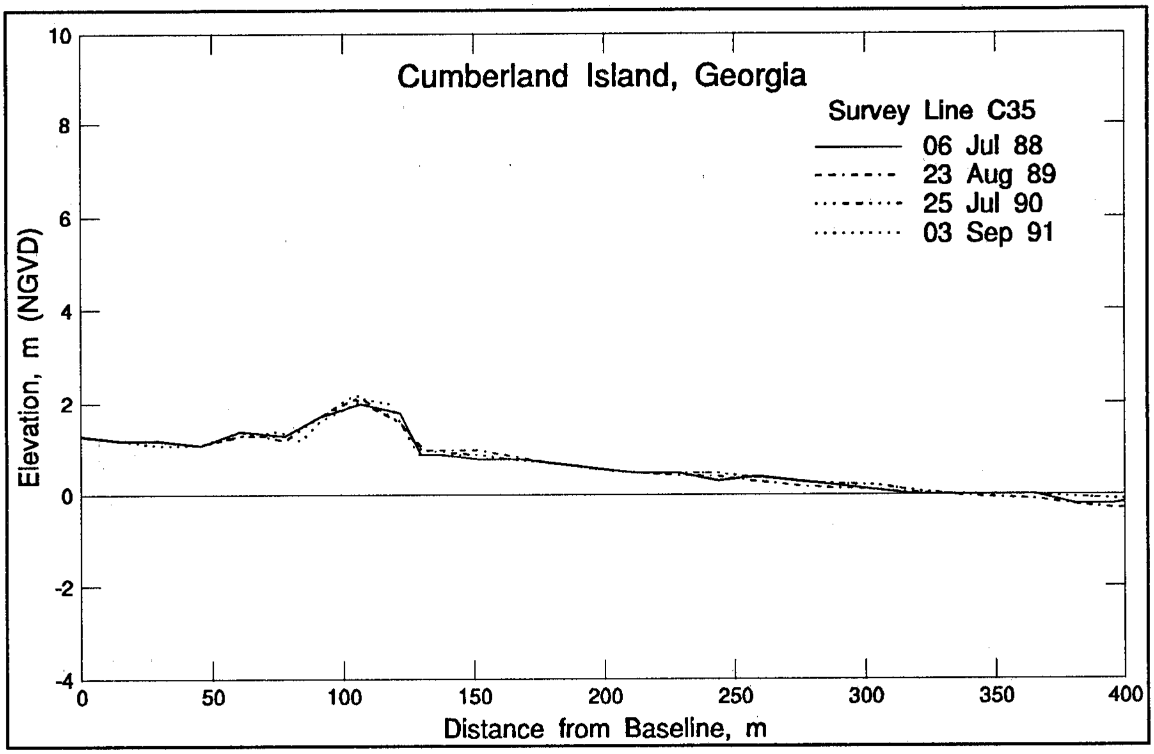


Figure D57. Cumberland Sound profiles, 1988-1991, Line C35

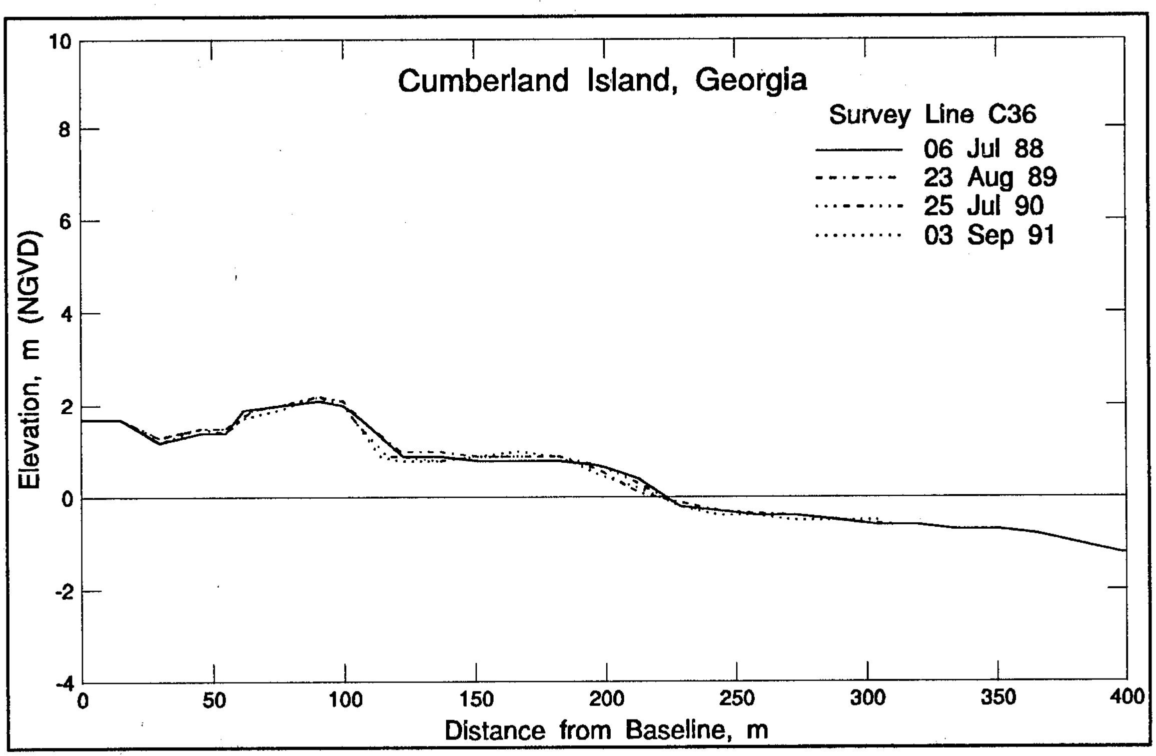


Figure D58. Cumberland Sound profiles, 1988-1991, Line C36

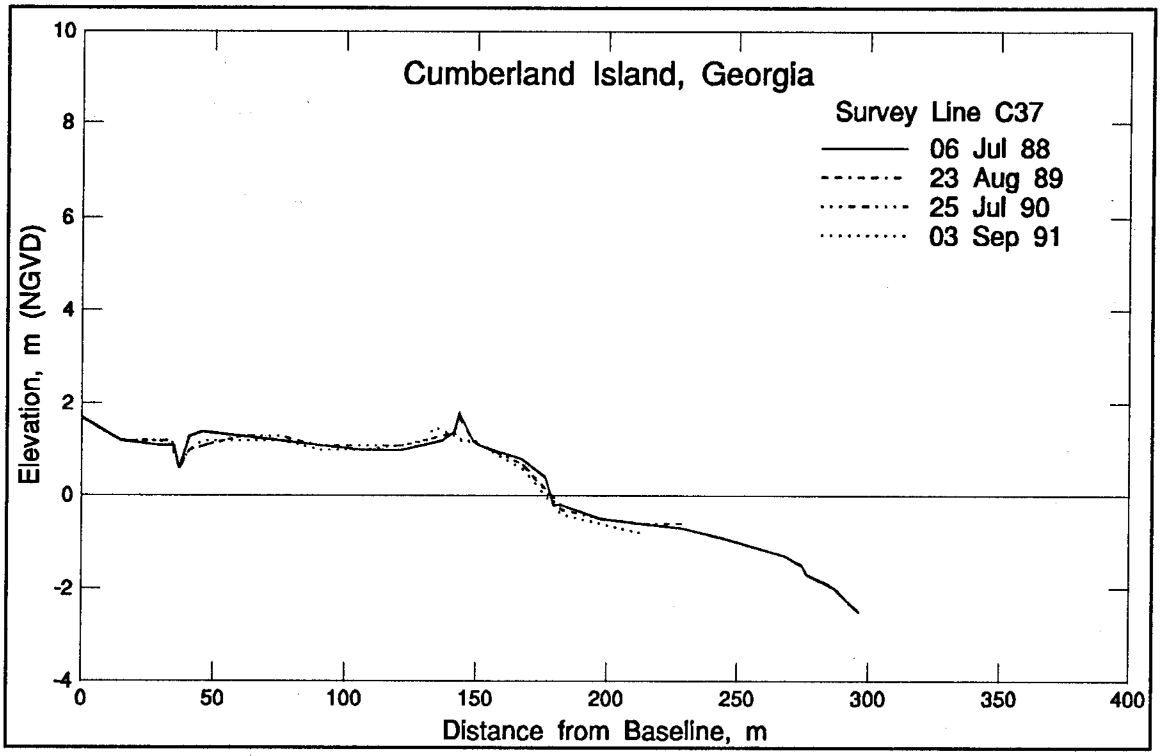


Figure D59. Cumberland Sound profiles, 1988-1991, Line C37

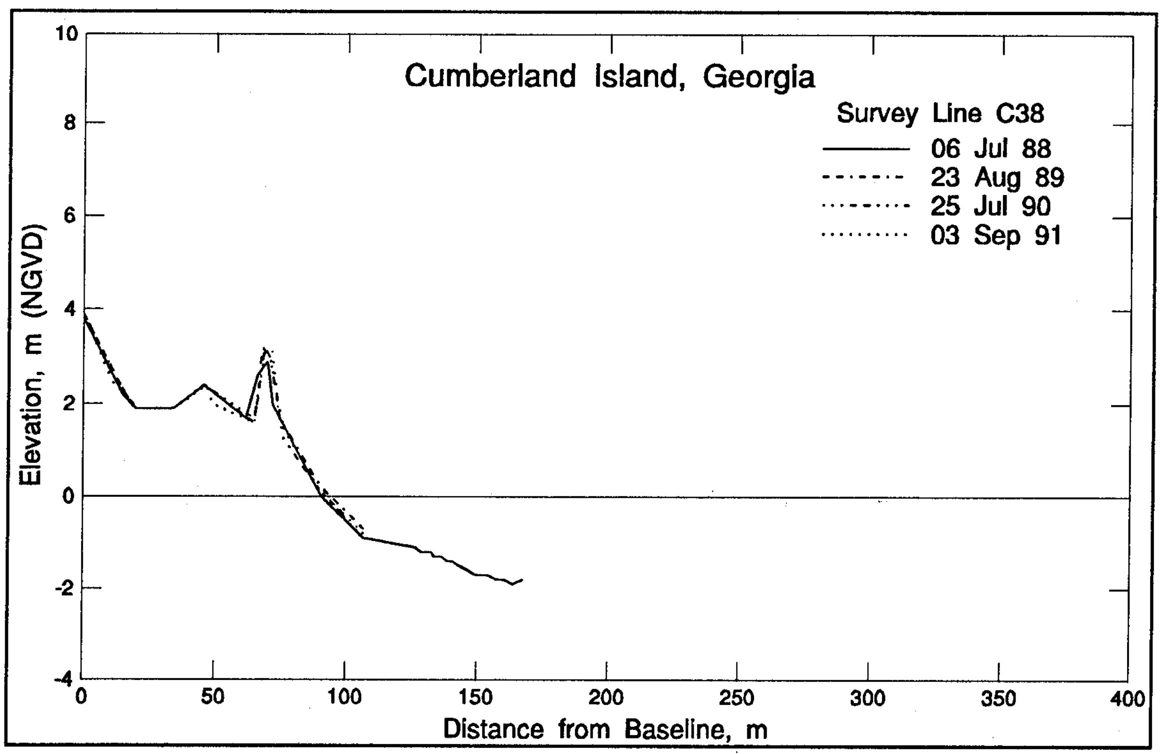


Figure D60. Cumberland Sound profiles, 1988-1991, Line C38

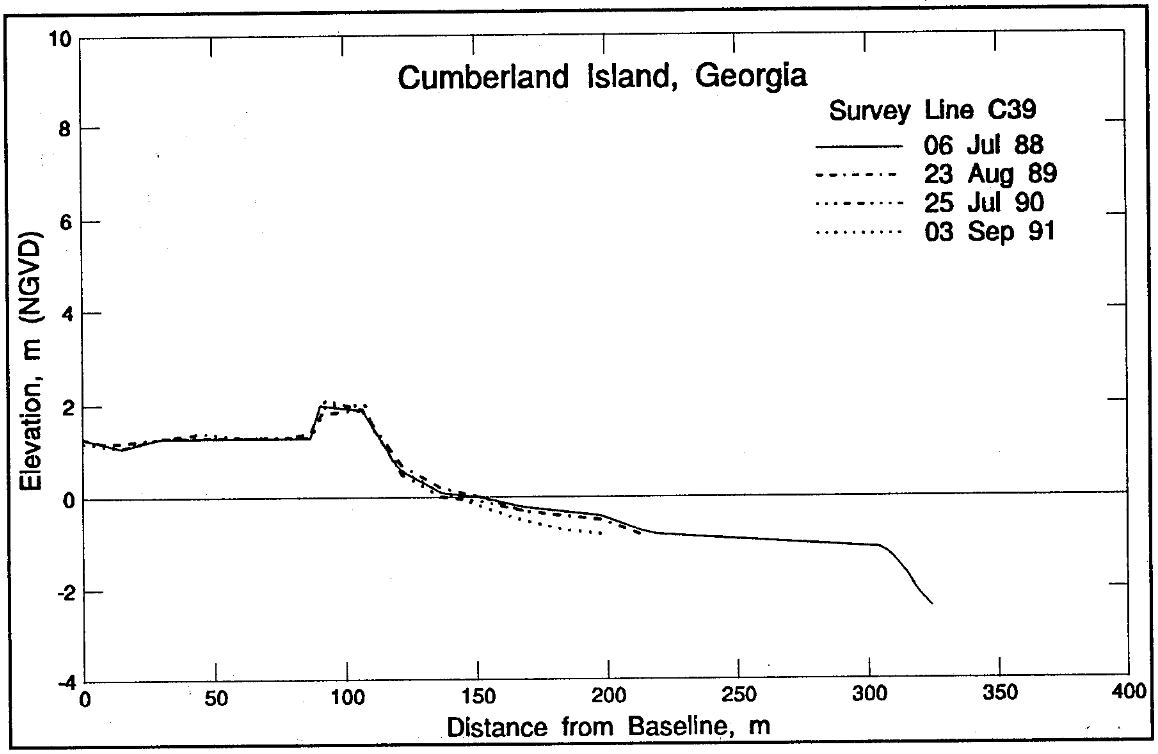


Figure D61. Cumberland Sound profiles, 1988-1991, Line C39

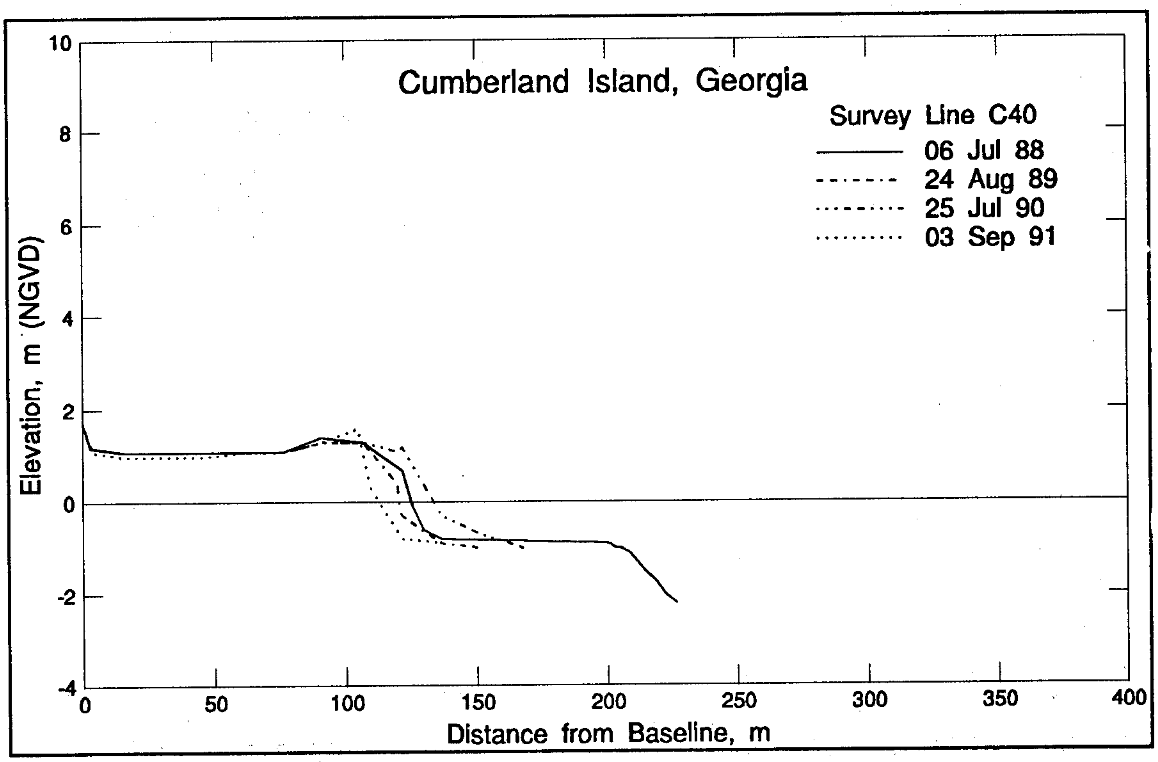


Figure D62. Cumberland Sound profiles, 1988-1991, Line C40

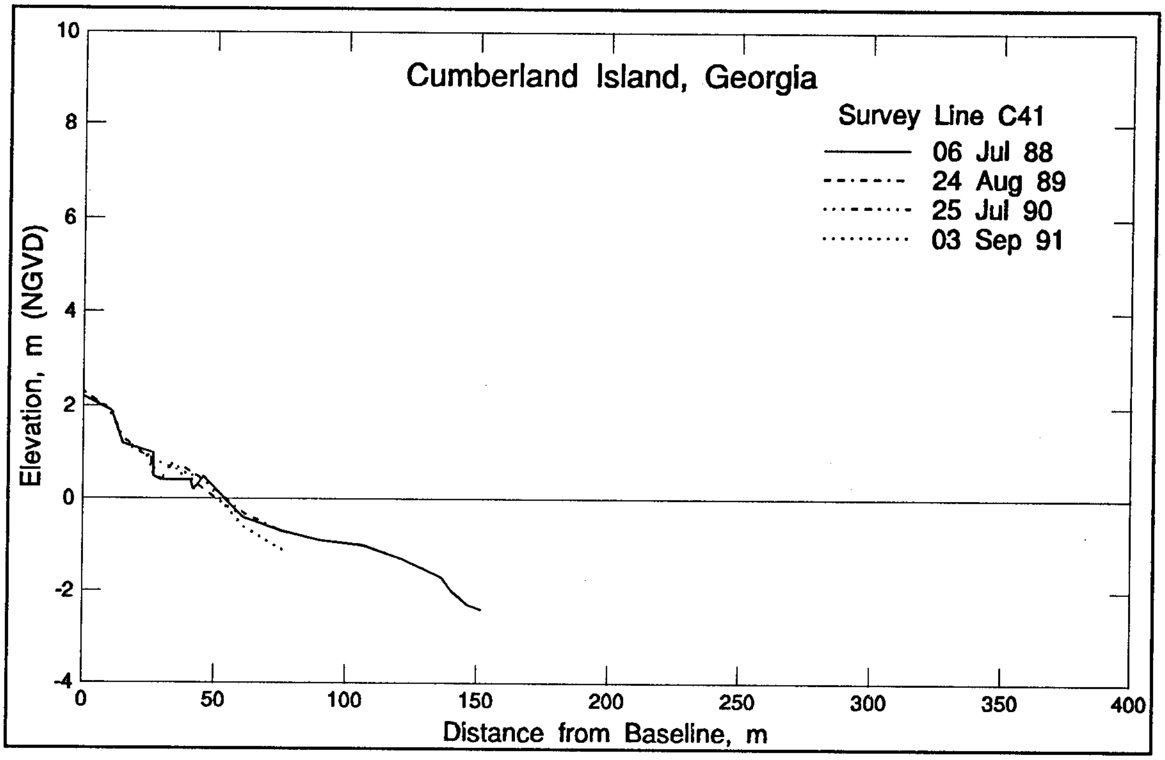


Figure D63. Cumberland Sound profiles, 1988-1991, Line C41

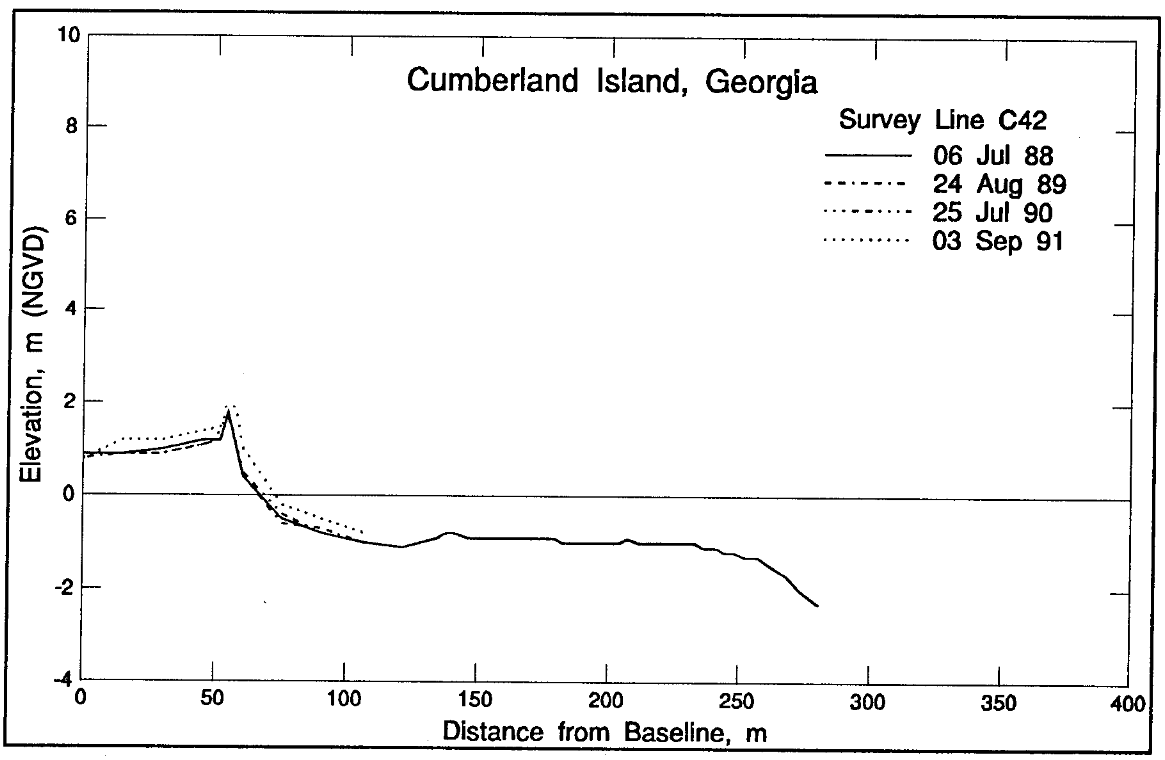


Figure D64. Cumberland Sound profiles, 1988-1991, Line C42

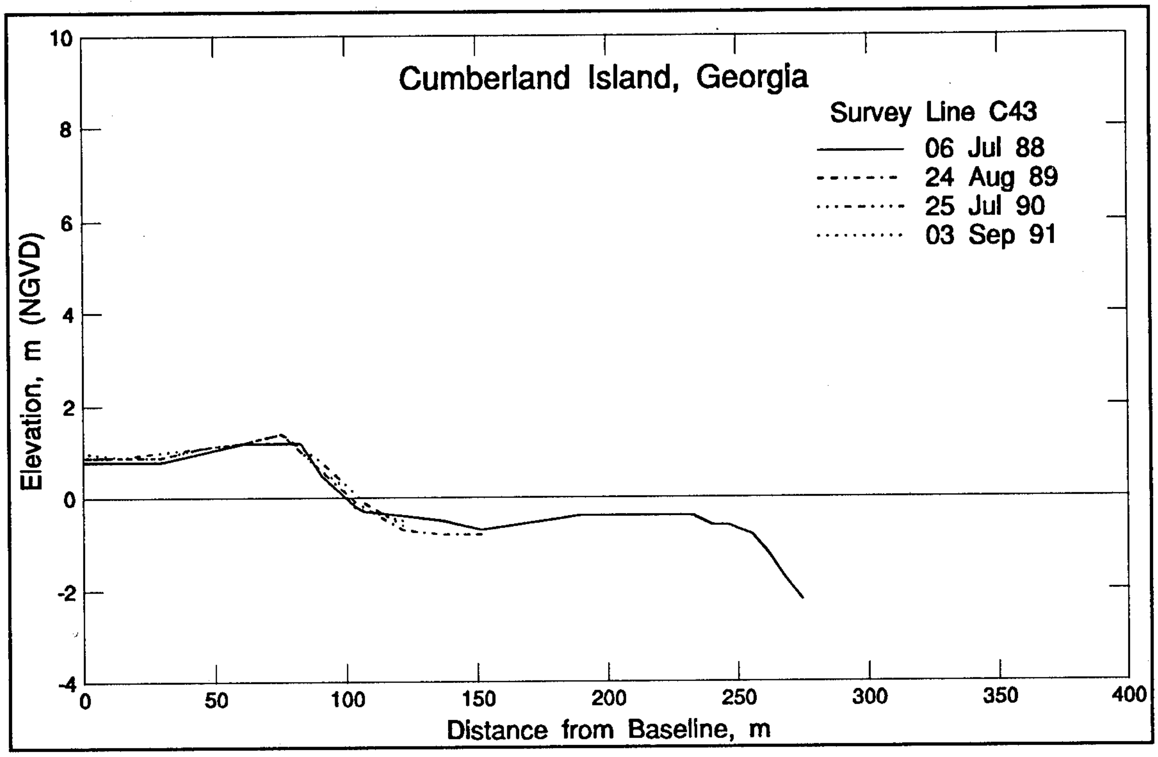


Figure D65. Cumberland Sound profiles, 1988-1991, Line C43

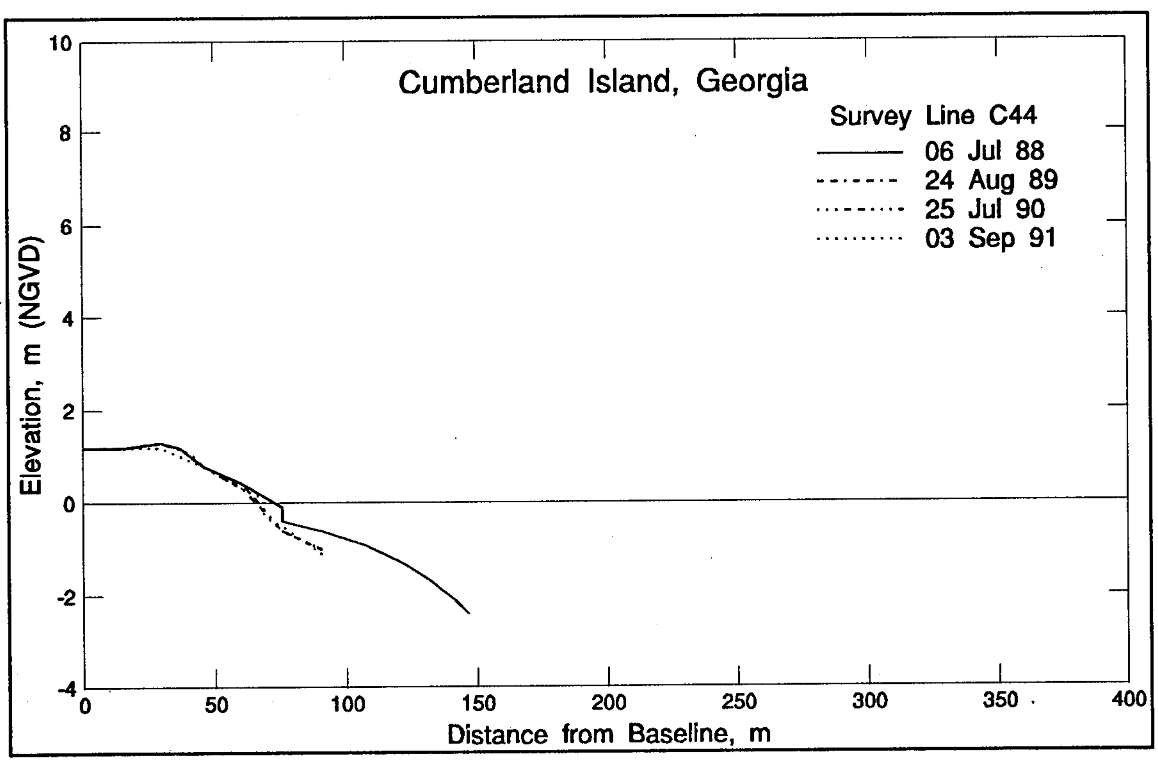


Figure D66. Cumberland Sound profiles, 1988-1991, Line C44

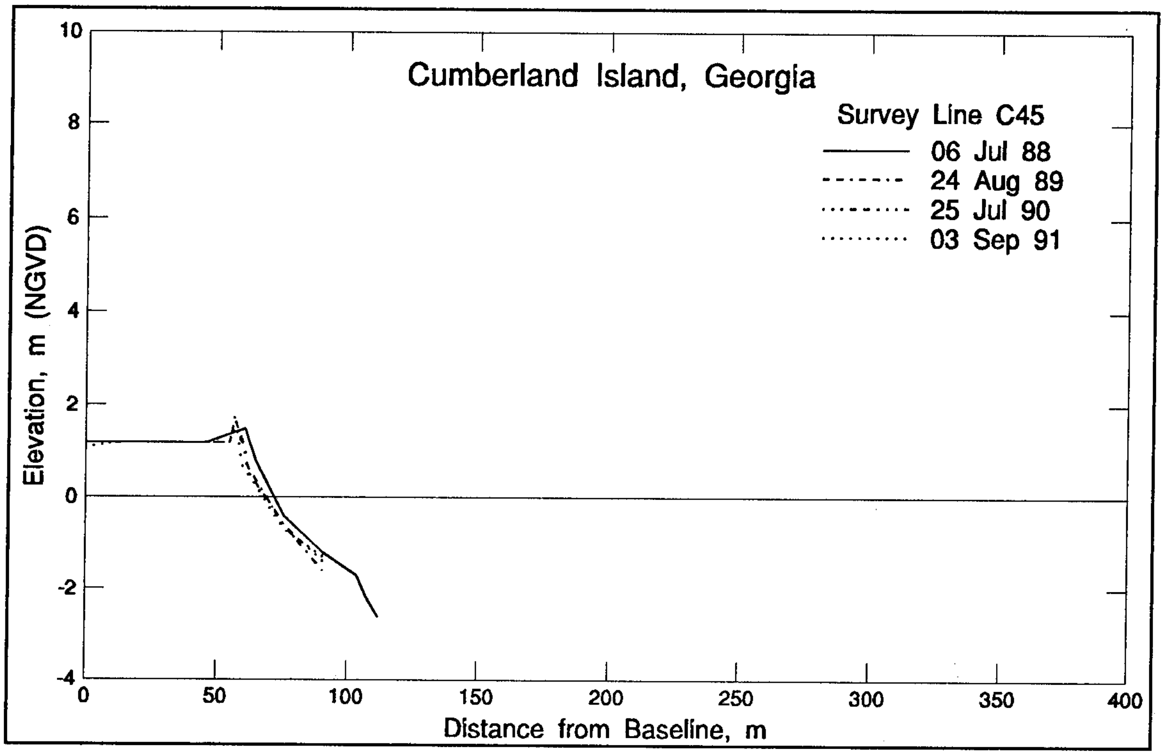


Figure D67. Cumberland Sound profiles, 1988-1991, Line C45

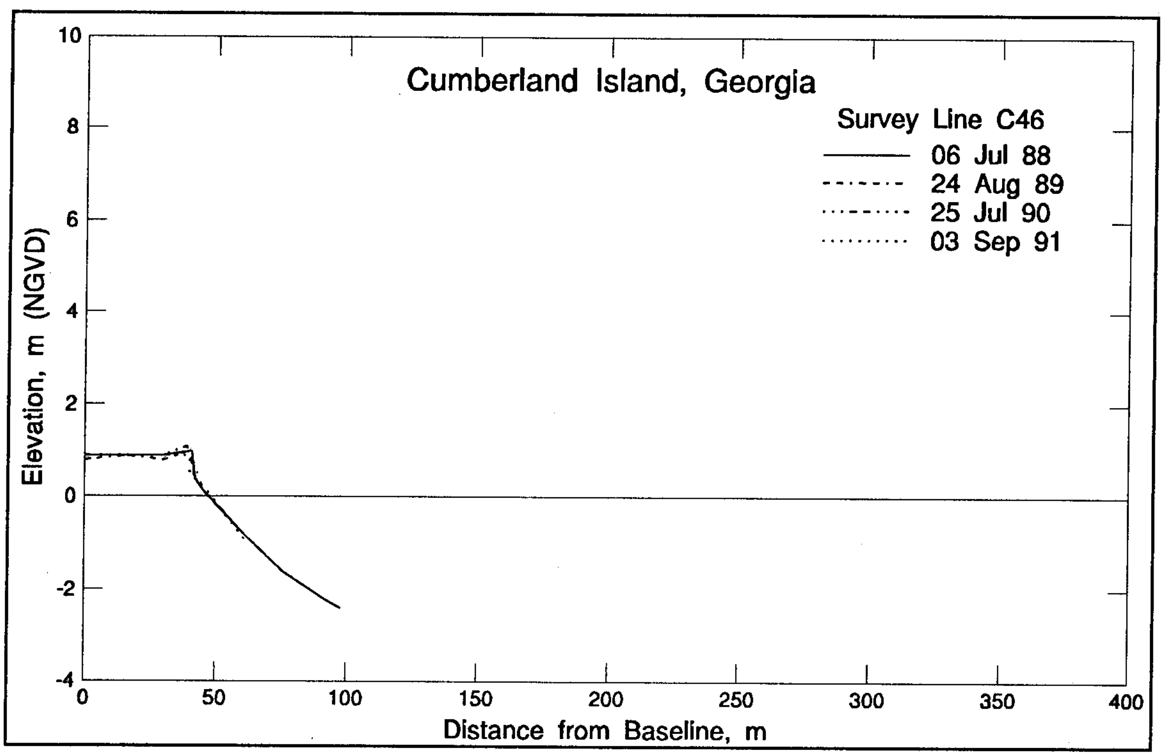


Figure D68. Cumberland Sound profiles, 1988-1991, Line C46

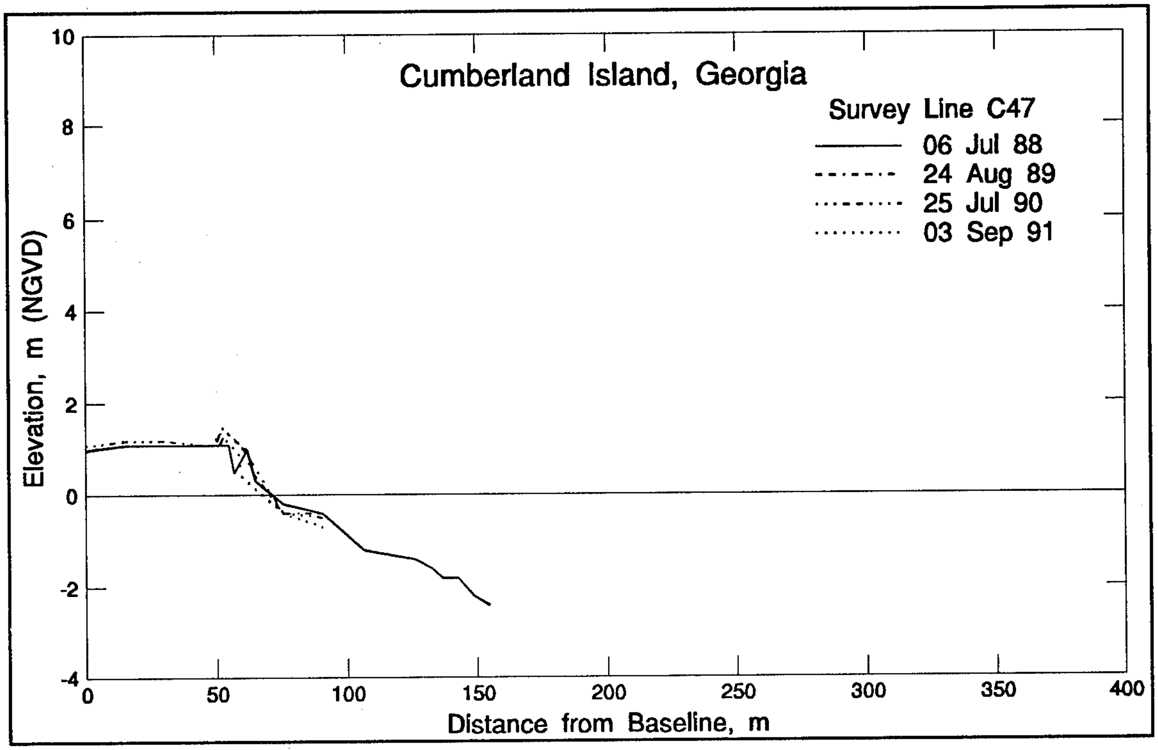


Figure D69. Cumberland Sound profiles, 1988-1991, Line C47

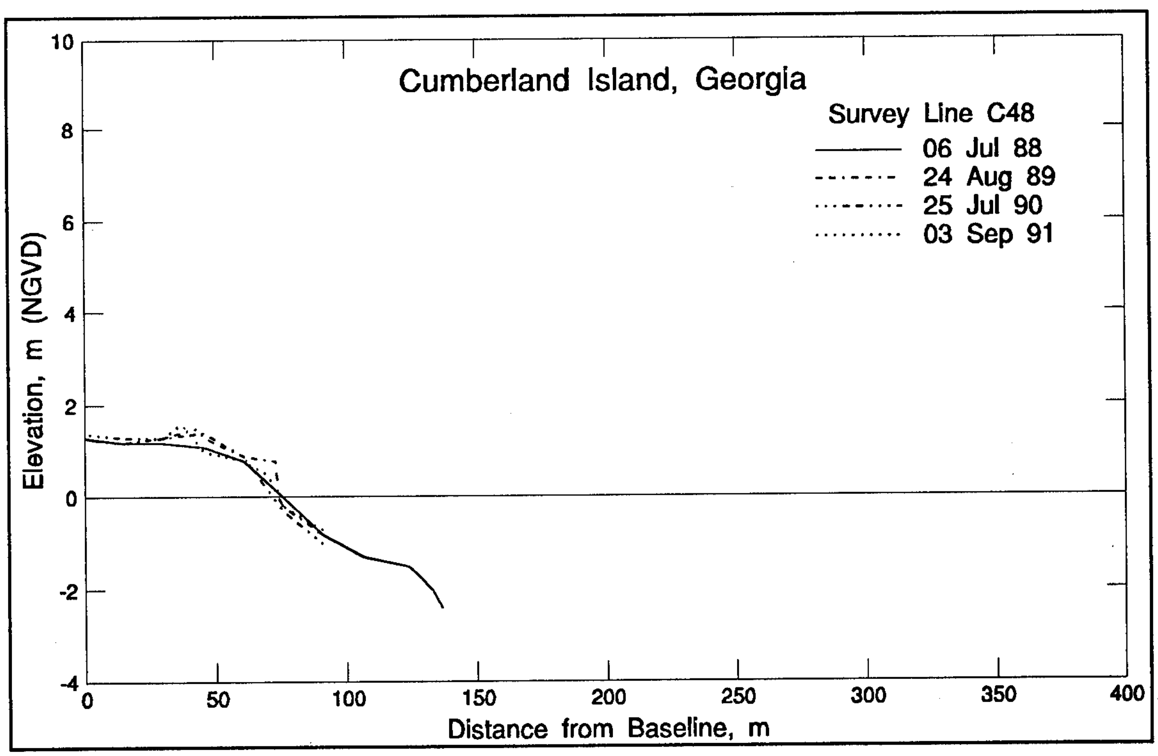


Figure D70. Cumberland Sound profiles, 1988-1991, Line C48

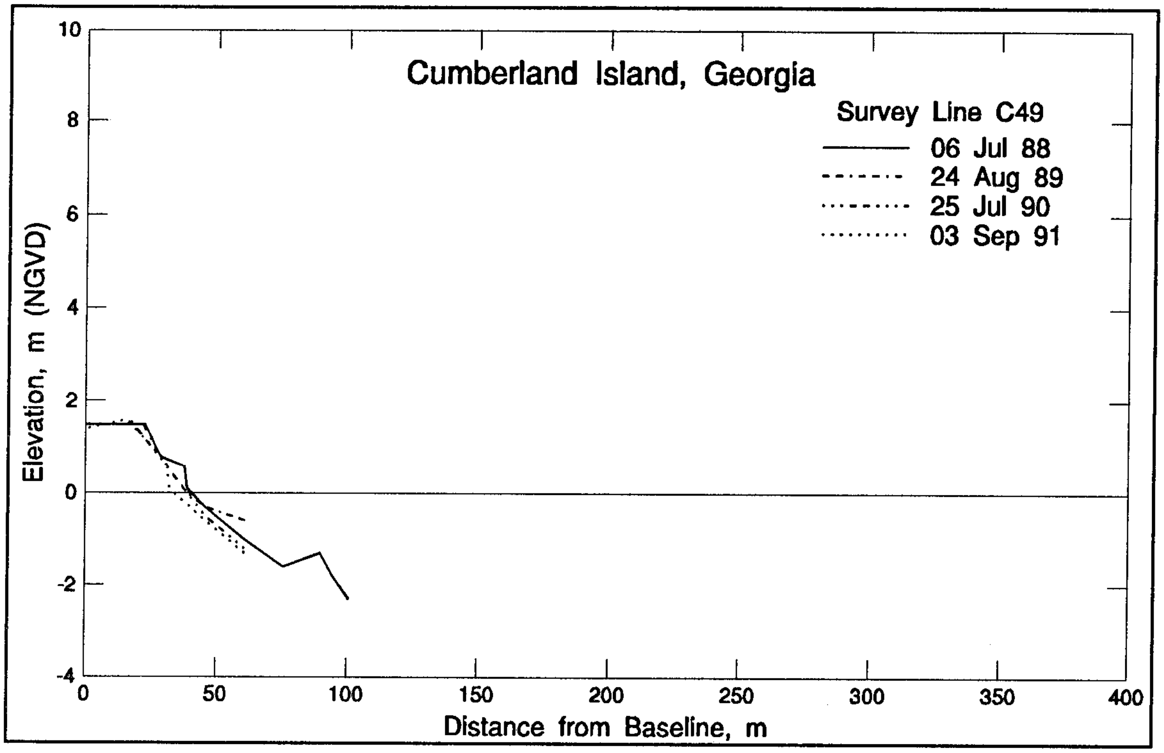


Figure D71. Cumberland Sound profiles, 1988-1991, Line C49

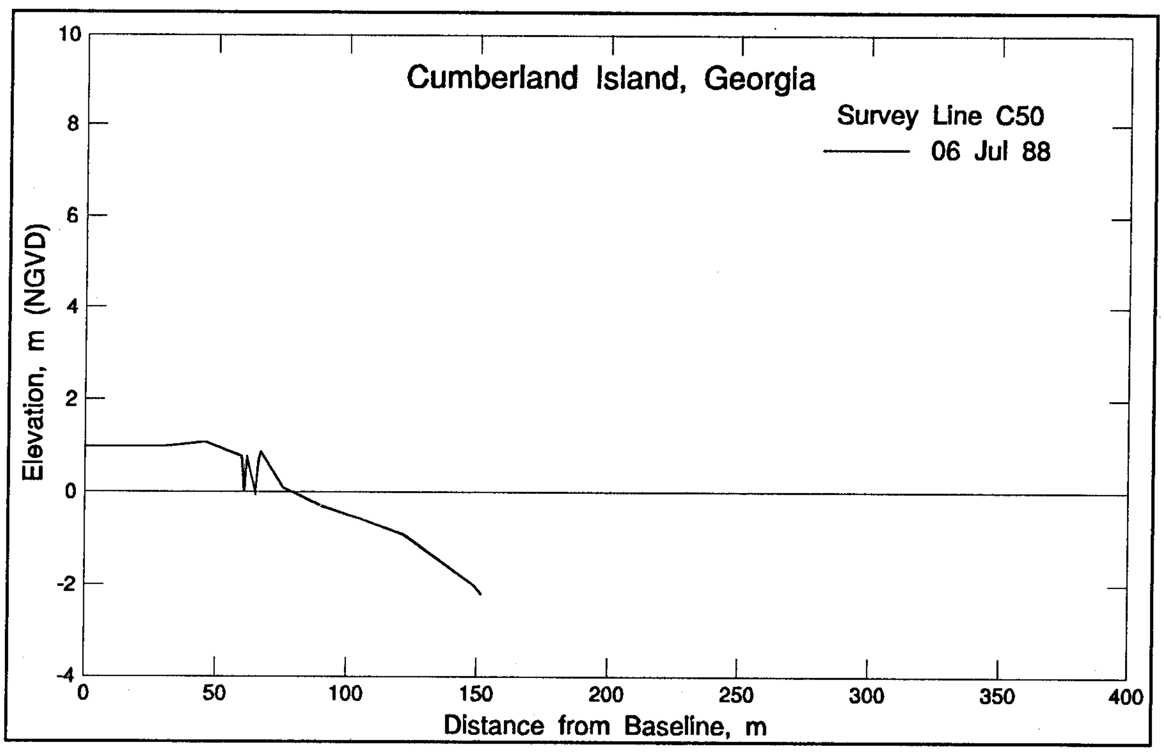


Figure D72. Cumberland Sound profile, 1988, Line C50

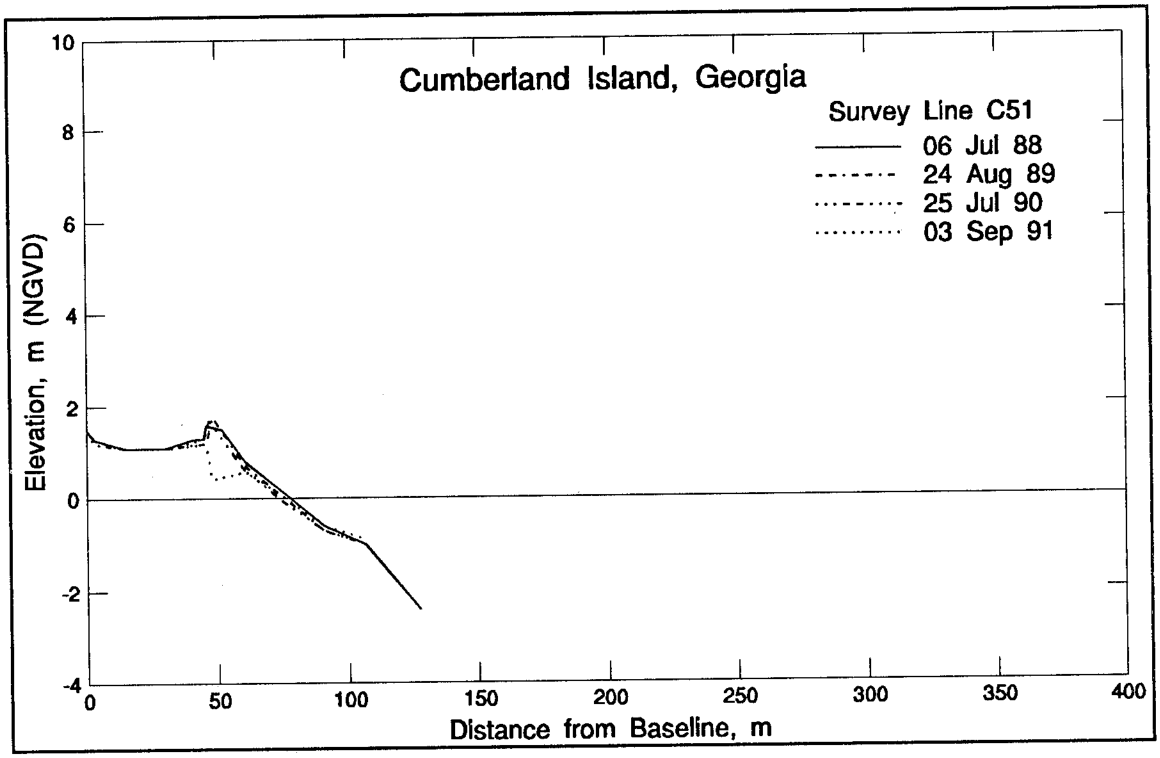


Figure D73. Cumberland Sound profiles, 1988-1991, Line C51

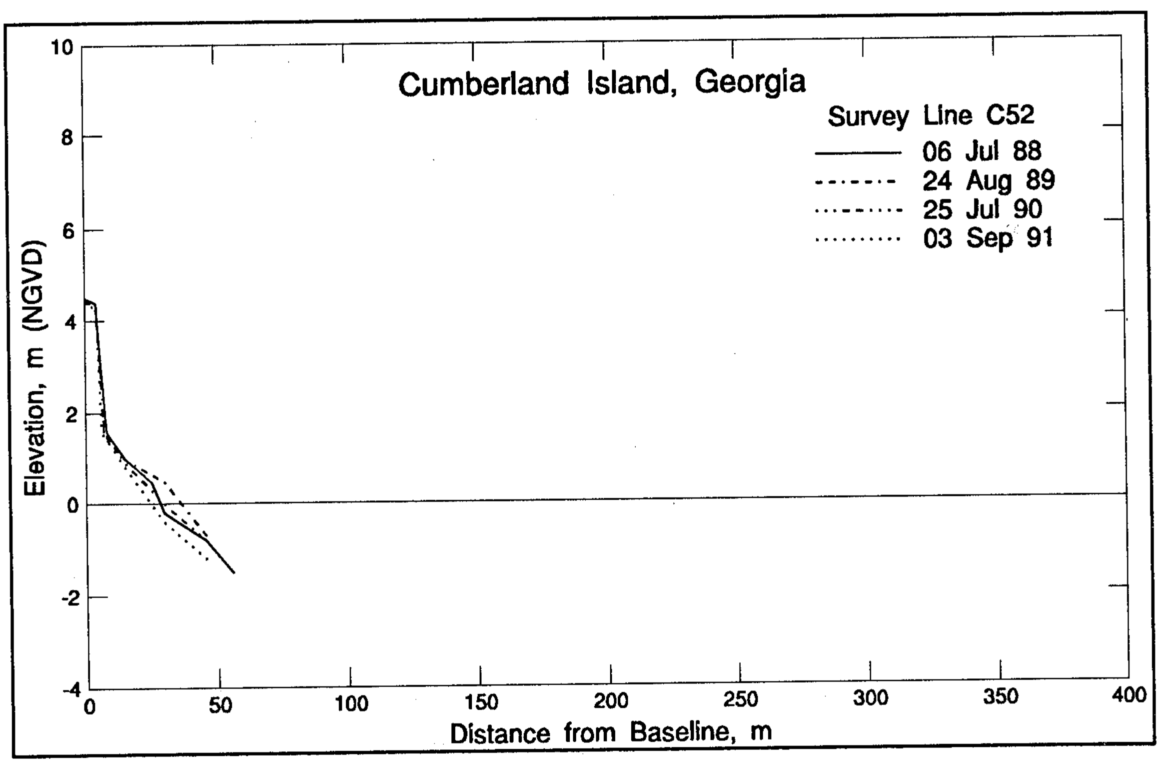


Figure D74. Cumberland Sound profiles, 1988-1991, Line C52

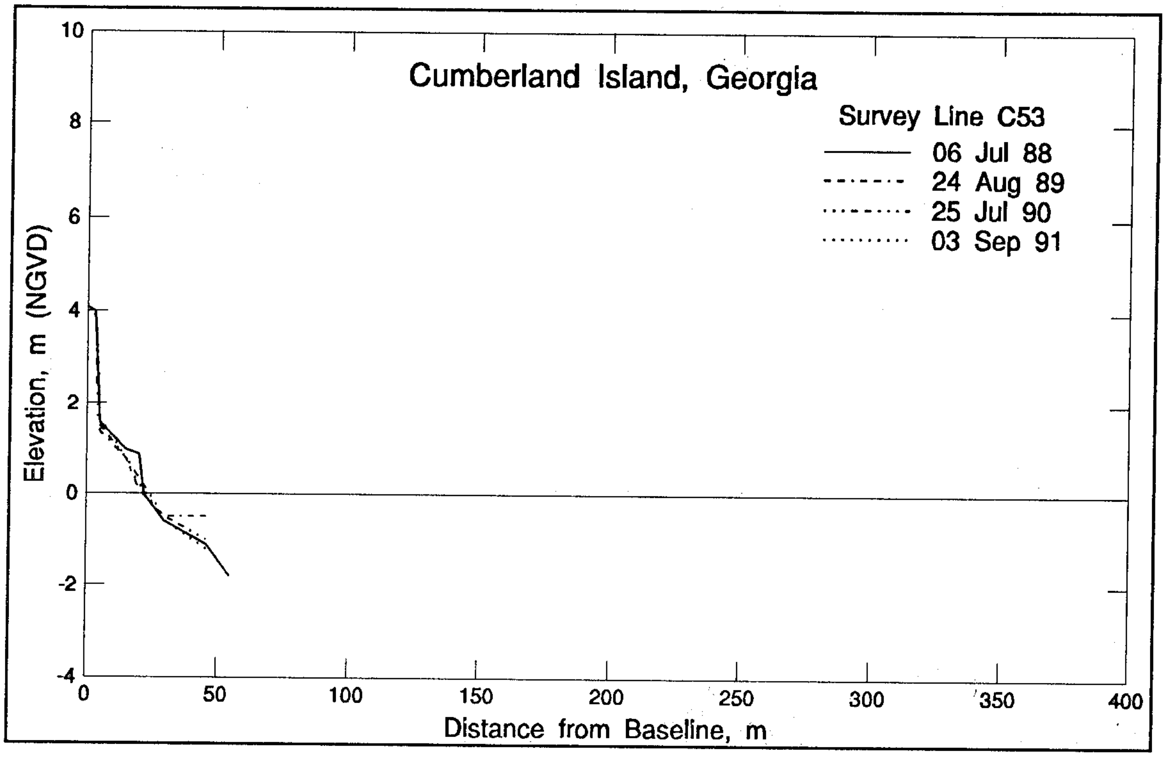


Figure D75. Cumberland Sound profiles, 1988-1991, Line C53

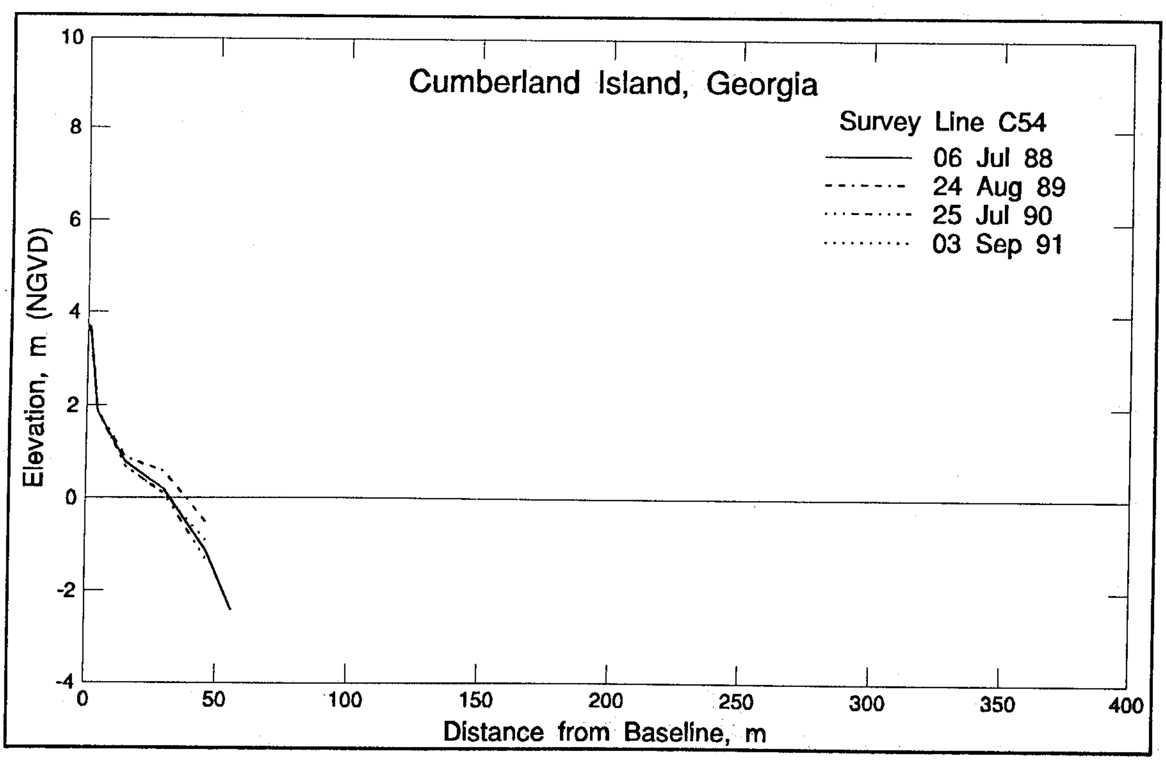


Figure D76. Cumberland Sound profiles, 1988-1991, Line C54

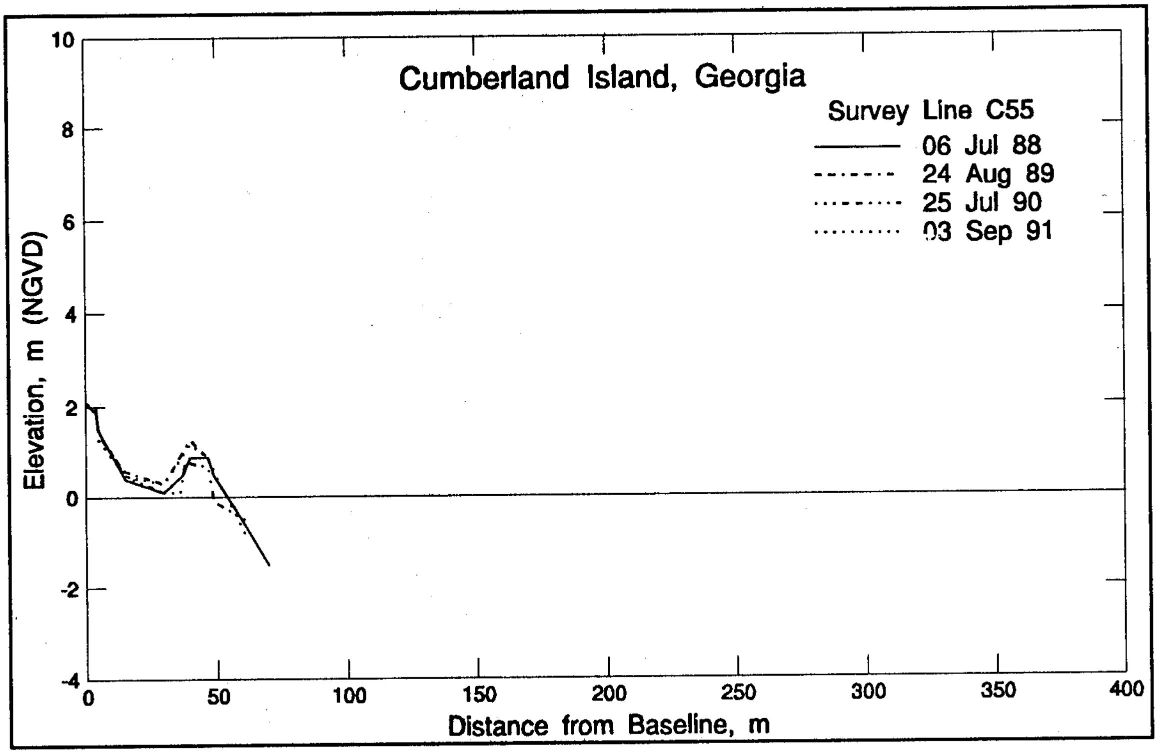


Figure D77. Cumberland Sound profiles, 1988-1991, Line C55

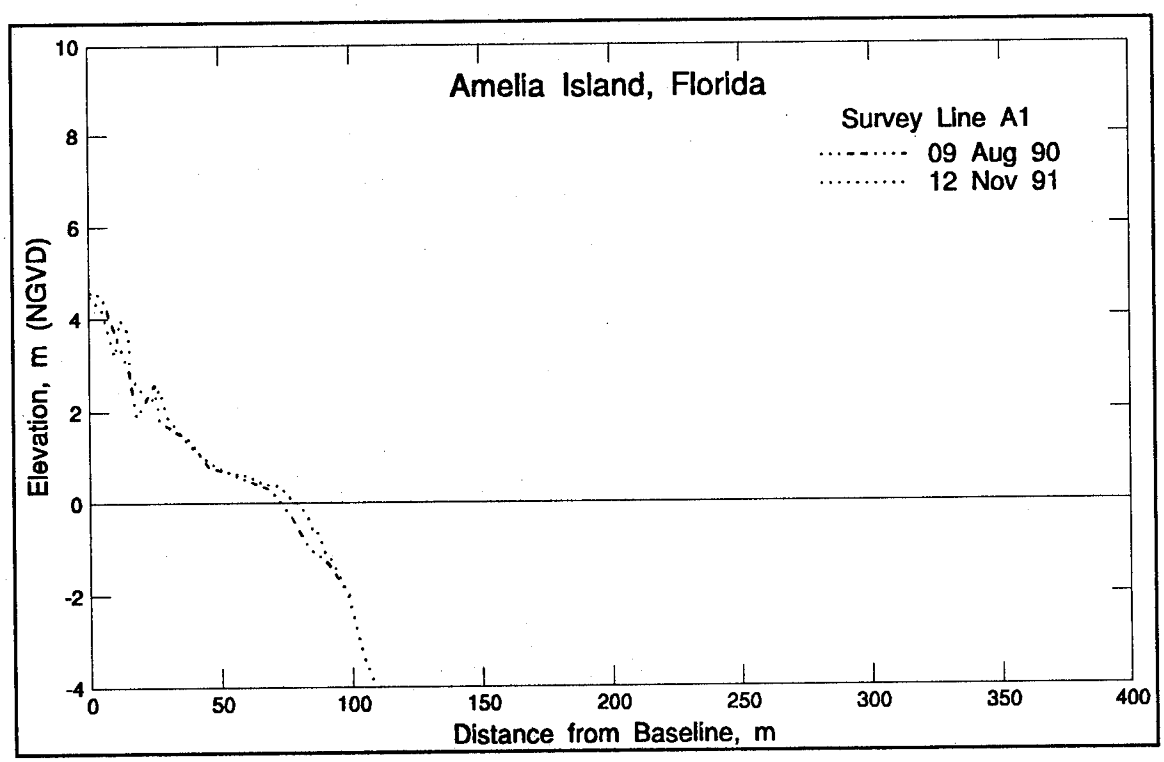


Figure D78. Beach and nearshore profiles, 1990 and 1991, Line A1

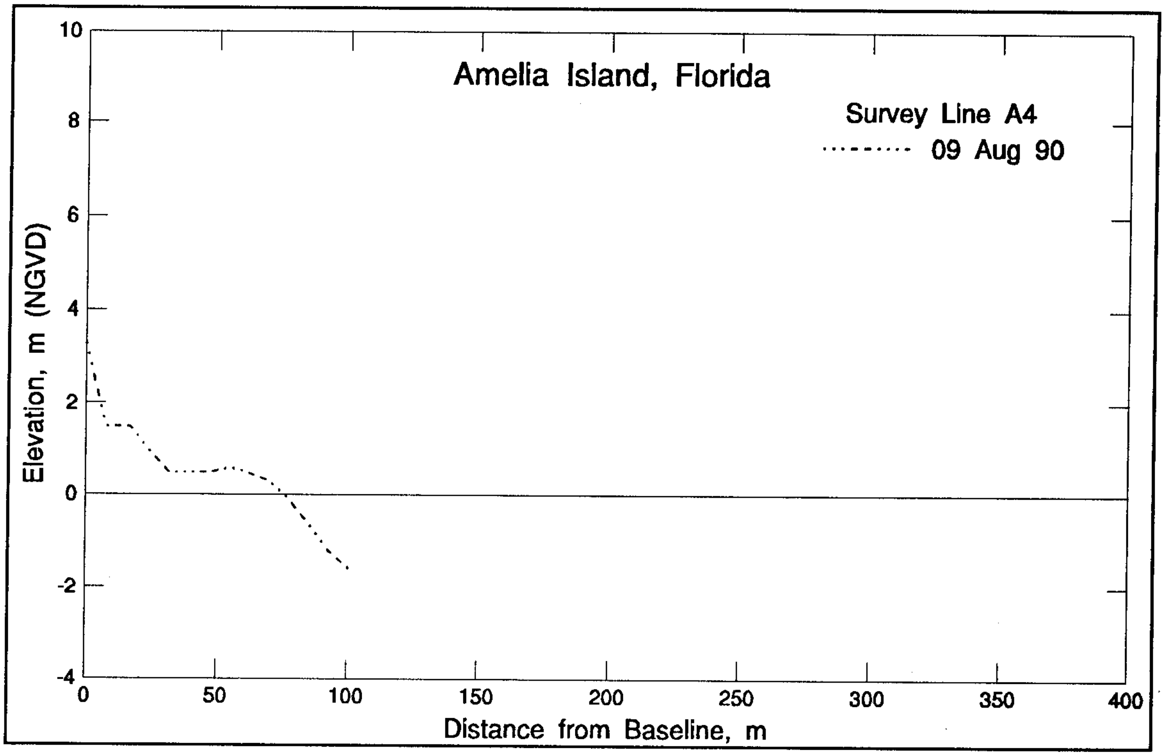


Figure D79. Beach and nearshore profile, 1990, Line A4

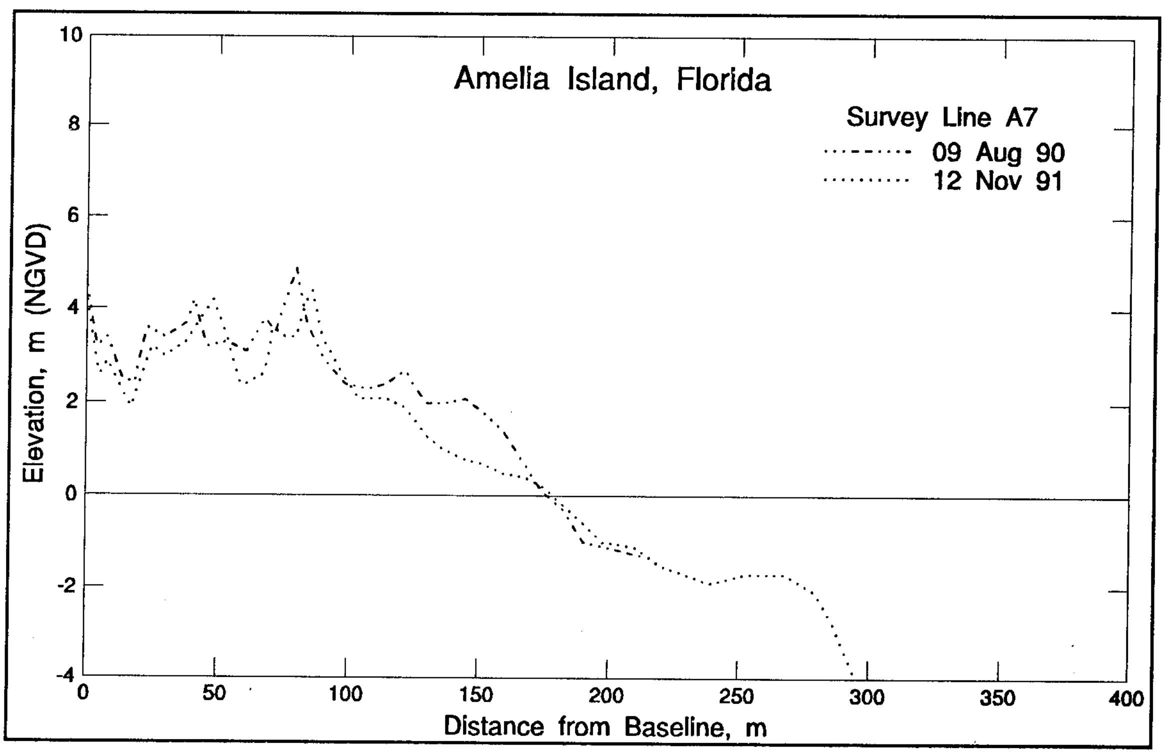


Figure D80. Beach and nearshore profiles, 1990 and 1991, Line A7

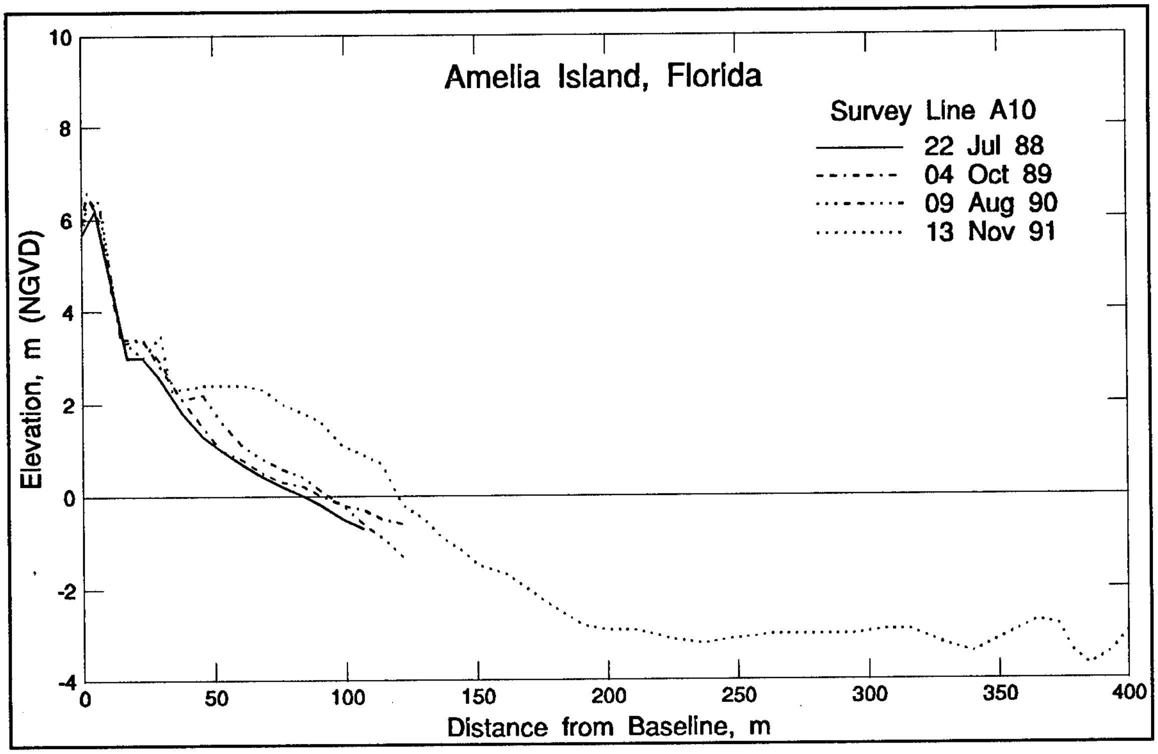


Figure D81. Beach and nearshore profiles, 1988-1991, Line A10

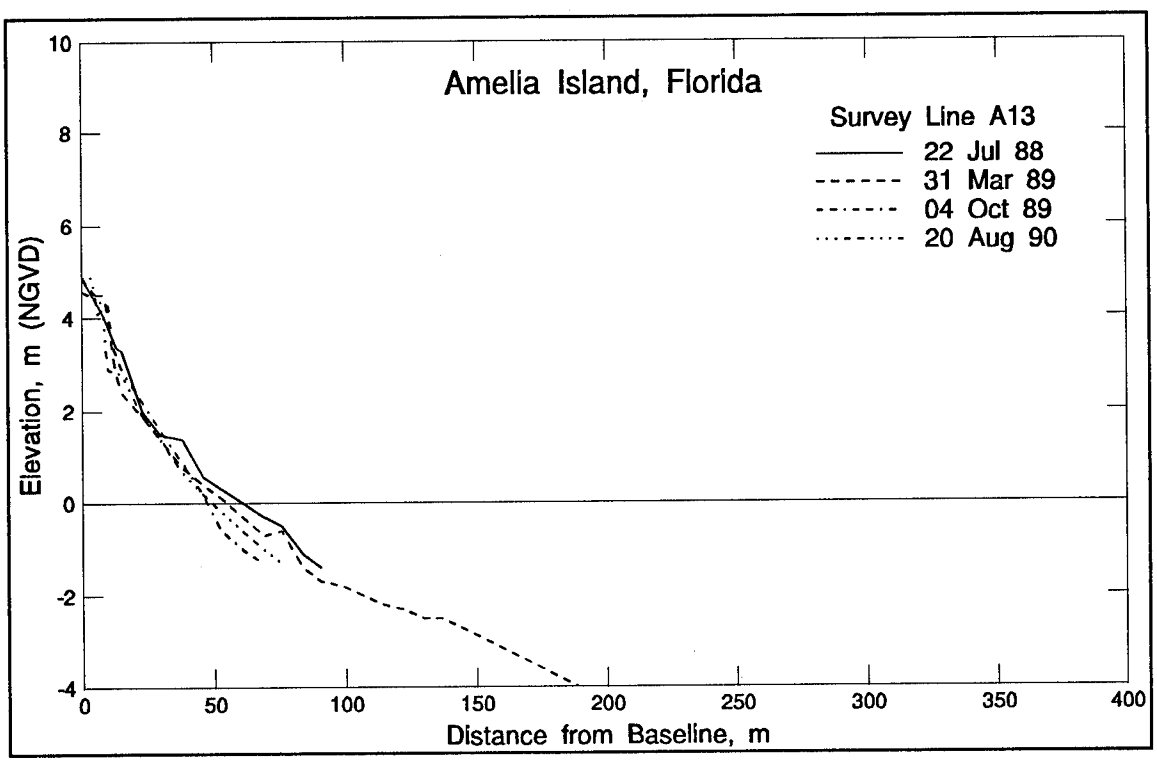


Figure D82. Beach and nearshore profiles, 1988-1990, Line A13

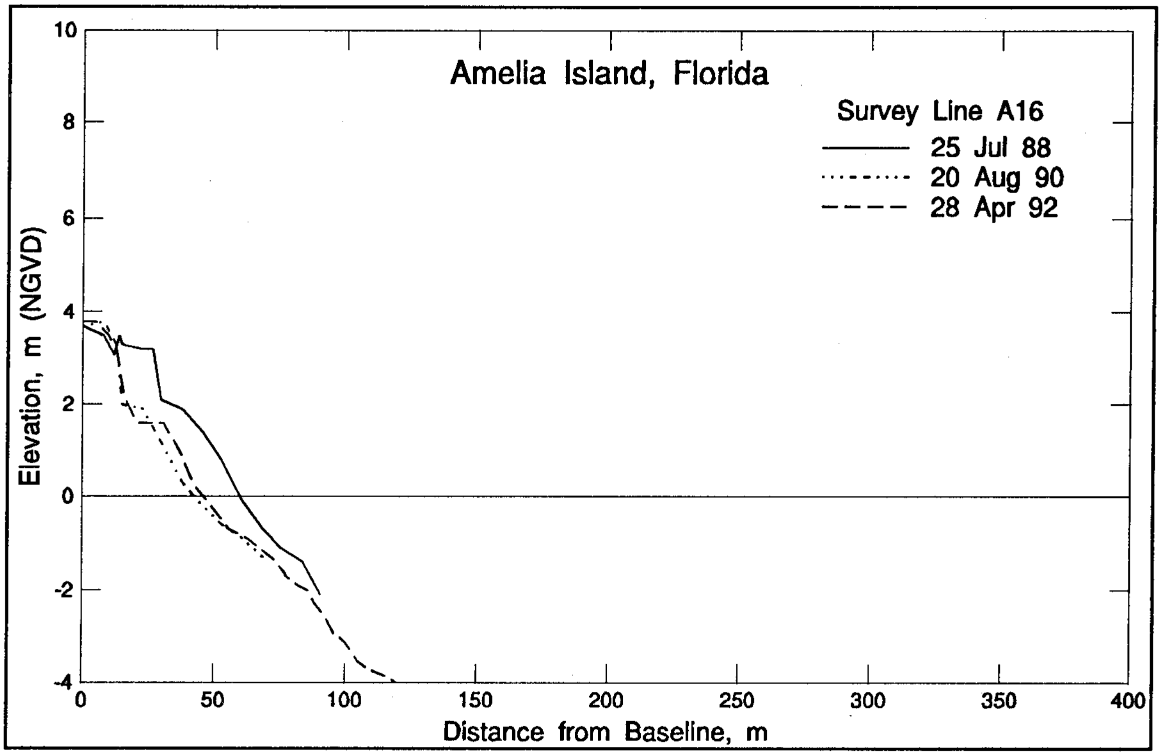


Figure D83. Beach and nearshore profiles, 1988-1992, Line A16

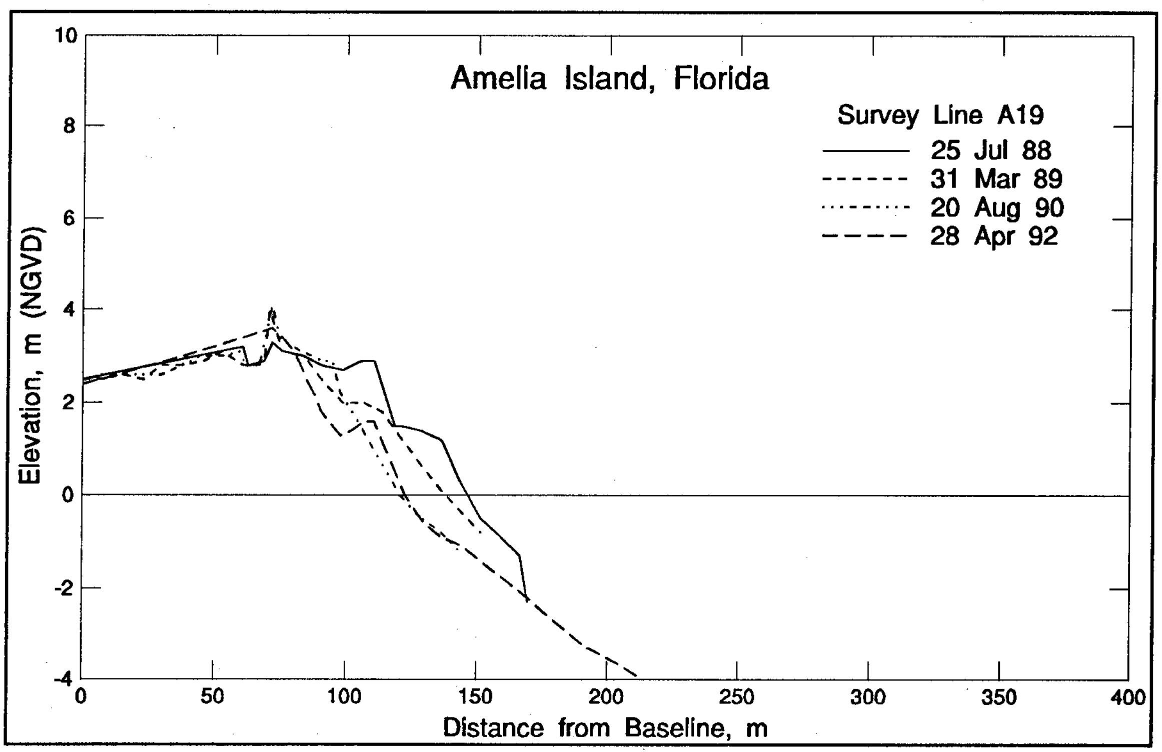


Figure D84. Beach and nearshore profiles, 1988-1992, Line A19

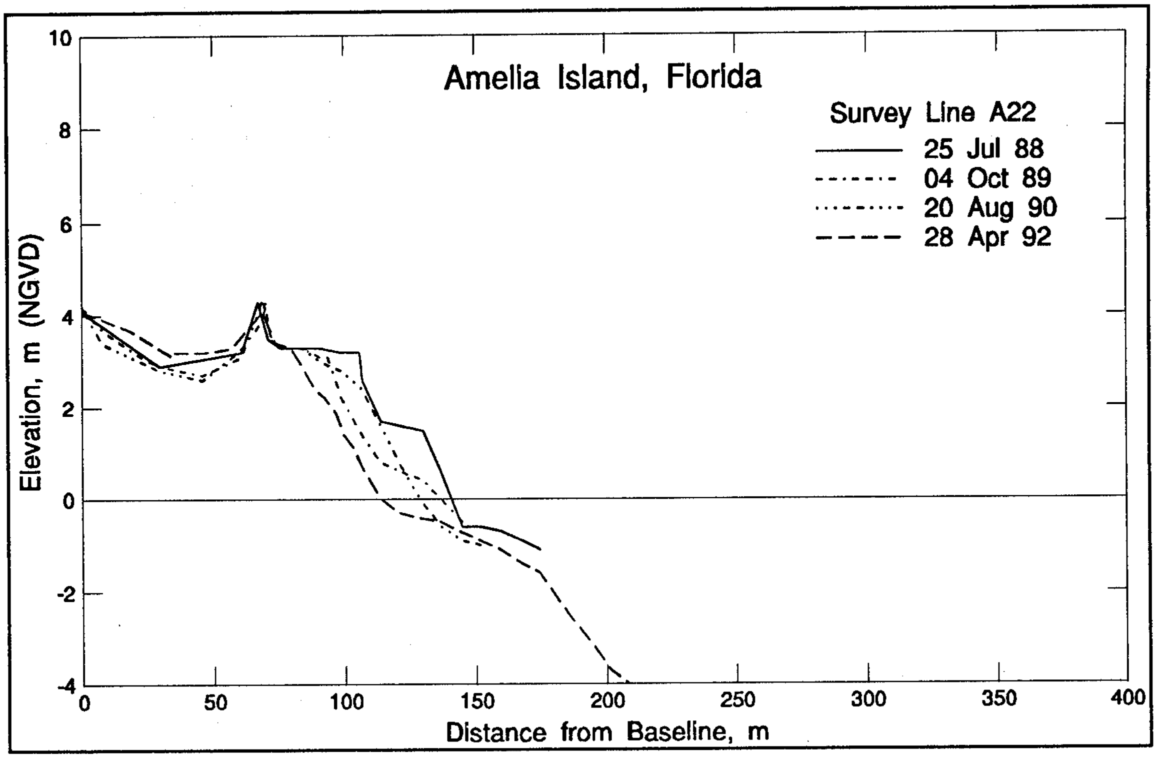


Figure D85. Beach and nearshore profiles, 1988-1992, Line A22

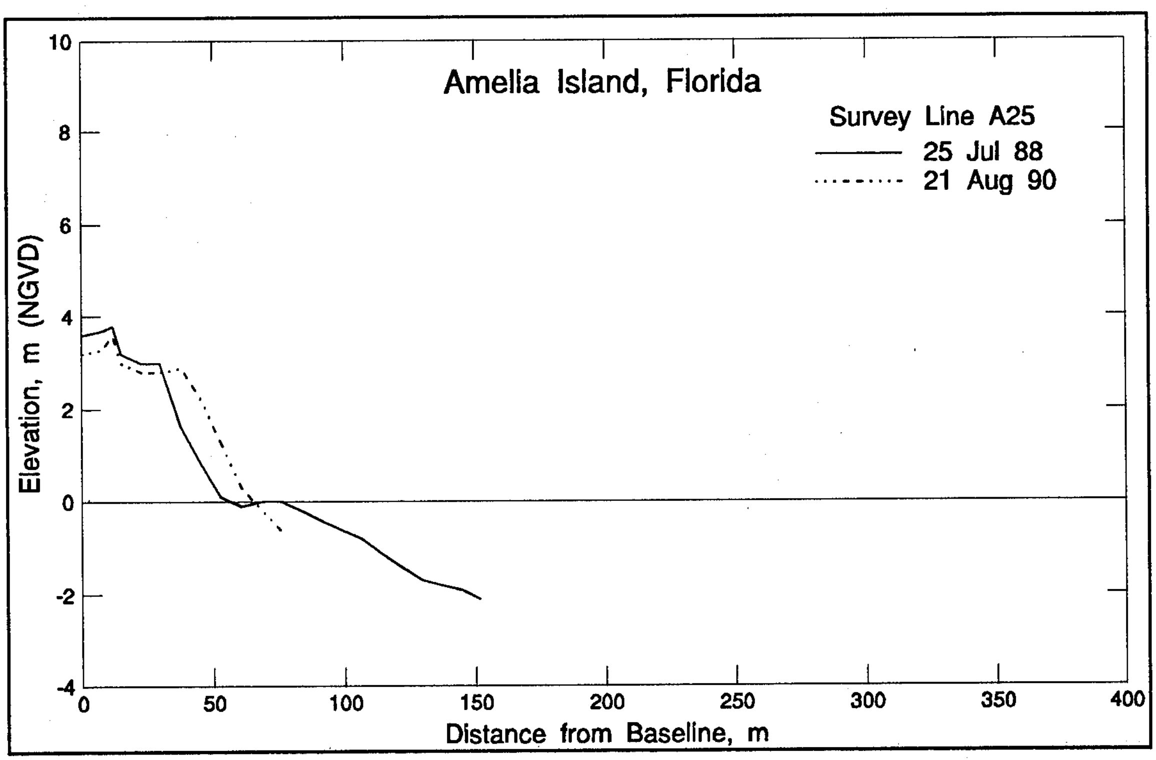


Figure D86. Beach and nearshore profiles, 1988 and 1990, Line A25

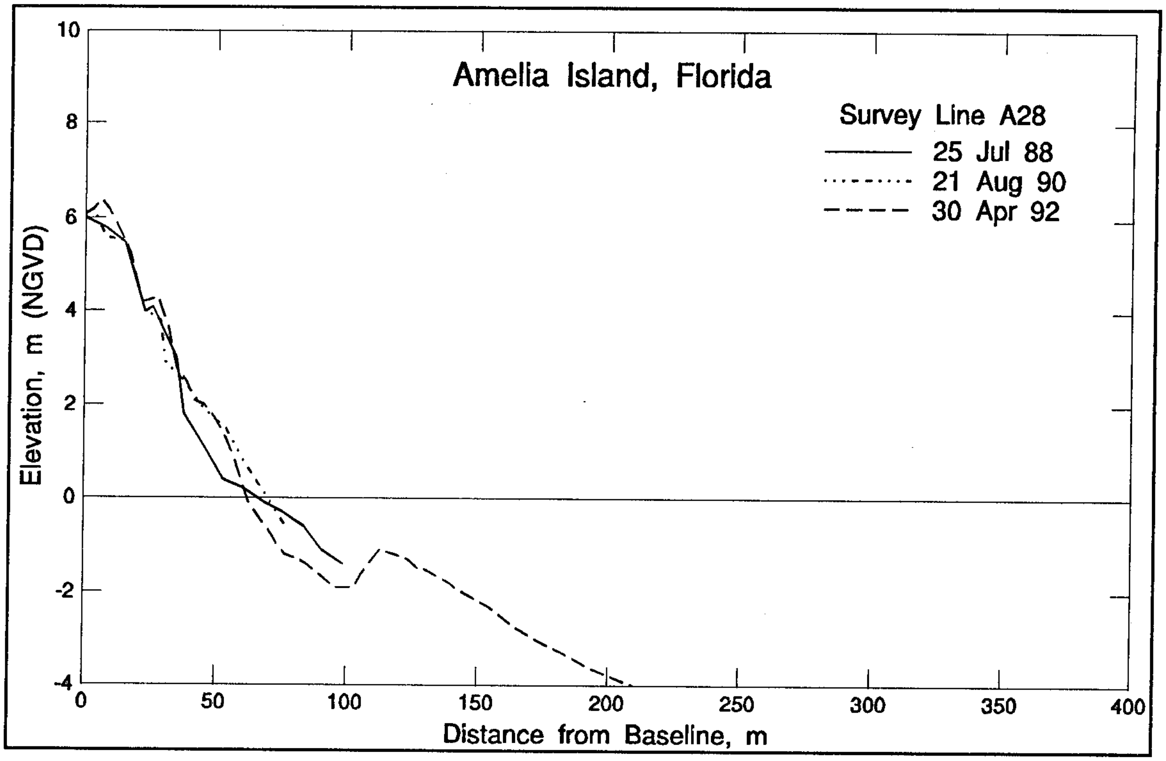


Figure D87. Beach and nearshore profiles, 1988-1992, Line A28

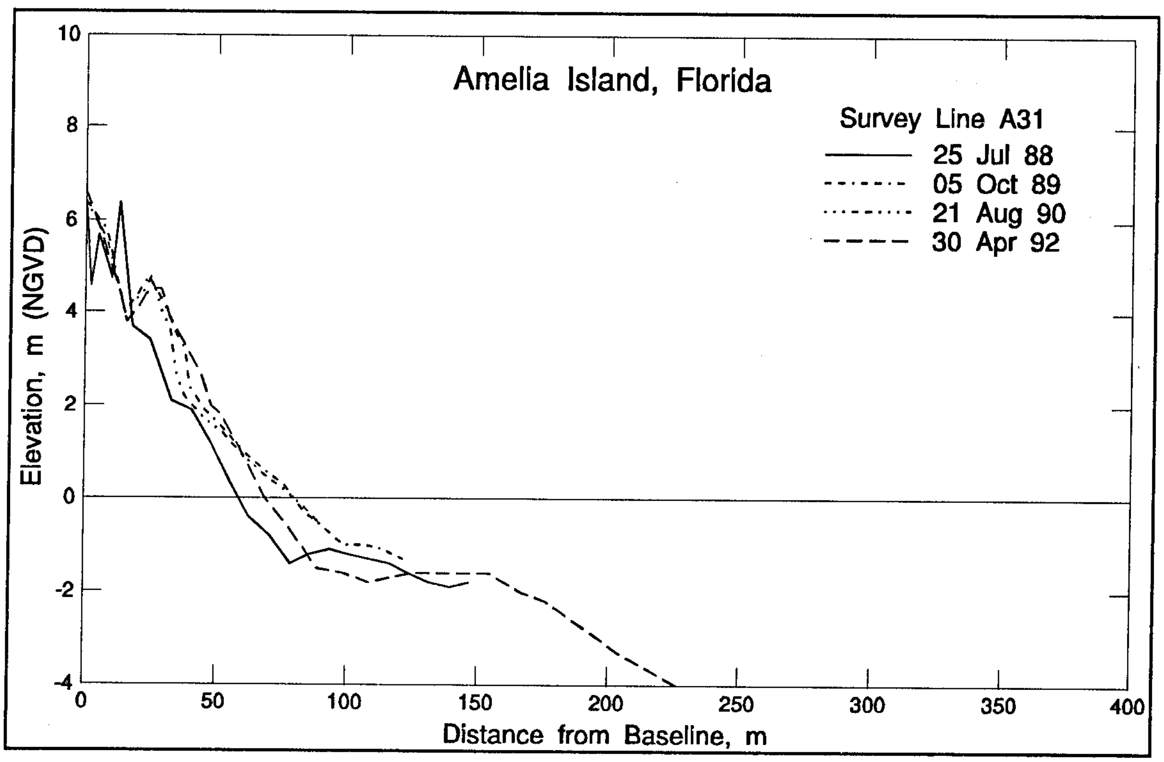


Figure D88. Beach and nearshore profiles, 1988-1992, Line A31

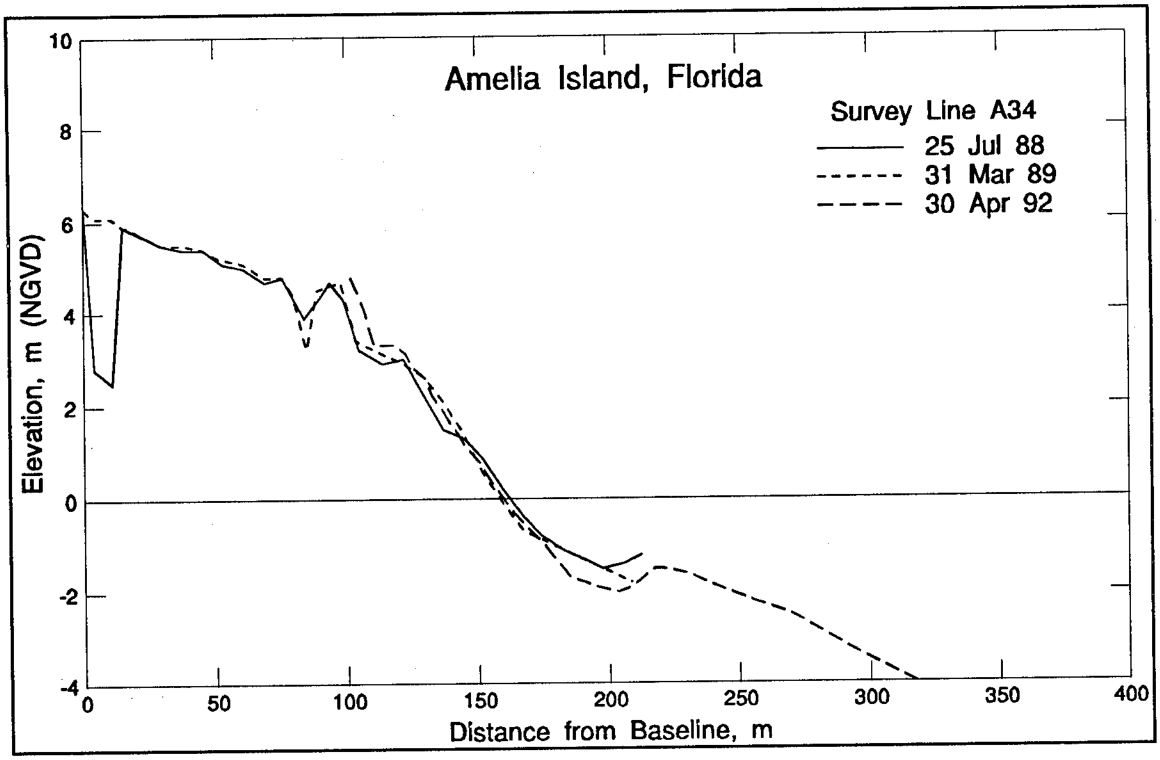


Figure D89. Beach and nearshore profiles, 1988-1992, Line A34

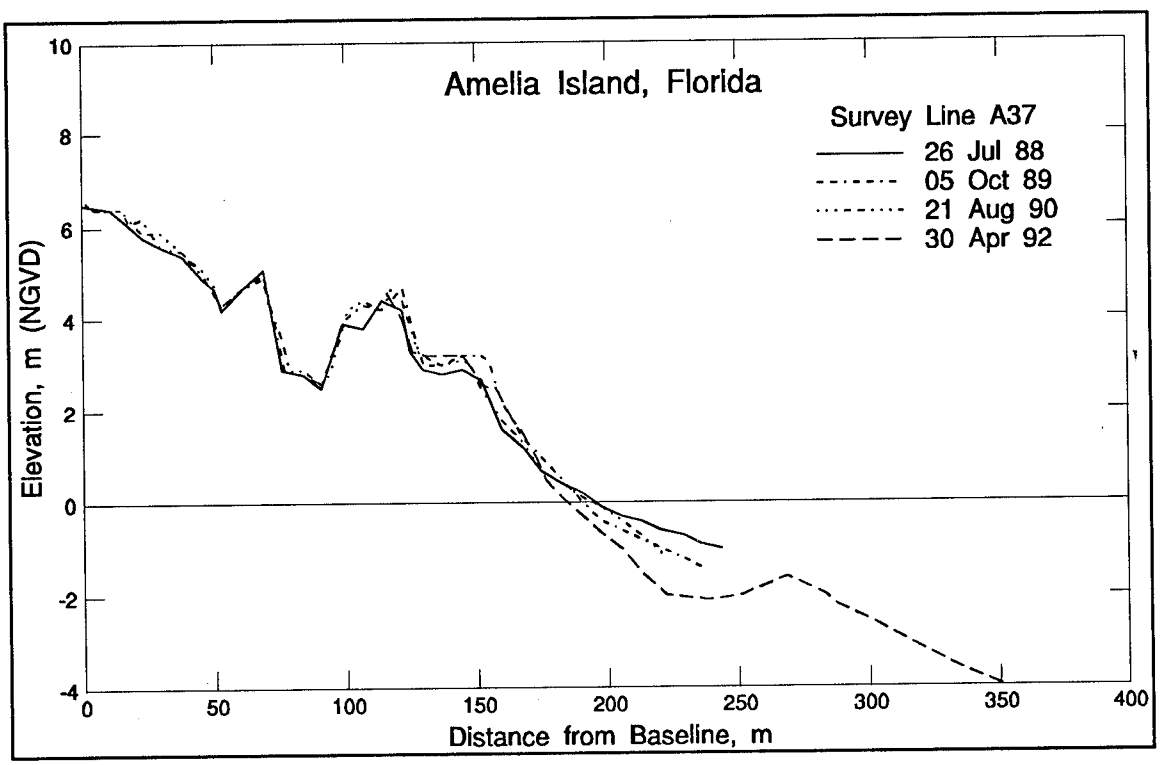


Figure D90. Beach and nearshore profiles, 1988-1992, Line A37

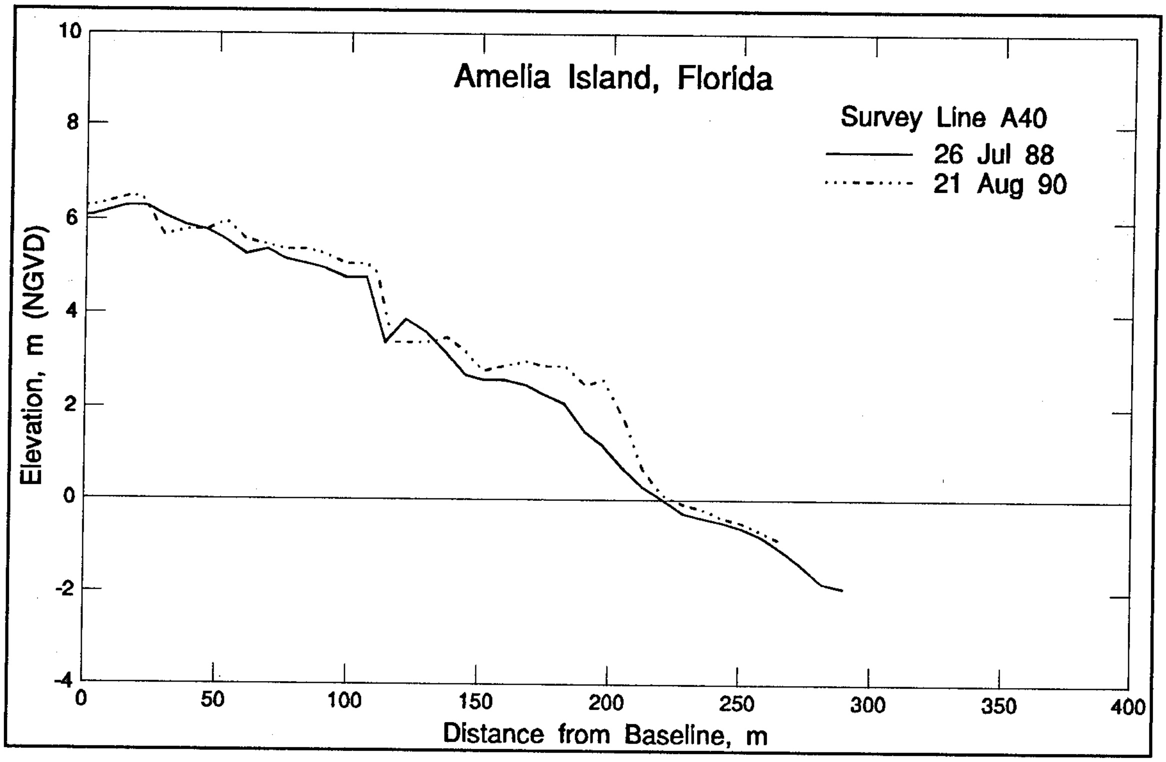


Figure D91. Beach and nearshore profiles, 1988 and 1990, Line A40

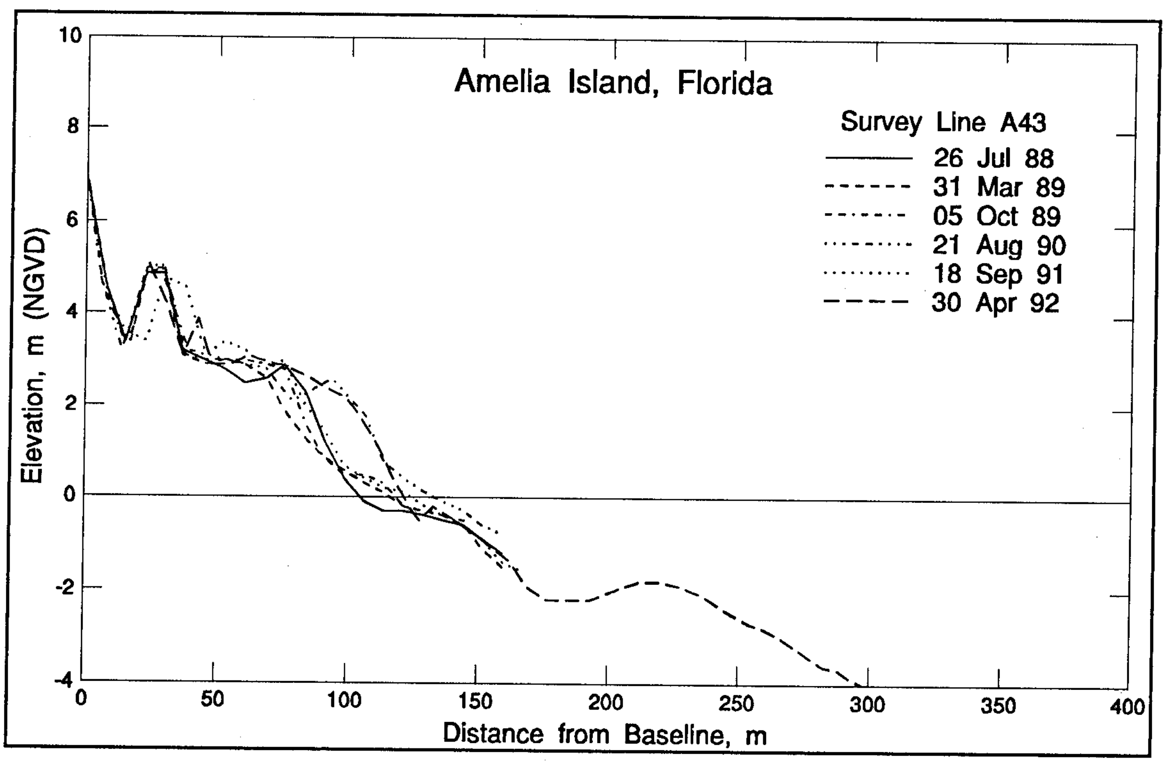


Figure D92. Beach and nearshore profiles, 1988-1992, Line A43

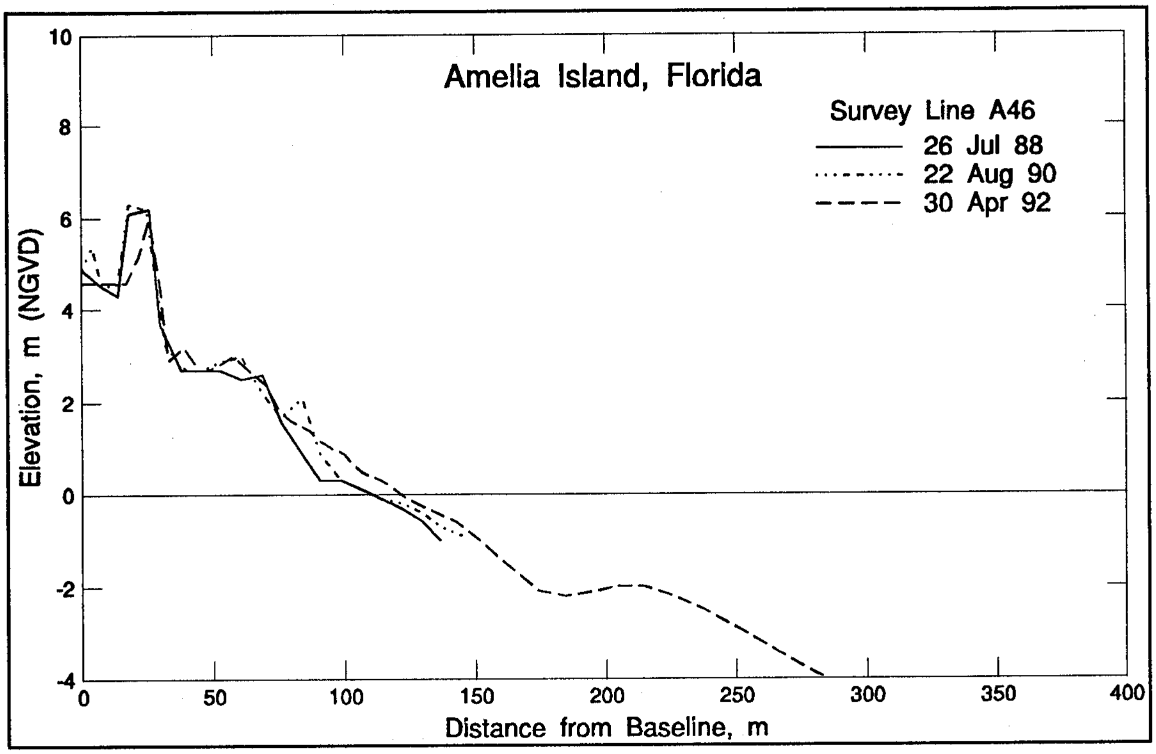


Figure D93. Beach and nearshore profiles, 1988-1992, Line A46

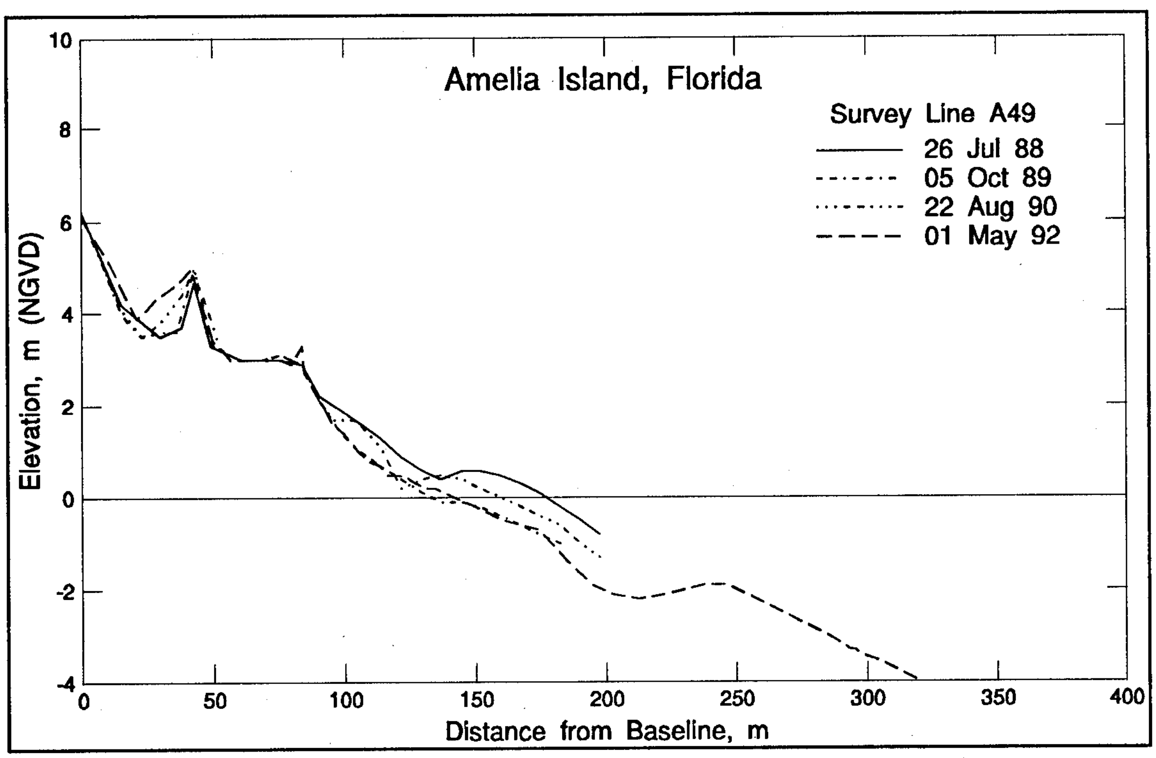


Figure D94. Beach and nearshore profiles, 1988-1992, Line A49

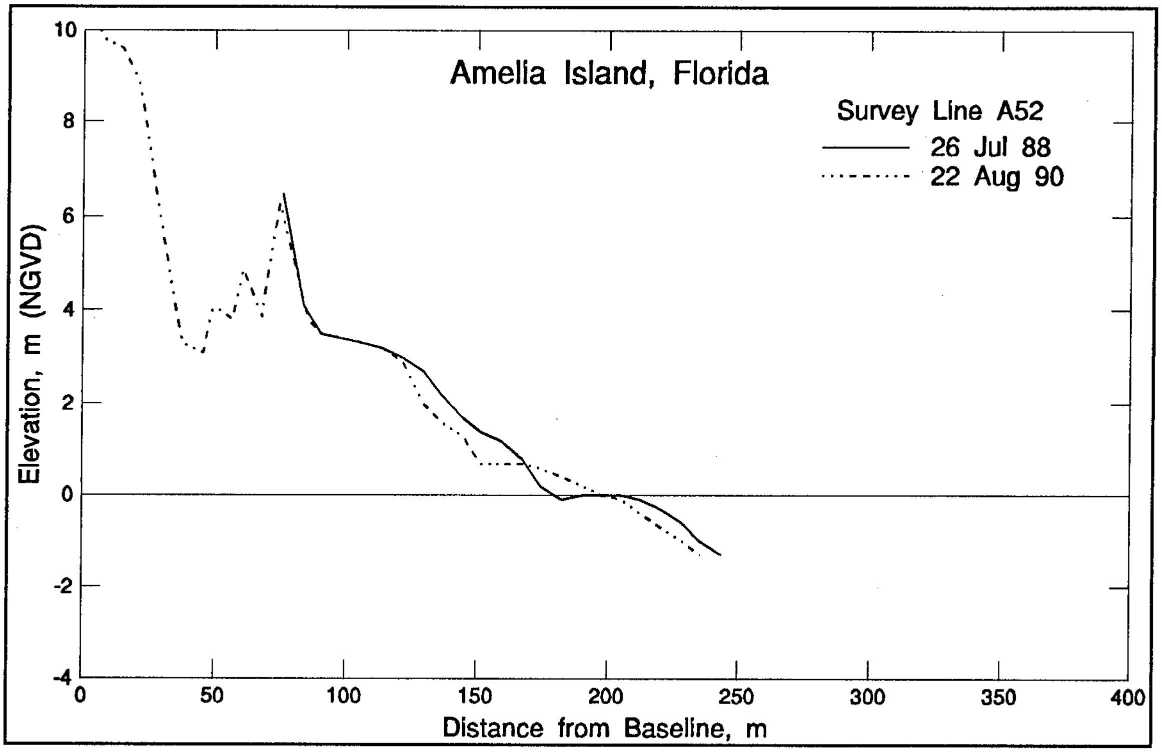


Figure D95. Beach and nearshore profiles, 1988 and 1990, Line A52

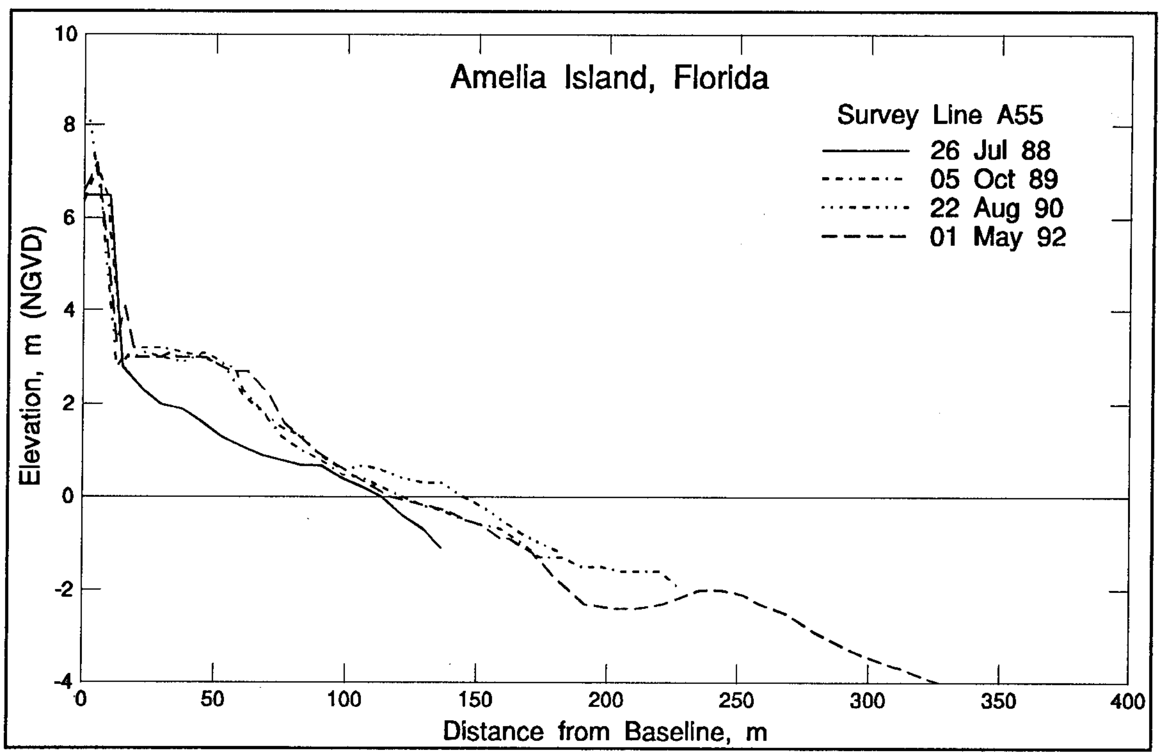


Figure D96. Beach and nearshore profiles, 1988-1992, Line A55

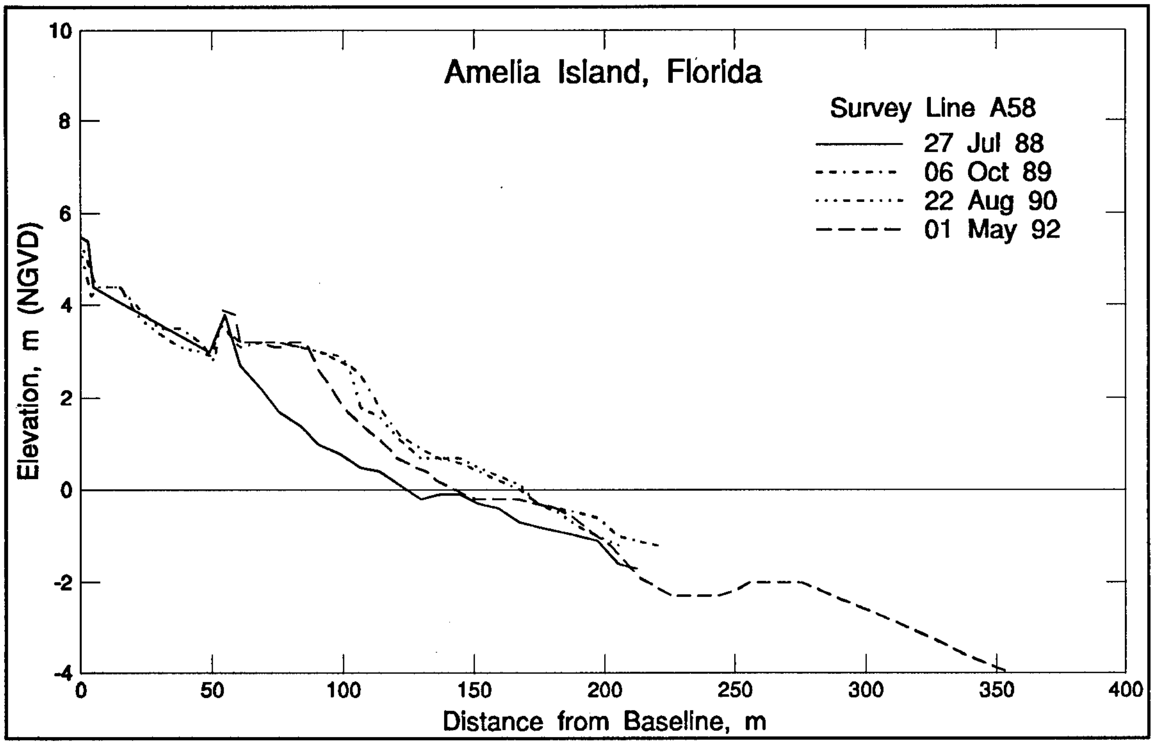


Figure D97. Beach and nearshore profiles, 1988-1992, Line A58

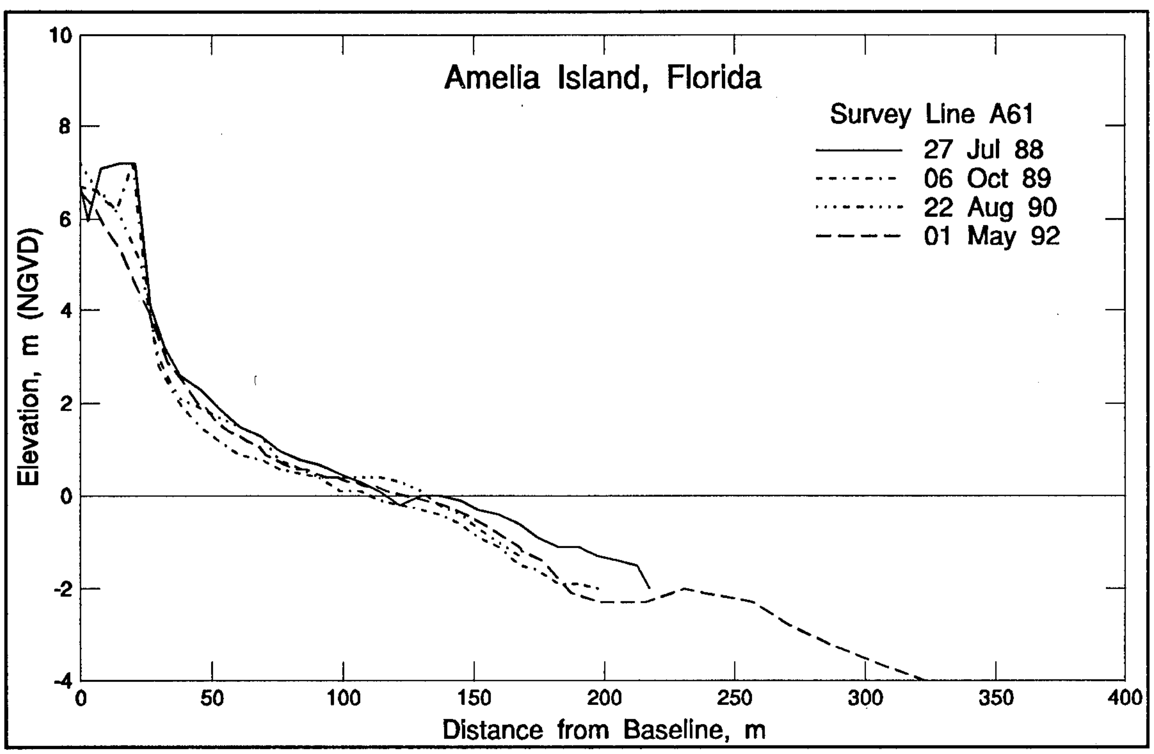


Figure D98. Beach and nearshore profiles, 1988-1992, Line A61

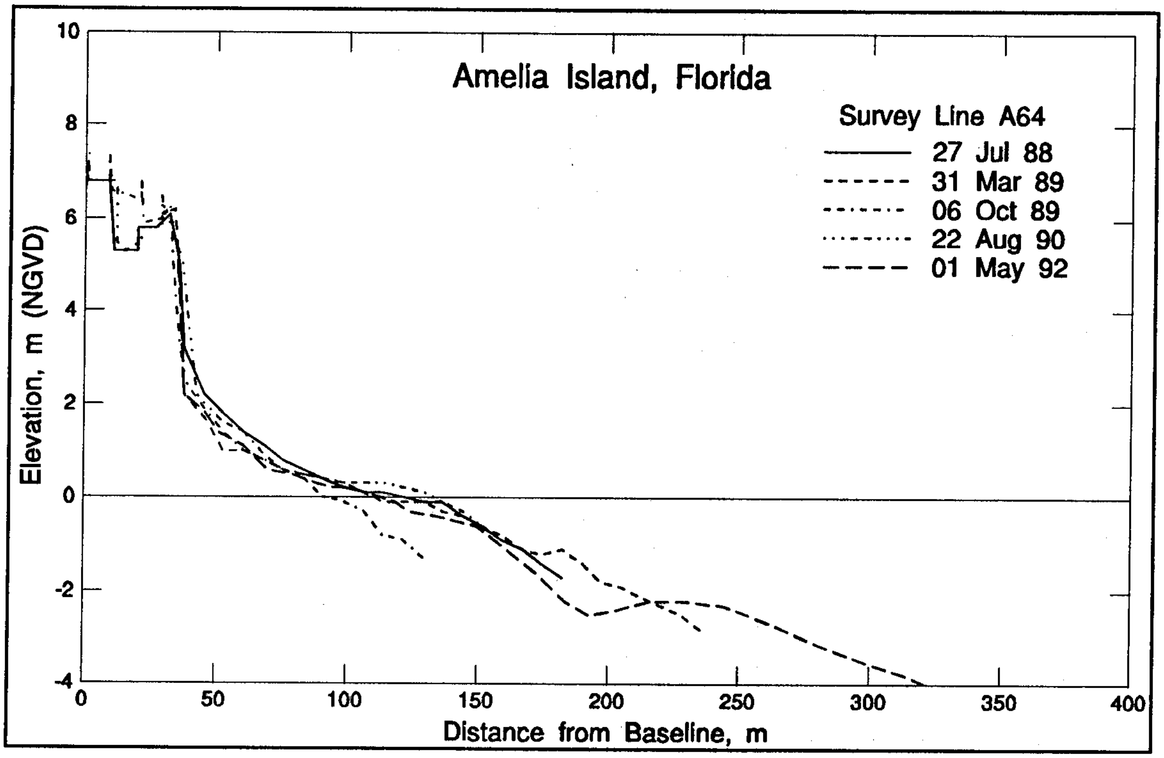


Figure D99. Beach and nearshore profiles, 1988-1992, Line A64

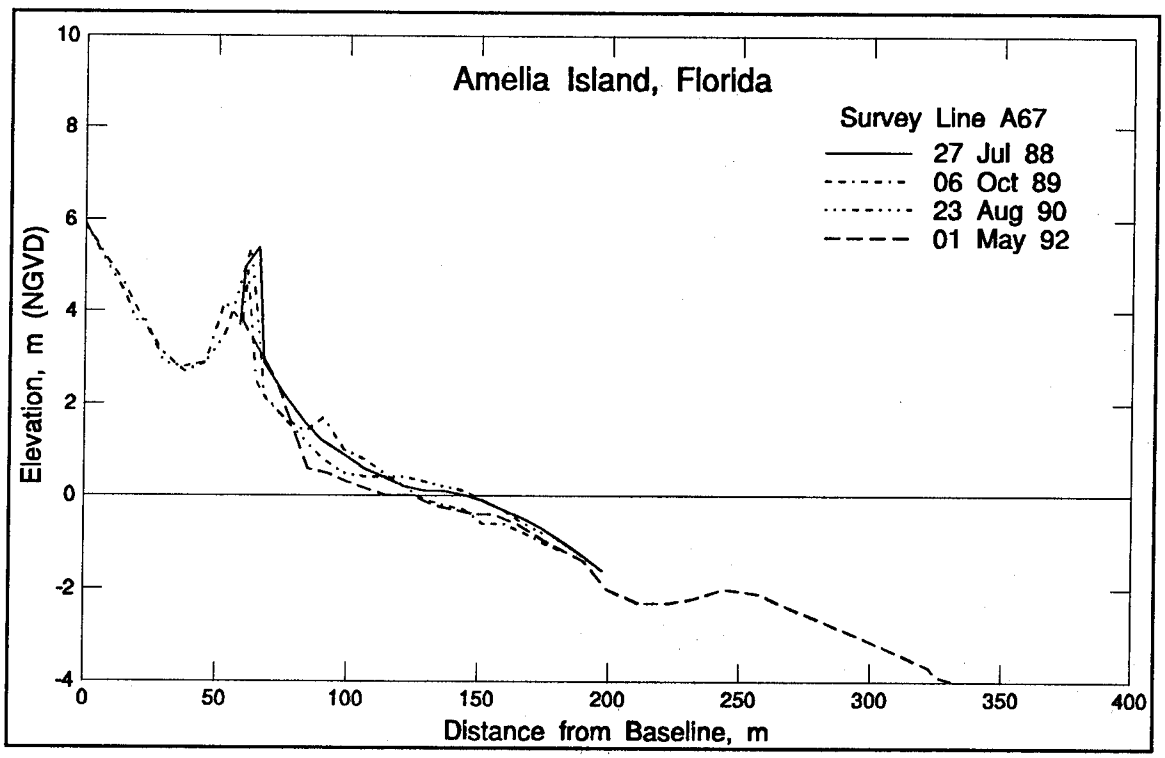


Figure D100. Beach and nearshore profiles, 1988-1992, Line A67

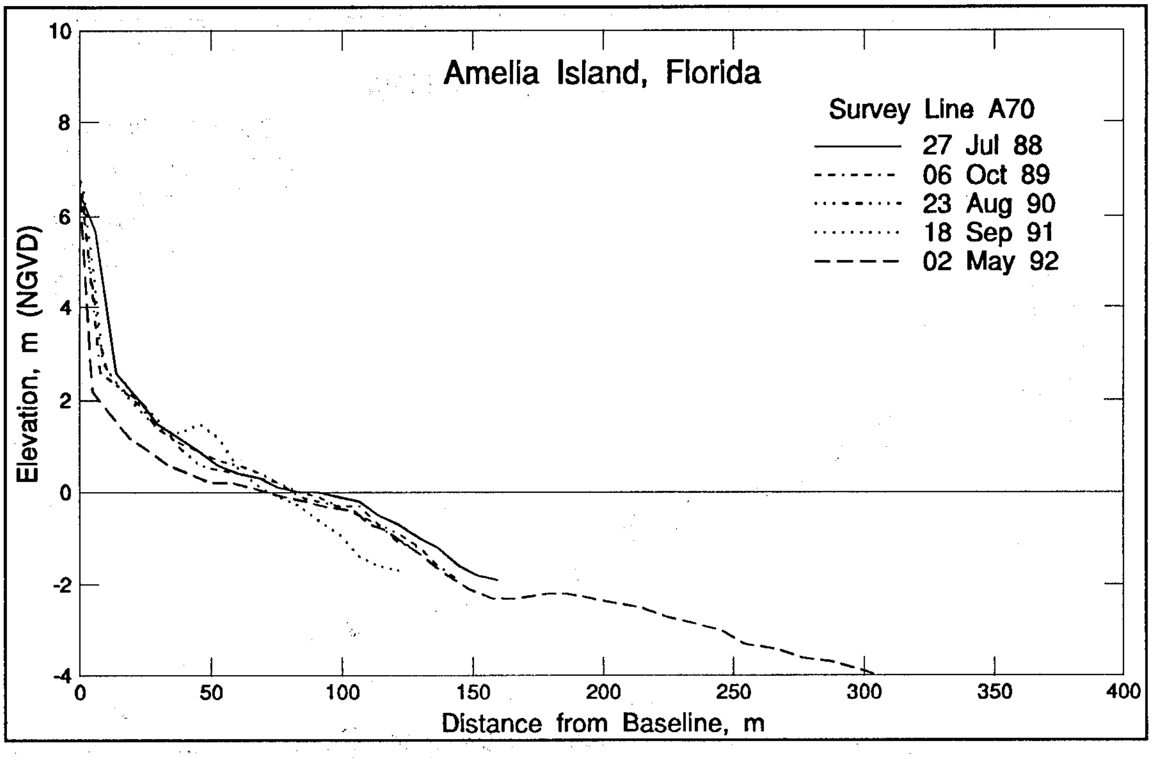


Figure D101. Beach and nearshore profiles, 1988-1992, Line A70

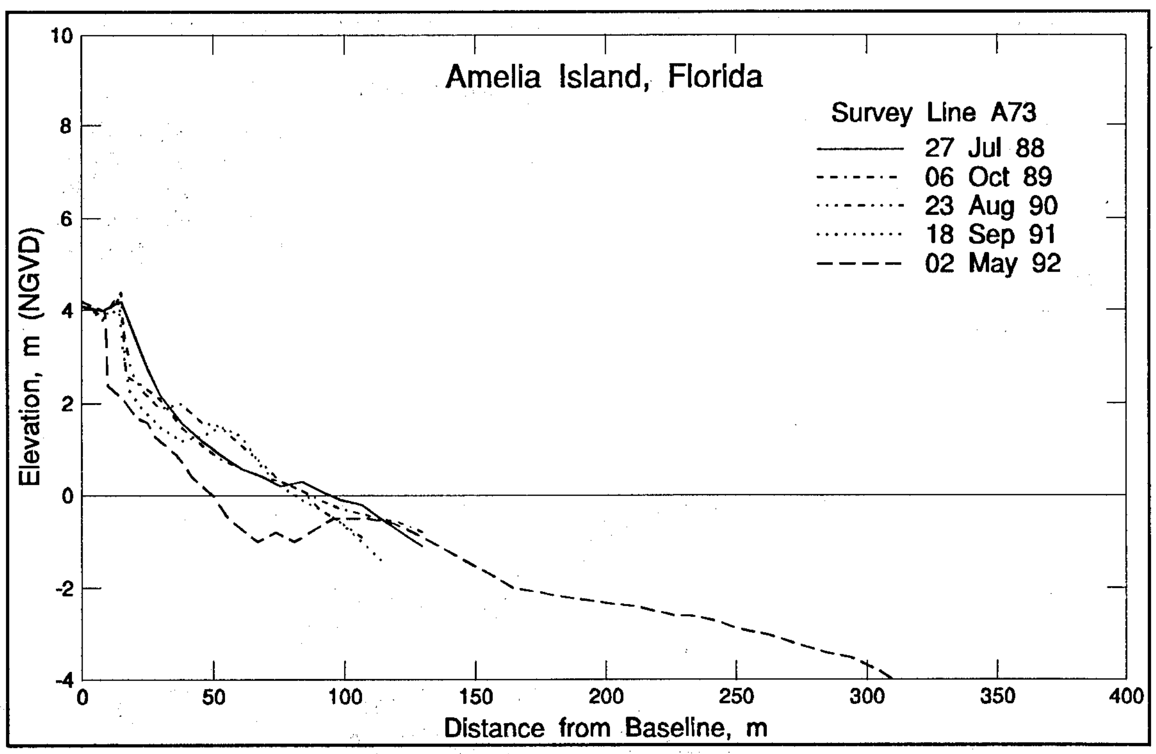


Figure D102. Beach and nearshore profiles, 1988-1992, Line A73

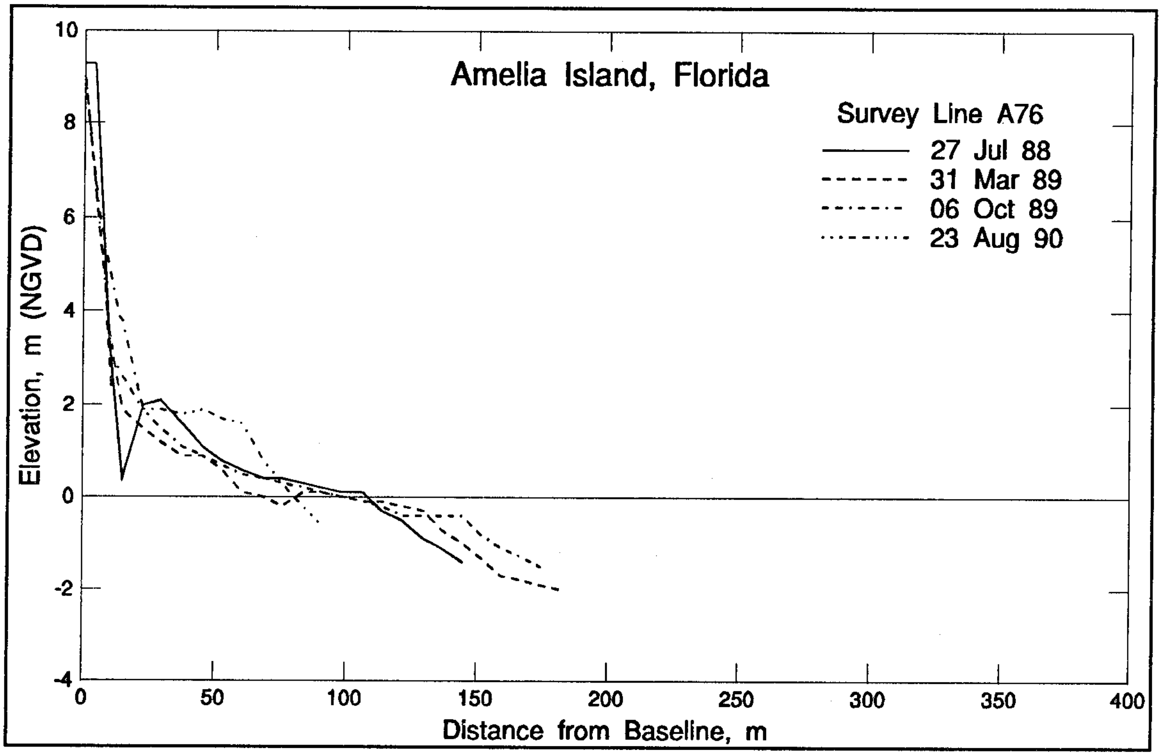


Figure D103. Beach and nearshore profiles, 1988-1990, Line A76

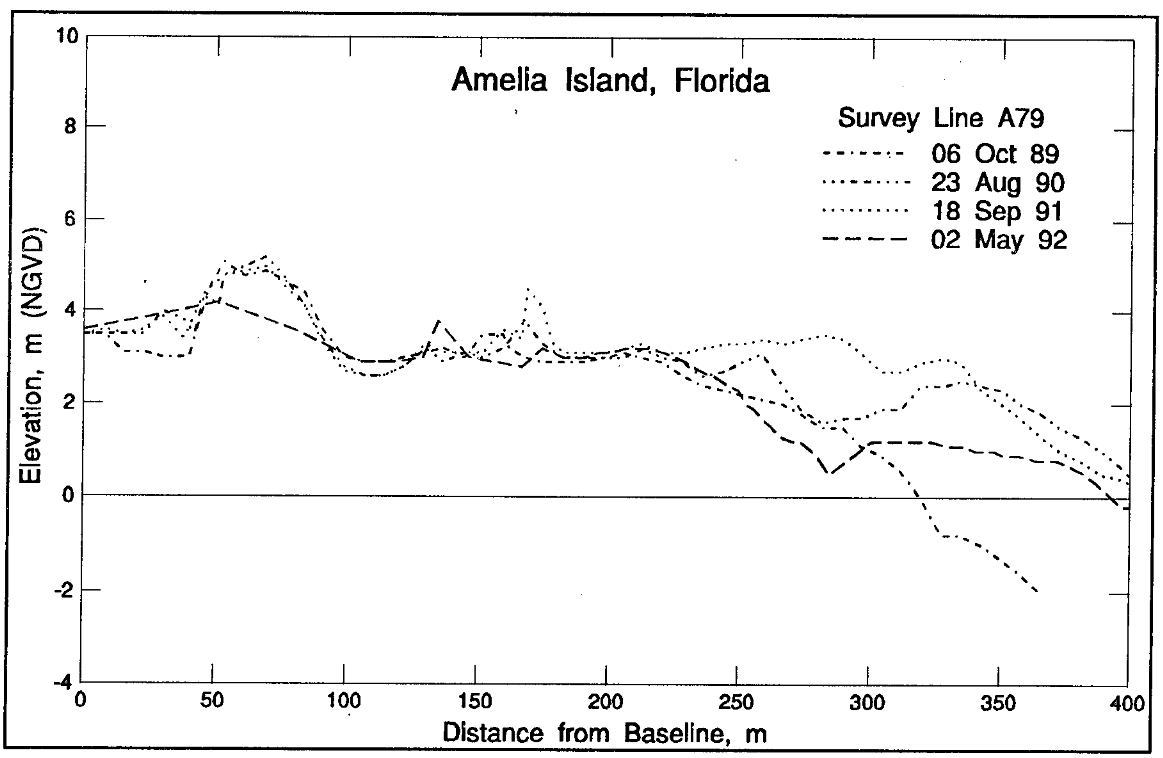


Figure D104. Beach and nearshore profiles, 1989-1992, Line A79

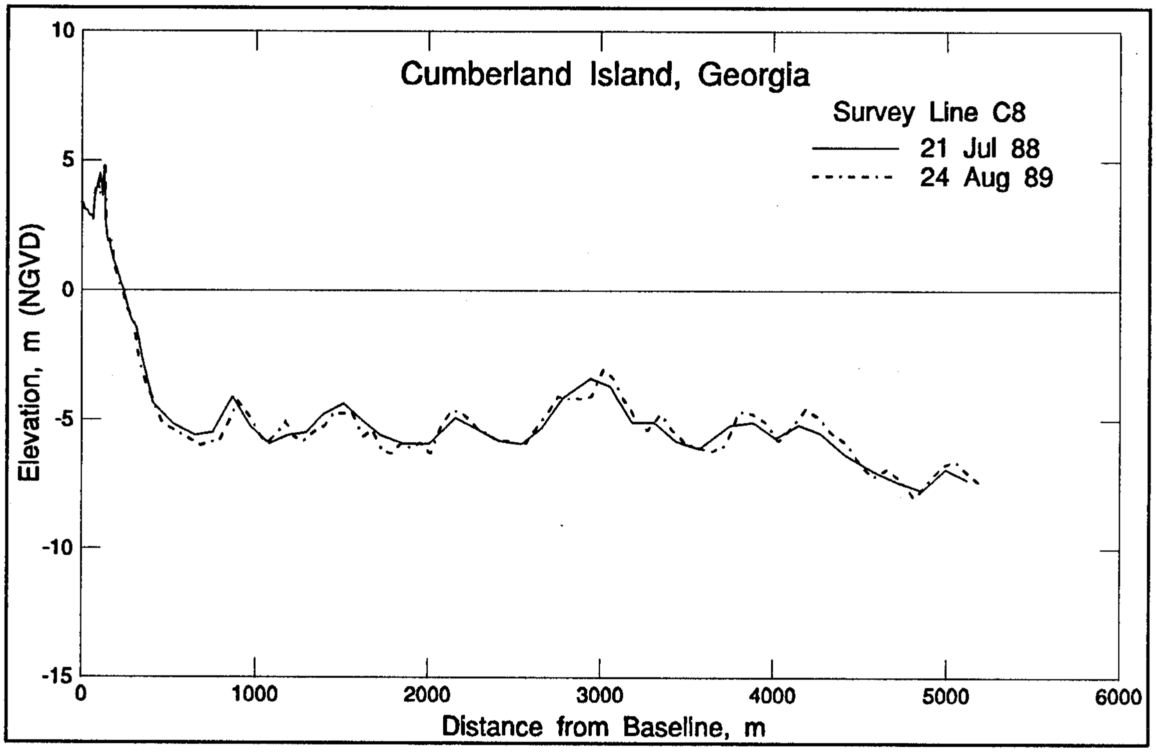


Figure D105. Beach, nearshore, and offshore profiles, 1988 and 1989, Line C8

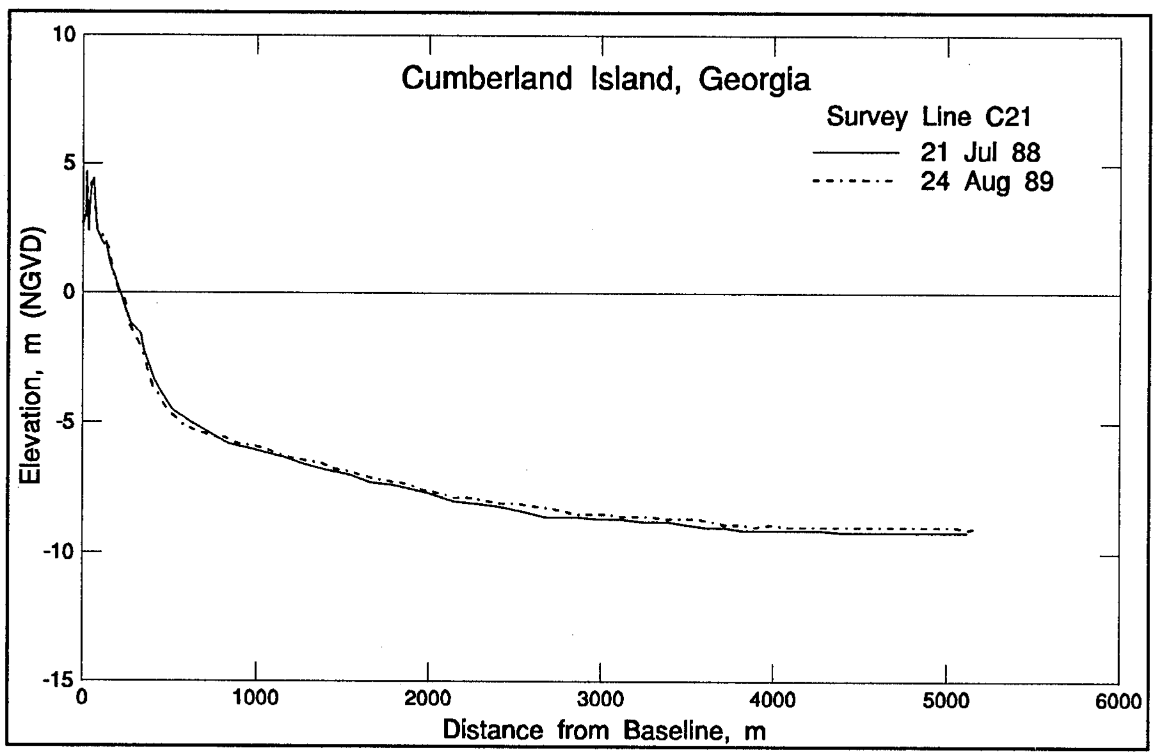


Figure D106. Beach, nearshore, and offshore profiles, 1988 and 1989, Line C21

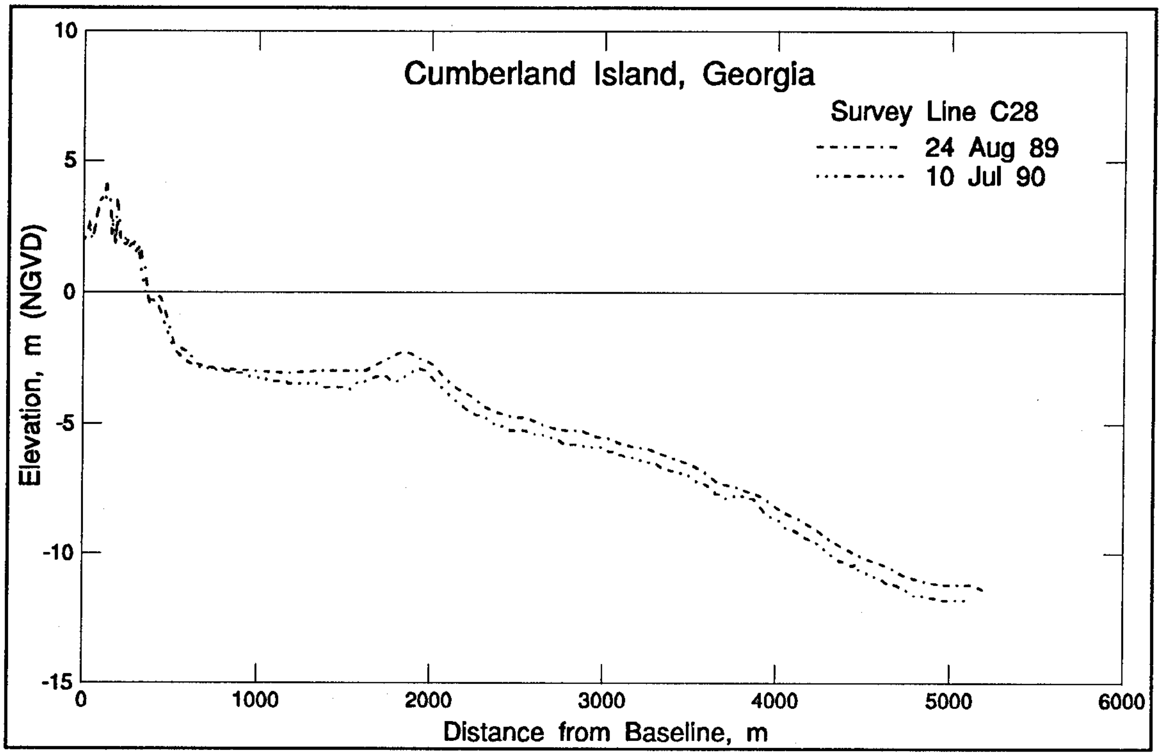


Figure D107. Beach, nearshore, and offshore profiles, 1989 and 1990, Line C28

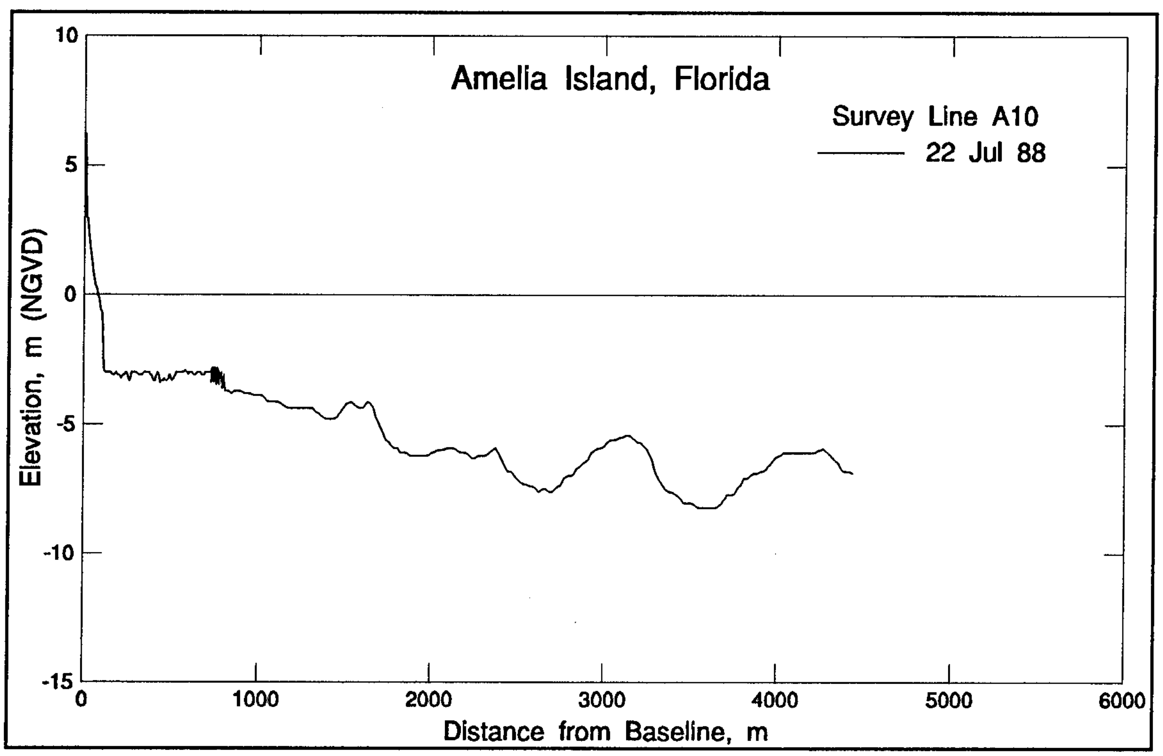


Figure D108. Beach, nearshore, and offshore profile, 1988, Line A10

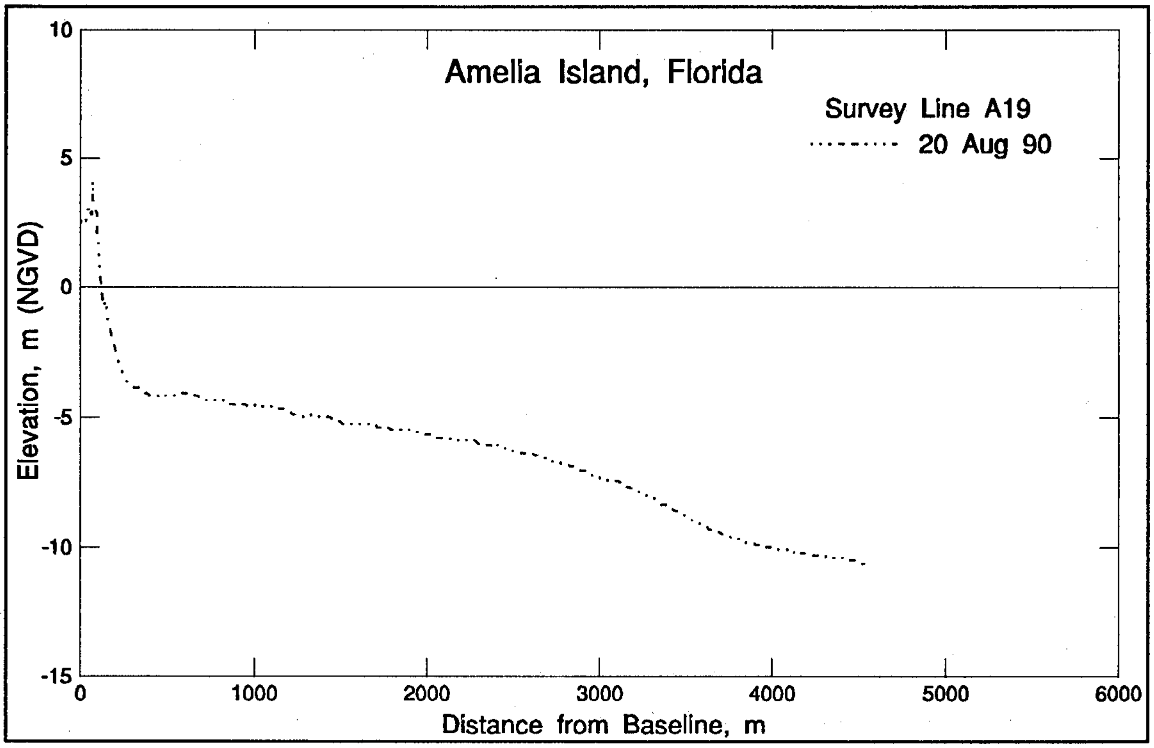


Figure D109. Beach, nearshore, and offshore profile, 1990, Line A19

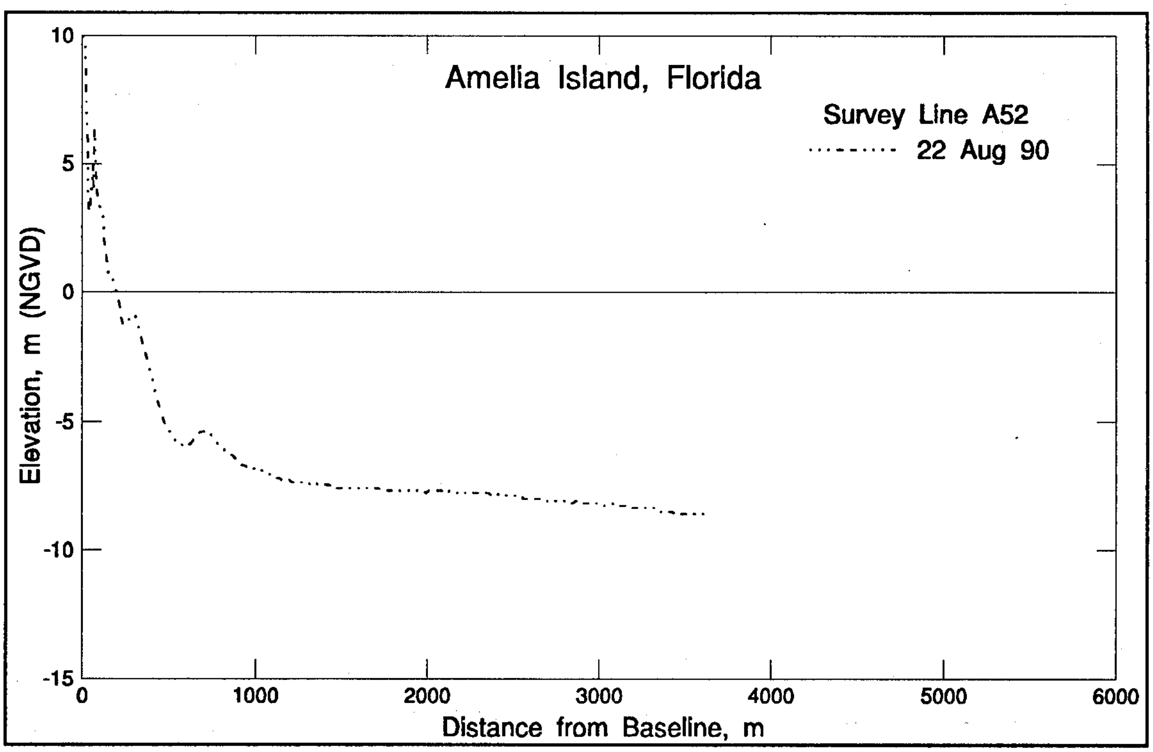


Figure D110. Beach, nearshore, and offshore profile, 1990, Line A52

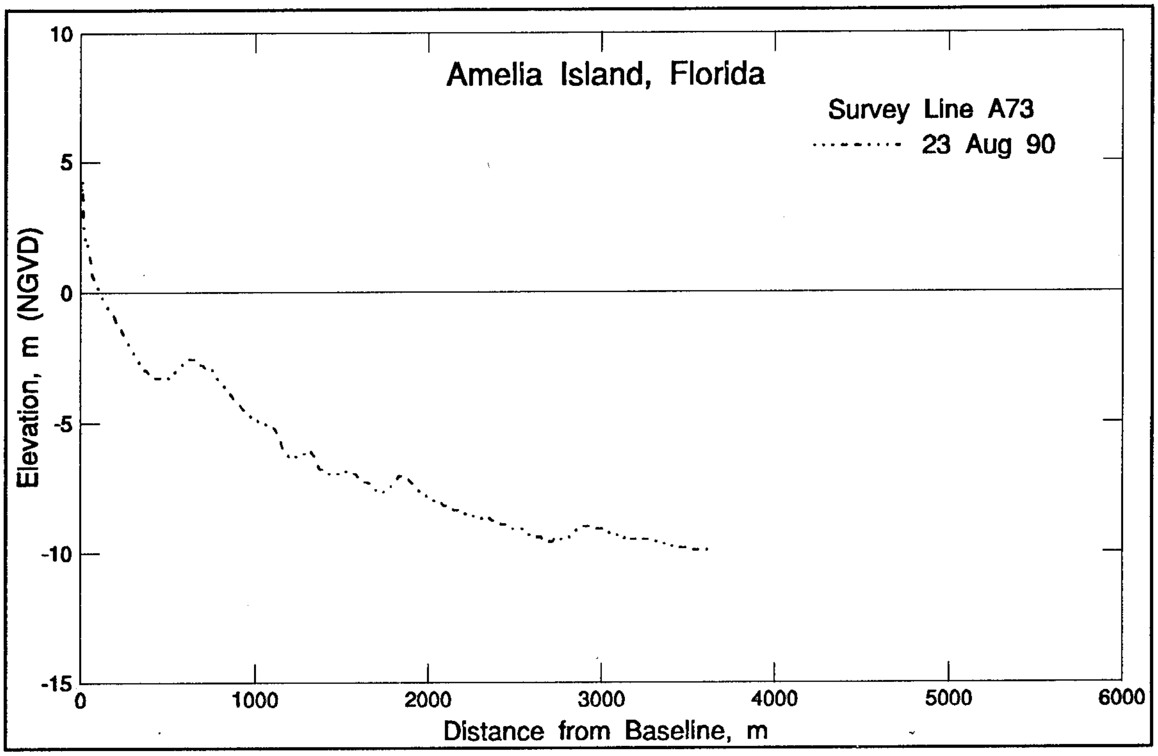


Figure D111. Beach, nearshore, and offshore profile, 1990, Line A73

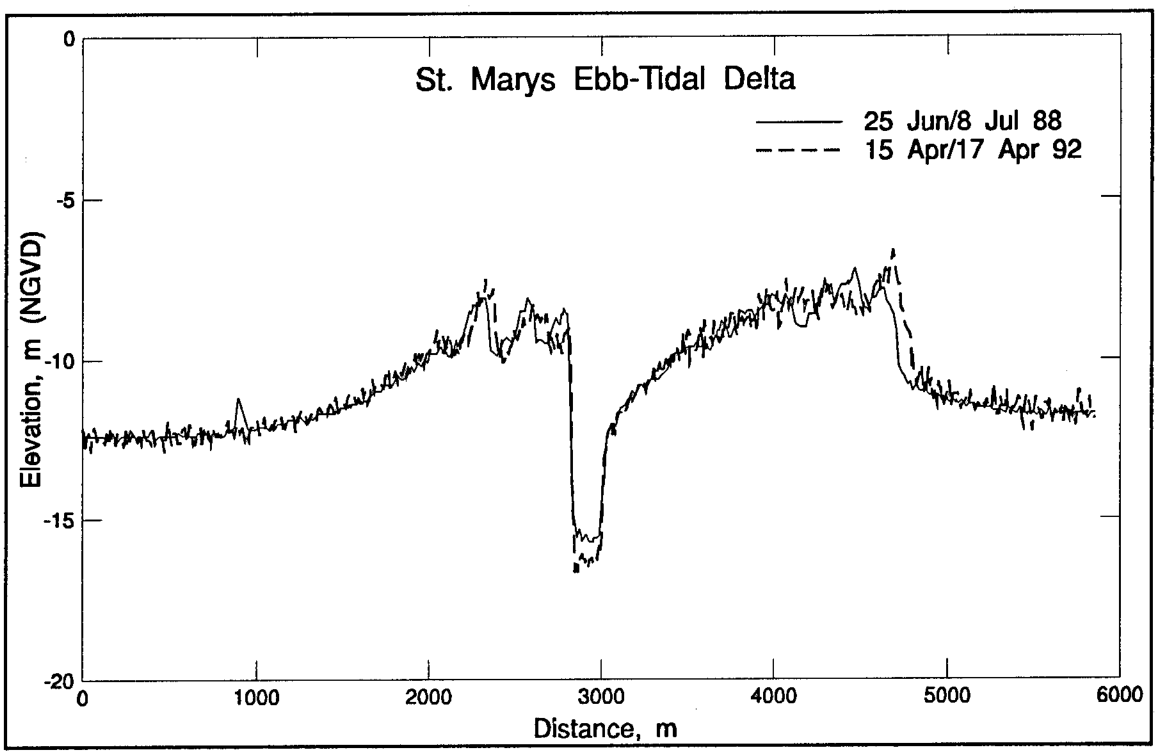


Figure D112. North-south profiles across grid surface 35 m east of Line 11

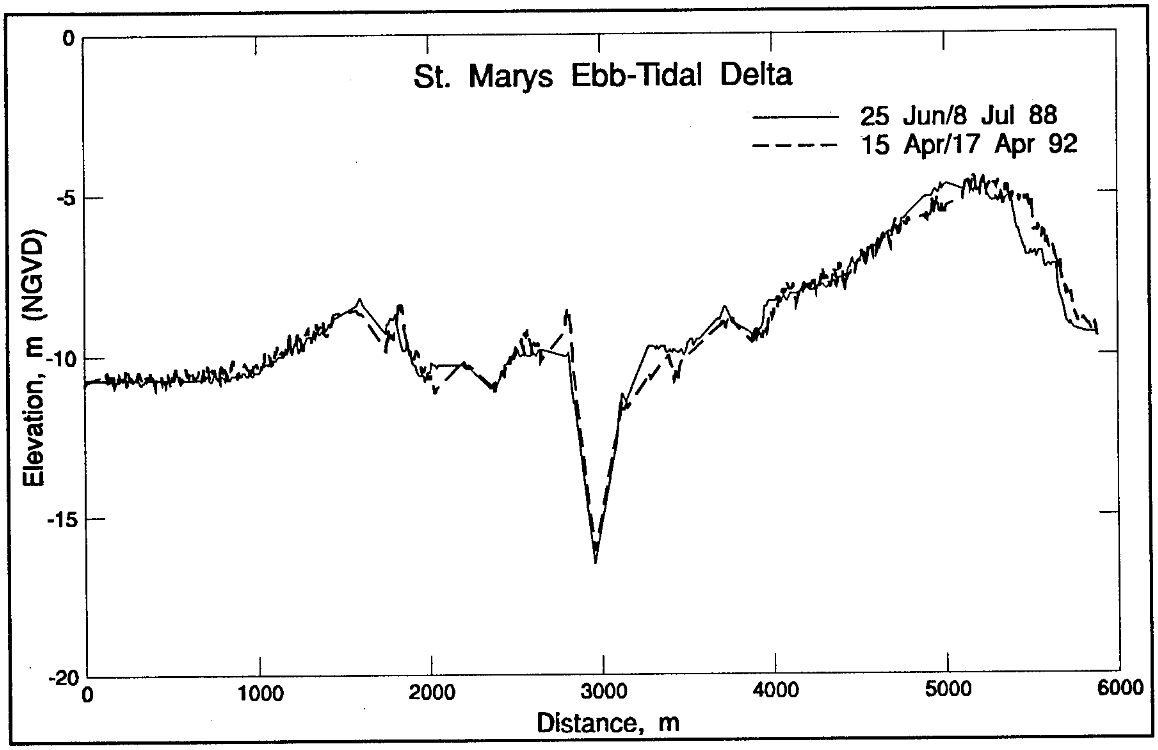


Figure D113. North-south profiles across grid surface midway between Lines 4 and 5

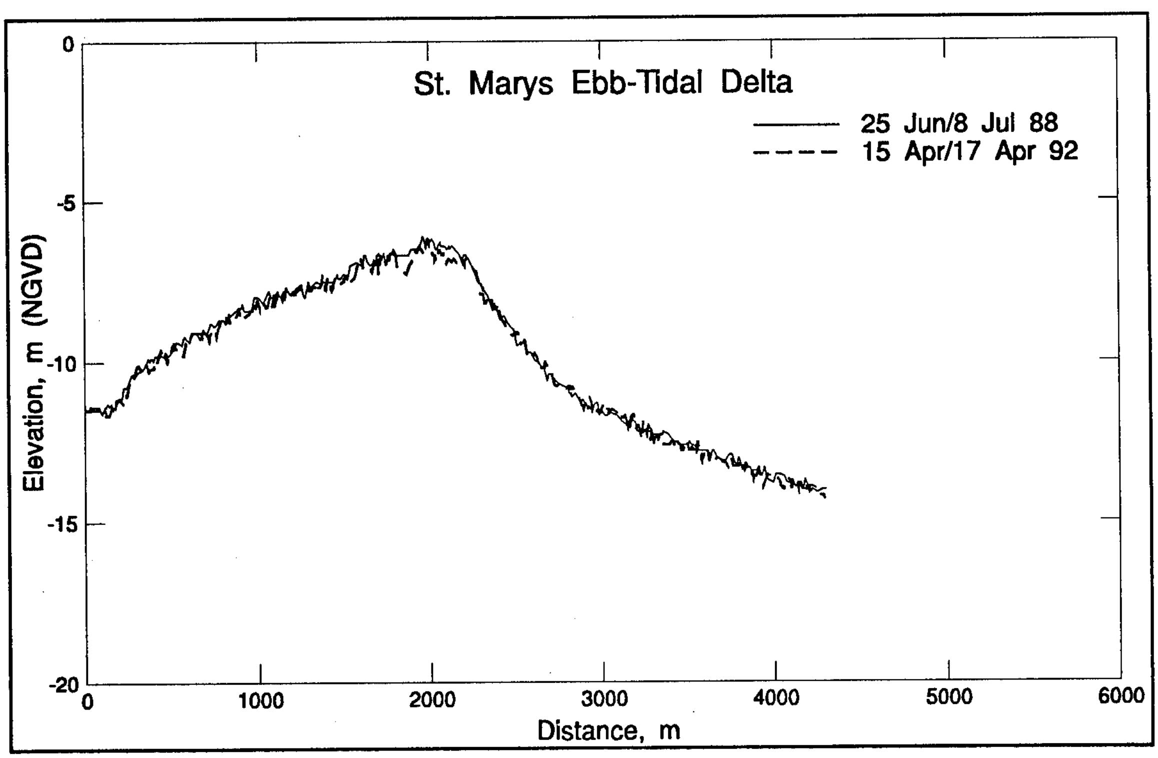


Figure D114. East-west profiles across grid surface 225 m north of Line 17

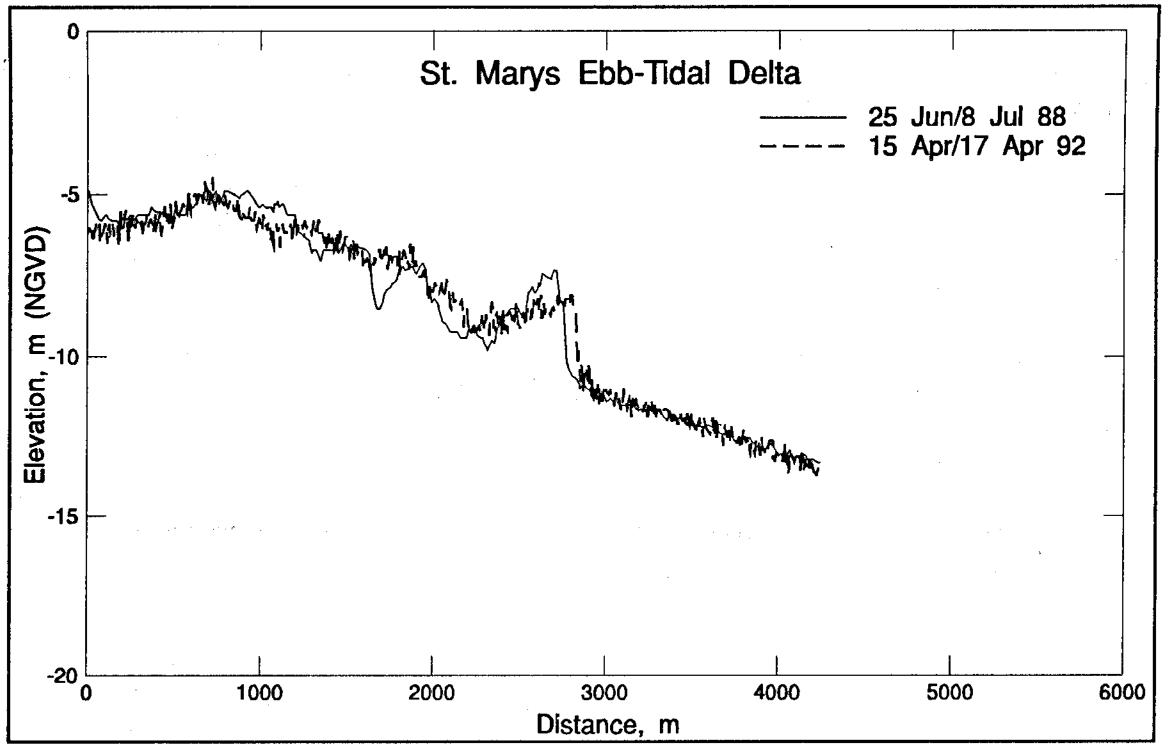


Figure D115. East-west profiles across grid surface 225 m north of Line 22

1988; USAED, Jacksonville 1993). The study area, however, is partially tide-dominated with low angle slopes and pronounced curvature of the shoreline, requiring a modified approach to profile analysis. Elevation rather than distance was chosen to define the profile measurement limits. A contributing factor to this selection was the variable distance from the baseline to the beach along the 50-km-long study area. The use of a geomorphic feature such as the berm crest was also explored as a boundary limit, but was not deemed practical since the Amelia Island morphology has been altered by multiple fill placements.

The profile measurements discussed herein were computed from several individual programs written in Turbo Pascal for an IBM-compatible personal computer. These programs accessed as input the digital ISRP format data files described in the *Data processing* section. Profile limits used in developing the measured distances were computed from the intercept of the profile with specified elevations, as discussed below. Individual values were interpolated between the nearest measured data points along the survey line. Profile measurements were computed for all available data sets except those along Cumberland Sound, where the marsh shoreline represents an estuarine environment rather than an open-ocean coastline. Calculations were done primarily for the surveys of the first (July 1988) and last (April/May 1992) years of the monitoring period, although some intermediate data are presented for shoreline position and volumetric change. Profile definitions and computations were limited to the beach segment of the profile due to vertical offsets in the fathometer portions of the surveys (refer to the *Data processing* section).

Definition of profile measurements. Selected profile measurement parameters were used to define the variable cross-shore morphologic features within the study area. Linear measurements which can be computed from an individual survey line are: beach width, location and depth of the inner bar, and beach and nearshore slope. The most variable of these parameters was the beach width, which was measured between elevation 2.5 and 0.0 m (NGVD) (Figure D116). Elevation 0.0 m (NGVD) was selected as the lower limit because, for most land-based surveys, this was the lowest elevation for which there was consistent data coverage. On Cumberland Island, the 2.5-m (NGVD) elevation corresponded to the minimum elevation of the dune base and defined most of the active beach. On Amelia Island, site of multiple beach fill placements, the 2.5-m (NGVD) elevation was most closely associated with the berm crest position. The natural dune base was located closer to the 4.0-m (NGVD) elevation due to the temporal and spatial variability in fill-related profile shape. Therefore, the 4.0-m (NGVD) elevation was chosen to represent the standardized upper limit of the active beach on Amelia Island.

The distance and depth of the inner bar were calculated for the April/May 1992 sled survey due to the accurate continuous coverage provided throughout the surf zone. The distance to the inner bar is measured from NGVD seaward to the crest of the first bar. This computation provided a measure of the relative bar position and its alongshore variability. Cross-shore migration of the bar crest is a function of breaker height and bottom slope and can represent surf zone width at low tide. High waves and flat nearshore slopes tend to produce wider surf zones and more seaward bar crest positions. Lower waves or steeper nearshore slopes result in narrower surf zones and bar crest positions which are closer to shore.

Profile slope was calculated at two positions in the cross-shore direction. The beach slope, between 2.5 (dune base along Cumberland Island, berm crest along Amelia Island) and -1.0 m (NGVD) (approximate MLW position), represented the subaerial berm and foreshore area. The slope in this portion of the profile is controlled by swash/backwash processes and interaction with incoming surf. During storms, elevated water levels may allow wave action to act directly on

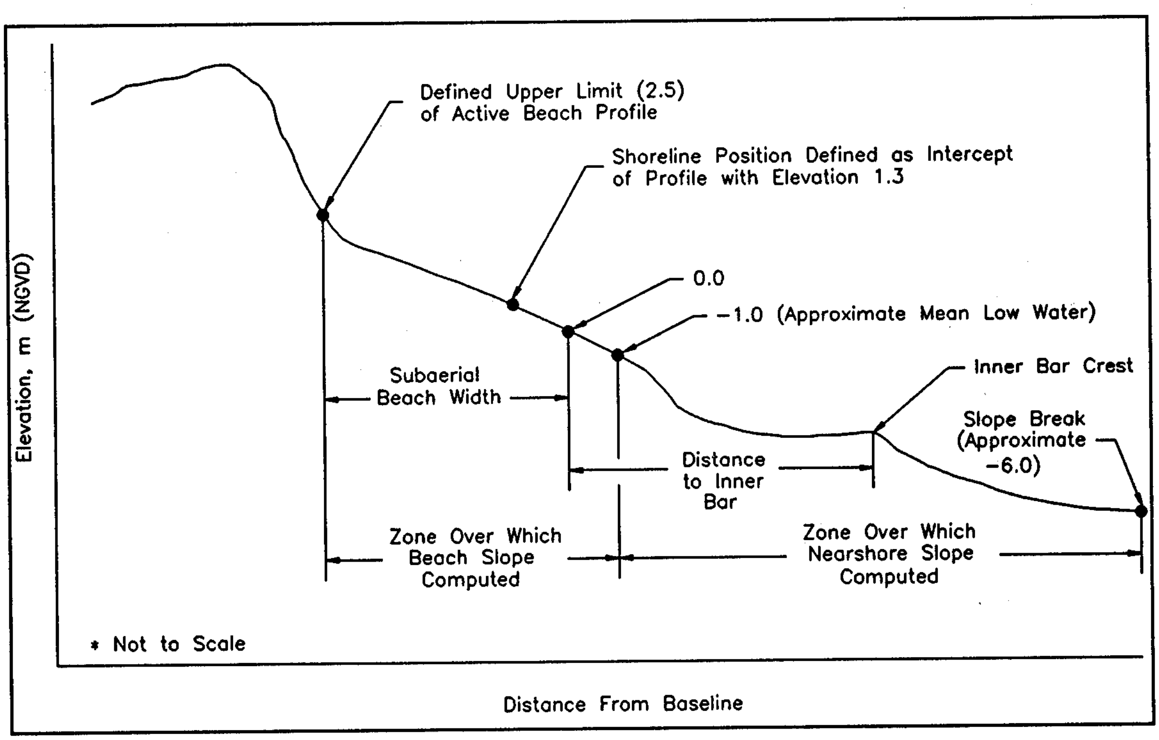


Figure D116. Location and limits of linear profile computations within the beach and nearshore zone this area. Sediment deposition is controlled by these processes and by local sediment supply, which in turn influences the beach slope. The nearshore slope, between -1.0 m (NGVD) and the slope break (approximate range from -4.0 to -6.0 m NGVD), represents the subaqueous bar/trough and nearshore area of the active profile envelope. This area is under the direct influence of breaking waves and longshore currents. Sediment in this area usually becomes finer from the bar crest seaward. The nearshore slope is controlled by the prevalent wave energy conditions and local sediment grain-size distributions (Bascom 1959). Slope measurements are presented as a ratio of rise over run (i.e. 1:28) and as an angle in degrees (i.e. 2 deg). Slope angle was calculated for comparison with other beach parameters, such as mean grain size (refer to the *Sediment Grain Size* section).

Shoreline position change is a commonly used indicator of beach stability. Shoreline position is determined either from historical aerial photographs and maps or from profile survey data. Shoreline determination from aerial photographs or maps usually represents the position of the high-water shoreline along the beach (Chapter 3, *Shoreline position change* section). Shoreline position as determined from profile survey data is based on the relative change in location of a specified elevation contour. A common elevation referenced for this type of analysis is 0.0 m (NGVD) (USAED, Jacksonville 1993). This elevation is provided for comparison. However, it constitutes a highly variable measure due to the movement of the bar or ridge and runnel features along the lower beach. Therefore, the approximate position of the high-water shoreline (elevation 1.3 m NGVD) was selected to provide continuity with the historic shoreline change analysis and to limit the influence of short-term, bar-related features active on the lower beach face. Shoreline position change is presented as a net rate for the monitoring period (m/year) and as a shoreline position relative to July 1988 for the intermediate surveys. The time interval used to calculate the net rate was based on the total months between the first and last surveys (i.e., 3.875 years for July 1988 - April/May 1992).

A detailed analysis of the pre-monitoring (prior to July 1988) DNR profile surveys available for Amelia Island was not within the scope of this project. However, results of a limited examination of the February 1974 and September/November 1981 historical surveys are included as part of the shoreline change analysis to identify pre- and post-monitoring conditions. This comparison revealed monument control discrepencies which could not be fully resolved at the time of publication. The problem stems from some monument resets which resulted in translations of some of the profiles. No translation or rectification was applied to the DNR profile data set. Any survey lines which displayed significant offsets were excluded from the analysis. Tolerances of monument locations for the remaining profiles were within ± 2 m in horizontal distance and ± 0.2 m in elevation.

Another commonly used indicator of beach stability is volumetric change within the active profile envelope. The zone over which volumetric calculations were computed was based on the cross-shore profile morphology (Figure D117). Elevation limits, rather than standard distances from a baseline, were used to define the boundaries of beach volume change between surveys. The upper limit differed for each island because of the varying dune line position and beach fill activities along Amelia Island. The upper boundary was determined to be 2.5 m (NGVD) for Cumberland Island and 4.0 m (NGVD) for Amelia Island. As most land-based surveys ended just seaward of the low water line, 0.0 m (NGVD) is the farthest seaward elevation for which there was consistent data coverage. These elevation limits define the subaerial beach used for all volumetric computations of the monitored profile lines. The defined elevations were converted to corresponding starting and ending distances. The starting distance was based on the

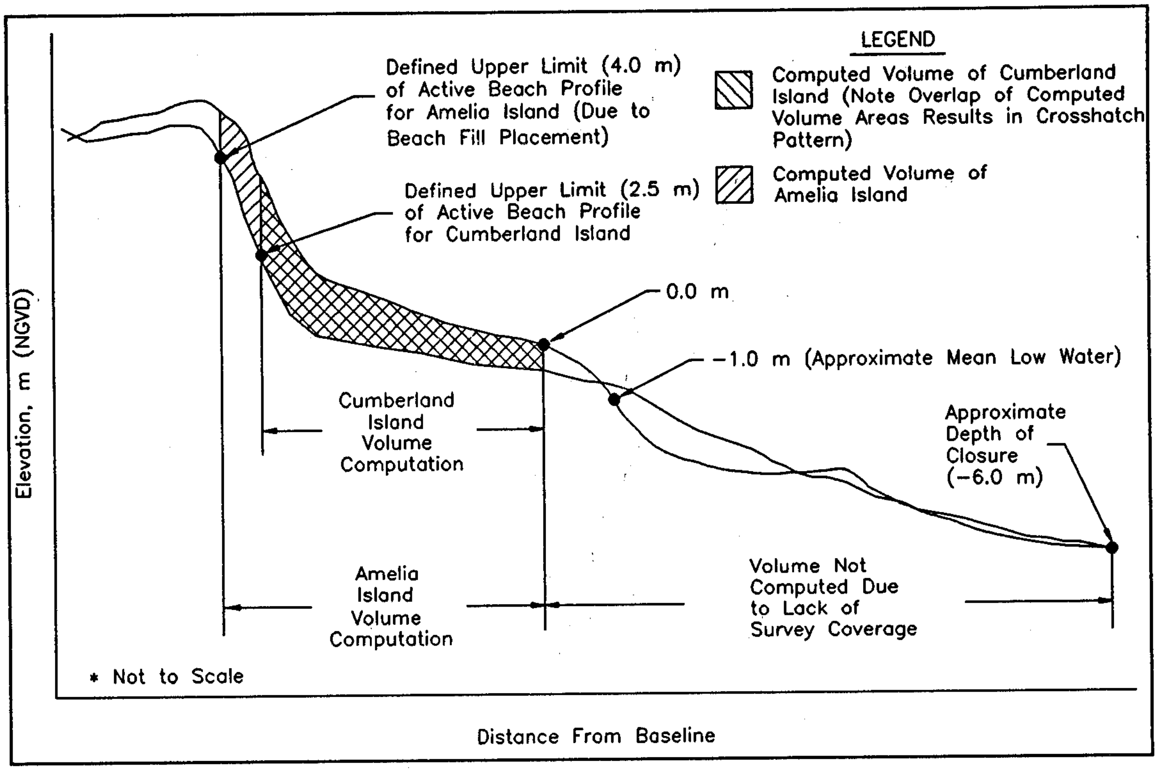


Figure D117. Location and limits of profile volume computations

upper elevation limit (2.5 m NGVD for Cumberland Island or 4.0 m NGVD for Amelia Island) from the landwardmost survey and the ending distance was based on the lower elevation limit (0.0 m NGVD) from the seawardmost survey (Figure D117). These distances were used as input to Volume PC, a program distributed as part of the ISRP package. Volume changes were calculated for all surveys with emphasis on net changes for the entire monitoring period.

The final profile measurement analysis involved seasonal profile response. Profile surveys represent an instantaneous view of a dynamic beach system. Therefore, survey timing can have a profound impact on subsequent calculations. The timing of the monitoring period surveys with respect to significant storm events and beach fill placements is presented in Figure D118. Major storms can be divided into two types, hurricanes and northeasters. Hurricanes are high-intensity and relatively short-duration events, whereas northeasters are usually less intense but can have a significantly longer duration. Average northeasters have a normal duration of 2 to 3 days; however, an unusual event may last up to 5 days (USACE 1961; USAED, Jacksonville 1984a, 1993). Particularly severe northeasters were clustered near the beginning and end of the monitoring period (Chapter 6). Also noteworthy is the increase in winter storm conditions of 1991 and 1992, which were bracketed by the last two surveys.

Weighting methodology. In order to summarize the profile measurements by compartment and for each island, a weighting methodology by distance was used to compute each average. These values are presented in the last section of this appendix (*Summary of profile measurements and the morphologic compartments* section). Figure D119 illustrates the weighting methodology used for all the profile measurements (beach width, inner bar distance, inner bar elevation, beach slope, nearshore slope, shoreline position change, and volume change). The distance between

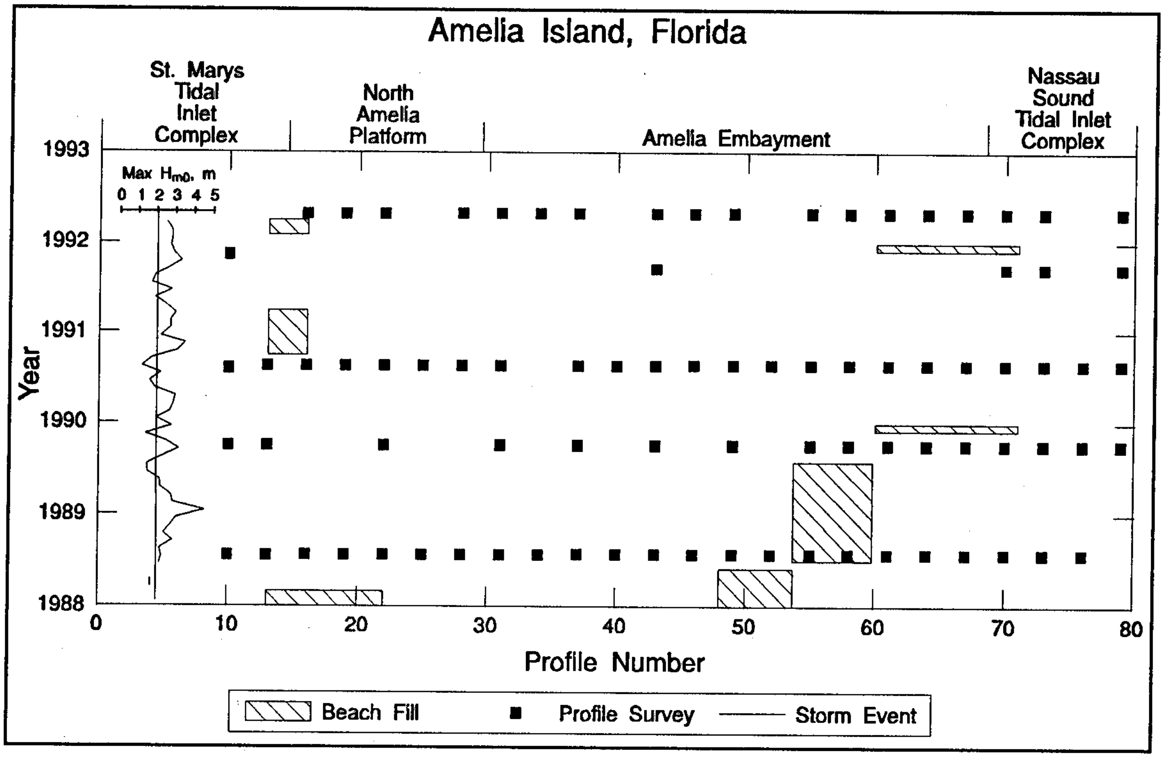


Figure D118. Comparison of monthly largest H_{m0} (based on NDBC gage, Appendix E) and fill placements relative to the profile survey data collection for Amelia Island

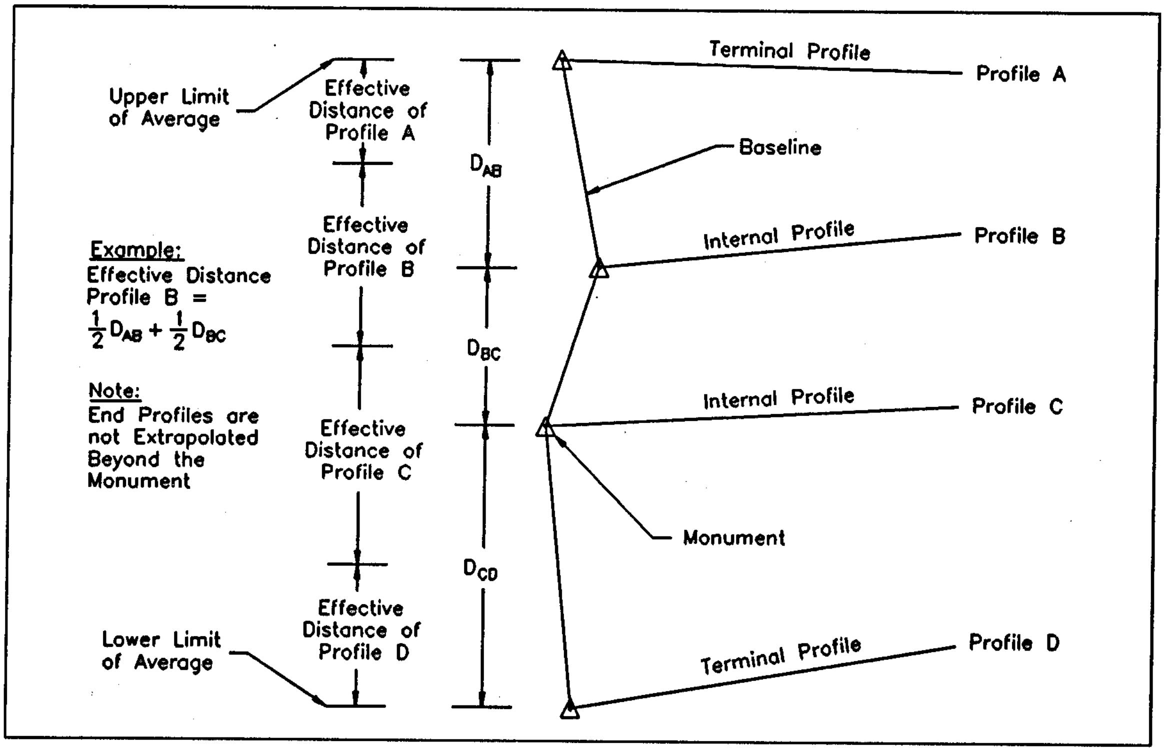


Figure D119. Schematic of weighting methodology profiles was determined as the alongshore component between successive monument positions. These distances were used to calculate effective distances for each profile. For an internal profile, the effective distance is equal to half the total distance to adjoining profiles. For a terminal profile, the effective distance is equal to half the distance to the adjacent profile. Finally, the overall average is the sum of the measurements of individual profiles multiplied by their effective distances and then divided by the sum of all distances.

The methodology employed to weight measurements can have a significant impact on the computed average. For this reason, the method used was conservative. Measurements were not extrapolated beyond the monument position in the case of a terminal profile. All individual measurements were used to determine the final weighted average, except in the situation of a suite of measurements which did not share a common terminal profile. For this case, data beyond the last common profile were excluded. All summary values used in this appendix (*Summary of profile measurements and the morphologic compartments* section) and Chapter 5 were weighted in this manner unless otherwise noted.

Results of the monitoring profile measurements

This section presents a detailed discussion of the coastal monitoring profile data set and the spatial and temporal variability of the Cumberland and Amelia beach system. The specific area of the profile described herein was surveyed from the primary dune seaward to wading depth. The individual profile measurements are described below and then used to interpret the morphologic changes by compartment as presented in the *Summary of profile measurements and the morphologic compartments* section. Further discussion of the net changes and potential impacts of the channel modifications during the monitoring period are presented in Chapter 5.

Beach width. Beach width is the most variable profile measurement because it can be influenced by short-term changes of the beach face. It is useful, however, for identifying alongshore trends for the Cumberland and Amelia barrier island system. Within each morphologic compartment, the average beach width is indicative of the local available sediment supply, shoreline stability, and profile slope. Beach width was computed as the distance between 2.5 and 0.0 m (NGVD) for both islands, as presented in Tables D9 and D10 and Figures D120 and D121. Along northern Cumberland Island, there is a gradual decrease in beach width between Lines C1 and C8 ranging between a maximum of 136.3 m (Line C2) and a minimum of 63.2 m (Line C5) based on the first year measurements (July 1988) (Figure D120). South of the axis of Stafford Shoal (Line C10) the trend reverses with an increase in beach width from Line C10 (59.1 m) to Line C14 (103.6 m). Near the boundary line between Stafford Shoal and Cumberland Embayment (Line C14-C15), the beach width shifts with a slightly narrower beach between Lines C15 (84.0 m) and C18 (98.7 m). There is a gradual increase in beach width that continued along central Cumberland Embayment and the north fillet area ranging from a minimum width of 100.6 m (Line C19, July 1988) to a maximum width of 166.0 m (Line C27, July 1988). Similar trends along the entire shoreline length occurred in April/May 1992 (Figure D120). In places, there was very little difference in net change such as Lines C6 (-2.3 m), C8 (2.8 m), C24 (1.7 m), and C26 (-2.9 m) (Table D9).

In contrast to Cumberland Island, the Amelia Island beaches are considerably narrower, ranging in width between 24.1 m (Line A25,A43) and 97.3 m (Line A76) for July 1988. The North Amelia Platform had generally narrow beaches, whereas the Amelia Embayment and Nassau Sound Tidal Inlet Complex had wider beaches (Figure D121). The widest section of

Table D9
Beach Width and Inner Bar Measurements for Cumberland Island

Survey Line	Beach Width,[1] m			Apr/May 1992 Inner Bar Distance,[2] m	Apr/May 1992 Inner Bar Elevation, m
	Jul 1988	Apr/May 1992	Difference		
C1	131.0	--[3]	--	--	--
C2	136.3	104.0	-32.3	No Bar	No Bar
C3	90.5	70.0	-20.5	84.0	-1.3
C4	69.0	72.6	3.6	54.0	-0.9
C5	63.2	83.0	19.8	64.0	-1.0
C6	73.6	71.3	-2.3	80.0	-1.3
C7	70.4	81.9	11.5	52.0	-1.2
C8	71.0	73.8	2.8	74.0	-1.0
C9	--	90.0	--	56.0	-0.9
C10	59.1	90.0	30.9	No Bar	No Bar
C11	80.3	76.5	-3.8	No Bar	No Bar
C12	71.2	111.0	39.8	No Bar	No Bar
C13	89.8	61.7	-28.1	70.3	-1.0
C14	103.6	75.0	-28.6	56.5	-0.6
C15	84.0	98.0	14.0	53.0	-0.8
C16	92.4	96.0	3.6	110.0	-1.8
C17	90.6	73.5	-17.1	129.0	-1.4
C18	98.7	88.0	-10.7	102.0	-1.4
C19	100.6	92.5	-8.1	143.0	-1.6
C20	109.0	88.0	-21.0	144.0	-1.7
C21	121.4	97.0	-24.4	145.5	-1.7
C22	124.7	121.0	-3.7	135.0	-1.7
C23	144.5	124.5	-20.0	134.0	-1.8
C24	125.0	126.7	1.7	129.3	-1.8
C25	138.6	110.5	-28.1	115.5	-1.6
C26	139.9	137.0	-2.9	No Bar	No Bar
C27	166.0	201.7	35.7	No Bar	No Bar
C28	106.0	170.0	64.0	47.7	-0.3

[1] Beach width computed as distance between the intercept of the profile with elevations 2.5 and 0.0 m (NGVD).
[2] Inner bar distance relative to intercept of the profile with elevation 0.0 m (NGVD).
[3] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

Table D10
Beach Width and Inner Bar Measurements for Amelia Island

Survey Line	Beach Width,[1] m			Apr/May 1992 Inner Bar Distance,[2] m	Apr/May 1992 Inner Bar Elevation, m
	Jul 1988	Apr/May 1992	Difference		
A10	53.9	--[3]	--	--	--
A13	41.1	--	--	--	--
A16	31.2	31.1	-0.1	No Bar	No Bar
A19	33.7	38.0	4.3	No Bar	No Bar
A22	33.2	26.0	-7.2	No Bar	No Bar
A25	24.1	--	--	--	--
A28	30.1	23.4	-6.7	50.6	-1.1
A31	28.5	23.9	-4.6	86.0	-1.6
A34	35.7	29.4	-6.3	60.9	-1.5
A37	42.2	27.0	-15.2	84.0	-1.6
A40	53.0	--	--	--	--
A43	24.1	33.0	8.9	98.0	-1.8
A46	40.8	53.7	12.9	93.3	-2.0
A49	89.7	55.0	-34.7	105.0	-1.9
A52	47.5	--	--	--	--
A55	94.2	50.8	-43.4	127.0	-2.0
A58	60.5	50.7	-9.8	133.0	-2.0
A61	76.0	85.3	9.3	106.7	-2.0
A64	78.4	75.6	-2.8	117.7	-2.2
A67	72.4	42.0	-30.4	129.0	-2.0
A70	68.5	66.8	-1.7	115.5	-2.2
A73	67.5	40.1	-27.4	59.0	-0.5
A76	97.3	--	--	--	--
A79	--	149.5	--	No Bar	No Bar

[1] Beach width computed as distance between the intercept of the profile with elevations 2.5 and 0.0 m (NGVD).
[2] Inner bar distance relative to intercept of the profile with elevation 0.0 m (NGVD).
[3] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

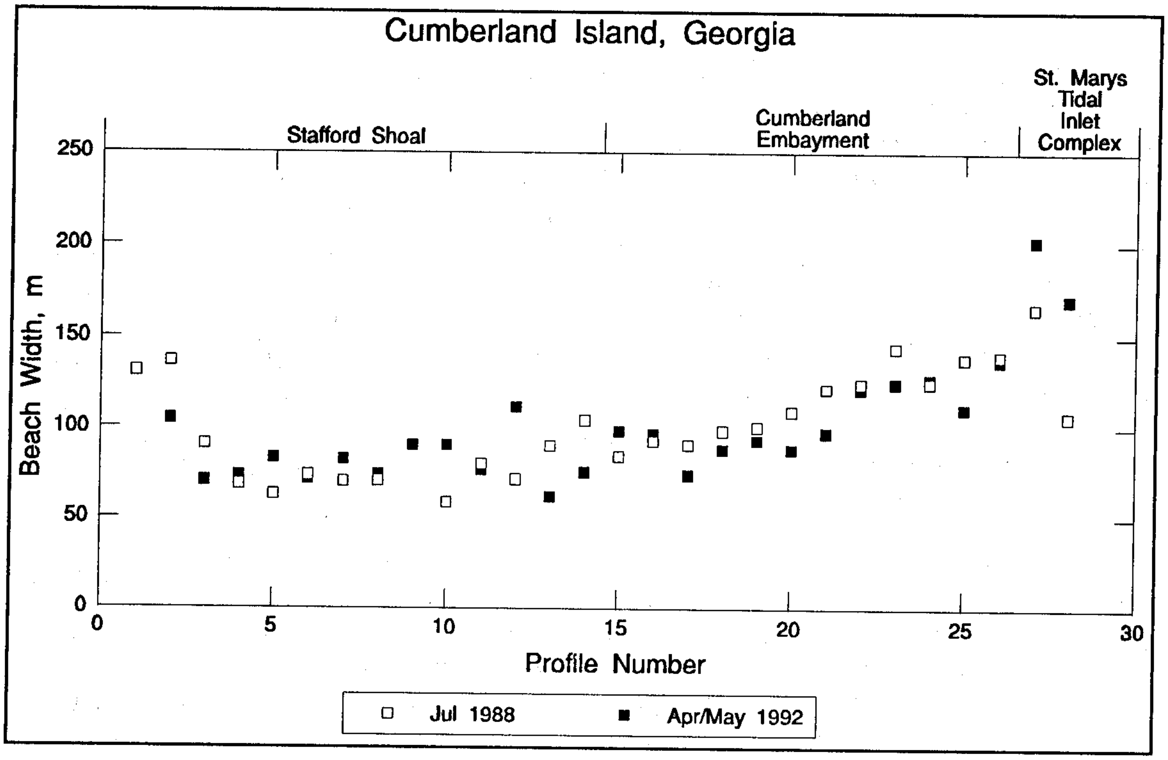


Figure D120. Beach width between elevations 2.5 and 0.0 m (NGVD), Cumberland Island

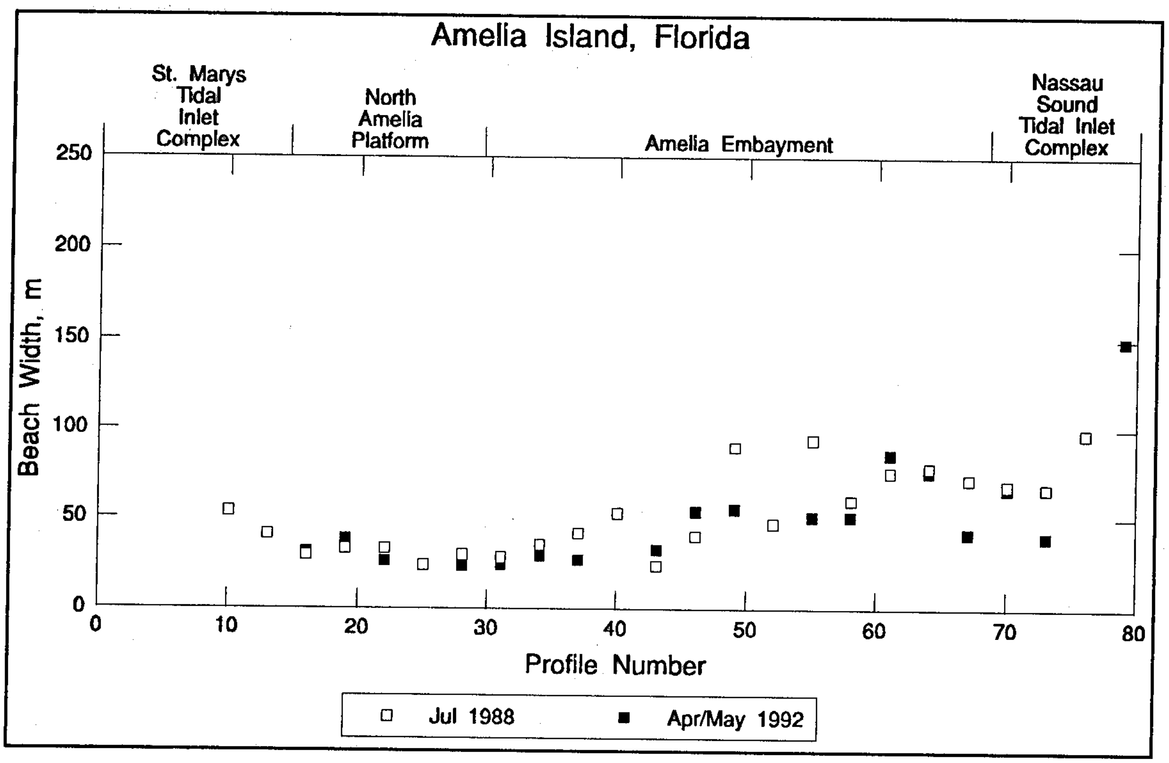


Figure D121. Beach width between elevations 2.5 and 0.0 m (NGVD), Amelia Island beach corresponded to the areas of the beach fill disposal between Lines A48 and A60 and the beach immediately to the south of this area. As an example, Line A49 had a width of 89.7 m in July 1988 (2 months after fill placement) and 55.0 m in April/May 1992, while Line A64 south of this fill area had a width of 78.4 m in July 1988 and 75.6 m in April/May 1992 (4 months after a small truck-hauled fill was placed between Lines A60 and A71). Areas of persistent erosion, such as the north central portion of Amelia Island (Lines A16-A34), have relatively narrow beach widths that changed less than 8 m over the monitoring period. The areas of the southern disposal site and near the south end of Amelia Island exhibited the most change, with a narrowing of beach width between Line A73 (27.4 m) and Line A55 (43.4 m) over the monitoring period (Table D10). The timing of beach fill placement and the change in seasons of profile monitoring (summer in 1988 and spring in 1992) altered the beach width along Amelia Island. Increased storm wave activity at the end of the monitoring period (1991 and 1992 in Chapter 6) also influenced the beach width, with a general trend to narrower widths in April/May 1992 relative to July 1988.

Inner bar distance and crest elevation. Sandbars play an important role in: (a) shoreface stability within the active beach envelope, (b) distribution of sediments in the nearshore zone, and (c) dissipation of wave energy (Hands 1976, Short 1991). Measurements of the inner bar were compiled using the April/May 1992 sled survey which provided continuous profile data through the surf zone. Most of the sled surveys did not exceed 2 km in length due to equipment limitations. No outer bars were detected within the profile coverage. As shown in Figure D122, the inner bar along Cumberland Island was continuous except in two areas, located at the Stafford Shoal axis (Lines C10-C11) and the north fillet area (Lines C27-C28). The longshore trend of the bar position follows the shoreline orientation and bottom slope. At the northern end of the

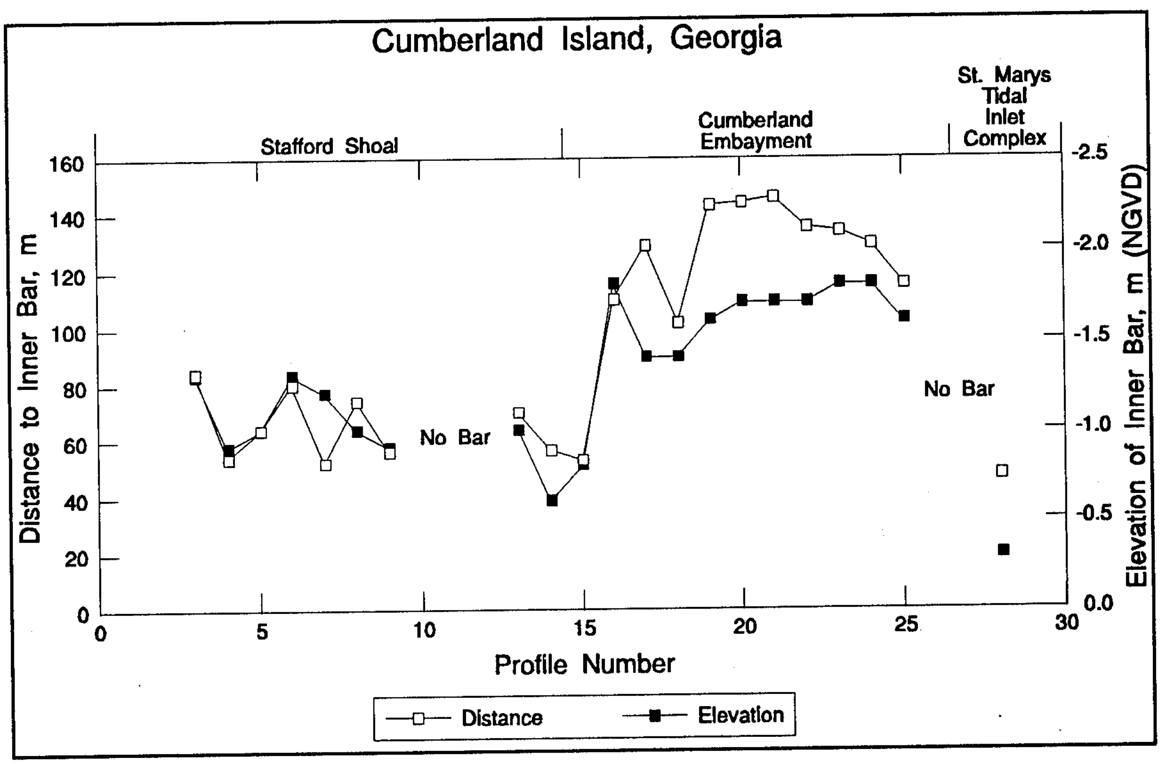


Figure D122. Distance to inner bar from elevation 0.0 m (NGVD) and inner bar crest elevation, Apr/May 1992, Cumberland Island study area, the bar distance is irregular (52.0 - 84.0 m) and close to the shoreline for Stafford Shoal, then gradually shifts seaward along the Cumberland Embayment compartment. Bar distance near the boundaries of Cumberland Embayment included a minimal measurement of 53.0 m at Line C15 and a maximum measurement of 145.5 m at Line C21 (Table D9). The bar is absent at the southern end of Cumberland Embayment, but sand features associated with the ebb-shoal of St. Marys Entrance are located seaward of the surf zone. However, adjacent to the north jetty, the inner bar is welded on to the shoreline. Bar elevations along Stafford Shoal varied between -0.6 and -1.3 m (NGVD) but gradually became deeper along the Cumberland Embayment compartment with a maximum depth of 1.8 m (NGVD) (Figure D122).

Along Amelia Island (Table D10 and Figure D123), the spatial trends are similar, with the absence of an inner bar associated with the presence of ebb shoals located on the south side of St. Marys Entrance (North Amelia Platform, Lines A16-A22) and the north side of Nassau Sound (Line A79). From Line A28, the bar crest was 50.6 m seaward of NGVD and gradually continued seaward to Line A70 with a bar position of 115.5 m (NGVD). At the distal end of Amelia Island, the bar distance decreased to 59.0 m (Line A73) as the bathymetry became shallower in the ebb delta area of Nassau Sound. The minimum bar distance occurred in the North Amelia Platform (Line A28, 50.6 m), where shoreline retreat and volumetric losses are relatively high. Maximum bar distance was located along southern Cumberland Embayment (Line A58, 133.0 m), where the shoreline advanced as discussed in the *Shoreline position change* section. Bar crest elevation along Amelia Island varied between the 0.5-m (NGVD) depth at Line A73 and the 2.2-m (NGVD) depth at Lines A64 and A70. Along central and southern Amelia Island, the bar crest was frequently at a maximum depth of 2.0 to 2.2 m (NGVD).

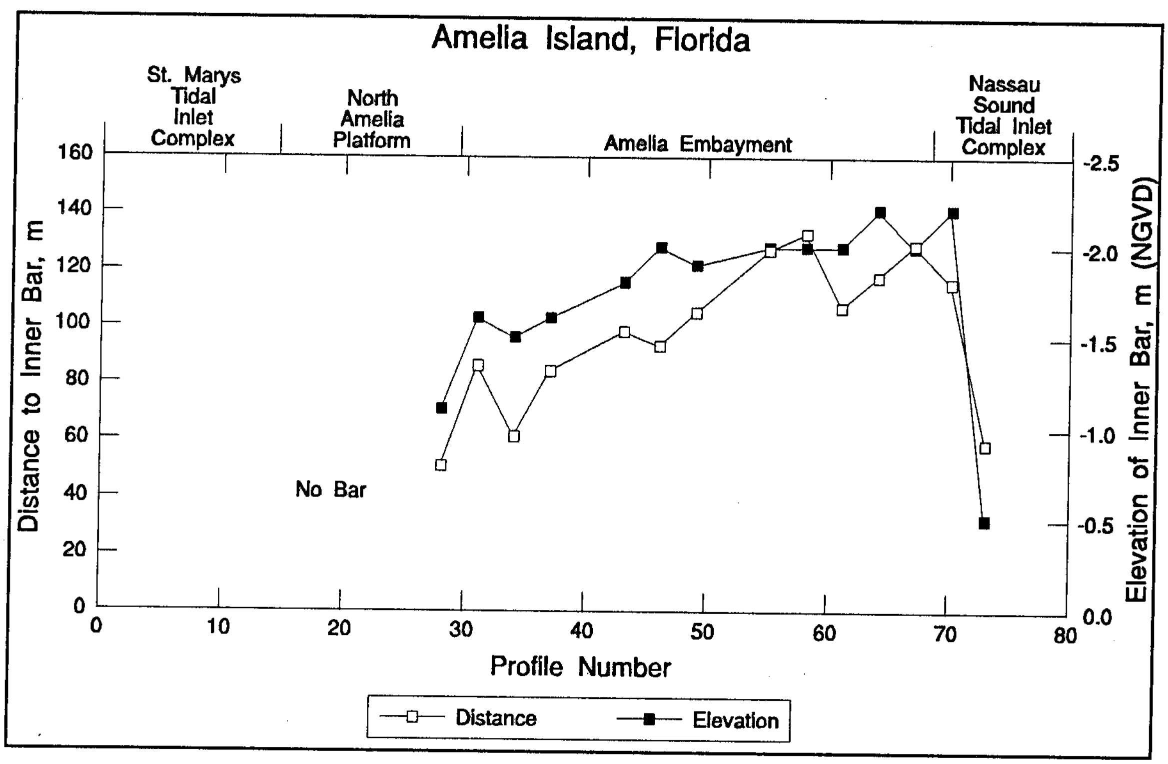


Figure D123. Distance to inner bar from elevation 0.0 m (NGVD) and inner bar crest elevation, Apr/May 1992, Amelia Island

Slope. Beach slope (2.5 to -1.0 m NGVD) was calculated from the July 1988 and April/May 1992 surveys and nearshore slope (-1.0 m NGVD to slope break between -4.0 and -6.0 m NGVD) was calculated for the July 1988 survey. The individual slope values are presented in Tables D11 and D12 and Figures D124 and D125 for both islands. Beach slope along Cumberland Island is relatively flat with a narrow range between 0.9 and 1.6 deg for the July 1988 profiles and a slightly steeper gradient for the April/May 1992 profiles, ranging between 0.7 and 2.3 deg (Figure D124). Noticeable slope differences between the two time periods of up to 1.1 deg (Line C13) occurred in the Stafford Shoal compartment, whereas the Cumberland Embayment was uniform with slope differences of 0.5 deg or less. Based on the July 1988 survey information, the nearshore is also relatively flat ranging between 1.0 and 1.6 deg along Stafford Shoal, 1.0 and 1.2 deg along Cumberland Embayment, and a uniform slope of 0.9 deg along the north fillet (Table D11). The minimum nearshore slope was 0.4 deg measured along several lines and the maximum slope was 1.3 deg at Line C9.

For Amelia Island, the beach and nearshore slopes are shown in Table D12 and Figure D125. As with most of the Amelia Island profile measurements, the beach slope is affected by local inlet processes and the multiple beach fill operations. In addition, geomorphic features influence the nearshore slope including the large shoal bars associated with St. Marys ebb-tidal delta, a narrow nearshore shelf along central Amelia Island, and another series of shoal bars at Nassau Sound inlet (Figure D1). The alongshore trend on Amelia Island can be subdivided into two beach sections: (a) the northern portion of the island (Lines A10-A46) where the slope angle is moderate (2.1-5.7 deg, July 1988 and April/May 1992) and (b) the southern portion (Lines A49-A79) where the slope angle is low to moderate (1.0-3.5 deg, July 1988 and April/May 1992). In areas where the beach gradient was low, the bar crest was farther offshore, such as Line A61 with a beach slope of 1.6 deg and a bar distance of 106.7 m (Table D10). Conversely, in areas with a steeper beach gradient (i.e., Line A28 with a beach slope of 5.7 deg), there was a minimal distance between 0.0 m (NGVD) and the inner bar (Line A28, 50.6 m NGVD).

Assessment of the 1988-1992 slope measurements indicated that the steepest beaches were located south of the northern disposal site between Lines A28 (5.7 deg, April/May 1992) and A37 (4.2 deg, April/May 1992). As discussed in Chapters 3 and 5, shoreline retreat and volumetric losses resulted in a disequilibrium and steeper profile along North Amelia Platform. The net changes in slope were low to moderate, reflecting beach fill adjustments and some seasonal variability between the July 1988 and April/May 1992 surveys. The largest differences occurred just south of the northern disposal site where the slope difference was a maximum of 2.5 deg (Line A28).

Shoreline position change. Shoreline position change was the principal measurement used to interpret the process/response of the beach system and to assess potential impacts of the TRIDENT channel modifications. Evaluation of the shoreline position was based on the intercept of the profile with the 1.3-m (NGVD) elevation contour. In addition, the position of elevation 0.0 m (NGVD) on each profile line was also calculated to assess change along the lower part of the subaerial beach. This elevation is a good indicator of swash bar migration occurring along the low-tide terrace. Comparison of the 1.3- and 0.0-m (NGVD) profile intercepts showed, in most cases, significantly different rates of change (m/year) between the two contours. In many cases, the pattern of shoreline advance and recession was reversed at the shoreline position of 1.3 m versus 0.0 m (NGVD). Further differences between the 1.3- and 0.0-m contour for the seasonal surveys are presented in the *Seasonal change* section.

Table D11
Beach and Nearshore Slope Measurements for Cumberland Island

Survey Line	Jul 1988 Beach Slope[1]		Apr/May 1992 Beach Slope[1]		Jul 1988 Nearshore Slope[2]	
	Ratio	Degrees	Ratio	Degrees	Ratio	Degrees
C1	1:46	1.3	--[3]	--	1:50	1.2
C2	1:56	1.0	1:43	1.3	1:74	0.8
C3	1:37	1.6	1:34	1.7	1:86	0.7
C4	1:41	1.4	1:34	1.7	1:66	0.9
C5	1:38	1.5	1:31	1.9	1:96	0.6
C6	1:41	1.4	1:27	2.1	1:93	0.6
C7	1:39	1.5	1:32	1.8	1:59	1.0
C8	1:41	1.4	1:35	1.6	1:83	0.7
C9	--	--	1:35	1.6	1:46	1.3
C10	1:38	1.5	1:42	1.4	1:95	0.6
C11	1:37	1.5	1:38	1.5	1:88	0.7
C12	1:41	1.4	1:49	1.2	1:143	0.4
C13	1:47	1.2	1:25	2.3	1:83	0.7
C14	1:48	1.2	1:29	2.0	1:116	0.5
C15	1:52	1.1	1:35	1.6	1:88	0.7
C16	1:50	1.2	1:38	1.5	1:84	0.7
C17	1:50	1.2	1:44	1.3	1:155	0.4
C18	1:52	1.1	1:42	1.4	1:104	0.6
C19	1:55	1.0	1:45	1.3	1:131	0.4
C20	1:52	1.1	1:46	1.2	1:113	0.5
C21	1:52	1.1	1:48	1.2	1:120	0.5
C22	1:57	1.0	1:48	1.2	1:119	0.5
C23	1:58	1.0	1:53	1.1	1:129	0.4
C24	1:52	1.1	1:54	1.1	1:145	0.4
C25	1:56	1.0	1:48	1.2	1:84	0.7
C26	1:57	1.0	1:55	1.0	1:101	0.6
C27	1:63	0.9	1:77	0.7	1:90	0.6
C28	1:63	0.9	1:82	0.7	1:85	0.7

[1] Beach slope computed between the intercept of the profile with elevations 2.5 and -1 m (NGVD).
[2] Nearshore slope computed between intercept of the profile with elevation -1 m (NGVD) and slope break.
[3] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

Table D12
Beach and Nearshore Slope Measurements for Amelia Island

Survey Line	Jul 1988 Beach Slope[1]		Apr/May 1992 Beach Slope[1]		Jul 1988 Nearshore Slope[2]	
	Ratio	Degrees	Ratio	Degrees	Ratio	Degrees
A10	1:23	2.5	--[3]	--	1:129	0.4
A13	1:18	3.2	--	--	1:55	1.0
A16	1:13	4.4	1:14	4.0	1:63	0.9
A19	1:14	4.1	1:16	3.6	1:66	0.9
A22	1:18	3.1	1:19	2.9	1:49	1.2
A25	1:23	2.5	--	--	1:32	1.8
A28	1:18	3.2	1:10	5.7	1:102	0.6
A31	1:16	3.6	1:11	5.3	1:81	0.7
A34	1:21	2.7	1:13	4.4	1:77	0.7
A37	1:25	2.3	1:14	4.2	1:99	0.6
A40	1:27	2.1	--	--	1:105	0.5
A43	1:20	2.9	1:19	3.1	1:131	0.4
A46	1:19	3.0	1:24	2.4	1:110	0.5
A49	1:34	1.7	1:26	2.2	1:67	0.9
A52	1:29	1.9	--	--	1:62	0.9
A55	1:33	1.7	1:29	2.0	1:103	0.6
A58	1:35	1.6	1:30	1.9	1:83	0.7
A61	1:40	1.4	1:36	1.6	1:114	0.5
A64	1:34	1.7	1:35	1.7	1:141	0.4
A67	1:32	1.8	1:30	1.9	1:71	0.8
A70	1:33	1.8	1:33	1.7	1:137	0.4
A73	1:29	2.0	1:16	3.5	1:152	0.4
A76	1:35	1.6	--	--	1:111	0.5
A79	--	--	1:55	1.0	1:284	0.2

[1] Beach slope computed between the intercept of the profile with elevations 2.5 and -1 m (NGVD).
[2] Nearshore slope computed between intercept of the profile with elevation -1 m (NGVD) and slope break.
[3] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

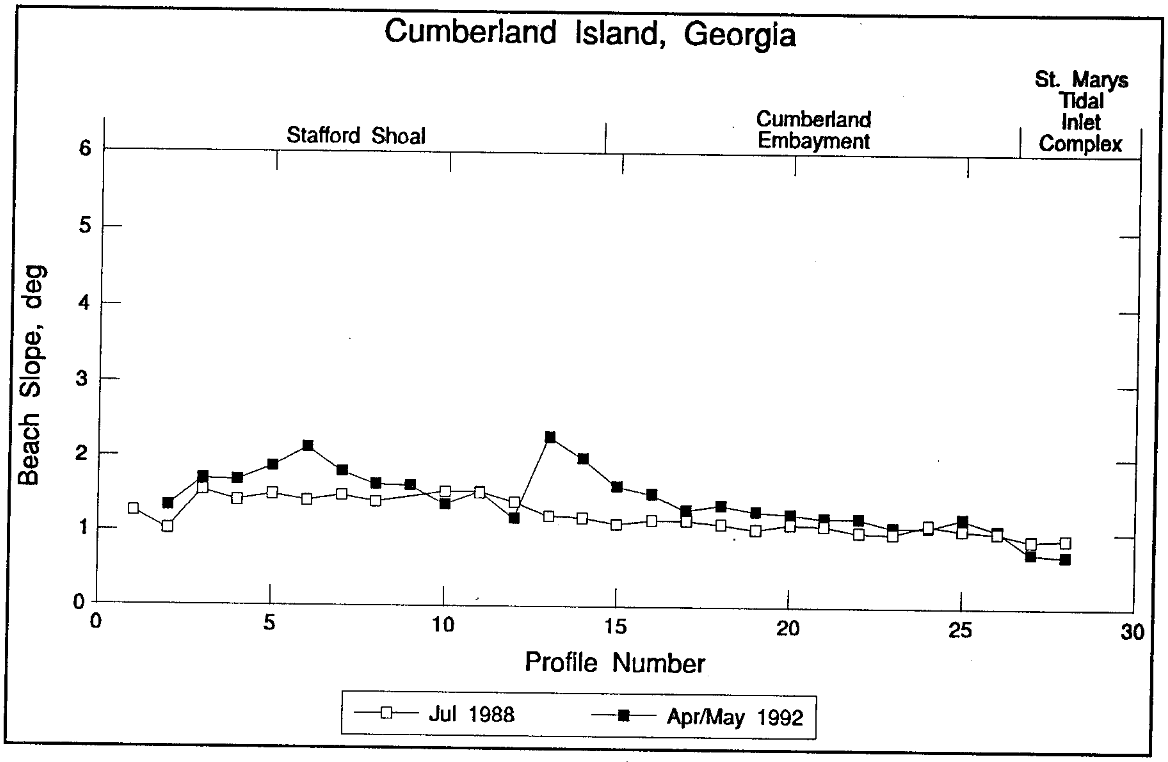


Figure D124. Beach slope computed between elevations 2.5 and -1 m (NGVD), Cumberland Island

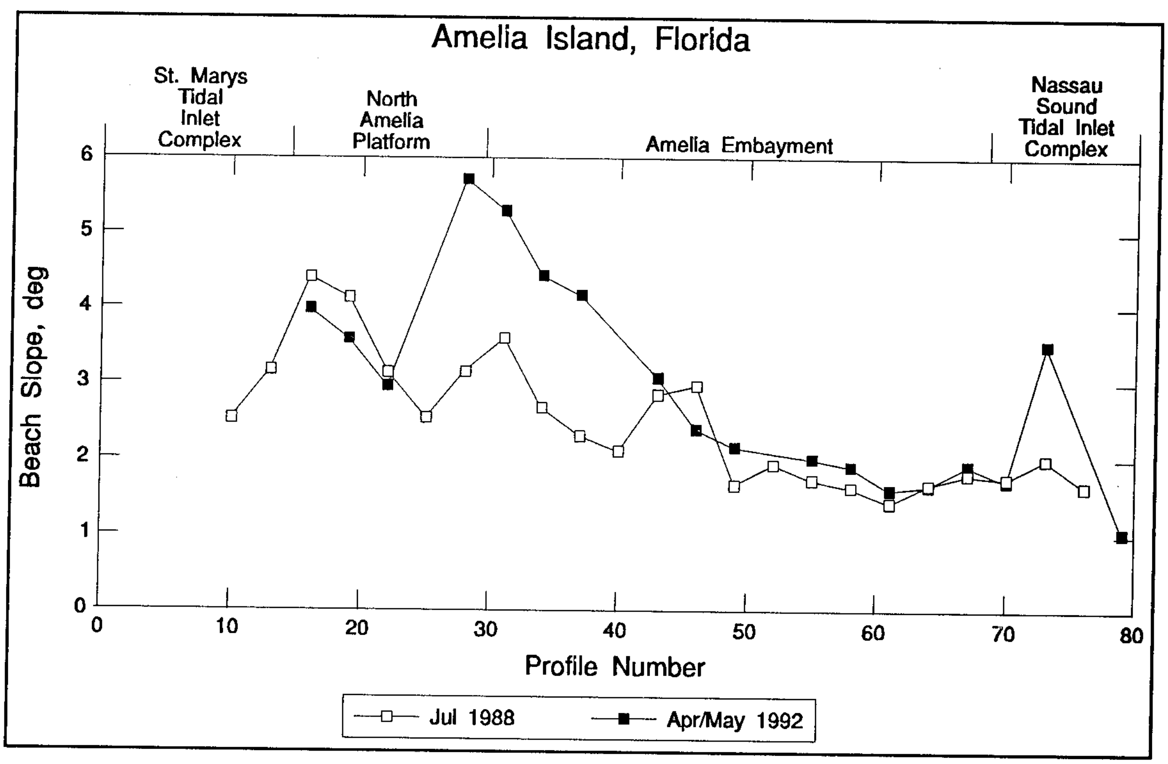


Figure D125. Beach slope computed between elevations 2.5 and -1 m (NGVD), Amelia Island

The shoreline change results for the monitoring period are presented in a series of tables and graphs that show the annual rate of shoreline change (m/year) and the shoreline position relative to the July 1988 baseline survey. Spatial trends for the July 1988 - April/May 1992 net shoreline change (i.e., Tables D13 and D14 and Figures D126 and D127) are followed by the temporal trends of the intermediate year surveys (i.e., Tables D15 and D16 and Figures D128 and D129). This order is followed throughout Appendix D.

As shown in Table D13 and Figure D126, the overall net changes along Cumberland Island followed a well-defined trend where the shoreline recedes along most of the Stafford Shoal compartment (Lines C2-C14) and the shoreline advances along Cumberland Embayment and the north fillet area (Lines C15-C28). This trend follows the sediment movement pattern as discussed in Chapter 3. The St. Andrew Sound Tidal Inlet Complex and Stafford Shoal compartments act as sediment sources for the shoreline and nearshore zone. For instance, along the northern limits of the Stafford Shoal compartment, the shoreline advanced 4.3 m/year (Line C2) due to sediment transport south from St. Andrew Tidal Inlet Complex. The maximum shoreline recession of 3.6 m/year (Lines C7-C8) is located just to the north of the Stafford Shoal axis, and the maximum shoreline advance of 5.6 m/year (Line C27) is located along the north fillet of the St. Marys Tidal Inlet Complex.

Examination of shoreline position at the 0.0-m (NGVD) contour showed similar change trends, although typically the rates were much higher. For example, at Line C6 the net change at 0.0 m was -5.4 m/year compared to -2.4 m/year at the 1.3-m contour, and at Line C19 the shoreline advanced 8.1 m/year compared to 1.5 m/year at the 1.3-m contour. In other areas, there is a reversal in accretion and erosion such as at Line C11 with a rate of 0.5 m/year at 0.0 m and -0.2 m/year at the 1.3-m contour, and at Line C20 with a rate of -0.3 m/year at 0.0 m and 1.9 m/year at the 1.3-m contour. It is cautioned that values of shoreline change on the order of 0.2 and 0.3 m/year over a short time frame (i.e. a few years) may be dominated by random noise and not express a true trend. These opposite values in shoreline retreat and advance indicate the cut and fill sections of the active profile envelope, which can vary considerably at the point of shoreline change along the flat-sloping Cumberland Island beaches. In addition, the ridge and runnel morphology in the swash zone causes large changes in shoreline position and volumetric changes along the lower beach profile. Similar trends were found along Amelia Island.

Annual individual measurements of shoreline change are referenced to the July 1988 1.3-m (NGVD) shoreline position (Tables D15 and D16 and Figures D128 and D129) and show the shoreline variability on an annual and seasonal basis during the July 1988 - April/May 1992 period. At the end of the first year of monitoring (August/September 1989), shoreline position advanced along the Cumberland Island profile lines. The range of Cumberland Island's shoreline position relative to July 1988 was 1.4 to 18.7 m (Figure D128). During the second monitoring year (July 1990), the shoreline predominantly retreated along the Stafford Shoal compartment with a maximum movement of -12.3 m, Line C10) and continued shoreline advance along Cumberland Embayment (maximum movement of 14.0 m, Line C26). At the end of the third year (August 1991), shoreline position showed an overall trend of advance. In the last year, the net change in shoreline position was relatively low (Figure D128). A general trend over the monitoring period was recession along Stafford Shoal and accretion along Cumberland Embayment and the north fillet of St. Marys Tidal Inlet Complex.

Along Amelia Island, the net shoreline position is highly variable because of the beach fill operations (Table D2). The alongshore pattern of shoreline change follows the geographic zones

Table D13
Shoreline Change Rates for Cumberland Island

Survey Line	Shoreline Change Rate,[1] m/year (Jul 1988 to Apr/May 1992)	
	0 m NGVD	1.3 m NGVD
C2	8.3	4.3
C3	-4.8	-1.0
C4	-5.4	-1.8
C5	-2.5	-2.1
C6	-5.4	-2.4
C7	-3.4	-3.6
C8	-3.8	-3.6
C10	-1.0	-0.6
C11	0.5	-0.2
C12	-6.2	-0.4
C13	-6.5	-1.3
C14	-5.5	-2.1
C15	-3.6	0.8
C16	4.8	0.1
C17	8.9	1.2
C18	3.4	0.3
C19	8.1	1.5
C20	-0.3	1.9
C21	1.3	1.8
C22	4.5	3.0
C23	1.1	2.6
C24	1.5	2.2
C25	1.8	2.0
C26	2.3	2.7
C27	6.0	5.6
C28	-4.6	0.0

[1] Shoreline change rate computed as distance between the intercept of the profile with the specified elevation and divided by the time interval to the nearest month.

Table D14
Shoreline Change Rates for Amelia Island

Survey Line	Shoreline Change Rate,[1] m/year							
	Feb 1974 to Sep/Nov 1981		Sep/Nov 1981 to Jul 1988		Jul 1988 to Apr/May 1992		Feb 1974 to Apr/May 1992	
	0 m NGVD	1.3 m NGVD	0 m NGVD	1.3 m NGVD	0 m NGVD	1.3 m NGVD	0 m NGVD	1.3 m NGVD
A10	4.9	4.2	-1.8	-3.2	--[2]	--	--	--
A16	4.2	1.2	0.5	3.1	-3.6	-3.4	1.2	0.9
A19	0.9	2.6	4.1	5.2	-6.2	-5.1	0.6	1.9
A22	-1.0	0.4	5.0	6.5	-7.0	-7.8	0.0	0.9
A28	-2.7	0.5	0.6	-0.3	-1.0	2.7	-1.2	0.7
A31	0.0	2.5	-2.5	-1.5	2.6	2.5	-0.4	1.0
A34	3.6	5.0	-5.4	-2.3	-0.7	-0.3	-0.6	1.2
A37	-0.5	-0.6	1.1	3.1	-2.8	1.0	-0.4	1.1
A43	--	--	--	--	4.3	4.9	--	--
A46	1.3	-0.8	-1.7	4.5	2.9	2.3	0.5	1.8
A49	--	--	8.2	5.9	-9.2	-3.2	--	--
A55	--	--	--	--	0.8	7.7	--	--
A58	-1.9	-2.3	-0.7	0.7	4.7	6.3	-0.1	0.6
A61	-1.5	0.4	3.3	-0.2	-3.3	-2.1	-0.1	-0.3
A64	0.0	-0.9	0.0	-1.2	-2.2	-2.4	-0.5	-1.3
A67	--	--	--	--	-5.2	-2.2	--	--
A70	-2.3	-1.1	-1.9	-3.6	-5.0	-4.6	-2.8	-2.8
A73	--	--	-2.2	-3.5	-11.6	-4.1	--	--

[1] Shoreline change rate computed as distance between the intercept of the profile with the specified elevation and divided by the time interval to the nearest month.
[2] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

of Amelia Island, where the northern section beyond the fillet area (North Amelia Platform) mostly retreated at a rate of between 3.4 and 7.8 m/year, the central section was variable, ranging between 7.7 and -3.2 m/year, and the southern end (Nassau Sound Tidal Inlet Complex) retreated between 4.1 and 4.6 m/year. The increase in erosion from Lines A16 (-3.4 m/year) to A22 (-7.8 m/year) follows the net littoral transport pattern to the north (Chapter 3). The increase in shoreline advance between Lines A31 (2.5 m/year) and A58 (6.3 m/year) along Amelia Embayment coincides with the dominant southerly transport direction. An exception to the accretional trend occurred outside a fill placement area at Line A34 (-0.3 m/year) and in an area where reported fine material winnowed from the southern disposal site at Line A49 (-3.2 m/year). At the southern end of Amelia Island, the increase in shoreline recession is related not only to the southerly littoral transport but also to tidal inlet currents moving material into the inlet

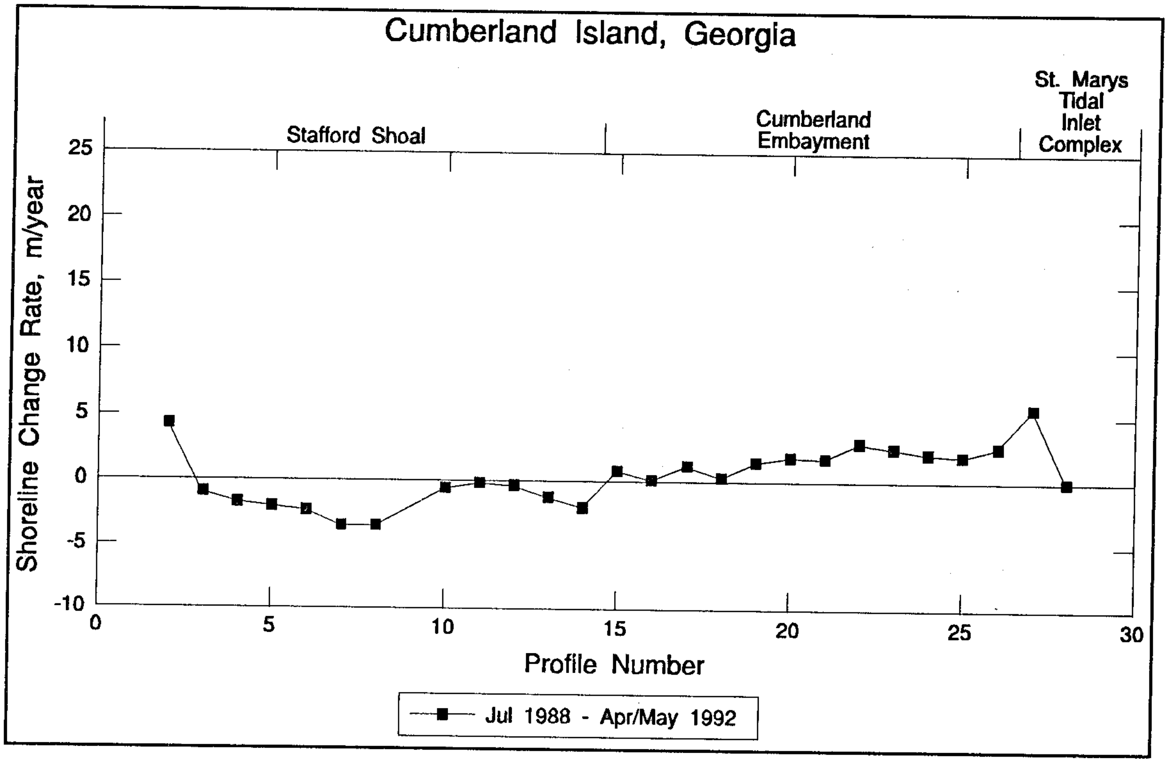


Figure D126. Shoreline change rates, Jul 1988 - Apr/May 1992, Cumberland Island

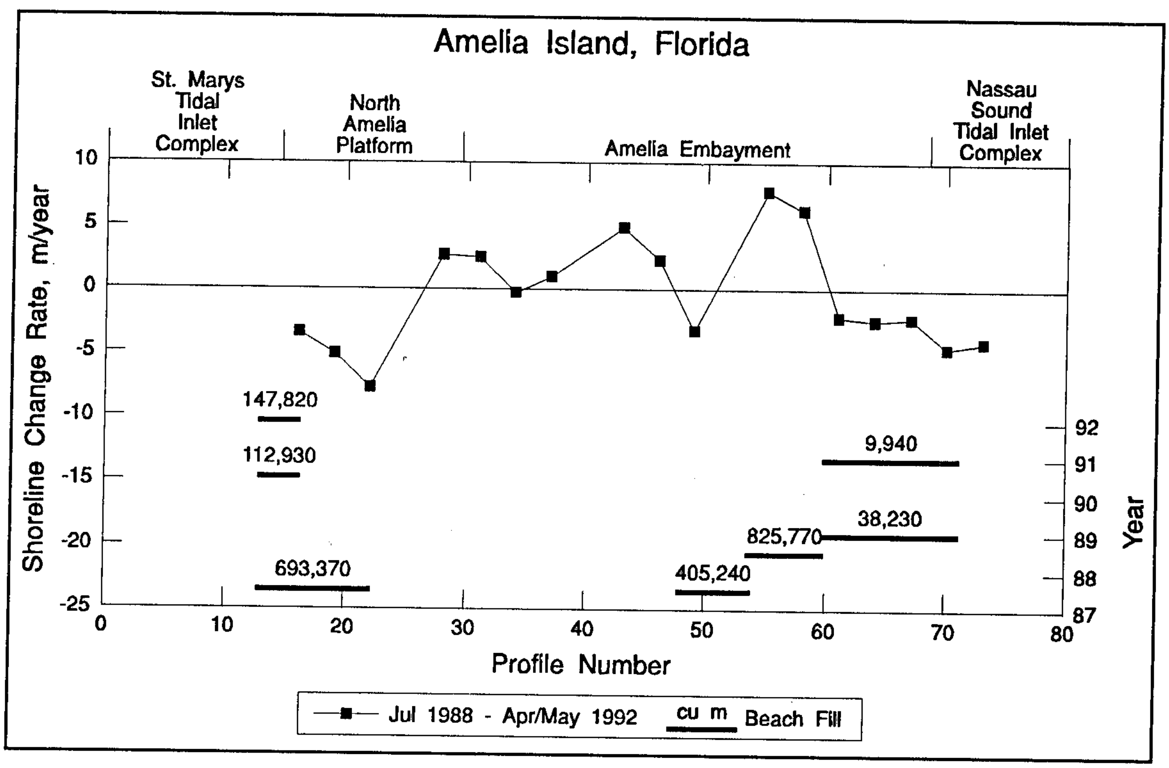


Figure D127. Shoreline change rates, Jul 1988 - Apr/May 1992, Amelia Island

Table D15
Shoreline Position Change During the Monitoring Period for Cumberland Island

Survey Line	Shoreline Position Relative to Jul 1988,[1] m			
	Aug/Sep 1989	Jul 1990	Aug 1991	Apr/May 1992
C1	3.0	4.1	25.7	--[2]
C2	8.9	3.9	12.5	16.5
C3	--	--	--	-4.0
C4	5.6	-2.3	-6.9	-7.0
C5	--	--	--	-8.0
C6	--	-0.9	12.1	-9.2
C7	6.3	4.1	2.0	-14.0
C8	1.4	-3.0	0.8	-14.0
C10	--	-12.3	5.0	-2.3
C11	3.7	5.3	17.1	-0.7
C12	--	10.7	0.0	-1.5
C13	--	--	--	-5.2
C14	--	--	--	-8.0
C15	3.0	-3.0	6.0	3.0
C16	--	--	--	0.5
C17	--	--	--	4.8
C18	5.6	5.6	16.3	1.0
C19	--	--	--	6.0
C20	2.5	5.0	7.7	7.5
C21	5.9	10.5	19.8	6.8
C22	--	--	--	11.5
C23	--	--	--	10.0
C24	9.4	6.5	9.5	8.5
C25	--	--	17.0	7.7
C26	14.1	14.0	11.4	10.3
C27	18.7	10.0	--	21.7
C28	10.0	-0.7	14.0	0.0

[1] Shoreline position computed as distance between the intercept of the profile with elevation 1.3 m (NGVD) for the specified year and Jul 1988.
[2] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

Table D16
Shoreline Position Change During the Monitoring Period for Amelia Island

Survey Line	Shoreline Position Relative to Jul 1988,[1] m			
	Oct 1989	Aug 1990	Sep/Nov 1991	Apr/May 1992
A10	2.8	11.8	49.8	--[2]
A13	-5.6	-7.9	--	--
A16	--	-18.2	--	-13.2
A19	--	-25.0	--	-19.8
A22	-23.4	-14.9	--	-30.2
A25	--	12.0	--	--
A28	--	12.3	--	10.3
A31	9.2	7.6	--	9.9
A34	--	--	--	-1.0
A37	3.8	2.0	--	4.0
A40	--	13.5	--	--
A43	-4.0	19.5	2.0	19.0
A46	--	9.2	--	9.1
A49	-13.0	-3.0	--	-12.5
A52	--	-11.0	--	--
A55	23.0	31.0	--	30.0
A58	34.9	33.1	--	24.2
A61	-18.3	0.0	--	-8.0
A64	-8.7	-1.1	--	-9.3
A67	6.3	-6.8	--	-8.7
A70	-2.7	-1.3	15.3	-17.7
A73	-2.0	13.0	17.0	-16.0
A76	-8.8	21.2	--	--

[1] Shoreline position computed as distance between the intercept of the profile with elevation 1.3 m (NGVD) for the specified year and Jul 1988.
[2] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

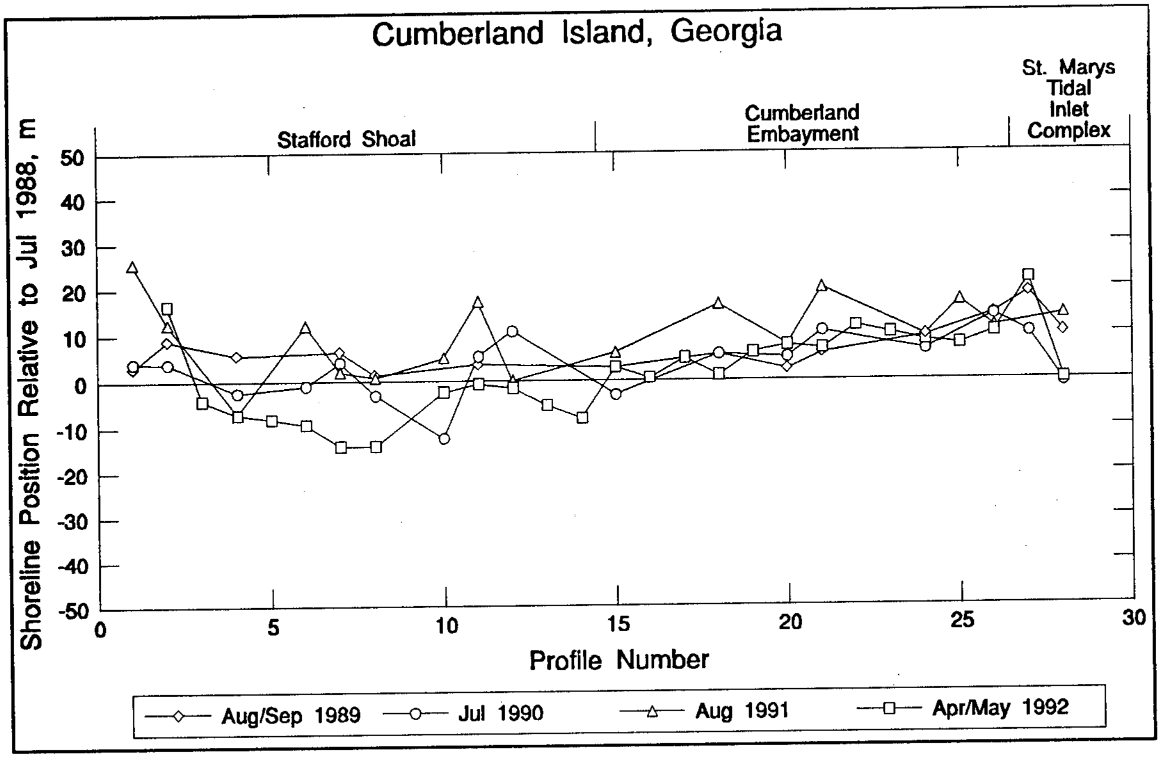


Figure D128. Shoreline position relative to Jul 1988, Cumberland Island

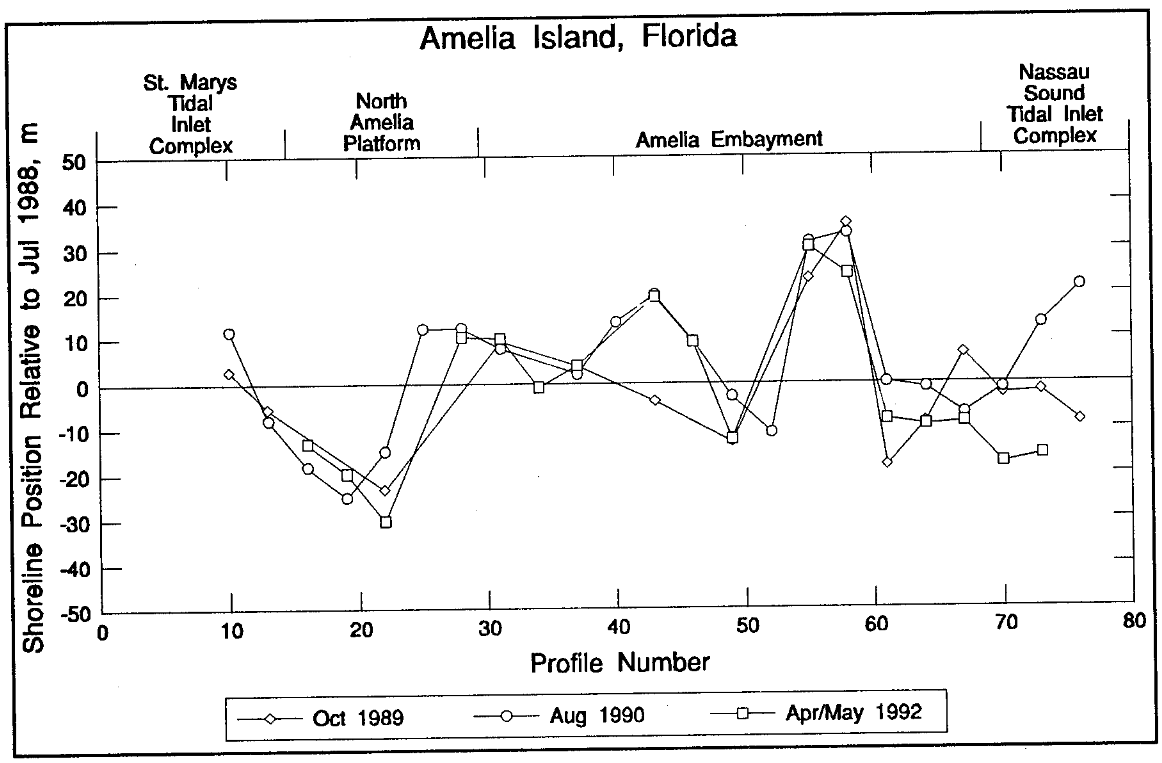


Figure D129. Shoreline position relative to Jul 1988, Amelia Island channel of Nassau Sound. The atypical values indicating shoreline advance are primarily attributed to the placement of 1,134,690 cu m of material during the July 1988 - April/May 1992 period (Chapter 5, *Trend Analysis and Implications of Recent Engineering Activities* section).

Evaluation of the intermediate year surveys, as listed in Table D16, indicates that the alongshore trend of July 1988 - October 1989 followed the same recession and advance pattern as historic trends with erosion along the North Amelia Platform and Nassau Sound Tidal Inlet Complex compartments. The high loss at Line A22 (-23.4 m) is probably due to fill adjustment from the June 1987 - February 1988 fill (which extended between Lines A13-A22) and material following the northerly transport pattern identified by the shoreline position and nearshore bathymetric change analysis in Chapter 3. Two other localities where shoreline recession occurred were at Line A43 (-4.0 m), an area with no prior history of disposal placements, and Line A49 (-13.0 m), an area with a pre-monitoring fill of 405,240 cu m (September 1987 - May 1988). The most pronounced shoreline advance was measured between Lines A55 (23.0 m) and A58 (34.9 m), where the largest fill of 825,770 cu m was placed during the July 1988 - July 1989 period. Comparison of the shoreline position between July 1988 and August 1990 showed the same general trends as the first survey. However, shoreline recession was greater along the North Amelia Platform with a maximum change of 25.0 m (Line A19). Along the central portion of the island (Amelia Embayment), the pattern is mostly one of shoreline advance except at Line A49 (-3.0 m) and Line A52 (-11.0 m). Noticeable accretion continued between Lines A55 and A58, reflecting the July 1988 - July 1989 disposal placement and material moving downdrift from adjacent beaches. Shoreline change was variable in the Nassau Sound Tidal Inlet Complex compartment, ranging between 21.2 and -1.3 m. The substantially lower values of shoreline recession occurred because of a modest fill placement of 38,230 cu m in December 1989 between Lines A60 and A71. Shoreline advancement at Lines A73 and A76 resulted from the downdrift movement of fill from north of Line A71 and bar migration associated with the inlet shoals. Available storm records and field inspections by USAED, Jacksonville indicate a relatively quiescent storm period during 1990, which resulted in lower rates of shoreline recession (Chapter 6, Figure 155).

For the next period, July 1988 to September/November 1991, a very limited profile data set was taken. The most northern profile (Line A10) in the north fillet area indicated the highest shoreline advance for the monitoring period. This shoreline advance is due to the accumulation of transported fill material moving toward the inlet from the North Amelia Platform compartment. Stability of the fillet was enhanced by sand sealing of the landward 457-m section of the south jetty which occurred from June 1987 - October 1988. The other three available profiles indicated a normal pattern of accretion (ranging between 2.0 and 17.0 m) for central and southern Amelia Island.

By the end of the monitoring period (July 1988 - April/May 1992), the trend was generally one of shoreline recession except in beach sections adjacent to the northern and southern disposal sites. Although the shoreline advance was moderate (4.0-19.0 m) between Lines A28 and A43, a substantial advance of 30.0 and 24.2 m was measured for Lines A55 and A58, respectively. Chronic shoreline recession was identified from Lines A61 to A73, with a range of -8.0 to -17.7 m despite a small private fill placement (9,940 cu m) in December 1991. A contributing factor to the overall trend of shoreline recession was an active period of storms in late 1991 and early 1992.

Shoreline position from the profile intercept of 1.3 m (NGVD) was also evaluated for the pre-monitoring period of February 1974 to July 1988. Two DNR profile survey sets, February 1974 and September/November 1981, were selected based on data coverage and used to evaluate the pre-monitoring shoreline changes along Amelia Island (Table D14 and Figure D130). Although trends were variable along the entire island, there was continuous accretion from Lines A10 (4.2 m/year) to A34 (5.0 m/year) during the February 1974 to September/November 1981 period. On northern Amelia Island, seaward movement of the shoreline coincided with the large placement of dredged fill material of 765,000 cu m (Lines A12-A22) during the POSEIDON channel deepening (November 1978 - June 1979). The maximum shoreline advance rate was 5.0 m/year, which occurred along Line A34 (Table D14). Along the central portion of the island, mild shoreline recession increased toward the south between Lines A37 and A58. A maximum recession rate of 2.3 m/year for the island was measured at Line A58. At the southern end of Amelia Island, between Lines A61 and A73, the shoreline change rates are variable, ranging between 0.4 and -1.1 m/year.

The September/November 1981 to July 1988 period represents conditions prior to the TRIDENT channel modifications. During this period, four maintenance dredging fills and two private fills were placed along Amelia Island (Table D2 and Figure D14), which resulted in shoreline advancement. The highest rates of shoreline advance occurred in areas of fill placements; in particular, Lines A16 (3.1 m/year), A19 (5.2 m/year), A22 (6.5 m/year) along the northern disposal site, and Lines A46 (4.5 m/year) and A49 (5.9 m/year) along the southern disposal site (Table D14 and Figure D130). The southern end of Amelia Island progressively increased in shoreline recession rates between Lines A61 (-0.2 m/year) and A73 (-3.5 m/year).

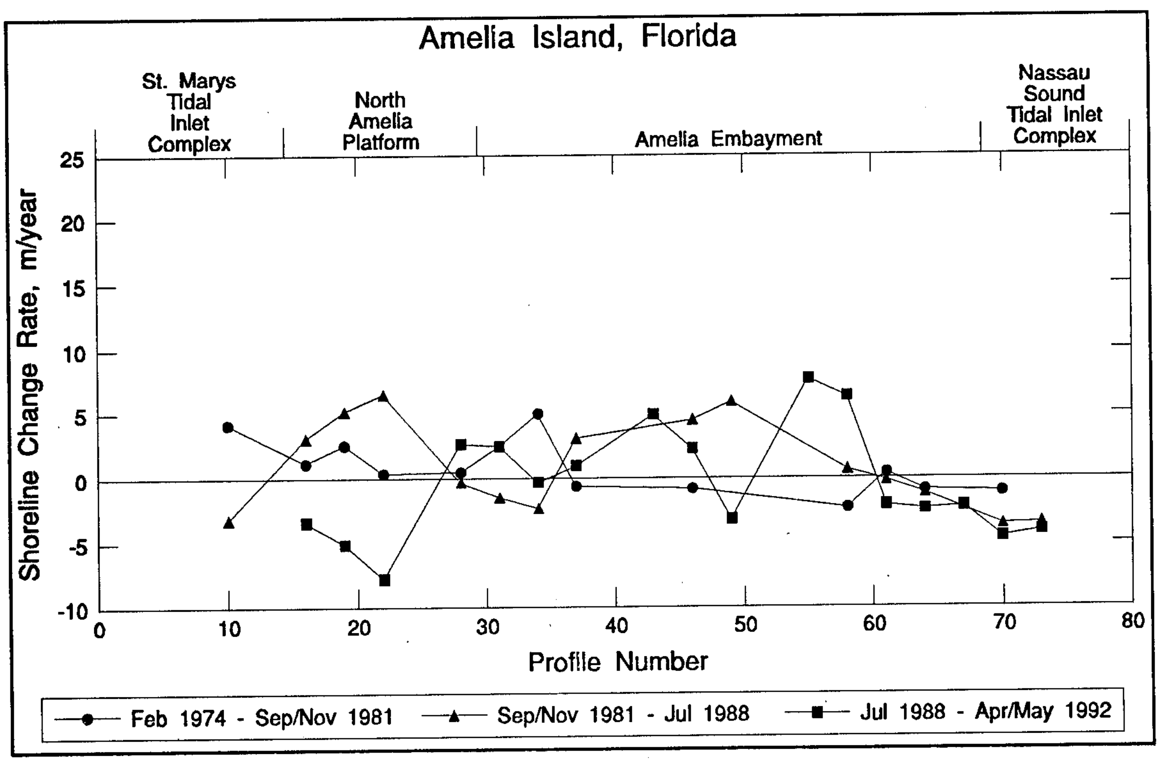


Figure D130. Shoreline change rates, Feb 1974 - Apr/May 1992, Amelia Island

Because of overlapping beach fill activity between July 1988 and April/May 1992, the pattern of shoreline position is much more variable as the fills adjusted alongshore and across shore. Comparison of the pre- and post-monitoring shoreline positions showed compartmental trends of recession and advance. Most of the variability can be attributed to the timing and location of the Federal and private disposal fill operations and subsequent adjustment to the local transport pattern and wave climate.

Net volumetric change. Volumetric data results for Cumberland and Amelia Islands are presented in Tables D17 and D18 and Figures D131-D134. The net volume trends for Cumberland Island closely follow the morphologic compartments with erosion dominant along the Stafford Shoal compartment and accretion along Cumberland Embayment and the north fillet of St. Marys Tidal Inlet Complex (Figure D131). Furthermore, the beach volumetric changes correspond to the regional sediment pattern as identified in Chapter 3. At the northern boundary of the Stafford Shoal compartment, large volumetric gains (Line C2, 79.9 cu m/m) are due to sediment transport from the St. Andrew Sound inlet system (Table D17). There is a gradual increase in erosion toward the center of the Stafford Shoal compartment from Lines C3 to C6 as material is transported to the south. A stable zone with negligible shoreline and volumetric change located at Lines C10-C11 is referred to as the "Stafford Shoal axis." Beyond the Stafford Shoal axis, erosion continues along the leeward side of the shoal complex. Another persistent point of change occurs near Lines C14-C15, which has been defined as the boundary between the Stafford Shoal and Cumberland Embayment compartments. For Cumberland Embayment and the north fillet area, the trend reverses to accretion from 21.0 cu m/m at Line C15 to 50.4 cu m/m at Line C27. Immediately adjacent to the jetty at Line C28, accretion decreases significantly to 1.7 cu m/m (Table D17), since material is transported into the inlet through the porous jetty structure.

During the first year of monitoring, atypical beach volumetric gains took place along the northern Stafford Shoal compartment between Lines C1 and C8, with corresponding values of 30.5 and 1.3 cu m/m (Figure D133), respectively. The only available survey along the southern Stafford Shoal compartment, Line C11, exhibited moderate erosion (14.2 cu m/m). In the next compartment, Cumberland Embayment, a general accretionary trend increased with variable amounts of erosion (Line C20, -7.4 cu m/m) and accretion (Line C21, 13.0 cu m/m) occurring along the central portion of this compartment. Negligible volumetric loss (0.2 cu m/m) was computed for Line C28, next to the jetty. The typical pattern of accretion at northern Stafford Shoal, erosion along most of Stafford Shoal, and accretion along Cumberland Embayment was prevalent during the August/September 1989 to July 1990 period. An exception to this general pattern was at Line C15 (-16.5 cu m/m), the southern portion of Cumberland Embayment at Line C24 (-5.2 cu m/m), and the north fillet area at Line C28 (-25.7 cu m/m).

During the next survey period, July 1990 - August 1991, volumetric gains occurred along the three Cumberland Island compartments for most of the profile lines (Figure D133). Anomalous high amounts of accretion were identified along the Stafford Shoal compartment with maximum volumetric gains of 62.9 cu m/m at Line C1 and 53.7 cu m/m at Line C11 (Table D17). This trend quickly reversed to volumetric losses of 64.9 cu m/m at Line C12. Farther south, there were moderate volumetric gains along both Cumberland Embayment and the north fillet area with a substantial volumetric gain of 39.2 cu m/m at Line C28 for this time period. As discussed in Chapter 6, this survey period had the lowest frequency of storms during the monitoring program. During the last survey period (August 1991 - April/May 1992), the normal pattern of erosion ranging between 0.5 cu m/m (Line C4) and 65.6 cu m/m (Line C11) was prevalent along the

Table D17
Net and Incremental Volume Change for Cumberland Island

Survey Line	Volume Change,[1] cu m/m				
	Jul 1988 to Apr/May 1992	Jul 1988 to Aug/Sep 1989	Aug/Sep 1989 to Jul 1990	Jul 1990 to Aug 1991	Aug 1991 to Apr/May 1992
C1	--[2]	30.5	18.4	62.9	--
C2	79.9	10.0	3.5	2.2	64.3
C3	-21.5	--	--	--	--
C4	-19.1	5.0	-10.4	-13.1	-0.5
C5	-18.6	--	--	--	--
C6	-30.3	--	--	42.5	-64.2
C7	-32.5	4.5	-13.4	12.5	-36.0
C8	-27.6	1.3	-13.8	3.2	-18.3
C9	--	--	-6.6	0.8	-12.7
C10	-1.3	--	--	15.6	2.8
C11	1.0	-14.2	27.0	53.7	-65.6
C12	-36.4	--	--	-64.9	11.7
C13	-16.9	--	--	--	--
C14	-24.2	--	--	--	--
C15	21.0	8.7	-16.5	34.8	-6.0
C16	15.7	--	--	--	--
C17	28.3	--	--	--	--
C18	19.8	15.4	8.0	21.2	-24.8
C19	24.0	--	--	--	--
C20	22.6	-7.4	49.7	-28.2	8.5
C21	33.3	13.0	8.4	20.6	-8.7
C22	43.0	--	--	--	--
C23	39.9	--	--	--	--
C24	24.7	26.4	-5.2	17.0	-13.5
C25	42.2	--	--	--	-29.5
C26	34.3	19.8	9.0	10.2	-4.7
C27	50.4	37.2	14.4	--	--
C28	1.7	-0.2	-25.7	39.2	-11.6

[1] Volume change computed over distance defined by intercept of profiles with elevation 2.5 to 0 m (NGVD).
[2] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

Table D18
Net and Incremental Volume Change for Amelia Island

Survey Line	Volume Change[1], cu m/m				
	Jul 1988 to Apr/May 1992	Jul 1988 to Oct 1989	Oct 1989 to Aug 1990	Aug 1990 to Sep/Nov 1991	Sep/Nov 1991 to Apr/May 1992
A10	--[2]	18.6	19.1	78.6	--
A13	--	-16.9	-5.4	--	--
A16	-52.5	--	--	--	--
A19	-70.2	--	--	--	--
A22	-87.1	-44.7	9.0	--	--
A28	17.8	--	--	--	--
A31	63.5	69.1	-12.8	--	--
A34	15.3	--	--	--	--
A37	7.7	20.3	-12.7	--	--
A43	59.6	10.5	49.2	-21.3	21.3
A46	30.7	--	--	--	--
A49	-51.1	-54.4	31.1	--	--
A55	94.4	85.1	10.8	--	--
A58	115.5	134.0	-11.1	--	--
A61	-13.8	-43.5	35.2	--	--
A64	-26.2	-46.1	49.8	--	--
A67	-39.1	-19.9	4.1	--	--
A70	-68.0	-16.9	-1.1	7.3	-57.3
A73	-102.2	-14.1	16.5	-18.9	-85.7
A76	--	3.6	14.9	--	--
A79	--	--	205.5	101.5	-247.4

[1] Volume change computed over distance defined by intercept of profiles with elevation 4.0 to 0 m (NGVD).
[2] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

Stafford Shoal compartment. Along Cumberland Embayment, an abnormal trend of erosion was computed between Lines C15 (6.0 cu m/m) and C26 (4.7 cu m/m). This consistent trend of subaerial beach losses can be attributed to the high number of storms during the 1991-1992 period (Appendix E). The volumetric losses during the August 1991 - April/May 1992 period continued into the south fillet area with a value of 11.6 cu m/m identified at Line C28.

Net changes along Amelia Island were computed across the 4.0- to 0.0-m (NGVD) beach section between Lines A16 and A73. Although individual values over the entire island range between 115.5 (Line A58) and -102.2 cu m/m (Line A73), spatial trends can be grouped into three geographic sections similar to shoreline position change, as discussed above. Lines A16

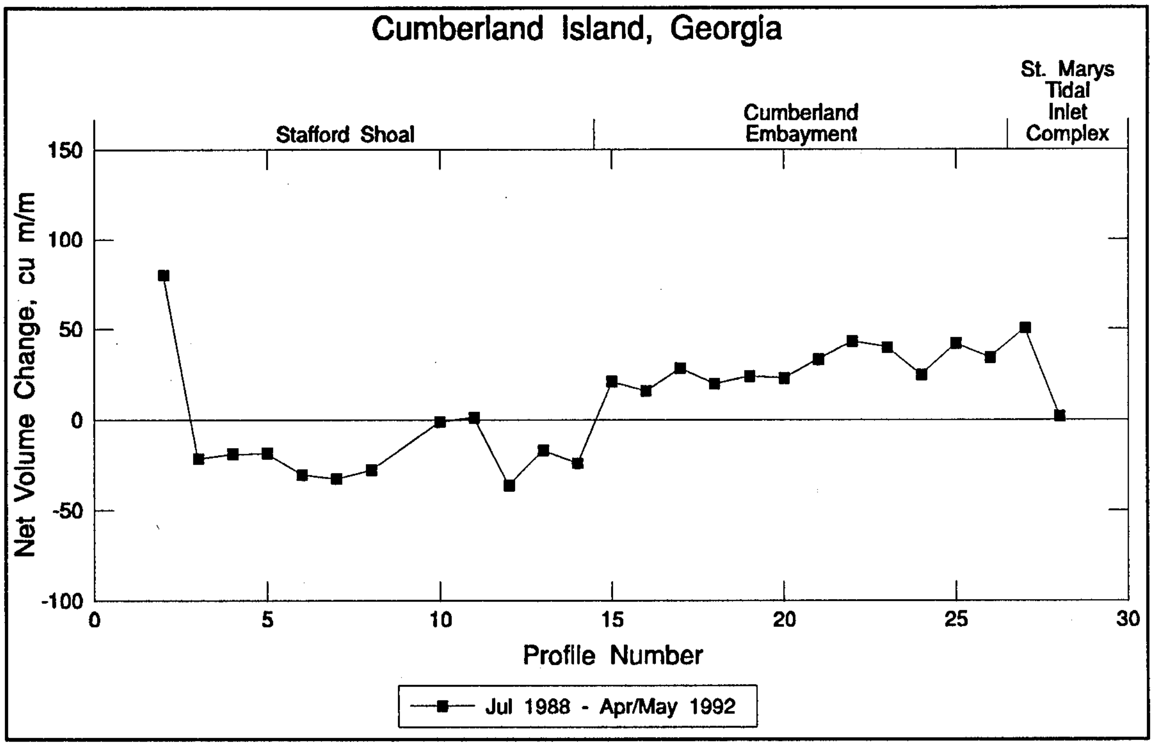


Figure D131. Net volume change, Jul 1988 - Apr/May 1992, Cumberland Island

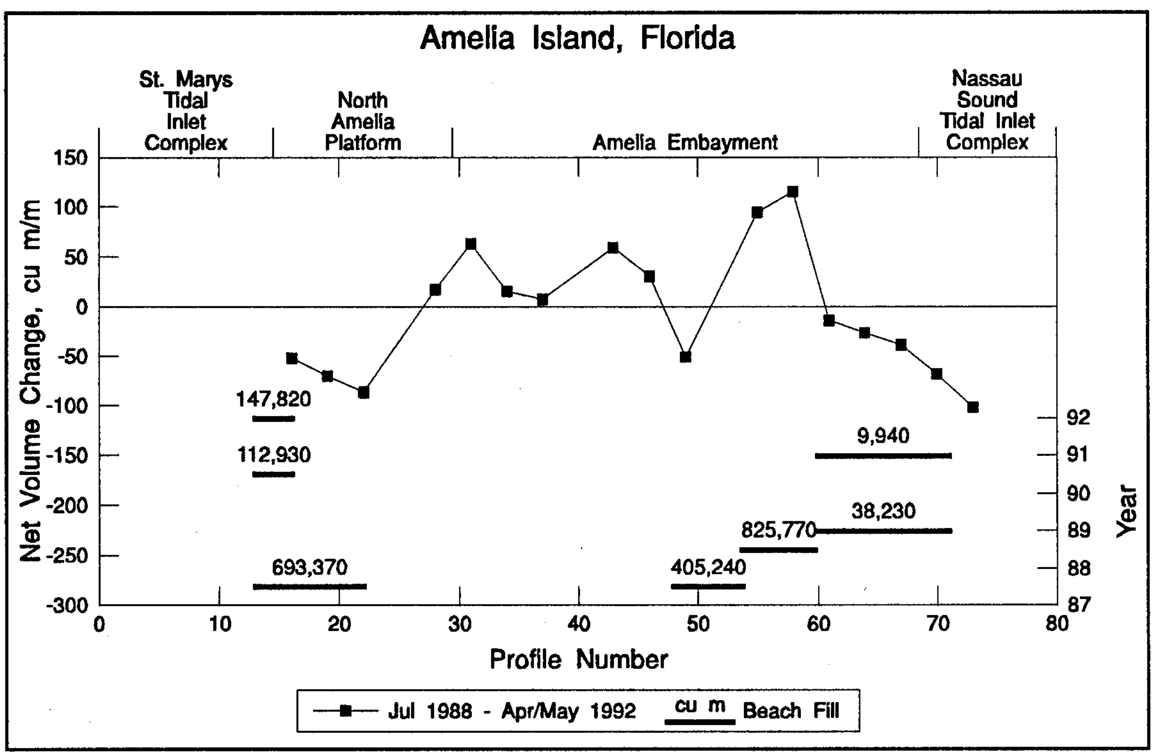


Figure D132. Net volume change, Jul 1988 - Apr/May 1992, Amelia Island

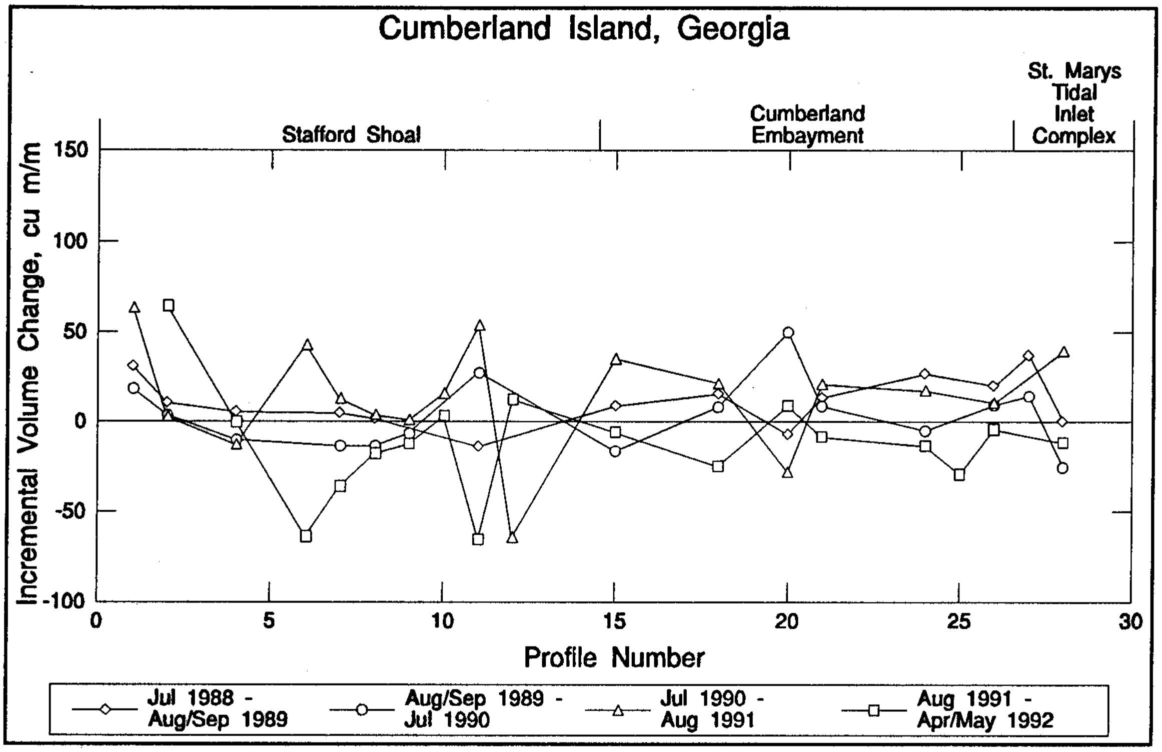


Figure D133. Incremental volume change, Cumberland Island

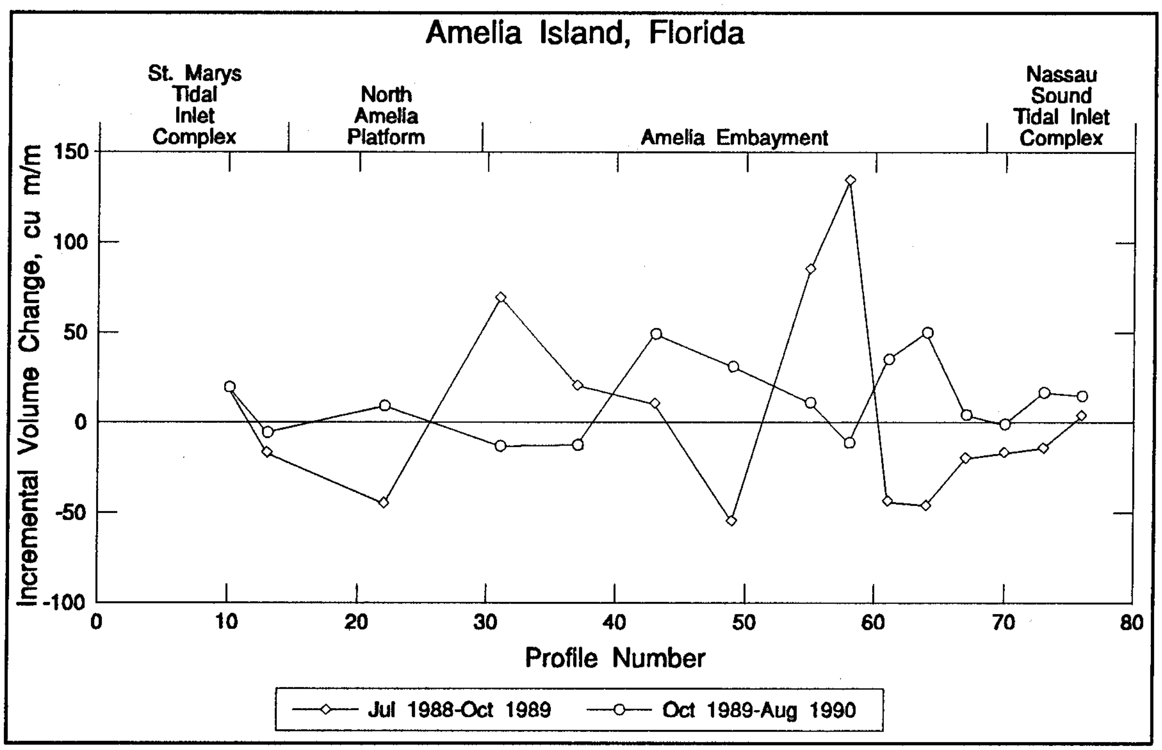


Figure D134. Incremental volume change, Amelia Island to A22 along the northern portion of North Amelia Platform exhibited increased volumetric losses toward the south from 52.5 to 87.1 cu m/m, respectively. This erosional trend is a continuum of historical beach losses and profile beach fill adjustment to a relatively steep slope. The central portion of Amelia Island, Amelia Embayment, had the greatest range of volumetric gains between 7.7 (Line A37) and 115.5 cu m/m (Line A58). A combination of a Federal beach fill placement between Lines A53.7 and A59.8 during the monitoring period and the downdrift movement of fill material from the northern and southern disposal sites influenced the pattern of accretion. The moderate erosion on Line A49 (51.1 cu m/m) occurred in an area which was not filled during the monitoring period. At the southern end, erosion increased from Line A61 (13.8 cu m/m) to A73 (102.2 cu m/m) due to the southerly transport of sediment and inlet transport processes associated with Nassau Sound.

The following discussion of volumetric change and trend analysis for Amelia Island is based on two nearly complete survey periods, July 1988 - October 1989 and October 1989 - August 1990, and two partial periods, August 1990 - September/November 1991 and September/November 1991 - April/May 1992. Table D18 lists the individual volumetric losses and Figure D134 illustrates the spatial trends of the intermediate year surveys. Corresponding to the shoreline position trends, the annual and net volumetric changes showed erosional trends adjacent to the St. Marys and Nassau Sound inlet systems and an accretionary trend along the central portion of the island. However, there were deviations from these geographic trends for the following reasons: (a) beach fill placements and subsequent fill adjustments, (b) frequency of storms, and (c) seasonal variability.

The first intermediate survey, July 1988 - October 1989, exhibited the typical alternating pattern of accretion and erosion for the four morphologic compartments, as described above for the overall net changes. This survey and the next survey, October 1989 - August 1990, provided good data coverage for the south fillet area of St. Marys Tidal Inlet Complex (Lines A10 and A13). Modest accretion occurred at Line A10 (18.6 cu m/m) during the July 1988 - October 1989 period which coincided with the sand-sealing of the landward 457 m of the south jetty. Farther south at Line A13, the trend reversed to erosion which continued into the next compartment (North Amelia Platform) to Line A22 (-44.7 cu m/m). Persistent erosion along North Amelia Platform is attributed to sediment transported alongshore to the north and offshore. Probable local sinks for this material are the various sand bodies located between the 2- and 6-m depth contours, as shown in Figure D108. The trend varies along Amelia Embayment ranging between 134.0 (Line A58) and -54.4 cu m/m (Line A49) which is a function of the timing of beach fill placements (Table D2). High volumetric losses were computed at Line A49 (Figure D134) where no disposal fills have been placed during the monitoring period. As with most surveys, Line A61 is a persistent transition point between accretion along the central portion of the island and erosion along the southern section of the island. Volumetric losses along most of the southern end of Amelia Island ranged from 14.1 (Line A73) to 46.1 cu m/m (Line A64).

Similar to Cumberland Island, most of the individual surveys during the October 1989 - August 1990 period showed higher accretion and lower erosion values. This trend coincides with a relatively calm period of storm activity (Chapter 6) and the post-fill survey, following the placement of 825,770 cu m of material along the southern disposal site. At the south fillet area, where accretion increased slightly after the completion of the sand sealing at the south jetty, volumetric changes of the subaerial beach ranged between 19.1 (Line A10) and -5.4 cu m/m (Line A13). The second compartment, North Amelia Platform, had only one surveyed line

(Line A22) which showed atypical accretion across the upper beach due to fill adjustment from pre-monitoring fill events in the northern disposal site (Lines A12 to A25).

During the third year, survey coverage was limited to five profile lines which represent seasonal changes as discussed in the next section. Notably large volumetric gains occurred at the northern end of the island at Line A10 (78.6 cu m/m) which was probably a result of fill material transported from the northern disposal site (Lines A16 to A22). A similar accretional trend occurred at the southern end of the island at Line A79 (101.5 cu m/m) in response to the net southerly transport and onshore movement. Because the third year was limited to five surveys and additional benchmark problems were encountered at Line A10, the September/November 1991 to April/May 1992 survey included only four lines. These few lines exhibited high rates of erosion except for Line A43 (21.3 cu m/m). These beach losses occurred following several sequential storms that passed through the area during the fall of 1991 and winter of 1992 (Figure D118).

Seasonal change. As on all U.S. continental beaches, sediment moves offshore during the winter months of higher and steeper waves and is typically stored in bars in the subtidal zone. During the summer months of lower and less steep waves, sediment migrates from the surf zone to the berm. In addition to cross-shore sand movement, seasonal-dependent longshore movement also occurs due to shifts in incident wave direction, causing the longshore transport to change direction. Two surveys selected from the monitoring data set, March 1989 and April/May 1992, provide seasonal change information within the study area. After pairing these surveys to the appropriate annual survey, shoreline position measurements were computed between the winter-summer pairs. The profile line number, date of survey, and calculated shoreline change between these seasonal surveys for the 1.3- and 0.0-m contours are listed in Tables D19 and D20. These surveys documented the cyclic changes along the beach face and swash zone. Visual geomorphic evidence of seasonal effects along the study area include escarpment of the berm and dunes on the upper beach profile and sandbar migration on the lower beach profile. Since there are frequent local storm surges during the winter months, the berm and dune crest often retreat; however, in most areas, sand recovery takes place during the summer months as littoral material moves onshore and alongshore (Figure D30, Line C8 and Figure D102, Line A73). Significant sediment exchange occurs along the well-defined ridge and runnel system of both islands from summer to winter (Figure D92, Line A43).

Another natural feature that is modified by varying wave conditions is the berm crest, which represents the approximate limit of wave runup reached by storm waves. At about elevation 2.0 m (NGVD), a pronounced berm crest typically appears along the Cumberland Island foreshore (Figure D46, Line C24), except at the terminus of the island where wide, relatively flat upper beaches with no distinct berm are prevalent. Because of repeated beach fill placements on Amelia Island (Table D2 and Figure D14), the natural berm crest there is difficult to identify. Prior to beach fill placement, the average berm crest (when present) is near elevation 2.0 m (NGVD) (Figure D11). During the monitoring period, the berm crest, which follows the edge of the beach fill, was located at about elevation 3.0 m (NGVD). On the lower part of the profile in the surf zone, sandbars typically migrate onshore and offshore between the summer and winter profiles. Many lines show bars welding onto the beach, producing either a ridge and runnel topography or low-tide terrace.

At the beginning of the monitoring period, the seasonal surveys indicated mostly accretion ranging between 7.3 and 15.7 m at elevation 1.3 m (NGVD). However, in contrast, the second

Table D19
Seasonal Change in Shoreline Position for Cumberland Island

Survey Line	Shoreline Position Change, m			
	Jul 1988 - May 1989		Aug 1991 - Apr/May 1992	
	1.3 m NGVD	0.0 m NGVD	1.3 m NGVD	0.0 m NGVD
C2	7.3	-25.3	4.0	38.0
C4	--[1]	--	-0.1	-6.4
C6	--	--	-21.3	-17.0
C7	--	--	-16.0	-2.3
C8	--	--	-14.8	-6.7
C9	--	--	-18.0	22.3
C10	--	--	-7.3	6.0
C11	15.7	-25.0	-17.7	-33.0
C12	--	--	-1.5	-31.7
C15	--	--	-3.0	2.0
C18	--	--	-15.3	-22.0
C20	-2.0	-14.0	-0.2	-9.0
C21	--	--	-13.0	-7.8
C24	--	--	-1.0	-13.6
C25	--	--	-9.3	-5.6
C26	--	--	-1.0	1.5
C27	10.0	5.0	--	--
C28	--	--	-14.0	2.3

[1] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

seasonal set (September 1991 - April/May 1992) showed moderate shoreline recession ranging between 0.1 and 21.3 m. The average difference in shoreline position for Cumberland Island between the August 1991 and April/May 1992 survey was 7.8 m. Only a few survey lines along Amelia Island were available for seasonal comparison. Typically, the range of the calculated high-water line was variable for the July 1988 to March 1989 period between 0.9 (Line A34) and -15.1 m (Line A76) because of beach fill activity and the dominant southerly littoral transport. However, for the second seasonal data set (September/November 1991 - April/May 1992), a higher range occurred between 17.0 (Line A43) and -100.0 m (Line A79). Although there is limited survey coverage of seasonal shoreline change comparisons, the total absolute average is calculated as 13.6 m.

Shoreline position change at elevation 0.0 m (NGVD) indicates the stability of the beach face. As can be seen in Tables D19 and D20, shoreline movement can vary greatly in magnitude and sign, resulting in a profile that does not translate landward and seaward in parallel to itself, but typically adjusts to the natural slope on the beach face and surf zone.

Table D20
Seasonal Change in Shoreline Position for Amelia Island

Survey Line	Shoreline Position Change, m			
	Jul 1988 - Mar 1989		Sep/Nov 1991 - Apr/May 1992	
	1.3 m NGVD	0.0 m NGVD	1.3 m NGVD	0.0 m NGVD
A13	-7.7	-6.0	--[1]	--
A19	-12.3	-8.4	--	--
A34	0.9	-3.8	--	--
A43	-7.0	11.3	17.0	-2.7
A64	-13.7	-11.5	--	--
A70	--	--	-33.1	-1.0
A73	--	--	-33.0	-31.3
A76	-15.1	-39.7	--	--
A79	--	--	-100.0	-30.0

[1] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.

Summary of profile measurements and the morphologic compartments

This section summarizes the morphologic characteristics within each compartment based on the profile survey data sets obtained during the coastal monitoring period. In order to assess spatial and temporal trends during the 1988-1992 period and identify any short-term impacts of the channel modifications, a methodology based on specific elevations and corresponding distances across the profile envelope and final weighted averages of these profile lines was developed for this project. Because the project shoreline is about 50 km long and subject to a large tidal range and variable wave conditions, the analysis precluded using a specific distance to measure volumetric changes. For each morphologic compartment, a series of profile measurements were calculated, including:

a. Beach width (2.5 to 0.0 m NGVD).

b. Inner bar position (distance from 0.0 m NGVD) and bar crest elevation.

c. Beach slope (2.5 to -1.0 m NGVD).

d. Nearshore slope (-1.0 m NGVD to computed slope change, about 4.0- to 6.0-m depth NGVD).

e. Shoreline position (elevation 1.3 m NGVD).

f. Net beach volumetric change (2.5 to 0.0 m NGVD for Cumberland Island and 4.0 to 0.0 m NGVD for Amelia Island).

Table D21 lists the average computed profile parameters for each compartment per island. A stable barrier island/inlet system is apparent, with moderate changes occurring at Stafford Shoal and in the vicinity of the project inlets, including St. Andrew Sound, St. Marys Entrance, and Nassau Sound.

The beach and nearshore system along Cumberland Island have been stable to accretional at a net rate of 0.3 m/year during the monitoring period. Profile comparisons and beach measurements show a large dune complex and a broad, flat, subaerial, fine-grained beach adjacent to complex bathymetry due to shoal and inlet-related features. Local characteristics were further defined along the three morphologic compartments of Stafford Shoal, Cumberland Embayment, and the north fillet of St. Marys Tidal Inlet Complex. Along north central Cumberland Island (Stafford Shoal compartment), the shoreline and nearshore zone exhibited erosional trends that generally decreased from north to south. For the south central portion of Cumberland Island (Cumberland Embayment), the trend of shoreline and beach volumetric changes reverses to shoreline advance and volumetric accretion. This same accretional trend gradually increased to the distal end of the island or north fillet area of St. Marys Entrance. The south jetty allows for sediment to be transported over and through the porous, rubble-mound structure and creates small-scale scour and bar features immediately adjacent to the structure.

Differences in shoreline position and bathymetric gradient were used to delineate the four morphologic compartments along Amelia Island. These are the south fillet of St. Marys Tidal Inlet Complex, North Amelia Platform, Amelia Embayment, and Nassau Sound Tidal Inlet Complex. In contrast to Cumberland Island, Amelia Island was stable to slightly erosional with a net shoreline change rate of 0.2 m/year during the July 1988 - April/May 1992 period. Amelia Island trends are highly variable because of the many beach fill placements and inlet processes associated with St. Marys Entrance and Nassau Sound. Along Amelia Island, the shoreline exhibited alternate patterns of advance and retreat between the four morphologic compartments. Because of the sheltering effect of the sand-tightened south jetty and northerly sediment transport, the fillet area advanced during the October 1989 - September/November 1991 period. The second area of shoreline advance occurred along Amelia Embayment as a result of beach fill and the net southerly transport there. The two sections of shoreline retreat included the North Amelia Platform where material is transported to the north and offshore, and Nassau Sound Tidal Inlet Complex where the shoreline and nearshore zone responds to the inlet and the southerly transport direction.

Stafford Shoal. The northernmost compartment, Stafford Shoal, consists of a three-ridge barrier dune system next to a flat beach averaging 80.4 m (April/May 1992) in width. Most surveys started behind the primary transgressive dunes which are the highest in the study area with a maximum height of 8.4 m (NGVD) along the foredunes. The subaerial beach consisted of uniform, fine-grained material averaging 0.17 mm on a moderate angle beach with a slope of 1.7 deg based on the April/May 1992 survey data. Along the subaerial beach, the net shoreline position and volumetric change followed a pattern of retreat (1.4 m/year) and volumetric loss (14.2 cu m/m). The nearshore bathymetry is the most complex in comparison with the other morphologic compartments. The Stafford Shoal feature consists of multiple sand ridges with a maximum bar height of 3 m and fine-grained swale features (Figure D105). A strong influence on the Stafford Shoal compartment is the downdrift transport of sediments from the St. Andrew Tidal Inlet Complex. Simultaneously, sediments are moving within the beach and nearshore zone and are redistributed along Cumberland Embayment and the north fillet.

Table D21
Weighted Average Summary of Profile Measurements for Cumberland and Amelia Islands

Morphologic Compartment	Survey Line	Beach Width, m		Apr/May 1992 Inner Bar Distance, m	Apr/May 1992 Inner Bar Elevation, m	Jul 1988 Beach Slope		Apr/May 1992 Beach Slope		Jul 1988 Nearshore Slope	
		Jul 1988	Apr/May 1992			Ratio	Degrees	Ratio	Degrees	Ratio	Degrees
Stafford Shoal	C1 to C14	79.5	80.4	64.6	-1.0	1:41	1.4	1:34	1.7	1:86	0.7
Cumberland Embayment	C15 to C26	111.7	102.0	123.0	-1.6	1:53	1.1	1:46	1.3	1:116	0.5
St. Marys Tidal Inlet Complex (north fillet)	C27 to C28	148.0	192.2	47.7[2]	-0.3[2]	1:63	0.9	1:79	0.7	1:88	0.6
Cumberland Island	C1 to C28	98.2	95.0	101.6[3]	-1.4[3]	1:48	1.2	1:42	1.5	1:102	0.6
St. Marys Tidal Inlet Complex (south fillet)	A10 to A13	--[1]	--	--	--	--	--	--	--	--	--
North Amelia Platform	A16 to A28	30.4	28.3	50.6[2]	-1.1[2]	1:18	3.4	1:15	4.1	1:62	1.1
Amelia Embayment	A31 to A67	57.3	46.9	103.8	-1.9	1:28	2.2	1:24	2.8	1:96	0.6
Nassau Sound Tidal Inlet Complex	A70 to A79	68.2	58.0	96.8	-1.6	1:31	1.8	1:28	2.3	1:142	0.4
Amelia Island	A10 to A79	51.9	43.4	101.3	-1.8	1:26	2.4	1:22	3.1	1:92	0.7

(Sheet 1 of 3)

[1] Profile line not surveyed or line omitted from analysis due to survey error and/or control problems.
[2] Value represents a single profile measurement.
[3] Cumberland Island total did not include Line C28 to maintain consistent weighting methodology.

Table D21 (Continued)

Morphologic Compartment	Survey Line	Shoreline Change Rate, m/year								Shoreline Position Relative to Jul 1988, m			
		Feb 1974 to Sep/Nov 1981		Sep/Nov 1981 to Jul 1988		Jul 1988 to Apr/May 1992		Feb 1974 to Apr/May 1992		Aug/Oct 1989[4]	Jul/Aug 1990[4]	Aug/Nov 1991[4]	Apr/May 1992
		0 m NGVD	1.3 m NGVD	0 m NGVD	1.3 m NGVD	0 m NGVD	1.3 m NGVD	0 m NGVD	1.3 m NGVD	1.3 m NGVD	1.3 m NGVD	1.3 m NGVD	1.3 m NGVD
Stafford Shoal	C1 to C14	--	--	--	--	-3.2	-1.4	--	--	4.8	0.2	3.9	-5.5
Cumberland Embayment	C15 to C26	--	--	--	--	3.0	1.6	--	--	6.0	5.6	12.6	6.2
St. Marys Tidal Inlet Complex (north fillet)	C27 to C28	--	--	--	--	2.8	3.9	--	--	16.1	6.8	13.2	15.2
Cumberland Island	C1 to C28	--	--	--	--	0.2	0.3	--	--	5.8	3.2	8.6	1.2
St. Marys Tidal Inlet Complex (south fillet)	A10 to A13	--	--	--	--	--	--	--	--	--	--	--	--
North Amelia Platform	A16 to A28	-0.6	1.0	2.8	3.6	-4.4	-3.2	-0.2	1.1	-10.5	6.8	--	-5.8
Amelia Embayment	A31 to A67	0.0	-0.3	0.7	1.6	-0.8	1.6	-0.2	0.7	3.0	7.8	--	6.1
Nassau Sound Tidal Inlet Complex	A70 to A79	-2.3[2]	-1.1[2]	-1.9[2]	-3.6[2]	-5.0[2]	-4.6[2]	-2.8[2]	-2.8[2]	-2.5	3.4	--	-17.1
Amelia Island	A10 to A79	-0.2	0.0	1.1	1.9	-1.8	0.2	-0.3	0.7	0.6	7.3	--	2.3

(Sheet 2 of 3)

[4] Date specified encompasses the range of the surveys for both Cumberland and Amelia Islands (Tables D3-D5).

Table D21 (Concluded)

Morphologic Compartment	Survey Line	Volume Change, cu m/m				
		Jul 1988 to Apr/May 1992	Jul 1988 to Aug/Oct 1989[4]	Aug/Oct 1989[4] to Jul/Aug 1990[4]	Jul/Aug 1990[4] to Aug/Nov 1991[4]	Aug/Nov 1991[4] to Apr/May 1992
Stafford Shoal	C1 to C14	-14.2	0.5	-1.7	2.1	-9.1
Cumberland Embayment	C15 to C26	28.4	12.9	7.2	15.1	-11.2
St. Marys Tidal Inlet Complex (north fillet)	C27 to C28	35.8	26.0	2.4	30.5	-9.5
Cumberland Island	C1 to C28	9.3	7.7	3.0	9.6	-10.1
St. Marys Tidal Inlet Complex (south fillet)	A10 to A13	--	-5.0	2.9	--	--
North Amelia Platform	A16 to A28	-44.3	-16.8	1.9	--	--
Amelia Embayment	A31 to A67	24.8	17.0	16.0	--	--
Nassau Sound Tidal Inlet Complex	A70 to A79	-79.3	-11.9	8.9	--	--
Amelia Island	A10 to A79	0.6	4.7	11.1	--	--

(Sheet 3 of 3)

Cumberland Embayment. The morphology of Cumberland Embayment along the arc-shaped portion of the shoreline (Lines C15-C26) is less pronounced than Stafford Shoal. The foredunes are generally between 3 and 6 m high adjacent to a flat (1.3 deg, April/May 1992), fine-grained beach with a moderate width averaging 102.0 m. The net shoreline change along Cumberland Embayment is accretional (averaging 1.6 m/year) with moderate amounts of volumetric gains (28.4 cu m/m). Similar trends are found in the nearshore zone where typically accretion occurs out to the depth of closure, as shown in Figure D106 (Line C21). Because the nearshore zone is moderately flat (1.3 deg, April/May 1992) and wide, the inner bar is the farthest seaward (averaging 123.0 m) following the shoreline orientation (Figure D122).

North Fillet of St. Marys Tidal Inlet Complex. In order to monitor the effects of the Cumberland Island jetty, the north fillet area of St. Marys Entrance was defined along 1.7 km of shoreline. Because of the strong southerly transport, material continues to move downdrift and accumulate in the fillet area at a rate of 3.9 m/year (July 1988 - April/May 1992). Typically, the beach width averaged 192.2 m on a flat slope of 0.7 deg (April/May 1992). There are slight variations in all the profile measurements due to the scour and bar features in the vicinity of the jetty structure and complex current patterns from the ebb-flood flow and littoral transport.

South Fillet of St. Marys Tidal Inlet Complex. The beach and nearshore zones are strongly influenced by tidal inlet currents and the northerly transport direction. Additionally, the south or downdrift fillet has different beach and nearshore morphology due the sheltering by the south jetty and the seaward movement of channel material. No net changes were computed for this compartment due to monument control problems from storm damage. However, based on the intermediate survey sets, the beach face consists of medium sands on a moderately steep slope ranging from 2.5 deg (Line A10) to 3.2 deg (Line A13) (Table D12). The nearshore slope is at a low angle, ranging from 0.4 deg (Line A10) to 1.0 deg (Line A13), as a result of material accumulating from the northerly littoral transport. An interesting nearshore feature is the large bar and swale features that are located seaward of the 2-m contour (Figure D108). A combination of the littoral transport deflected seaward from the jetty structure and tidal currents moving through and over the rubble-mound structure has modified these large shoal bars.

North Amelia Platform. Dune characteristics similar to the south fillet area were found along the North Amelia Platform compartment. The shore is bounded by vegetated dunes of moderate height averaging 4 m high with a narrow beach face of 28.3 m (April/May 1992). This area has experienced consistent erosion with a net upper profile deficit of 44.3 cu m/m. Similarly, high rates of shoreline retreat occurred within this compartment at a net rate of 3.2 m/year. The steepest beach slopes in the study area were determined to be 3.4 deg (July 1988) and 4.1 deg (April/May 1992) along the North Amelia Platform compartment. The steeper slopes along the shoreline of Amelia Island are attributed to the coarser grain size and exposure to an open ocean coastline. Unlike the south fillet compartment, the bathymetry is featureless with no large shoal bars. Similar to the beach zone, the nearshore slope along the study area had a compartmental average of 1.1 deg (July 1988).

Amelia Embayment. In addition to the arc-shaped shoreline orientation, the Amelia Embayment is characterized by moderately high dunes adjacent to a beach width of 57.3 m (July 1988) and 46.9 m (April/May 1992) with fairly steep beach slope of 2.8 deg (April/May 1992). Along Amelia Embayment, shoreline advance (1.6 m/year) and volumetric gains (24.8 cu m/m) were the result of multiple beach fills placed during the monitoring period (Table D2). Beach fill adjustment plays a major role in the stability of this compartment, as further discussed in Chapter 5 (*Trend Analysis and Implications of Recent Engineering Activities* section). A total of 873,940 cu m of Federal and privately funded fill operations were placed along the Amelia Embayment compartment during the monitoring period.

Nassau Sound Tidal Inlet Complex. The southernmost compartment in the study area is influenced by an oceanic wave climate along its northern boundary, while the southern end is strongly modified by the ebb-dominated Nassau Sound inlet. Unique to this compartment are the steep-scarped dunes, which are susceptible to storm wave runup. The very fine to fine sandy beach in this region is narrow (58.0-68.2 m) and steep (1.8-2.3 deg). Overall the shoreline recession rates were the highest in the study area, averaging 4.6 m/year during the monitoring period despite placement of four minor private fills. Equally high volumetric losses averaging 79.3 m were measured along the upper beach profile. Littoral transport and shifting of the beach material offshore are continually removing sediments from the beach system. The nearshore zone consists of multiple shoal bars associated with the ebb-tidal delta system of Nassau Sound.

Sediment Grain Size

Background and previous work

Previous sedimentological studies pertaining to Cumberland and Amelia Islands reported beach and dune sediments as predominantly fine, well-sorted quartz sands. Martens (1935), USACE (1961), Giles and Pilkey (1965), and Roberts (1975) identified the local beach and dune mineral composition as light gray, fine-to-medium grain size, with a shell content of between 5 and 10 percent, and with a heavy mineral fraction consisting of ilmenite, magnetite, epidote, hornblende, and sillimanite. The origins of the sands and heavy minerals are believed to be marine sediments exposed during a lower sea-level stand and terrigenous sediments that were fluvially deposited from the Piedmont (base of the Appalachian Mountains). Sediments brought into the littoral system derive from adjacent inlets including St. Andrew Sound, Christmas Creek (which separates Little Cumberland Island and Cumberland Island), St. Marys Entrance, and Nassau Sound. The primary sources of beach sediments are: (a) reworked deposits from the dune ridge complex located along both islands, (b) material transported inshore from the shelf by wave action, and (c) material transported alongshore from adjacent inlets and islands.

The barrier island beach and dune complex formed when sea level was approximately 2 m higher than present, during the Late Pleistocene (50,000 years BP). During the past 5,000 years, the modern or Holocene beach/dune deposits formed. Pleistocene and Holocene beach and dune sands are similar in composition and texture, because sediment sources and nearshore processes appear to have been the same throughout both epochs (Griffin and Henry 1984). Further discussion of the geology and geomorphology for Cumberland and Amelia Islands is presented in Chapter 2.

Sediment data reported in previous studies for the Kings Bay project area are summarized in Table D22. These studies concluded that Cumberland Island consists of predominantly fine-to-very-fine quartz sands, whereas the Amelia Island sands are fine-to-medium quartz sands. The most comprehensive beach sand assessments in the study area were performed by USAED, Savannah (USACE 1961) and more recently by USAED, Jacksonville (1984a, 1993) in support

Table D22
Summary of Previous Beach Sediment Data Results

Study	Location	Median Grain Size, mm
Martens (1935)	Northern Amelia Island	0.20
USACE (1961)	Southern Cumberland Island	0.12
	Northern Amelia Island	0.21
	Central Amelia Island	0.14
Giles and Pilkey (1965)	Cumberland Island	0.18
	Amelia Island	0.24
USAED, Jacksonville (1984a)	Northern Amelia Island	0.25

of potential Amelia Island beach nourishment projects. Figure D135 shows the location of profile lines where nine sediment samples were collected between the dune crest and -9-m depth (NGVD) in 1960. Based on this data set of surface beach and nearshore sands (USACE 1961), the median sand diameter prior to the monitoring period averaged 0.12 mm on southern Cumberland Island, 0.21 mm on northern Amelia Island, and 0.14 mm on central Amelia Island. Cumberland Island was only sampled along two profile lines near the north jetty to evaluate the inlet influence on adjacent beaches, versus eight profile lines sampled along northern and central Amelia Island (Figure D135). Generally for Amelia Island, the dune samples consisted of fine-to-medium, well-sorted sands (average 0.22 mm), the beach zone consisted of medium sands (average 0.26 mm), and the nearshore zone (elevation 0 to -10 m NGVD) consisted of fine sands with occasionally medium-to-coarse sands (average 0.19 mm). A comparison of nearshore samples collected at depths of 1.7, 2.6, and 4.5 m (NGVD) indicated sands became finer with depth corresponding to an average median grain size of 0.21, 0.19, and 0.16 mm, respectively (Figure D136). Between depths of 6.3 and 8.1 m (NGVD), grain size increased due to the presence of shell fragments. Seaward of the 8.1-m depth, sands became finer with an average median diameter of 0.15 mm. These native beach and nearshore samples showed a distinctive trend of increasing grain size south of the south jetty for a distance of 1.2 km (Lines A-B, Figure D135). From Line B (1.2 km south of the jetty) to Line J (9.1 km south of the jetty), the grain size decreased to very fine sands (0.14 mm). Amelia Island was resampled in 1975 (USAED, Jacksonville 1984a) along eight Florida DNR survey lines (DNR-04, DNR-10, DNR-17, DNR-25, DNR-32, DNR-36, DNR-55, and DNR-76) covering the length of the island. No individual sample grain size data were reported, but composite sample mean data of four lines (DNR-10, DNR-17, DNR-25, and H26+80, a survey line reoccupied from the USACE 1961 data set) were included in the report. A comparison of the sample composite means calculated from the 1975 data set is shown with the closest sample composites collected in 1960 in Table D23. A slight coarsening of the composite mean was found over the 15-year period between studies. This trend is supported by the historical median data shown in Table D22, where a coarsening of the median grain size occurred from 1930 to 1975 along northern Amelia Island. Historical bathymetric and shoreline position data indicate that this area beyond the fillet section (3-5 km south of the jetty) has exhibited a consistent pattern of erosion, and the profile has steepened over time (Chapter 3, *Nearshore Bathymetric Change* section).

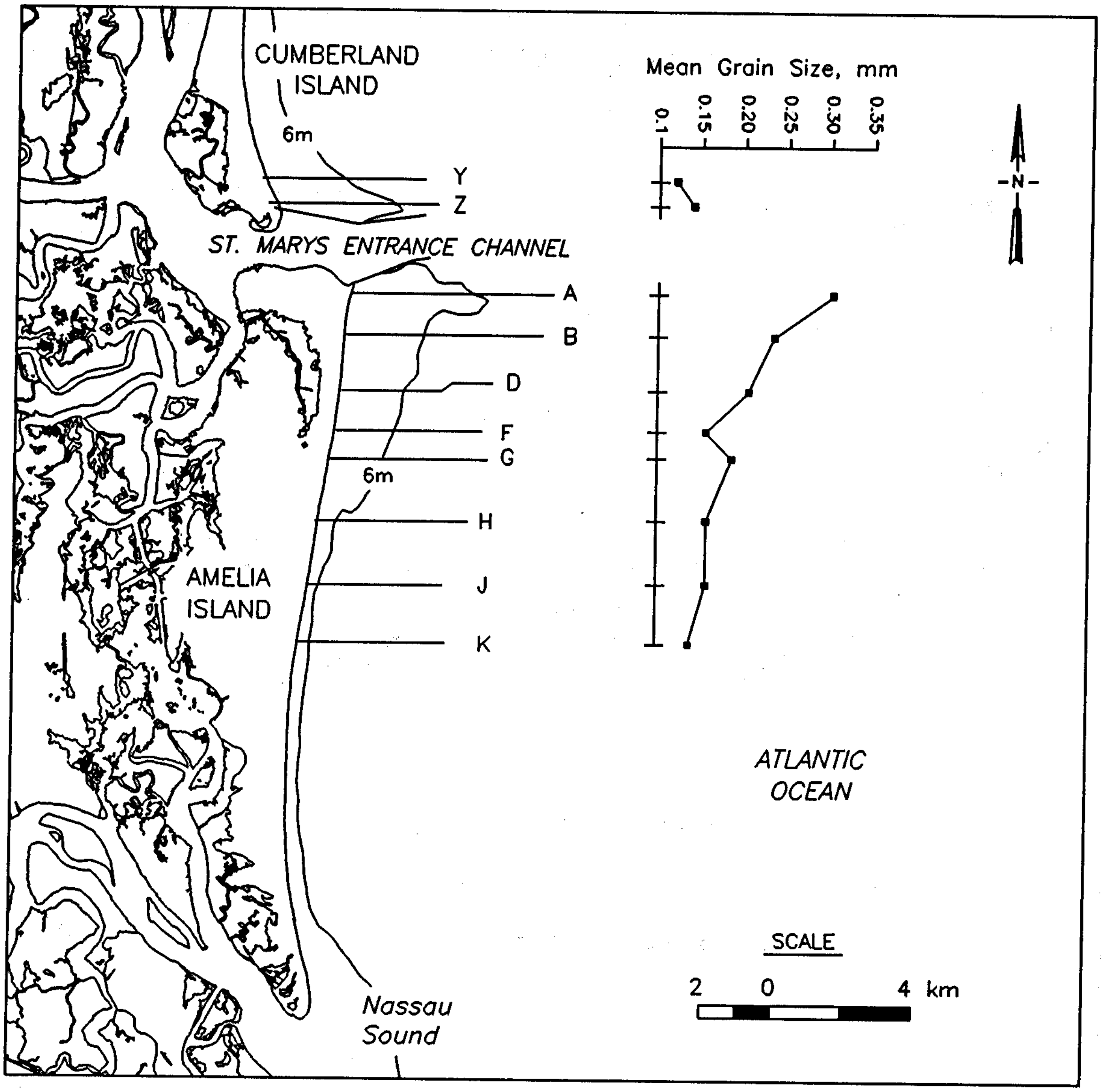


Figure D135. Location of profile lines used in the surface sample study in 1960 showing trend in decreasing grain size to the south on Amelia Island (after USACE (1961))

Sediment sampling plan

As part of the present coastal monitoring program, sediment samples were collected along selected profile lines to determine changes in sediment textural characteristics during the July 1988 through April/May 1992 period (Figure D137, Table D24). The plan was designed to sample sediments in the nearshore morphologic compartments (Figure D1) and the major cross-shore zones between the dune line and depth of closure. Surface sediments were sampled along established profile lines at the following geomorphic features or elevations (original sampling was based on units of feet): berm crest, estimated MHW level, estimated MLW level, trough of inner bar, inner bar crest, 4.5-, 8.1-, and 11.8-m (NGVD) depths, as illustrated in Figure D138. Along Cumberland Island, five profile lines were selected to delineate the sediment trends on the natural barrier island system:

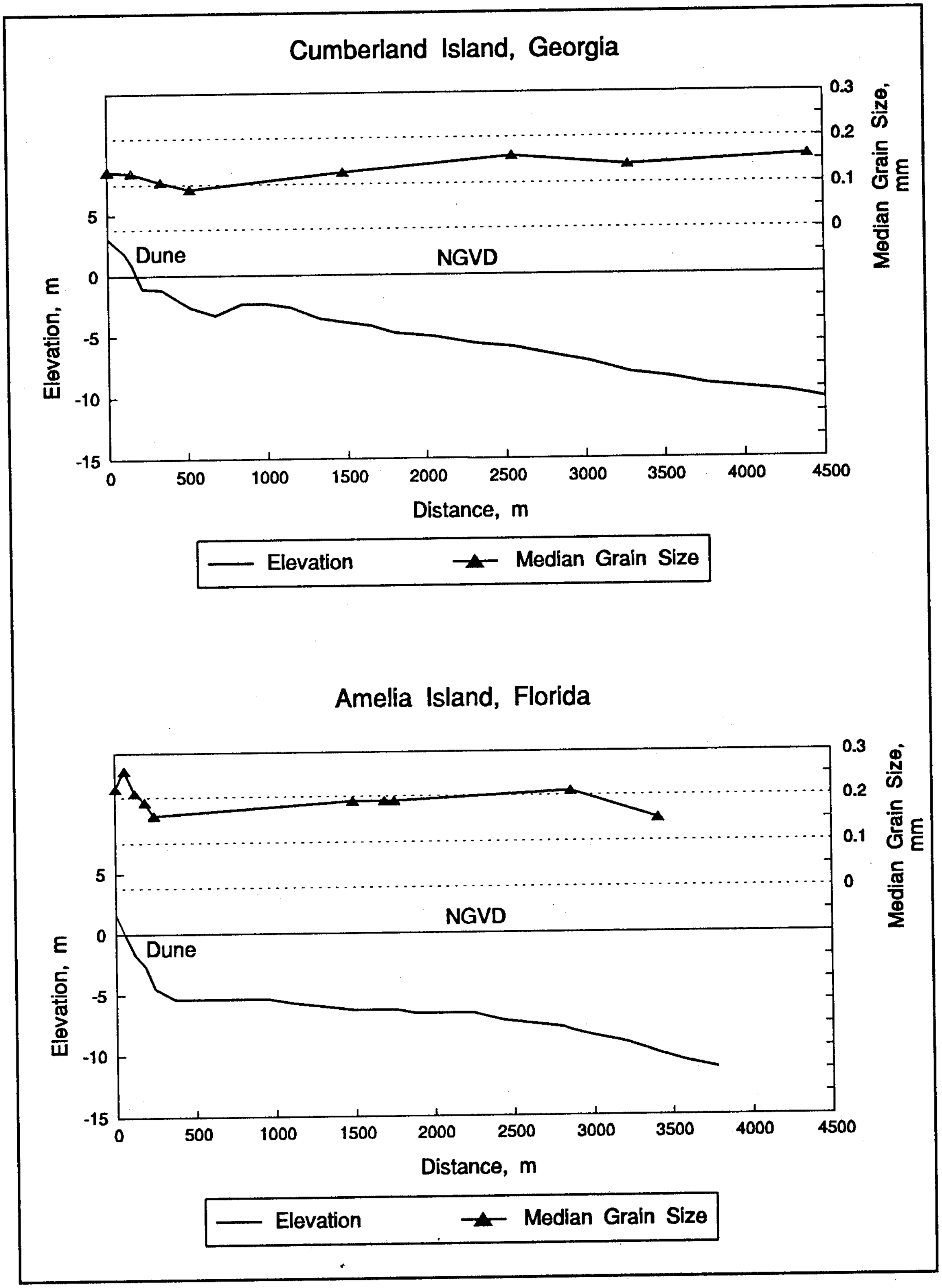


Figure D136. Averaged median grain size and representative beach profile from south Cumberland and north Amelia Islands for 1960 sediment sampling (data from USACE (1961))

Table D23
Composite Median Grain Size from 1960 and Median and Mean Grain Size from 1975 Sediment Sampling along Amelia Island

1960		1975		
Line	Composite Median mm	Line	Composite Median mm	Composite Mean mm
A	0.31	DNR10	0.24	0.31
D	0.21	DNR17	0.23	0.46
G	0.19	DNR25	0.22	0.31
H	0.16	H26+80	0.17	0.20
		Native Beach Composite (R10 to H26+80)	0.21	0.28

a. Lines C1 and C10 across the active Stafford Shoal Compartment.

b. Line C20 across the stable Cumberland Embayment Compartment.

c. Line C28 across the accretional north fillet of St. Marys Tidal Inlet Complex.

d. Line C31 across the inlet throat north shoreline of St. Marys Tidal Inlet Complex.

For Cumberland Island, 76 sediment samples were taken during the monitoring period.

Because there have been considerable engineering activities and fill placements on Amelia Island, eight lines were selected to identify spatial and temporal sediment trends within the project morphologic compartments:

a. Line A4 across the inlet throat south shoreline of St. Marys Tidal Inlet Complex.

b. Line A10 across the accretional south fillet of St. Marys Tidal Inlet Complex.

c. Line A22 across the erosional Northern Amelia Platform compartment.

d. Lines A31, A43, and A55 across the stable Amelia Embayment compartment.

e. Lines A64 and A76 across the updrift side of the Nassau Sound Tidal Inlet Complex.

During the monitoring period, 150 sediment samples were collected and analyzed for the Amelia Island data set.

Sediment sampling coincided with the annual summer profile surveys. During 1989 and 1990 the sediment data collection program was modified to sample only the upper beach face between the berm crest and the trough of the inner bar. Samples were not collected during 1991 because

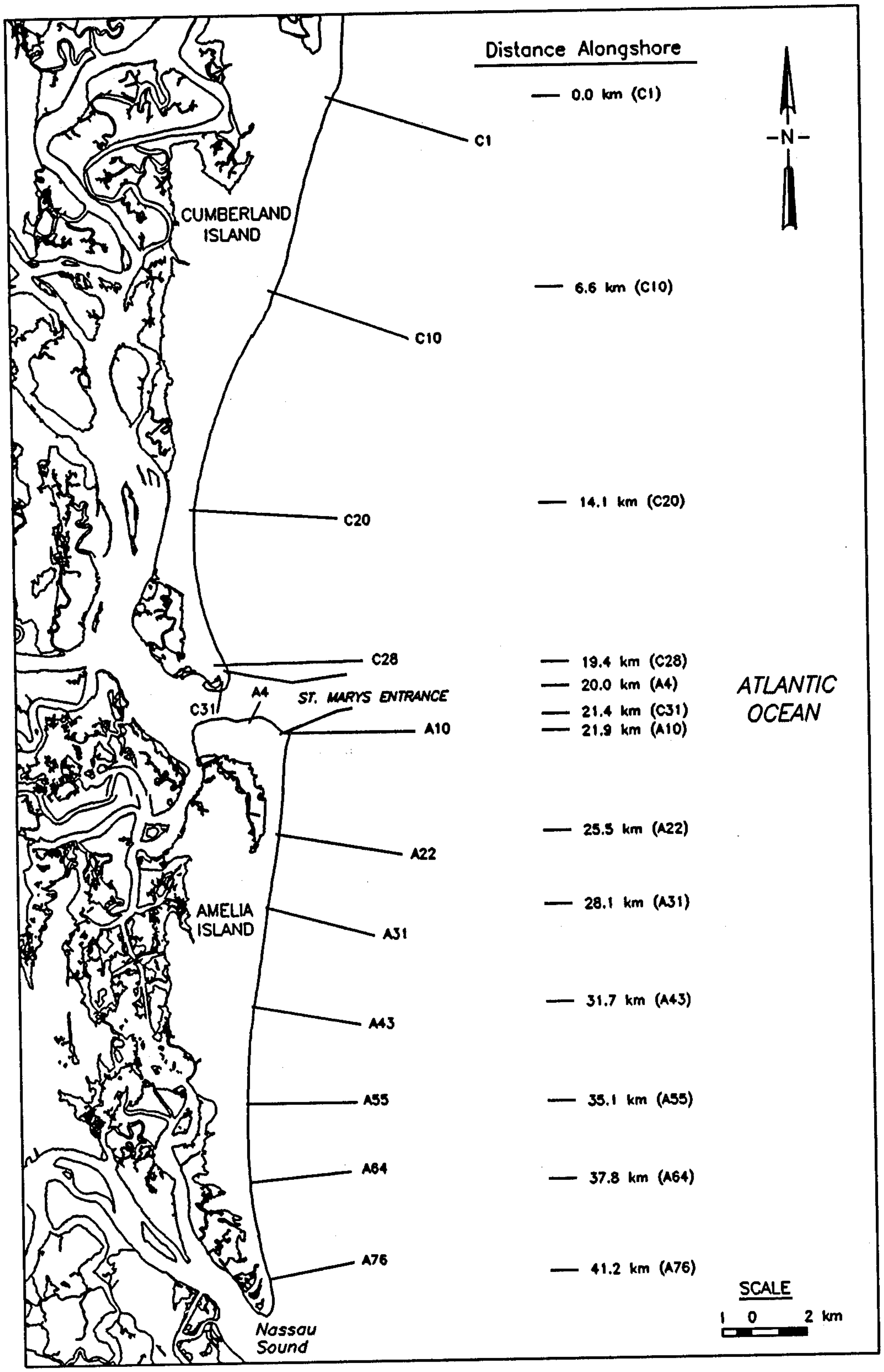


Figure D137. Sediment sampling plan for Cumberland and Amelia Islands. Distance alongshore is referenced south from Line C1

Table D24
Cumberland and Amelia Islands Sampling Data

Survey Line	Annual Jul 1988	Annual Aug\Oct 1989	Annual Jul/Aug 1990	Annual Apr/May 1992
Cumberland Island				
C1	X[1]	X	X	X
C10	X	X	X	X
C20	X	X	X	X
C28	X	X		X
C31	X	X	X	
Amelia Island				
A4	X	X	X	
A10	X	X	X	X
A22	X	X	X	X
A31	X	X	X	X
A43	X	X	X	X
A55	X	X	X	X
A64	X	X	X	X
A76	X	X	X	X

[1] Sediment samples collected.

of funding limitations. An exception to the summer sediment collection was the October 1989 sampling for Amelia Island and the April/May 1992 sampling on both islands, which describe late winter conditions. The final sediment data collected in April/May 1992 included all cross-shore samples between the berm crest and 11.8-m depth (NGVD).

Field data collection and analysis

Similar sediment sampling techniques and equipment were used by USAED, Savannah and USAED, Jacksonville from 1988 to 1991 and by OCTI-EC in 1992. Subaerial samples were collected by scooping material from the sediment surface using a small trowel, while the subaqueous samples were collected using either a Peterson or Ponar grab sampler. Sample size was about 450 g (1 lb) and samples were stored in either a glass jar or a zipped storage bag. Original samples were split to a final sample size of about 20 g. Laboratory analysis was performed at CERC using a sonic sifter and microbalance. Sediments were sieved using U.S. Standard sieves at 1/4-phi (ϕ) unit[1] intervals. The ϕ scale is the negative logarithm of the grain

[1] For convenience, symbols are listed in the notation (Appendix A, Volume I).

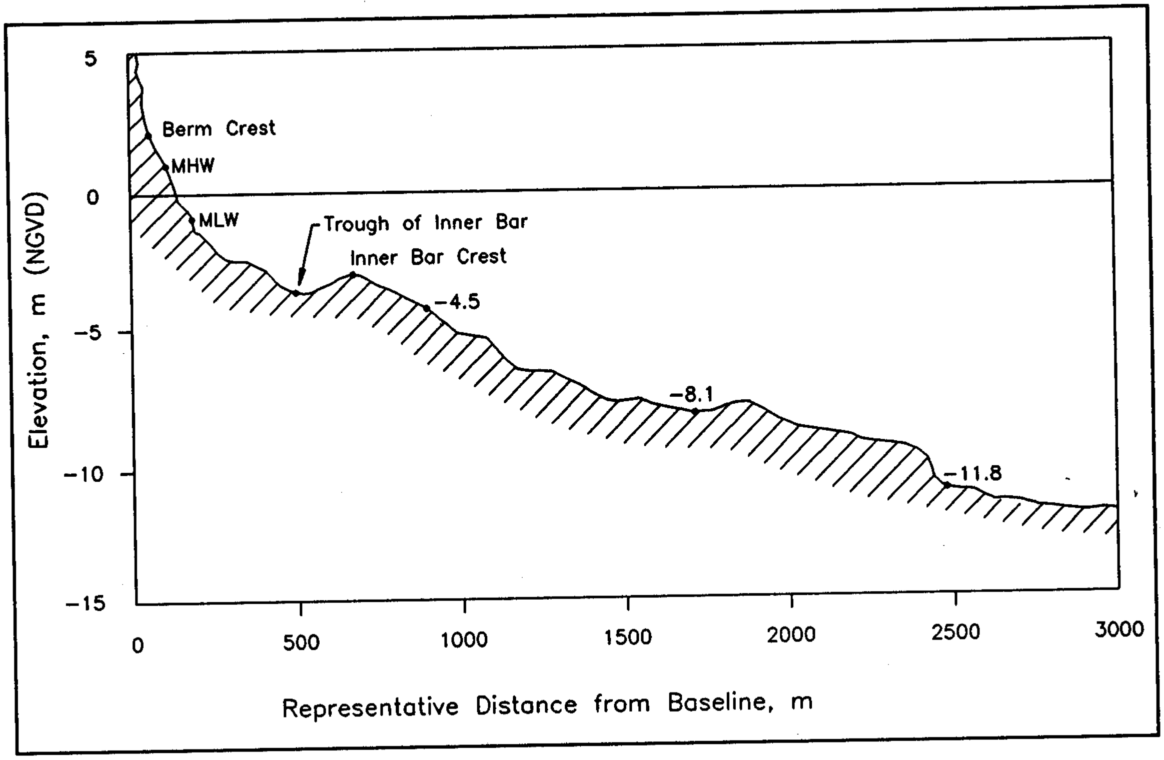


Figure D138. Location of sampled surface sediments along a representative profile

dimension in millimeters to the base 2. The equation for the relationship of millimeters to ϕ scale is as follows:

$$\phi = -1o2(d_{mm}) \qquad \text{(D1)}$$

where

d_{mm} = particle diameter in millimeters

Once the sediment samples were sieved, the contents of each sieve were weighed on an electronic balance and the weights entered automatically into a computer. A grain-size analysis software package was used to produce grain-size distribution tables, statistics and graphics of frequency, cumulative frequency and probability distribution (*Calculation of Composite Grain Size Distribution* section in the *Automated Coastal Engineering System (ACES) User's Guide* by Leenknecht, Szuwalski, and Sherlock (1992)). Standard grain-size distribution statistics were calculated, which included the median grain size or d_{50}, the particle size in the center of the population; the mean grain size or average grain size; the standard deviation or the spread of the distribution about the mean, which defines the concept of sorting; the skewness or measure of symmetry of the distribution around the mean; and the kurtosis or measure of the peakedness of the frequency distribution. Each of these statistical parameters provides information on the grain-size distribution and its depositional environment. The mean is the most commonly used statistic to characterize the average grain size of the distribution. The median value can be read directly off a cumulative curve and is near-normal to the mean in a normal distribution, but differs if the distribution is non-normal. The sorting gives the spread of the various grain sizes in the distribution. A well-sorted distribution contains a limited range of grain sizes and usually indicates that the depositional environment is limited to a narrow range of grain sizes and depositional energies, whereas a poorly sorted distribution contains a wide range of grain sizes indicating multiple sources of sediment or a wide range of energies of deposition. Positive skewness indicates an excess of fine grain sizes, whereas negative skewness indicates an excess of coarser grain sizes. The kurtosis measures the ratio between the sorting in the tails (fine sands and coarse sands and shell) of the distribution relative to the central portion (sand size) of the distribution.

These statistical parameters are commonly calculated by two different methods. The Folk (1974) graphic method uses specific percentiles of a grain-size distribution (i.e., 5, 16, 25, 50, 75, 84, and 95) that are read from graphical data plots and used in simple equations to produce the approximate statistical parameters. Phi values are used to calculate these parameters. Only the mean and median should be converted to millimeter values. The method of moments uses entire grain-size distribution values to mathematically produce the statistical parameters. This method is more accurate, but was time-consuming to calculate before the use of computers. Older sediment statistical data will commonly use the Folk graphic method. The parameters used in this appendix and Chapter 3 to characterize grain-size distributions are Folk-based graphic statistics to be comparable to the earlier data. The method of moments mean and median values are also presented in the summary tables. The statistics calculated by the method of moments are used in this appendix to discuss the spatial and temporal trends along the study area.

The following is a list of the equations and the verbal description of the scale of sediment grain-size parameters (graphic method of Folk and Ward 1957, method of moments in Friedman and Sanders (1978)). The mean or average grain-size values are classified as:

Mean Grain Size:

Graphic Mean, M:

$$M = \frac{\phi 16 + \phi 50 + \phi 84}{3} \tag{D2}$$

Moment Mean, x:

$$\bar{x} = \frac{\Sigma f\, m_{\phi}}{100} \tag{D3}$$

where

ϕn = grain size of *nth* weight percentile in phi units

f = frequency weight percent

m_{ϕ} = midpoint of size class

mm	ϕ	Wentworth Classification
2.00	-1.0	
		Very coarse sand
1.00	0.0	
		Coarse sand
0.50	1.0	
		Medium sand
0.25	2.0	
		Fine sand
0.125	3.0	
		Very fine sand
0.0625	4.0	

The standard deviation or measure of sorting uses the following equations and verbal descriptors.

Standard Deviation (Sorting):

Graphic Sorting, σ:

$$\sigma = \frac{\phi 84 - \phi 16}{4} + \frac{\phi 95 - \phi 5}{6.6} \qquad \text{(D4)}$$

Moment Sorting, σ:

$$\sigma = \left[\frac{\Sigma f(m_{\phi} - \bar{x})^2}{100}\right]^{\frac{1}{2}} \qquad \text{(D5)}$$

Sorting Range	Description of Sorting
$<0.35\ \phi$	Very well sorted
0.35 to 0.50 ϕ	Well sorted
0.50 to 0.71 ϕ	Moderately well sorted
0.71 to 1,00 ϕ	Moderately sorted
1.00 to 2.00 ϕ	Poorly sorted
2.00 to 4.00 ϕ	Very poorly sorted
$>4.00\ \phi$	Extremely poorly sorted

The skewness or measure of symmetry shows excess fine or coarse material in the grain size distribution. The following equations are used for the graphic method and method of moments, with the range of verbal descriptors.

Skewness

Graphic Skewness, *Sk*:

$$Sk = \frac{\phi 16 + \phi 84 - 2(\phi 50)}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2(\phi 50)}{2(\phi 95 - \phi 5)} \tag{D6}$$

Moment Skewness, *Sk*:

$$Sk = \frac{\Sigma f(m_\phi - \bar{x})^3}{100\ \sigma^3} \tag{D7}$$

Skewness Range	Description of Skewness
+1.0 to +0.3	Very fine-skewed
+0.3 to +0.1	Fine-skewed
+0.1 to —0.1	Near-symmetrical
—0.1 to —0.3	Coarse-skewed
—0.3 to —1.0	Very coarse-skewed

Kurtosis or measure of the peakedness of the grain-size distribution relates sorting of the tails compared to sorting of the central portion of the distribution. The following equations are used for the graphic method, which centers around graphic kurtosis K_G = 1.00 and the method of moments, which centers around *the moment kurtosis* k = 3.00. The range of verbal descriptors of peakedness is based on the platykurtic (flat) curve versus the leptokurtic (peaked curve, with a mesokurtic curve as normal.

Kurtosis:

Graphic Kurtosis, K_G:

$$K_G = \frac{\phi 95 - \phi 5}{2.44(\phi 75 - \phi 25)} \tag{D8}$$

Graphic Kurtosis Range	Description of Kurtosis
<0.67	Very platykurtic (flat)
0.65 to 0.90	Platykurtic
0.90 to 1.11	Mesokurtic (normal distribution)
1.11 to 1.50	Leptokurtic
1.50 to 3.00	Very leptokurtic
>3.00	Extremely leptokurtic (peaked)

Moment Kurtosis, k:

$$K = \frac{\Sigma f(m_\phi - \bar{x})^4}{100\ \sigma^4)} \quad \text{(D9)}$$

Moment Kurtosis Range	Description of Kurtosis
<3.00	Platykurtic (flat)
around 3.00	Mesokurtic (normal distribution)
>3.00	Leptokurtic

To remove some of the complexity in the cross-shore grain-size distributions, a mathematical composite was computed by grouping specific samples from locations in the cross-shore direction. The beach composite was comprised of samples from the berm crest, MHW, and MLW, and the nearshore composite was comprised of samples (if present) from the 4.5-, 8.1-, and 11.8-m (NGVD) depths. The surf zone samples at the trough and bar crest were not used in the composite analysis because of the limited number of samples collected in that area. The beach composite represents the active foreshore area of the beach profile that is directly under the influence of runup and backwash. The nearshore composite area is seaward of the breaker zone in most cases, and represents a lower energetic hydrodynamic environment.

Results

Cumberland Island. Based on the sediment data collected as part of this monitoring program, Cumberland Island is characterized by remarkedly uniform, well- to very well-sorted, unimodal, fine-skewed sands along a flat beachface and a shallow, gentle bathymetric gradient. Tables D25-D28 summarize grain-size statistics for the Cumberland Island sediment database. The sediment texture varied slightly from year to year. The average mean grain size of the subaerial beach for Cumberland Island is 0.16 mm for 1988, 0.18 mm for 1989, 0.18 mm for 1990, and 0.18 mm for 1992. Corresponding mean grain sizes for the nearshore zone, which included the 1988 and 1992 data sets, averaged 0.18 and 0.22 mm, respectively.

The mean grain size for all but four of the Cumberland Island samples corresponded to fine sand (finer than 0.25 mm) regardless of location or time of sample. The four coarser samples contained some shell material. The sorting was typically in the well to moderately well sorted range (0.35 to 0.71 ϕ). The few exceptions (14 samples) were moderately to poorly sorted (0.71 to 2.0 ϕ) and most of these samples were collected in the MLW and nearshore area. Typically, native beach samples have symmetrical skewness values around the +0.1 to −0.1 range (Folk and Ward 1957, Folk 1974, Davis 1989). A positive skewness indicates an excess of fine material in the distribution and a negative skewness indicates an excess of coarse material. The majority of Cumberland Island sediments were negatively skewed, ranging from the symmetrical −0.01 to the very coarse skewed −0.64. The bulk of the samples had skewness values between −0.01 to −0.30, with a few slightly positively skewed samples located mainly on the berm and MHW area. Samples with a very coarse skewness (greater than −0.30) were predominantly associated with the MLW and nearshore samples. These samples were collected in either the higher turbulence environments or where relict shell material was located.

Table D25
Cumberland Island Grain-Size Data: Jul 1988

Sample Name[1]	Elev,[2] m	Range,[3] m	Folk Graphic Measures,[4] phi					Grain Size,[5] mm	
			Med	Mean	Dev	Skew	Kurt	Med	Mean
KBC-01-BM	2.2	144	2.55	2.56	0.28	0.02	1.02	0.17	0.17
KBC-01-HW	1.5	170	2.57	2.57	0.31	0.00	0.98	0.17	0.17
KBC-01-LW	-0.4	251	2.38	2.33	0.49	-0.16	0.87	0.19	0.20
KBC-01-TR	-1.8	287	2.66	2.66	0.30	0.00	1.20	0.16	0.16
KBC-01-04	-4.5	--[6]	2.93	2.94	0.35	-0.02	1.66	0.13	0.14
KBC-01-08	-8.1	--	2.95	2.92	0.89	-0.41	4.72	0.13	0.16
KBC-10-BM	2.2	218	2.72	2.70	0.29	-0.06	0.98	0.15	0.15
KBC-10-HW	1.5	236	2.67	2.66	0.31	-0.06	0.98	0.16	0.16
KBC-10-LW	-0.4	326	2.75	2.64	0.50	-0.36	1.03	0.15	0.16
KBC-10-TR	-1.8	372	2.83	2.82	0.31	-0.13	1.14	0.14	0.14
KBC-10-04	-4.5	--	2.90	2.87	0.44	-0.31	2.23	0.13	0.15
KBC-10-08	-8.1	--	2.97	2.96	0.50	-0.17	2.01	0.13	0.14
KBC-20-BM	2.1	176	2.64	2.63	0.33	-0.08	1.12	0.16	0.16
KBC-20-HW	1.4	206	2.76	2.77	0.26	0.03	1.03	0.15	0.15
KBC-20-LW	0.6	302	2.39	2.25	0.68	-0.28	0.77	0.19	0.21
KBC-20-TR	-1.3	347	2.86	2.85	0.34	-0.13	1.22	0.14	0.14
KBC-20-BR	-1.9	372	2.75	2.73	0.45	-0.29	2.08	0.15	0.16
KBC-20-04	-4.5	--	3.23	3.13	1.05	-0.38	2.13	0.11	0.13
KBC-20-08	-8.1	--	3.21	3.19	0.88	-0.33	2.63	0.11	0.13
KBC-28-BM	1.5	320	2.90	2.88	0.29	-0.13	1.08	0.13	0.14
KBC-28-HW	1.1	335	2.87	2.88	0.28	0.03	1.04	0.14	0.14
KBC-28-LW	-0.1	411	2.96	2.95	0.29	-0.04	1.23	0.13	0.13
KBC-28-TR	-0.6	457	2.99	2.94	0.60	-0.37	2.60	0.13	0.15
KBC-28-04	-4.5	--	2.77	2.76	0.45	-0.10	1.51	0.15	0.15
KBC-28-08	-8.1	--	2.74	2.72	0.36	-0.15	1.17	0.15	0.15
KBC-31-HW	2.4	198	2.67	2.64	0.38	-0.21	1.61	0.16	0.16
KBC-31-LW	1.7	234	2.75	2.45	0.90	-0.60	2.11	0.15	0.19
KBC-31-04	-4.5	--	2.56	2.60	0.35	0.18	1.31	0.17	0.17
KBC-31-08	-8.1	--	2.86	2.86	0.29	0.07	1.36	0.14	0.14
KBC-31-12	-11.8	376	1.13	1.06	0.93	-0.18	1.43	0.46	0.49

[1] Sample Name Symbols: KB = Kings Bay; C = Cumberland Island; # = Survey Line; BM = Berm; HW = Mean High Water; LW = Mean Low Water; TR = Trough; BR = Bar; 04 = Elevation -4.5 m; 08 = Elevation -8.1 m; 12 = Elevation -11.8 m.
[2] Elevation relative to NGVD.
[3] Distance from survey baseline.
[4] Abbreviation of moment statistics and units: Med = median, phi; Mean, phi; Dev = standard deviation, phi; Skew = skewness, Kurt = kurtosis.
[5] Calculated by method of moments.
[6] Range not recorded at time of sampling.

Table D26
Cumberland Island Grain-Size Data: Aug/Sep 1989

Sample Name[1]	Elev,[2] m	Range,[3] m	Folk Graphic Measures,[4] phi					Grain Size,[5] mm	
			Med	Mean	Dev	Skew	Kurt	Med	Mean
KBC-01-BM	2.7	144	2.59	2.59	0.31	0.00	1.19	0.17	0.17
KBC-01-HW	1.8	191	2.58	2.58	0.35	-0.02	1.03	0.17	0.17
KBC-01-LW	0.5	259	2.51	2.46	0.47	-0.16	1.00	0.18	0.18
KBC-10-BM	1.8	218	2.68	2.69	0.29	0.08	1.10	0.16	0.15
KBC-10-HW	1.7	236	2.73	2.74	0.28	0.03	1.02	0.15	0.15
KBC-10-LW	0.0	320	2.51	2.17	0.95	-0.56	1.22	0.18	0.23
KBC-20-BM	2.6	176	2.60	2.59	0.37	-0.10	1.19	0.16	0.17
KBC-20-HW	2.0	213	2.70	2.72	0.28	0.03	1.14	0.15	0.15
KBC-20-LW	0.2	302	2.54	1.93	1.31	-0.64	0.76	0.17	0.28
KBC-28-BM	2.6	320	2.70	2.65	0.42	-0.26	1.42	0.15	0.16
KBC-28-HW	2.0	335	2.61	2.38	0.69	-0.45	0.86	0.16	0.19
KBC-28-LW	0.0	457	2.88	2.87	0.39	-0.18	1.47	0.14	0.15
KBC-31-HW	2.0	207	2.76	2.71	0.41	-0.26	1.34	0.15	0.16
KBC-31-LW	0.0	213	1.74	1.79	1.48	-0.16	1.09	0.30	0.31

[1] Sample Name Symbols: KB = Kings Bay; C = Cumberland Island; # = Survey Line; BM = Berm; HW = Mean High Water; LW = Mean Low Water.
[2] Elevation relative to NGVD.
[3] Distance from survey baseline.
[4] Abbreviation of moment statistics: Med = median, Dev = standard deviation, Skew = skewness, Kurt = kurtosis.
[5] Calculated by method of moments.

Table D27
Cumberland Island Grain-Size Data: Jul 1990

Sample Name[1]	Elev,[2] m	Range,[3] m	Folk Graphic Measures,[4] phi					Grain Size,[5] mm	
			Med	Mean	Dev	Skew	Kurt	Med	Mean
KBC-01-BM	2.7	144	2.51	2.48	0.34	-0.11	1.05	0.18	0.18
KBC-01-HW	1.8	191	2.47	2.45	0.31	-0.08	1.02	0.18	0.18
KBC-01-LW	0.5	259	2.62	2.59	0.39	-0.14	1.07	0.16	0.17
KBC-10-HW	1.7	236	2.77	2.77	0.30	-0.05	0.98	0.15	0.15
KBC-10-LW	0.0	320	2.78	2.66	0.62	-0.46	1.68	0.15	0.17
KBC-20-LW	0.2	302	2.58	2.33	0.96	-0.45	1.05	0.17	0.21
KBC-31-HW	2.0	--[6]	2.78	2.77	0.33	-0.13	1.07	0.15	0.15
KBC-31-LW	0.0	--	2.53	2.30	0.76	-0.42	0.78	0.17	0.21

[1] Sample Name Symbols: KB = Kings Bay; C = Cumberland Island; # = Survey Line; BM = Berm; HW = Mean High Water; LW = Mean Low Water.
[2] Elevation relative to NGVD.
[3] Distance from survey baseline.
[4] Abbreviation of moment statistics: Med = median, Dev = standard deviation, Skew = skewness, Kurt = kurtosis.
[5] Calculated by method of moments.
[6] Range not recorded at time of sampling.

Table D28
Cumberland Island Grain-Size Data: Apr/May 1992

Sample Name[1]	Elev,[2] m	Range,[3] m	Folk Graphic Measures,[4] phi					Grain Size,[5] mm	
			Med	Mean	Dev	Skew	Kurt	Med	Mean
KBC-01-BM	16.3	182	2.62	2.62	0.30	-0.01	1.07	0.16	0.16
KBC-01-HW	14.0	403	2.60	2.59	0.30	-0.05	1.02	0.17	0.17
KBC-01-LW	9.0	636	2.39	2.31	0.54	-0.23	0.89	0.19	0.20
KBC-01-TR	5.1	761	2.73	2.69	0.36	-0.25	1.45	0.15	0.16
KBC-01-04	2.0	2386	2.61	2.53	0.47	-0.30	1.13	0.16	0.18
KBC-01-08	-1.3	4697	2.92	2.91	0.42	-0.24	2.04	0.13	0.14
KBC-10-BM	6.6	788	2.62	2.62	0.31	0.00	1.09	0.16	0.16
KBC-10-HW	3.2	934	2.43	2.29	0.61	-0.40	1.17	0.19	0.21
KBC-10-LW	-2.2	1211	2.66	2.64	0.39	-0.18	1.21	0.16	0.17
KBC-10-TR	-5.0	1263	2.52	2.30	0.75	-0.46	1.04	0.17	0.21
KBC-10-04	-15.2	3037	2.49	2.23	0.84	-0.46	0.88	0.18	0.22
KBC-10-08	-10.5	5376	2.90	2.87	0.44	-0.33	2.13	0.13	0.13
KBC-20-BM	7.1	701	2.54	2.53	0.36	-0.11	1.09	0.17	0.18
KBC-20-HW	3.3	826	2.66	2.64	0.33	-0.09	1.05	0.16	0.16
KBC-20-LW	-2.2	1106	2.71	2.72	0.28	-0.01	1.15	0.15	0.15
KBC-20-TR	-3.4	1352	2.90	2.89	0.32	-0.08	1.20	0.13	0.14
KBC-20-BR	-6.3	1447	2.87	2.85	0.35	-0.12	1.19	0.14	0.15
KBC-20-04	-14.9	2361	3.47	3.46	0.57	-0.24	1.59	0.09	0.10
KBC-28-BM	8.7	1006	2.81	2.79	0.32	-0.15	1.10	0.14	0.15
KBC-28-HW	3.2	1229	2.21	2.07	0.94	-0.30	0.87	0.22	0.25
KBC-28-LW	-2.1	1704	2.78	2.69	0.59	-0.43	1.93	0.15	0.17
KBC-28-TR	-5.9	2139	3.19	2.99	0.85	-0.42	1.31	0.11	0.13
KBC-28-04	-6.8	3026	2.93	2.93	0.54	-0.09	1.41	0.13	0.14
KBC-28-08	-8.7	5419	0.88	0.76	0.72	-0.30	1.21	0.54	0.61

[1] Sample Name Symbols: KB = Kings Bay; C = Cumberland Island; # = Survey Line; BM = Berm; HW = Mean High Water; LW = Mean Low Water; TR = Trough; BR = Bar; 04 = Elevation -4.5 m; 08 = Elevation -8.1 m.
[2] Elevation relative to NGVD.
[3] Distance from survey baseline.
[4] Abbreviation of moment statistics: Med = median, Dev = standard deviation, Skew = skewness, Kurt = kurtosis.
[5] Calculated by method of moments.

Kurtosis values along Cumberland Island ranged between a platykurtic (flat) 0.76 and an extremely leptokurtic (peaked) 4.72, with a mesokurtic (normal) curve being around 1 using the Folk graphic kurtosis. The samples with a flat curve are usually poorly sorted with the coarse and fine tails sorted better than the central sand size fraction. The peaked samples have a well-sorted grain size grouped around only a few size classes, relative to the tail fractions. Figure D139 shows examples of skewness and kurtosis values for Cumberland Island sediment samples. The Line C1 sediment sample collected in 1988, at MHW, shows a normal bell-shaped curve with a well-sorted, fine sand, with no asymmetry and near mesokurtic kurtosis. Deposition at MHW is controlled by swash processes at maximum runup. The Line C20 sediment sample collected in 1988, at MLW, exhibits a negatively skewed and platykurtic curve due to excess medium sand indicative of a higher energy environment of deposition in the lower backwash/wave interaction zone. During the 1988 sampling of Line C1 at the 8.1-m depth nearshore shows a very negatively skewed but peaked grain-size distribution. This type of grain-size distribution indicates a fine-grained, well-sorted, low-energy nearshore hydrodynamic environment that also included a coarse shell component (most likely a shell lag deposit typical of nearshore shelf areas).

A series of plots shows the alongshore variability in the subaerial beach environments from the berm crest, through MHW to the MLW area, as depicted by the mean grain size (Figures D140-D142). Along Cumberland Island, there is very little variation in the means for the berm crest samples, suggesting a relatively uniform subaerial depositional environment along the entire island. The uniform fine grain size (average mean of 0.16 mm) was present throughout the monitoring period from July 1988 to April/May 1992 (Figure D140). This area of the beach is impacted by swash processes only during storms. The mean grain size of the MHW beach area

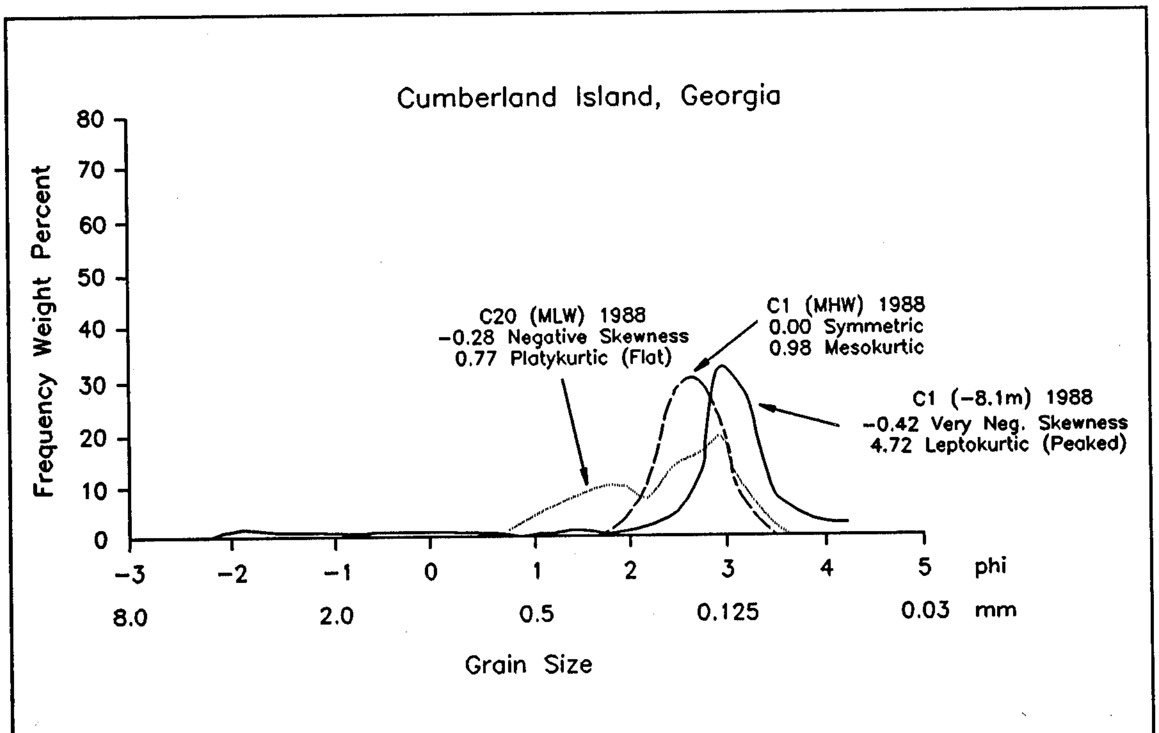


Figure D139. Examples of frequency curves of grain-size distributions for Cumberland Island

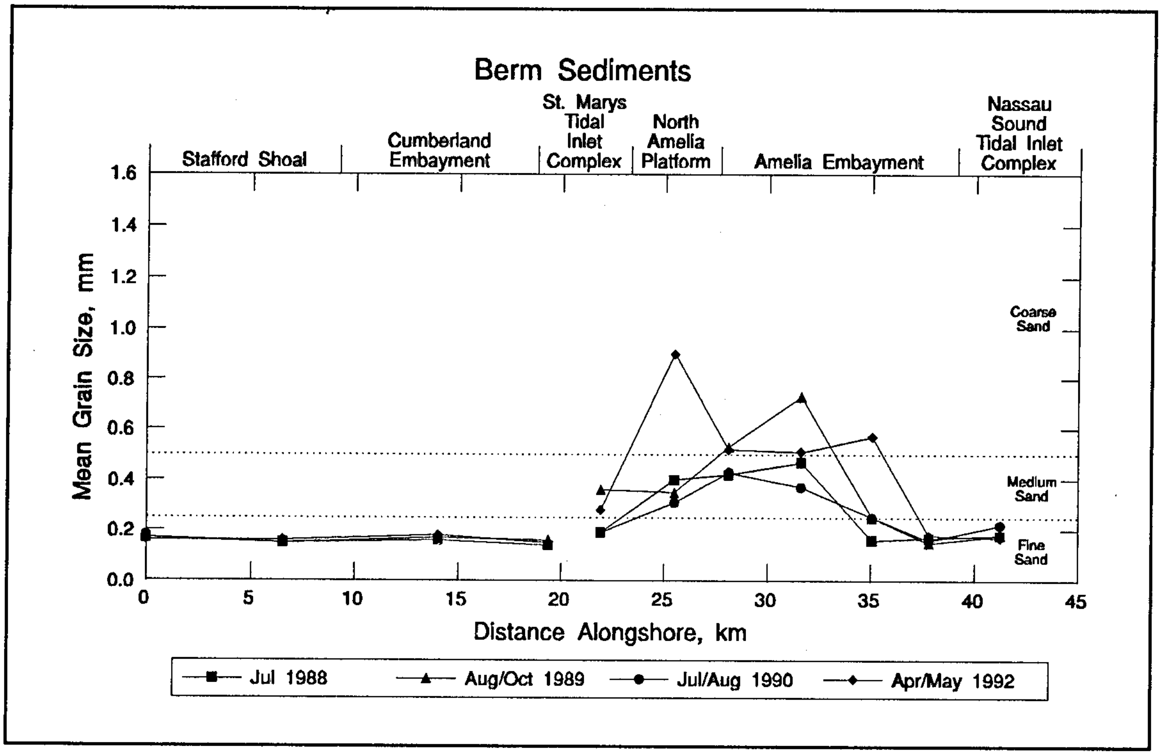


Figure D140. Mean grain size, Jul 1988 - Apr/May 1992, for berm

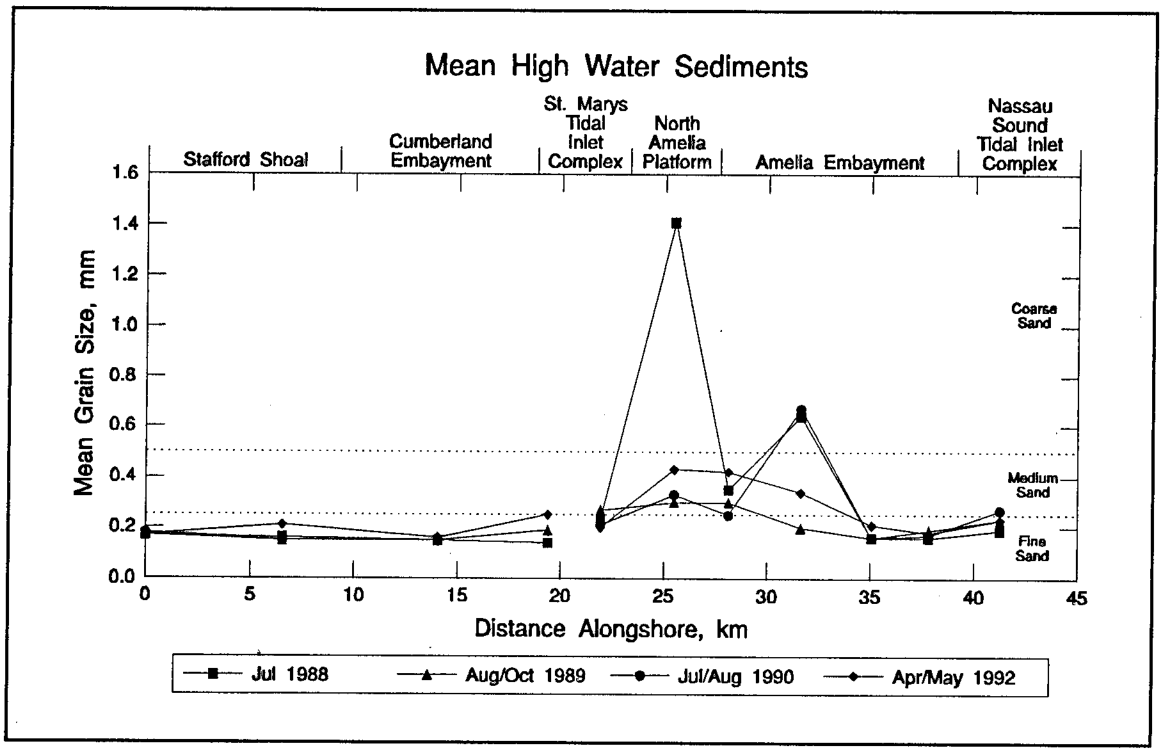


Figure D141. Mean grain size, Jul 1988 - Apr/May 1992, for mean high water

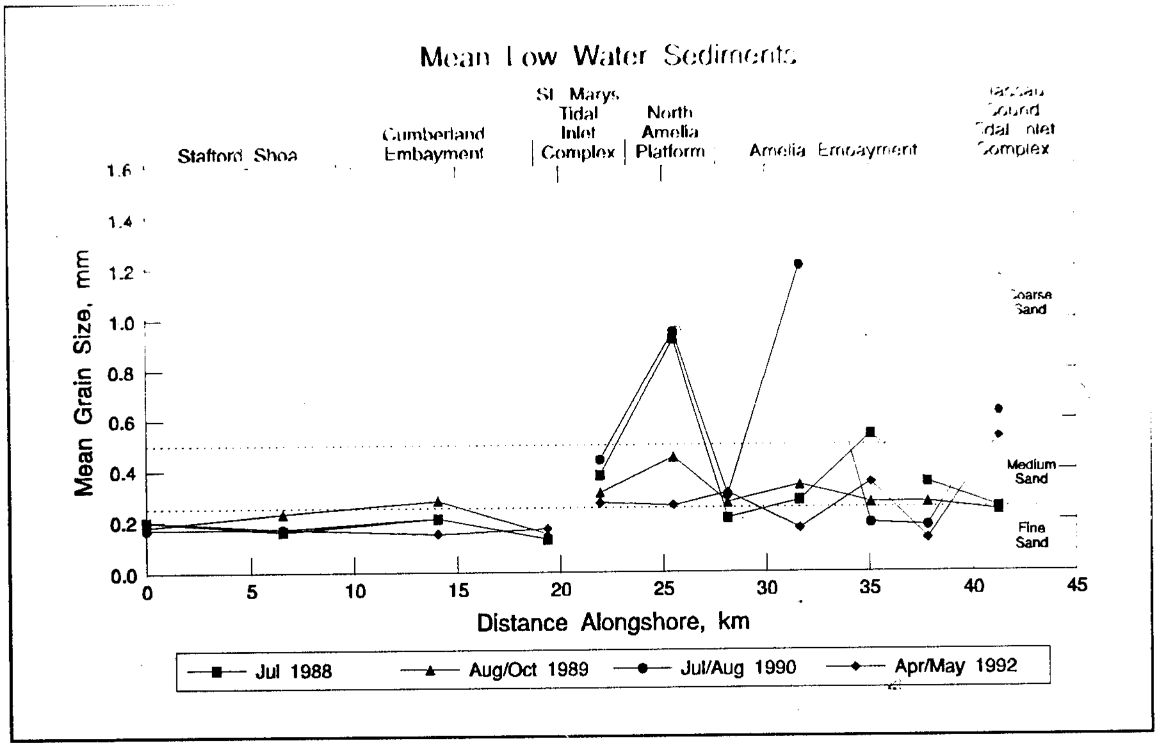


Figure D142. Mean grain size, Jul 1988 - Apr/May 1992, for mean low water

varies slightly alongshore with a slight increase from north to south within the Stafford Shoal Compartment during the April/May 1992 sampling. A slight decrease was measured within the Cumberland Embayment and then a temporal slight increase in mean size at the north fillet of the St. Marys Tidal Inlet Complex (Figure D141). The MHW area of the beach depicts the deposition of runup around high tide. The alongshore pattern of the mean grain size of the MLW area was more variable through time, but the range was still small between these values. With only four sediment sampling lines available, only general trends in alongshore change can be presented. The MLW area represents the area of the beach where the backwash interacts with the incoming waves and can vary both spatially and temporally as wave conditions change. The July 1988, August/October 1889, and July/August 1990 trend was for an increase in grain size to the south through most of the compartments on Cumberland Island and then decreased slightly within the north fillet of St. Marys Inlet Complex, whereas the opposite trend of a decrease in grain size was observed in April/May 1992. The highest variability in mean grain size was at Cumberland Embayment Line C20 (Figure D142).

The nearshore was sampled only during the July 1988 and April/May 1992 profile surveys. Sampling was done in the trough, inner bar crest, and the 4.5- and 8.1-m depth (NGVD) locations. The trough samples landward of the inner bar showed little change alongshore throughout the study period, except for a slight coarsening in the Stafford Shoals Compartment during the last sampling period (Figure D143). Mean values of the trough samples ranged from 0.13 to 0.21 mm, with an average of 0.15 mm in 1988 and 0.16 mm in 1992. These mean values indicate a uniform depositional environment during the two sampling times. An inner bar was sampled only at Line C20 (*Results of the monitoring profile measurements* section) and no alongshore analysis was possible. The mean grain size was similar to the trough with an average

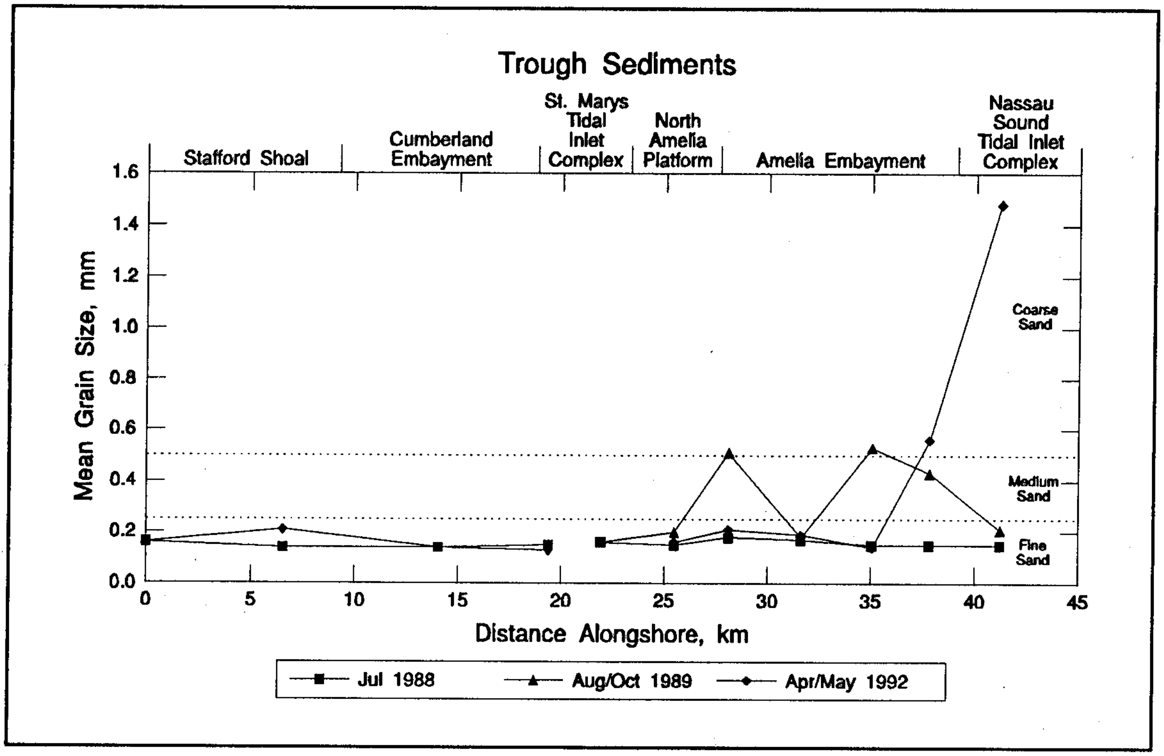


Figure D143. Mean grain size, Jul 1988 - Apr/May 1992, for trough

of 0.16 mm in 1988 and 0.15 mm in 1992. Seaward of the breaker zone, the 4.5- and 8.1-m depth samples were relatively uniform in the alongshore in 1988 (Figures D144 and D145). However, an anomalous coarse sand component was found at the 4.5-m depth along Line C10 and at the 8.1-m depth along Line C28 in 1992.

Sediments sampled within the inlet throat (i.e. Line C31) had a different hydrodynamic environment than the open ocean beach (Figure D137). These samples reflect the depositional environment of both reduced waves and an increase in along beach ebb- and flood-tidal currents. The subaerial beach samples followed the means of the open ocean beach samples in 1988 and were coarser in 1989. Sand flats were located in the low tide area and had fine to medium sand (mean between 0.15 and 0.31 mm). The deeper sample at -12 m (NGVD) within the channel bottom under the direct influence of the tidal currents showed a coarser mean grain size of 0.49 mm, in the medium to coarse sand range.

Cross-shore samples taken between the berm crest and the nearshore exhibited textural trends typical of ocean beaches (Bascom 1959, Davis 1989), where the mean grain size becomes finer landward of MHW and seaward of MLW. For the 1988 Cumberland Island sample set, the mean grain sizes of the berm crest, MHW, MLW, trough, 4.5- and 8.1-m depth locations were 0.16, 0.16, 0.18, 0.15, 0.14, and 0.14 mm, respectively. The other complete sample set collected in 1992 had mean grain sizes of 0.16, 0.20, 0.17, 0.16, 0.16, and 0.29 mm, respectively. A coarse sample mean at the 8.1-m depth on Line C28 in 1992 caused the offshore mean to be anomalously coarse. A scatter plot of mean versus standard deviation (sorting) was constructed for both Cumberland and Amelia Islands for the 1992 data set (Figures D146 and D147). A general trend of coarser material on the subaerial beach and finer material in the nearshore area was found on

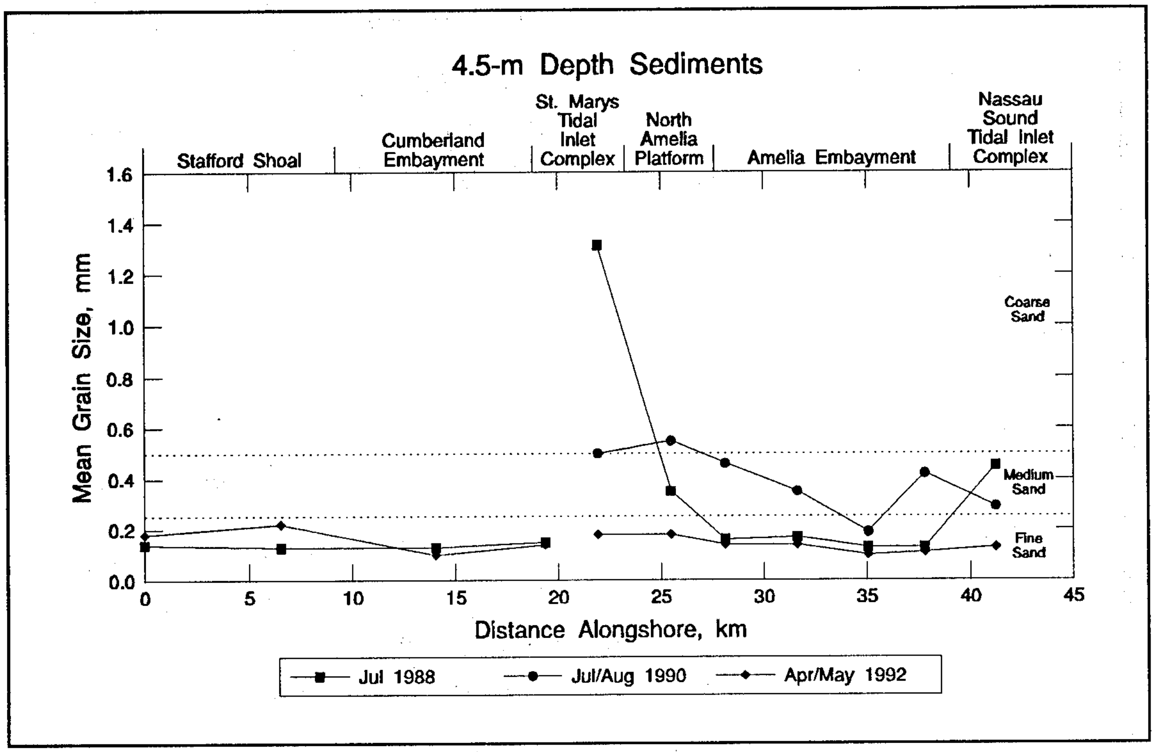


Figure D144. Mean grain size, Jul 1988 - Apr/May 1992, for 4.5-m depth

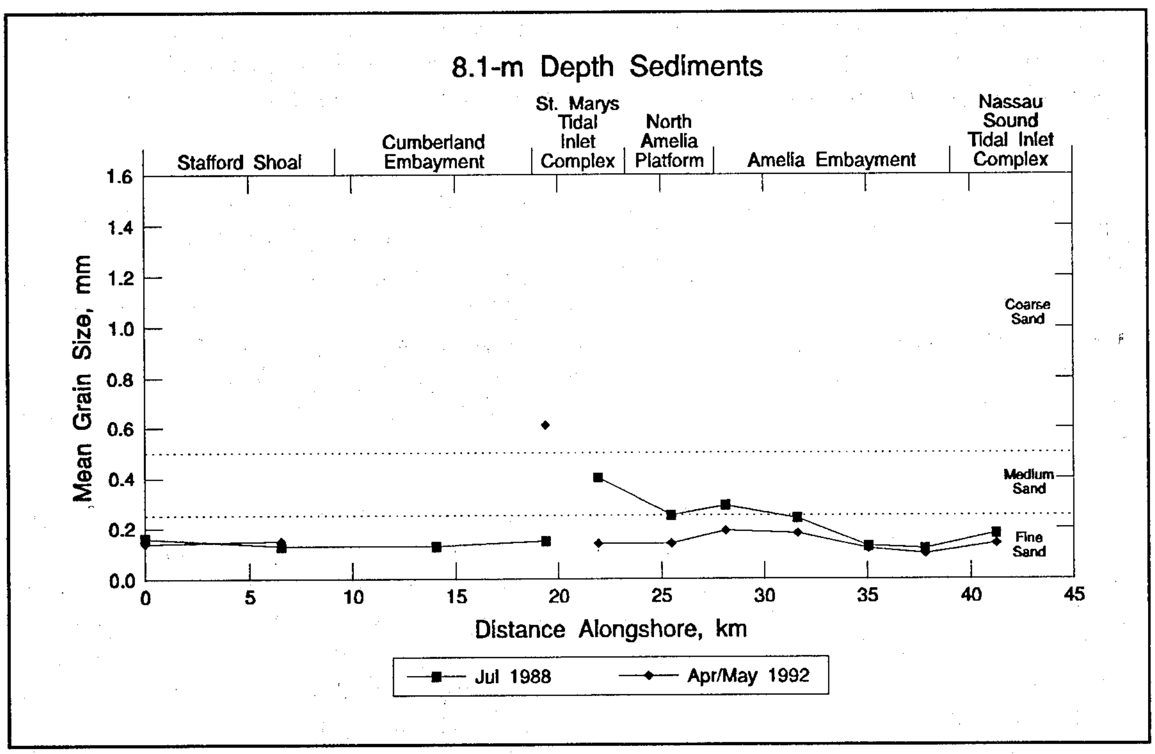


Figure D145. Mean grain size, Jul 1988 - Apr/May 1992, for 8.1-m depth

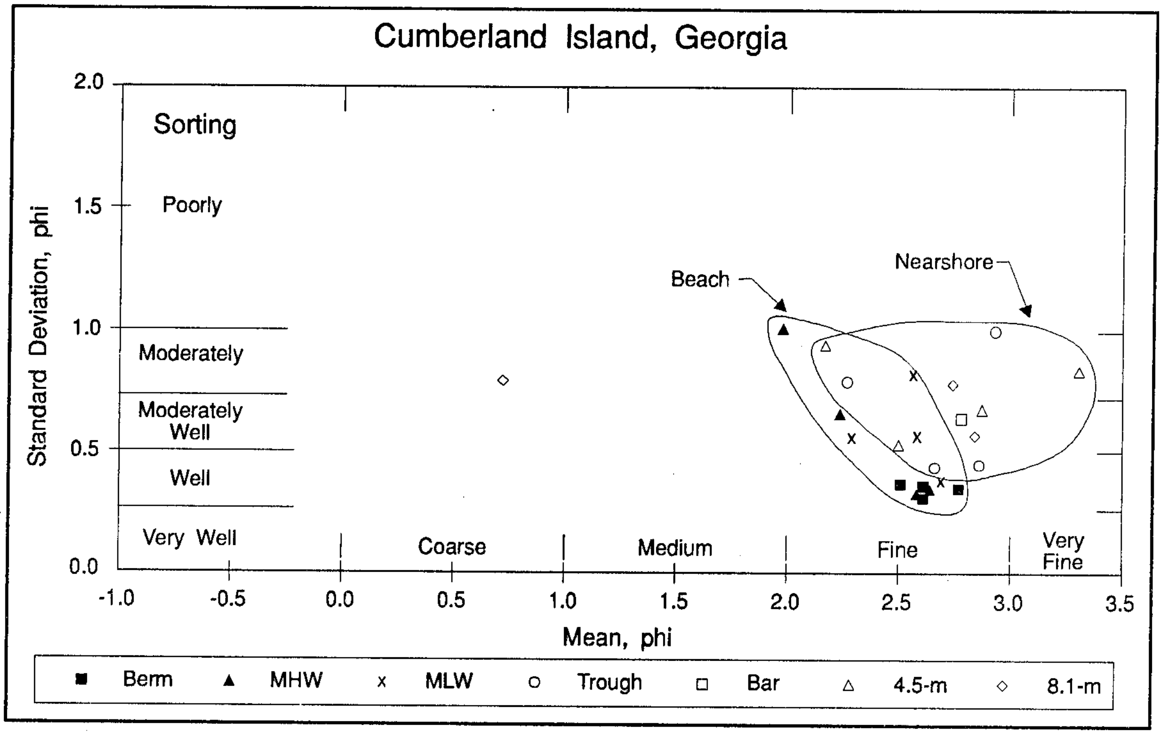


Figure D146. Mean grain size, phi, versus standard deviation (sorting) for individual samples, Cumberland Island

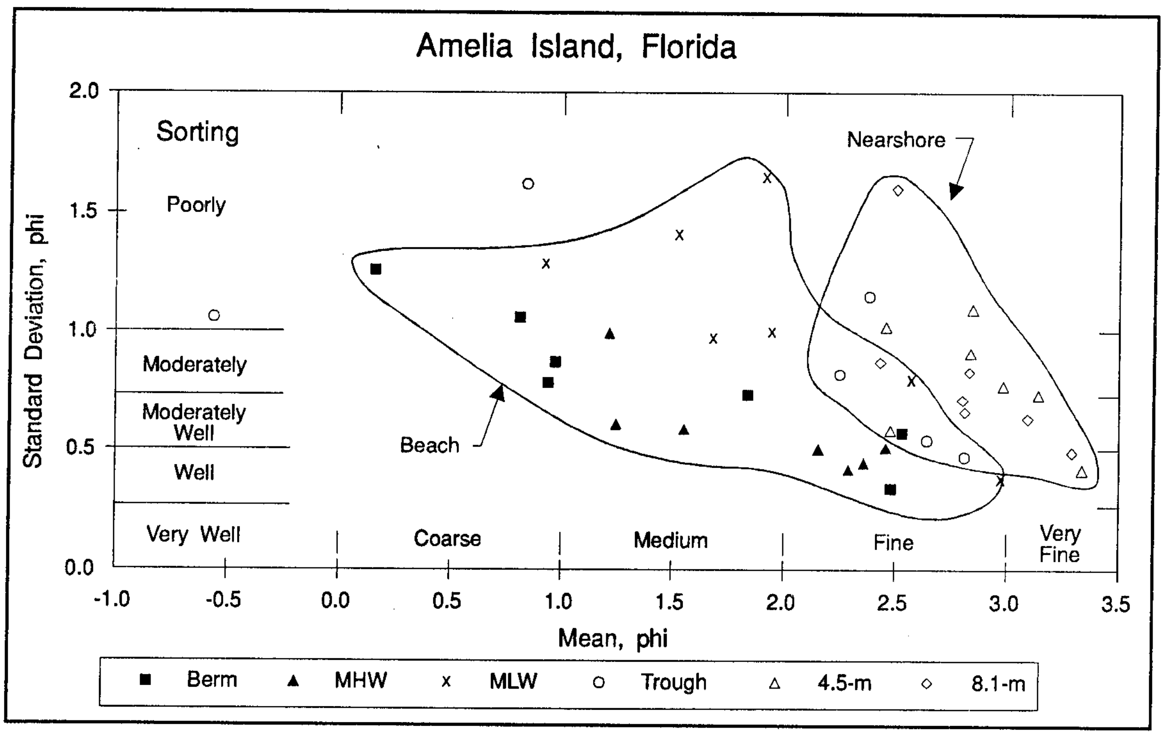


Figure D147. Mean grain size, phi, versus standard deviation (sorting) for individual samples, Amelia Island

Cumberland Island, with a narrow range in both the means and sorting values. The berm to MLW samples become more poorly sorted as mean grain size increases, while there is no distinct trend in sorting in the nearshore (Figure D146).

Based on the 1988 and 1992 data, the beach composite of the berm crest, MHW, and MLW samples composing the beach face were computed and correlated with the beach slope between the berm crest and MLW sample points. Figure D148 shows a somewhat linear correlation with finer mean foreshore grain size and flatter foreshore slope. The composite means had a narrow range from 0.14 to 0.21 mm and the foreshore slopes ranged from 0.7 to 1.5 deg. A general trend of increasing foreshore slope toward the north on Cumberland Island was present.

A comparison between the three morphologic compartments on Cumberland Island over the study period from 1988 to 1992 shows that there was little change in the general sediment grain-size distribution over the 4-year period. The Stafford Shoal Compartment represented by Line C10 and the Cumberland Embayment represented by Line 20 show basically the same profile composite frequency curves (Figure D149). The profile composite included the berm crest, MHW, MLW, trough, 4.5- and 8.1-m depth samples. There was a slight coarsening of the St. Marys Tidal Inlet Complex compartment represented by Lines C28 over the study period as coarser sediment was collected in the nearshore and foreshore areas of the fillet.

The net result of the sediment data shows negligible change along Cumberland Island during the monitoring period. The net change between the July 1988 and April/May 1992 sampling dates for all beach and nearshore sediment samples and for the beach only between the August/October 1989 and July/August 1990 sampling dates is shown in Figures D150-D155. For

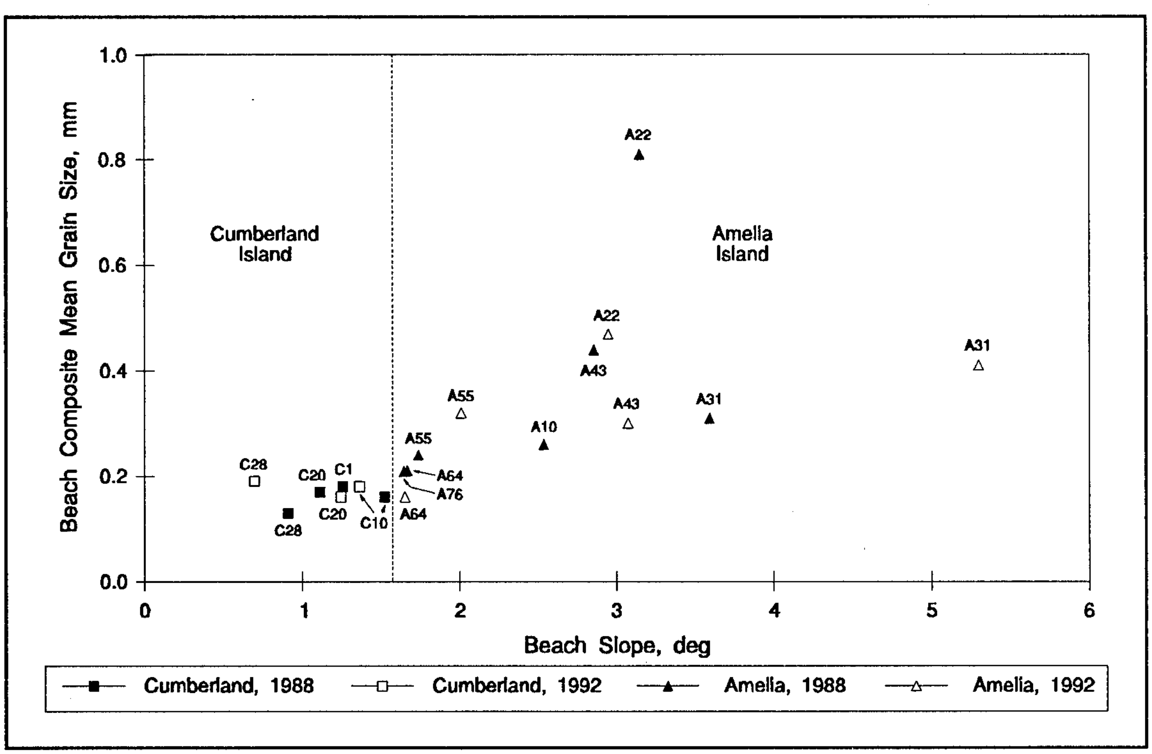


Figure D148. Comparison of beach slope, deg, and beach composite grain size, phi, Cumberland and Amelia Islands

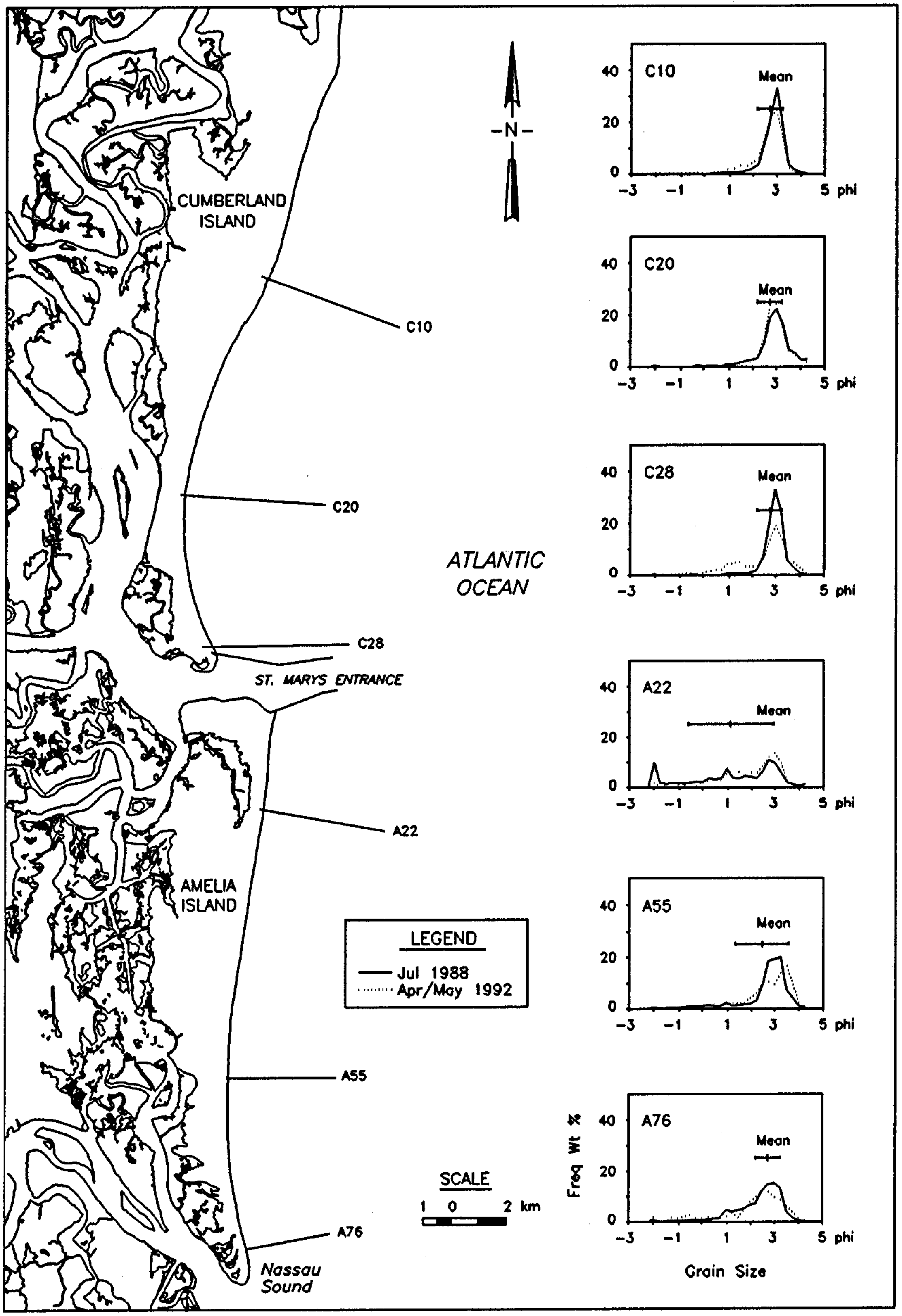


Figure D149. Representative profile composite frequency curves for Jul 1988 and Apr/May 1992

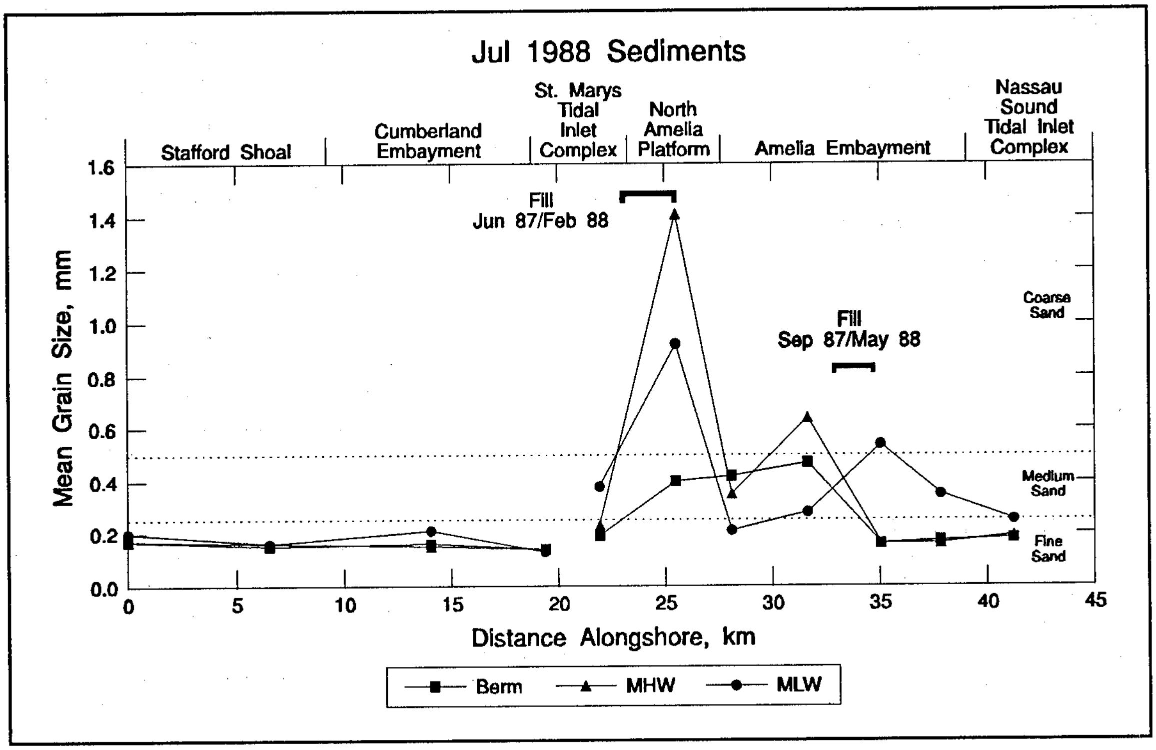


Figure D150. Mean grain size, Jul 1988, for berm, mean high water, and mean low water

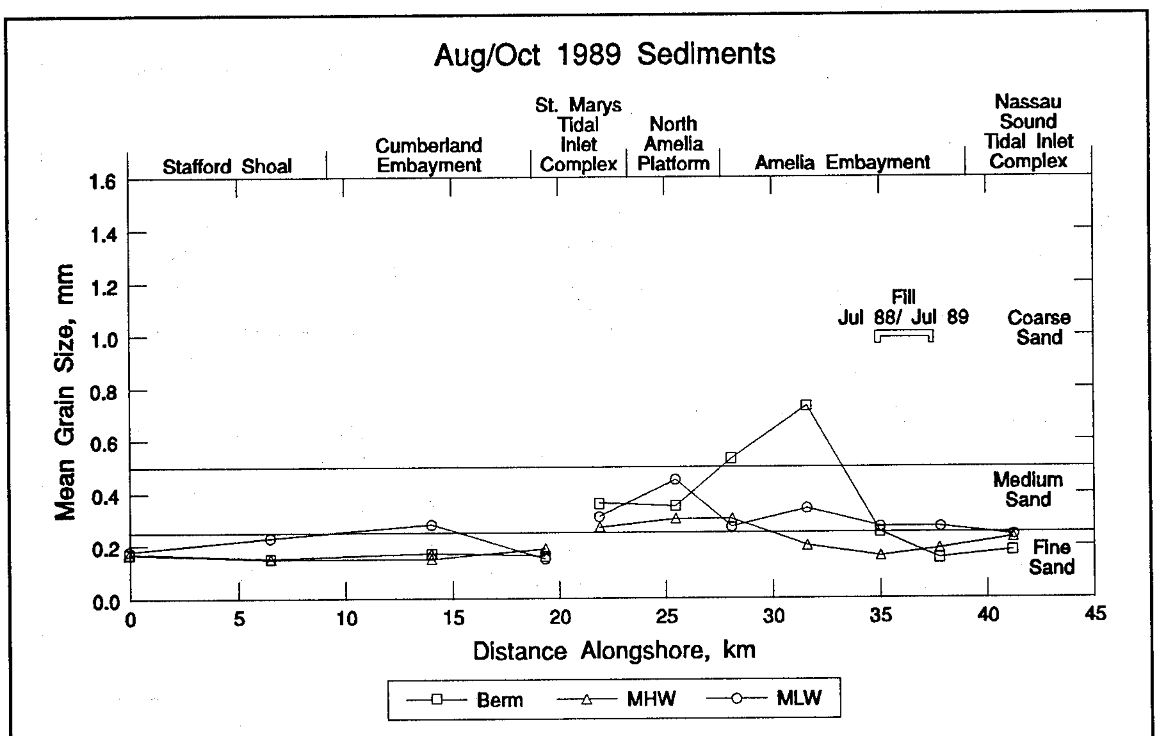


Figure D151. Mean grain size, Aug/Oct 1989, for berm, mean high water, and mean low water, with locations and dates of beach fill

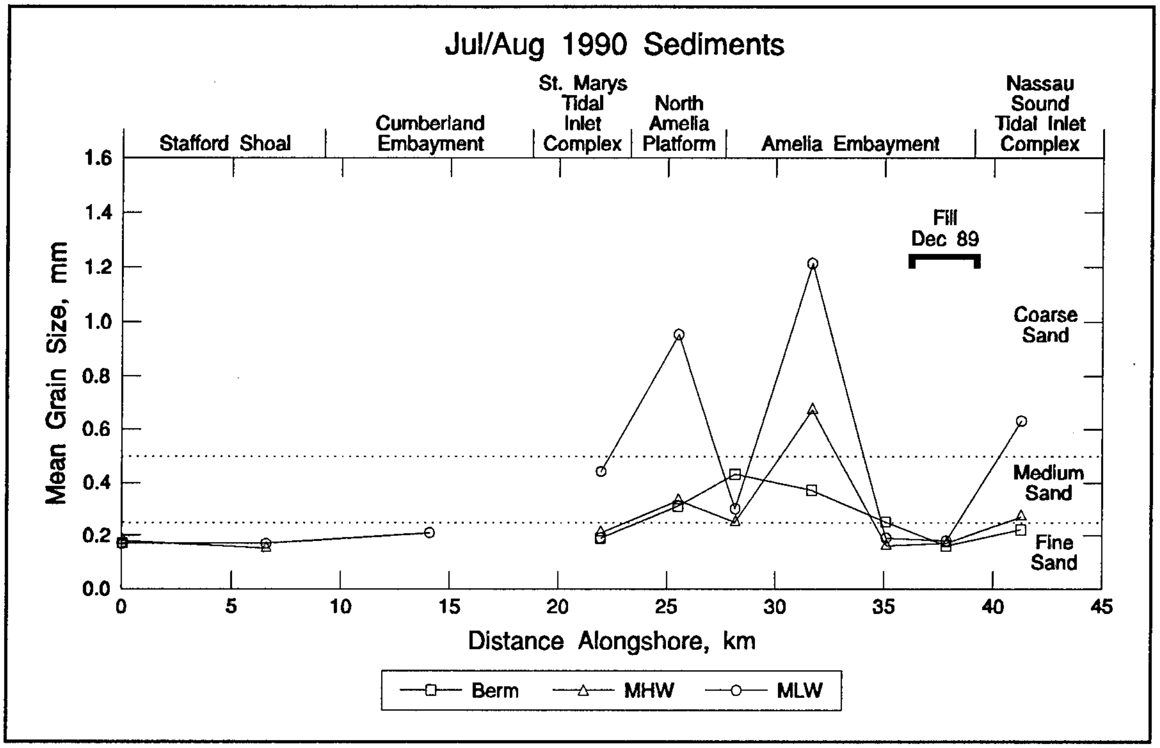


Figure D152. Mean grain size, Jul/Aug 1990, for berm, mean high water, and mean low water, with locations and dates of beach fill

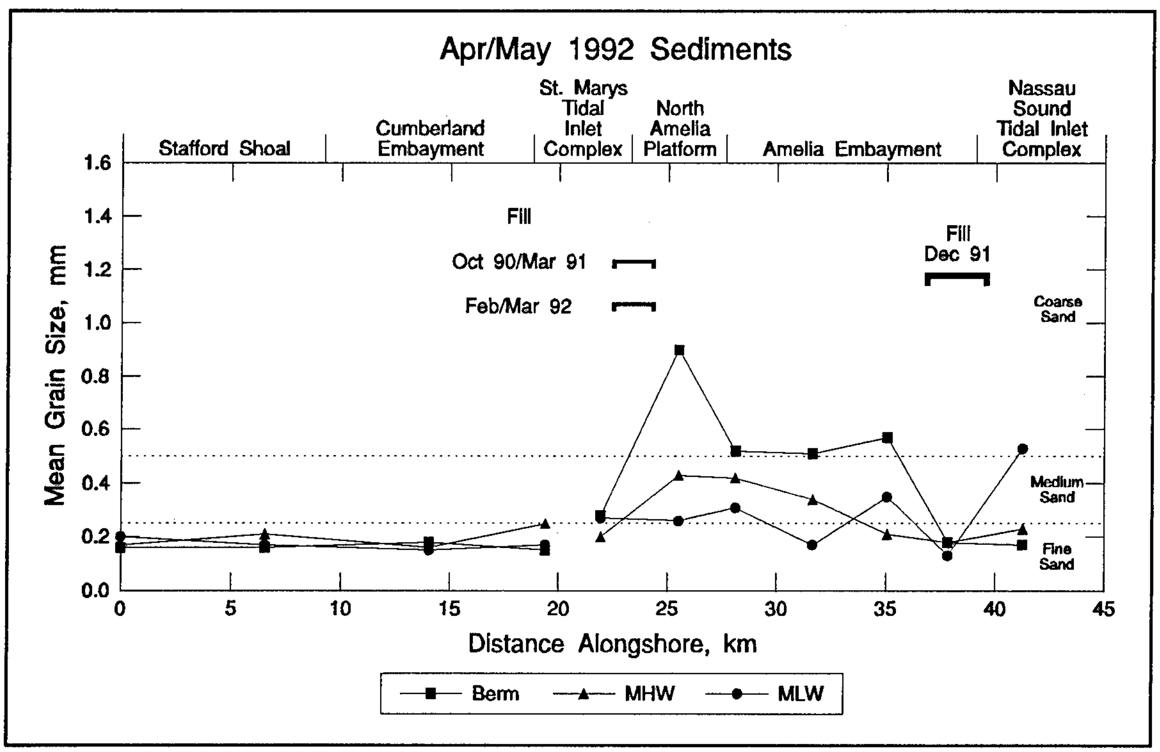


Figure D153. Mean grain size, Apr/May 1992, for berm, mean high water, and mean low water, with locations and dates of beach fill

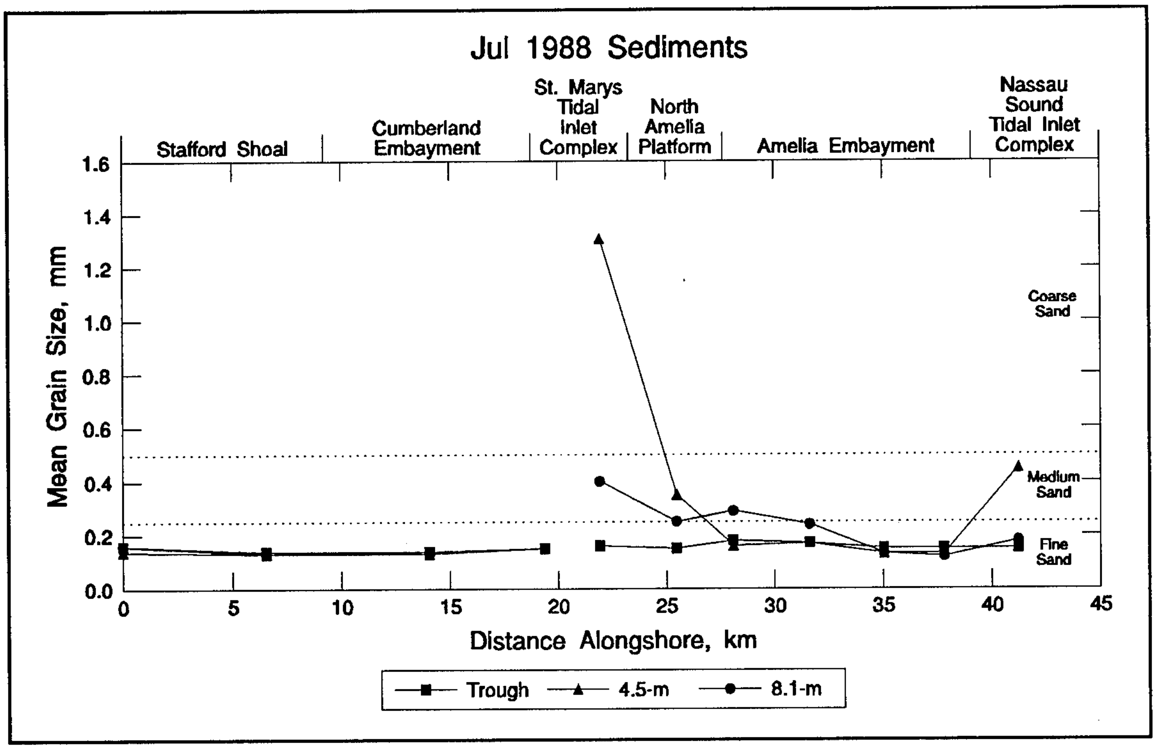


Figure D154. Mean grain size, Jul 1988, for trough, 4.5-m depth, and 8.1-m depth

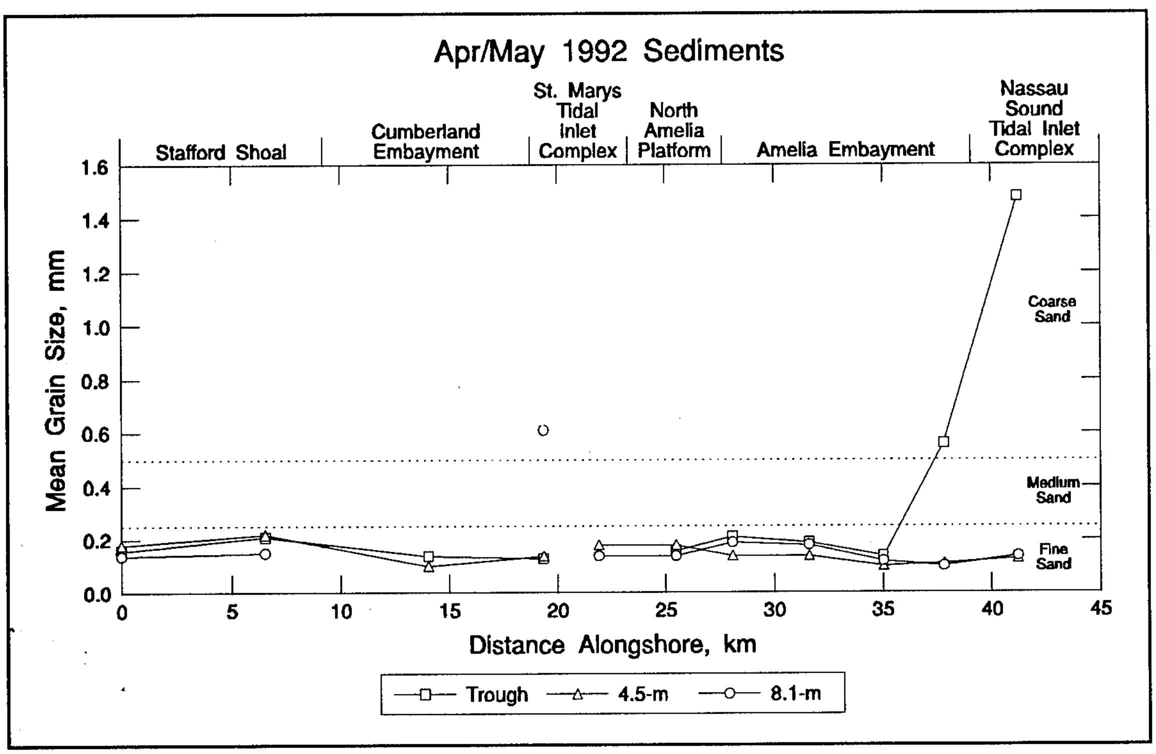


Figure D155. Mean grain size, Apr/May 1992, for trough, 4.5-m depth, and 8.1-m depth the 1988-1992 data, the uniformity of fine grain size is an indicator of low-energy conditions, a stable hydrodynamic environment, and a lack of significant influx of terrigenous sediments. No beach fills have been placed on Cumberland Island, and the only structure is the north jetty adjacent to St. Marys Entrance. The local sources of beach sand are the dune headland area located along central Cumberland Island and the St. Andrew ebb delta at the northern end of Cumberland Island.

For the beach along Cumberland Island, the grain-size composites show stable temporal distributions, as plotted in Figures D156-D159. The beach samples are predominantly fine with minor amounts of medium to coarse sands (less than 5 percent). The medium-to-coarse sand size fraction is derived in large part from sediments sampled at MLW where medium and coarse materials settle from the interaction of backwash with incoming surf. A comparison of the 1988 and 1992 beach composites verified the uniformity of the fine sandy beach with overall mean grain sizes of 0.16 and 0.18 mm, respectively. The only change in mean grain size occurred at Line C28 where the average varied between a mean grain size of 0.14 mm in 1988 and 0.19 mm in 1992. The variability along Line C28 can be attributed to lag deposits of coarse material trapped by the north jetty as variable currents move through the rubble-mound structure or as relict nearshore shell deposits. Large grains generally accumulate at points of maximum turbulence. Nearshore composites were slightly finer with a mean of 0.14 mm in 1988 and 0.19 mm in 1992, as summarized in Tables D29 and D30. Differences between profile lines sampled in 1988 and 1992 were small. The maximum mean of 0.28 mm was found at Line C28 in 1992.

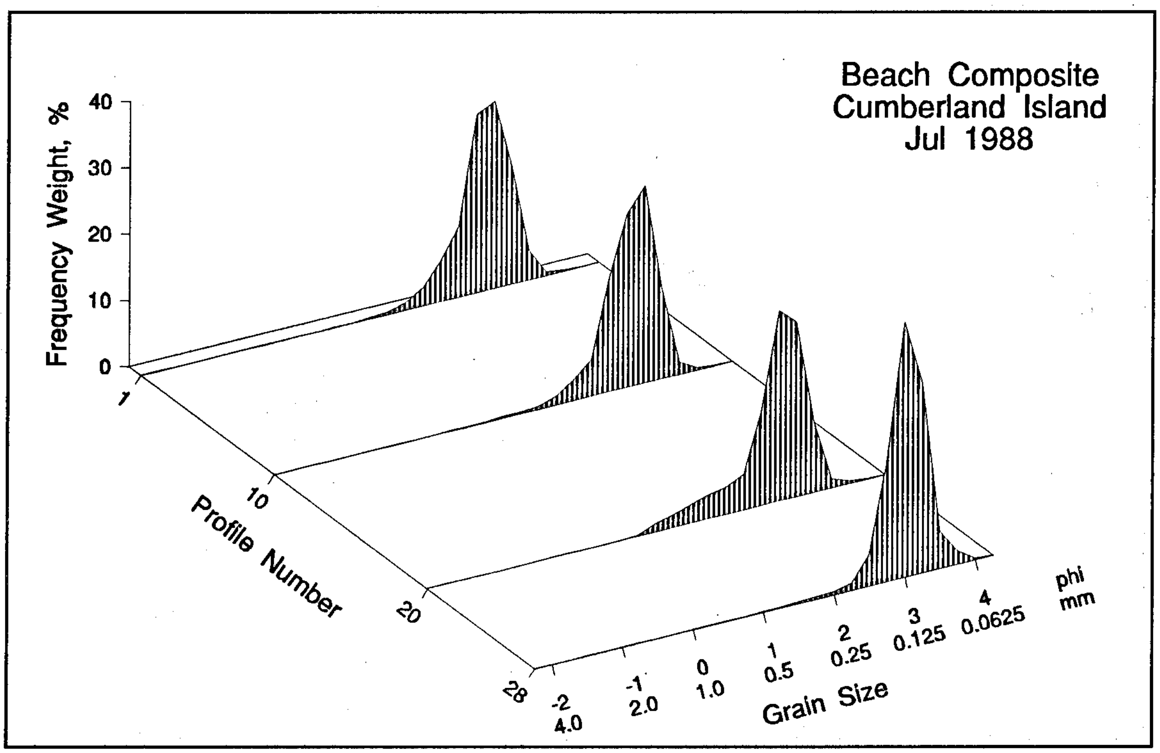


Figure D156. Beach composite, Jul 1988, Cumberland Island

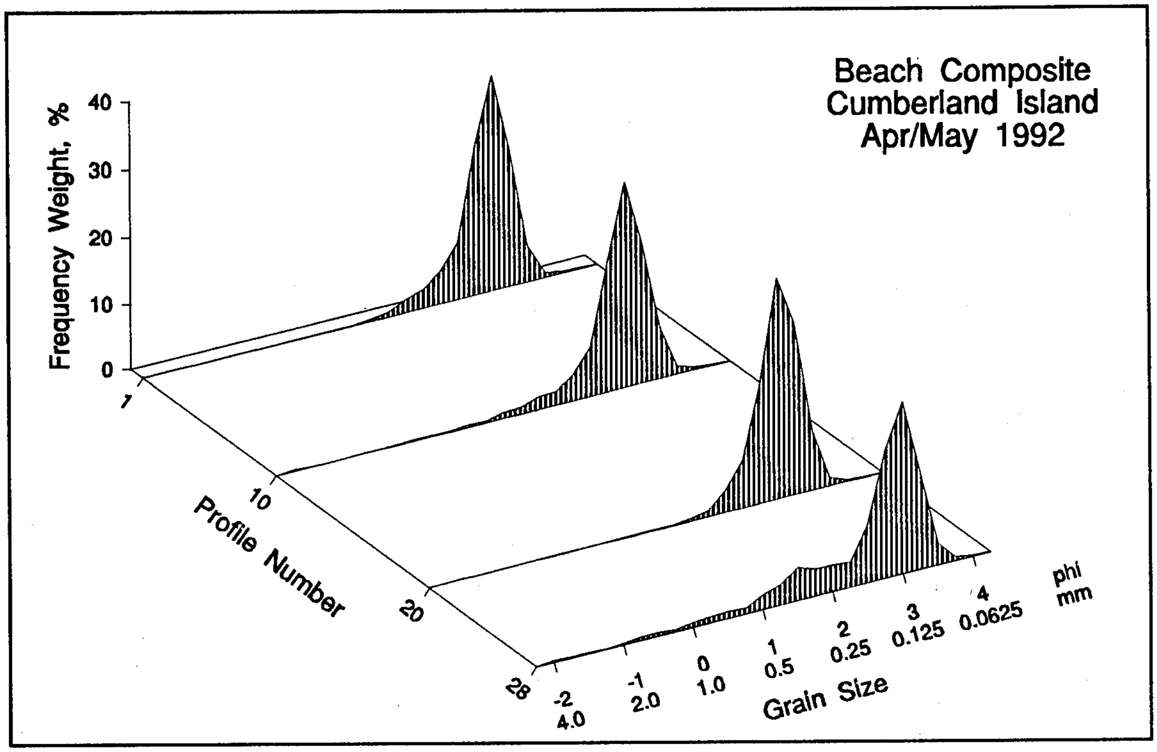


Figure D157. Beach composite, Apr/May 1992, Cumberland Island

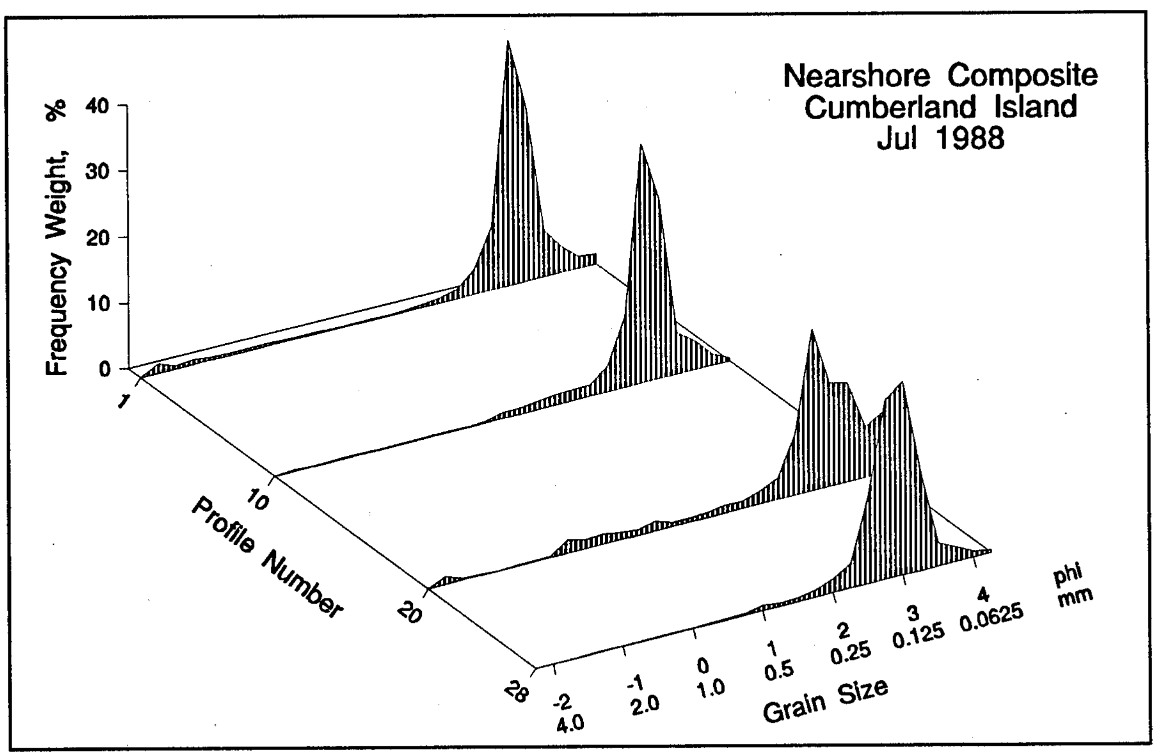


Figure D158. Nearshore composite, Jul 1988, Cumberland Island

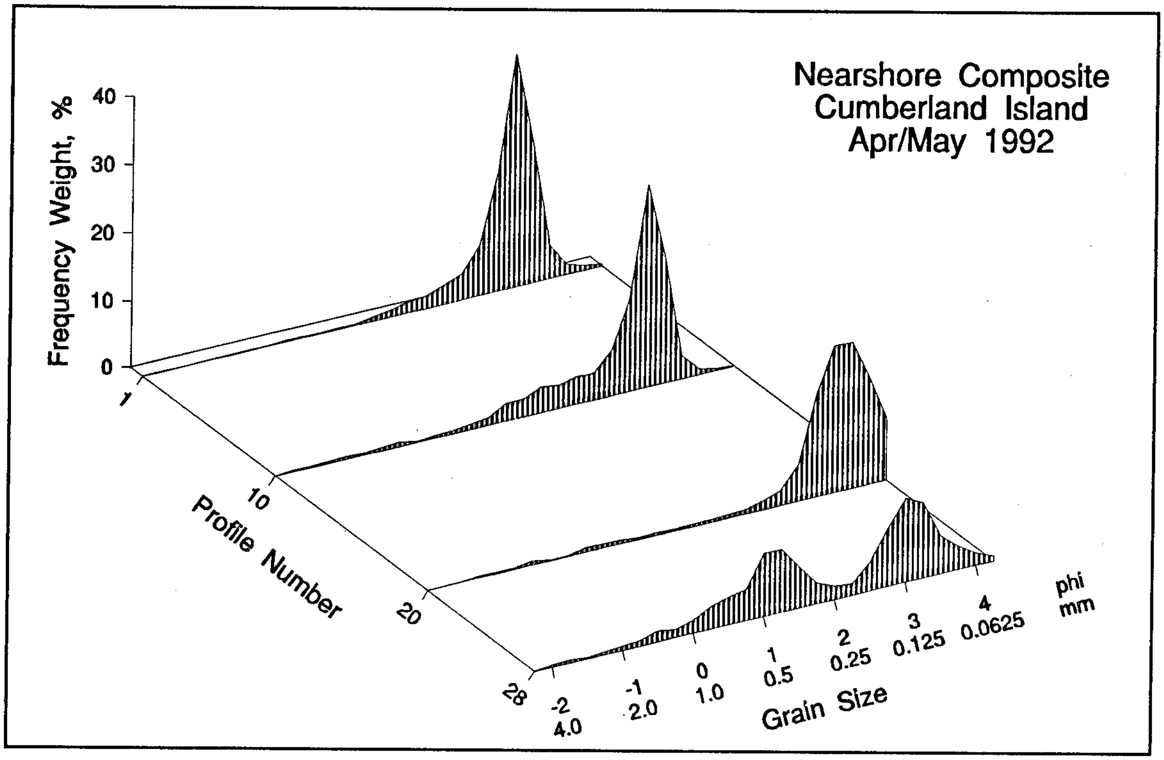


Figure D159. Nearshore composite, Apr/May 1992, Cumberland Island

Amelia Island. Amelia Island sediments have a wider range of grain-size distributions than Cumberland Island, with moderately to poorly sorted, coarse-skewed sands. During the monitoring period 1988-1992, local sources of beach sediments included the multiple dredged fill placements, seaward migration of dune sands, and the landward movement of surf zone sediments. Tables D31-D34 list the individual grain-size statistics for Amelia Island for 1988, 1989, 1990, and 1992. For these years, the mean grain sizes for the subaerial beach along the entire island were 0.40, 0.31, 0.37, and 0.34 mm, respectively. Additional total averages of the cross-shore samples tabulated for the berm, beach (MHW and MLW), surf (inner bar and trough), and nearshore (4.5-, 8.1-, and 11.8-m depths) samples were 0.34, 0.35, 0.30, and 0.28 mm, respectively.

Because most of the beach is influenced by swash processes at high tide, sediments are redistributed both cross-shore and alongshore. A dominant net transport to the south influences the sediment distribution trends. The sediment distribution pattern for the 1988-1992 period is highly variable (ranging from 0.13 to 1.41 mm) along the beach (berm, MHW, and MLW samples) as shown in Figures D140-D142. The berm sample represents the landward limit of the multiple beach fill events. There is an abundance of medium to coarse (0.51 to 0.90 mm) sands on the berm (particularly at Lines A22 and A43, where fills were placed). Fine-grained sands (less than 0.25 mm) were generally found in several areas outside the Federal disposal sites such as the south fillet area (Line A10), Amelia Embayment (Line A31), and Nassau Sound Tidal Inlet Complex (Lines A64 and A76), where smaller dune/beach fills trucked from upland sources have been placed. An exception to this trend was found at Line A55 (in the area of fill placement in 1987/88 and 1988/89, where fine sands (around 0.16 mm) were found on the berm in 1988, at MHW in 1988, 1989, 1990, and 1992, and at MLW in 1990.

Table D29
Beach Composite Grain-Size Data for Cumberland and Amelia Islands

Sample Name[1]	Folk Graphic Measures,[2] phi					Grain Size,[3] mm	
	Med	Mean	Dev	Skew	Kurt	Med	Mean
Cumberland Island: Jul 1988							
KBC-01-BCH	2.51	2.49	0.37	-0.14	1.14	0.18	0.18
KBC-10-BCH	2.71	2.68	0.36	-0.18	1.09	0.15	0.16
KBC-20-BCH	2.65	2.58	0.48	-0.33	1.39	0.16	0.17
KBC-28-BCH	2.91	2.90	0.29	-0.05	1.16	0.13	0.13
Amelia Island: Jul 1988							
KBA-10-BCH	2.24	2.13	0.76	-0.41	1.69	0.21	0.26
KBA-22-BCH	0.64	0.20	1.53	-0.32	0.90	0.64	0.81
KBA-31-BCH	1.81	1.76	0.89	-0.16	0.88	0.29	0.31
KBA-43-BCH	1.27	1.24	1.23	-0.11	0.99	0.42	0.44
KBA-55-BCH	2.53	2.09	1.09	-0.64	1.57	0.17	0.24
KBA-64-BCH	2.52	2.38	0.66	-0.53	2.21	0.17	0.21
KBA-76-BCH	2.44	2.37	0.73	-0.31	1.39	0.18	0.21
Cumberland Island: Apr/May 1992							
KBC-01-BCH	2.57	2.53	0.40	-0.21	1.27	0.17	0.18
KBC-10-BCH	2.59	2.56	0.44	-0.24	1.41	0.17	0.18
KBC-20-BCH	2.65	2.63	0.34	-0.10	1.10	0.16	0.16
KBC-28-BCH	2.68	2.42	0.77	-0.55	1.26	0.16	0.19
Amelia Island: Apr/May 1992							
KBA-10-BCH	2.29	2.15	0.91	-0.39	1.57	0.20	0.25
KBA-22-BCH	1.29	1.17	1.28	-0.22	1.06	0.41	0.47
KBA-31-BCH	1.30	1.31	0.84	0.02	0.97	0.41	0.41
KBA-43-BCH	1.86	1.82	0.96	-0.12	0.83	0.28	0.30
KBA-55-BCH	2.06	1.71	1.10	-0.53	1.05	0.24	0.32
KBA-64-BCH	2.63	2.65	0.44	0.03	1.03	0.16	0.16
KBA-76-BCH	2.15	1.95	0.97	-0.46	1.57	0.22	0.28

[1] Sample Name Symbols: KB = Kings Bay; C or A = Cumberland or Amelia Island; # = Survey Line; BCH = Beach (composite comprised of berm, MHW, and MLW).
[2] Abbreviation of moment statistics and units: Med = median, phi; Mean, phi; Dev = standard deviation, phi; Skew = skewness, Kurt = kurtosis.
[3] Calculated by method of moments.

Table D30
Nearshore Composite Grain-Size Data for Cumberland and Amelia Islands

Sample Name[1]	Folk Graphic Measures,[2] phi					Grain Size,[3] mm	
	Med	Mean	Dev	Skew	Kurt	Med	Mean
Cumberland Island: Jul 1988							
KBC-01-NSH	2.94	2.93	0.67	-0.33	3.69	0.13	0.15
KBC-10-NSH	2.93	2.91	0.47	-0.23	2.18	0.13	0.14
KBC-20-NSH	3.22	3.15	0.96	-0.36	2.40	0.11	0.13
KBC-28-NSH	2.76	2.74	0.41	-0.10	1.38	0.15	0.15
Amelia Island: Jul 1988							
KBA-10-NSH	0.58	0.44	1.64	-0.13	0.71	0.67	0.74
KBA-22-NSH	2.55	1.54	1.96	-0.64	1.14	0.17	0.30
KBA-31-NSH	2.81	2.39	1.32	-0.70	3.27	0.14	0.22
KBA-43-NSH	2.75	2.50	1.15	-0.56	2.10	0.15	0.21
KBA-55-NSH	3.12	3.12	0.42	-0.12	1.48	0.12	0.13
KBA-64-NSH	3.11	3.11	0.38	-0.07	1.32	0.12	0.12
KBA-76-NSH	1.80	1.89	1.11	-0.02	0.88	0.29	0.29
Cumberland Island: Apr/May 1992							
KBC-01-NSH	2.84	2.78	0.47	-0.32	1.57	0.14	0.15
KBC-10-NSH	2.78	2.50	0.75	-0.60	1.31	0.15	0.18
KBC-20-NSH	3.47	3.46	0.57	-0.24	1.59	0.09	0.10
KBC-28-NSH	2.06	1.92	1.25	-0.19	0.78	0.24	0.28
Amelia Island: Apr/May 1992							
KBA-10-NSH	2.38	2.19	0.91	-0.42	1.40	0.19	0.23
KBA-22-NSH	2.85	2.77	0.57	-0.39	1.75	0.14	0.16
KBA-31-NSH	2.79	2.70	0.65	-0.39	1.50	0.14	0.17
KBA-43-NSH	3.09	3.00	1.05	-0.53	3.78	0.12	0.15
KBA-55-NSH	3.32	3.29	0.36	-0.16	1.23	0.10	0.11
KBA-64-NSH	3.27	3.26	0.41	-0.09	1.06	0.10	0.11
KBA-76-NSH	3.08	2.98	0.67	-0.33	1.39	0.12	0.13

[1] Sample Name Symbols: KB = Kings Bay; C or A = Cumberland or Amelia Island; # = Survey Line; NSH = Nearshore (composite comprised of 4.5-m, 8.1-m, and 11.8-m depths).
[2] Abbreviation of moment statistics and units: Med = median, phi; Mean, phi; Dev = standard deviation, phi; Skew = skewness, Kurt = kurtosis.
[3] Calculated by method of moments.

Table D31
Amelia Island Grain-Size Data: Jul 1988

Sample Name[1]	Elev,[2] m	Range,[3] m	Folk Graphic Measures,[4] phi					Grain Size,[5] mm	
			Med	Mean	Dev	Skew	Kurt	Med	Mean
KBA-04-HW	1.0	47	2.40	2.37	0.47	-0.20	1.25	0.19	0.21
KBA-04-LW	-0.8	112	0.87	0.70	1.34	-0.19	1.04	0.55	0.62
KBA-04-04	-4.5	--[6]	1.18	1.20	1.73	-0.51	0.70	0.28	0.46
KBA-04-08	-8.1	--	1.70	1.18	1.42	-0.59	1.33	0.31	0.45
KBA-04-12	-11.8	117	1.48	0.61	1.84	-0.54	0.71	0.36	0.58
KBA-10-BM	2.4	29	2.40	2.39	0.37	-0.08	1.04	0.19	0.19
KBA-10-HW	1.0	35	2.32	2.27	0.53	-0.26	1.30	0.20	0.23
KBA-10-LW	-0.8	67	1.75	1.53	1.21	-0.47	1.67	0.30	0.38
KBA-10-TR	-2.0	125	2.64	2.64	0.40	-0.06	1.23	0.16	0.16
KBA-10-04	-4.5	--	0.45	0.41	1.15	0.06	0.85	1.37	1.31
KBA-10-08	-8.1	--	1.84	1.37	1.42	-0.57	1.43	0.28	0.40
KBA-22-BM	1.4	70	1.43	1.39	0.80	-0.18	1.15	0.37	0.40
KBA-22-HW	1.0	107	0.78	0.53	1.55	0.29	0.62	1.72	1.41
KBA-22-LW	-0.8	158	0.31	0.13	1.00	-0.31	1.11	0.81	0.92
KBA-22-TR	-2.0	163	2.74	2.76	0.35	0.02	1.27	0.15	0.15
KBA-22-04	-4.5	--	2.49	1.37	2.19	-0.58	0.68	0.18	0.35
KBA-22-08	-8.1	--	2.61	1.98	1.48	-0.67	1.67	0.16	0.25
KBA-31-BM	3.5	34	1.34	1.31	0.83	-0.14	1.07	0.39	0.42
KBA-31-HW	1.0	42	1.57	1.54	0.63	-0.08	0.91	0.34	0.35
KBA-31-LW	-0.8	91	2.55	2.45	0.73	-0.49	2.66	0.17	0.21
KBA-31-TR	-2.0	107	2.66	2.60	0.63	-0.32	1.82	0.16	0.18
KBA-31-04	-4.5	--	2.82	2.82	0.46	-0.20	2.01	0.14	0.16
KBA-31-08	-8.1	--	2.79	1.56	1.97	-0.79	1.09	0.14	0.29
KBA-43-BM	3.0	80	1.08	1.09	0.90	-0.04	1.16	0.47	0.47
KBA-43-HW	1.0	87	0.85	0.65	1.22	-0.24	1.05	0.56	0.64
KBA-43-LW	-0.8	144	2.28	1.88	1.14	-0.55	1.08	0.21	0.28
KBA-43-TR	-2.0	168	2.83	2.78	0.82	-0.41	3.00	0.14	0.17
KBA-43-04	-4.5	--	2.96	2.84	1.02	-0.54	3.68	0.13	0.17
KBA-43-08	-8.1	--	2.92	1.92	1.74	-0.78	1.28	0.13	0.24

(Continued)

[1] Sample Name Symbols: KB = Kings Bay; A = Amelia Island; # = Survey Line; BM = Berm; HW = Mean High Water; LW = Mean Low Water; TR = Trough; 04 = Elevation -4.5 m; 08 = Elevation -8.1 m; 12 = -11.8 m; EL = End of line.
[2] Elevation relative to NGVD.
[3] Distance from survey baseline.
[4] Abbreviation of moment statistics and units: Med = median, phi; Mean, phi; Dev = standard deviation, phi; Skew = skewness, Kurt = kurtosis.
[5] Calculated by method of moments.
[6] Range not recorded at time of sampling.

Table D31 (Concluded)									
			Folk Graphic Measures, phi					Grain Size, mm	
Sample Name	Elev, m	Range, m	Med	Mean	Dev	Skew	Kurt	Med	Mean
KBA-43-EL	-8.1	--	2.38	2.32	0.60	-0.28	1.46	0.19	0.21
KBA-55-BM	2.3	36	2.72	2.72	0.32	-0.03	1.01	0.15	0.16
KBA-55-HW	1.0	43	2.63	2.64	0.31	0.06	1.17	0.16	0.16
KBA-55-LW	-0.8	141	0.90	0.93	1.34	-0.03	0.88	0.54	0.54
KBA-55-TR	-2.0	166	2.83	2.81	0.45	-0.21	1.34	0.14	0.15
KBA-55-04	-4.5	--	3.14	3.14	0.39	-0.10	1.32	0.11	0.13
KBA-55-08	-8.1	--	3.10	3.10	0.44	-0.13	1.67	0.12	0.13
KBA-64-BM	2.9	46	2.52	2.52	0.29	0.03	1.17	0.17	0.17
KBA-64-HW	1.0	67	2.64	2.65	0.23	0.06	1.41	0.16	0.16
KBA-64-LW	-0.8	174	1.82	1.56	1.20	-0.38	1.09	0.28	0.35
KBA-64-TR	-2.0	183	2.91	2.88	0.53	-0.29	1.82	0.13	0.15
KBA-64-04	-4.5	--	3.12	3.13	0.37	-0.04	1.24	0.12	0.13
KBA-64-08	-8.1	--	3.11	3.10	0.40	-0.10	1.37	0.12	0.12
KBA-76-BM	2.4	16	2.46	2.45	0.37	-0.05	1.14	0.18	0.18
KBA-76-HW	1.0	51	2.45	2.45	0.52	-0.04	0.89	0.18	0.19
KBA-76-LW	-0.8	116	2.36	2.07	1.14	-0.45	0.92	0.19	0.25
KBA-76-TR	-2.0	149	2.88	2.83	0.48	-0.29	1.50	0.14	0.15
KBA-76-04	-4.5	--	1.21	1.21	0.93	-0.09	2.35	0.43	0.45
KBA-76-08	-8.1	--	2.69	2.53	0.86	-0.41	1.39	0.16	0.18

Alongshore trends in temporal and spatial grain-size distributions cannot be easily identified within the morphologic compartments on Amelia Island because of the multiple beach fills placed at different times and locations during and prior to the July 1988 to April/May 1992 monitoring period. Table D2 lists the location and dates of the fill placement. The correlation of survey data collection and fill placements is shown in Figure D118. Four fills were placed (two between Lines A12 and A25 and two between Lines A60 and A71) between 1978 and 1984 and presumably have had an effect on the grain-size distributions along Amelia Island. Within a year prior to the first sampling of the monitoring period in July 1988, beach fills were placed at the northern end between Lines A13 and A22 (June 1987 to February 1988) and at the south central section between Lines A48 and A54 (September 1987 to May 1988). This first sediment sampling occurred 4 months after the north fill and 2 months after the south fill placement. Just after the first sampling, a fill was placed at the southern end of the island between Lines A54 and A60 (July 1988 to July 1989). The second sampling period during October 1989, 3 months after this fill placement, included only samples from the berm crest, MHW, MLW, and trough. Additional fill was placed between Lines A60 and A71 in December 1989. The third sediment sampling period occurred 7 months later in August 1990. This data set included samples from the berm crest, MHW, MLW, and the 4.5-m depth locations. Fill was again placed along the northern end of the island between Lines A13 and A16 from October 1990 to March 1991. No sediment sampling was done during 1990. Fill was placed for a second time at the southern end

Table D32
Amelia Island Grain-Size Data: Oct 1989

Sample Name[1]	Elev,[2] m	Range,[3] m	Folk Graphic Measures,[4] phi					Grain Size,[5] mm	
			Med	Mean	Dev	Skew	Kurt	Med	Mean
KBA-04-HW	1.8	46	2.60	2.61	0.32	0.00	1.11	0.16	0.17
KBA-04-LW	0.0	115	2.35	2.34	0.49	-0.07	1.03	0.20	0.20
KBA-10-BM	2.9	38	1.57	1.56	0.85	-0.09	1.15	0.34	0.36
KBA-10-HW	1.8	54	2.09	1.89	0.80	-0.32	0.80	0.23	0.27
KBA-10-LW	0.0	126	2.15	1.74	1.19	-0.49	0.83	0.23	0.31
KBA-10-TR	-1.2	141	2.71	2.70	0.36	-0.09	1.16	0.15	0.16
KBA-22-BM	3.9	94	1.52	1.52	0.69	0.00	0.90	0.35	0.35
KBA-22-HW	1.8	110	1.71	1.72	0.56	0.03	0.98	0.31	0.30
KBA-22-LW	0.0	142	0.94	1.16	0.90	0.33	0.82	0.52	0.45
KBA-22-TR	-1.2	157	2.44	2.40	0.45	-0.23	1.22	0.18	0.20
KBA-31-BM	14.2	35	0.91	0.94	0.72	0.01	1.19	0.53	0.53
KBA-31-HW	1.8	58	1.82	1.74	0.65	-0.18	0.99	0.28	0.30
KBA-31-LW	0.0	96	2.04	1.90	0.69	-0.36	1.14	0.24	0.27
KBA-31-TR	-1.2	104	1.08	0.98	1.04	-0.18	0.96	0.47	0.51
KBA-43-BM	11.8	76	0.31	0.46	1.10	0.17	0.91	0.81	0.73
KBA-43-HW	1.8	90	2.40	2.34	0.50	-0.23	1.00	0.19	0.20
KBA-43-LW	0.0	154	1.96	1.63	1.34	-0.39	0.77	0.26	0.34
KBA-43-TR	-1.2	165	2.62	2.56	0.53	-0.34	1.65	0.16	0.18
KBA-55-BM	11.7	58	2.18	2.07	0.86	-0.31	1.35	0.22	0.25
KBA-55-HW	1.8	84	2.60	2.61	0.33	0.03	1.12	0.16	0.16
KBA-55-LW	0.0	160	2.13	1.92	0.99	-0.37	1.07	0.23	0.27
KBA-55-TR	-1.2	194	0.84	0.94	1.32	0.06	0.78	0.56	0.53
KBA-64-BM	10.8	38	2.66	2.68	0.37	0.14	1.12	0.16	0.15
KBA-64-HW	1.8	62	2.42	2.40	0.40	-0.07	0.99	0.19	0.19
KBA-64-LW	0.0	114	1.98	1.92	0.78	-0.19	1.10	0.25	0.27
KBA-64-TR	-1.2	134	1.56	1.25	1.42	-0.37	1.07	0.34	0.43
KBA-76-BM	15.3	14	2.52	2.51	0.38	-0.07	1.13	0.17	0.18
KBA-76-HW	1.8	43	2.49	2.22	0.92	-0.55	1.44	0.18	0.23
KBA-76-LW	0.0	148	2.30	2.20	0.70	-0.37	1.38	0.20	0.24
KBA-76-TR	-1.2	172	2.35	2.30	0.49	-0.19	1.01	0.20	0.21

[1] Sample Name Symbols: KB = Kings Bay; A = Amelia Island; # = Survey Line; BM = Berm; HW = Mean High Water; LW = Mean Low Water; TR = Trough.
[2] Elevation relative to NGVD.
[3] Distance from survey baseline.
[4] Abbreviation of moment statistics and units: Med = median, phi; Mean, phi; Dev = standard deviation, phi; Skew = skewness, Kurt = kurtosis.
[5] Calculated by method of moments.

Table D33
Amelia Island Grain-Size Data: Aug 1990

Sample Name[1]	Elev,[2] m	Range,[3] m	Folk Graphic Measures,[4] phi					Grain Size,[5] mm	
			Med	Mean	Dev	Skew	Kurt	Med	Mean
KBA-04-HW	5.9	46	2.38	2.01	1.21	-0.59	1.51	0.19	0.27
KBA-04-LW	0.0	115	2.64	2.64	0.31	-0.01	0.97	0.16	0.16
KBA-10-BM	13.9	38	2.40	2.41	0.46	0.06	1.14	0.19	0.19
KBA-10-HW	5.9	54	2.26	2.25	0.53	-0.05	1.23	0.21	0.21
KBA-10-LW	0.0	126	1.73	1.22	1.55	-0.49	0.86	0.30	0.44
KBA-10-04	-4.5	--[6]	1.20	1.01	1.34	-0.21	0.77	0.44	0.50
KBA-22-BM	13.3	94	1.77	1.71	0.61	-0.14	1.00	0.29	0.31
KBA-22-HW	5.9	110	1.67	1.62	0.83	-0.13	0.91	0.31	0.33
KBA-22-LW	0.0	142	0.13	0.11	0.84	-0.09	1.16	0.91	0.95
KBA-22-04	-4.5	--	0.81	0.90	0.95	0.10	0.96	0.57	0.55
KBA-31-BM	14.8	35	1.17	1.23	0.61	0.10	1.12	0.44	0.43
KBA-31-HW	5.9	58	2.03	2.02	0.47	-0.03	1.05	0.25	0.25
KBA-31-LW	0.0	96	1.87	1.76	0.86	-0.19	0.77	0.27	0.30
KBA-31-04	-4.5	--	1.42	1.18	1.33	-0.32	0.92	0.37	0.46
KBA-43-BM	11.8	76	1.78	1.44	1.20	-0.41	1.01	0.29	0.37
KBA-43-HW	5.9	90	0.48	0.60	1.14	0.14	0.96	0.72	0.67
KBA-43-LW	0.0	154	-0.41	-0.37	1.29	0.15	1.14	1.33	1.21
KBA-43-04	-4.5	--	2.19	1.56	1.50	-0.59	0.80	0.22	0.35
KBA-55-BM	12.2	58	2.51	1.91	1.42	-0.58	1.06	0.17	0.25
KBA-55-HW	5.9	84	2.67	2.67	0.31	0.01	0.94	0.16	0.16
KBA-55-LW	0.0	160	2.49	2.48	0.44	-0.10	1.26	0.18	0.19
KBA-55-04	-4.5	--	2.48	2.46	0.54	-0.15	1.20	0.18	0.19
KBA-64-BM	9.8	38	2.65	2.65	0.33	0.04	1.01	0.16	0.16
KBA-64-HW	5.9	62	2.57	2.58	0.31	0.02	1.01	0.17	0.17
KBA-64-LW	0.0	114	2.57	2.55	0.49	-0.14	1.11	0.17	0.18
KBA-64-04	-4.5	--	1.29	1.32	1.00	-0.05	1.21	0.41	0.42
KBA-76-BM	11.1	14	2.30	2.24	0.55	-0.22	1.03	0.20	0.22
KBA-76-HW	5.9	43	1.84	1.88	0.53	0.11	1.04	0.28	0.27
KBA-76-LW	0.0	148	0.84	0.70	1.57	-0.15	0.81	0.56	0.63
KBA-76-04	-4.5	--	2.10	1.88	1.14	-0.37	0.98	0.23	0.29

[1] Sample Name Symbols: KB = Kings Bay; A = Amelia Island; # = Survey Line; BM = Berm; HW = Mean High Water; LW = Mean Low Water; 04 = Elevation -4.5 m.
[2] Elevation relative to NGVD.
[3] Distance from survey baseline.
[4] Abbreviation of moment statistics and units: Med = median, phi; Mean, phi; Dev = standard deviation, phi; Skew = skewness, Kurt = kurtosis.
[5] Calculated by method of moments.
[6] Range not recorded at time of sampling.

Table D34
Amelia Island Grain-Size Data: Apr/May 1992

Sample Name[1]	Elev,[2] m	Range,[3] m	Folk Graphic Measures,[4] phi					Grain Size,[5] mm	
			Med	Mean	Dev	Skew	Kurt	Med	Mean
KBA-10-BM	6.7	115	1.94	1.87	0.68	-0.20	0.97	0.26	0.28
KBA-10-HW	2.9	208	2.38	2.36	0.43	-0.06	1.03	0.19	0.20
KBA-10-LW	-2.4	304	2.65	1.80	1.68	-0.74	1.63	0.16	0.27
KBA-10-04	-15.1	409	2.58	2.57	0.41	-0.19	1.63	0.17	0.18
KBA-10-08	-22.7	3134	2.91	2.87	0.55	-0.20	1.23	0.13	0.14
KBA-10-EL	-22.7	5313	1.70	1.46	1.02	-0.41	1.20	0.31	0.38
KBA-22-BM	6.1	318	0.38	0.12	1.31	-0.26	0.85	0.77	0.90
KBA-22-HW	3.6	340	1.34	1.26	0.97	-0.18	1.11	0.39	0.43
KBA-22-LW	-2.2	474	2.23	2.02	0.94	-0.40	1.17	0.21	0.26
KBA-22-TR	-5.4	574	2.70	2.69	0.40	-0.11	1.13	0.15	0.16
KBA-22-04	-15.3	803	2.70	2.63	0.75	-0.41	2.16	0.15	0:18
KBA-22-08	-20.9	5425	2.94	2.90	0.44	-0.33	1.97	0.13	0.14
KBA-31-BM	6.7	159	0.88	0.94	0.78	0.13	1.01	0.54	0.52
KBA-31-HW	3.5	195	1.26	1.27	0.60	-0.01	0.98	0.42	0.42
KBA-31-LW	-2.0	255	1.90	1.72	0.95	-0.31	0.99	0.27	0.31
KBA-31-TR	-6.4	549	2.42	2.35	0.68	-0.30	1.46	0.19	0.21
KBA-31-04	-14.8	805	3.03	2.99	0.49	-0.42	2.35	0.12	0.14
KBA-31-08	-23.5	4972	2.61	2.56	0.66	-0.32	1.65	0.16	0.19
KBA-43-BM	6.5	335	1.03	1.02	0.85	-0.10	1.16	0.49	0.51
KBA-43-HW	2.9	373	1.53	1.55	0.60	0.05	0.91	0.35	0.34
KBA-43-LW	-1.7	467	2.70	2.68	0.43	-0.19	1.26	0.15	0.17
KBA-43-TR	-6.1	555	2.67	2.62	0.83	-0.42	2.80	0.16	0.19
KBA-43-04	-16.0	1099	3.11	3.05	0.73	-0.42	2.51	0.12	0.14
KBA-43-08	-27.1	2775	3.07	2.89	1.18	-0.62	3.48	0.12	0.18
KBA-55-BM	7.2	232	0.94	0.86	1.08	-0.20	1.31	0.52	0.57
KBA-55-HW	3.3	292	2.33	2.31	0.37	-0.14	1.12	0.20	0.21
KBA-55-LW	-2.0	500	2.12	1.57	1.40	-0.60	0.94	0.23	0.35
KBA-55-TR	-6.6	610	2.86	2.85	0.36	-0.06	1.00	0.14	0.14
KBA-55-04	-15.8	1183	3.37	3.36	0.32	-0.09	1.13	0.10	0.10
KBA-55-08	-27.0	2339	3.20	3.15	0.42	-0.26	1.34	0.11	0.12

(Continued)

[1] Sample Name Symbols: KB = Kings Bay; A = Amelia Island; # = Survey Line; BM = Berm; HW = Mean High Water; LW = Mean Low Water; TR = Trough; 04 = Elevation -4.5 m; 08 = Elevation -8.1 m; EL = End of line.

[2] Elevation relative to NGVD.

[3] Distance from survey baseline.

[4] Abbreviation of moment statistics and units: Med = median, phi, Mean, phi; Dev = standard deviation, phi; Skew = skewness, Kurt = kurtosis.

[5] Calculated by method of moments.

Table D34 (Concluded)										
			Folk Graphic Measures, phi					Grain Size, mm	
Sample Name	Elev, m	Range, m	Med	Mean	Dev	Skew	Kurt	Med	Mean
KBA-64-BM	7.3	124	2.47	2.47	0.31	0.00	1.09	0.18	0.18
KBA-64-HW	3.5	200	2.51	2.49	0.44	-0.10	1.14	0.18	0.18
KBA-64-LW	-2.1	491	2.99	2.98	0.36	-0.05	1.10	0.13	0.13
KBA-64-TR	-6.4	588	1.17	0.82	1.69	-0.29	0.71	0.44	0.56
KBA-64-04	-15.1	1155	3.19	3.21	0.40	0.01	1.00	0.11	0.11
KBA-64-08	-26.4	2155	3.35	3.32	0.40	-0.16	1.15	0.10	0.10
KBA-76-BM	-31.4	170	2.59	2.59	0.36	-0.08	1.15	0.17	0.17
KBA-76-HW	-32.7	270	2.17	2.18	0.47	-0.07	1.14	0.22	0.23
KBA-76-LW	-36.7	400	1.16	0.91	1.34	-0.29	0.86	0.45	0.53
KBA-76-TR	-40.2	550	-0.72	-0.55	1.02	0.22	1.01	1.65	1.48
KBA-76-04	-46.0	2700	3.12	3.07	0.61	-0.27	1.63	0.12	0.13
KBA-76-08	-58.4	5450	3.03	2.90	0.71	-0.35	1.16	0.12	0.14

between Lines A60 and A71 during December 1991. Additional fill was placed in the north between Lines A13 and A16 from February to March 1992. The final sediment sampling was done 1 month after this fill during April/May 1992. This 1992 sampling provided a complete set that included the same beach and nearshore locations as in the first sampling period of July 1988.

The native beach morphology along Amelia Island differs from that along Cumberland Island. There is little dry beach at high tide on Amelia Island. The cross-shore sample locations are subject to wave action on a daily basis at high tide, including the berm crest sample, except in the vicinity of the fill placement where the berm sample remained dry except during storms. The berm crest samples on Cumberland Island were subject to wave action mainly during storm events. The beach fill created a dry berm for a period of time after each fill placement until the initial fill profile was redistributed to a more equilibrium state. Fill material was re-sorted in both the alongshore and cross-shore direction. As a result of the multiple beach fills, the sediment grain-size distribution pattern for the monitoring period was highly variable (individual sample means ranging from 0.13 to 1.41 mm). As a general rule, the coarse means correspond to the beach (berm, MHW, MLW) close to the sites of beach fills placed within a few months of the sampling period. In most cases, these coarse fill sands had a poor sorting owing to their origin as dredged material from the channel, and they contained a large component of shell fragments. Sorting values ranged from a very well-sorted 0.23 ϕ to a poorly sorted 1.84 ϕ. Samples that were taken at locations distant from the influence of the fills had finer means and were more well sorted. A comparison of prefill sediment means located along the north central portion of the island from Table D23 and the closest sediment sample lines from 1988 and 1992 (Table D35) shows that the multifill influence has complicated any trend in the mean. The 1988 samples collected within 5 months of a fill placement were the coarsest, whereas the 1992 sample means collected within 2 months of a fill placement were only slightly coarser than the 1975 prefill means. Time of sampling relative to the fill placement and fill versus native beach grain-size distributions both play a role in characterizing changes in the sediment. Little information is available on the composition of the fill material at each placement. Additionally, the grain-size

Table D35
Comparison of Composite Means for Northern Amelia Island, 1960 to 1992

1960		1975		1988		1992	
Line	Composite Mean, mm	Line	Composite Mean, mm	Line	Composite Mean, mm	Line	Composite Mean, mm
A	0.31	DNR-10	0.31	DNR-10	0.45	DNR-10	0.21
D	0.21	DNR-17	0.46				
				DNR-22	0.56	DRN-22	0.35
G	0.19	DNR-25	0.31				
H	0.16	H	0.21	DNR-31	0.27	DNR-31	0.30

distributions from 1960 and 1975 sampling show that the northern end of Amelia Island has historically had coarser means that became finer to the south (Figure D135). When fill from the coarsest 1988 samples is adjusted for this factor, the 1992 data show trends similar to this historic trend.

Sediment samples along Amelia Island were mostly negatively skewed, as were those found along Cumberland Island, indicating excess coarse-grained material. The wide variance in sediments caused the skewness values to range from a very fine-skewed +0.33 to a very coarse-skewed -0.78. The positively skewed samples were mostly found on the berm, MHW, and MLW areas, where excess fine material was deposited. The very negatively skewed samples were found mostly in the trough and 4.5-m depth and on the beach when a fill was recently placed. This excess coarse material was composed of coarse sand and shell material. The kurtosis values ranged from the very platykurtic (flat) 0.62 to the extremely leptokurtic (peaked) 3.68, with the majority of the values in the leptokurtic to very leptokurtic range. Because of the input of fill material, the kurtosis values varied within each cross-shore location depending on its location and collection date relative to a fill. The platykurtic values were loosely associated with poorly sorted material that had a wide range of grain sizes and the leptokurtic values were associated with well-sorted samples that had most material in the central part of the distribution. Figure D160 shows an example frequency distribution curve of fill material within 5 months of placement at the MHW location of Line A22 in July 1988. A large percentage of the fill dredged from the channel was composed of coarse (4.0-mm) shell along with a broad range of sand size material with diameters from 2.0 to 0.25 mm. The positive skewness is indicative of this excess finer material relative to the high percentage of coarse shell material. The low kurtosis value indicates that the tails of the distribution are as well sorted as the main central part of the distribution producing a flat frequency curve spread over a wide range of grain sizes. An example of a representative well-sorted Amelia Island sediment distribution is shown in the near normal frequency curve of the berm crest sample at Line A55. The bell-shaped curve indicates a well-sorted distribution of a narrow range of sand size material is present at this location. An example of a very peaked and negatively skewed sample is found in the nearshore (4.5-m depth) of Line A43 collected in July 1988. This distribution was similar to some found in the nearshore along Cumberland Island (Figure D139, Line C1 at 8.1-m depth) and contained a small percentage of coarse shell material with an otherwise well-sorted fine sand, indicative of the low-energy environment seaward of the breakers. The coarse shell material may be a nearshore shelf

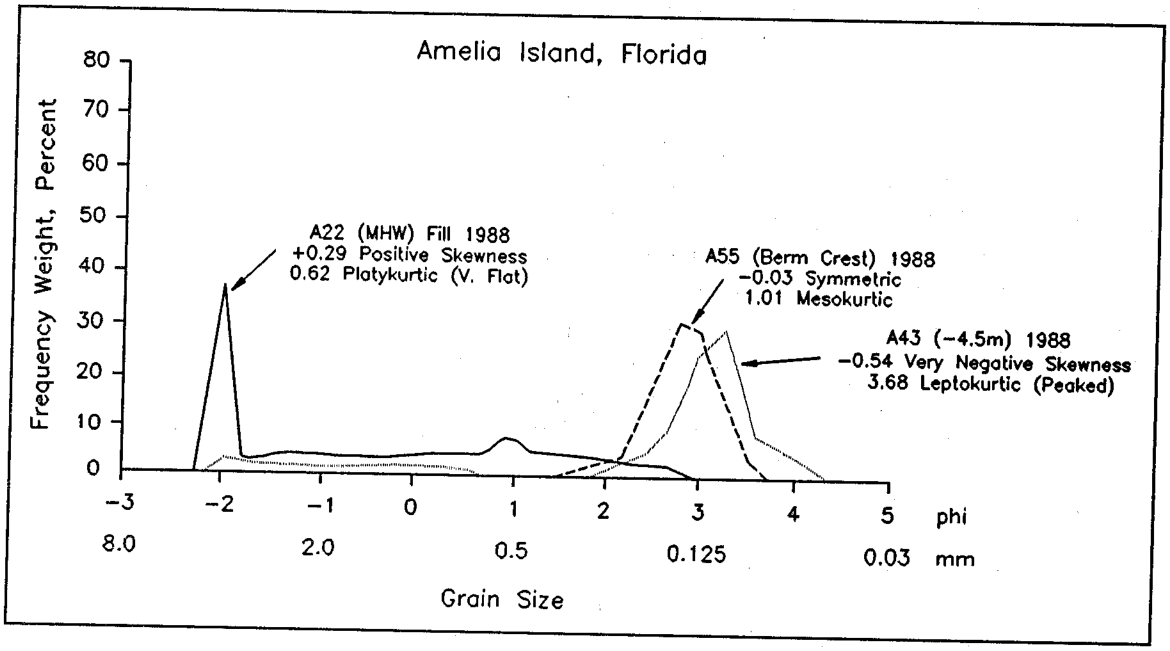


Figure D160. Examples of frequency curves of grain-size distributions for Amelia Island

lag deposit or the beginning of northward transport of fill material, because this location is just north of the southern fill area.

The alongshore variability and dependence on fill events is shown in Figures D140-D142. The berm samples on Amelia Island represent the narrow area between the MHW area and the dune or seawall. This is the landward limit of any beach fill material that was placed. Medium to coarse mean grain sizes (0.51 - 0.90 mm) were found on the berm crest samples throughout the study period (Figure D140). The July 1988 samples show finer berm crest means (less than 0.25 mm) were generally found in areas outside of the Federal fill placements between Lines A13 and A22 (placed Jul 1987/Feb 1988) and Lines A48 and A54 (placed Sep 1987/May 1988) as shown in Figure D150. The berm crest means on Line A10 and to the south from Line A55 were outside the influence of these fills at the time of sampling. The berm samples fall within the medium sand classification and can be explained by the fact that Line A22 was within the fill limits and Lines A31 and A43 were between the fills and most likely were influenced by the coarser fill material re-sorting and being deposited between the two fills. These berm samples were probably re-sorted by storm-influenced runup onto the backshore.

The 1988 MHW and MLW sample means also exhibit a similar pattern of influence from the fills. The mean on Line A22 within the northern fill was in the coarse range and may indicate winnowing of the fines after placement by daily swash processes. The MHW sample mean on Line A31 was in the medium sand range downdrift of the northern fill, and Line A43 was in the coarse sand range just updrift of the southern fill. The MHW sample means along Lines A10 and A55 and to the south were out of the influence of the fills and fell in the native beach fine sand range. The MLW mean grain-size values are under the influence of the backwash/surf interaction and show the same coarse sand pattern within the fill placement at Line A22. However, this summer sample period may show the seasonal drift reversal with medium sand at Line A10 to the north of the fill and a fine sand mean at Line A31 south of the fill. Mean values of medium-sized sand were found south of this line at the MLW area, with a peak in the coarse sand range just to the south of the southern fill at Line A55.

The nearshore area is generally composed of fine-grained sands (Figure D154). The trough sample means were all within the fine sand range in 1988. Samples collected at the 4.5-m depth at the ends of Amelia Island (Lines A10 and A76) were in the coarse and medium sand category. The central part of the island exhibited fine sand means except for Line A22 in the fill placement area. Further seaward sample means at the 8.1-m depth exhibited a medium sand value at the northern end of the island, while the central and southern areas had medium-to-fine sand values. These patterns of nearshore mean values may be more affected by tidal circulation in the vicinity of the adjacent inlets than the beach fill. Other studies of beach fill sediment change have shown that the nearshore grain-size distributions are usually finer than the beach and remain the same over the fill readjustment period (Stauble and Hoel 1986). Samples from the 1960 data set also showed more coarse material along the northern end of Amelia Island in the nearshore area (USACE 1961).

The October 1989 sediment sampling was limited to the beach samples (berm, MHW, and MLW) and the trough. One fill was placed between Lines A54 and A60 prior to this sampling period from July 1988 to July 1989, using material dredged from the St. Marys Inlet channel. This material was stockpiled in a nearshore disposal area from a previous channel dredging, and was redredged and placed on the beach during these dates. Figure D151 shows the distribution of beach means. Except for Lines A64 and A76 at the southern end, the berm crest means all fall in the medium to coarse range. The coarsest material was found on the berm at Lines A43 and A31, north of the fill placement limits. The MHW sample means were classified at the lower limit of medium sand range (0.30 mm) around the site of the June 1987 - February 1988 fill on Lines A22 and A31 and at A10, whereas the other means were in the fine sand range (0.23 to 0.16 mm). The MLW sample means were slightly coarser, with a maximum at Line A22 (0.45 mm), site of the June 1987 - February 1988 fill placement. A secondary maximum was located at Line A43, north of the September 1989 - May 1988 fill (0.34 mm). The remainder of the means were uniform ranging from 0.31 mm at the north end to 0.24 mm at the southern end. The fill was placed 3 months before the sediment sampling, and for the most part, the sediment was re-sorting uniformly except for the berm that was exposed to wave action only during high waves.

The only nearshore samples collected were from the trough (Figure D143). Coarse sand means were found at Lines A55 and A64 around the July 1988/July 1989 fill and at Line A22, the site of the June 1987/February 1988 fill. Coarse material apparently was collecting in the trough area in front of the fill sites. All of the other sample lines had fine means in this trough area.

A small trucked fill was placed at the southern end of the island between Lines A60 and A71 in December 1989. The next sediment sampling was collected during August 1990. This was a limited data set with samples from the beach (berm, MHW, and MLW) and from the 4.5-m depth in the nearshore (Figure D152). The coarsest berm mean was found in the medium sand range at Line A31 (0.43 mm), with the next two coarsest means on either side at Lines A43 (0.37 mm) and A22 (0.31 mm). The MHW pattern of mean values has a maximum value (0.67 mm, coarse sand) at Line A43 between the two fills, with a secondary maximum at Line A22 (0.33 mm, medium sand), site of the 1987/1988 fill. The other lines all have mean values in the lower end of the medium to fine sand range. The summer sampling period may explain the predominance of fine means during this low-energy time of the year. The more energetic area of MLW exhibited three sample means in the coarse sand range at Lines A43 (1.21 mm), A22 (0.95 mm), and the south end at A76 (0.63 mm). Medium sand range means were found at the northern Lines A10 and A31 while fine sand means were found at Lines A55 and A64, site of the December 1989 beach fill. Coarse sand remained in the area of the earlier beach fills, particularly in the MLW zone.

The only nearshore area sampled in 1990 was from the 4.5-m depth (Figure D144). Coarse sand means were found at the northern end of the island at Lines A10 (0.50 mm) and A22 (0.55 mm), with a fining to the south to Line A55 (0.19 mm). South of that location, the nearshore sand means increase again to the medium sand range. The coarsest nearshore material is in the location of the northern June 1987/February 1988 beach fill.

Three additional beach fills were placed along Amelia Island prior to the last sediment sampling period of April/May 1992. A Federal channel dredged material placement was done between Lines A13 and A16 from October 1990 to March 1991, an additional private trucked-in fill between Lines A60 and A71 during December 1991, and another Federal channel dredged material placement between Lines A13 and A16 during February and March 1992. As a result of the two channel dredged placements, the berm sample on Line A22 had a coarse sand mean (0.90 mm) 2 months after the second placement. Additional coarse sand means were found south to Line A55 (Figure D153). A fine berm mean of 0.18 mm was found at Line A64. The trend of mean values for the MHW samples indicates a maximum medium sand mean located just south of the north fill placement at Line A22 and decreasing mean values to fine sand to the north at Line A10 and south to fine sand at Line A76. The MLW sample means were finer than the MHW means except at Lines A10, A55, and A76. Line A64 contained the finest MLW mean (0.13 mm) in front of the 1991 private fill placement area. A coarse sand mean was found at MLW to the south at Line A76.

Nearshore mean grain-size data for Amelia Island from the 1992 sampling period are shown in Figure D155. The trend is of uniform fine sands (average around 0.14 mm) along the entire island for the trough, 4.5-, and 8.1-m depths, except for the trough sample means of Lines A64 (0.56 mm) and A76 (1.48 mm). These trough sample means increase to the coarse sand range at the south end of the island, and may represent a lag deposit of shell material either as a relict nearshore shell deposit or as a result of southward transport from the fill areas. Little effect of the three beach fills is seen in the other nearshore samples, so it is reasoned that the shell material is concentrated in the trough by currents.

Cross-shore trends were slightly different for Amelia Island as compared to those of Cumberland Island where slightly coarser sands were located between the berm and MLW and seaward of the surf zone (Figures D140-D143). As described below, beach and nearshore composites are considered to be a more accurate indicator of beach fill movement and adjustment for a monitoring program. In general, winnowing of fines and fill losses were less at the berm than at MHW or MLW (Figure D140). Because there was limited sampling in the fill locations, the actual pattern of fill adjustment was not discernible. However, at Line A22, coarse-to-medium sands coincided with beach fill placements. The average cross-shore distribution of mean values for 1988 from the berm crest, MHW, MLW, trough, 4.5- and 8.1-m depths were 0.28, 0.45, 0.42, 0.16, 0.39, and 0.23 mm, respectively. The coarsest means were found on the foreshore where the majority of the two 1987/1988 fills were placed. This average cross-shore distribution had changed by 1992 with the addition of five fills since 1988. The cross-shore distributions of the means in 1992 were 0.45, 0.29, 0.29, 0.46, 0.14, and 0.14 mm, respectively. The berm and trough contained the coarsest material.

In correlating the mean grain size with beach slope, the medium sands correspond to slightly steeper beach slopes (2.0 to 5.3 deg) than in areas with finer sands (Figure D148). Fine sands occurred with slightly flatter beach slopes, averaging 1.7 deg. In comparison to Cumberland Island, the slope of Amelia Island during the first year of monitoring (1988) was almost twice as steep (2.4 deg), with a corresponding mean grain size of 0.33 mm. At the end of the monitoring period (1992), a slightly steeper slope (3.1 deg) was calculated with a similar average mean grain size of 0.29 mm. The changes along Amelia Island are a function of seasonality and beach fill adjustment. Coarse fill material dredged from the channel was placed in the vicinity of Line A22 five months before the first sampling in 1988. Fill from the channel was also placed in the vicinity of Line A22 twice during the monitoring period, with the last fill placed 2 months before the 1992 sampling. The initial fill material had a coarser mean grain size than the last fill, and the beach slope remained around 3 deg from the 1988 to 1992 monitoring period. Line A55 was influenced by placement of one fill 2 months prior to the first monitoring and another fill in 1989, 38 months before the 1992 sampling. Mean grain size became slightly coarser and the slope increased slightly between 1988 and 1992. The grain size was reduced slightly on Line A64, but the slope remained the same over the monitoring period. Lines A31 and A43 were located between the northern and southern channel fill placement areas. The grain size slightly increased on Line A31, while the slope steepened over the 4-year period. Line A43 became slightly finer as the slope slightly increased.

In several areas, atypical coarse sands were found offshore. The samples along Lines A22, A31, and A43 show an abundance of whole and fragmented shells. The lithologic portion of these samples is micaceous, dark grey, fine to very fine sands and silts, which is the dominant texture of the inner shelf. The biogenic portion appears to be derived from several shallow-water mollusk species (ranging from 1 to 6 mm in width) and in some cases is relict shells reworked from previous deposits. Shoals along the southern end of Amelia Island (Line A76 at the 4.5-m depth) consist of light tan, medium-to-fine sands with abundant shell fragments indicative of variable conditions. Typically, the relict shells are black as a result of burial under reducing conditions in fine sediments. These shells originated in nearshore and estuarine environments formed during the last transgression (Pilkey et al. 1969). This coarse shell material was apparently present prior to the recent dredging, as coarse means were found in the nearshore at the northern end of Amelia Island during the 1959 sampling (USACE 1961). Anomalous coarse sands were found in some samples collected at the 6.3-, 8.1-, and 10-m depths.

From the 1992 data set, a scatter plot was produced of the mean grain size versus standard deviation (sorting) for Amelia Island. As found for Cumberland Island, the beach samples were coarser than the nearshore. Because of the numerous beach fills, the range of mean and sorting values are much larger than on Cumberland Island (Figures D146 and D147). A general trend of coarser means on the beach corresponds to more poorly sorted samples. The areas where the coarse fills were placed had the coarsest means and generally the most poorly sorted samples, whereas the samples on the ends of the island had more tightly grouped mean and sorting values in the fine sand and well-sorted range. In general, the MLW samples had the poorest-sorted sediment while the MHW and berm samples had the more well-sorted values. The nearshore samples were separated from the beach samples by a generally finer mean grain size range. The 4.5-m depth samples had the poorest sorting values, whereas the trough samples had the best sorting of the nearshore samples.

Along Amelia Island, the July 1988 and April/May 1992 beach composites varied from fine to coarse grain size. As shown in Figures D161 and D162, most samples had a multimodal distribution. Samples with a distinct coarse fraction included Lines A22, A31, A43, and A55. At both ends of the island, the beach sediments were finer, although the alongshore trend was variable. Composites of the entire profile line showed similar trends of multimodal distribution located between the North Beach Disposal Sites (A13 to A22 and A48 to A60) and the more unimodal distribution to the south (Figure D149). By the end of the monitoring period (April/May 1992), a fining trend alongshore occurred between Lines A22 (0.47 mm) and A43 (0.30 mm) as the fill material adjusted to the local waves and a southerly littoral transport. At the time of the April/May 1992 sampling, the beach fill material was placed only at the North Beach Disposal Site (Lines A13-A16), whereas trucked fills in small quantities were placed on the south beach (Lines A60-A71).

The nearshore composite (4.5-, 8.1-, and 11.8-m depths, if present) consisted of coarse-to-fine sands that decreased in grain size to the south from Lines A10 (0.74 mm for 1988 and 0.23 mm for 1992) to A64 (0.12 mm for 1988 and 0.11 mm for 1992), Figures D163 and D164. At the southern end, Line A76, the subaqueous sands were variable (0.13-1.48 mm) due to the presence of shoals associated with Nassau Sound. Both the 1988 and 1992 data sets showed similar trends with a slight decrease in grain size over the monitoring period. Similar to the alongshore pattern of Cumberland Island, the mean grain size decreased from north to south except for the southern end of both islands. The coarser multimodal composite grain-size distributions in the nearshore along Line A10 in 1988 and, to some extent, in 1992 are similar to the sediment distributions in the 1959 sampling (USACE 1961). Coarse sand is probably trapped in the area just to the south of the south jetty at St. Marys Entrance. The influence of the beach fill placements can be seen in the 1988 composite set because the two fills were placed within 5 and 2 months, respectively, at the northern (Lines A13-A22) and southern (Lines A48-A54) placement areas. The 1992 nearshore composites show a more unimodal distribution with a shift of the dominant mode to finer grain sizes. This shift was despite the fact that a channel fill was placed on the northern area (Lines A13-A16) only 1 month before the sampling. This new fill was just beginning to re-sort and, most likely only the finer fill material reached into the nearshore area by winnowing processes. A trucked fill was also placed 4 months earlier between Lines A60 and A71 and may have supplied fine-grained material to the nearshore (particularly in the area of Lines A55-A64).

Summary

Sediment data were collected during four sampling activities between July 1988 and April\May 1992. Beach (berm, MHW, and MLW) and nearshore (trough, 4.5-, and 8.1-m NGVD depth) samples were collected during the first and fourth sampling, and only beach samples were collected consistently during the second and third. Four profile survey lines were selected for sediment collection along Cumberland Island (Lines C1, C10, C20, and C28) and seven survey lines along Amelia Island (Lines A10, A22, A31, A43, A55, A64, and A76). Sediment samples were also collected along two survey lines within the inlet throat area (Lines C31 and A4). The sampling intervals occurred between and during beach fill placements. The first sampling (July 1988) was 5 months after the northern fill and 2 months after the southern fill. The second sampling (October 1989) was 8 months after a fill placement in the southern area. The third sampling (August 1990) was 9 months after the small trucked-in fill at the southern end. The

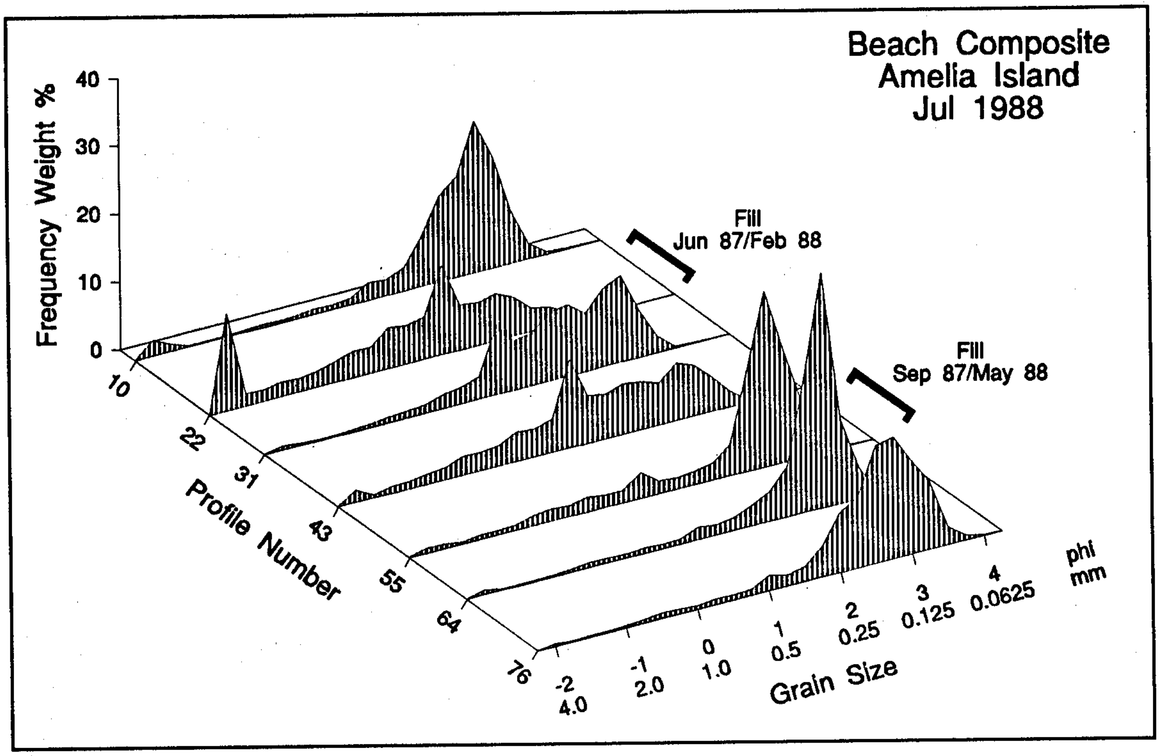


Figure D161. Beach composite, Jul 1988, for Amelia Island

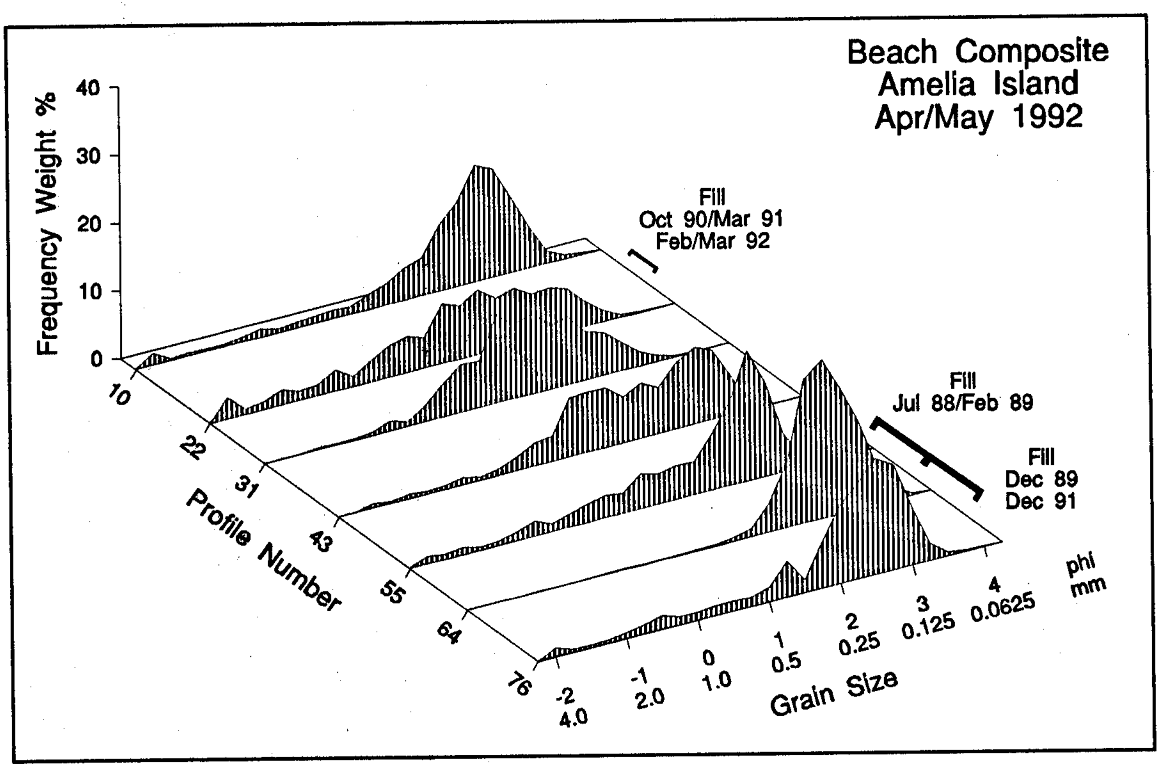


Figure D162. Beach composite, Apr/May 1992, for Amelia Island

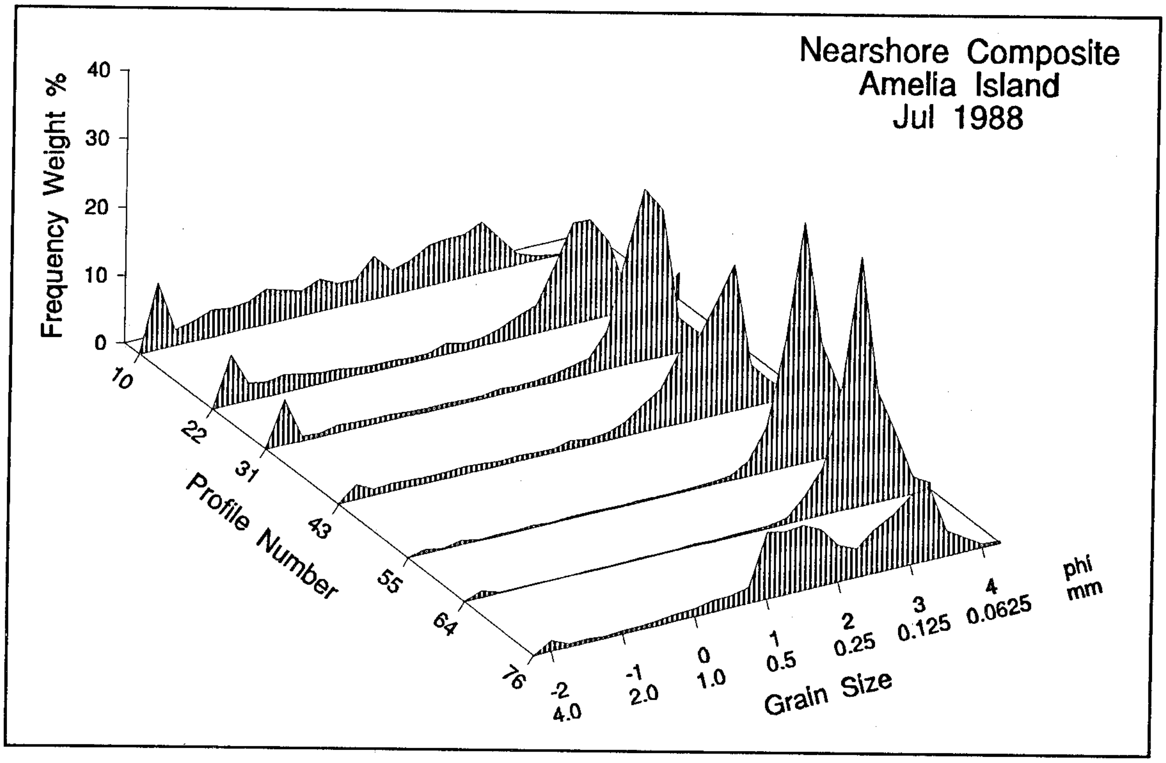


Figure D163. Nearshore composite, Jul 1988, for Amelia Island

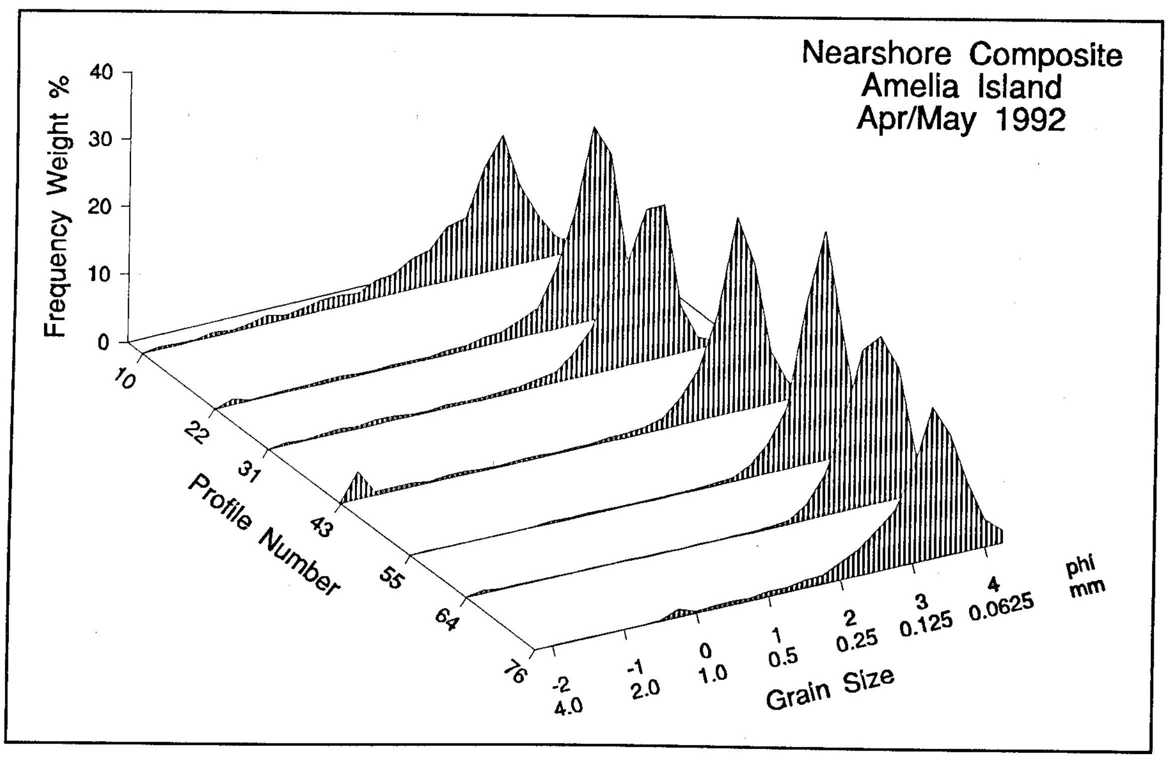


Figure D164. Nearshore composite, Apr/May 1992, for Amelia Island fourth sampling was 13 months after a fill placement in the northern area, 4 months after the trucked-in fill at the south, and 1 month after a second fill in the northern area.

Previous work showed that Cumberland Island was composed of fine sand-size material that had a mean of 0.12 mm (USACE 1961), and 0.18 mm (Giles and Pilkey 1965). The present study found that the composite island mean was 0.15 mm in 1988 and 0.19 mm in 1992. These sediments were characterized as well-sorted, fine-grained quartz sands with a predominantly negative skewness. Little change was found in the grain-size distributions of the Cumberland Island samples over the monitoring period. The cross-shore sediment distribution showed that the beach was coarser and better sorted than the nearshore samples in 1988 and changed little through time. The largest mean grain sizes were found on the MHW and MLW locations with a fining in the offshore. The only exception was some larger shell hash material found in the nearshore at the 8.1-m depth, just north of the north jetty (Line C28) in 1992. There appears to be a fining trend in both the beach and nearshore in the alongshore direction from north to south between Lines C1 and C20. The trend reverses at Line C28 where the mean grain size increases.

Previous studies found that Amelia Island has had coarser sand than Cumberland Island. The sand was still in the fine size range and was listed as 0.20 mm for northern Amelia Island (Martens 1935), 0.21 mm for northern Amelia Island and 0.14 mm for central Amelia Island (USACE 1961), 0.24 mm for the entire island (Giles and Pilkey 1965), and 0.25 mm for the northern end (USAED, Jacksonville 1984a). The present study found that the mean grain size varied along the island and across the shore because of the location and time of sampling relative to placement of fills and season of the year. With the placement of 11 fills in basically three different areas of the island since 1978, reporting of one mean value for the grain size of Amelia Island would misrepresent a complex pattern of grain-size distribution. The placement of the fills did produce a change in grain size on a line-by-line basis. The sediment along Lines A22 through A43 contained the coarsest and most poorly sorted sands, which ranged from medium to coarse sand. This area was heavily influenced by the north and south-central fill placement areas. Sediment became finer toward the north (Line A10, although a historic coarser nearshore component still provided medium sand means) and the south (Lines A55, A64, and A76). Two fills placed around Line A64 have added small amounts of material to the southern end of the island since 1989.

Variances in grain size in both the cross-shore and alongshore directions on both islands reflect the difference between a natural barrier island system with fine sands along Cumberland Island and an artificially nourished beach of Amelia Island. The placement of mainly coarse to medium sands and abundant shell material from the St. Marys Entrance navigation channel has altered the grain-size distributions of Amelia Island. Coarser fill material is most prevalent in the northern and central portion of the island near the placement areas and grades to more native fine sands at the southern end of the island.

Appendix E[1] Wave Data

The following wave data products are provided:

a. Sample wave parameter listings for CERC pressure (P) and velocity component (UV) wave gage, CERC slope array (SA), and NDBC buoy 41008 (Tables E1, E2, E3).

b. Data availability tables for SA and NDBC buoy 41008 (Tables E4 and E5).

c. Percent occurrence tables for the buoy (Table E6).

d. Time-series plots of H_{m0}, T_p, and Θ_p for available data (Plates E1-E62).

The sample wave parameter listings (Tables E1, E2, E3) include date, time, H_{m0}, T_p, Θ_p, and water depth. Similar data files can be provided for all available wave data.

The data availability tables (Tables E4 and E5) provide the number of records for each month and year for the SA and NDBC buoy 41008. Because data are available for several years for NDBC buoy 41008, percent occurrence tables were prepared for the buoy data (Table E6). Data from the very short deployment of the PUV and the relatively short and interrupted deployment from the SA do not allow development of climatological summaries. The percent occurrence tables are designed to provide as much detail as possible in a summary data product. Table E7 lists the ranges for the direction bands used in the tables, and Table E8 lists the frequency and period ranges for the tables.

Monthly time-series plots of H_{m0}, T_p, and Θ_p are provided for all available data for each measurement system (Plates E1-E62). Abrupt, large shifts in Θ_p for the data from NDBC buoy 41008 are likely related to abrupt changes in local winds at the buoy. The Θ_p changes are often accompanied by changes in T_p, as might be expected as sea conditions change. Intervals of no data in the SA and buoy records are associated with system failures during which time data were not recorded; poor quality data were deleted from the records.

[1] Written by William D. Corson.

Table E1
Sample Data, Kings Bay, Georgia, PUV, May 1989

Month	Day	Year	HRMN[1] GMT[2]	H_{m0} m	T_p sec	Θ_p Deg	Depth m
5	2	89	1705	0.29	7.8	127	8.8
5	2	89	2005	0.29	6.2	129	10.5
5	2	89	2305	0.25	8.3	116	10.9
5	3	89	205	0.22	7.8	132	9.5
5	3	89	505	0.23	7.3	131	8.8
5	3	89	805	0.26	6.6	139	10.1
5	3	89	1105	0.27	6.6	129	10.9
5	3	89	1405	0.20	7.3	124	9.6
5	3	89	1705	0.21	7.3	126	8.7
5	3	89	2005	0.24	6.6	125	10.2
5	3	89	2305	0.25	15.1	121	11.3

[1] Hour and minutes.
[2] Greenwich Mean Time.

Table E2
Sample Data, Kings Bay, Georgia, SA, May 1989

Month	Day	Year	HRMN[1] GMT[2]	H_{m0} m	T_p sec	Θ_p Deg	Depth m
5	2	89	1700	0.32	7.1	127	7.7
5	2	89	1800	0.34	7.5	132	8.2
5	2	89	1900	0.34	7.1	130	8.8
5	2	89	2000	0.34	6.7	122	9.3
5	2	89	2100	0.35	7.5	134	9.7
5	2	89	2200	0.32	8.0	125	9.8
5	2	89	2300	0.33	7.5	129	9.8
5	3	89	0	0.33	8.0	126	9.4
5	3	89	100	0.29	7.5	129	8.9
5	3	89	200	0.32	7.5	132	8.4
5	3	89	300	0.27	8.0	127	8.0

[1] Hour and minutes.
[2] Greenwich Mean Time.

Table E3
Sample Data, Kings Bay, Georgia, NDBC Buoy 41008, May 1989

Month	Day	Year	HRMN[1] GMT[2]	H_{m0} m	T_p sec	Θ_p Deg	Depth m
5	2	89	1700	0.7	3.6	306	18.0
5	2	89	1800	0.7	3.8	323	18.0
5	2	89	1900	0.6	3.7	317	18.0
5	2	89	2000	0.6	3.6	314	18.0
5	2	89	2100	0.6	7.1	100	18.0
5	2	89	2200	0.5	3.6	331	18.0
5	2	89	2300	0.5	7.7	100	18.0
5	3	89	0	0.6	3.4	321	18.0
5	3	89	100	0.6	3.6	336	18.0
5	3	89	200	0.5	3.4	339	18.0
5	3	89	500	0.4	7.1	115	18.0

[1] Hour and minutes.
[2] Greenwich Mean Time.

Table E4
Number of Records by Month and Year, SA (30.63 °N, 81.42 °W)

Year	Month												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1989				417	345	16	183	159	152	111			1,383
1990	50	163	24	138	176	48							599
Total	50	163	24	555	521	64	183	159	152	111	0	0	1,982

Table E5
Number of Records by Month and Year, NDBC Buoy 41008 (30.73 °N, 81.08 °W)

Year	Month												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1988			269	713		719	737	730	713	738	714	741	6,074
1989	738	655	730	702	685	681	725	722	702	443	140	723	7,646
1990	734	663	619	386	724	712	727	741	718	731	719	743	8,217
1991	742	610	741	714	741	717	739	734	717	742	712	740	8,649
1992	739	682	734										2,115
Total	2,953	2,610	3,093	2,515	2,150	2,829	2,928	2,927	2,850	2,654	2,285	2,947	32,741

Table E6
NDBC Buoy 41008 (30.73 °N, 81.08 °W)
Percent Occurrence (x1,000) of Height and Period by Direction

	Peak Period, T_p (sec)										
H (m)	2.2-6.0	6.1-8.0	8.1-9.5	9.6-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	18.2-22.2	22.3+	Total
Azimuth (deg) = 0.0											
0.0-0.4	131										131
0.5-0.9	641										641
1.0-1.4	589										589
1.5-1.9	198	12									210
2.0-2.4	33	3									36
2.5-2.9											0
3.0-3.4											0
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	1,592	15	0	0	0	0	0	0	0	0	1,607
Mean H_{m0} (m) = 1.0; Largest H_{m0} (m) = 2.3; Mean T_p (sec) = 4.4; No. of Cases = 527											
Azimuth (deg) = 22.5											
0.0-0.4	45										45
0.5-0.9	986	6				3	12	3			1,010
1.0-1.4	974	24					3				1,001
1.5-1.9	354	36									390
2.0-2.4	48	67									115
2.5-2.9	12	24									36
3.0-3.4											0
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	2,419	157	0	0	0	3	15	3	0	0	2,597
Mean H_{m0} (m) = 1.1; Largest H_{m0} (m) = 2.8; Mean T_p (sec) = 5.1; No. of Cases = 852											

(Sheet 1 of 9)

Table E6 (Continued)

H (m)	Peak Period, T_p (sec) 2.2-6.0	6.1-8.0	8.1-9.5	9.6-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	18.2-22.2	22.3+	Total
Azimuth (deg) = 45.0											
0.0-0.4	42	3	12	24	51	12	3				147
0.5-0.9	986	195	61	88	134	140	39	9			1,652
1.0-1.4	1,429	467	39	33	61	48	48	9			2,134
1.5-1.92	1,090	729	6	9	9	3	12				1,858
2.0-2.4	268	1,087	12		3						1,370
2.5-2.9	30	448	42					3			523
3.0-3.4		36	6					6			48
3.5-3.9											0
4.0-4.4		3									3
4.5-4.9											0
5.0+											0
Total	3,845	2,968	178	154	258	203	102	27	0	0	7,735
Mean H_{m0} (m) = 1.5; Largest H_{m0} (m) = 4.0; Mean T_p (sec) = 6.6; No. of Cases = 2,538											
Azimuth (deg) = 67.5											
0.0-0.4	15	88	177	207	180	116	24	12			819
0.5-0.9	586	846	1,462	1,136	1,215	998	158	21			6,422
1.0-1.4	690	650	867	647	635	305	253	39	6		4,092
1.5-1.9	412	1,038	253	161	76	54	39	3			2,036
2.0-2.4	45	659	88	12	15	18					837
2.5-2.9		244	58	3	6		3	3			317
3.0-3.4		3	3					6			12
3.5-3.9											0
84.0-4.4											0
4.5-4.9											0
5.0+											0
Total	1,748	3,528	2,908	2,166	2,127	1,491	477	84	6	0	14,535
Mean H_{m0} (m) = 1.1; Largest H_{m0} (m) = 3.2; Mean T_p (sec) = 9.0; No. of Cases = 4,765											

(Sheet 2 of 9)

Table E6 (Continued)

H (m)	Peak Period, T_p (sec)										Total
	2.2-6.0	6.1-8.0	8.1-9.5	9.6-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	18.2-22.2	22.3+	
Azimuth (deg) = 90.0											
0.0-0.4	42	430	1,429	595	360	247	122	18			3,243
0.5-0.9	476	3,717	8,338	2,709	1,212	806	167	33	6		7,464
1.0-1.4	598	1,734	2,382	1,346	702	439	216	73	33		7,523
1.5-1.9	158	842	1,117	397	180	116	36	36			2,882
2.0-2.4	24	299	390	149	42	36		36			946
2.5-2.9		36	54	21	3						114
3.0-3.4			15	3							18
3.5-3.9		3	9								12
4.0-4.4				3	9						12
4.5-4.9											0
5.0+											0
Total	1,298	7,061	13,734	5,223	2,508	1,644	541	166	39	0	32,214
Mean H_{m0} (m) = 0.9; Largest H_{m0} (m) = 4.4; Mean T_p (sec) = 9.0; No. of Cases = 10,555											
Azimuth (deg) = 112.5											
0.0-0.4	67	513	1,075	403	119	39	88	12			2,316
0.5-0.9	1,502	3,362	5,971	1,658	461	238	128	36			13,356
1.0-1.4	1,157	1,939	1,392	794	329	122	73	33	6		5,845
1.5-1.9	128	604	488	134	106	36	27	12			1,535
2.0-2.4	9	171	109	45	18			9			361
2.5-2.9		45	33	3	9	3					93
3.0-3.4		15	6								21
3.5-3.9				3							3
4.0-4.4			3			3					6
4.5-4.9					3						3
5.0+											0
Total	2,863	6,649	9,077	3,040	1,045	441	316	102	6	0	23,539
Mean H_{m0} (m) = 0.9; Largest H_{m0} (m) = 4.6; Mean T_p (sec) = 8.3; No. of Cases = 7,713											

(Sheet 3 of 9)

Table E6 (Continued)

H (m)	Peak Period, T_p (sec) 2.2-6.0	6.1-8.0	8.1-9.5	9.6-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	18.2-22.2	22.3+	Total
Azimuth (deg) = 135.0											
0.0-0.4	186	18	42	39	3		15	6			309
0.5-0.9	2,809	308	354	94	42	45	15	3			3,670
1.0-1.4	1,353	491	109	45	15		21	3			2,037
1.5-1.9	76	268	27	24	6		9				410
2.0-2.4		106	9	6	6						127
2.5-2.9		6				3					9
3.0-3.4											0
3.5-3.9						3					3
4.0-4.4						3					3
4.5-4.9											0
5.0+											0
Total	4,424	1,197	541	208	72	54	60	12	0	0	6,568
Mean H_{m0} (m) = 0.9; Largest H_{m0} (m) = 4.2; Mean T_p (sec) = 6.0; No. of Cases = 2,155											
Azimuth (deg) = 157.5											
0.0-0.4	232						3				235
0.5-0.9	2,651						6				2,657
1.0-1.4	849	30									879
1.5-1.9	125	33		3							161
2.0-2.4	6	9									15
2.5-2.9		3									3
3.0-3.4		3									3
3.5-3.9											0
4.0-4.4						3					3
4.5-4.9											0
5.0+											0
Total	3,863	78	0	3	0	3	9	0	0	0	3,956
Mean H_{m0} (m) = 0.8; Largest H_{m0} (m) = 4.0; Mean T_p (sec) = 4.4; No. of Cases = 1,296											

(*Sheet 4 of 9*)

Table E6 (Continued)											
	Peak Period (sec)										
H (m)	2.2-6.0	6.1-8.0	8.1-9.5	9.6-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	18.2-22.2	22.3+	Total
Azimuth (deg) = 180.0											
0.0-0.4	91		3				3				97
0.5-0.9	998										998
1.0-1.4	342										342
1.5-1.9	27										27
2.0-2.4		3									3
2.5-2.9											0
3.0-3.4											0
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	1,458	3	3	0	0	0	3	0	0	0	1,467
Mean H_{m0} (m) = 0.8; Largest H_{m0} (m) = 2.3; Mean T_p (sec) = 3.9; No. of Cases = 481											
Azimuth (deg) = 202.5											
0.0-0.4	39										39
0.5-0.9	311										311
1.0-1.4	64										64
1.5-1.9	6										6
2.0-2.4		3									3
2.5-2.9											0
3.0-3.4											0
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	420	3	0	0	0	0	0	0	0	0	423
Mean H_{m0} (m) = 0.8; Largest H_{m0} (m) = 2.0; Mean T_p (sec) = 3.7; No. of Cases = 139											
(Sheet 5 of 9)											

Table E6 (Continued)

H (m)	Peak Period, T_p (sec) 2.2-6.0	6.1-8.0	8.1-9.5	9.6-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	18.2-22.2	22.3+	Total
Azimuth (deg) = 225.0											
0.0-0.4	15										15
0.5-0.9	403		3					3			409
1.0-1.4	131										131
1.5-1.9	24										24
2.0-2.4	3										3
2.5-2.9											0
3.0-3.4											0
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	576	0	3	0	0	0	0	3	0	0	582
Mean H_{m0} (m) = 0.8; Largest H_{m0} (m) = 2.4; Mean T_p (sec) = 3.7; No. of Cases = 191											
Azimuth (deg) = 247.5											
0.0-0.4	33										33
0.5-0.9	464										464
1.0-1.4	97					3					100
1.5-1.9	15					3					18
2.0-2.4						3					3
2.5-2.9											0
3.0-3.4											0
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	609	0	0	0	0	9	0	0	0	0	618
Mean H_{m0} (m) = 0.8; Largest H_{m0} (m) = 2.2; Mean T_p (sec) = 3.6; No. of Cases = 203											

(Sheet 6 of 9)

Table E6 (Continued)											
	Peak Period, T_p (sec)										
H (m)	2.2-6.0	6.1-8.0	8.1-9.5	9.6-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	18.2-22.2	22.3+	Total
Azimuth (deg) = 270.0											
0.0-0.4	33				3						36
0.5-0.9	488						3				491
1.0-1.4	207					6					213
1.5-1.9	54										54
2.0-2.4	15					3					18
2.5-2.9				3							3
3.0-3.4											0
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	797	0	0	3	3	9	3	0	0	0	815
Mean H_{m0} (m) = 0.9; Largest H_{m0} (m) = 2.8; Mean T_p (sec) = 3.9; No. of Cases = 268											
Azimuth (deg) = 292.5											
0.0-0.4	24										24
0.5-0.9	494					3					497
1.0-1.4	259										259
1.5-1.9	58										58
2.0-2.4	24										24
2.5-2.9	3										3
3.0-3.4											0
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	862	0	0	0	0	3	0	0	0	0	865
Mean H_{m0} (m) = 0.9; Largest H_{m0} (m) = 2.7; Mean T_p (sec) = 3.9; No. of Cases = 284											
											(Sheet 7 of 9)

Table E6 (Continued)											
	Peak Period, T_p (sec)										
H (m)	2.2-6.0	6.1-8.0	8.1-9.5	9.6-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	18.2-22.2	22.3+	Total
Azimuth (deg) = 315.0											
0.0-0.4	24										24
0.5-0.9	516										516
1.0-1.4	433										433
1.5-1.9	149										149
2.0-2.4	24	3									27
2.5-2.9	3										3
3.0-3.4											0
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	1,149	3	0	0	0	0	0	0	0	0	1,152
Mean H_{m0} (m) = 1.1; Largest H_{m0} (m) = 2.7; Mean T_p (sec) = 4.1; No. of Cases = 378											
Azimuth (deg) = 337.5											
0.0-0.4	36										36
0.5-0.9	479										479
1.0-1.4	485										485
1.5-1.9	186										186
2.0-2.4	18										18
2.5-2.9		3									3
3.0-3.4											0
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	1,204	3	0	0	0	0	0	0	0	0	1,207
Mean H_{m0} (m) = 1.1; Largest H_{m0} (m) = 2.5; Mean T_p (sec) = 4.3; No. of Cases = 396											
											(*Sheet 8 of 9*)

Table E6 (Concluded)

H (m)	Peak Period, T_p (sec) 2.2-6.0	6.1-8.0	8.1-9.5	9.6-10.5	10.6-11.7	11.8-13.3	13.4-15.3	15.4-18.1	18.2-22.2	22.3+	Total
For All Directions											
0.0-0.4	106	105	273	127	71	41	25	4			752
0.5-0.9	1,479	843	1,619	568	306	223	53	10			5,101
1.0-1.4	966	533	479	286	174	92	61	15	4		2,610
1.5-1.9	306	356	189	72	37	21	12	5			998
2.0-2.4	52	241	61	21	8	6		1			390
2.5-2.9	4	81	18	3	1						107
3.0-3.4		5	3					1			9
3.5-3.9											0
4.0-4.4											0
4.5-4.9											0
5.0+											0
Total	2,913	2,164	2,642	1,077	597	383	151	36	4	0	9,967

Mean H_{m0} (m) = 1.0; Largest H_{m0} (m) = 4.6; Mean T_p (sec) = 7.7; No. of Cases = 32,741

(Sheet 9 of 9)

Table E7
Ranges for Direction Intervals in Percent Occurrence Tables

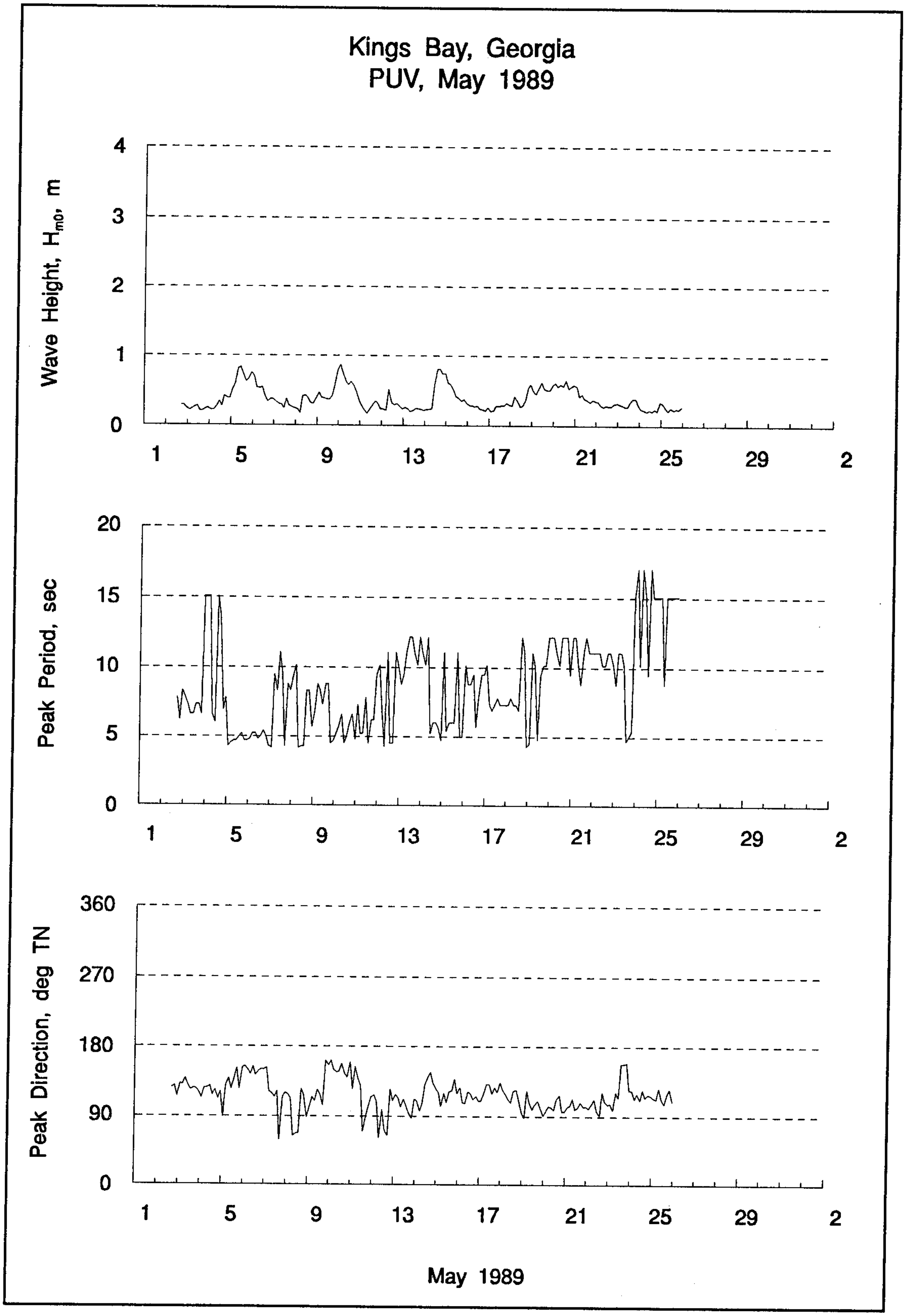
Midband[1] deg	Range deg				
0.0	348.75	≤	Θ_p	<	11.25
22.5	11.25	≤	Θ_p	<	33.75
45.0	33.75	≤	Θ_p	<	56.25
67.5	56.25	≤	Θ_p	<	78.75
90.0	78.75	≤	Θ_p	<	101.25
112.5	101.25	≤	Θ_p	<	123.75
135.0	123.75	≤	Θ_p	<	146.25
157.5	146.25	≤	Θ_p	<	168.75
180.0	168.75	≤	Θ_p	<	191.25
202.5	191.25	≤	Θ_p	<	213.75
225.0	213.75	≤	Θ_p	<	236.25
247.5	236.25	≤	Θ_p	<	258.75
270.0	258.75	≤	Θ_p	<	281.25
292.5	281.25	≤	Θ_p	<	303.75
315.0	303.75	≤	Θ_p	<	326.25
337.5	326.25	≤	Θ_p	<	348.75

[1] From true north.

Table E8
Frequency Ranges Used in NDBC Buoy Data Analysis

Midband Frequency[1] sec	Midband Period sec	Band Range for Period sec	Grouping for Percent Occurrence Tables sec
0.40	2.5	$2.22 \le T_p < 2.86$	
--[1]	--	--	
--	--	--	
--	--	--	
--	--	--	2.2 - 6.0
--	--	--	
--	--	--	
--	--	--	
--	--	--	
0.17	5.9	$5.71 \le T_p < 6.06$	
0.16	6.2	$6.06 \le T_p < 6.45$	
0.15	6.7	$6.45 \le T_p < 6.90$	6.1 - 8.0
0.14	7.1	$6.90 \le T_p < 7.41$	
0.13	7.7	$7.41 \le T_p < 8.00$	
0.12	8.3	$8.00 \le T_p < 8.70$	8.1 - 9.5
0.11	9.1	$8.70 \le T_p < 9.52$	
0.10	10.0	$9.52 \le T_p < 10.53$	9.6 - 10.5
0.09	11.1	$10.53 \le T_p < 11.76$	10.6 - 11.7
0.08	12.5	$11.76 \le T_p < 13.33$	11.8 - 13.3
0.07	14.3	$13.33 \le T_p < 15.38$	13.4 - 15.3
0.06	16.7	$15.38 \le T_p < 18.18$	15.4 - 18.1
0.05	20.0	$18.18 \le T_p < 22.22$	18.2 - 22.2
0.04	25.0	$22.22 \le T_p < 28.57$	22.3 - longer
0.03	33.3	$28.57 \le T_p < 40.00$	

[1] Frequencies from 0.40 to 0.17 are represented in the 2.2 - 6.0 sec category.



Kings Bay, Georgia
PUV, May 1989
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
May 1989

Plate E1

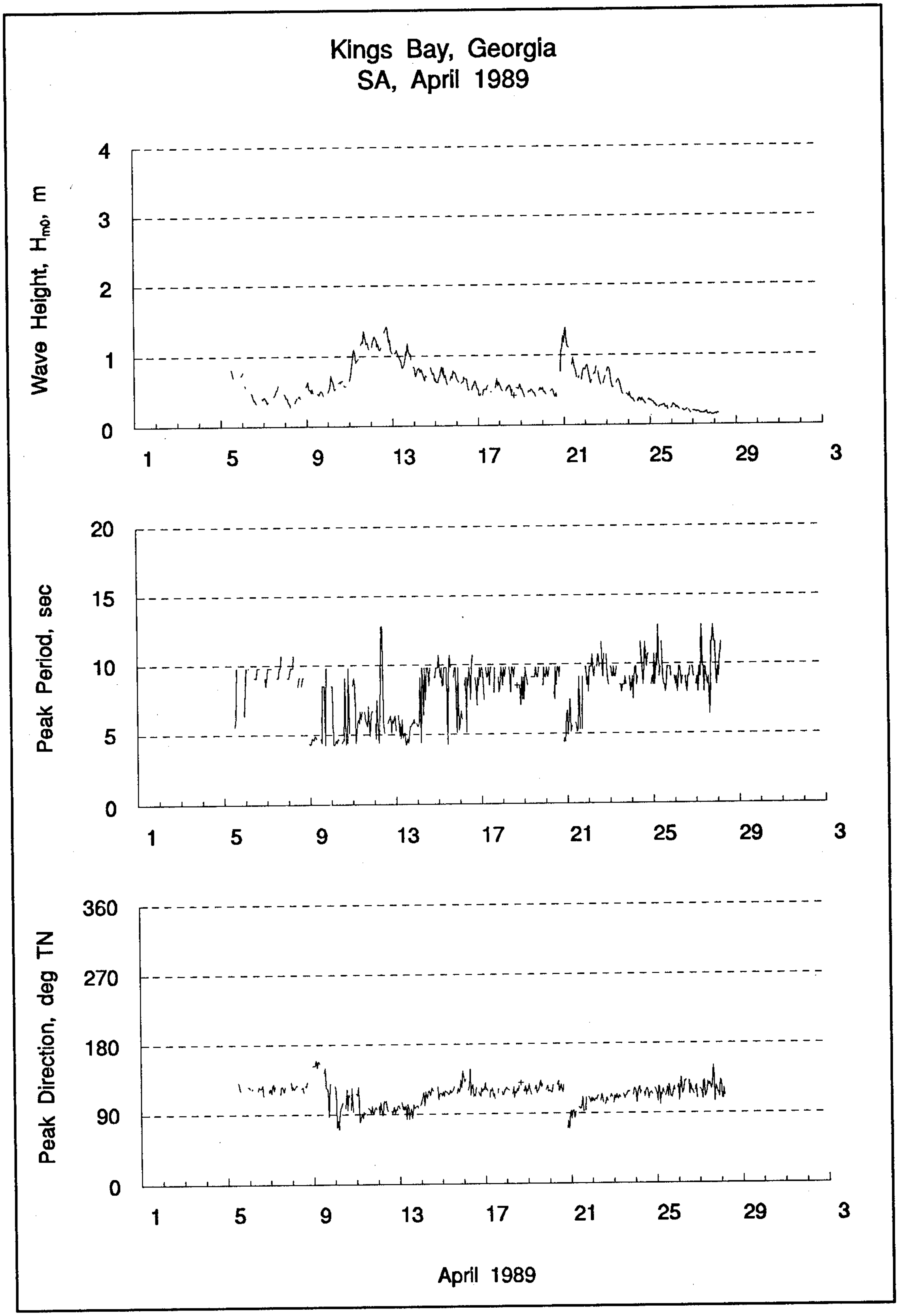
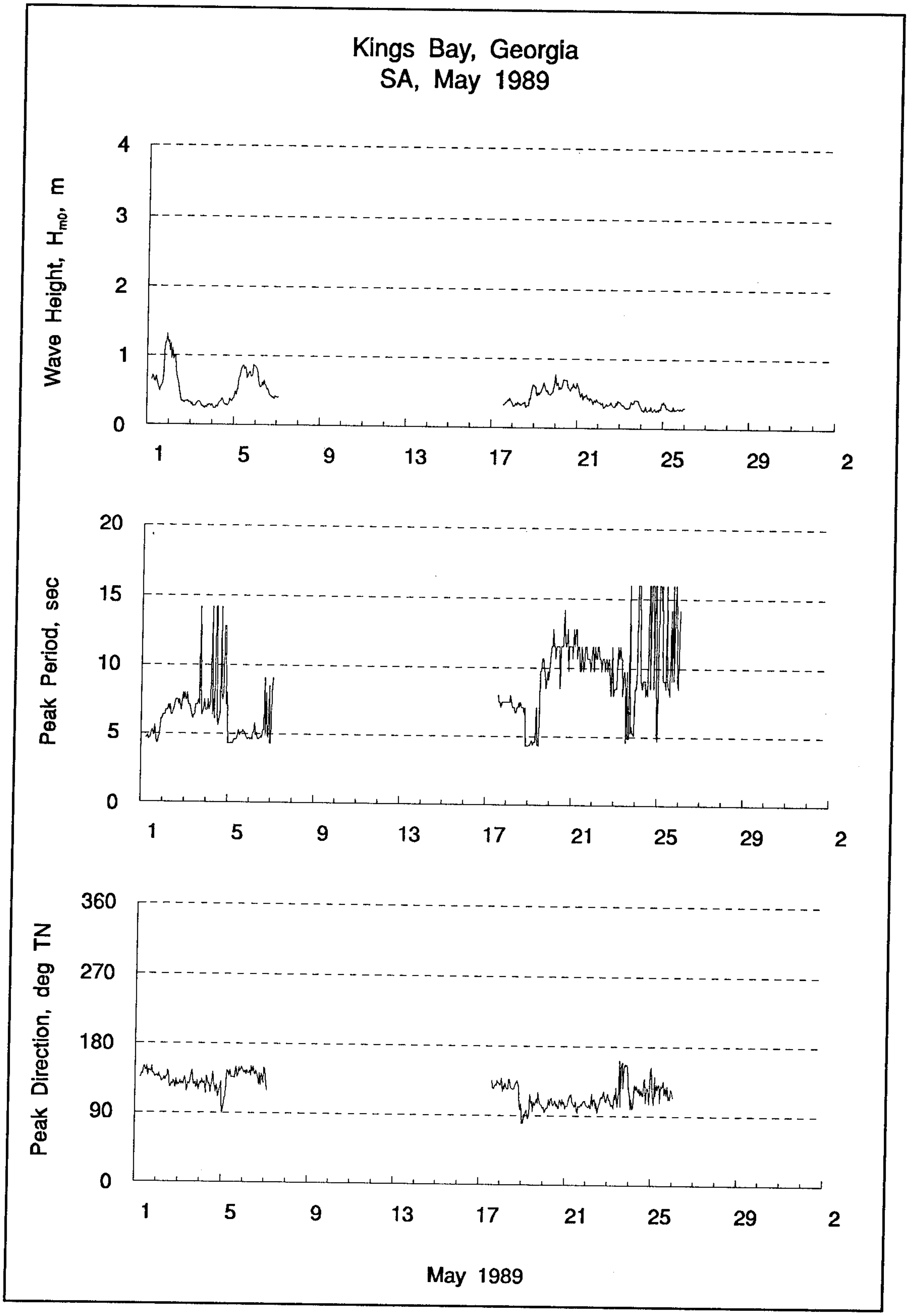

Kings Bay, Georgia
SA, April 1989
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
3
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
3
April 1989

Plate E2



Kings Bay, Georgia
SA, May 1989
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
May 1989

Plate E3

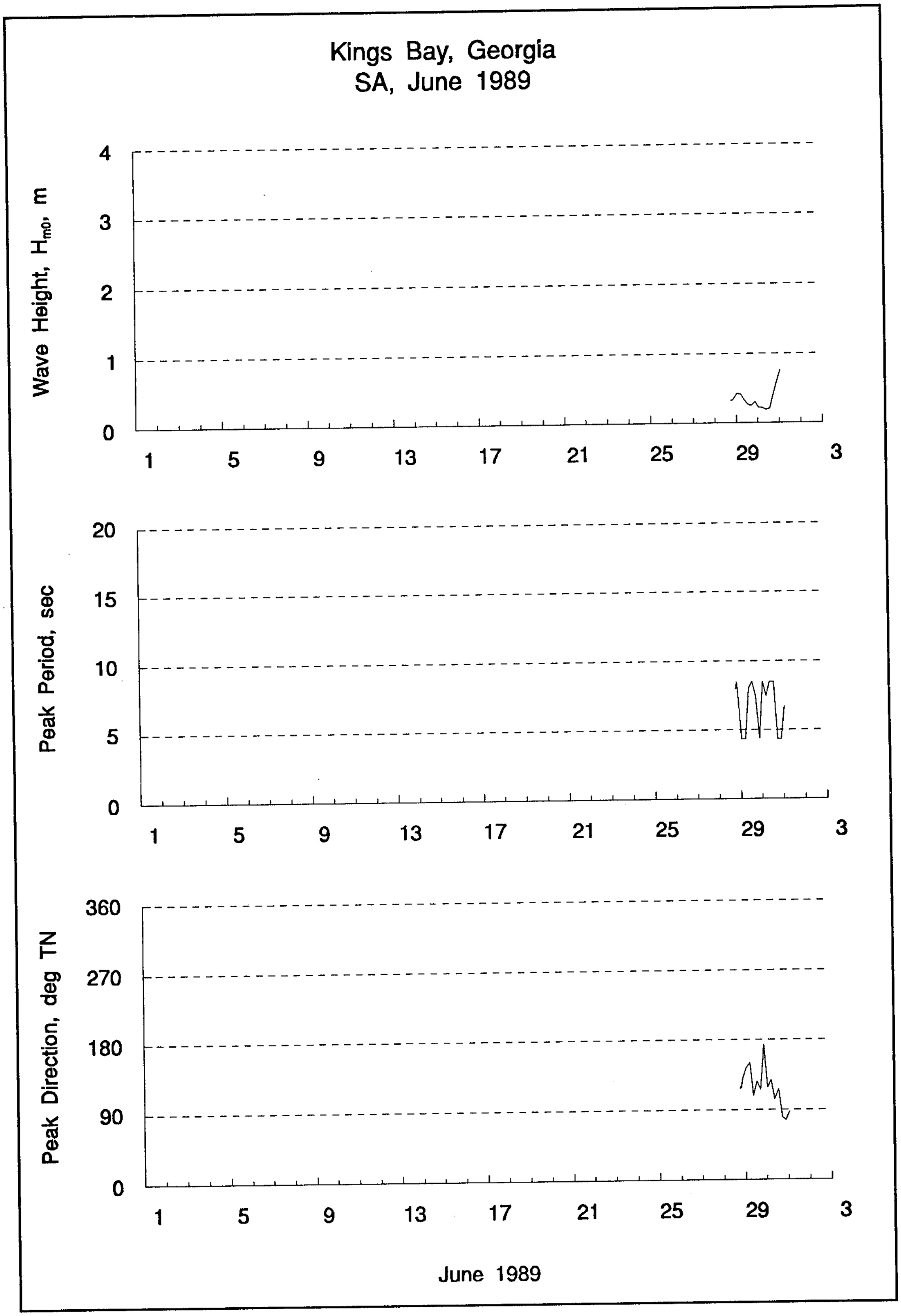

Kings Bay, Georgia
SA, June 1989
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
Peak Direction, deg TN
360
270
180
90
0
June 1989

Plate E4

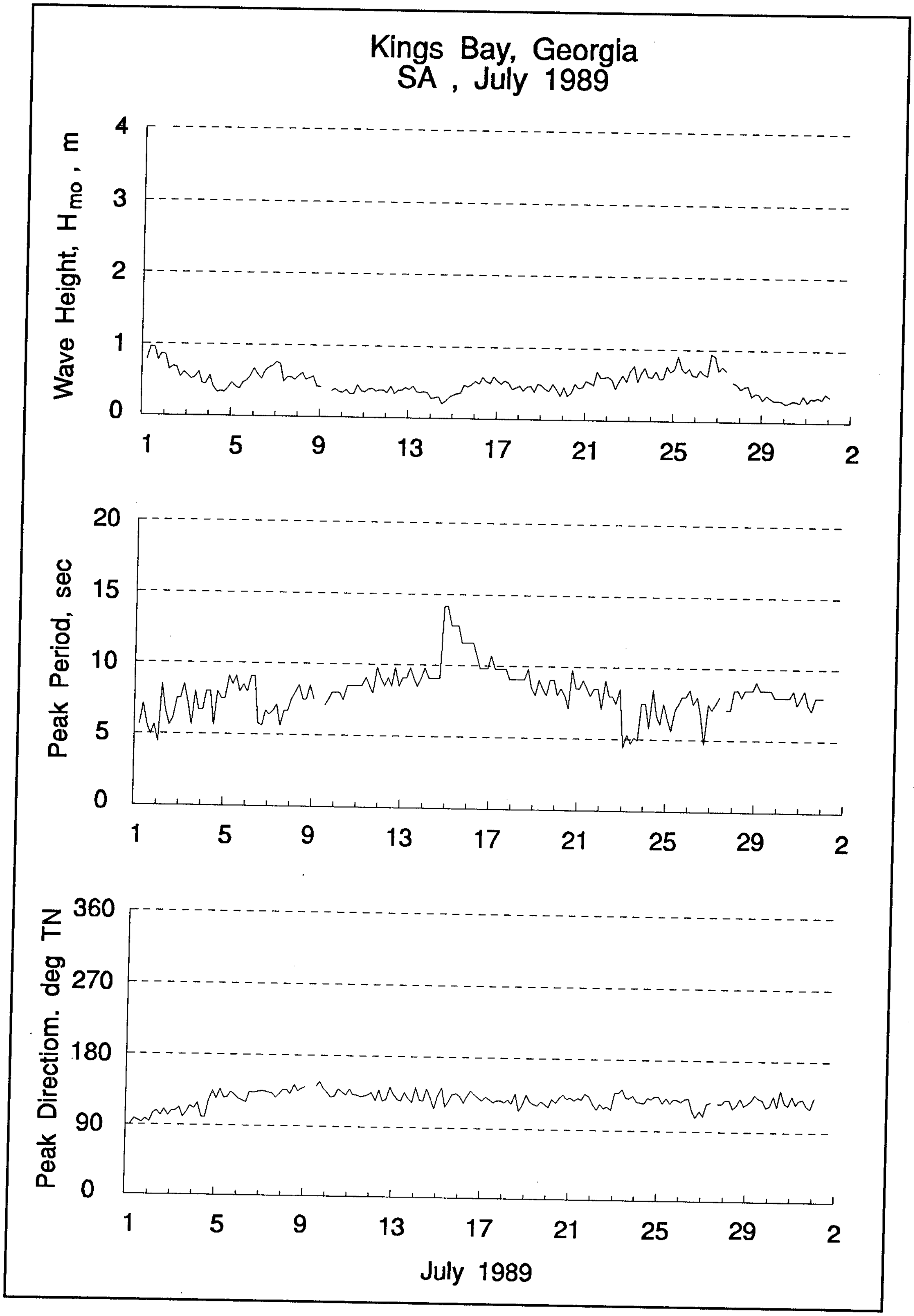
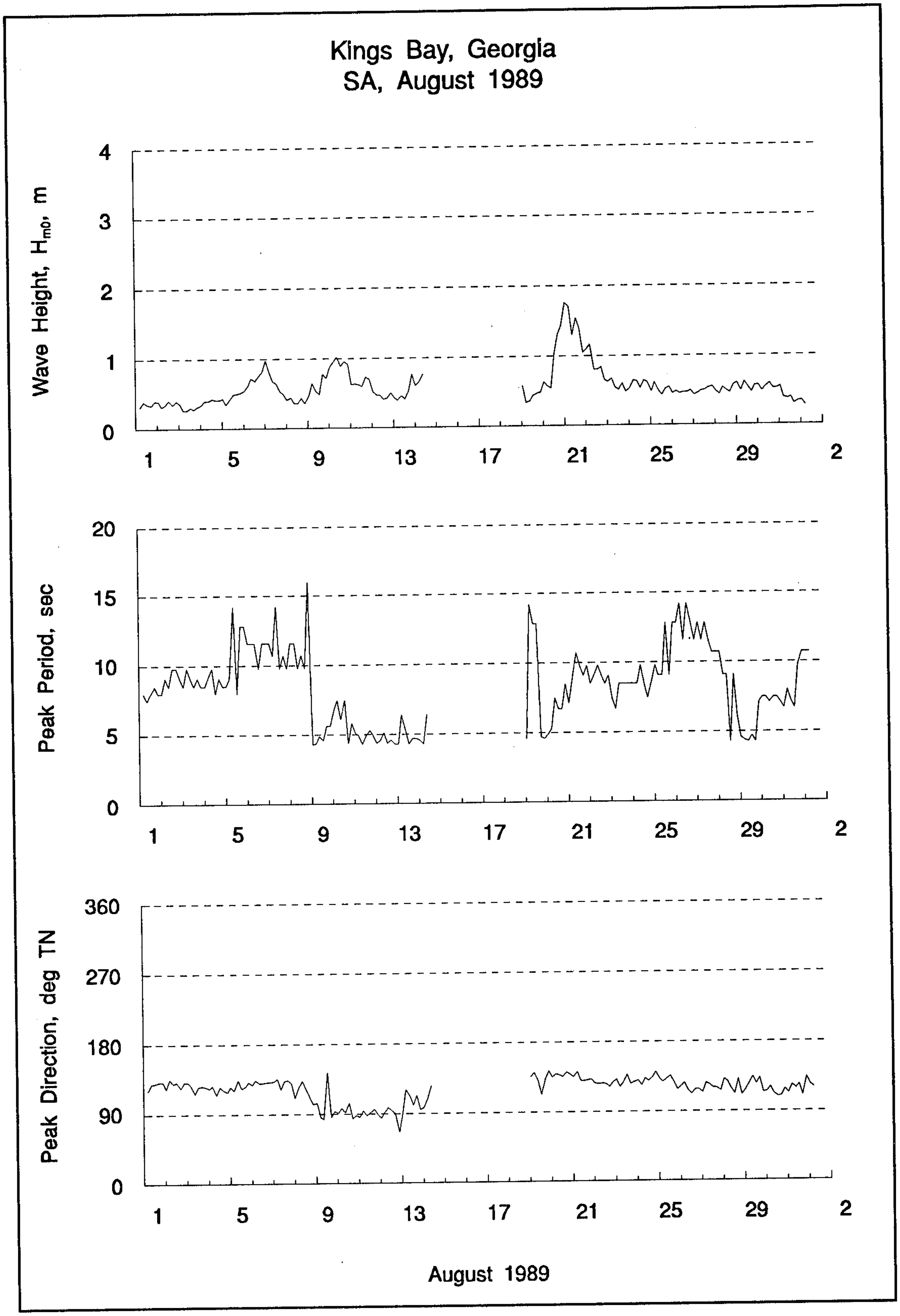

Kings Bay, Georgia
SA , July 1989
Wave Height, H_{mo} , m
4
3
2
1
0
1 5 9 13 17 21 25 29 2
Peak Period, sec
20
15
10
5
0
1 5 9 13 17 21 25 29 2
Peak Directiom. deg TN
360
270
180
90
0
1 5 9 13 17 21 25 29 2
July 1989

Plate E5



Kings Bay, Georgia
SA, August 1989
Wave Height, H_{m0}, m
0
1
2
3
4
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
August 1989

Plate E6

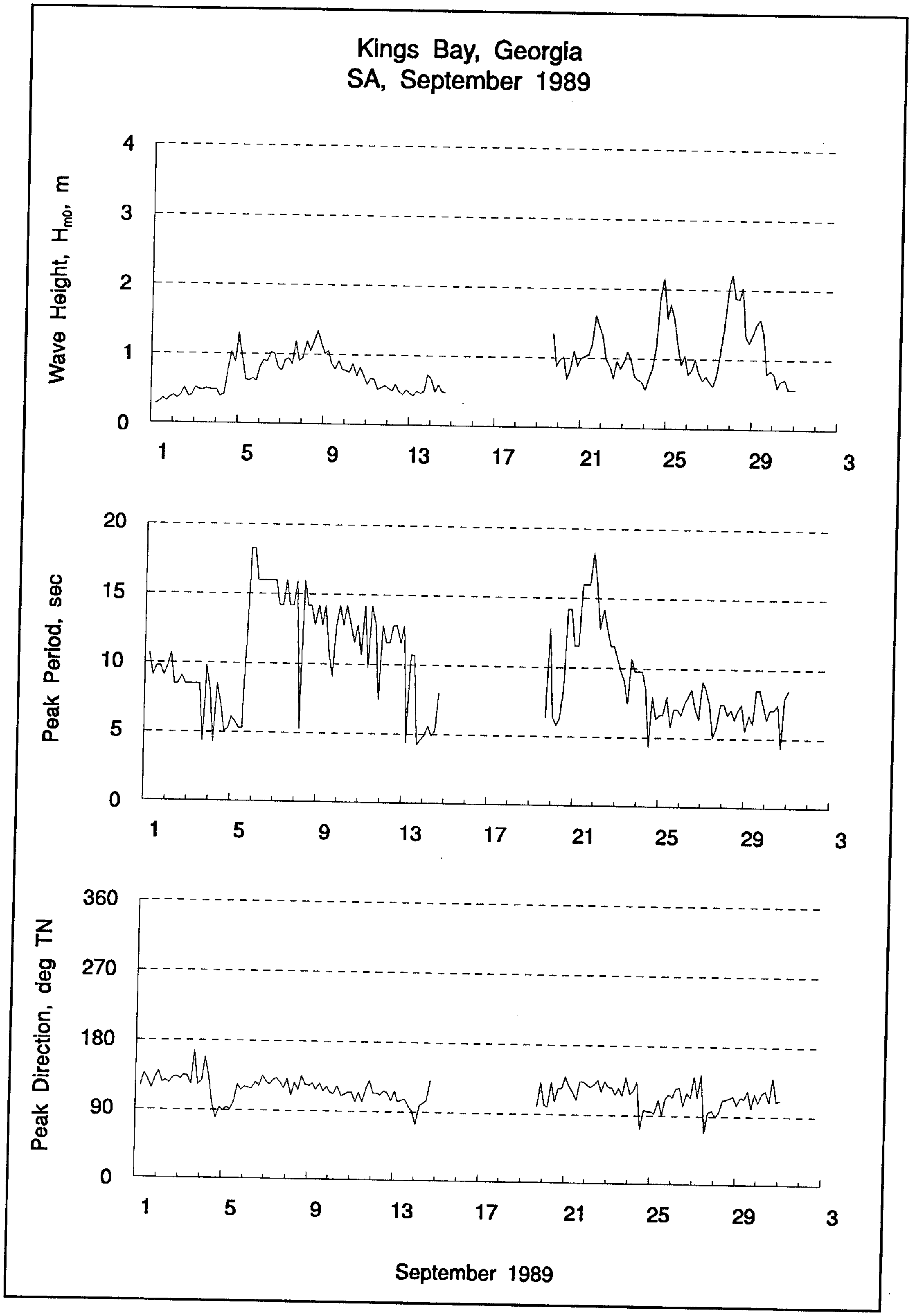
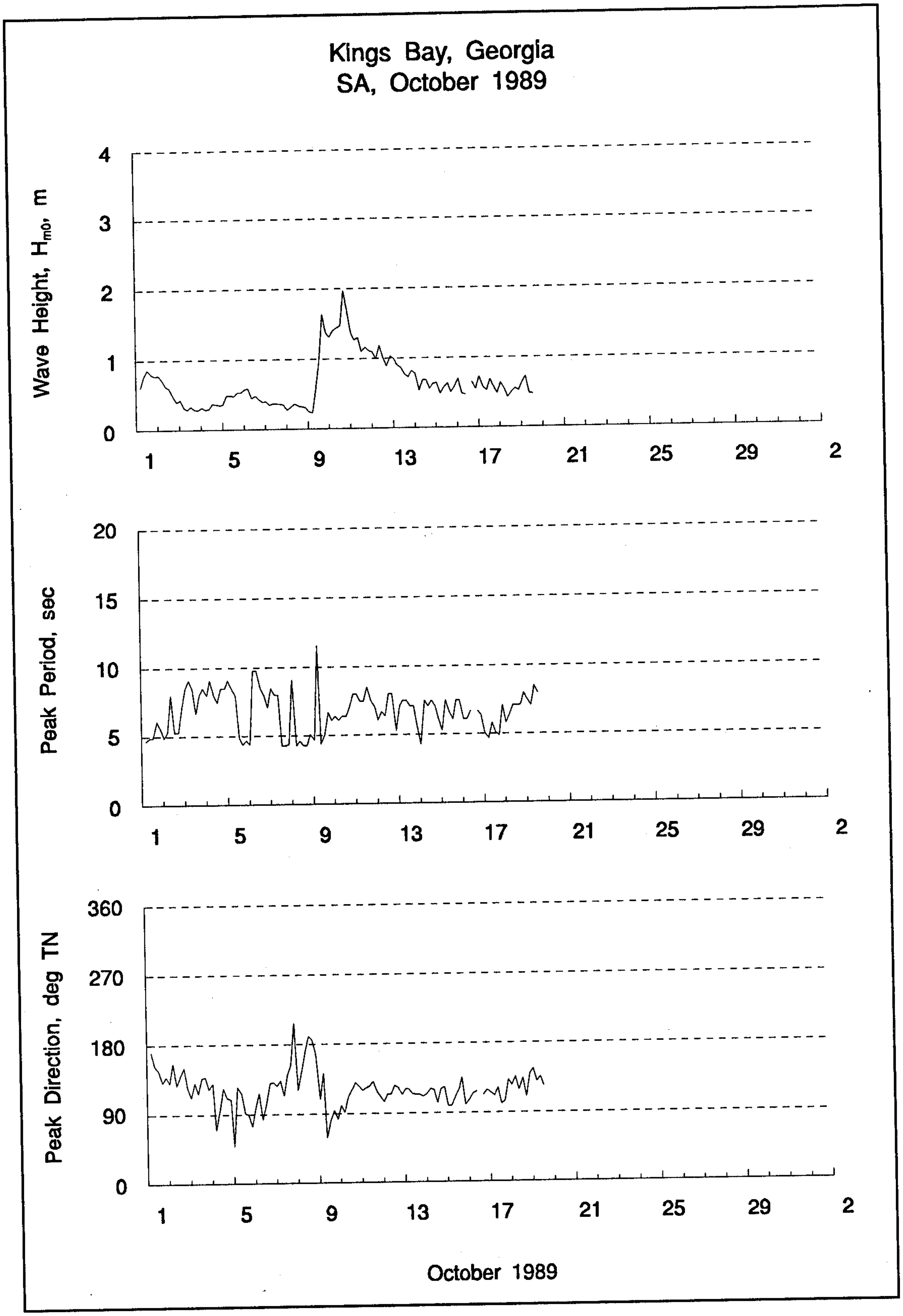
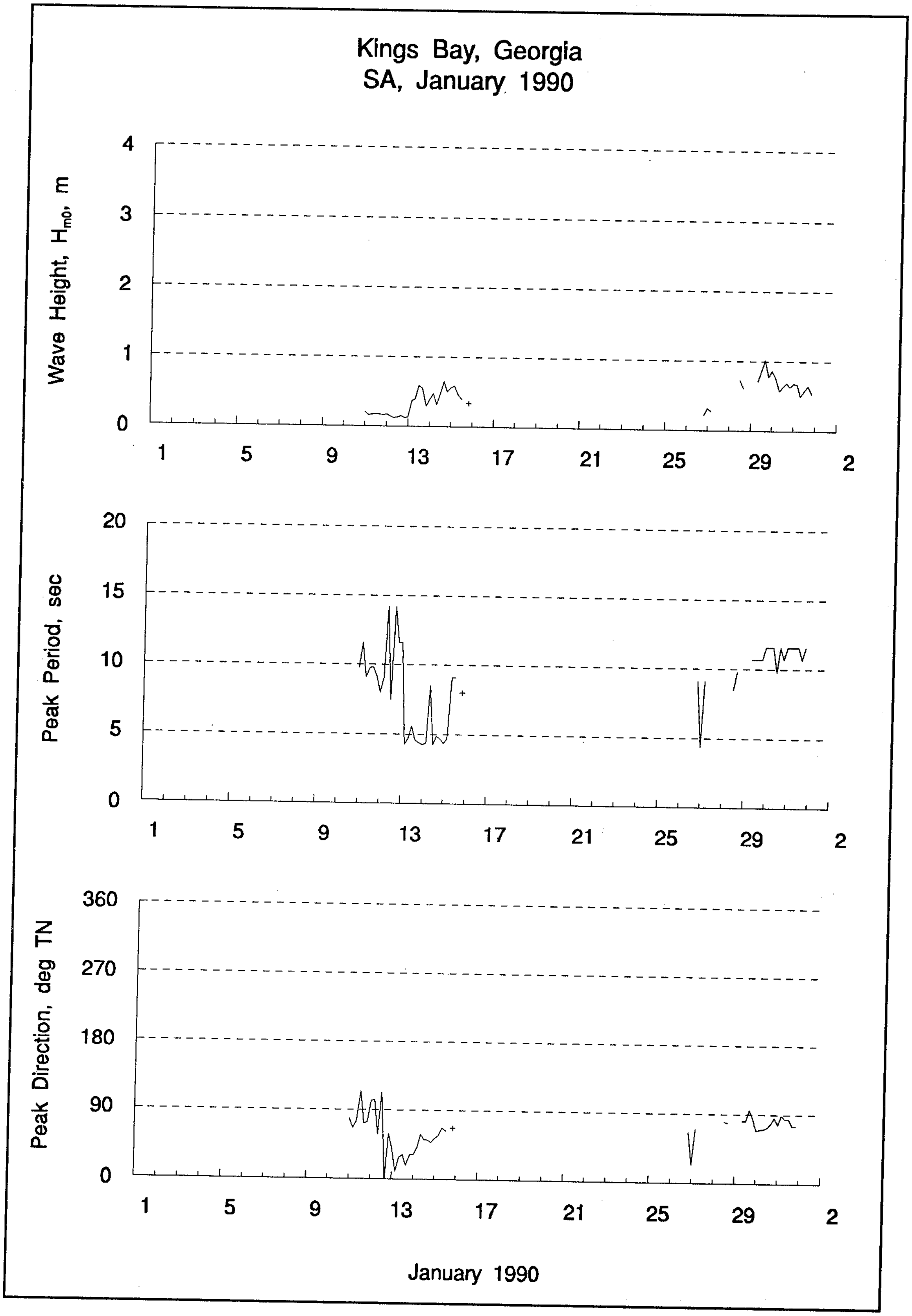

Kings Bay, Georgia
SA, September 1989
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
3
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
3
September 1989

Plate E7



Kings Bay, Georgia
SA, October 1989
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
October 1989

Plate E8



Kings Bay, Georgia
SA, January 1990
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
January 1990

Plate E9

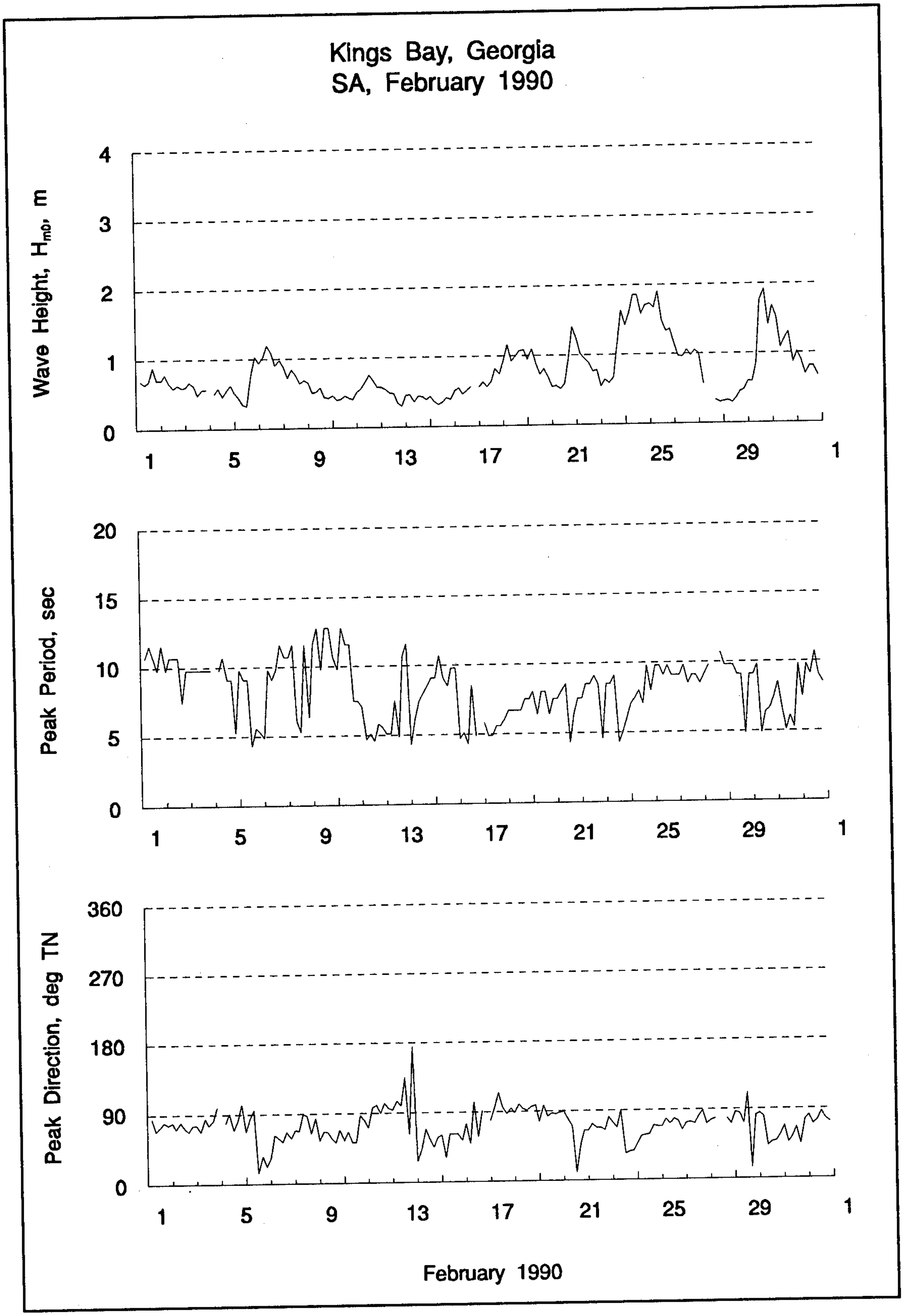
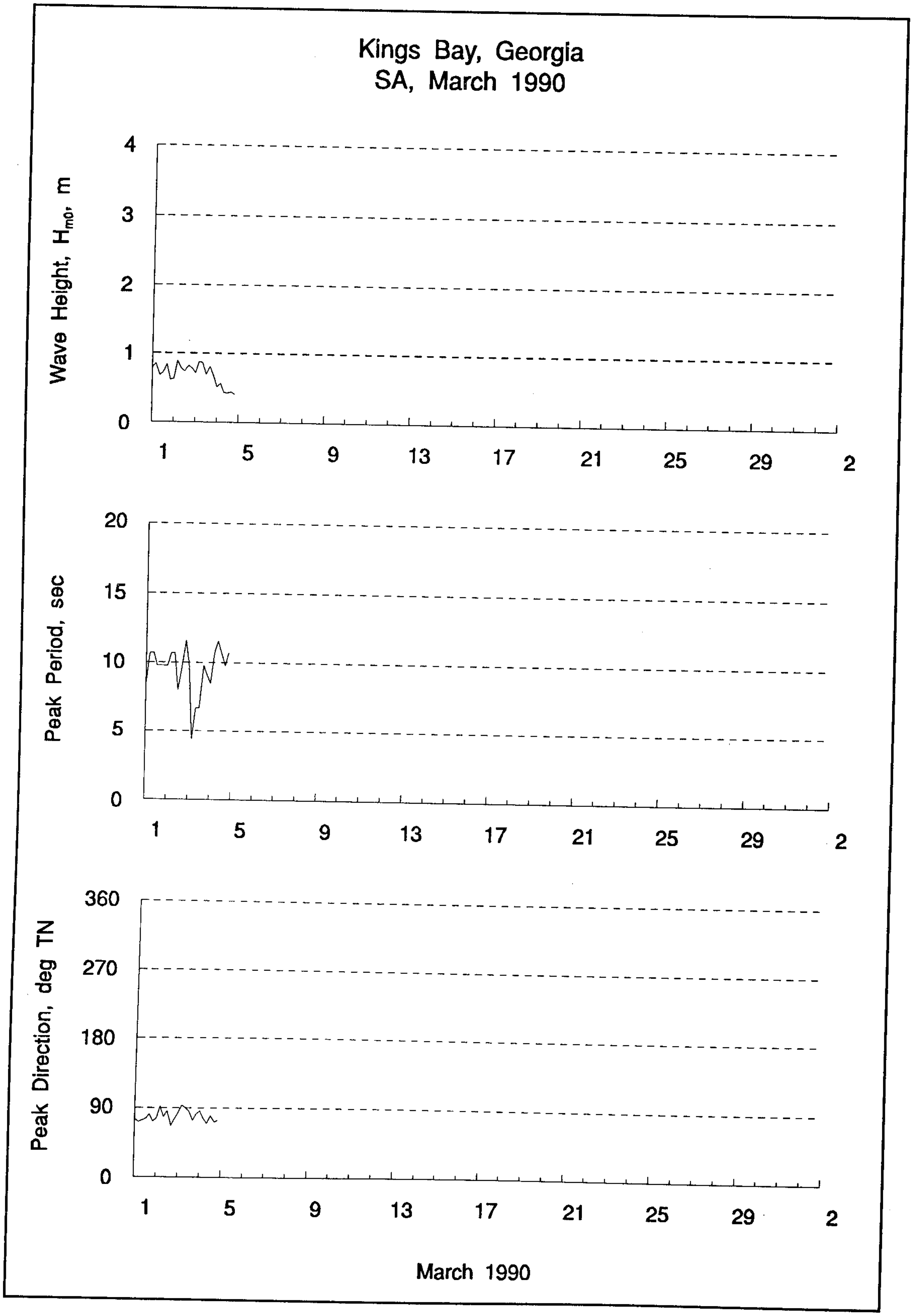
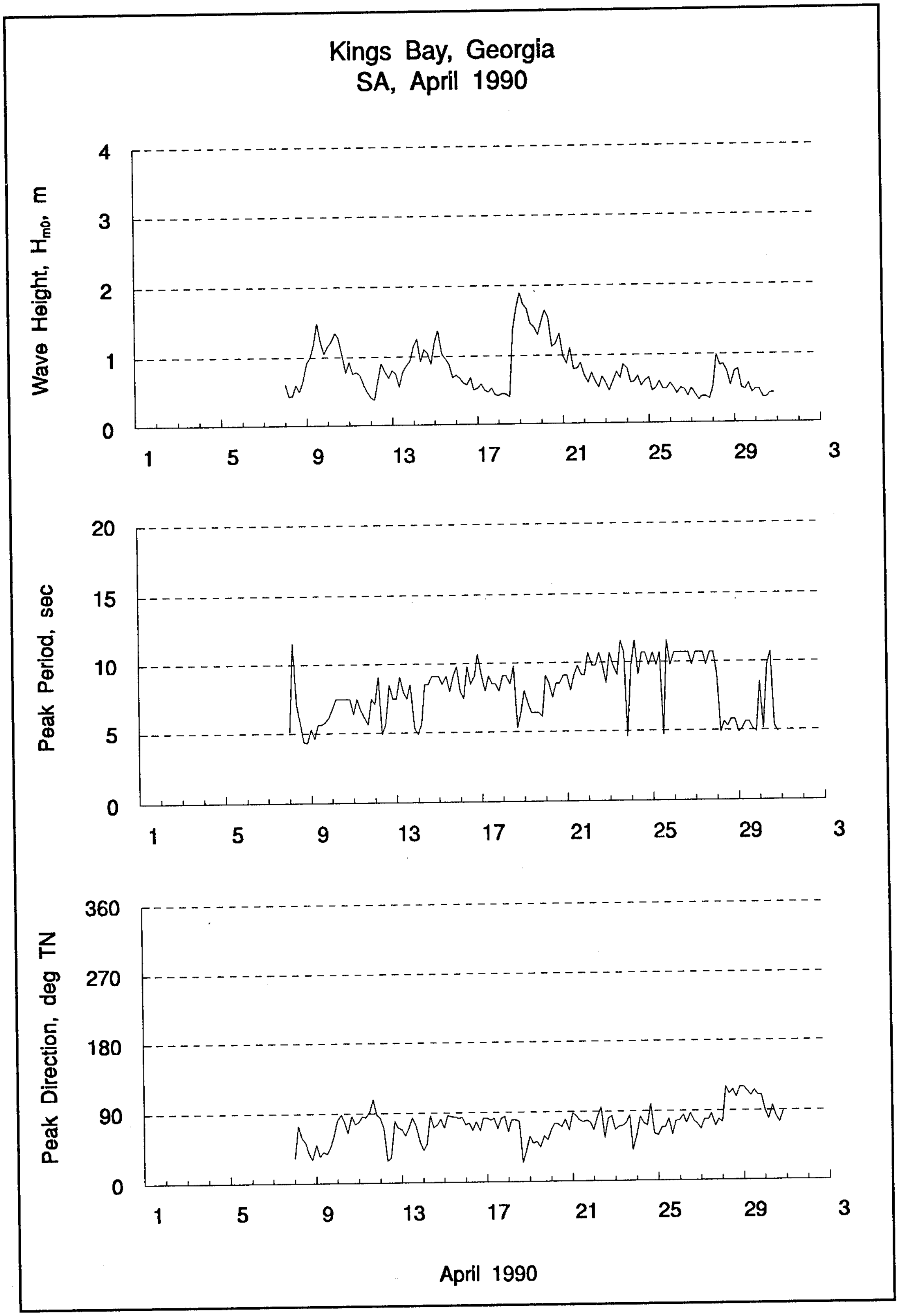

Kings Bay, Georgia
SA, February 1990
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
1
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
1
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
1
February 1990

Plate E10



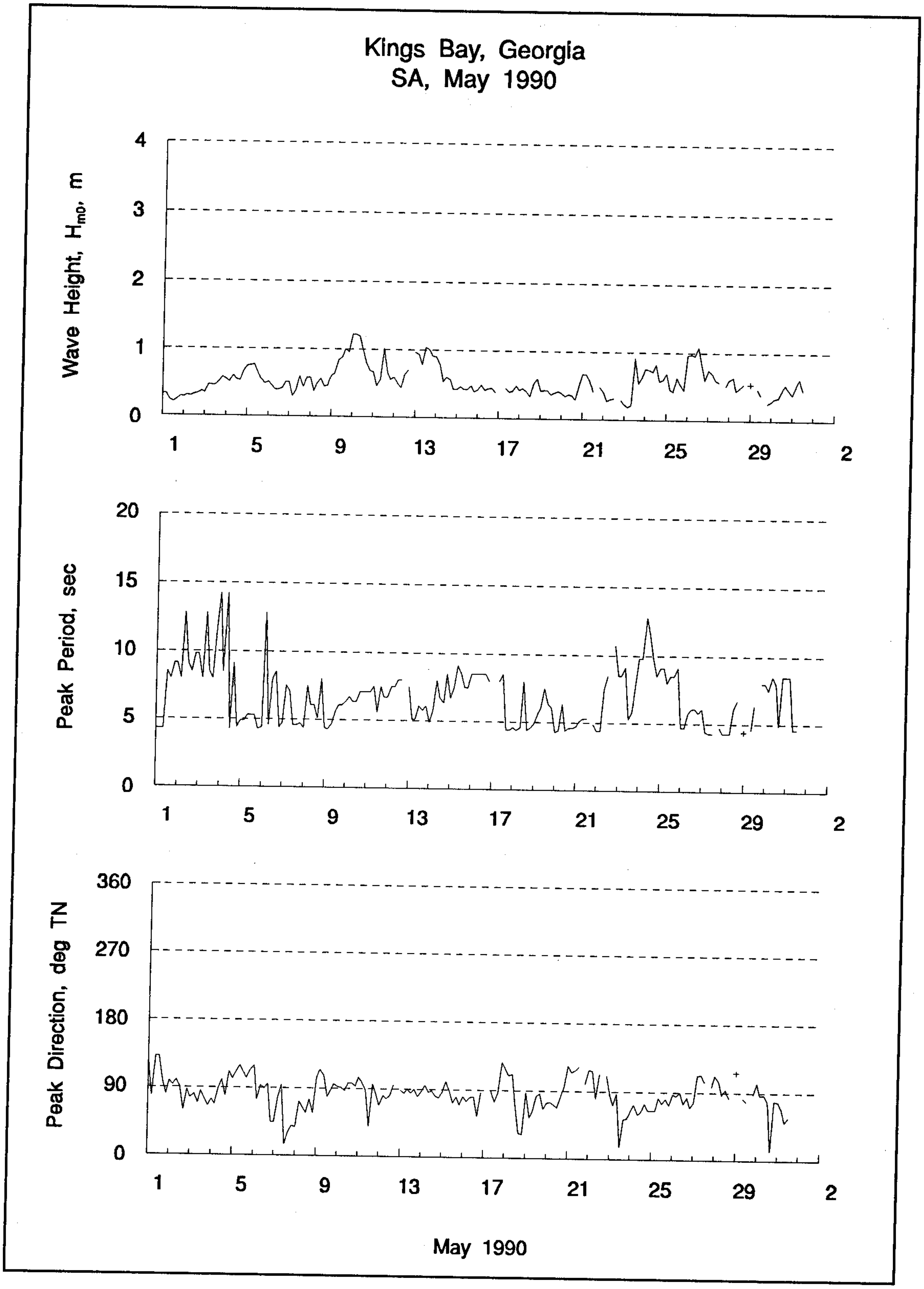
Kings Bay, Georgia
SA, March 1990
Wave Height, H_{mo}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
March 1990

Plate E11



Kings Bay, Georgia
SA, April 1990
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
3
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
3
April 1990

Plate E12



Kings Bay, Georgia
SA, May 1990
Wave Height, H_{m0}, m
0
1
2
3
4
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
May 1990

Plate E13

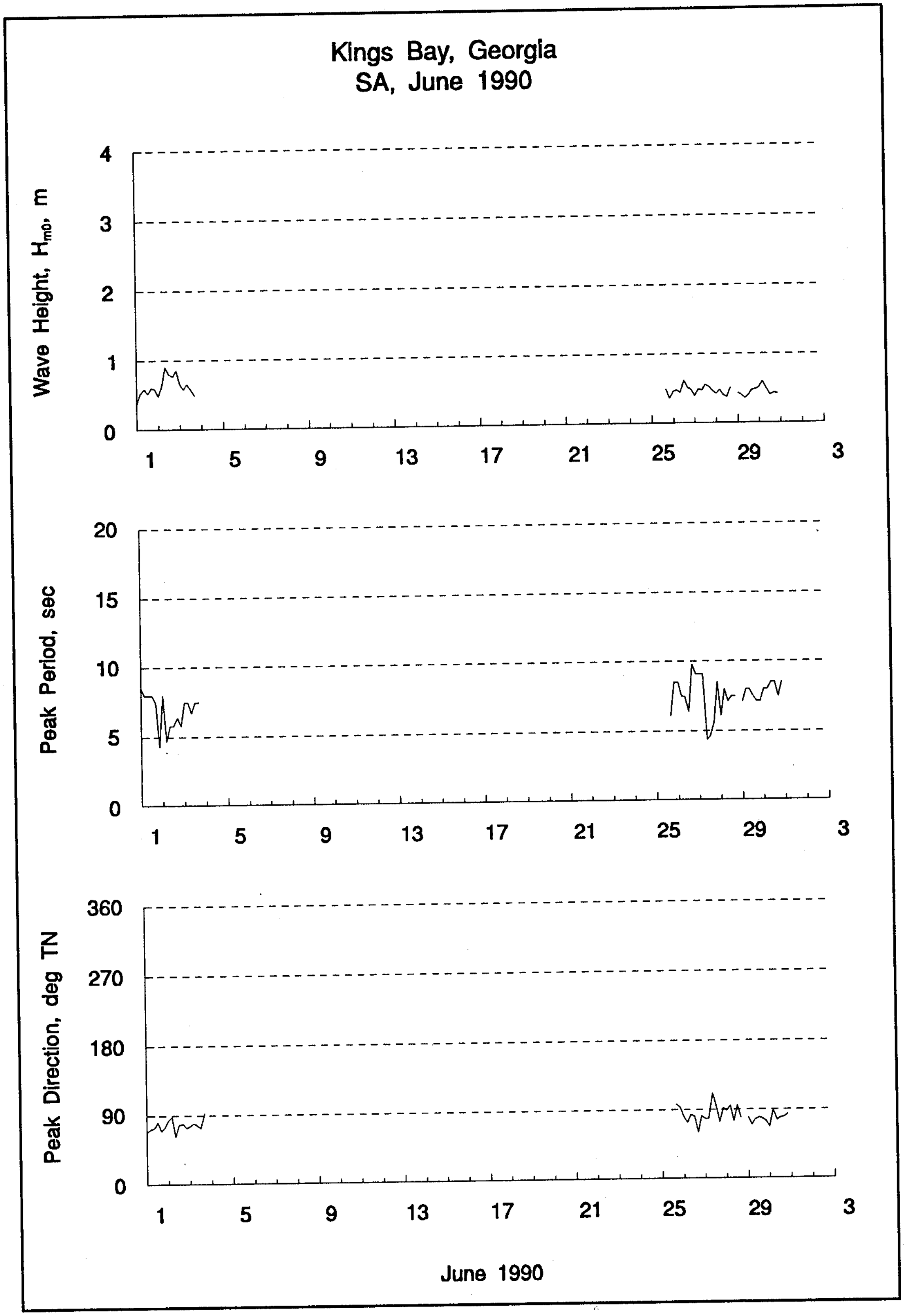
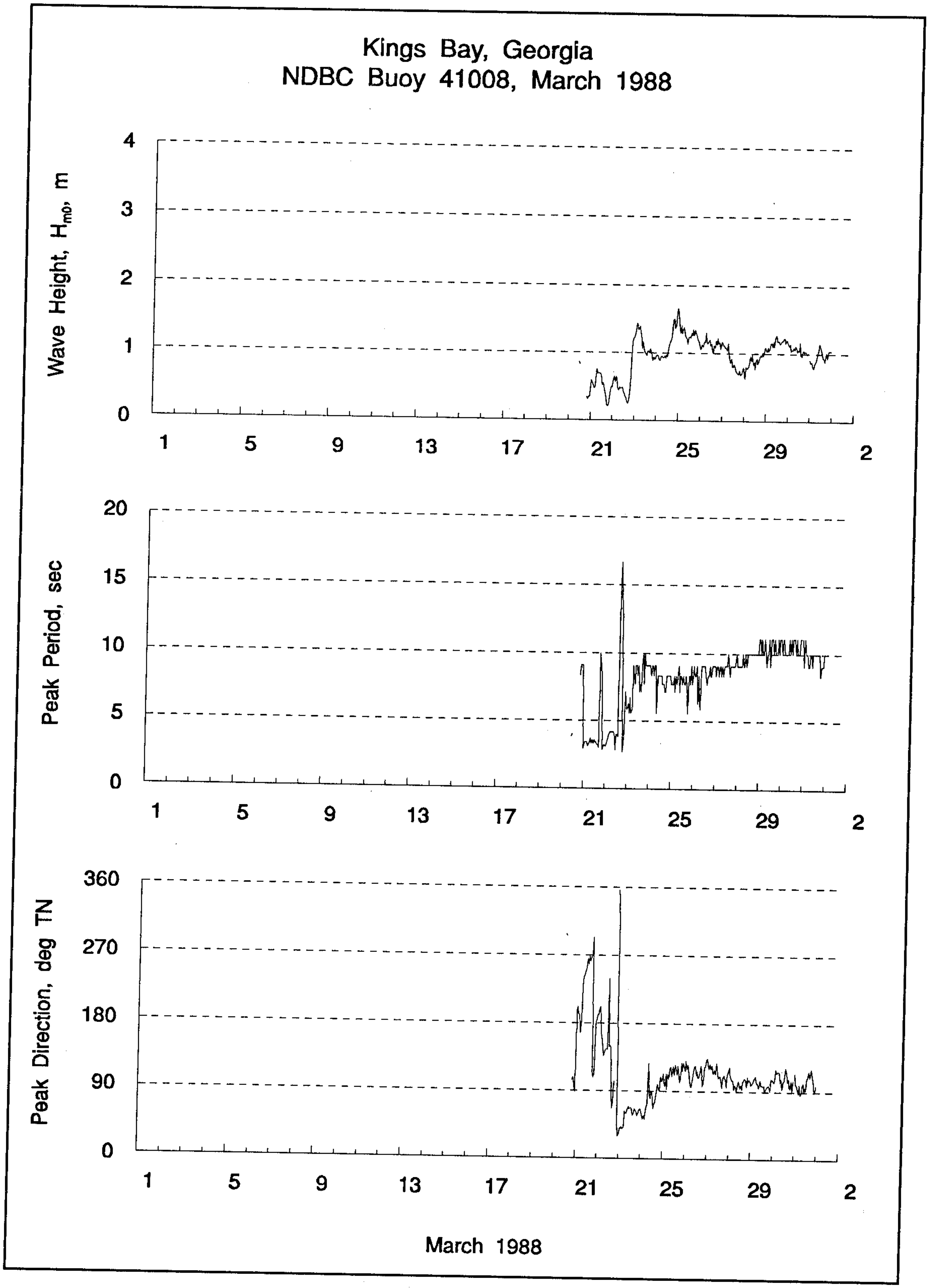

Kings Bay, Georgia
SA, June 1990
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
3
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
3
June 1990

Plate E14



Kings Bay, Georgia
NDBC Buoy 41008, March 1988
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
March 1988

Plate E15

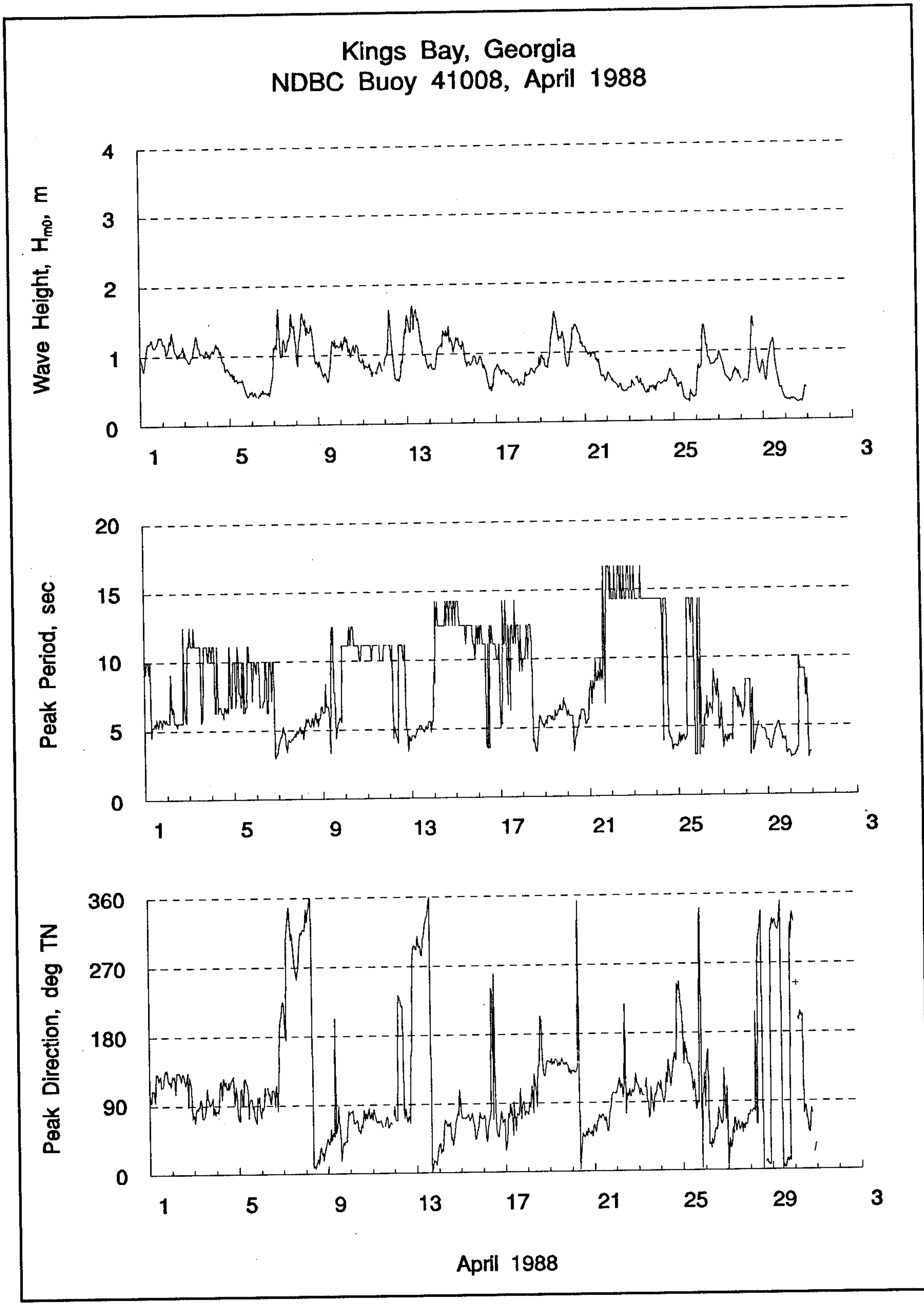
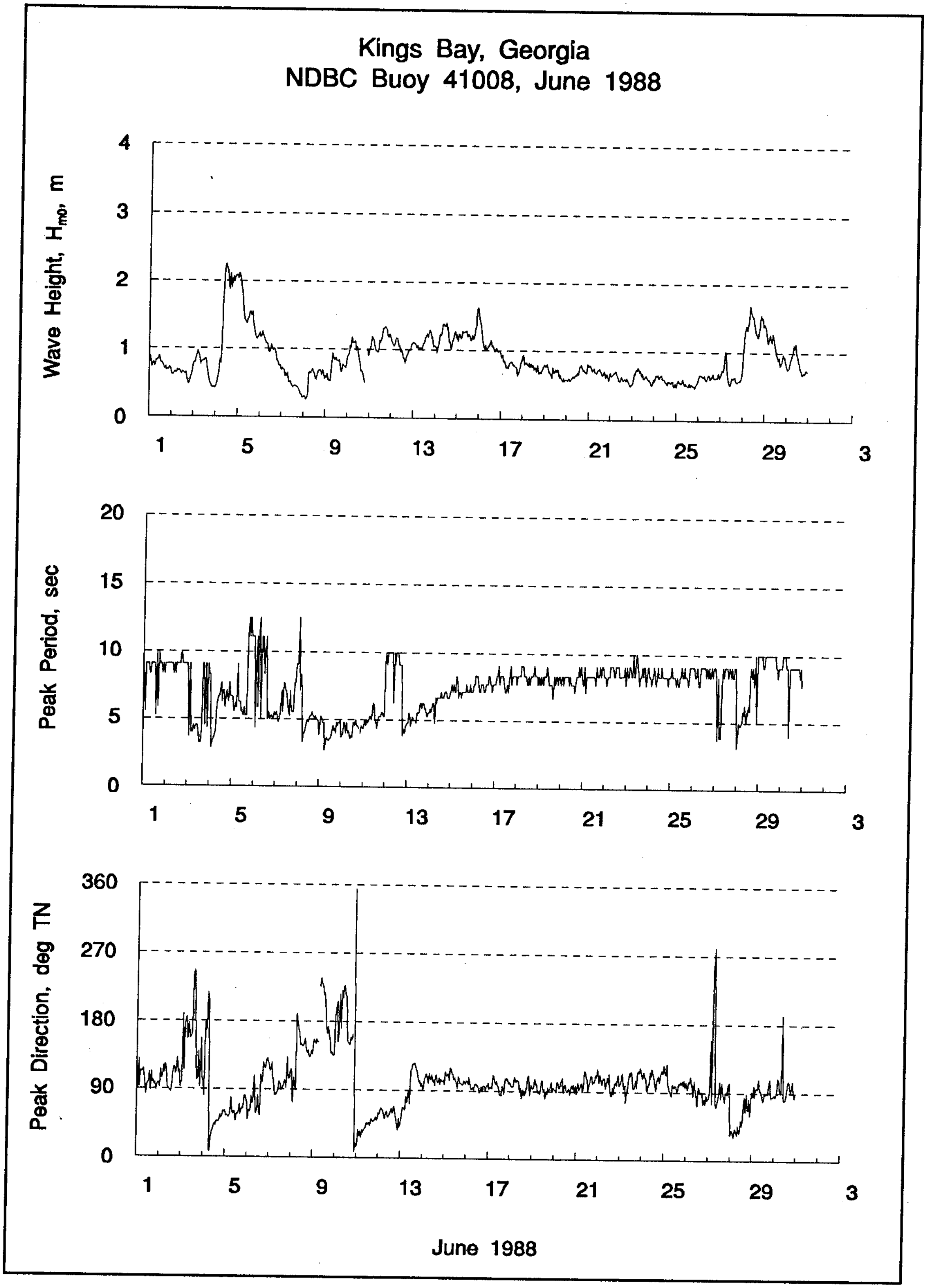
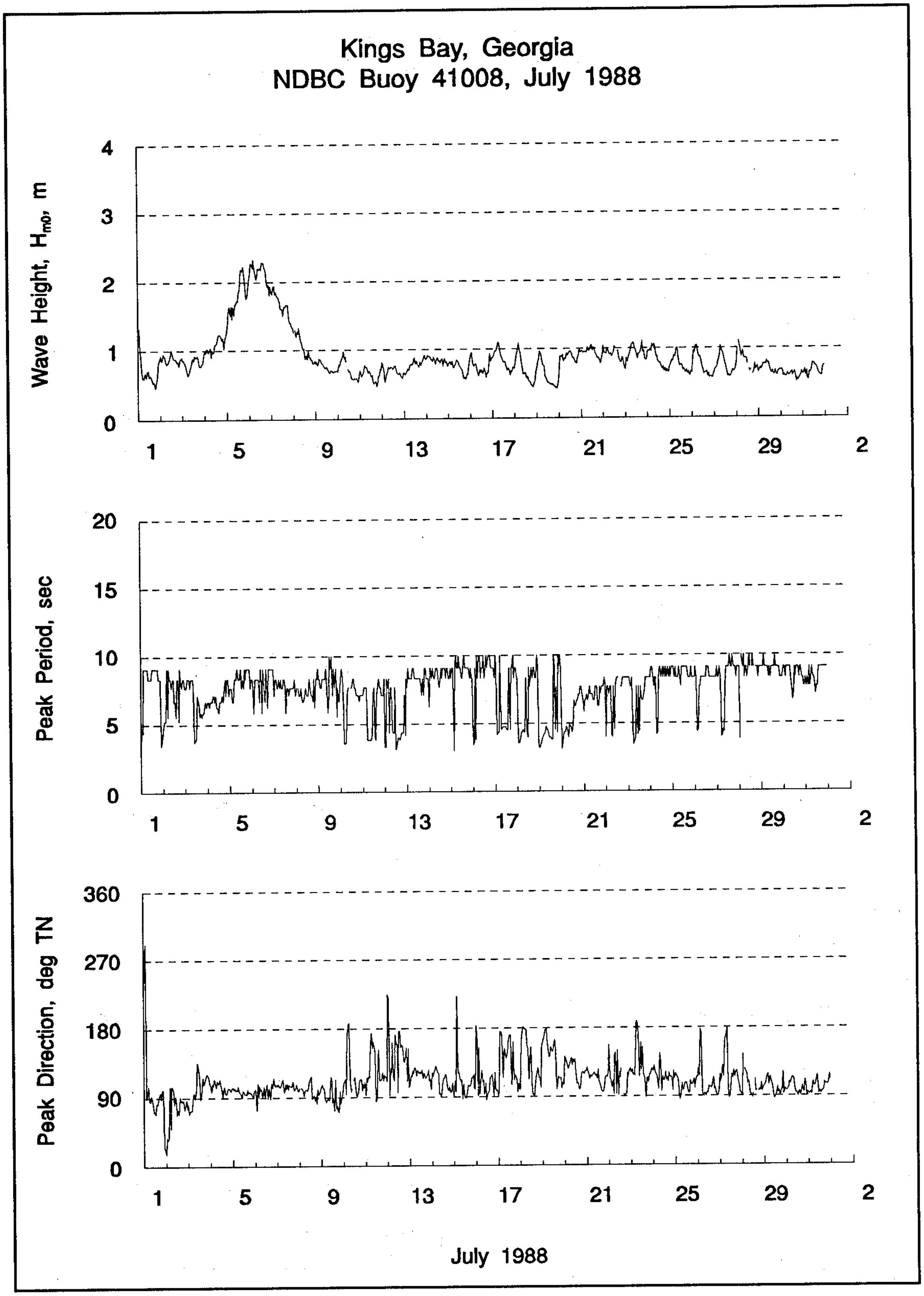

Kings Bay, Georgia
NDBC Buoy 41008, April 1988
Wave Height, H_{m0}, m
4
3
2
1
0
1 5 9 13 17 21 25 29 3
Peak Period, sec
20
15
10
5
0
1 5 9 13 17 21 25 29 3
Peak Direction, deg TN
360
270
180
90
0
1 5 9 13 17 21 25 29 3
April 1988

Plate E16



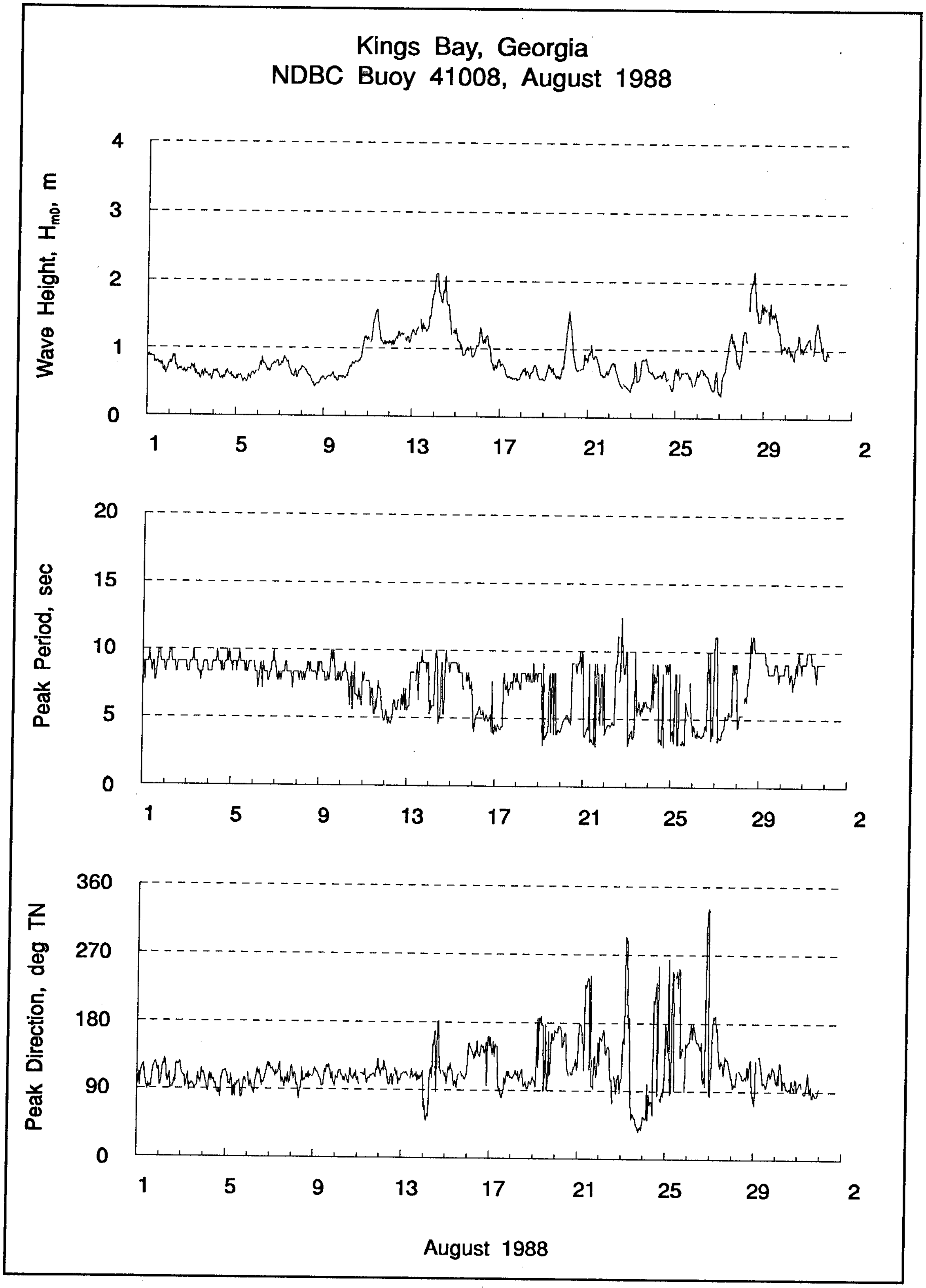
Kings Bay, Georgia
NDBC Buoy 41008, June 1988
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
3
Peak Period, sec
0
5
10
15
20
1
5
9
13
17
21
25
29
3
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
3
June 1988

Plate E17



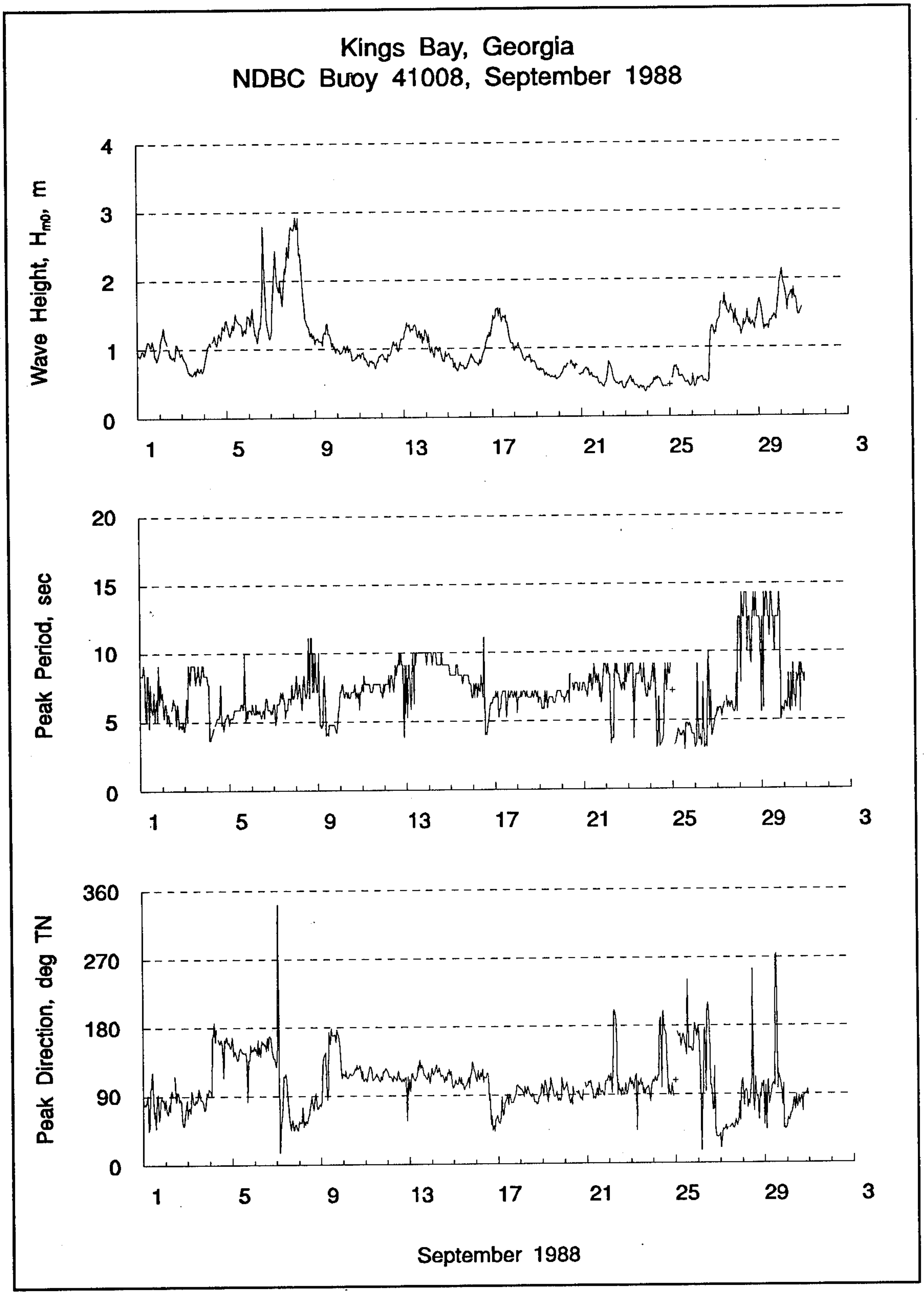
Kings Bay, Georgia
NDBC Buoy 41008, July 1988
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
July 1988

Plate E18



Kings Bay, Georgia
NDBC Buoy 41008, August 1988
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
August 1988

Plate E19



Kings Bay, Georgia
NDBC Buoy 41008, September 1988
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
3
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
September 1988

Plate E20

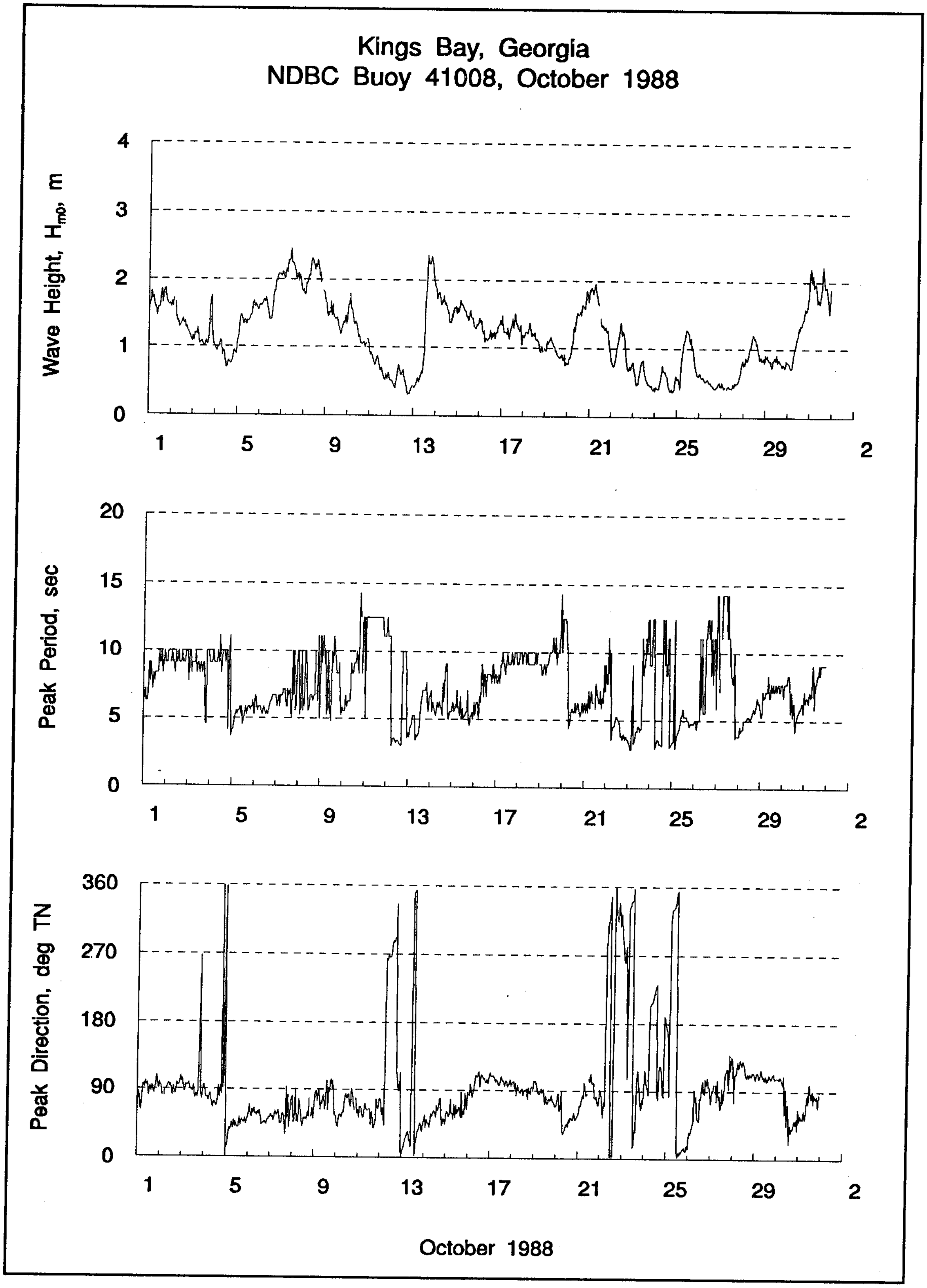

Kings Bay, Georgia
NDBC Buoy 41008, October 1988
Wave Height, H_{m0}, m
0
1
2
3
4
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
October 1988

Plate E21

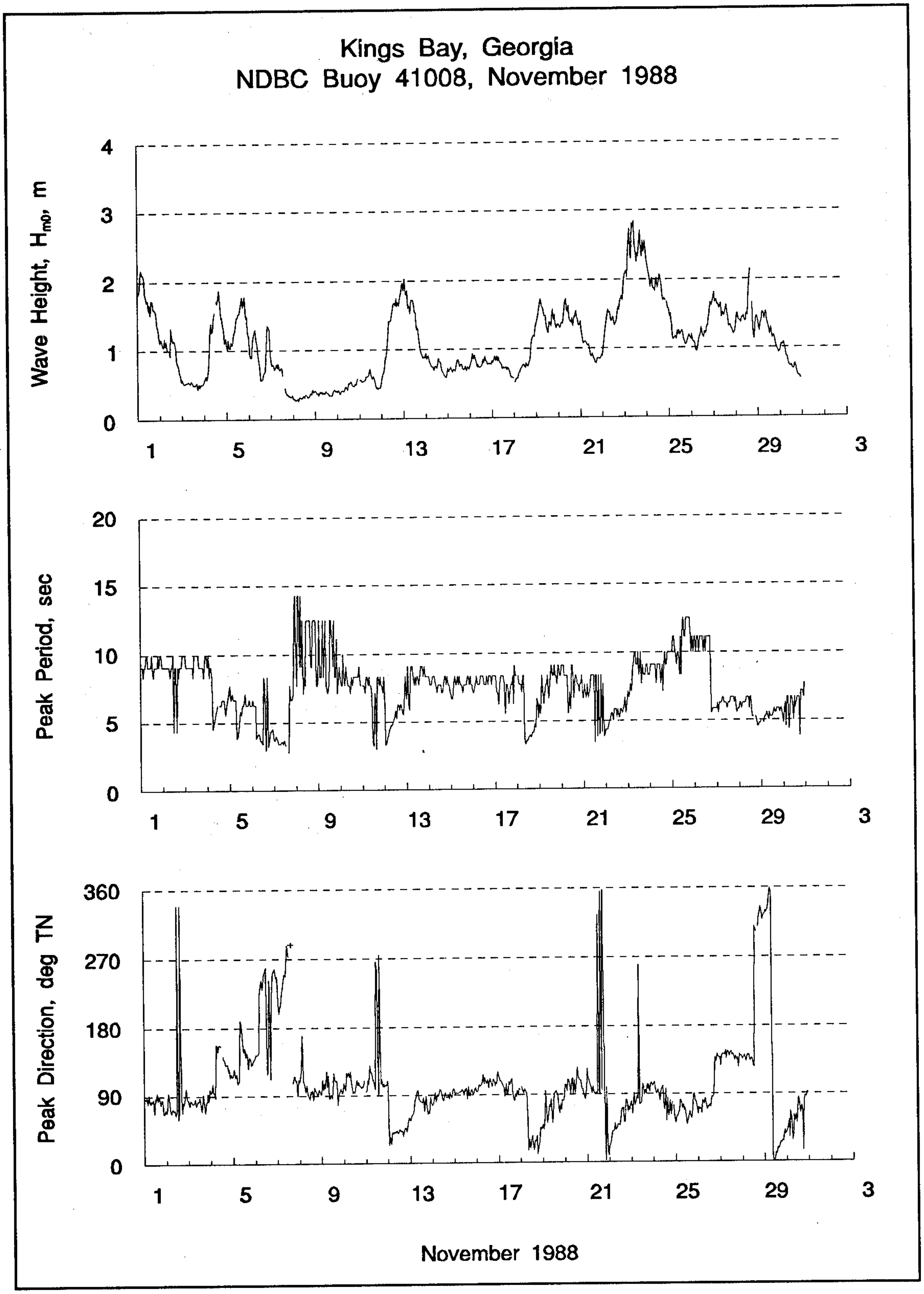

Kings Bay, Georgia
NDBC Buoy 41008, November 1988
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
3
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
3
November 1988

Plate E22

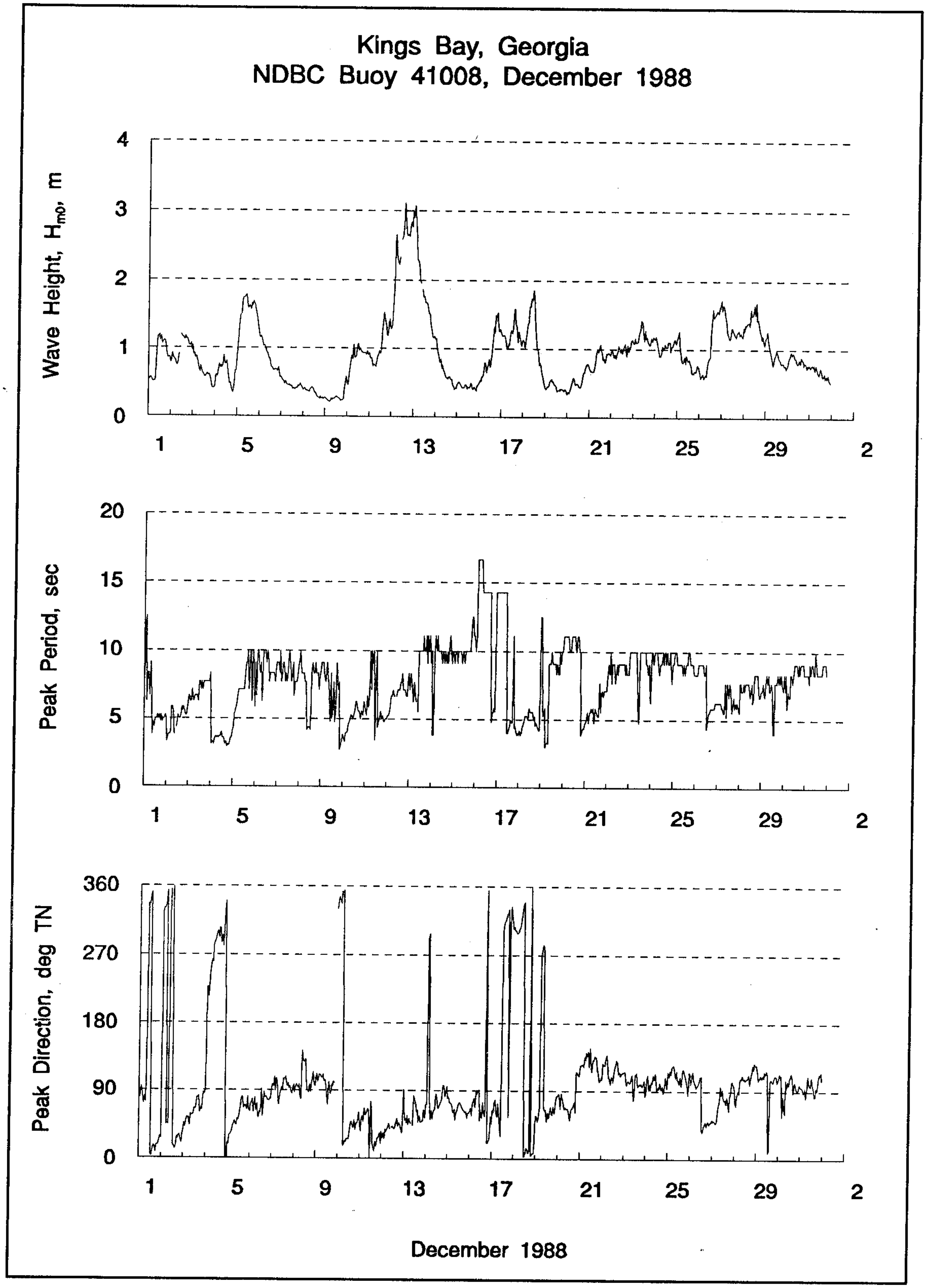
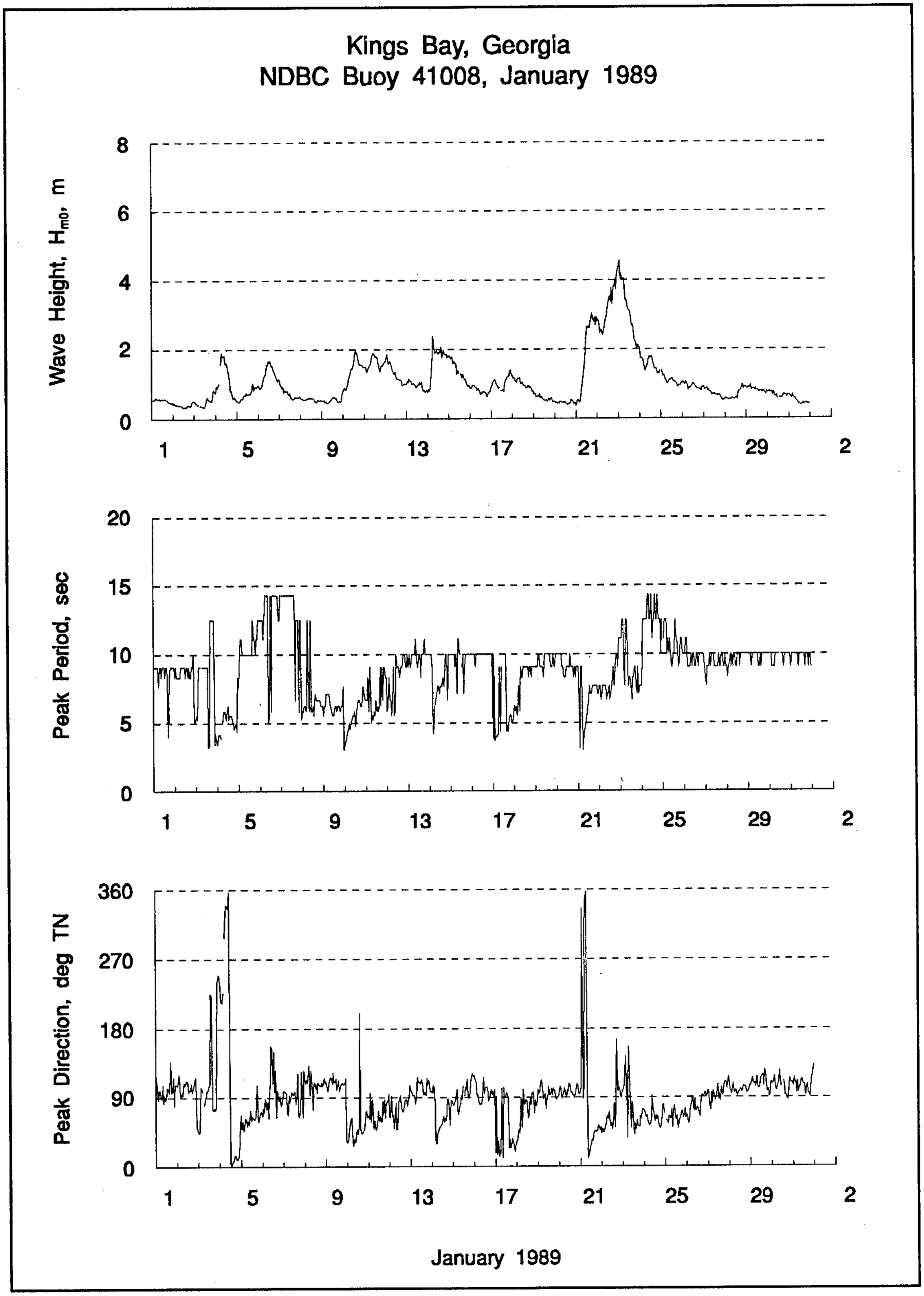

Kings Bay, Georgia
NDBC Buoy 41008, December 1988
Wave Height, H_{m0}, m
0
1
2
3
4
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
December 1988

Plate E23



Kings Bay, Georgia
NDBC Buoy 41008, January 1989
Wave Height, H_{m0}, m
8
6
4
2
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
January 1989

Plate E24

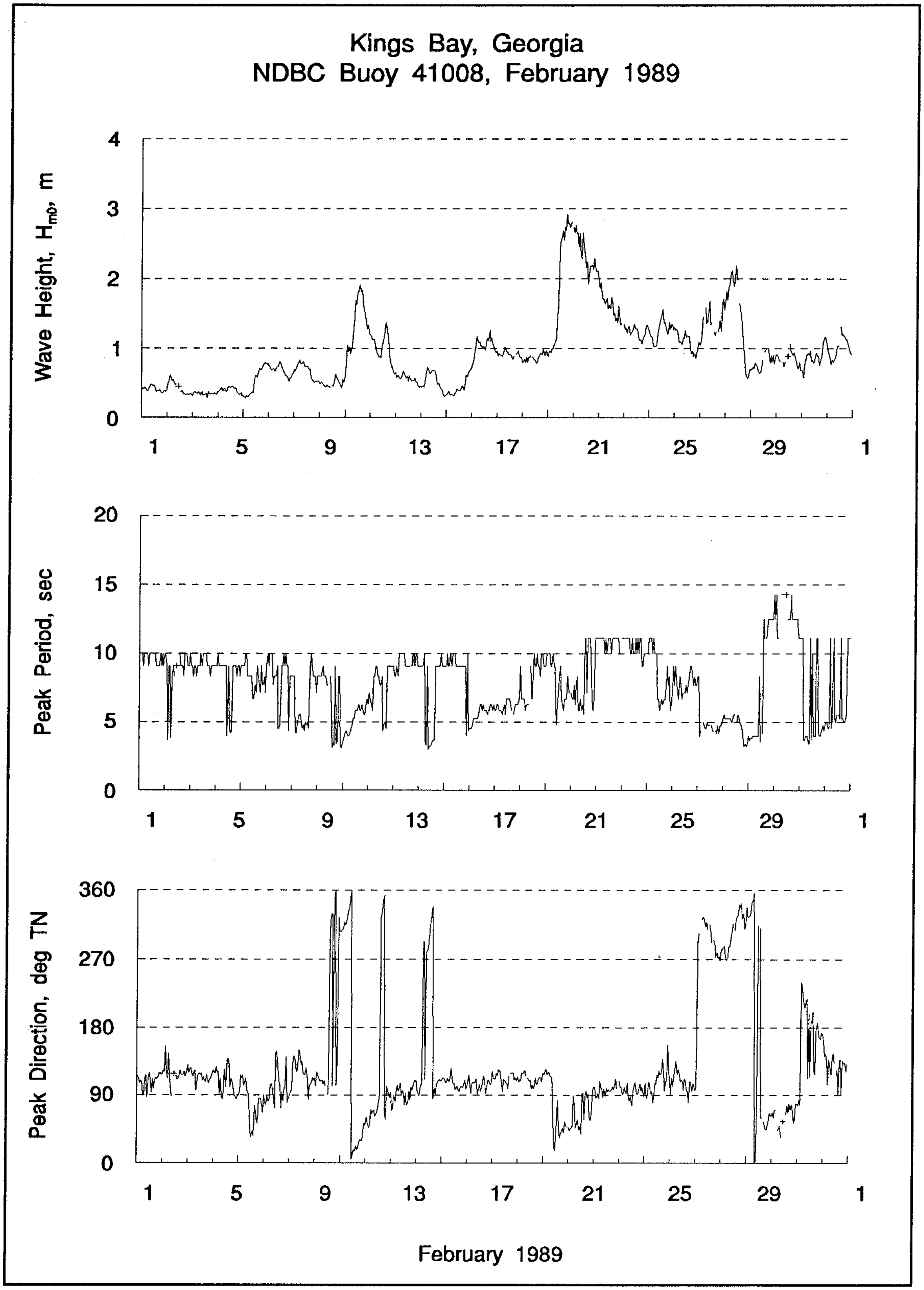

Kings Bay, Georgia
NDBC Buoy 41008, February 1989
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
1
Peak Period, sec
20
15
10
5
0
Peak Direction, deg TN
360
270
180
90
0
February 1989

Plate E25

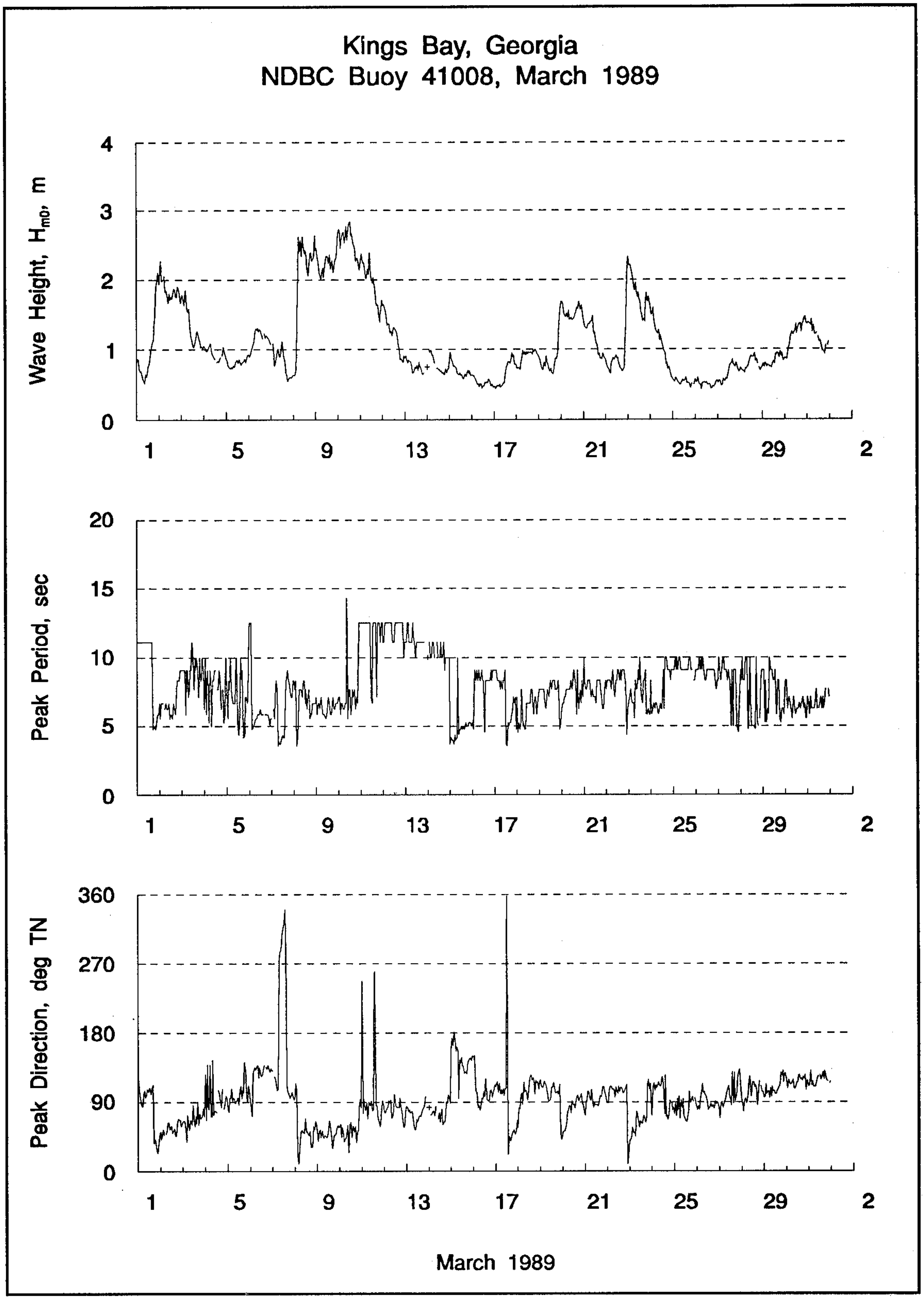

Kings Bay, Georgia
NDBC Buoy 41008, March 1989
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
March 1989

Plate E26

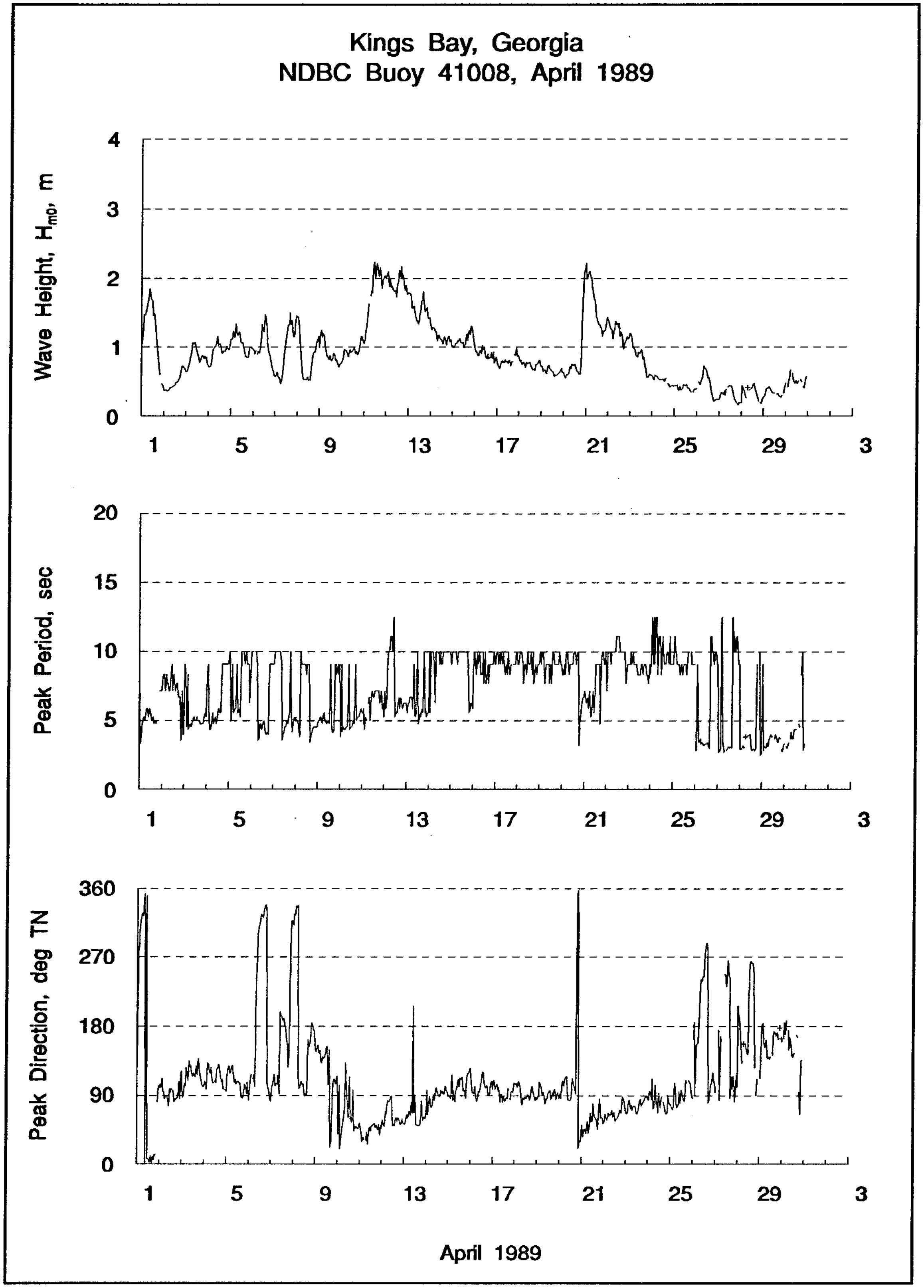
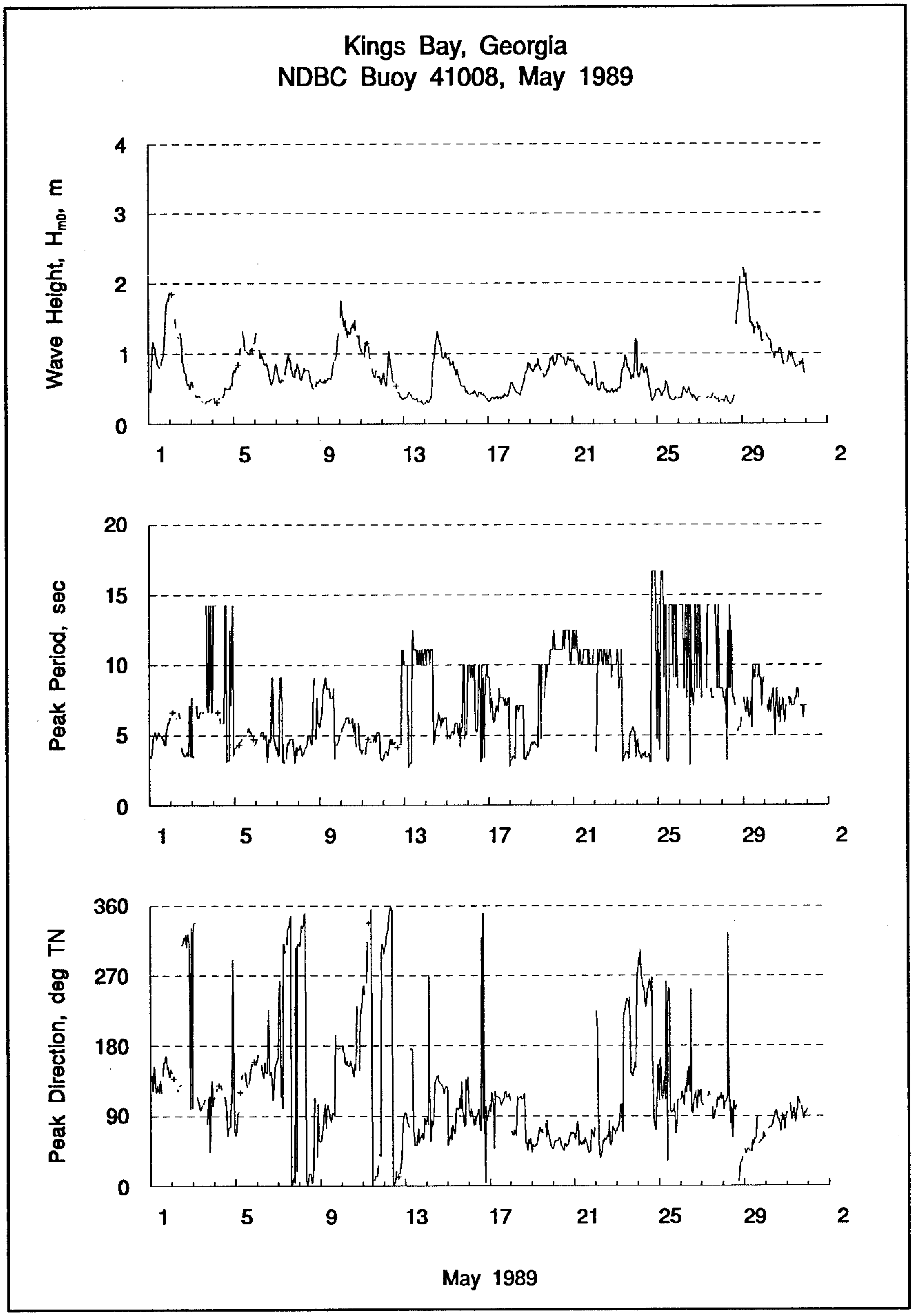

Kings Bay, Georgia
NDBC Buoy 41008, April 1989
Wave Height, H_{m0}, m
Peak Period, sec
Peak Direction, deg TN
April 1989

Plate E27



Kings Bay, Georgia
NDBC Buoy 41008, May 1989
Wave Height, H_{m0}, m
0
1
2
3
4
1 5 9 13 17 21 25 29 2
Peak Period, sec
0
5
10
15
20
1 5 9 13 17 21 25 29 2
Peak Direction, deg TN
0
90
180
270
360
1 5 9 13 17 21 25 29 2
May 1989

Plate E28

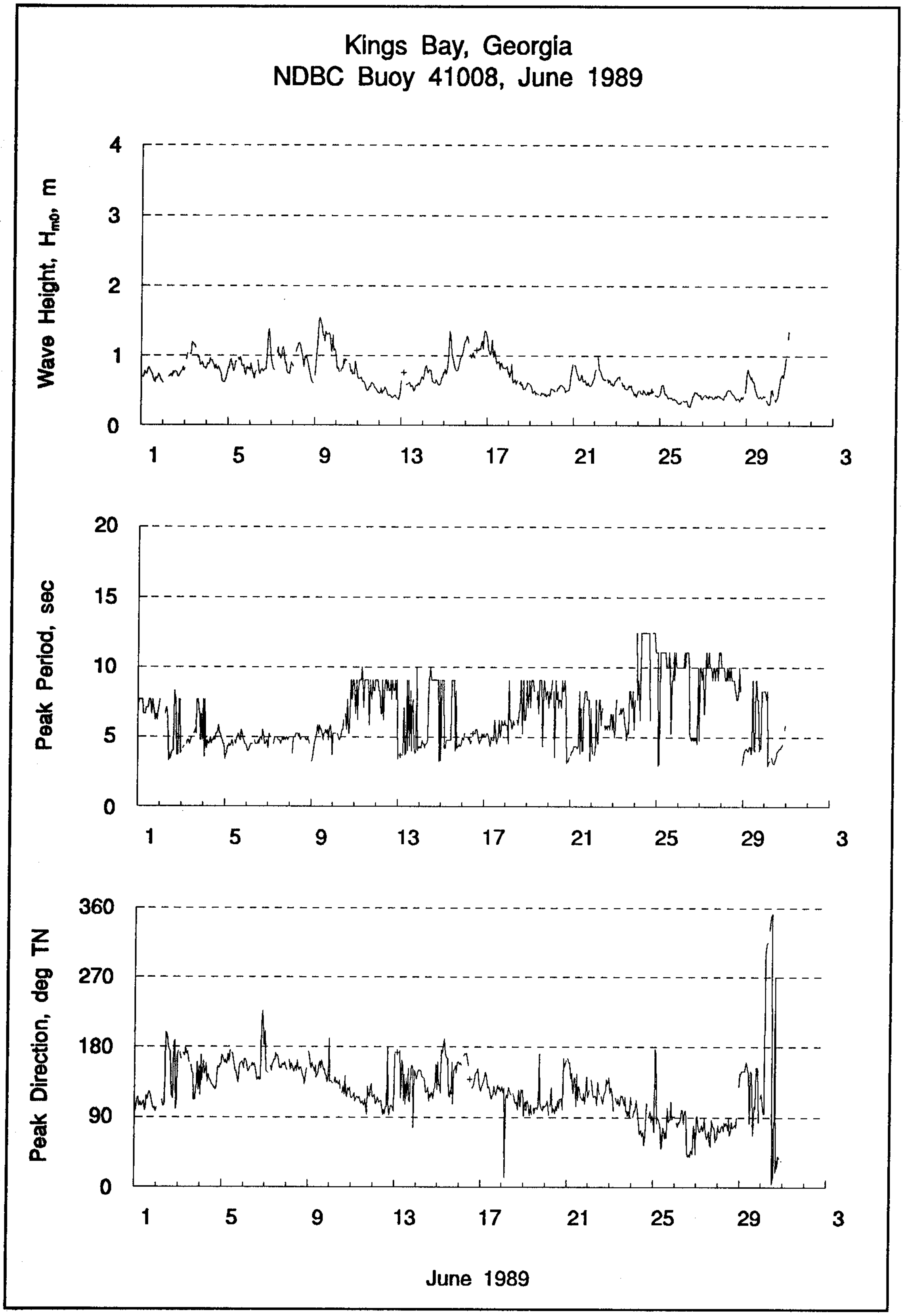
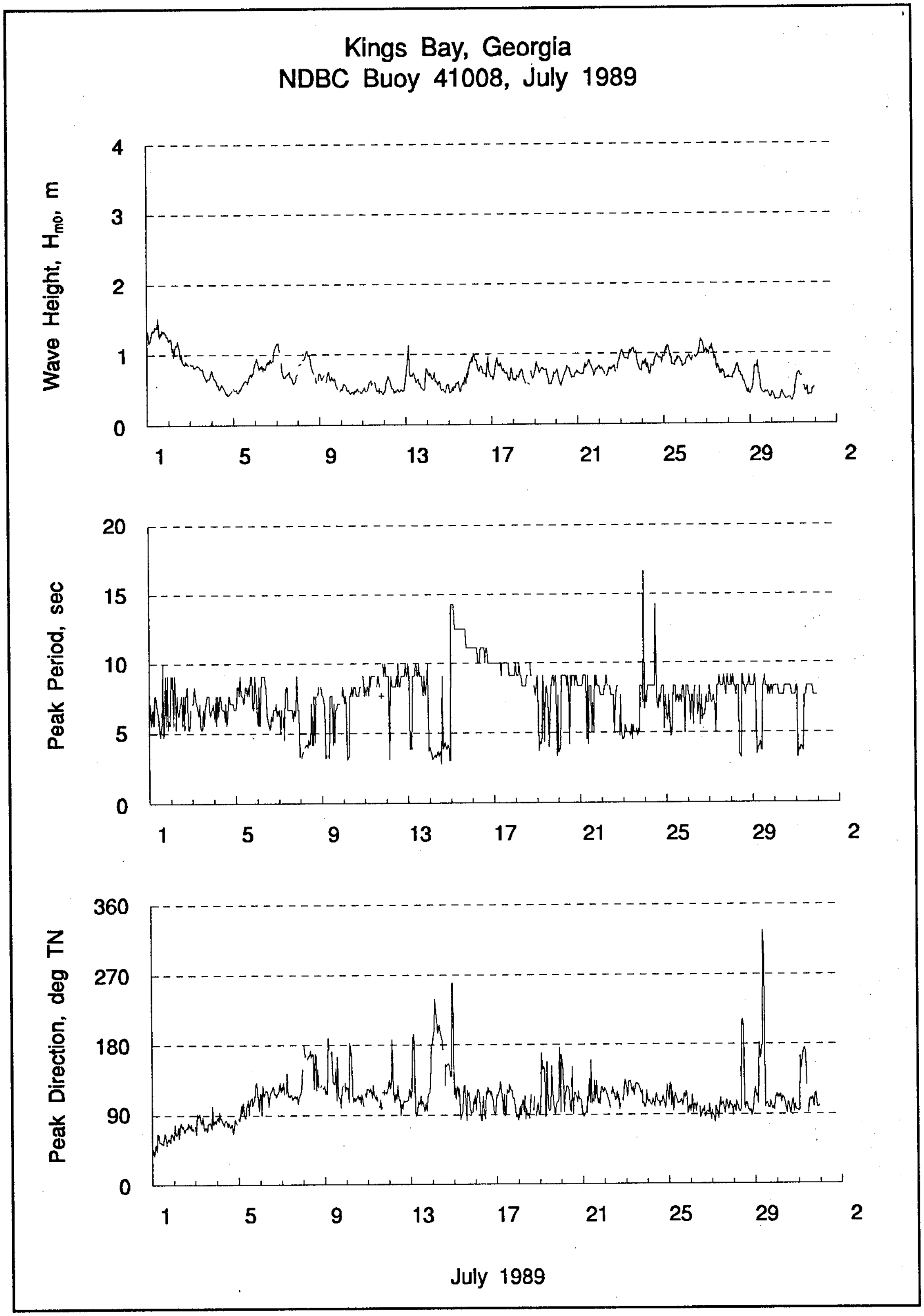
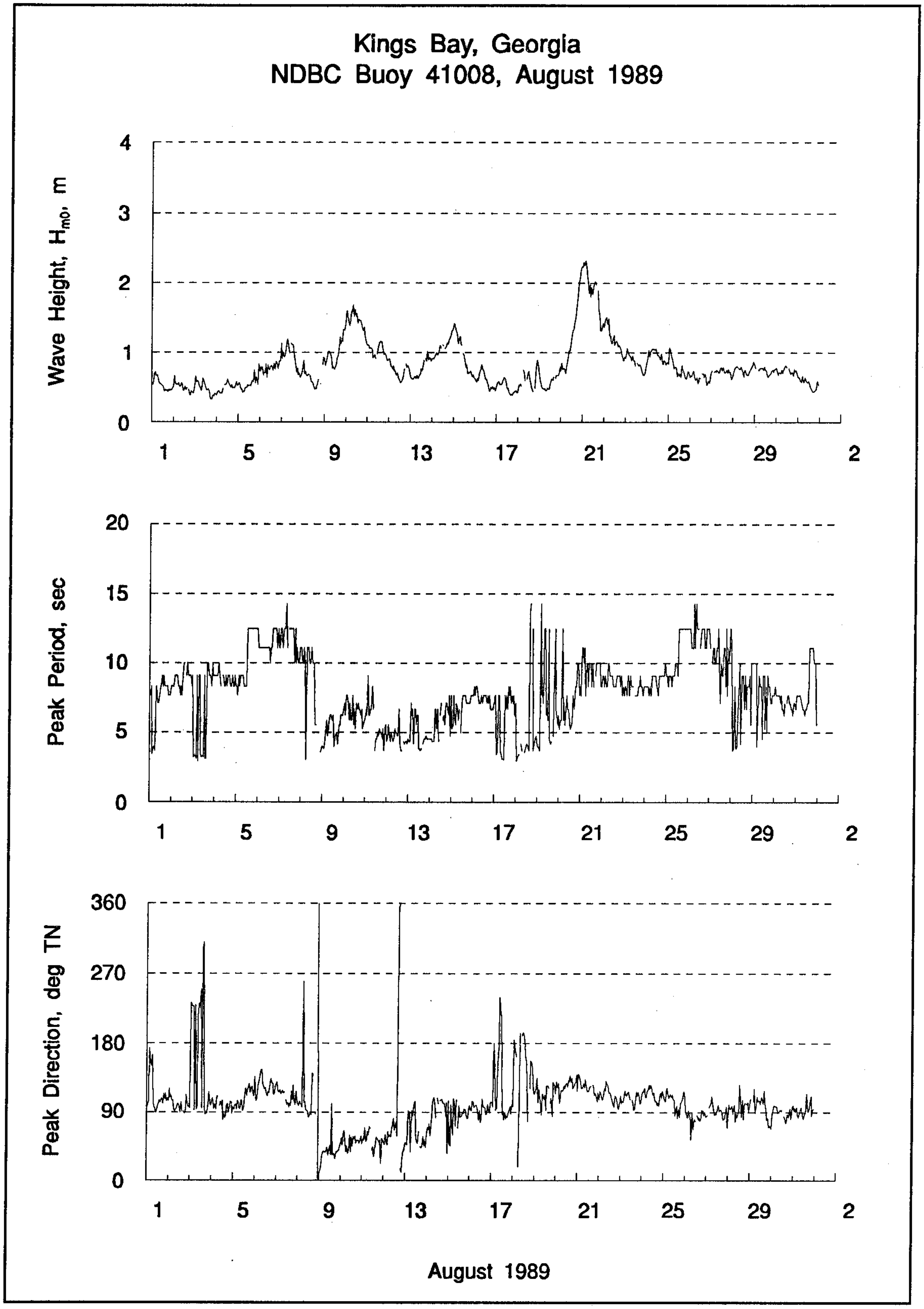

Kings Bay, Georgia
NDBC Buoy 41008, June 1989
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
Peak Direction, deg TN
360
270
180
90
0
June 1989

Plate E29



Kings Bay, Georgia
NDBC Buoy 41008, July 1989
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
July 1989

Plate E30



Kings Bay, Georgia
NDBC Buoy 41008, August 1989
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
August 1989

Plate E31

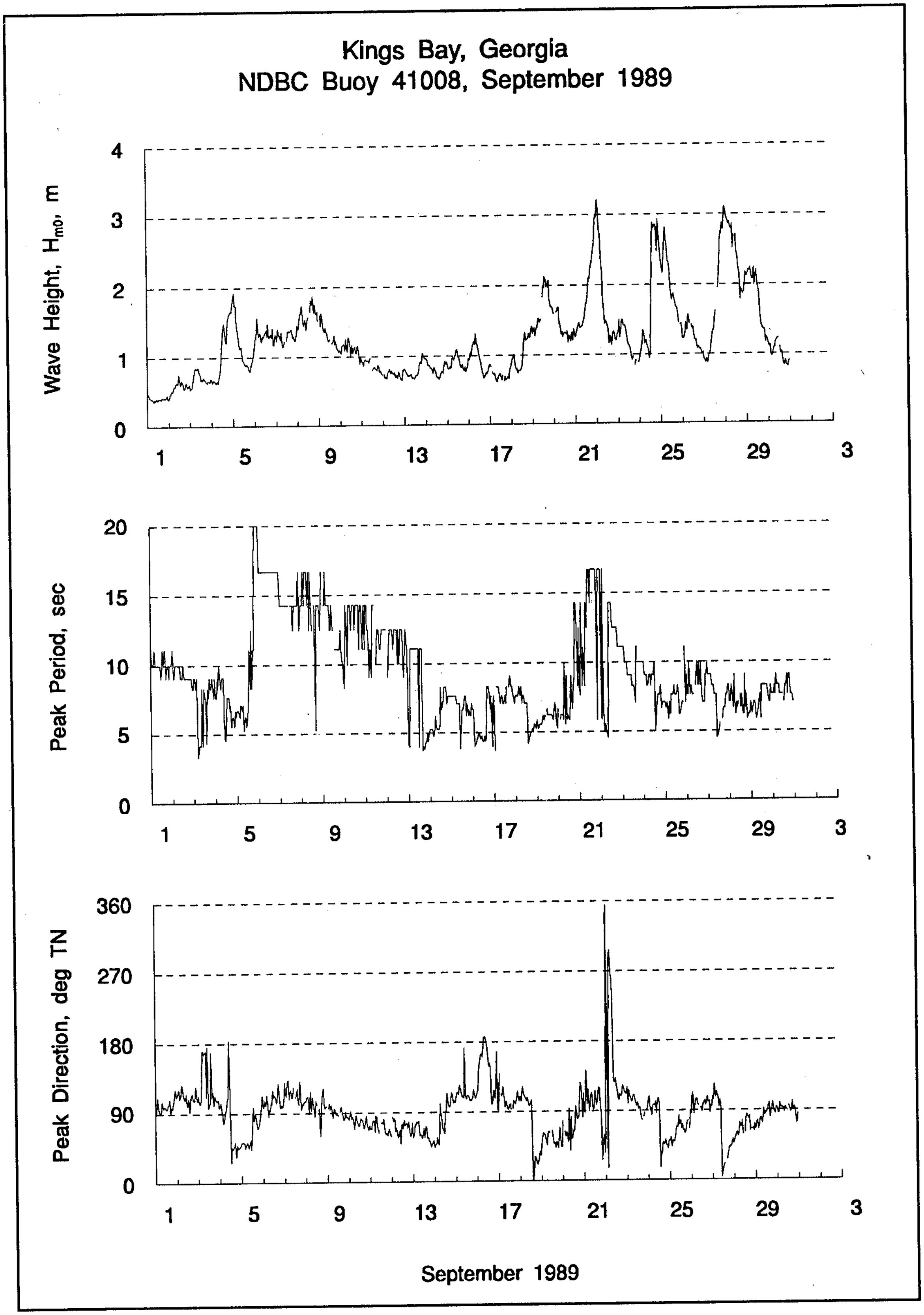

Kings Bay, Georgia
NDBC Buoy 41008, September 1989
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
3
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
September 1989

Plate E32

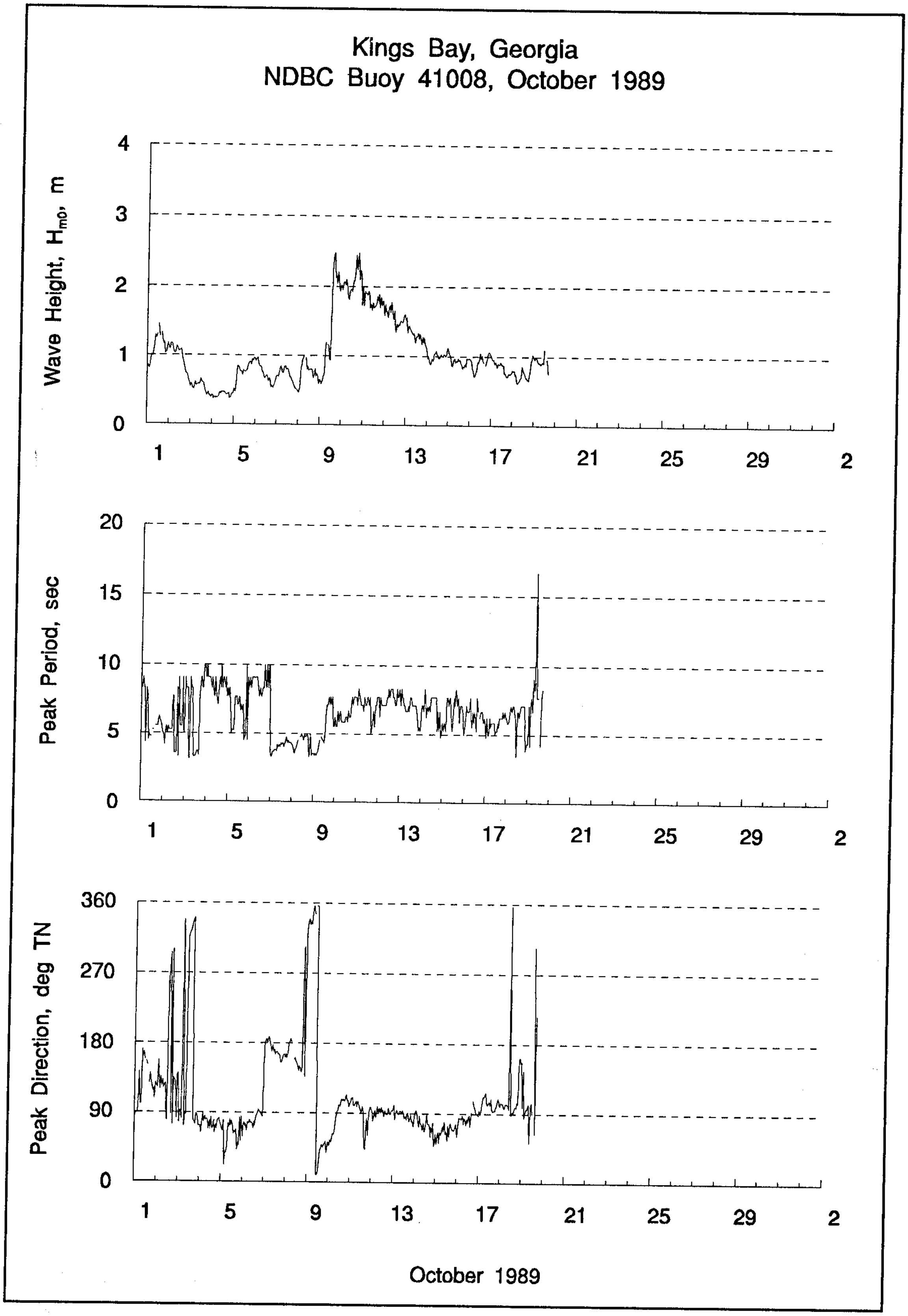
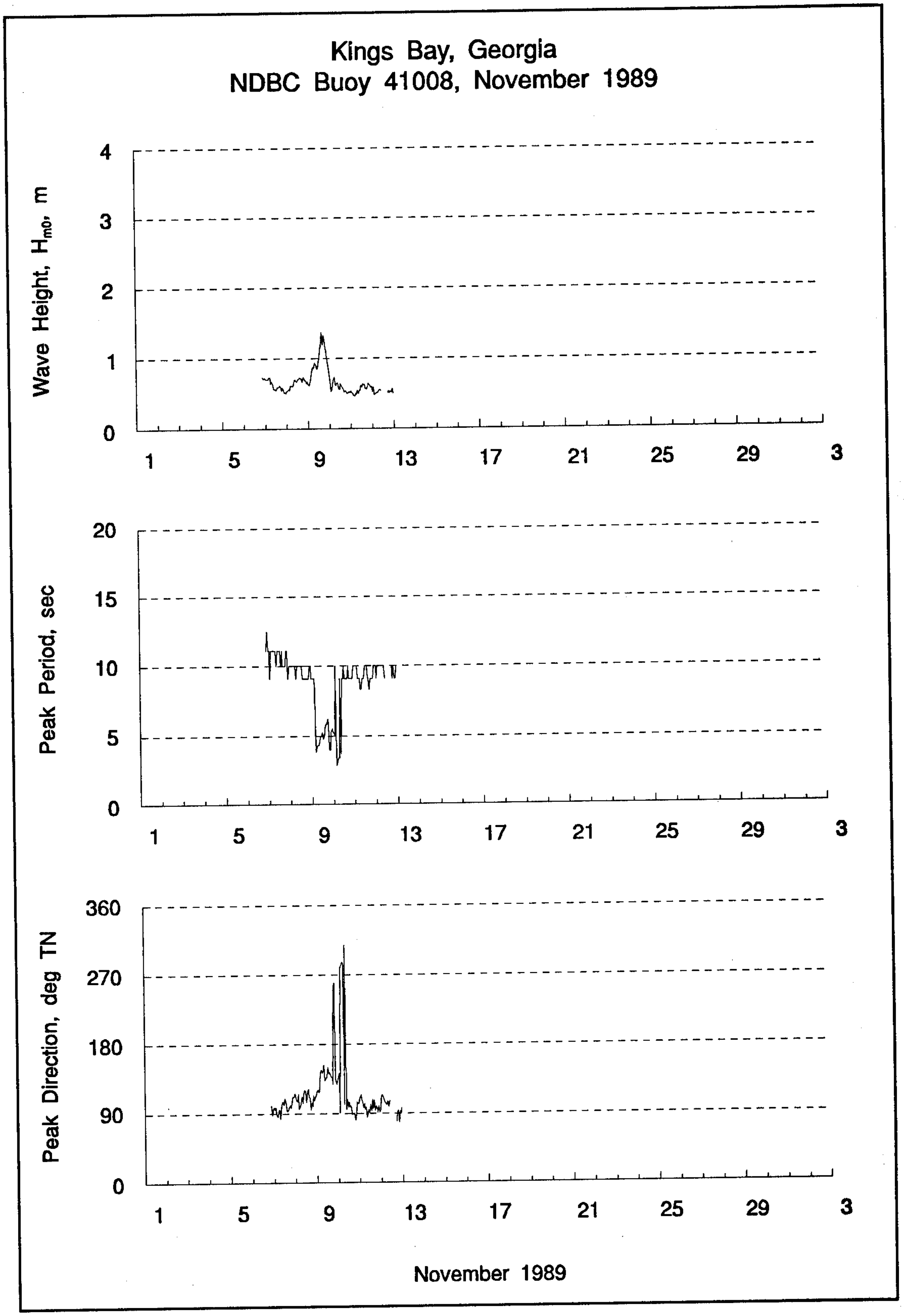
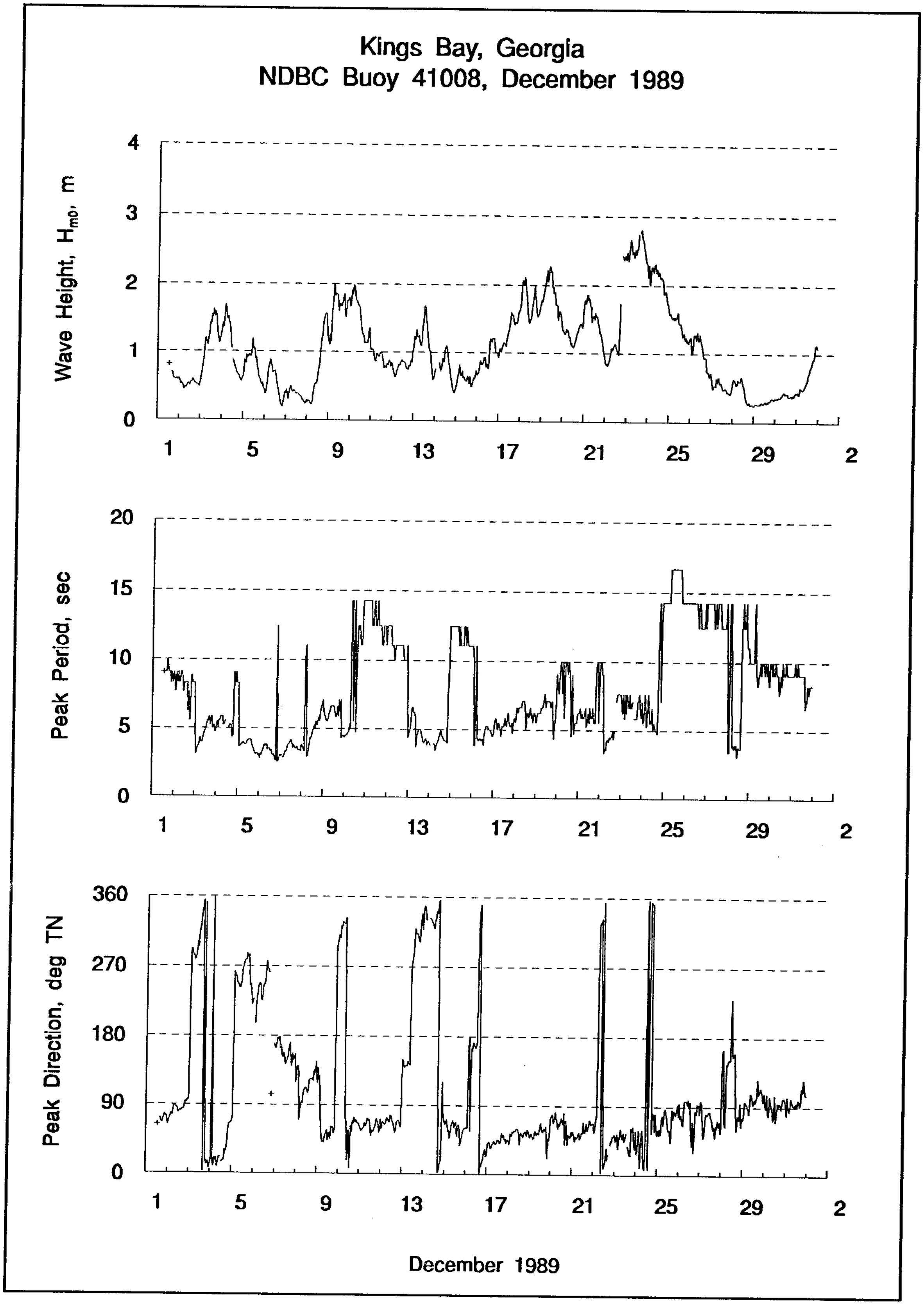

Kings Bay, Georgia
NDBC Buoy 41008, October 1989
Wave Height, H_{mo}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
October 1989

Plate E33



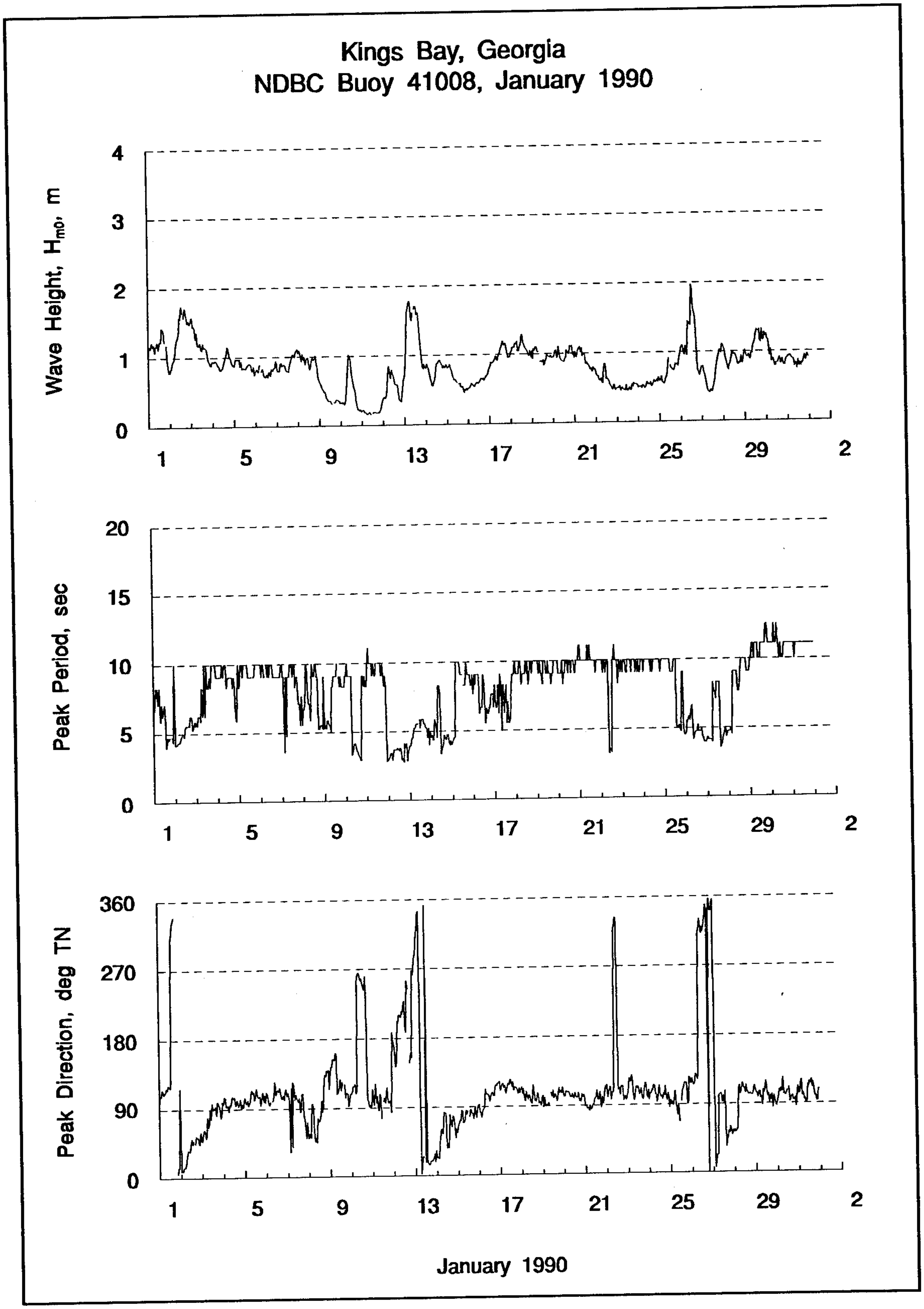
Kings Bay, Georgia
NDBC Buoy 41008, November 1989
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
Peak Direction, deg TN
360
270
180
90
0
November 1989

Plate E34



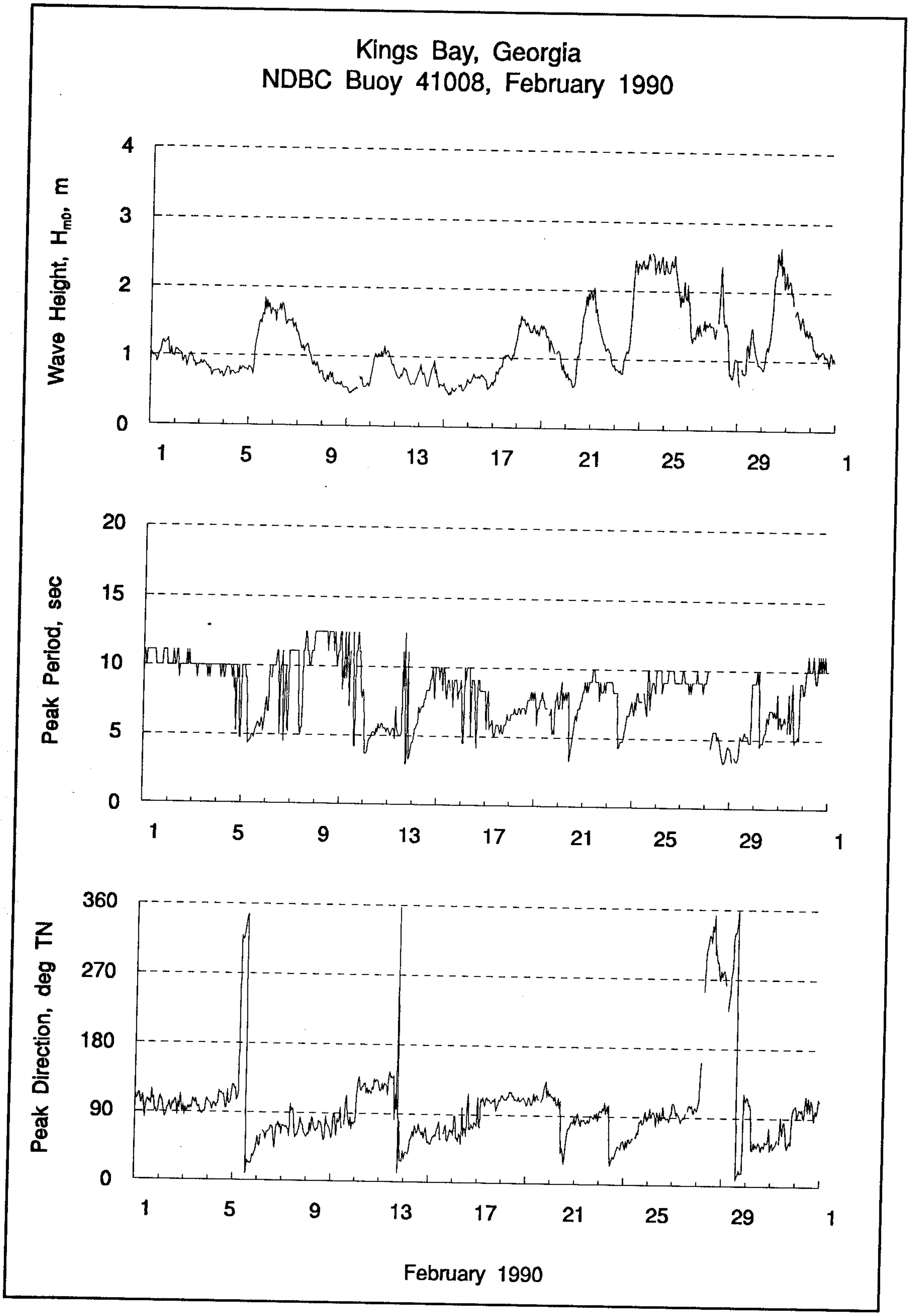
Kings Bay, Georgia
NDBC Buoy 41008, December 1989
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
December 1989

Plate E35



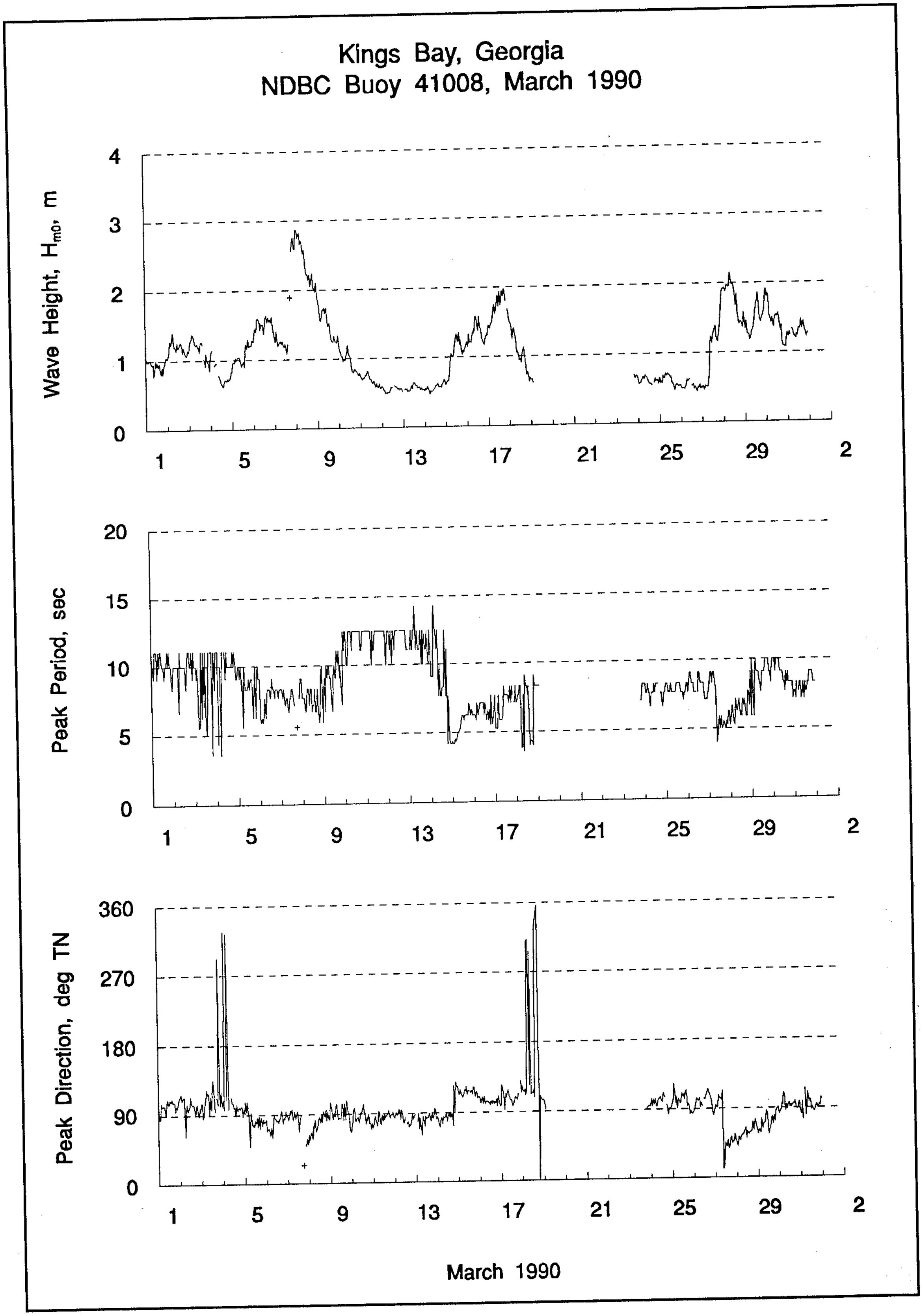
Kings Bay, Georgia
NDBC Buoy 41008, January 1990
Wave Height, H_{m0}, m
0
1
2
3
4
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
January 1990

Plate E36



Kings Bay, Georgia
NDBC Buoy 41008, February 1990
Wave Height, H_{m0}, m
0
1
2
3
4
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
1
February 1990

Plate E37



Kings Bay, Georgia
NDBC Buoy 41008, March 1990
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
March 1990

Plate E38

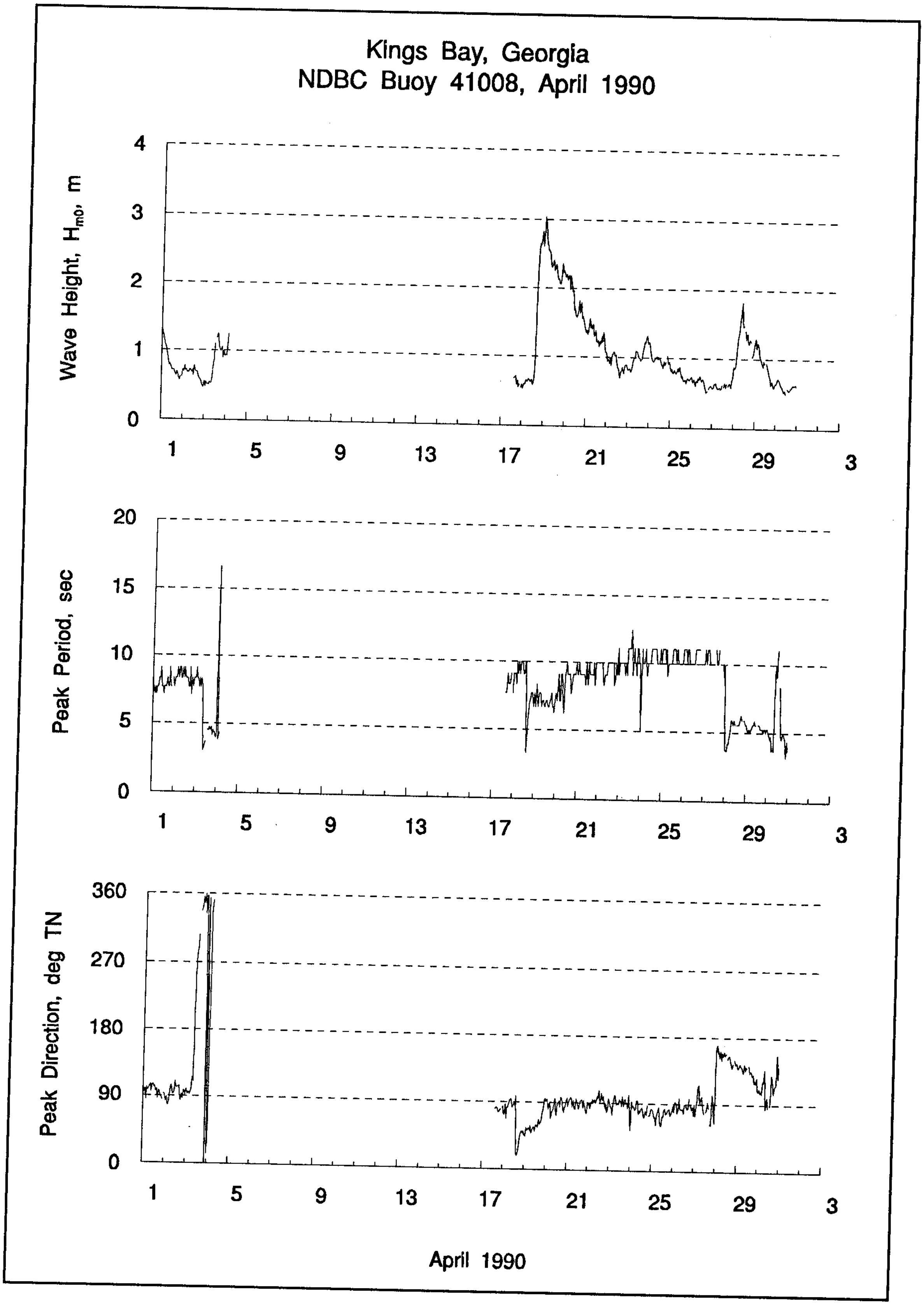

Kings Bay, Georgia
NDBC Buoy 41008, April 1990
Wave Height, Hm0, m
0
1
2
3
4
1 5 9 13 17 21 25 29 3
Peak Period, sec
0
5
10
15
20
1 5 9 13 17 21 25 29 3
Peak Direction, deg TN
0
90
180
270
360
1 5 9 13 17 21 25 29 3
April 1990

Plate E39

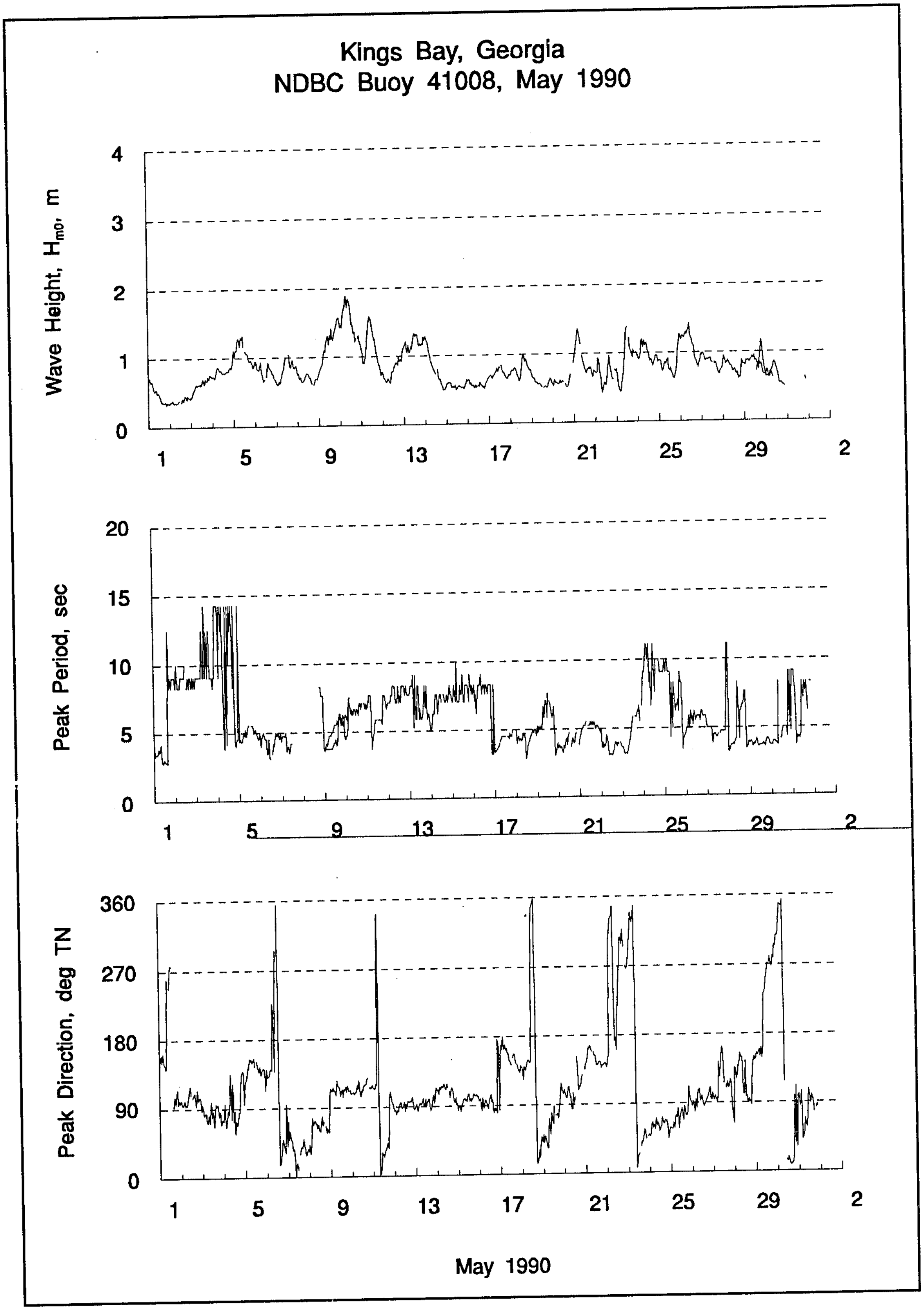

Kings Bay, Georgia
NDBC Buoy 41008, May 1990
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
May 1990

Plate E40

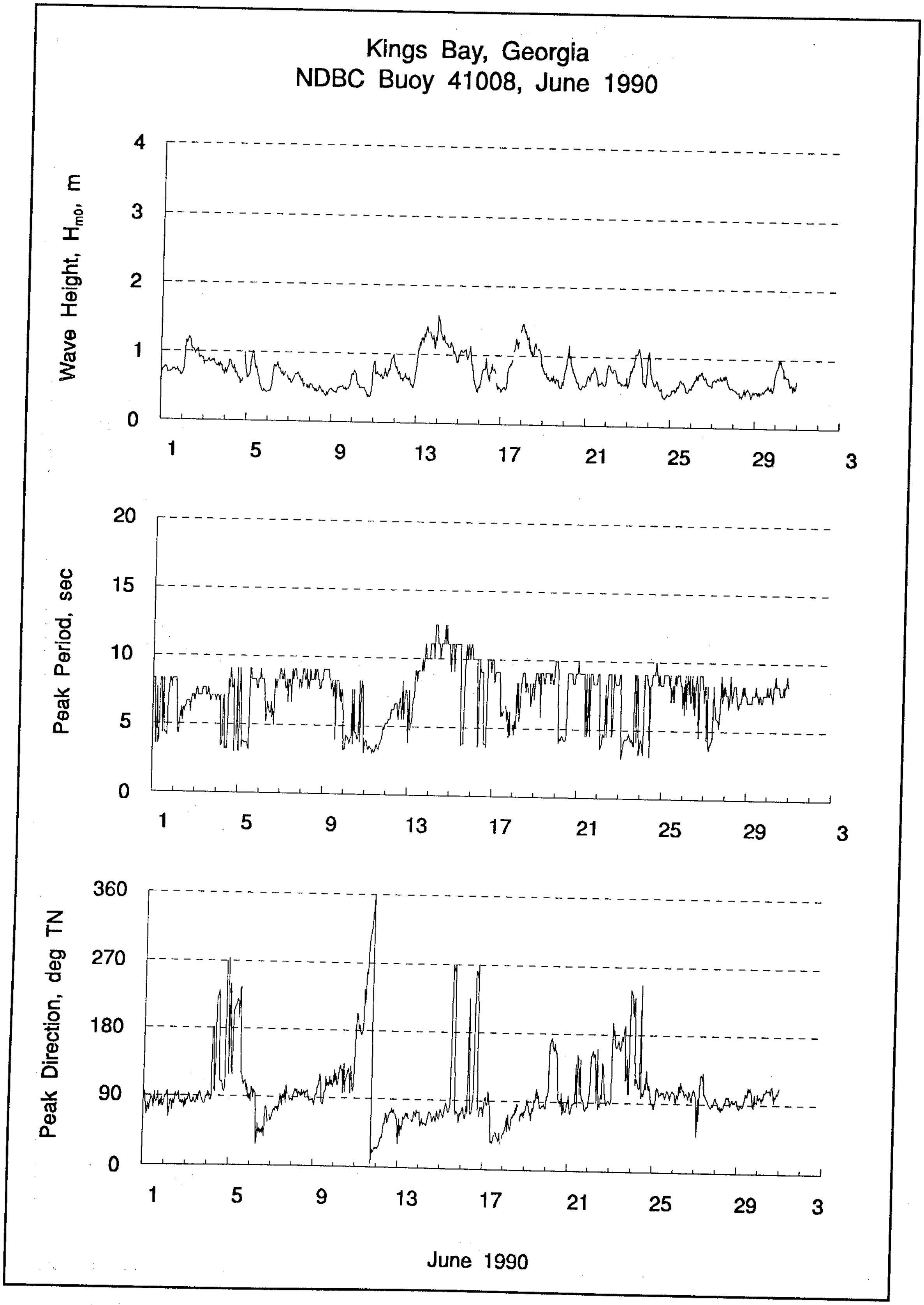

Kings Bay, Georgia
NDBC Buoy 41008, June 1990
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
3
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
June 1990

Plate E41

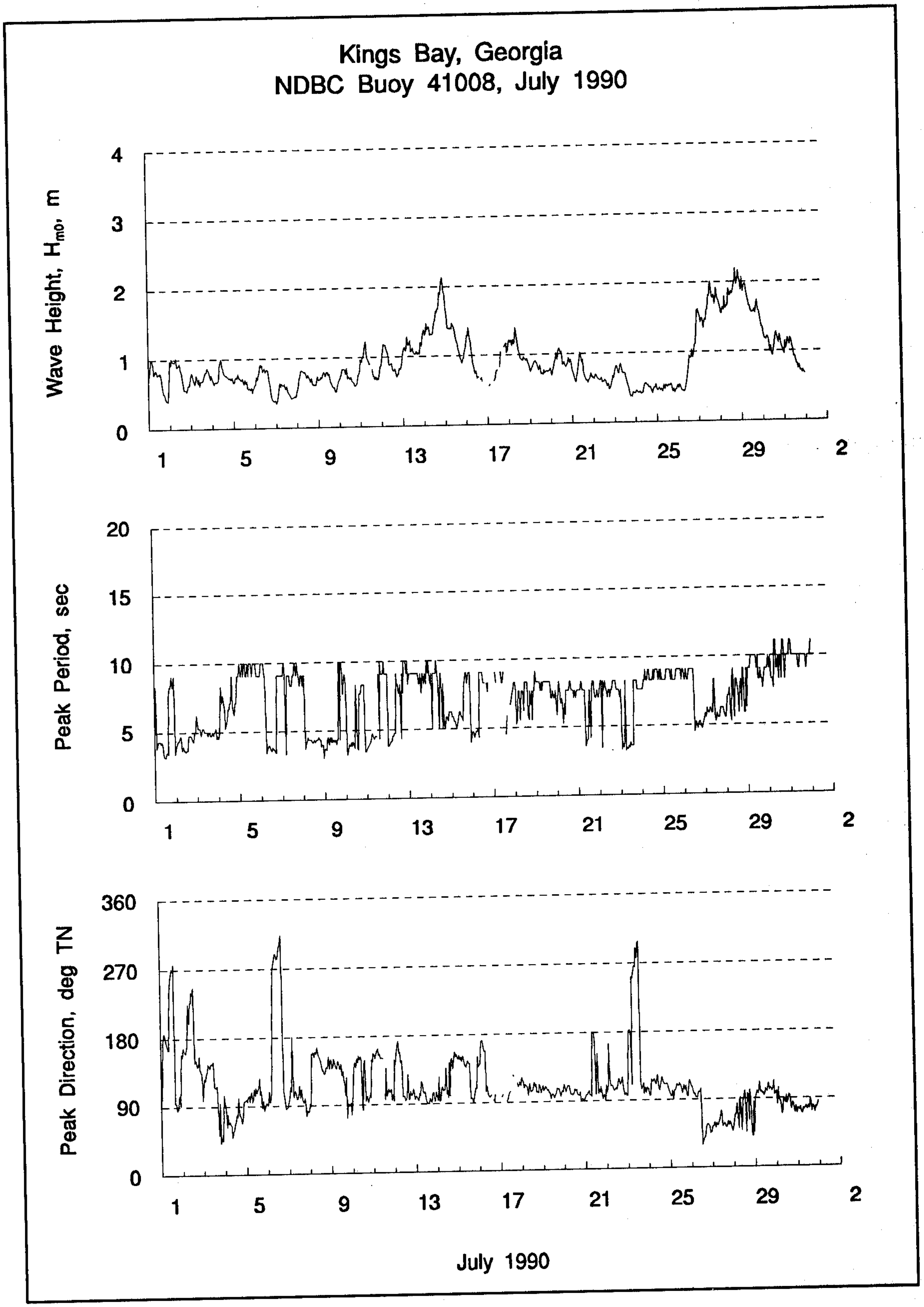
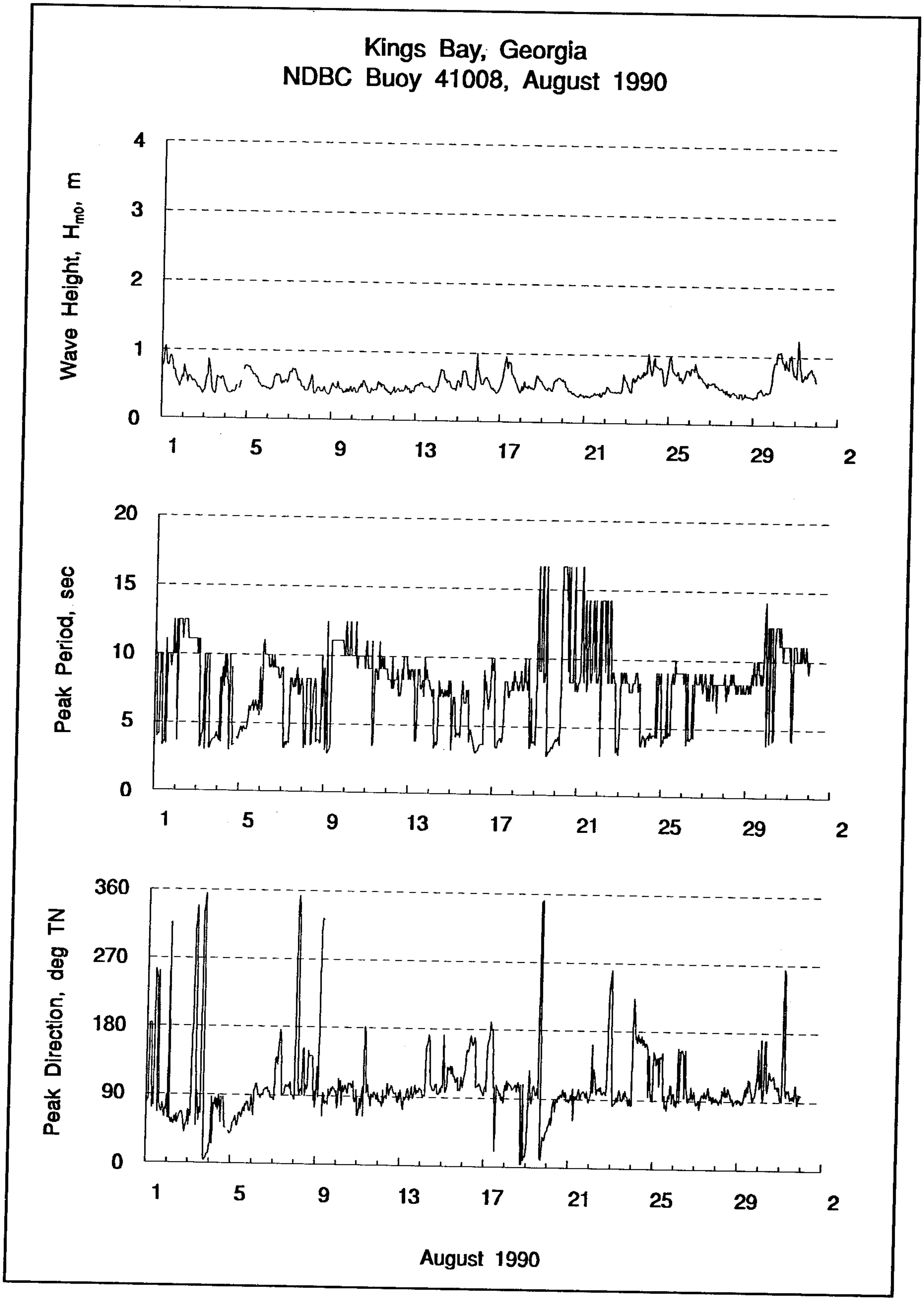

Kings Bay, Georgia
NDBC Buoy 41008, July 1990
Wave Height, H_{m0}, m
0
1
2
3
4
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
1 5 9 13 17 21 25 29 2
July 1990

Plate E42



Kings Bay, Georgia
NDBC Buoy 41008, August 1990
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
August 1990

Plate E43

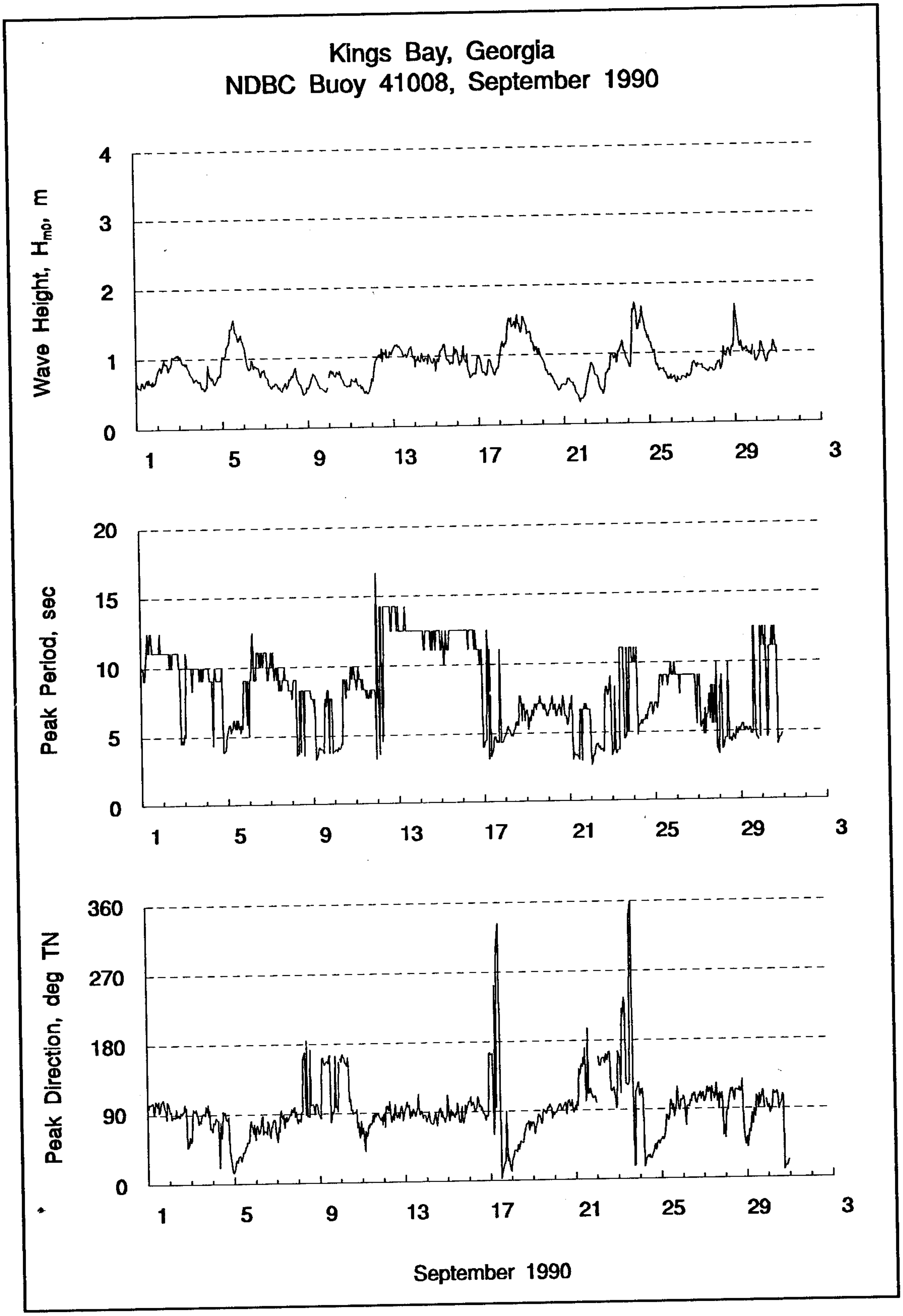

Kings Bay, Georgia
NDBC Buoy 41008, September 1990
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
3
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
3
September 1990

Plate E44

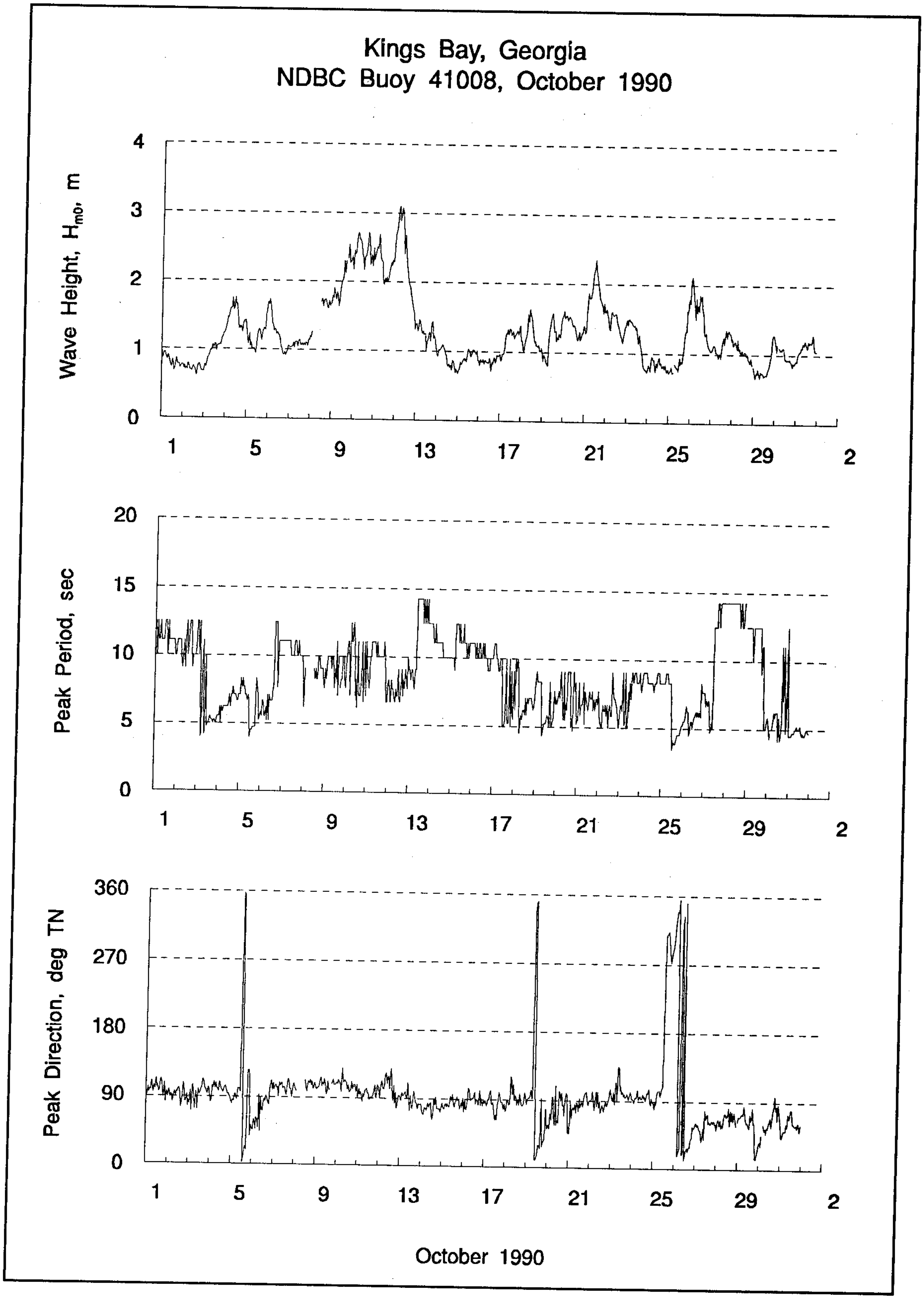

Kings Bay, Georgia
NDBC Buoy 41008, October 1990
Wave Height, H_{mo}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
October 1990

Plate E45

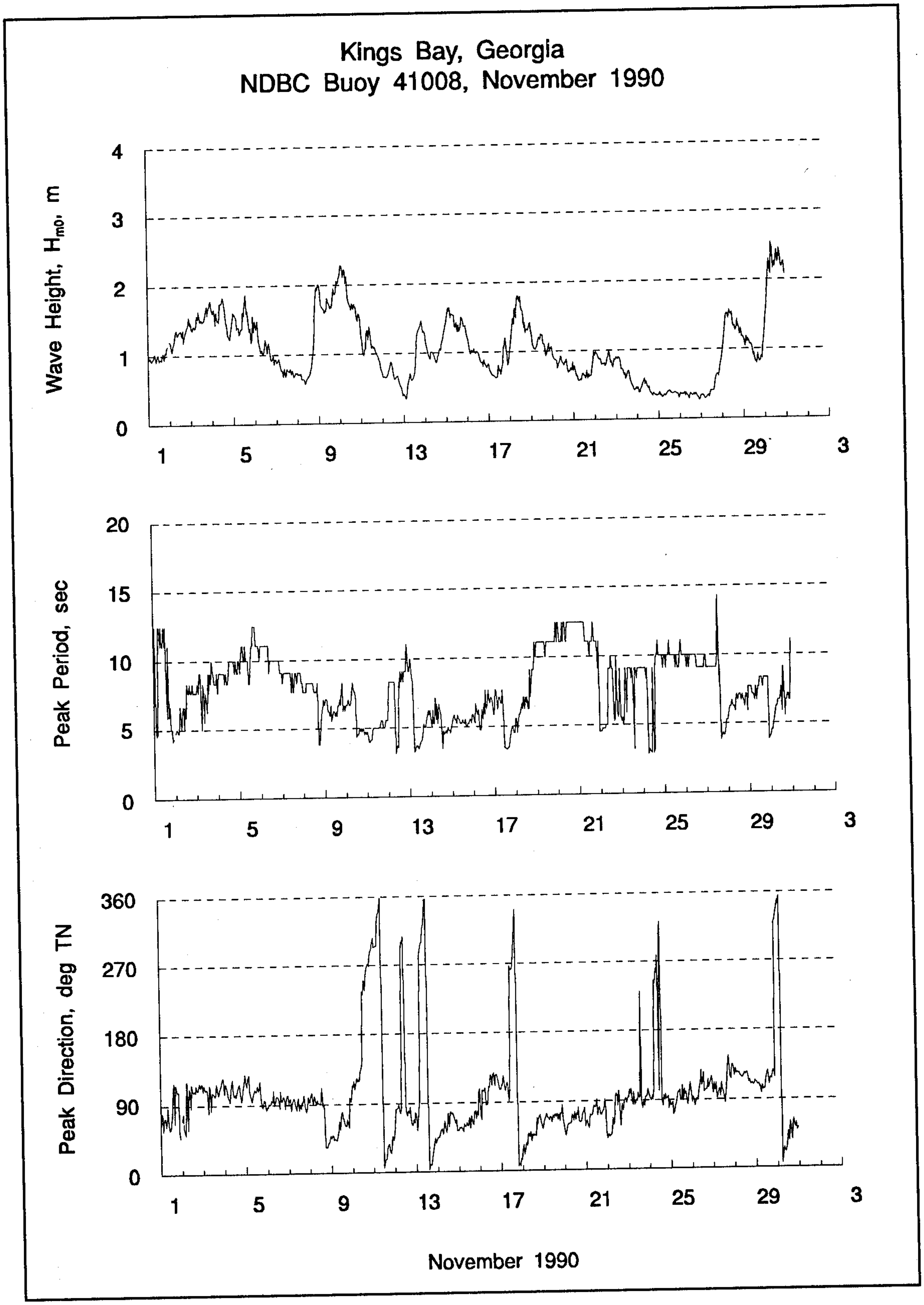

Kings Bay, Georgia
NDBC Buoy 41008, November 1990
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
3
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
3
November 1990

Plate E46

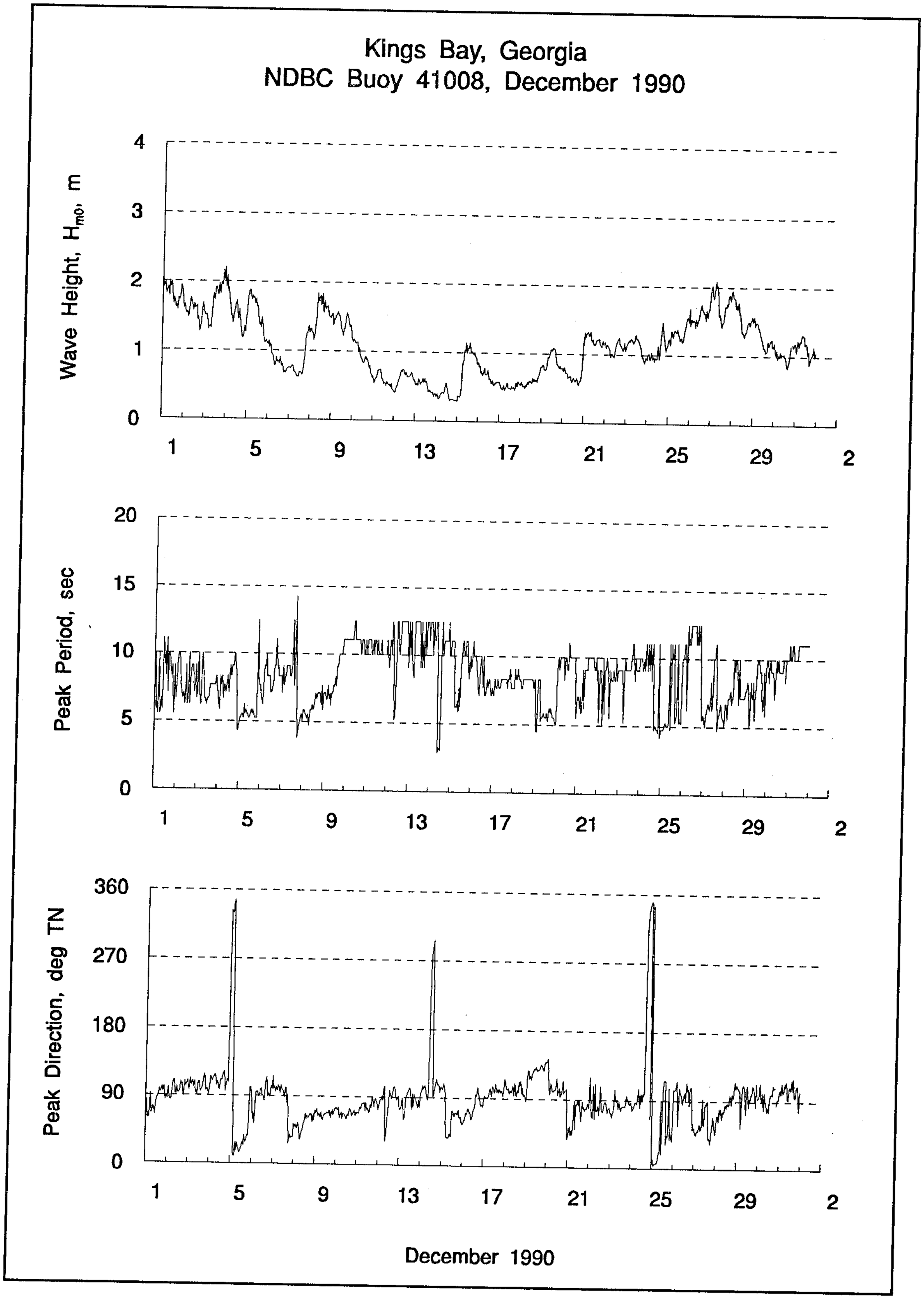

Kings Bay, Georgia
NDBC Buoy 41008, December 1990
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
December 1990

Plate E47

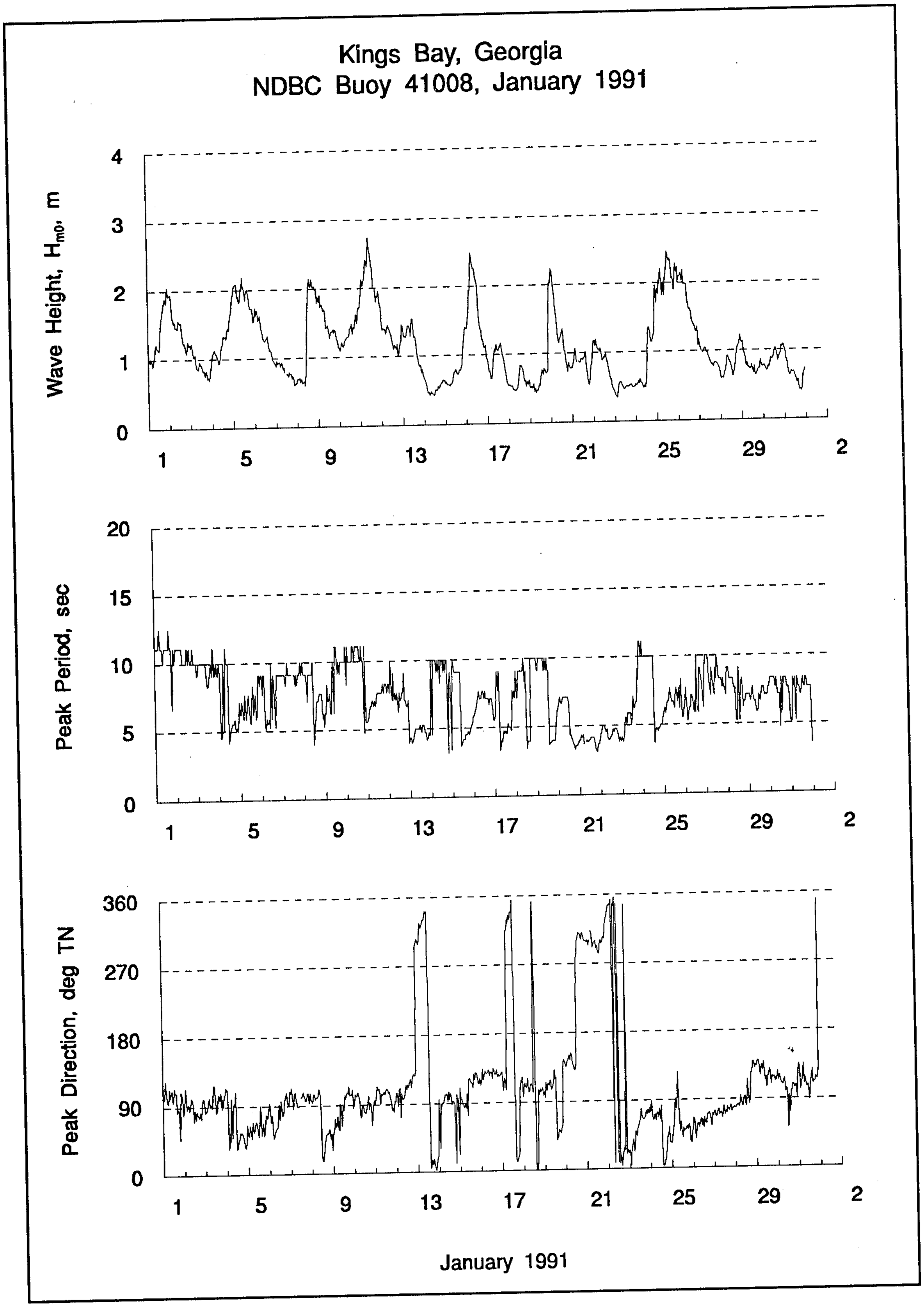

Kings Bay, Georgia
NDBC Buoy 41008, January 1991
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
January 1991

Plate E48

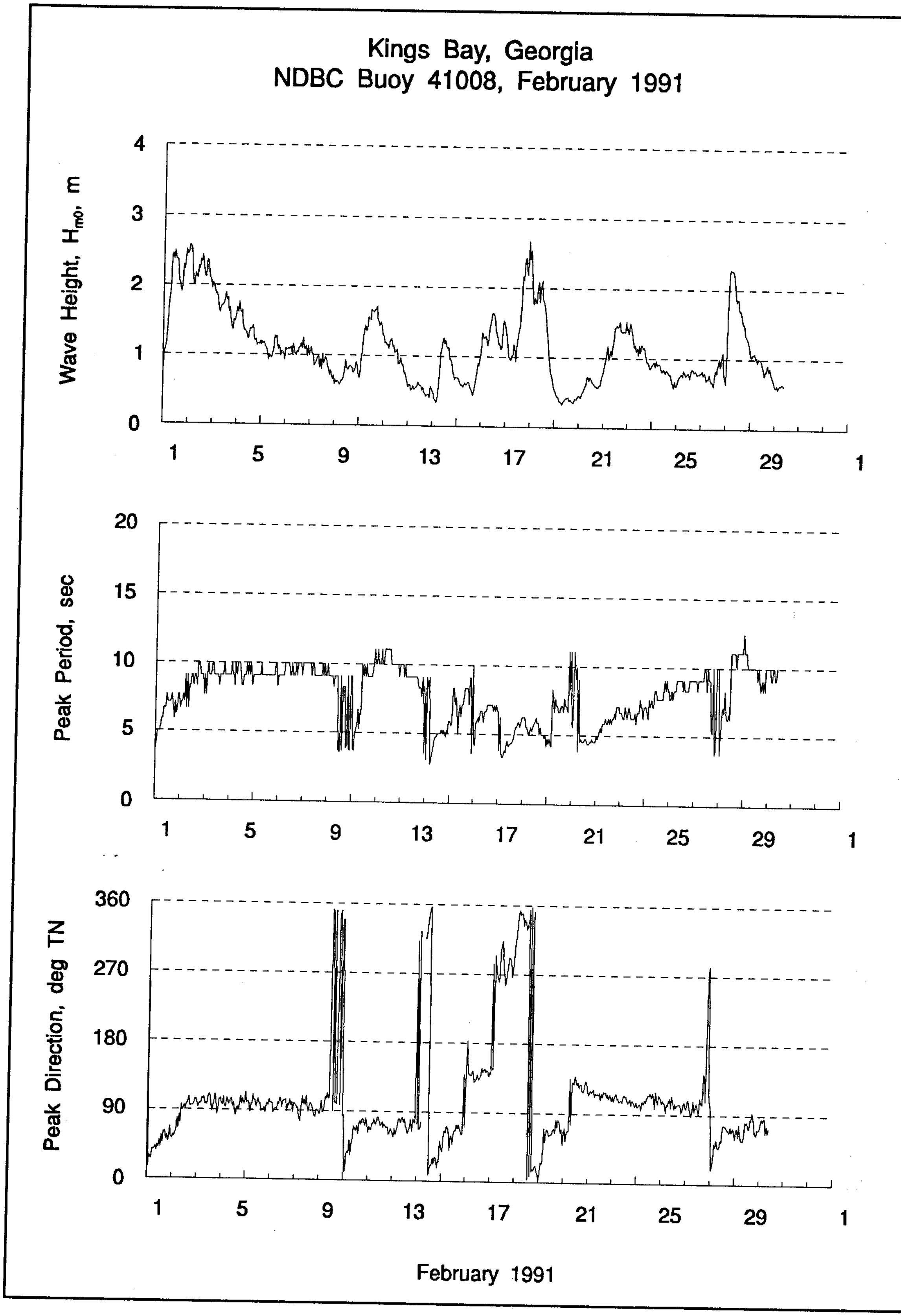
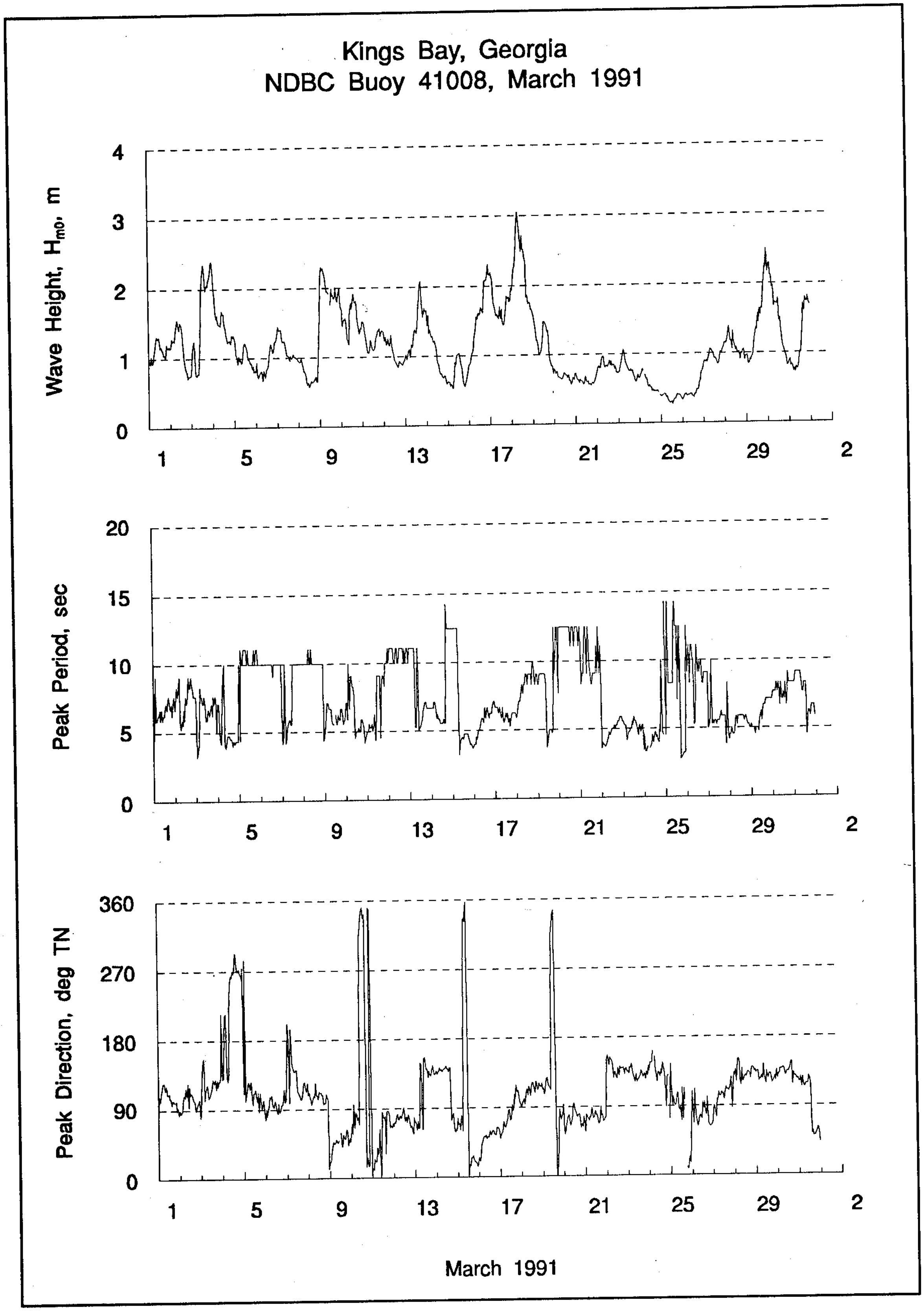

Kings Bay, Georgia
NDBC Buoy 41008, February 1991
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
1
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
1
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
1
February 1991

Plate E49



Kings Bay, Georgia
NDBC Buoy 41008, March 1991
Wave Height, H_{mo}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
March 1991

Plate E50

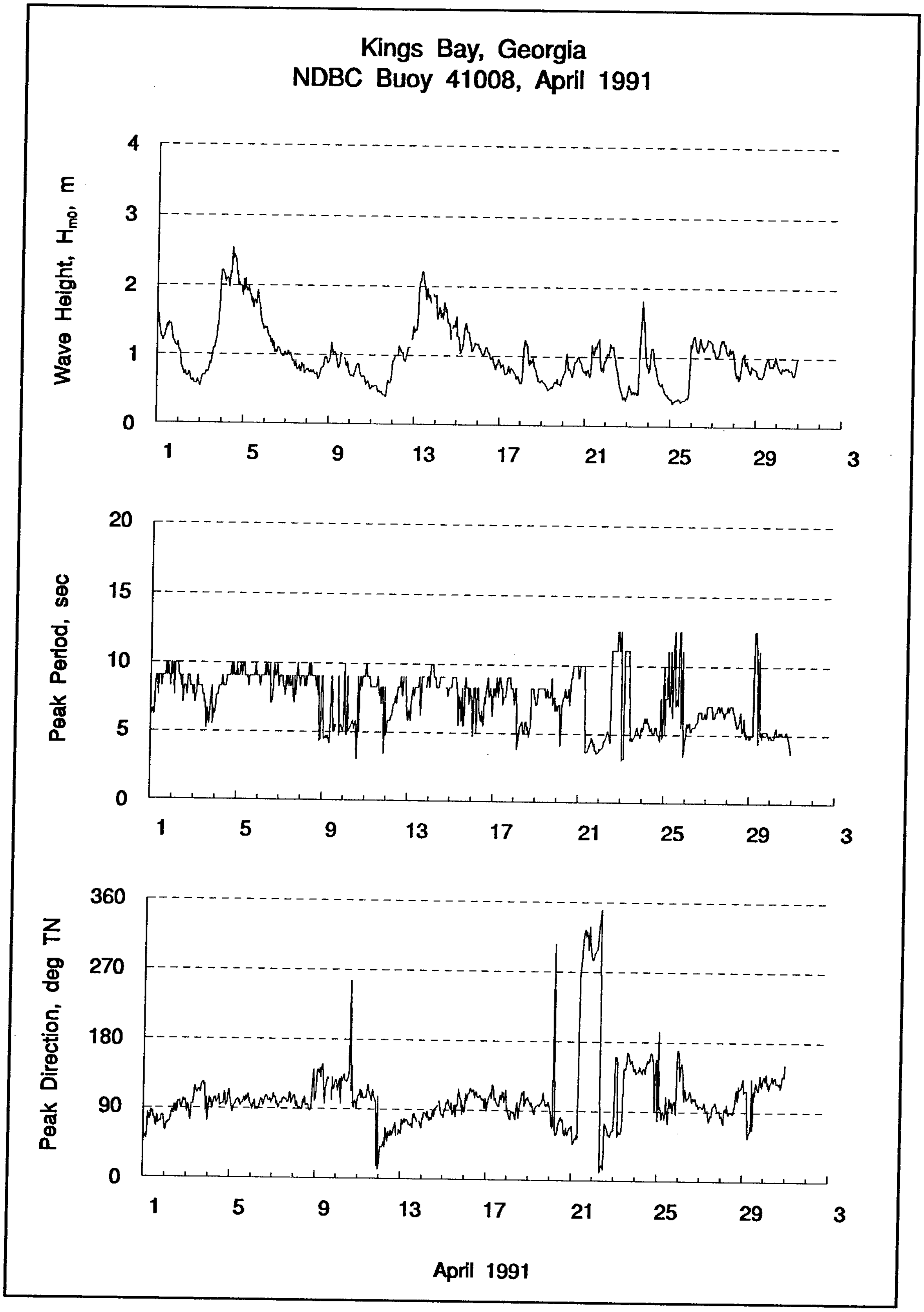
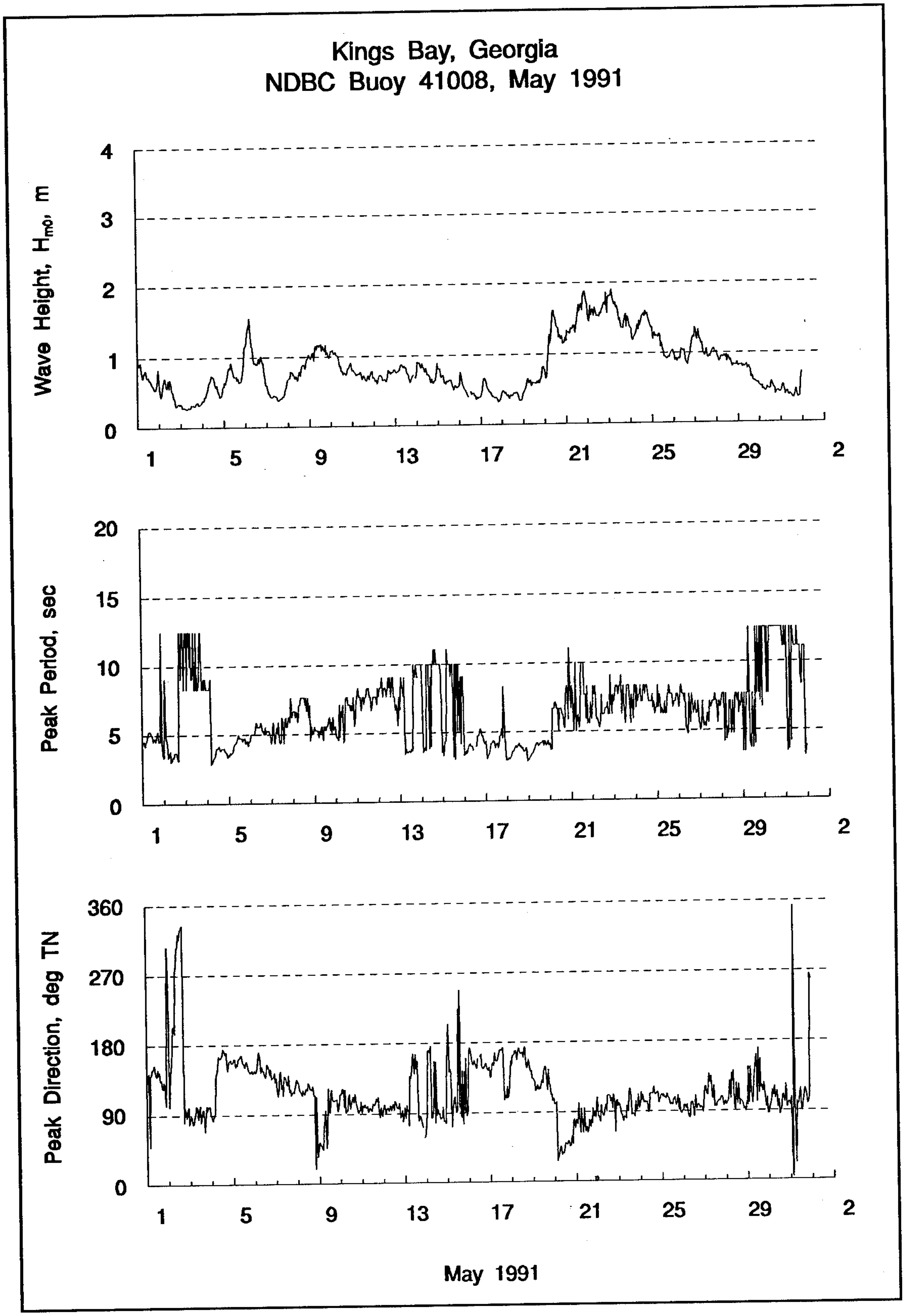
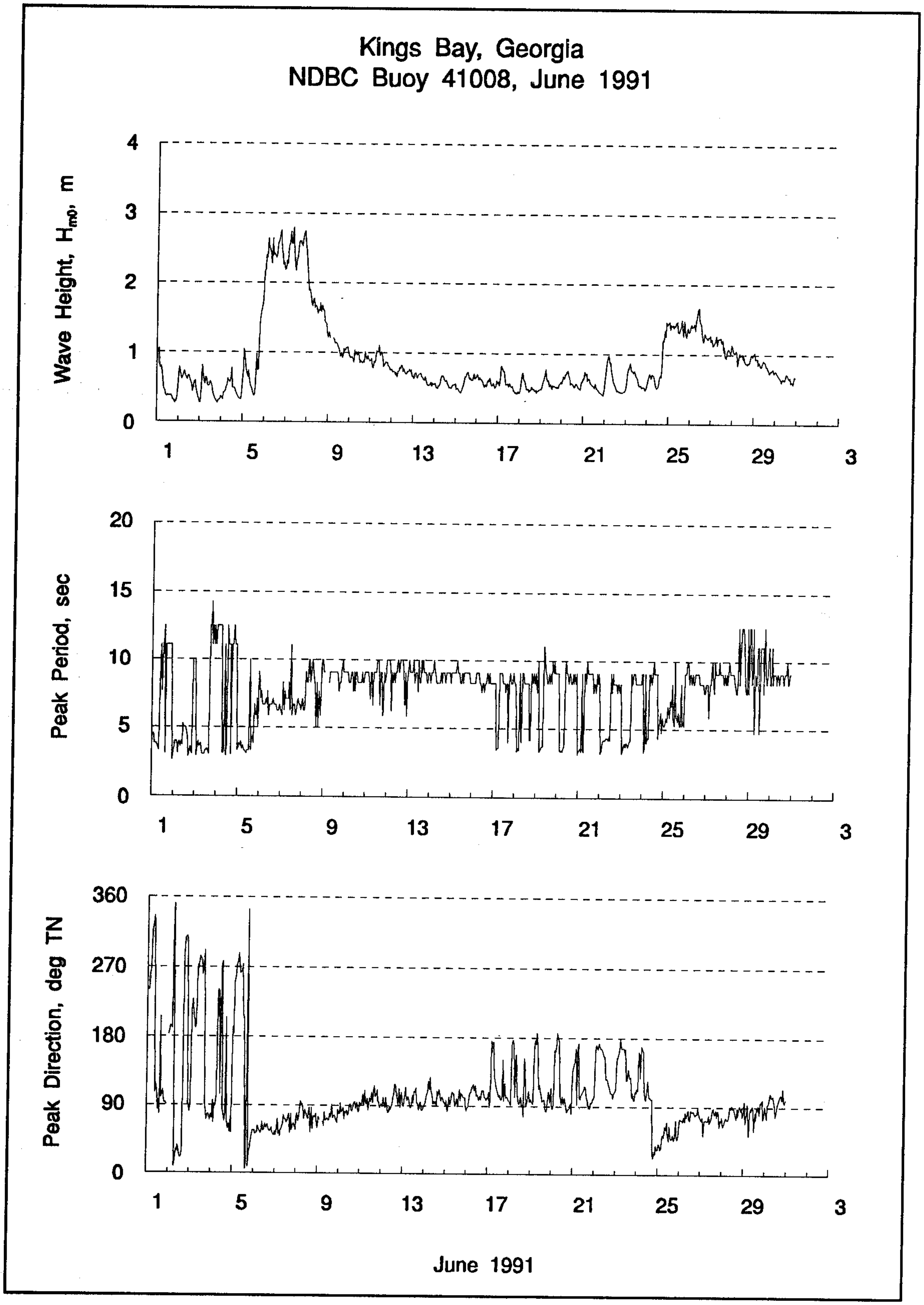

Kings Bay, Georgia
NDBC Buoy 41008, April 1991
Wave Height, H_{m0}, m
0
1
2
3
4
1 5 9 13 17 21 25 29 3
Peak Period, sec
0
5
10
15
20
1 5 9 13 17 21 25 29 3
Peak Direction, deg TN
0
90
180
270
360
1 5 9 13 17 21 25 29 3
April 1991

Plate E51



Kings Bay, Georgia
NDBC Buoy 41008, May 1991
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
Peak Direction, deg TN
0
90
180
270
360
May 1991

Plate E52



Kings Bay, Georgia
NDBC Buoy 41008, June 1991
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
Peak Direction, deg TN
360
270
180
90
0
June 1991

Plate E53

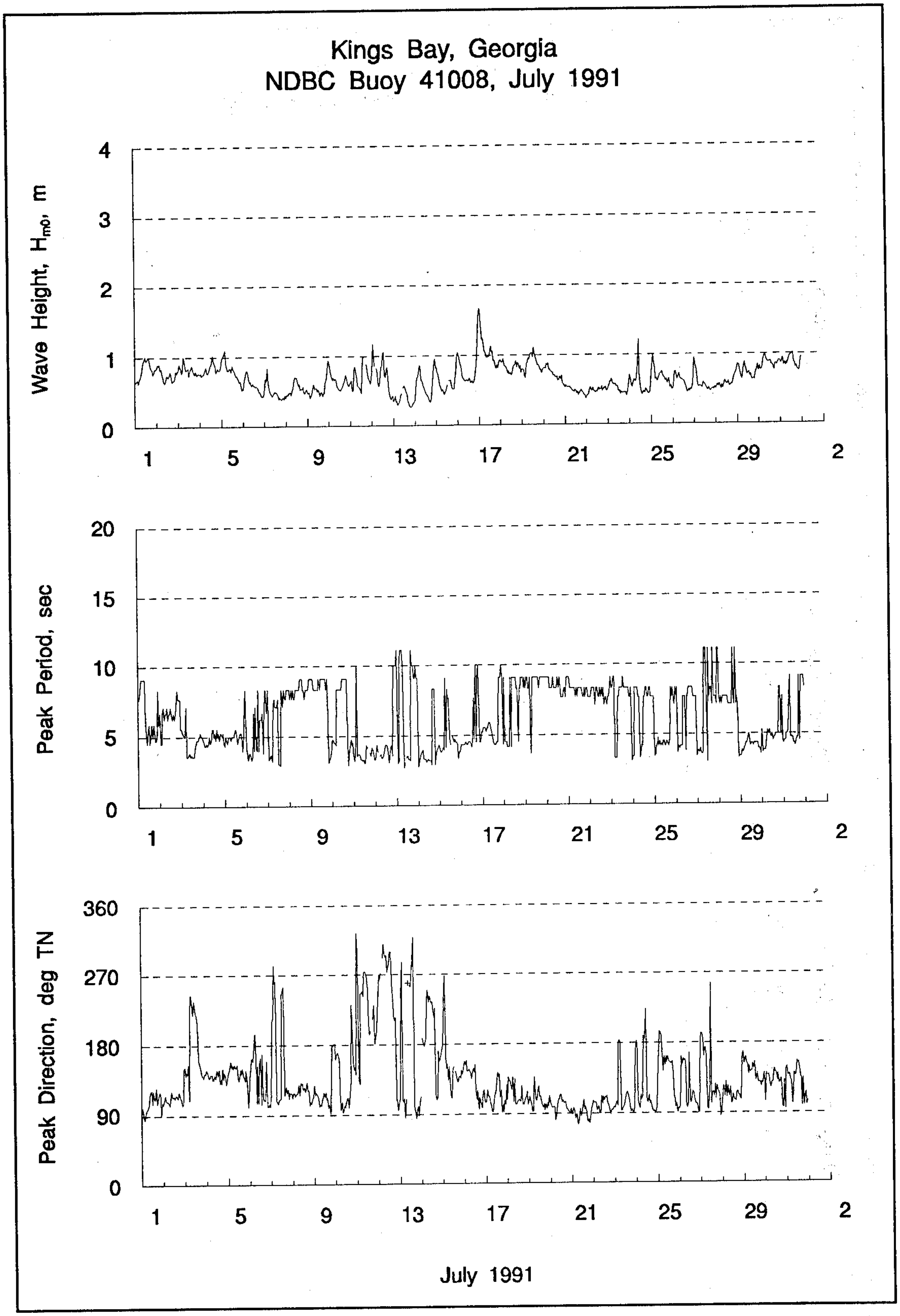

Kings Bay, Georgia
NDBC Buoy 41008, July 1991
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
July 1991

Plate E54

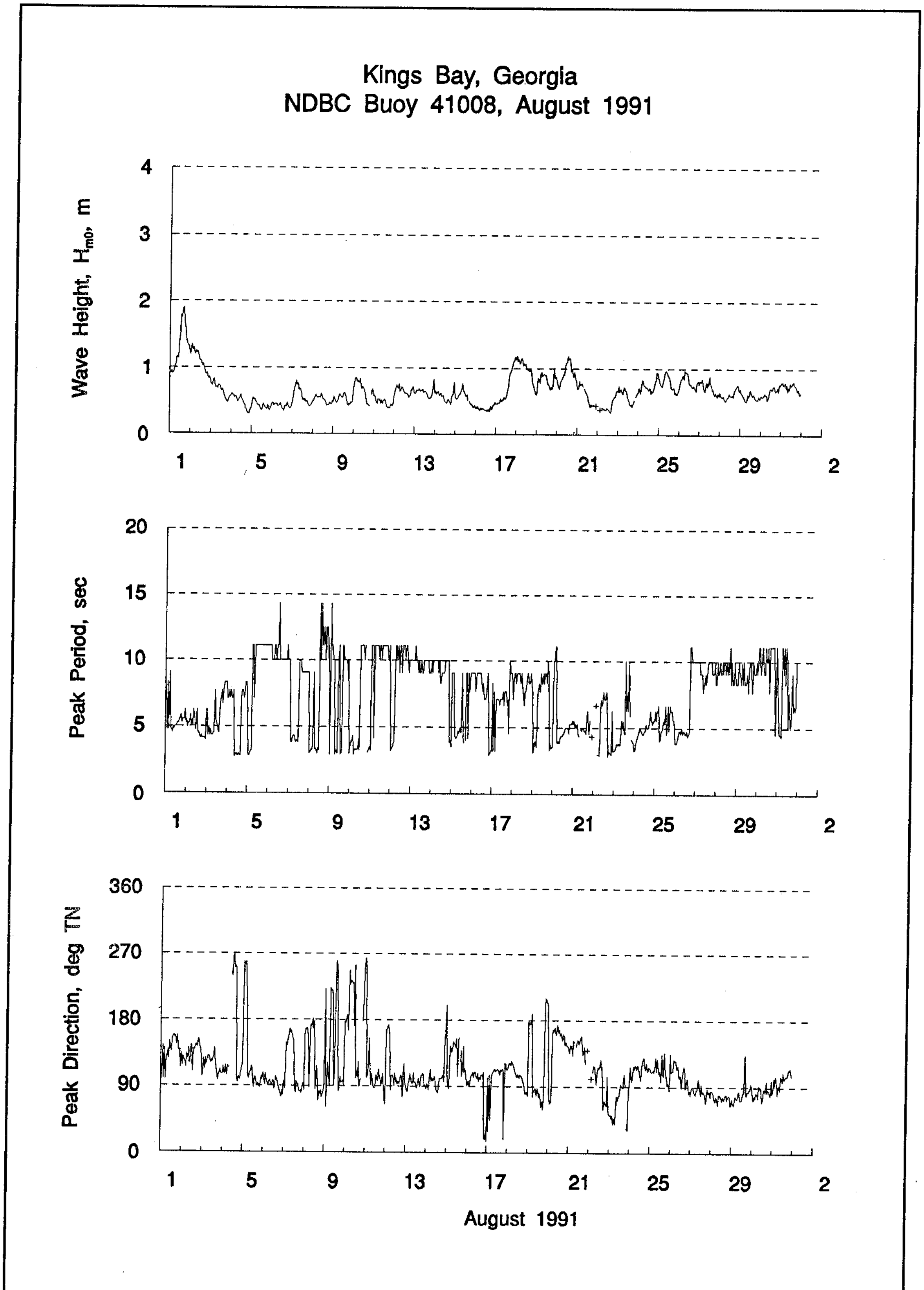

Kings Bay, Georgia
NDBC Buoy 41008, August 1991
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
August 1991

Plate E55

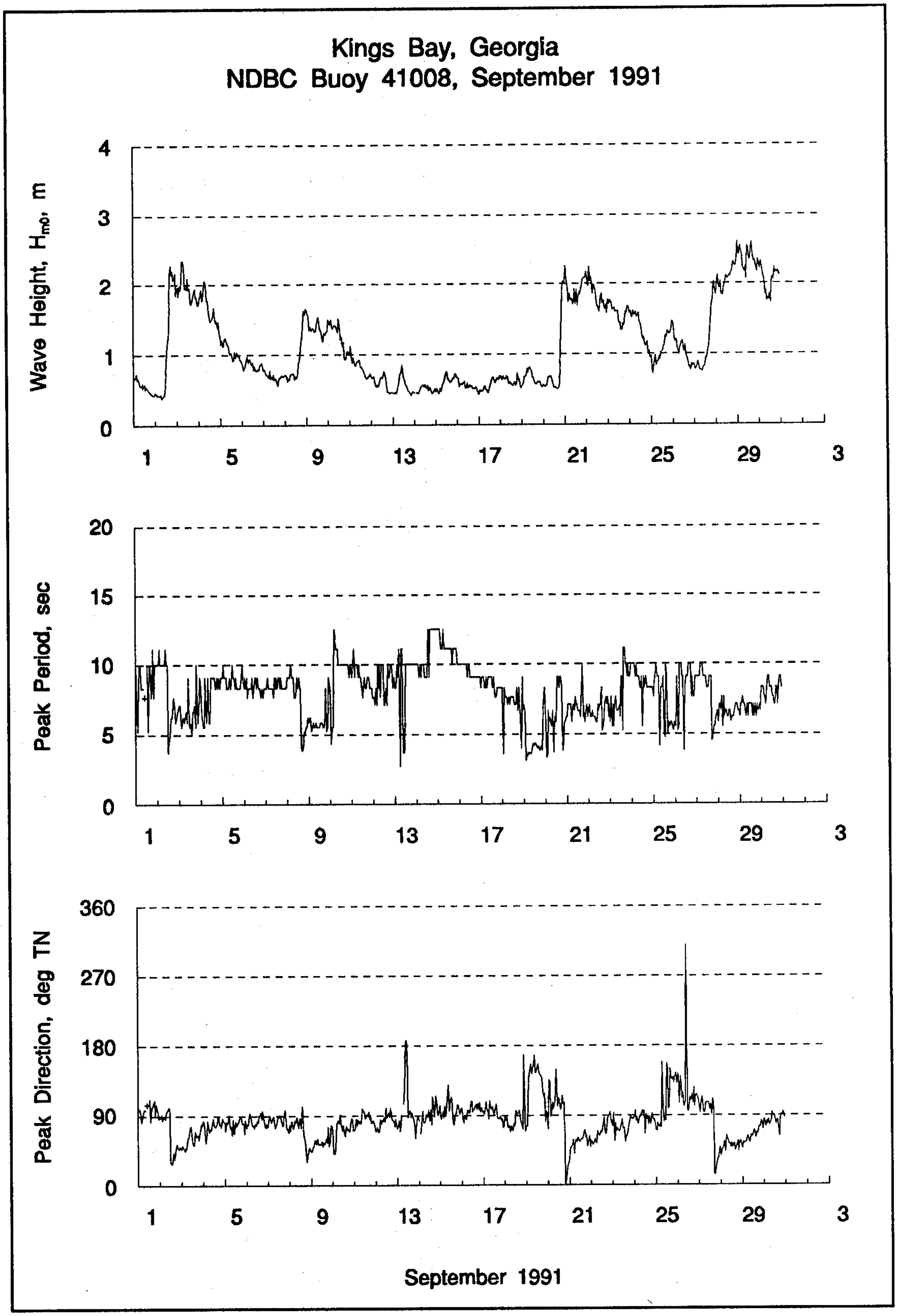
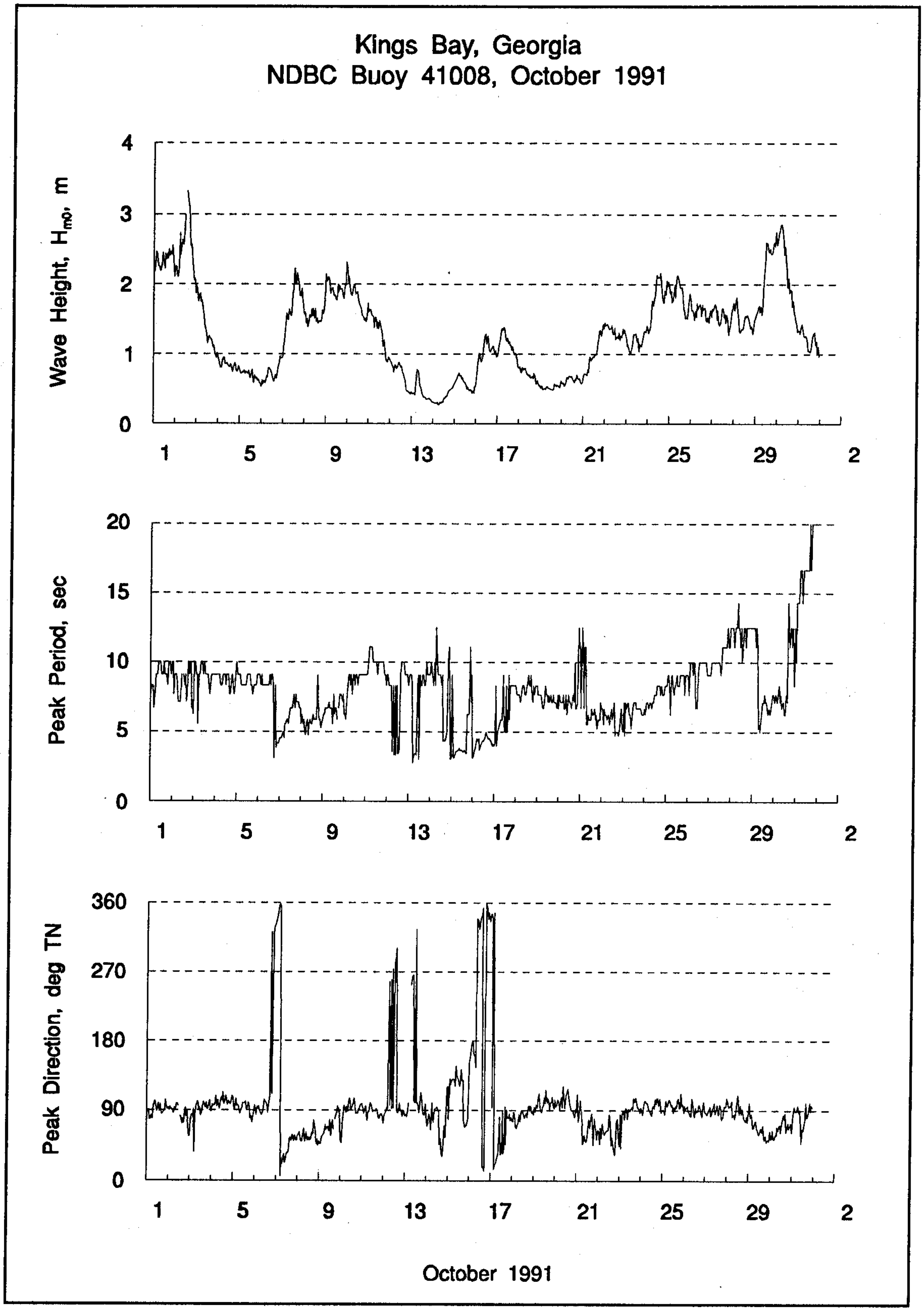
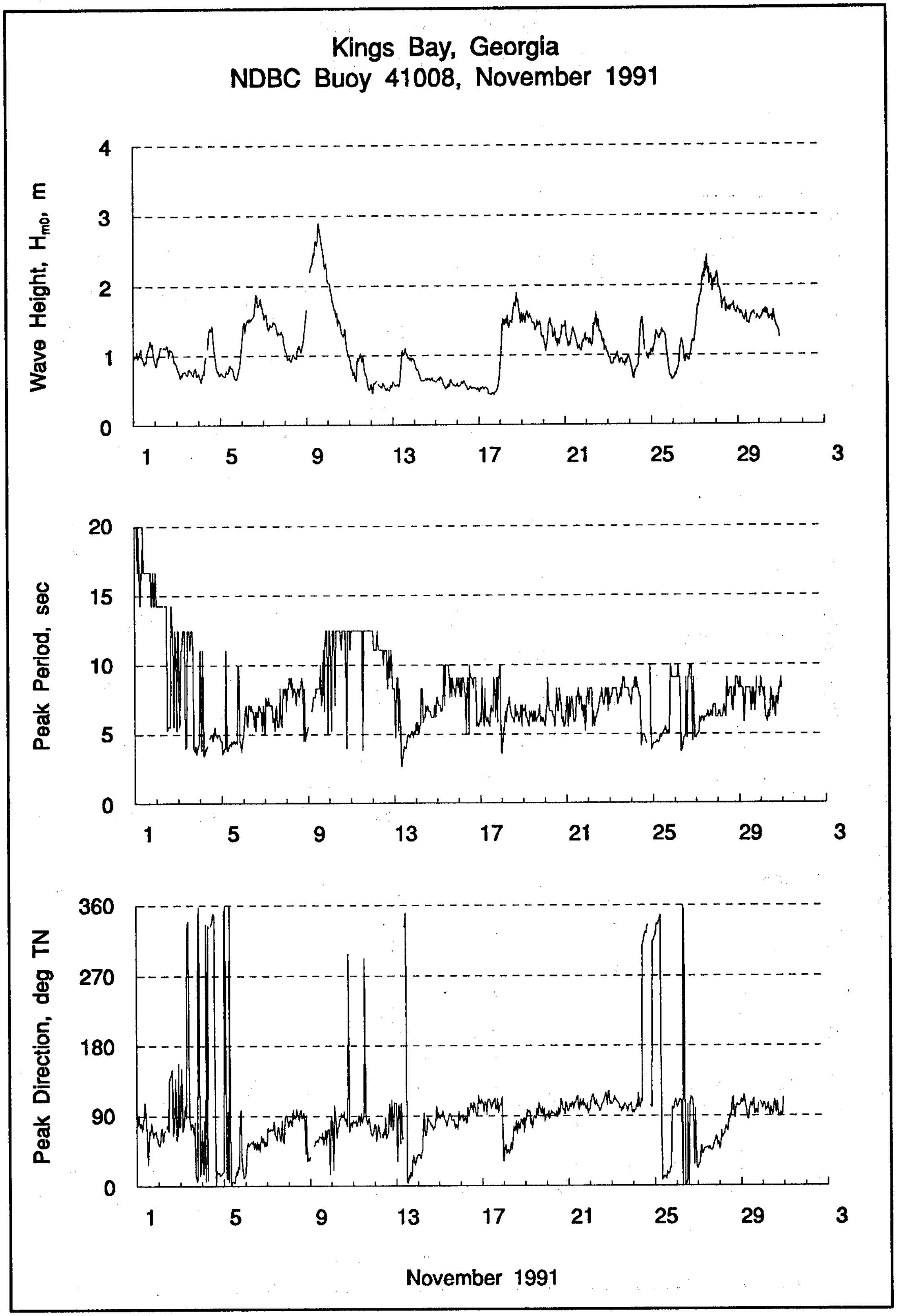

Kings Bay, Georgia
NDBC Buoy 41008, September 1991
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
Peak Direction, deg TN
360
270
180
90
0
September 1991

Plate E56



Kings Bay, Georgia
NDBC Buoy 41008, October 1991
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
October 1991

Plate E57



Kings Bay, Georgia
NDBC Buoy 41008, November 1991
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
3
Peak Period, sec
20
15
10
5
0
Peak Direction, deg TN
360
270
180
90
0
November 1991

Plate E58

Kings Bay, Georgia
NDBC Buoy 41008, December 1991

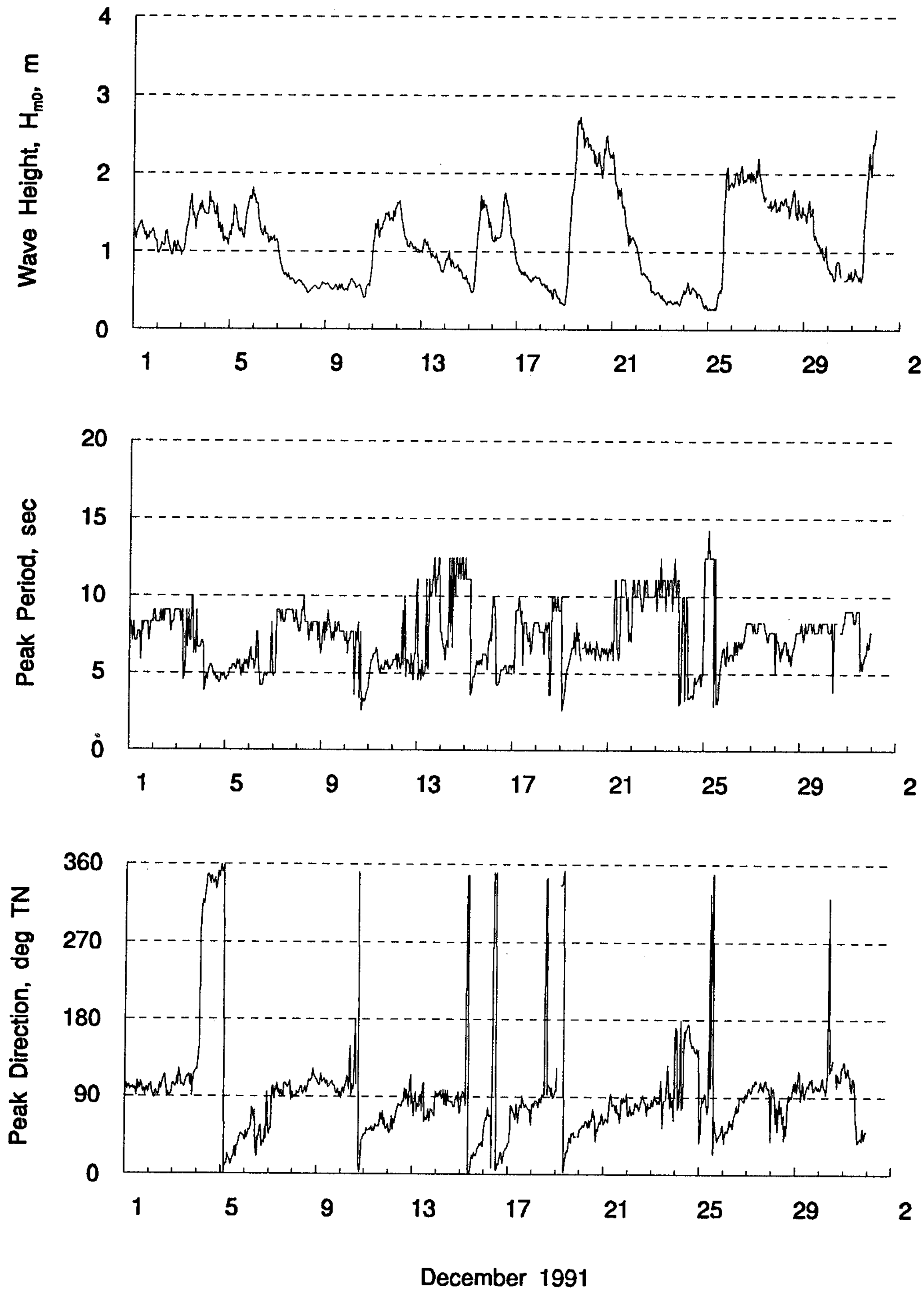


Plate E59

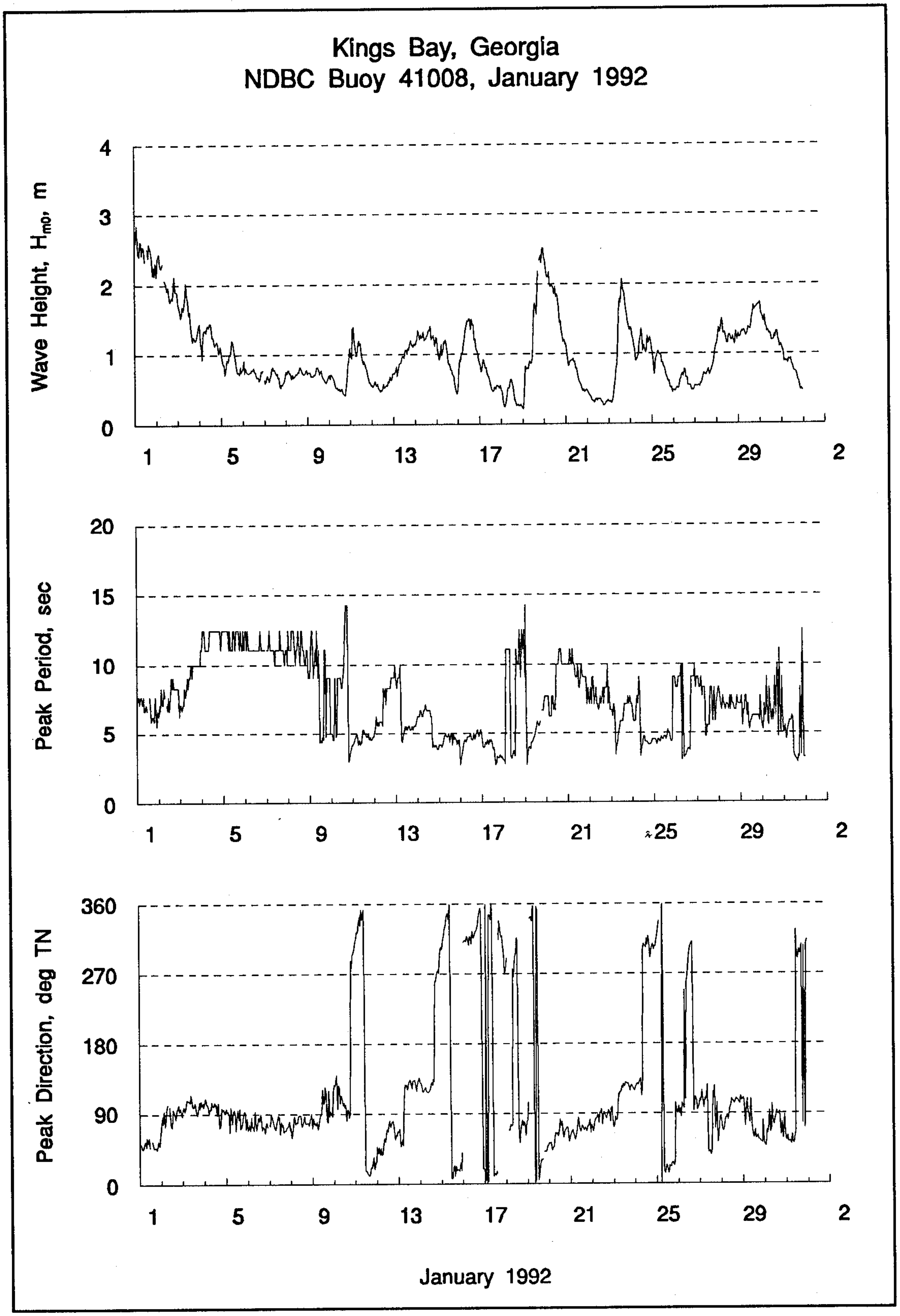
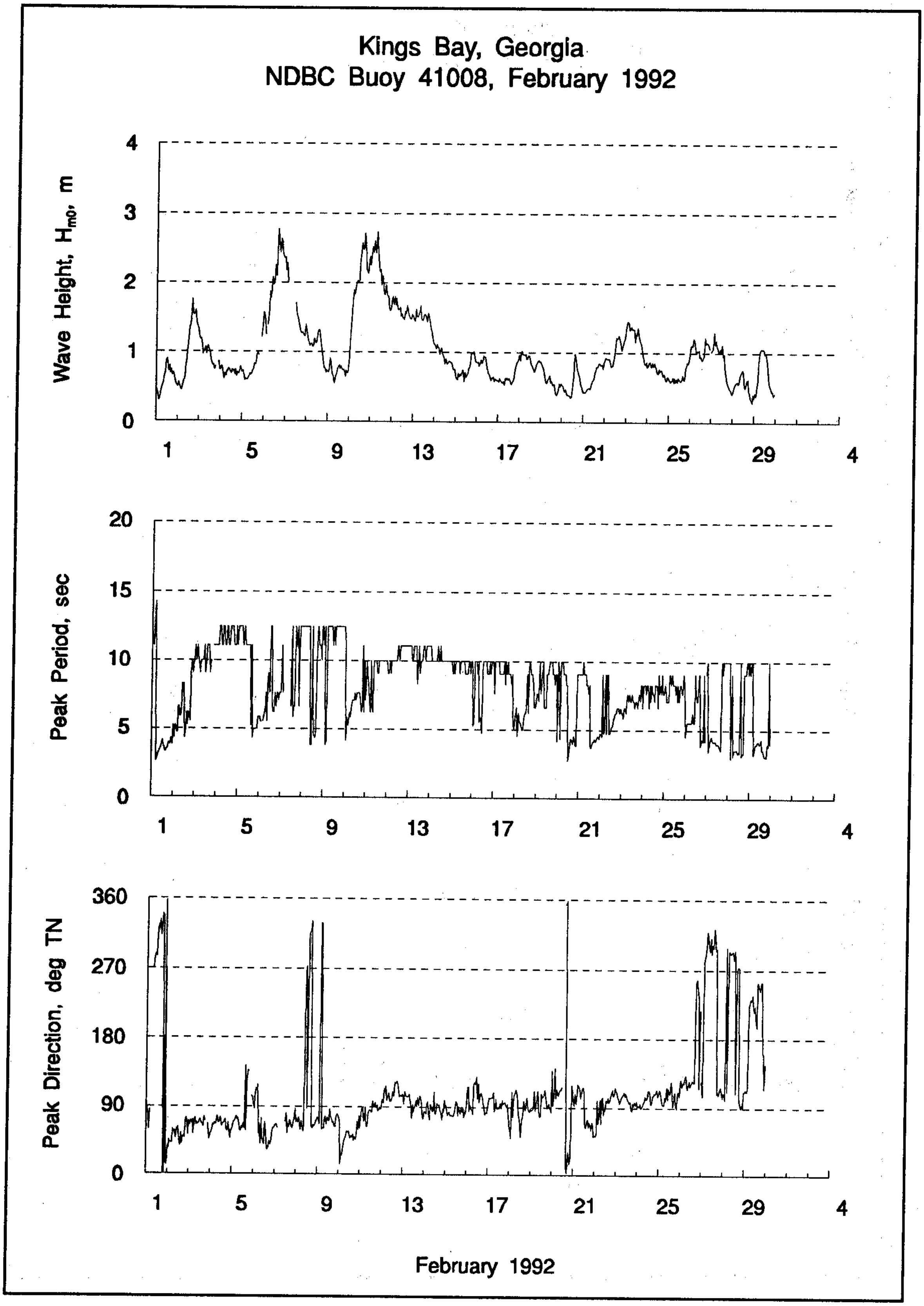
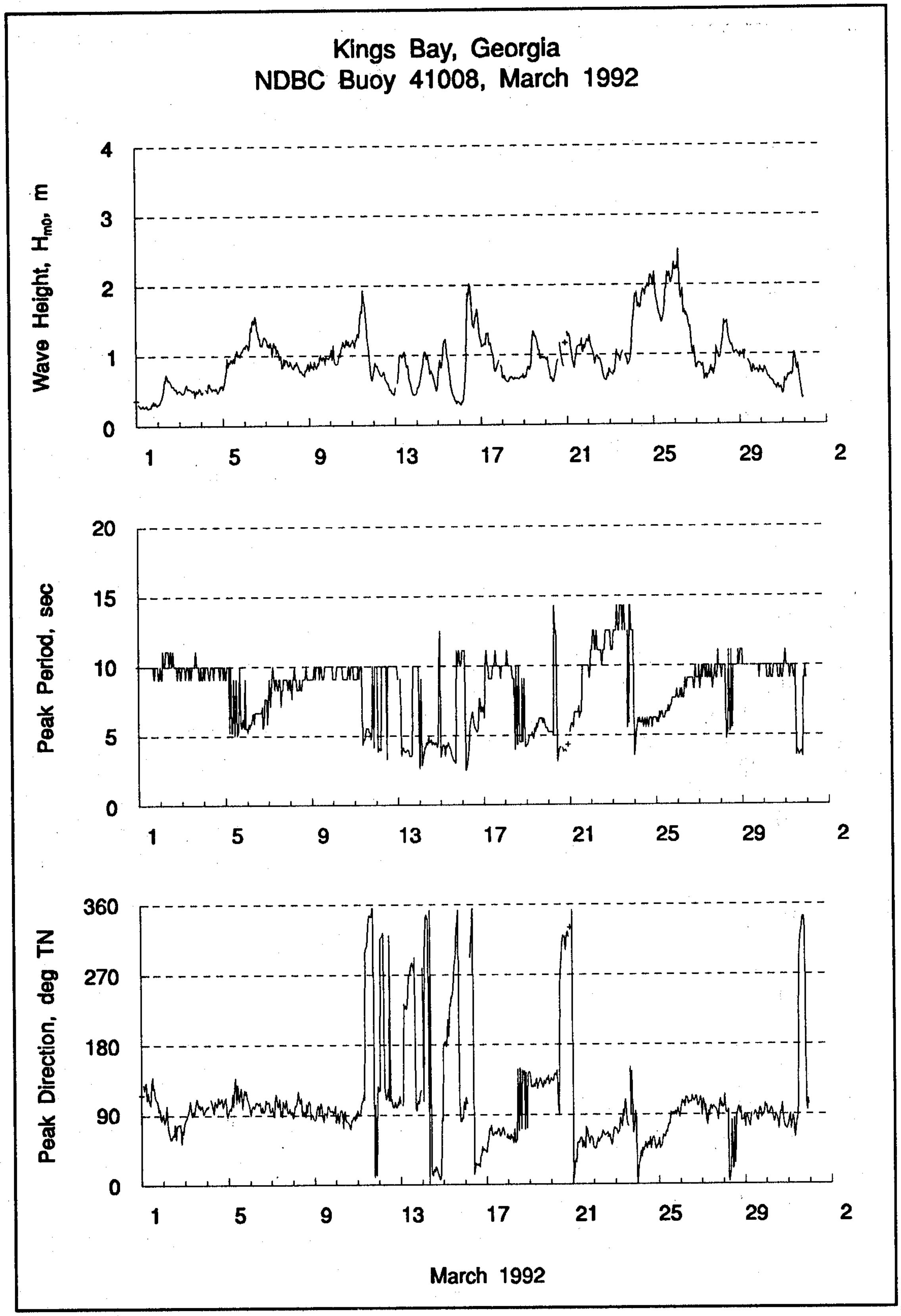

Kings Bay, Georgia
NDBC Buoy 41008, January 1992
Wave Height, H_{m0}, m
0
1
2
3
4
1
5
9
13
17
21
25
29
2
Peak Period, sec
0
5
10
15
20
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
0
90
180
270
360
1
5
9
13
17
21
25
29
2
January 1992

Plate E60



Kings Bay, Georgia
NDBC Buoy 41008, February 1992
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
4
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
4
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
4
February 1992

Plate E61



Kings Bay, Georgia
NDBC Buoy 41008, March 1992
Wave Height, H_{m0}, m
4
3
2
1
0
1
5
9
13
17
21
25
29
2
Peak Period, sec
20
15
10
5
0
1
5
9
13
17
21
25
29
2
Peak Direction, deg TN
360
270
180
90
0
1
5
9
13
17
21
25
29
2
March 1992

Plate E62

Appendix F[1]
Wave Analysis

Introduction

Directional wave data were collected off St. Marys Entrance, Georgia/Florida, during May 1989 as part of the Kings Bay Coastal and Estuarine Physical Monitoring and Evaluation Program. Nearshore directional wave information is needed for calculating shoreline change for the beaches adjacent to St. Marys Entrance to assess the impact of inlet modifications. Three directional gages were deployed in the project: a pitch-roll buoy offshore, a pressure-velocity component (PUV) gage nearshore off Cumberland Island, and a sea-surface slope array nearshore off Amelia Island. Although the three gages operate on different principles as discussed below, each measures wave height, direction, and period. Figure F1 shows the locations of the gages relative to St. Marys Entrance. These directional wave measurements provide not only a short-term climatology for estimating longshore sediment transport rates, but also a unique opportunity to verify the numerical wave transformation model STWAVE (Cialone et al. 1992, Resio 1993)[2] that provides breaking wave height and direction for shoreline change modeling based on offshore gage data or hindcasts.

The purpose of this appendix is to document comparisons of STWAVE simulations (driven with the offshore buoy data) with the nearshore wave measurements available at the Cumberland Island and the Amelia Island nearshore gages. Although such a comparison appears straightforward, factors such as data quality, model limitations, and the complexity of the inlet environment contributed to a challenging task. Field measurements are discussed in the next section, including a description of the measurements, estimate of errors, postprocessing of the data, and intercomparisons of the outputs of the three gages. Then, STWAVE is applied to estimate nearshore waves and comparisons with the data are given. The comparisons and errors are discussed in reaching conclusions on the suitability of the wave transformation model.

---

[1] Written by Jane Smith.

[2] References cited in this appendix are located at the end of the main text, Volume I.

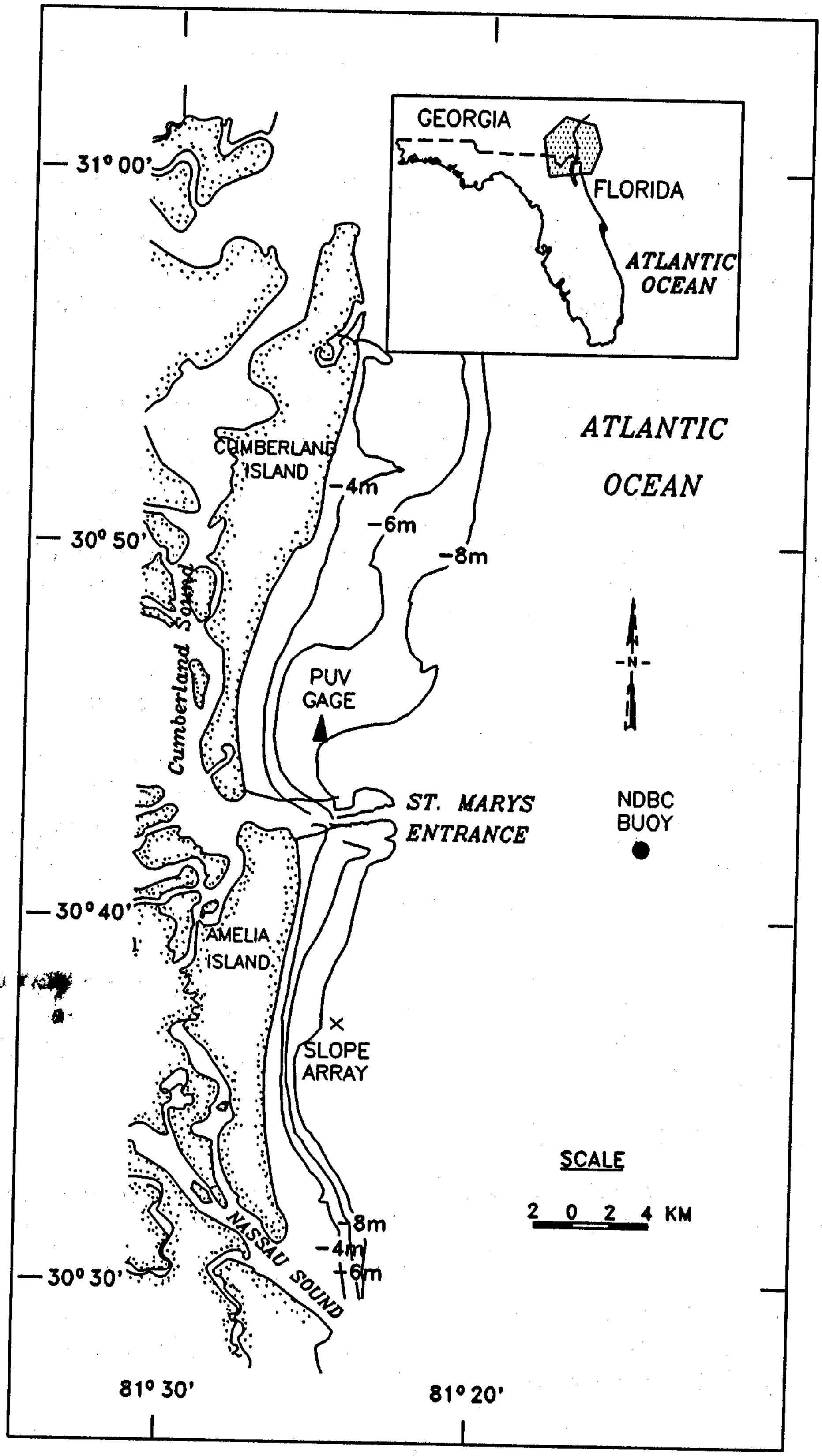


Figure F1. Location of wave gages relative to St. Marys Inlet

Field Measurements

Directional wave spectra were computed based on data taken at three sites off St. Marys Entrance with three different types of gages:

a. *NDBC 3-m discus buoy*. Directional spectra were computed from the auto- and cross-spectra of the surface displacement, slope, and acceleration of the pitch-roll buoy (Steele et al. 1990). Wind speed and direction were also measured at the buoy. Buoy No. 41008 was deployed and maintained by NDBC under contract with CERC. The buoy was deployed at 30°41'59" N, 81°6' W in approximately 18 m of water. Hourly directional wave spectra and winds are available from the buoy for March 1988 through March 1992.

b. *CERC PUV gage*. The PUV gage consists of a pressure sensor (P) and a 2-axis electromagnetic current meter (U and V horizontal current velocities) mounted on the bottom. The absolute horizontal velocities were not measured, only the relative magnitudes. Directional spectra were computed from the auto- and cross-spectra of the three, co-located measurements. The gage was deployed at 30°45'7.2" N, 81°24'18" W in approximately 10 m of water. Directional spectra are available at 3-hr intervals (with some gaps) from the PUV gage for May 1989. The gage was turned over by a trawler and stopped functioning in late May.

c. *CERC slope array*. The slope array consists of three pressure sensors mounted on an equilateral-triangle-shaped base (1.8 m on a side) that rests on the bottom. The directional spectra were computed from auto- and cross-spectra of the three measurements of surface elevation and the horizontal derivatives (cross-shore and longshore) of the surface elevation (surface slope). The slope array was deployed at 30°37'5.4" N, 81°25'9" W in approximately 10 m of water. Hourly directional spectra are available from the slope array from April 1989 to June 1990 (with numerous gaps). During the winter of 1989-90 the gage was overturned and, although the array was redeployed, the new gage orientation is unknown.

The data from each gage were analyzed based on the technique of Longuet-Higgins, Cartwright, and Smith (1963). This analysis procedure computes the energy and mean direction at each frequency. The estimator resolves multiple wave trains at different peak periods, but does not differentiate between two wave trains of the same peak period incident from different directions.

Measurement errors

It is very difficult to assess errors in directional wave measurements because no measurement standard exists. Measurement errors may be deterministic (e.g., gage orientation or calibration error) or statistical (dependent on sampling parameters and degree of averaging). Wave measurements are statistical estimates and inherently nondeterministic, so a certain amount of statistical variability is expected. Errors in measuring wave direction will be discussed in greater detail than errors in wave height, since differences in wave direction prompted the detailed wave analysis and wave height measurements are generally reliable.

Steele, Lau, and Hsu (1985) evaluated the directional accuracy of a discus buoy based on correlation of measured wind and wave directions for a 1984 experiment in the Pacific Ocean southwest of Los Angeles, California. Winds can be measured fairly easily and accurately (estimated ±10 deg). During a period of strong and relatively stationary winds (thus, assumed locally generated waves), the difference in wave and wind directions varied between +2 and -8 deg with an average difference of -3 deg. This suggests maximum potential wave direction errors of ±10 deg in the buoy measurement are possible. Errors in buoy direction tend to be less significant than nearshore directional measurements because offshore errors are reduced through refraction. During the Atlantic Ocean Remote Sensing Land-Ocean Experiment (ARSLOE) (Vincent and Lichy 1981) held during 1980 near Duck, North Carolina, five nearshore directional sensors were intercompared, including two PUV gages and a slope array. Grosskopf et al. (1983) outlined possible errors in these nearshore measurements. Potential errors entering estimates of wave direction include:

a. *Specification errors.* Accuracy of sensors, calibration error, spatial and temporal sampling adequacy, and measurement resolution (all considered negligible at ARSLOE).

b. *Construction deficiencies.* Sensor alignment (±1 deg at best), mount alignment (±2 deg), and sensor interference (negligible at ARSLOE).

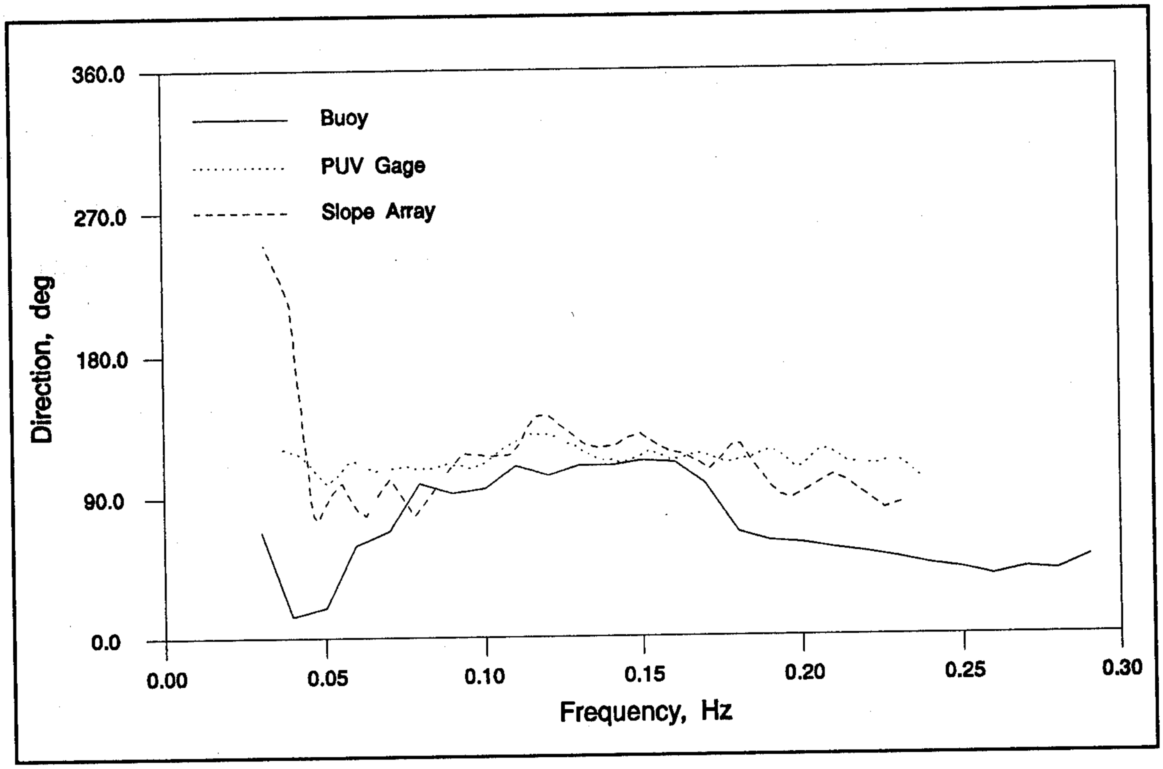
c. *Orientation errors.* Diver compass observation (±2 deg at best), compass deviation by magnetic material (negligible at ARSLOE), misalignment of compass with mount axis (±1 deg at best), and gage leveling (±1 deg at best).

These numbers do not set an absolute error, but give an indication of the magnitudes of possible errors. Intercomparison of the five nearshore directional ARSLOE measurements shows differences of 0 to 20 deg with mean differences in the range of 5 to 10 deg. This suggests that the accuracy is ±10 deg. A complicating factor at the Kings Bay site is the complex bathymetry. Tests of directional gages are typically conducted at sites with plane and parallel bottom contours (e.g. Duck, North Carolina), and the data analysis procedures verified at these sites may not produce meaningful results for complex bathymetry. Based on the intercomparison of ARSLOE gages, measured wave heights are expected to be accurate to ±10 percent for both the buoy and nearshore gages.

Postprocessing of wave spectra

Figure F2 shows an example of the frequency spectra and mean direction for the three gages for 0100 GMT on 19 May 1989. The wave directions are measured clockwise from true north. This example shows that the three gages give similar results; in this case, three wave trains with peak periods at 11, 7.5, and 4.5 sec. This example also illustrates the following potential problems with intercomparing gages:

a. A single peak wave period and corresponding peak direction will not give meaningful intercomparison between gages. For example, in Figure F2 the peak period at the buoy and slope array is 4.5 sec whereas the peak period at the PUV is 11 sec. Multiple wave trains are common in this data set, so wave trains must be identified and treated separately.



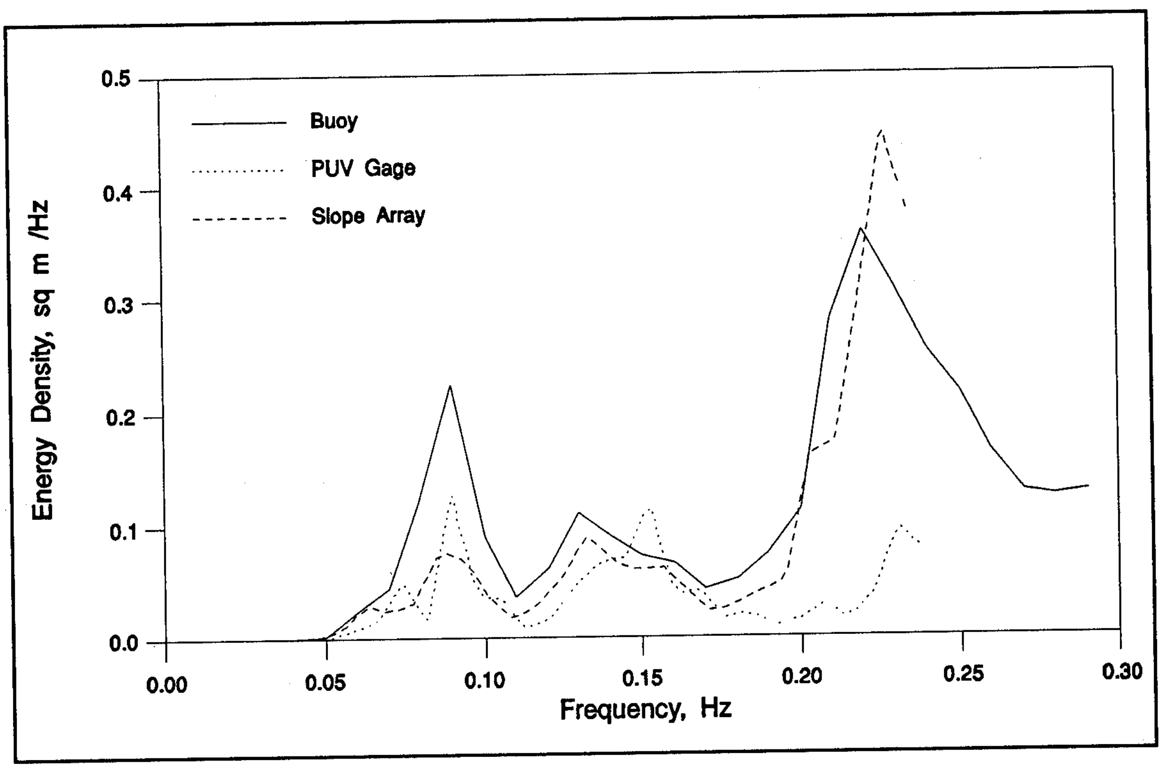


Figure F2. Example of frequency spectra and mean directions, 0100 GMT, 19 May 1989 *b.* Converse to item (a), each local maximum in the frequency spectrum does not represent a separate wave train. In Figure F2, the PUV spectrum has seven local maxima, but appears to have only three wave trains, so the confidence limits of the spectrum must be taken into account in identifying independent wave trains.

c. The quality of energy and direction estimates degrades at low energy levels. Note the variations in mean direction in the low-frequency portion of the spectrum where energy levels are low.

d. Locally generated waves growing over the fetch from the shoreline to the buoy and propagating offshore (wave direction greater than 180 deg) will not be significant at the nearshore gages even though they are well-defined at the buoy.

These factors require postprocessing of the wave spectra to intercompare gage data or to compare gage data and model results.

Postprocessing performed on the spectra included:

a. Weighted five-point, moving average on the energy in the energy spectra to smooth spurious peaks.

b. Three-point, moving average on the mean directions to complement the smoothing of the energy spectra.

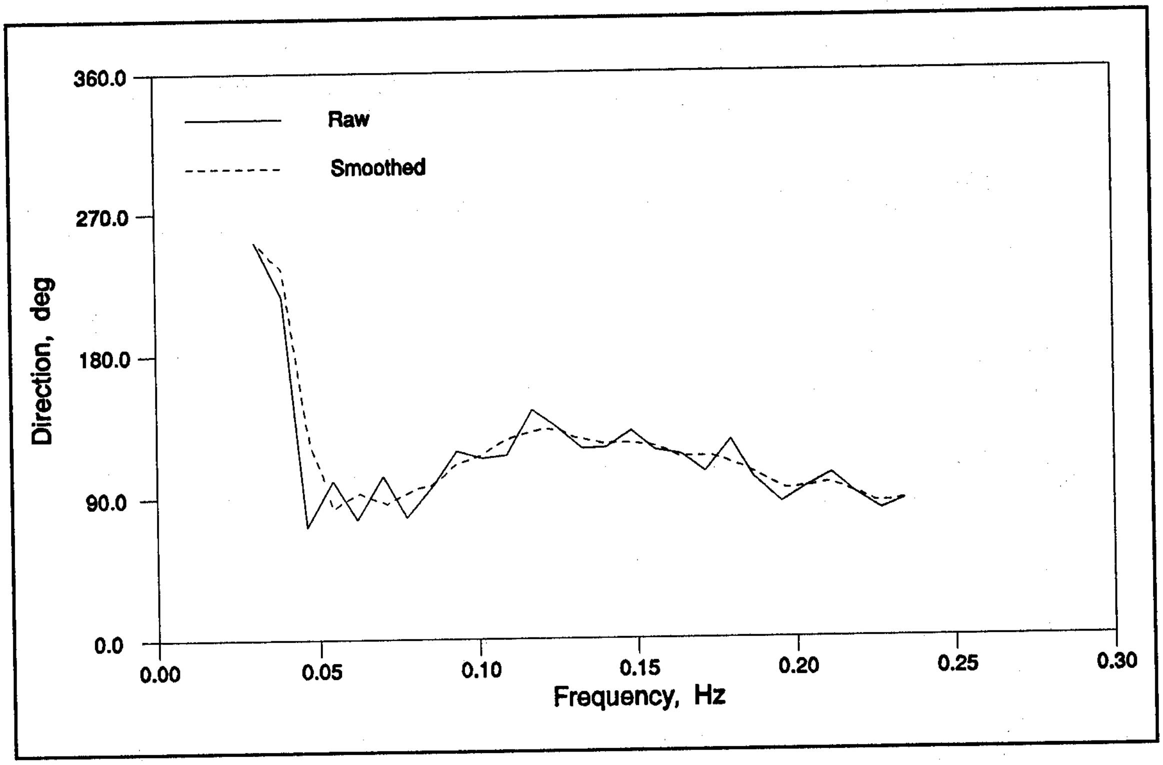
c. Minimum energy threshold (0.03 m^2/Hz for the nearshore gages and 0.05 m^2/Hz for the buoy) for selecting peaks to eliminate "low confidence" regions of the spectra.

Figure F3 shows an example of the slope array spectrum before (solid line) and after (dashed line) postprocessing. The dotted line indicates the threshold for identifying energy peaks. After postprocessing, the spectral peaks (representing individual wave trains) from the buoy were matched with the nearshore gages. The criteria for matching the wave trains were a difference in peak frequency of less than 0.02 Hz and wave direction between 0 and 180 deg (onshore propagating waves). Wave heights were calculated by summing the energy between local minima in the energy spectra. Table F1, which can be found at the end of this Appendix, lists the 67 wave trains identified through matching the Cumberland Island PUV gage with the buoy and the 287 wave trains identified through matching the Amelia Island slope array with the buoy for May 1989. The difference in the number of wave conditions at Cumberland and Amelia Islands is due to different sampling intervals and gaps in the gage records.

Intercomparison of gage data

Once wave trains were matched, the nearshore gage data were compared to the buoy data with scatter plots of wave direction and height (wave period was the criterion for matching wave trains). These plots reveal trends in the data and serve as a subjective check on the "reasonableness" of the data.

PUV gage versus buoy. Figures F4 and F5 show wave direction and height at the PUV gage versus those at the buoy. At the PUV gage, the shore-normal direction is approximately 97 deg.



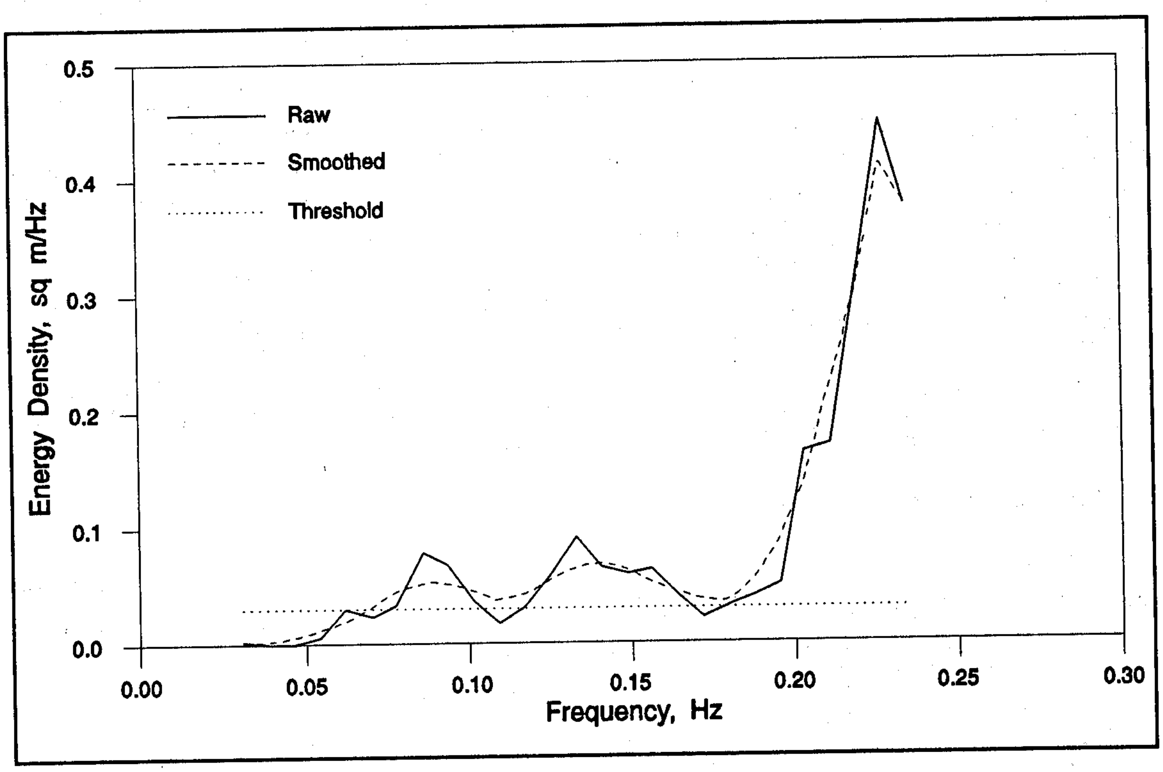


Figure F3. Smoothed versus unsmoothed slope array spectrum, 0100 GMT, 19 May 1989

Table F1
Wave Data

Date[1]	Buoy H_{mo} m	Buoy T sec	Buoy θ deg	PUV H_{mo} m	PUV T sec	PUV θ deg	STWAVE H_{mo} m	STWAVE θ sec
Cumberland PUV Gage Data								
50610	0.72	5.0	147	0.47	5.4	149	0.49	136
50616	0.44	5.0	137	0.44	4.8	150	0.29	131
50704	0.30	4.5	136	0.21	4.5	144	0.19	131
50710	0.36	8.3	99	0.28	8.8	127	0.19	104
50816	0.29	4.3	23	0.22	4.3	64	0.15	49
50816	0.35	8.3	111	0.25	8.3	118	0.19	108
50910	0.48	7.7	96	0.37	8.8	114	0.26	104
50913	0.55	7.7	91	0.29	8.8	112	0.30	100
50916	0.53	8.3	92	0.32	7.8	120	0.29	104
50919	0.44	8.3	107	0.36	8.3	118	0.24	108
51010	1.10	5.9	159	0.70	5.7	152	0.57	136
51022	0.67	5.9	140	0.53	5.7	148	0.38	127
51213	0.35	4.5	106	0.31	4.3	159	0.24	108
51301	0.27	10.0	92	0.19	10.2	115	0.16	105
51310	0.29	11.1	70	0.23	10.2	107	0.16	98
51319	0.28	10.0	72	0.24	11.1	104	0.16	99
51407	0.30	11.1	77	0.23	10.2	109	0.17	100
51416	0.31	10.0	72	0.23	11.1	109	0.18	99
51419	0.94	5.9	126	0.71	6.0	140	0.57	121
51419	0.38	10.0	82	0.20	10.2	109	0.23	102
51422	0.73	6.3	127	0.71	6.0	141	0.44	121
51422	0.28	10.0	83	0.23	11.1	109	0.17	102
51510	0.33	10.0	81	0.24	10.2	111	0.19	99
51513	0.61	5.3	95	0.38	5.7	115	0.38	102
51513	0.28	10.0	78	0.25	10.2	111	0.16	99
51616	0.32	9.1	89	0.21	9.5	117	0.20	101

(Sheet 1 of 13)

[1] Month, day, and hour, e.g., 50610 is 6 May 1989 at 10:00

Table F1 (Continued)								
	Buoy			PUV			STWAVE	
Date	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Cumberland PUV Gage Data								
51716	0.35	7.7	111	0.27	7.3	125	0.19	108
51719	0.41	7.1	115	0.26	7.8	125	0.22	113
51722	0.34	7.1	123	0.26	7.3	131	0.19	113
51801	0.31	7.7	118	0.31	6.9	125	0.16	112
51804	0.33	7.7	111	0.26	7.3	134	0.18	108
51810	0.33	7.1	115	0.22	7.8	113	0.18	113
51813	0.29	7.1	112	0.25	6.9	115	0.16	108
51819	0.29	6.7	115	0.21	7.3	119	0.16	113
51901	0.44	4.3	50	0.16	4.3	107	0.31	65
51901	0.26	7.1	110	0.24	6.9	114	0.14	108
51901	0.32	11.1	96	0.20	11.1	109	0.19	105
51904	0.42	4.5	54	0.30	4.3	85	0.26	70
51904	0.35	7.7	101	0.25	6.9	122	0.19	104
51910	0.43	9.1	61	0.21	10.2	121	0.25	94
51913	0.31	4.3	79	0.21	4.7	81	0.22	81
51913	0.52	9.1	58	0.24	9.5	114	0.29	91
51916	0.33	4.8	100	0.44	4.7	99	0.22	100
51916	0.50	9.1	64	0.32	9.5	92	0.29	94
52001	0.86	11.1	55	0.41	9.5	104	0.46	96
52004	0.75	11.1	58	0.51	11.1	98	0.40	96
52016	0.45	6.7	73	0.37	6.2	105	0.24	93
52016	0.71	11.1	56	0.42	10.2	103	0.38	96
52107	0.73	11.1	57	0.54	11.1	101	0.39	96
52110	0.65	10.0	59	0.39	11.1	105	0.35	94
52113	0.60	10.0	58	0.44	10.2	106	0.32	94
52116	0.58	11.1	44	0.35	9.5	99	0.29	94
52119	0.52	10.0	76	0.37	11.1	100	0.31	99
52122	0.53	10.0	66	0.32	11.1	107	0.30	96

(Sheet 2 of 13)

Table F1 (Continued)								
	Buoy			PUV			STWAVE	
Date	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Cumberland PUV Gage Data								
52201	0.45	10.0	74	0.37	10.2	103	0.26	99
52204	0.42	10.0	67	0.34	11.1	100	0.24	96
52207	0.40	10.0	48	0.33	10.2	101	0.20	92
52210	0.46	10.0	65	0.28	10.2	103	0.26	96
52213	0.41	10.0	64	0.27	11.1	113	0.23	96
52216	0.38	10.0	61	0.29	9.5	102	0.22	96
52219	0.38	10.0	71	0.27	10.2	92	0.22	99
52222	0.38	10.0	65	0.25	10.2	115	0.22	96
52301	0.40	9.1	79	0.26	10.2	108	0.24	97
52304	0.40	9.1	93	0.28	9.5	106	0.25	104
52307	0.39	10.0	66	0.27	9.5	108	0.22	96
52310	0.39	9.1	80	0.26	10.2	109	0.24	97
52410	0.29	9.1	99	0.19	9.5	116	0.18	104
Amelia Slope Array Data								
50105	0.95	4.8	148	0.61	4.9	134	0.75	131
50106	0.87	5.0	124	0.66	4.9	137	0.75	119
50107	0.84	5.0	125	0.65	4.9	139	0.71	119
50108	0.78	5.0	124	0.56	4.7	137	0.64	119
50109	0.78	5.0	123	0.58	4.7	144	0.64	119
50110	0.70	5.3	121	0.66	4.9	150	0.46	116
50111	0.71	5.0	134	0.60	5.1	144	0.54	126
50114	0.62	5.0	140	0.45	5.1	142	0.45	127
50116	0.61	4.5	164	0.47	4.6	146	0.34	142
50117	0.70	4.3	169	0.47	4.4	145	0.49	146
50118	0.86	4.3	165	0.63	4.6	151	0.60	146
50119	1.09	5.0	152	0.94	4.7	144	0.86	131
50121	1.48	5.6	147	1.13	5.3	141	1.02	124
50122	1.58	5.9	143	1.25	5.8	138	1.08	124

(Sheet 3 of 13)

Table F1 (Continued)

Date	Buoy			PUV			STWAVE	
	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Amelia Slope Array Data								
50123	1.54	6.3	151	1.14	6.4	137	1.05	124
50200	1.67	6.3	144	1.17	6.1	142	1.13	124
50202	1.67	6.7	139	1.13	6.7	141	1.09	117
50206	1.36	6.3	126	0.97	6.7	135	1.04	114
50207	1.16	6.3	123	0.97	6.4	136	0.83	115
50209	0.88	6.7	127	0.68	6.7	131	0.53	112
50210	0.86	6.7	130	0.64	6.4	142	0.52	112
50212	0.79	6.7	133	0.52	6.7	141	0.45	118
50213	0.73	6.7	134	0.43	7.1	140	0.42	118
50214	0.56	7.1	127	0.34	7.1	131	0.33	112
50215	0.53	6.7	126	0.34	7.5	128	0.31	112
50216	0.49	6.7	123	0.32	7.5	134	0.28	112
50217	0.44	7.1	110	0.32	7.5	130	0.26	107
50218	0.44	6.3	114	0.33	7.1	130	0.28	109
50219	0.45	6.3	112	0.33	6.7	128	0.29	109
50220	0.35	6.7	104	0.32	6.7	124	0.21	100
50221	0.41	6.7	102	0.34	7.1	133	0.25	100
50222	0.36	7.1	98	0.31	7.1	132	0.22	94
50223	0.37	7.7	101	0.32	7.5	131	0.21	99
50300	0.37	7.7	104	0.30	8.0	123	0.21	99
50301	0.34	7.7	128	0.25	8.0	129	0.19	109
50302	0.33	7.7	99	0.28	8.0	133	0.19	94
50305	0.37	7.1	112	0.25	7.5	128	0.22	107
50306	0.35	6.7	109	0.24	7.1	126	0.21	100
50307	0.35	6.3	109	0.29	6.7	135	0.22	102
50308	0.35	6.3	99	0.31	6.4	129	0.22	95
50309	0.37	6.7	98	0.31	6.4	126	0.22	94
50310	0.33	6.7	103	0.31	6.4	125	0.20	100

(Sheet 4 of 13)

Table F1 (Continued)

Date	Buoy			PUV			STWAVE	
	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Amelia Slope Array Data								
50407	0.29	6.3	129	0.25	6.7	136	0.18	115
50408	0.33	6.3	119	0.19	5.8	129	0.21	109
50412	0.27	5.9	115	0.33	6.1	132	0.17	109
50421	0.29	7.1	103	0.27	6.7	122	0.17	100
50502	0.41	4.3	77	0.26	4.4	93	0.32	75
50503	0.50	4.3	92	0.27	4.4	102	0.42	94
50505	0.50	4.3	121	0.33	4.4	125	0.41	122
50507	0.70	4.5	138	0.53	4.6	148	0.53	126
50508	0.83	4.8	144	0.68	4.6	142	0.64	132
50510	1.10	5.0	144	0.78	4.7	142	0.86	131
50511	1.06	5.0	145	0.79	4.9	140	0.83	131
50512	0.99	4.8	138	0.73	4.7	141	0.83	125
50513	0.85	5.0	129	0.79	4.9	133	0.73	119
50515	0.88	5.3	131	0.63	5.1	144	0.58	116
50516	0.87	5.3	142	0.65	5.3	149	0.52	128
50517	0.81	5.3	148	0.67	5.3	143	0.48	127
50518	0.76	5.0	161	0.67	5.1	142	0.52	137
50519	0.85	5.0	157	0.61	5.1	147	0.61	137
50521	0.79	4.8	161	0.60	4.7	147	0.55	137
50523	0.83	4.5	162	0.75	4.6	149	0.59	137
50600	0.83	4.3	161	0.76	4.6	145	0.65	141
50601	1.03	4.8	165	0.66	4.6	145	0.66	140
50605	0.92	5.0	155	0.56	5.1	142	0.67	137
50606	0.80	5.3	145	0.49	5.3	145	0.48	127
50607	0.76	5.3	139	0.47	5.1	142	0.48	122
50607	0.42	7.7	99	0.28	7.5	120	0.24	94
50608	0.76	5.3	140	0.52	4.9	144	0.48	122
50609	0.70	5.0	149	0.53	5.1	142	0.50	132

(Sheet 5 of 13)

Table F1 (Continued)								
	Buoy			PUV			STWAVE	
Date	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Amelia Slope Array Data								
50610	0.72	5.0	147	0.62	4.9	150	0.52	132
50611	0.58	5.0	146	0.45	4.7	145	0.39	133
50611	0.34	7.7	94	0.31	7.5	124	0.20	94
50612	0.59	4.8	144	0.41	4.7	147	0.40	133
50613	0.55	4.8	149	0.31	4.7	146	0.36	133
50614	0.34	10.0	120	0.27	8.5	121	0.21	102
50615	0.33	10.0	116	0.29	8.5	130	0.20	102
50616	0.44	5.0	137	0.34	5.1	137	0.30	127
50617	0.39	5.0	134	0.23	4.9	139	0.26	127
50617	0.37	10.0	118	0.26	9.1	125	0.23	102
50618	0.34	4.8	134	0.32	4.9	138	0.23	127
50619	0.37	9.1	116	0.27	8.0	127	0.24	103
50620	0.38	5.0	143	0.22	5.1	141	0.24	133
50620	0.37	8.3	122	0.27	8.5	123	0.20	109
50621	0.37	8.3	110	0.28	7.5	125	0.21	104
50622	0.36	4.3	158	0.21	4.4	152	0.23	142
50622	0.30	7.7	109	0.32	8.0	122	0.17	99
50623	0.36	8.3	112	0.29	8.0	128	0.20	104
50700	0.35	8.3	108	0.30	8.0	134	0.20	99
50701	0.34	8.3	120	0.32	8.0	132	0.19	104
50702	0.33	8.3	111	0.34	8.5	123	0.19	104
51714	0.37	7.1	110	0.32	7.5	132	0.22	107
51715	0.32	7.7	111	0.31	7.5	131	0.18	104
51716	0.35	7.7	111	0.32	7.5	126	0.20	104
51717	0.36	7.1	124	0.35	7.5	132	0.21	112
51718	0.35	7.1	120	0.36	7.5	130	0.21	107
51719	0.41	7.1	115	0.39	7.1	132	0.24	107
51720	0.39	7.1	117	0.37	7.1	131	0.23	107

(Sheet 6 of 13)

Table F1 (Continued)

Date	Buoy			PUV			STWAVE	
	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Amelia Slope Array Data								
51721	0.35	7.1	115	0.41	7.1	131	0.21	107
51722	0.34	7.1	123	0.38	7.1	136	0.19	112
51723	0.31	7.1	113	0.35	7.1	134	0.18	107
51801	0.31	7.7	118	0.28	7.1	134	0.17	104
51802	0.29	7.7	116	0.27	7.5	124	0.16	104
51803	0.27	7.7	105	0.28	7.5	128	0.15	99
51804	0.33	7.7	111	0.26	8.0	127	0.19	104
51806	0.31	7.7	111	0.28	7.5	124	0.17	104
51807	0.31	7.1	115	0.27	7.1	127	0.18	107
51808	0.33	6.7	110	0.29	7.1	128	0.19	107
51809	0.34	7.1	112	0.30	6.7	129	0.20	107
51810	0.33	7.1	115	0.27	7.1	133	0.19	107
51811	0.34	7.1	115	0.30	7.1	127	0.20	107
51812	0.32	7.1	110	0.30	7.1	126	0.19	107
51813	0.29	7.1	112	0.29	7.5	124	0.17	107
51814	0.32	7.7	112	0.33	7.1	126	0.18	104
51815	0.28	7.1	118	0.24	7.5	128	0.16	107
51816	0.31	7.1	109	0.25	7.5	129	0.19	100
51817	0.28	7.1	110	0.23	7.5	135	0.16	107
51818	0.29	7.1	110	0.25	7.1	132	0.17	107
51819	0.29	6.7	115	0.32	6.7	128	0.17	107
51820	0.28	6.7	108	0.28	6.7	123	0.17	100
51821	0.31	6.7	111	0.33	6.7	119	0.18	107
51823	0.31	6.7	113	0.23	6.7	127	0.18	107
51823	0.31	11.1	101	0.23	10.7	109	0.19	97
51900	0.50	4.3	43	0.34	4.4	89	0.37	53
51900	0.26	7.1	107	0.24	7.1	121	0.15	100
51900	0.27	11.1	82	0.23	11.6	117	0.16	91

(Sheet 7 of 13)

Table F1 (Continued)								
	Buoy			PUV			STWAVE	
Date	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Amelia Slope Array Data								
51901	0.44	4.3	50	0.38	4.4	87	0.33	59
51901	0.26	7.1	110	0.25	7.1	124	0.15	107
51901	0.32	11.1	96	0.20	11.6	98	0.20	94
51902	0.44	4.3	51	0.37	4.6	92	0.33	59
51902	0.26	7.7	106	0.24	7.5	134	0.15	99
51902	0.32	11.1	101	0.24	10.7	118	0.19	97
51903	0.45	4.8	56	0.33	4.6	94	0.30	62
51903	0.35	10.0	97	0.20	10.7	111	0.22	94
51904	0.42	4.5	54	0.33	4.6	97	0.28	62
51905	0.46	4.5	52	0.33	4.6	94	0.31	62
51905	0.26	7.1	104	0.21	7.5	125	0.15	100
51905	0.28	11.1	115	0.26	10.7	117	0.17	100
51906	0.39	10.0	107	0.19	9.8	116	0.25	98
51907	0.41	10.0	100	0.24	9.8	112	0.26	98
51908	0.45	9.1	82	0.25	9.8	116	0.29	90
51909	0.60	4.5	67	0.30	4.6	98	0.43	69
51909	0.46	10.0	71	0.29	9.8	118	0.28	87
51910	0.54	5.0	70	0.35	4.6	104	0.39	77
51910	0.43	9.1	61	0.27	9.1	109	0.26	81
51911	0.47	4.8	68	0.46	4.6	99	0.34	77
51911	0.51	8.3	62	0.38	9.1	106	0.27	80
51912	0.43	4.8	64	0.36	4.4	100	0.30	69
51912	0.50	9.1	60	0.36	9.8	104	0.30	81
51913	0.31	4.3	79	0.35	4.6	106	0.23	85
51913	0.52	9.1	58	0.42	9.1	107	0.31	81
51915	0.42	4.5	91	0.34	4.9	116	0.30	94
51915	0.49	8.3	65	0.40	9.8	106	0.26	80
51916	0.33	4.8	100	0.29	4.7	107	0.23	103

(Sheet 8 of 13)

Table F1 (Continued)								
Date	Buoy			PUV			STWAVE	
	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Amelia Slope Array Data								
51916	0.50	9.1	64	0.27	9.8	108	0.30	81
51917	0.30	4.8	96	0.26	4.6	110	0.21	94
51917	0.52	10.0	79	0.39	9.8	108	0.33	91
51918	0.24	4.8	93	0.26	4.6	124	0.17	94
51918	0.55	9.1	71	0.37	9.8	111	0.35	86
51919	0.60	9.1	67	0.36	9.1	115	0.36	81
51920	0.67	9.1	57	0.44	9.8	104	0.41	81
51921	0.64	10.0	53	0.40	9.8	103	0.35	80
51922	0.69	10.0	52	0.53	10.7	101	0.38	80
51923	0.42	5.6	80	0.25	6.1	113	0.27	87
51923	0.76	11.1	48	0.49	10.7	101	0.40	82
52000	0.79	11.1	50	0.66	10.7	103	0.41	82
52001	0.86	11.1	55	0.52	10.7	100	0.45	82
52002	0.89	11.1	58	0.50	11.6	98	0.50	85
52003	0.76	11.1	58	0.60	11.6	103	0.42	85
52004	0.75	11.1	58	0.46	11.6	102	0.42	85
52005	0.80	10.0	64	0.55	10.7	106	0.46	83
52006	0.81	10.0	67	0.48	11.6	108	0.47	83
52007	0.91	10.0	65	0.57	10.7	107	0.53	83
52008	0.93	10.0	60	0.42	10.7	110	0.54	83
52009	0.93	10.0	55	0.55	10.7	108	0.51	80
52010	0.58	6.7	61	0.35	7.5	105	0.33	76
52010	0.78	10.0	52	0.46	11.6	100	0.43	80
52011	0.92	11.1	52	0.35	11.6	102	0.48	82
52012	0.69	11.1	48	0.42	11.6	102	0.36	82
52013	0.74	11.1	57	0.47	11.6	104	0.41	85
52014	0.88	11.1	56	0.39	11.6	105	0.46	82
52015	0.86	11.1	55	0.42	11.6	102	0.45	82

(Sheet 9 of 13)

Table F1 (Continued)								
	Buoy			PUV			STWAVE	
Date	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Amelia Slope Array Data								
52016	0.45	6.7	73	0.31	6.1	104	0.26	82
52016	0.71	11.1	56	0.45	11.6	108	0.37	82
52017	0.47	5.9	81	0.26	5.6	105	0.30	87
52017	0.65	11.1	59	0.46	11.6	104	0.36	85
52018	0.83	11.1	63	0.47	11.6	105	0.46	85
52019	0.92	11.1	69	0.50	11.6	106	0.54	88
52020	0.89	10.0	68	0.53	10.7	106	0.54	87
52021	0.86	10.0	68	0.50	11.6	110	0.52	87
52022	0.90	10.0	69	0.48	10.7	108	0.55	87
52023	0.85	11.1	68	0.53	10.7	104	0.50	88
52100	0.86	10.0	64	0.57	10.7	105	0.50	83
52101	0.86	11.1	58	0.60	10.7	104	0.48	85
52102	0.81	11.1	75	0.58	11.6	103	0.47	88
52103	0.73	11.1	81	0.45	11.6	104	0.44	91
52104	0.69	11.1	71	0.39	11.6	105	0.41	88
52105	0.65	11.1	53	0.49	11.6	115	0.34	82
52106	0.74	11.1	57	0.50	10.7	113	0.41	85
52107	0.73	11.1	57	0.40	11.6	109	0.41	85
52108	0.74	10.0	57	0.46	9.8	109	0.43	83
52109	0.70	10.0	57	0.44	10.7	110	0.41	83
52110	0.65	10.0	59	0.48	9.8	105	0.38	83
52111	0.63	10.0	56	0.49	10.7	104	0.34	80
52112	0.62	10.0	65	0.36	10.7	106	0.36	83
52113	0.60	10.0	58	0.36	9.8	101	0.35	83
52114	0.63	11.1	56	0.39	10.7	100	0.33	82
52115	0.57	11.1	50	0.43	10.7	101	0.30	82
52116	0.58	11.1	44	0.41	10.7	107	0.28	79
52117	0.56	11.1	40	0.38	11.6	103	0.27	79
(Sheet 10 of 13)								

Table F1 (Continued)								
	Buoy			PUV			STWAVE	
Date	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Amelia Slope Array Data								
52118	0.59	11.1	47	0.34	10.7	108	0.31	82
52119	0.52	10.0	76	0.37	11.6	112	0.31	87
52120	0.56	10.0	72	0.41	10.7	110	0.34	87
52121	0.57	10.0	67	0.37	10.7	114	0.33	83
52122	0.53	10.0	66	0.42	10.7	107	0.31	83
52123	0.60	10.0	71	0.38	9.8	106	0.36	87
52201	0.45	10.0	74	0.36	10.7	107	0.27	87
52202	0.47	11.1	52	0.37	10.7	101	0.25	82
52203	0.43	11.1	55	0.34	11.6	108	0.23	82
52204	0.42	10.0	67	0.34	9.8	108	0.24	83
52205	0.41	10.0	43	0.36	10.7	104	0.21	77
52206	0.38	10.0	44	0.29	11.6	114	0.19	77
52207	0.40	10.0	48	0.31	10.7	107	0.22	80
52208	0.41	10.0	55	0.31	10.7	116	0.22	80
52209	0.46	10.0	61	0.35	9.8	113	0.27	83
52210	0.46	10.0	65	0.33	9.8	105	0.27	83
52211	0.48	10.0	62	0.33	9.8	110	0.28	83
52212	0.43	10.0	58	0.33	9.8	98	0.25	83
52213	0.41	10.0	64	0.34	9.8	104	0.24	83
52214	0.45	10.0	71	0.37	9.8	104	0.27	87
52215	0.38	10.0	79	0.34	10.7	109	0.24	91
52216	0.38	10.0	61	0.31	9.8	116	0.22	83
52217	0.40	10.0	61	0.28	10.7	122	0.23	83
52218	0.38	10.0	63	0.30	9.8	120	0.22	83
52219	0.38	10.0	71	0.31	9.1	118	0.23	87
52220	0.41	10.0	74	0.32	8.5	117	0.25	87
52221	0.41	9.1	80	0.31	9.8	110	0.27	90
52222	0.38	10.0	65	0.36	9.1	113	0.22	83
								(Sheet 11 of 13)

Table F1 (Continued)								
	Buoy			PUV			STWAVE	
Date	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Amelia Slope Array Data								
52223	0.36	10.0	72	0.33	8.5	114	0.22	87
52300	0.40	10.0	73	0.34	9.1	104	0.24	87
52301	0.40	9.1	79	0.34	9.1	110	0.26	90
52302	0.35	10.0	79	0.32	8.5	116	0.22	91
52303	0.38	9.1	91	0.31	9.8	111	0.25	94
52304	0.40	9.1	93	0.32	9.8	120	0.26	94
52305	0.36	10.0	80	0.31	9.8	109	0.23	91
52306	0.35	9.1	77	0.26	9.8	110	0.22	86
52307	0.39	10.0	66	0.26	9.8	117	0.23	83
52308	0.38	9.1	79	0.26	9.1	124	0.25	90
52309	0.37	9.1	73	0.27	9.1	112	0.23	86
52310	0.39	9.1	80	0.29	8.5	119	0.25	90
52311	0.34	9.1	78	0.27	9.1	116	0.22	86
52312	0.35	8.3	77	0.26	8.5	115	0.19	85
52313	0.32	9.1	81	0.25	9.1	109	0.21	90
52314	0.41	4.8	144	0.22	4.6	160	0.26	133
52314	0.31	8.3	81	0.25	9.1	109	0.17	90
52315	0.40	4.8	150	0.21	4.7	152	0.26	133
52315	0.30	9.1	85	0.28	8.5	123	0.20	90
52316	0.47	5.0	147	0.26	5.1	159	0.31	133
52316	0.34	9.1	95	0.22	9.1	114	0.23	94
52317	0.52	5.3	143	0.28	5.1	159	0.30	127
52317	0.28	9.1	94	0.23	9.1	118	0.19	94
52318	0.54	5.6	139	0.30	5.1	154	0.33	121
52318	0.27	9.1	86	0.22	9.1	119	0.18	90
52319	0.46	5.3	146	0.34	5.6	156	0.26	127
52320	0.49	5.3	147	0.29	5.3	156	0.28	127
52320	0.32	9.1	101	0.23	8.5	133	0.21	99
								(Sheet 12 of 13)

Table F1 (Concluded)								
	Buoy			PUV			STWAVE	
Date	H_{mo} m	T sec	θ deg	H_{mo} m	T sec	θ deg	H_{mo} m	θ sec
Amelia Slope Array Data								
52321	0.45	5.3	156	0.30	5.1	157	0.23	132
52322	0.41	5.3	152	0.24	4.9	154	0.23	127
52322	0.26	9.1	88	0.22	8.5	128	0.17	90
52323	0.30	9.1	88	0.23	8.5	122	0.20	90
52404	0.31	9.1	106	0.20	9.1	126	0.20	99
52405	0.31	9.1	103	0.26	9.1	120	0.20	99
52409	0.33	9.1	101	0.25	9.1	123	0.22	99
52410	0.29	9.1	99	0.22	8.5	126	0.19	94
52411	0.26	8.3	103	0.27	8.5	122	0.15	99
52412	0.30	8.3	88	0.24	8.0	126	0.17	90
52423	0.31	5.0	160	0.25	5.1	146	0.18	138
52500	0.28	4.8	163	0.23	4.7	157	0.14	142
52501	0.31	4.8	162	0.23	4.7	154	0.18	138
52510	0.26	14.3	123	0.18	14.2	113	0.13	101
52512	0.26	14.3	90	0.20	14.2	128	0.15	94
52518	0.24	14.3	82	0.17	14.2	112	0.14	92
52519	0.26	14.3	69	0.18	14.2	111	0.14	90
52520	0.32	9.1	93	0.20	9.1	122	0.21	94
52521	0.29	12.5	116	0.21	14.2	121	0.17	100
52522	0.29	8.3	112	0.22	8.5	123	0.16	104
52600	0.28	8.3	117	0.23	8.0	124	0.16	104
								(Sheet 13 of 13)

The buoy wave directions range from approximately 25 to 160 deg, and the range of directions compresses to 64 to 150 deg at the PUV gage. The solid line in the plots represents an exact match of the two variables being plotted. There are two interesting trends to note in the data. First, the wave direction consistently increases from offshore to nearshore (wave direction becomes more southerly). Second, waves incident from the northeast quadrant turn more than waves from the southeast. The second trend can be explained by the fact that waves approaching from the northeast quadrant in this May data set tend to be relatively longer in period (9 to 11 sec

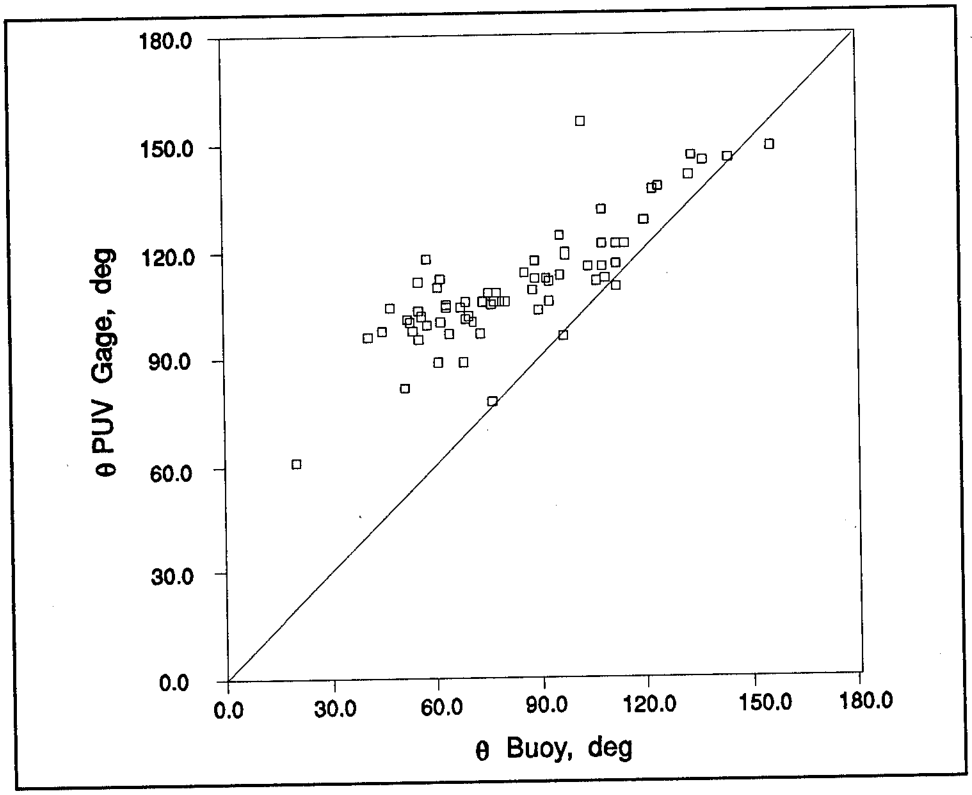


Figure F4. PUV gage versus buoy directions

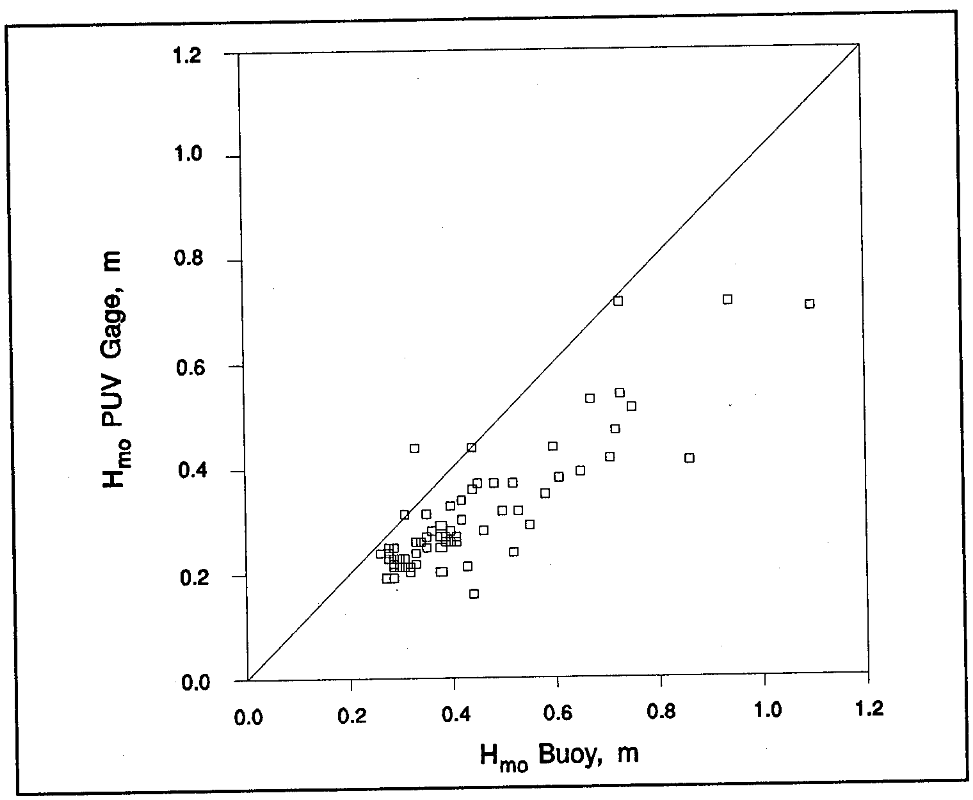


Figure F5. PUV gage versus buoy heights

as compared to 4 to 7 sec from the southeast), so they refract more. Also, the bathymetry contours north of the gage do not run parallel to the shoreline, but run offshore creating an apparent shore-normal direction at an angle larger than 97 deg, again causing greater refraction. The first trend, waves incident from the southeast turning away from shore normal, is contrary to refraction theory. Possible explanations for this trend include a rotation in one of the gages, wave-current interaction effects (waves approaching from the south pass across the inlet entrance), depth variations (tide range is 2 m), or local wind effects on the short-period southerly waves. The ratios of wave height at the PUV gage to wave height at the buoy range from 0.6 to 1.0 with a mean ratio of 0.75. Scatter in the direction and height data may be a function of wave period, tide (both changes in water depth and wave-current interaction), local wind effects, and gage error. Scatter in wave direction is on the order of 20 to 30 deg.

Slope array versus buoy. Figures F6 and F7 show wave direction and height at the slope array versus the buoy. At the slope array, the shore-normal direction is approximately 94 deg. Wave directions obtained from the slope array range from 85 to 160 deg. The trends are similar to the PUV gage data (all waves becoming more southerly and northern waves turning more than southern waves), but there are significant differences. The magnitude of the overall turning of the waves to south is larger (by approximately 10 deg) than at the PUV gage. Also, the most southerly waves (directions greater than 130 deg) do not follow this overall trend. These southerly waves have short periods (4 to 5 sec) and correlate highly to strong southerly winds (speeds greater than 5 m/sec). These waves may be locally altered by the wind. Eliminating these waves from the scatter plot in Figure F6, gives Figure F8, which is more similar to the PUV gage plot (Figure F4). The ratio of wave height at the slope array to buoy ranges from 0.6

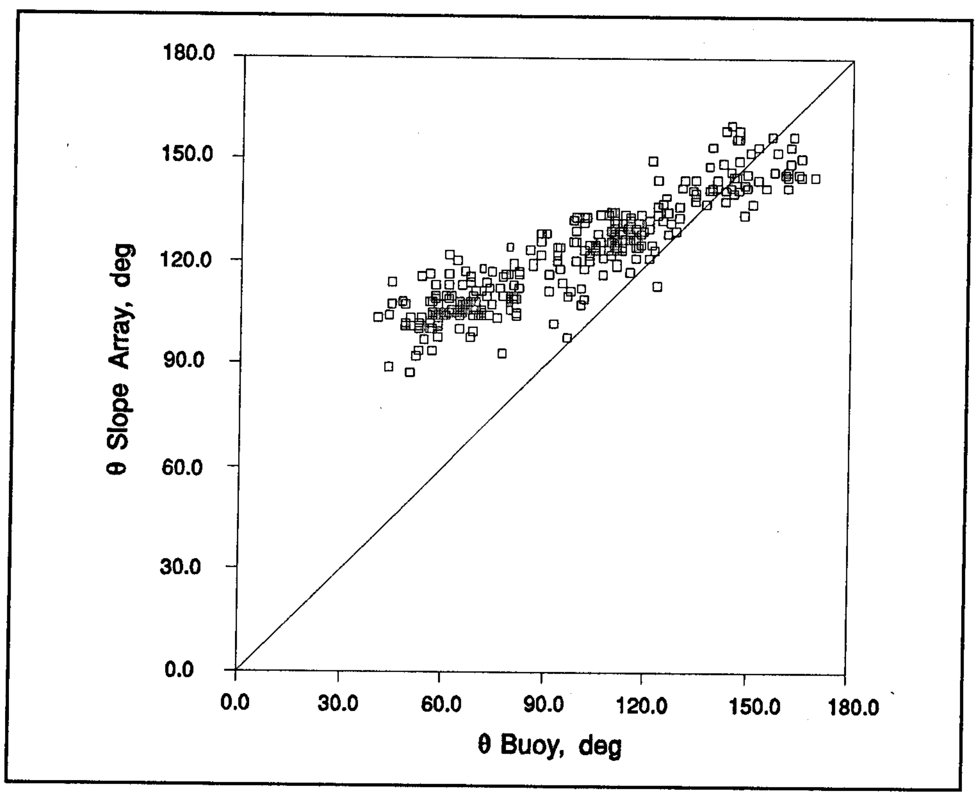


Figure F6. Slope array versus buoy directions

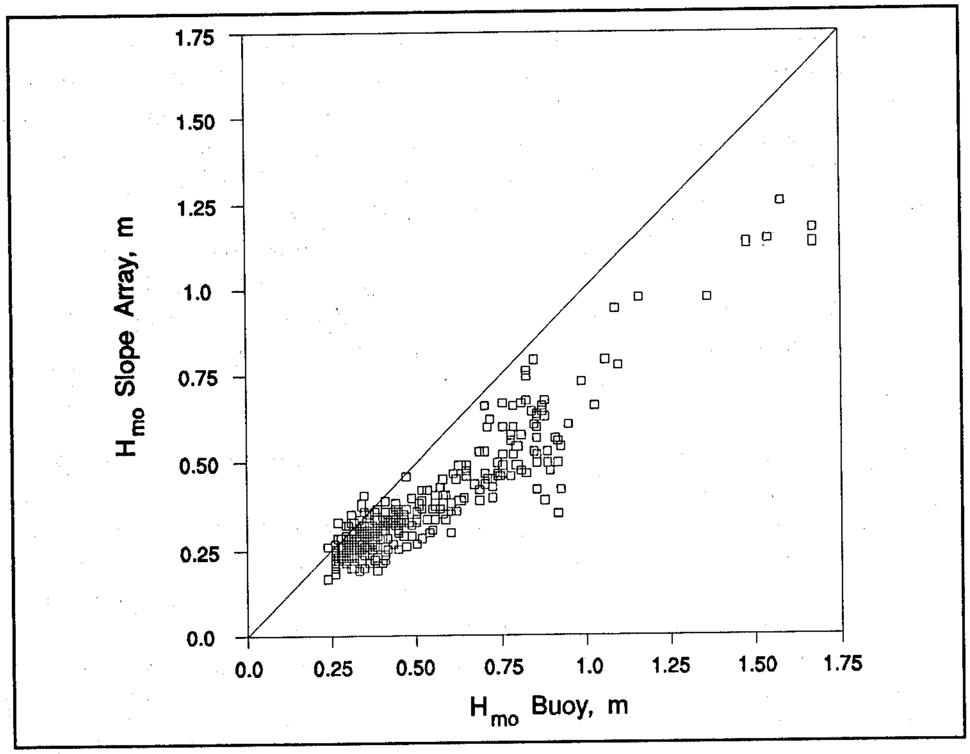


Figure F7. Slope array versus buoy heights

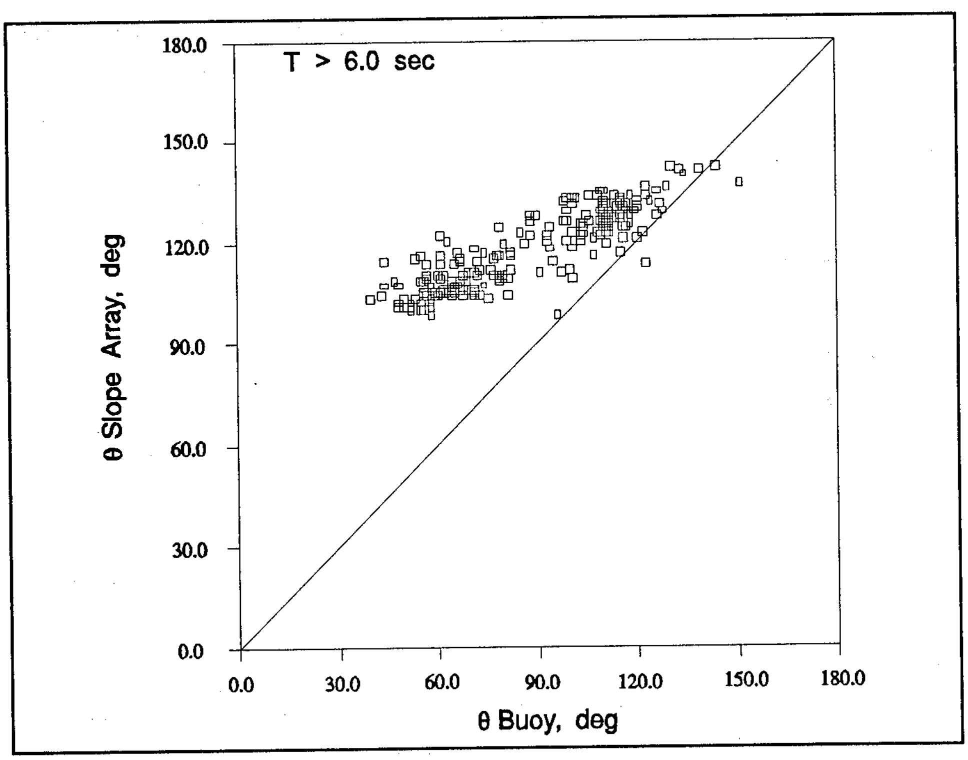


Figure F8. Slope array versus buoy directions (periods greater than or equal to 6 sec) to 1.0 with a mean ratio of 0.82. As discussed under the PUV gage analysis, scatter in the data may be caused by wave period, tide, wind, and gage errors. This directional scatter, similar to that for the PUV gage, is approximately 20 to 30 deg. Only the May 1989 data are shown in Figures F6, F7, and F8, to coincide with the PUV gage data, but the additional months of data showed the same tendencies.

Numerical Model Results

The spectral wave transformation model STWAVE (Cialone et al. 1992, Resio 1993) was selected to transform offshore Wave Information Study (WIS) wave hindcasts to the nearshore for shoreline change modeling at Kings Bay. The thrust of this appendix is to verify this application of STWAVE at Kings Bay. The STWAVE model numerically simulates wave refraction, shoaling, and bottom-induced diffraction under the assumptions:

a. Mild bottom slopes.

b. Negligible wave reflection.

c. Spatially homogeneous and steady offshore wave conditions.

The only dissipation mechanism in STWAVE is removal of energy exceeding a depth-dependent limiting spectrum (Davis, Smith, and Vincent 1991). Energy may be reduced across the entire spectrum in surf zone breaking or at a few frequencies in steepness-induced white capping. All comparisons made in this appendix concern wave conditions outside the surf zone. Wave height, peak period, and mean direction were input on the offshore boundary in the form of a TMA spectrum (parametric, self-similar spectral shape developed from the TEXEL storm, MARSEN, and ARSLOE data sets; Bouws et al. 1985) with a directional spread in the form $\cos^n$. The values of n used to define the directional spread were chosen as a function of peak wave period (T) (Table F2). The STWAVE model had not been previously applied to such complex bathymetry, so changes were required to the "sideways propagation" terms to ensure conservation of energy. These changes were made in conjunction with the developer of the code.[1]

Application of STWAVE

The STWAVE model was applied at St. Marys Entrance with 17 direction bands (10-deg resolution) and 20 frequency bands. The frequency resolution (Δf) was chosen as a function of the peak wave period as given in Table F2. Two separate bathymetric grids were used. The Cumberland Island grid has 441 cells across shore with a spacing of 91.4 m and 221 cells alongshore with a spacing of 182.9 m (Figure F9). The Amelia Island grid has 441 cells across shore with a spacing of 91.4 m and 261 cells alongshore with a spacing of 182.9 m (Figure F10). The grid depths were assigned by interpolating 1974 survey data. The bulk of the two grids overlap, but their alignment is slightly different to accommodate the different shoreline orientations (shore-normal is 97 deg for the Cumberland Island and 94 deg for the Amelia Island grid).

[1] Personal communication, Dr. Donald Resio, Professor, Department of Oceanography and Ocean Engineering, Florida Institute of Technology, 17 May 1991.

Table F2 Directional Spreading *n* and Frequency Resolution			
T (sec)	*n*	*f* initial (Hz)	Δ *f* (Hz)
4-5	4	0.050	0.040
6	4	0.040	0.032
7	5	0.036	0.027
8	5	0.031	0.023
9	6	0.028	0.021
10	6	0.025	0.019
11	7	0.0227	0.017
12	7	0.0208	0.0156
13	8	0.0192	0.0144
14	8	0.0179	0.0134
15	8	0.0167	0.0125

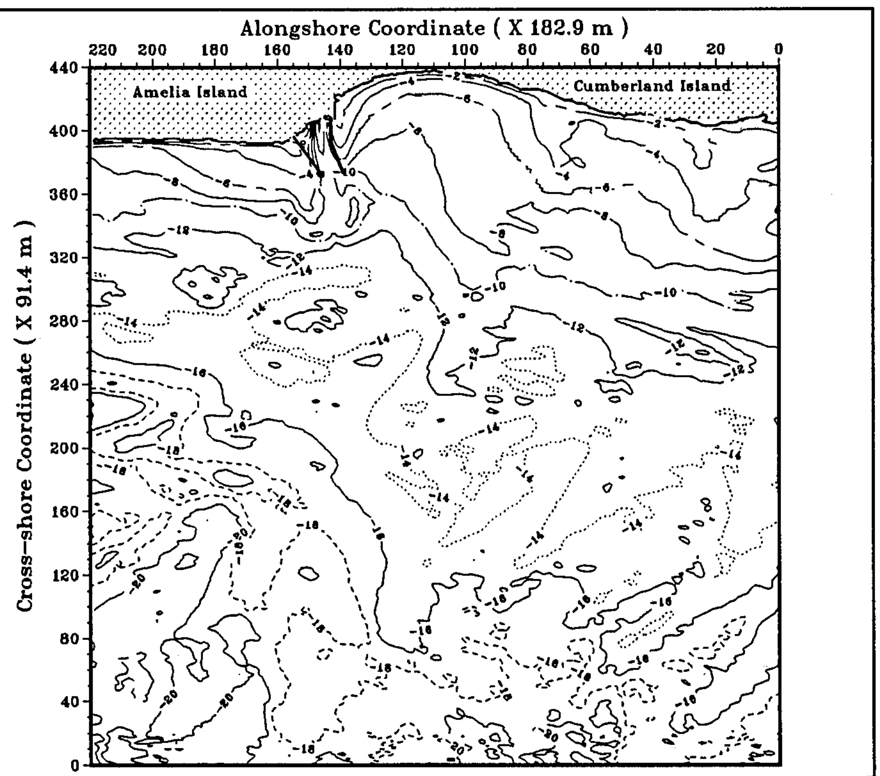


Figure F9. Cumberland Island STWAVE grid

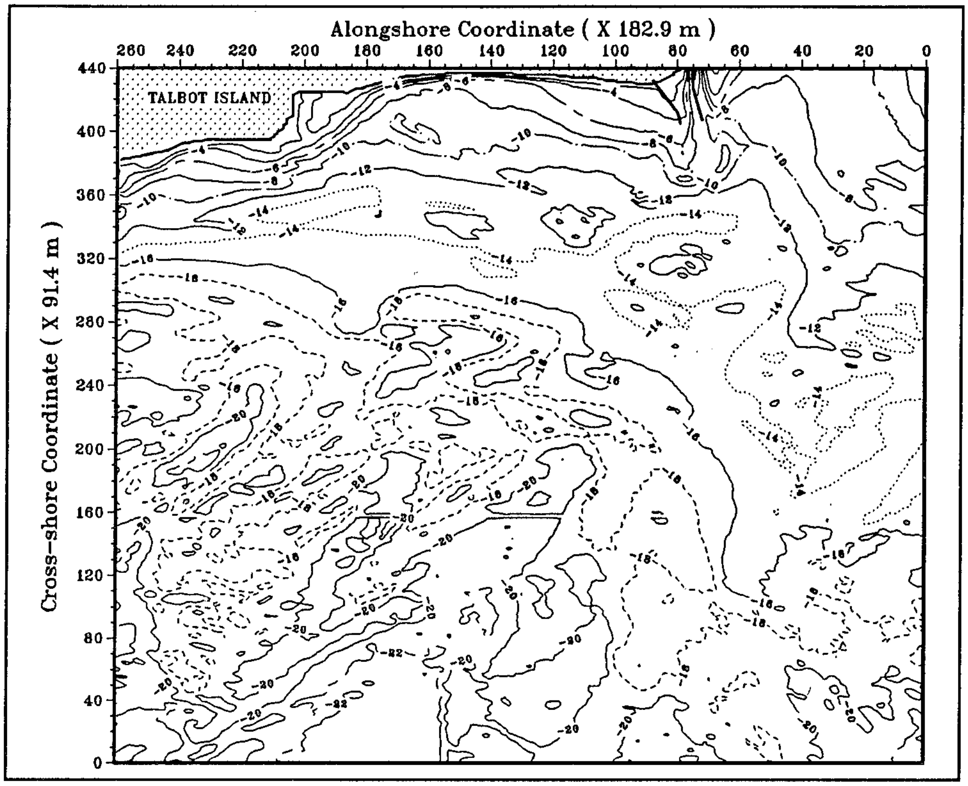


Figure F10. Amelia Island STWAVE grid

The STWAVE model was applied with the Cumberland Island grid for the 67 waves identified through matching the PUV gage and buoy for May 1989 (Table F1). The wave height, period, and direction at the buoy were used as STWAVE input. The wave height at the buoy is the energy-based, zero-moment wave height (H_{mo}), which is equivalent to the significant wave height ($H_{1/3}$) in deep water. Similarly, STWAVE was applied with the Amelia Island grid for 287 waves for May 1989 (Table F1). Tidal variations in the water depth, current, and local winds were not included in the simulations. These omissions will be discussed in a later section.

Cumberland Island results

Grid point (380, 120) on the Cumberland Island grid corresponds to the position of the PUV gage. Figure F11 is a scatter plot of the STWAVE estimates of wave direction (at the PUV gage position) versus the PUV gage measurements. The two estimates of direction are well correlated (correlation coefficient, $r^2 = 0.71$), but the STWAVE estimates are an average of 12 deg smaller than the measurements. Figure F12 is a scatter plot of the STWAVE estimates of wave direction (at the PUV gage position) versus the buoy measurements, which complements Figure F4. The STWAVE results show the same trends as the PUV gage data with two exceptions. First, there is far less scatter in the STWAVE results. This is expected because all the factors that contribute to scatter, except variation of wave period, are absent in the STWAVE simulations. Second, the STWAVE directions are shifted approximately 10 deg (smaller) from the PUV gage directions. The STWAVE results show the same trend of greater refraction of waves from the northeast than from the southeast, and the apparent shore-normal wave ray is approximately 120 deg, or 20 deg

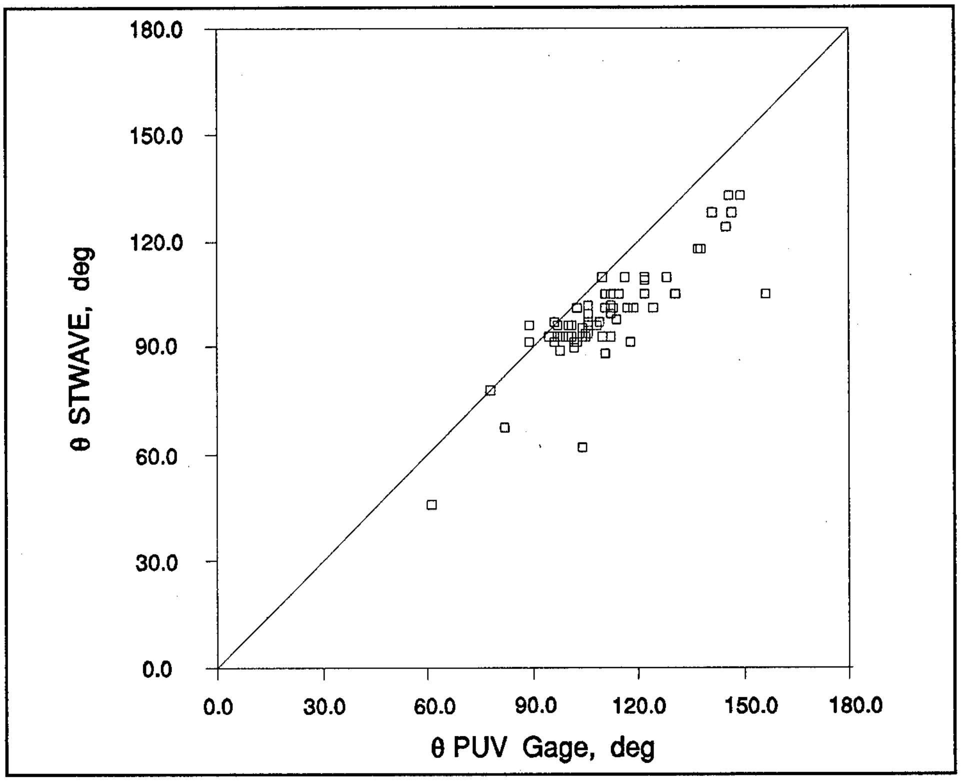


Figure F11. STWAVE versus PUV gage direction

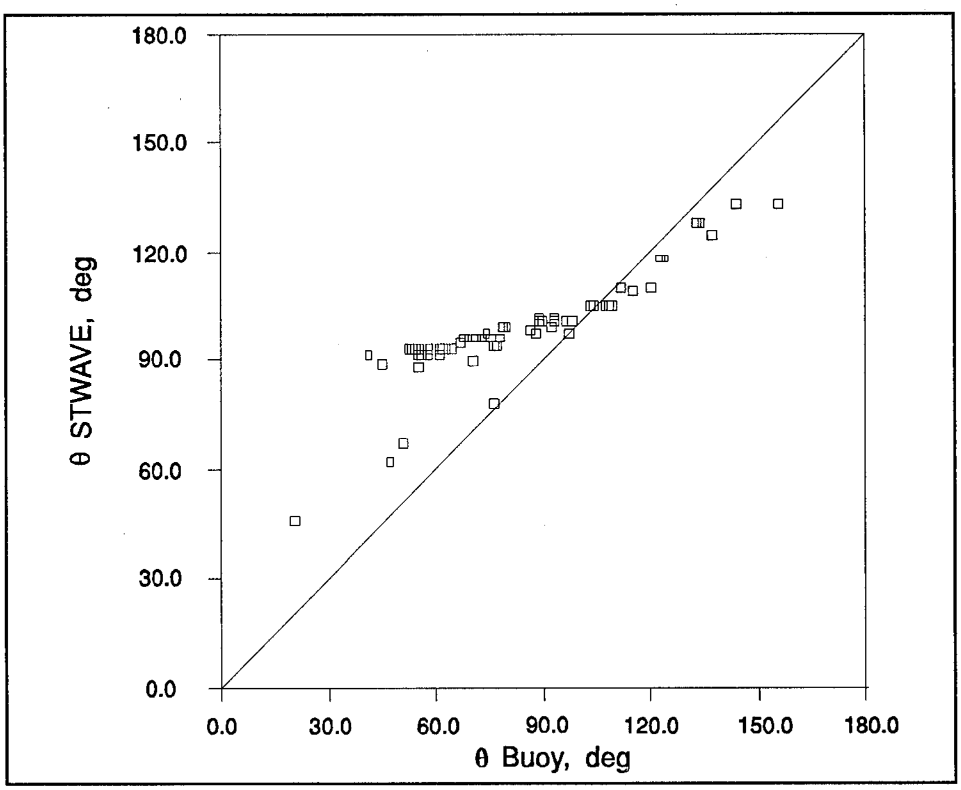


Figure F12. STWAVE versus buoy direction (Cumberland) south of a normal to the shoreline. Figure F13 is a scatter plot of the STWAVE estimate of wave height versus the PUV gage measurement. The STWAVE model underpredicts the gage measurements by an average of 19 percent, which converts to an average underprediction of 0.06 m. The correlation coefficient is 0.72; thus, the STWAVE results explain 72 percent of the variance in the gage wave heights. The omission of local wave generation (no wind input) has the greatest impact on wave spectra with peak periods less than 6 sec. If only cases with peak period of 6 sec or greater are considered (54 cases), the correlation coefficient for wave direction improves to 0.98, and the wave height correlation coefficient is unchanged.

Amelia Island results

Grid point (406, 136) on the Amelia Island grid corresponds to the position of the slope array. Figure F14 is a scatter plot of the STWAVE estimates of wave direction (at the slope array position) versus the slope array measurements. The two estimates of direction are well correlated (r^2 = 0.85), but the STWAVE estimates of direction are an average of 22 deg smaller than the measurements. Also, as discussed in the *Field Measurements* section, the most southerly waves do not follow the same trend (smaller angles from STWAVE) of the other wave directions. Figure F15 is a scatter plot of the STWAVE estimates of wave direction (at the slope array position) versus the buoy measurements. This plot complements Figure F6. The STWAVE results show the same trends as the slope array data with two exceptions. First, there is far less scatter in the STWAVE results. This is expected, as previously stated. Second, the STWAVE directions are shifted approximately 25 deg (smaller) from the slope array directions, on average. The STWAVE results show the same trend of greater refraction of waves from the northeast than

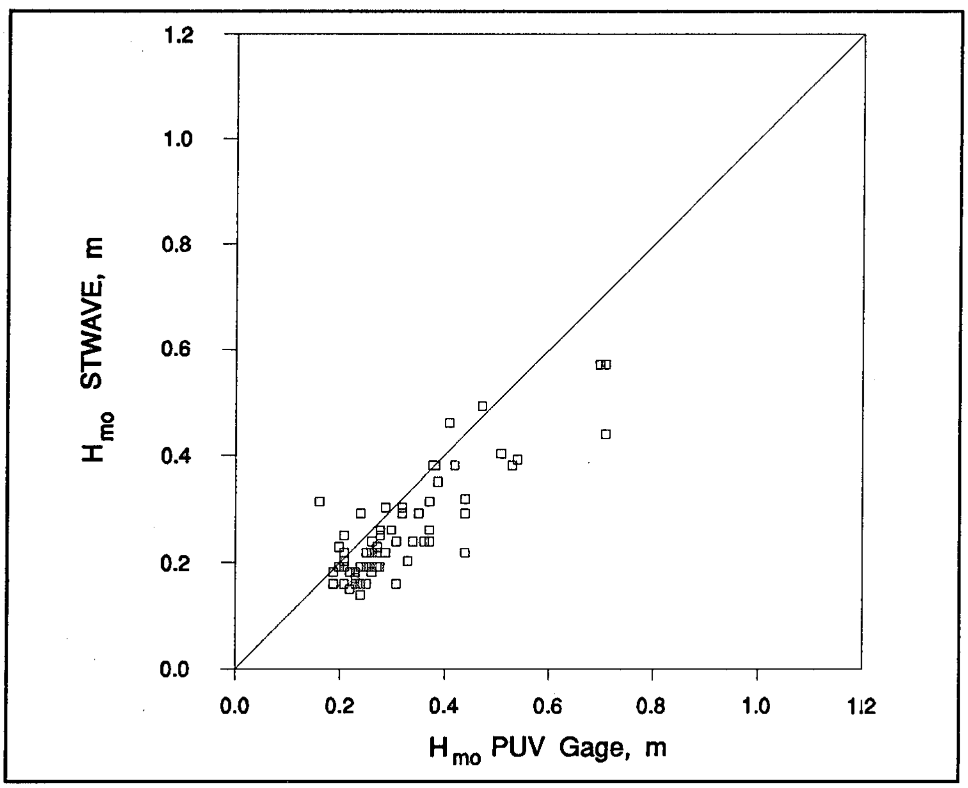


Figure F13. STWAVE versus PUV gage height

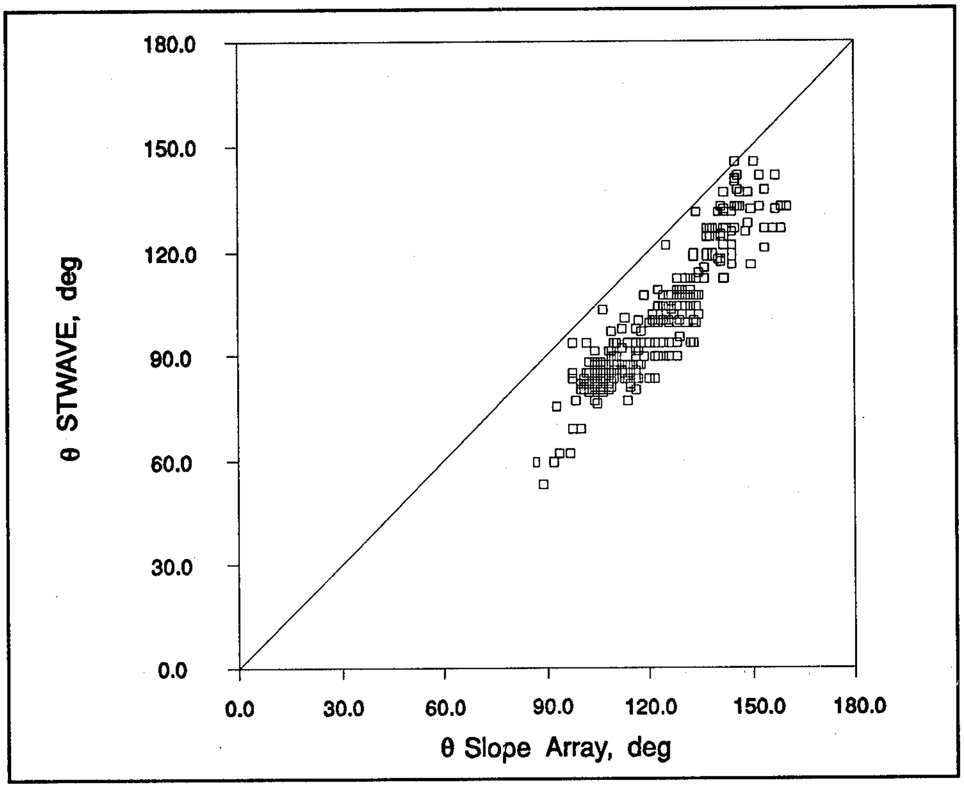


Figure F14. STWAVE versus slope array direction

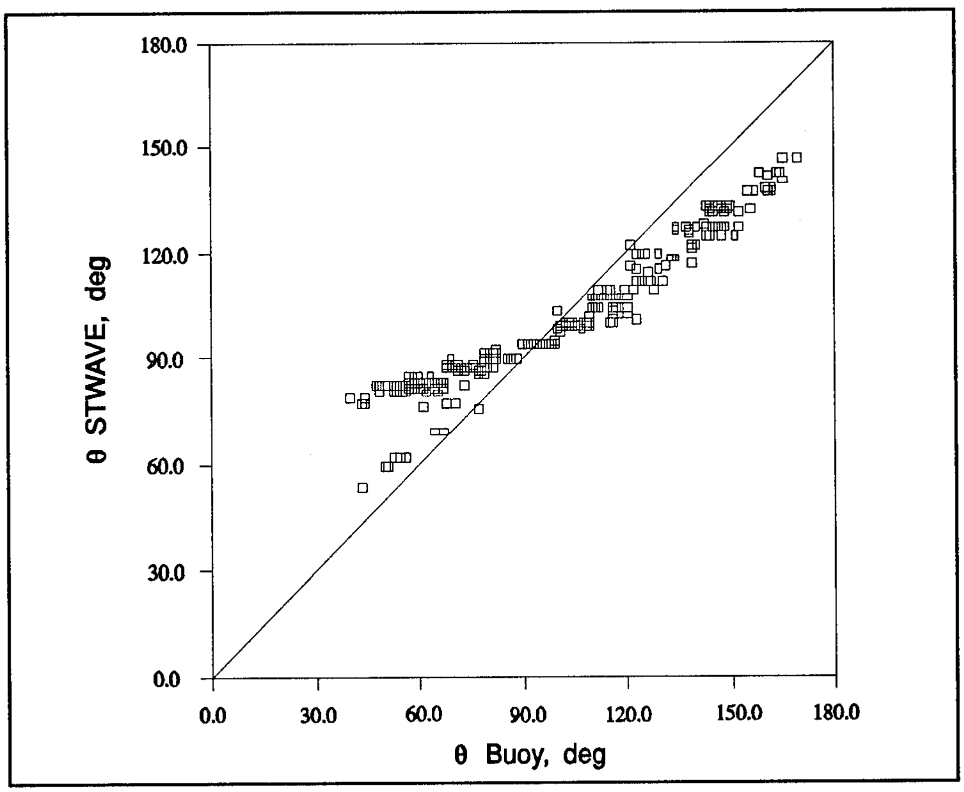


Figure F15. STWAVE versus buoy direction (Amelia) from the southeast, and the apparent shore-normal is approximately 90 deg, or 25 deg north of what the gage shows as shore-normal. Figure F16 is a scatter plot of the STWAVE estimate of wave height versus the slope array measurement. The STWAVE model underpredicts the gage measurement by an average of 14 percent, which converts to an average underprediction of 0.06 m. The correlation coefficient is 0.88. The STWAVE height estimates agree closely with the measurements. If only cases with peak period of 6 sec or greater are considered (211 cases), the correlation coefficient for wave direction improves to 0.99, and the wave height correlation coefficient is unchanged.

Discussion

The previous sections described comparisons between field measurements of wave height and direction and numerical model predictions. Ideally, the two should match exactly, but they do not. Differences could be caused by limitations of STWAVE or errors in the measurements, or both. In this section, the significance of these differences and their probable cause will be discussed. The discussion is given in three sections: data scatter, wave height differences, and wave direction differences.

Data scatter

The wave measurements show scatter in both wave direction and height. The scatter in measured wave direction is 20 to 30 deg (Figures F4 and F6). The STWAVE results show scatter in direction of 10 to 15 deg caused by variation in wave period. The greatest variations

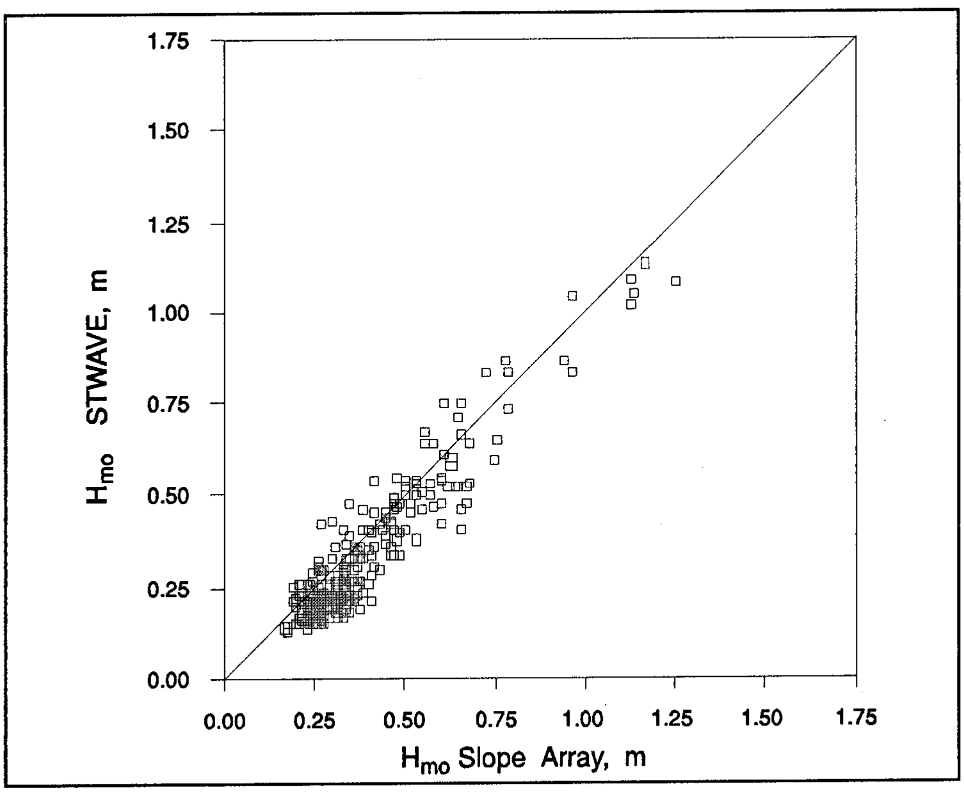


Figure F16. STWAVE versus slope array height in measured direction were for longer period waves from the northeast. Figure F17 shows depth variation at the slope array due to the tide and the difference between the measured wave direction and STWAVE-calculated wave direction for 21-23 May 1989. These waves are from the north with periods of 9 to 11 sec. Note the correlation between tide level and difference in wave angle, with greater differences in angle at low tide. The correlation coefficient is 0.25, so approximately 25 percent of the 20-deg scatter shown in Figure F17 is explained by the tide (depth variation and wave-current interaction; neither of which were included in the STWAVE simulations). The maximum angle difference due to the effect of depth variation on linear refraction for the wave conditions shown in Figure 17 is approximately 3 deg. The variation in local wind may also account for variation in nearshore wave direction. Excluding the shorter waves (the waves most affected by the local winds) from the regression analysis improved the correlation of the calculated and measured wave directions by 28 percent at Cumberland and 14 percent at Amelia. The scatter in the nearshore wave direction is plausibly explained by wave period, tidal effects, and local winds. The scatter in measured wave height is approximately 50 percent (Figures F5 and F7). The STWAVE results show somewhat smaller scatter, which is a function of wave period and direction. This difference in scatter is probably due to factors omitted in the STWAVE simulation (e.g., local winds and tide). Lack of spatial homogeneity and steadiness in the offshore wave conditions also contribute to the scatter in both wave height and direction.

Wave height differences

Differences in wave height between STWAVE results and measurements at the slope array and PUV were fairly small (STWAVE underestimates measurements on average by 0.06 m). This is close to the expected accuracy of the gage. The small, but consistent low bias of the STWAVE results may be caused by the removal of energy based on the limiting spectral shape or the omission of local wind input. Based on the statistical variability of the measurements and the accuracy of the gage (10 percent), the STWAVE wave height results at the slope array and PUV gage are judged to be reasonable.

Wave direction differences

Differences in wave direction between STWAVE predictions and nearshore measurements were 10 deg at the PUV gage and 25 deg at the slope array. The expected accuracy of the gages is ± 10 deg. The difference between the STWAVE results and slope array results has been the greatest concern in this study. The offset is consistent except for the short-period waves from the south that were previously discussed (the PUV gage data are very sparse in this area, so intercomparing is not helpful). If these data are eliminated from the comparison, the difference in STWAVE results and measurements correspond to a pure rotation of the gage. This type of error has been reported in other studies (e.g., a 20-deg rotation of a PUV gage was noted during ARSLOE and the "new" orientation was confirmed with a diver) and may be caused by error in determination of the original gage orientation or rotation of the gage due to interference from a trawler. Unfortunately, the slope array was completely turned over before the gage was retrieved, so the orientation cannot be verified. Other factors that could contribute to the difference in wave direction include wave-current interaction, depth variation due to the tide, accuracy of the STWAVE bathymetric grid (survey data are 15 years old), local winds, and accuracy of the buoy. The effect of the tide (Figure F17) only accounts for a variability in the direction and not the mean offset. Also, all these possible factors should affect the PUV gage and slope array approximately equally. An error in the buoy direction on the order of 25 to

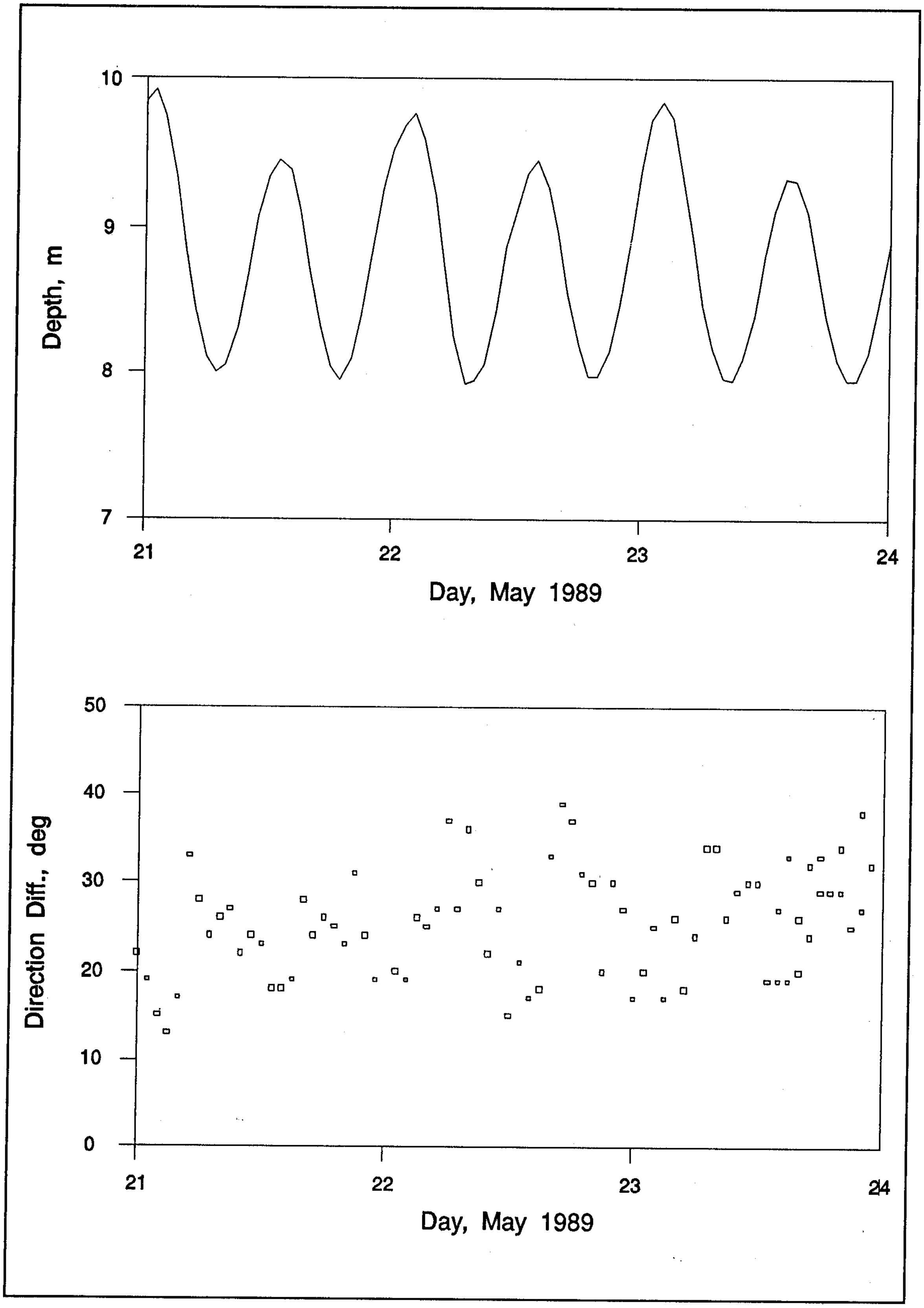


Figure F17. Tidal effects on wave direction

40 deg would be needed to account for the 25-deg difference in the STWAVE and slope array directions. The accuracy of the buoy directions was investigated by comparing wind and wave directions measured at the buoy for a strong onshore wind event on 28 and 29 May 1989. The wind direction ranged from 44 to 49 deg (average of 46 deg) and the wind speed ranged from 10.1 to 11.7 m/s (average of 11 m/s). The wave conditions measured at the buoy were consistent with local wave generation (2 m height, 7 sec period), and the average wave direction was coincident with the wind direction at 46 deg (ranging from 42 to 48 deg), supporting the wave direction measurement. Wave directions measured at the buoy are also consistent with the WIS 20-year hindcast climatology (Jensen 1983a).

The consistency of the offset in the slope array data and the smooth, shore-parallel nearshore contours at the slope array suggest that the STWAVE-slope array difference is a result of a misalignment of the slope array. Directional wave data collected in St. Marys Entrance navigational channel in 1984 (Lai, Lee, and Silver 1988) tend to support this conclusion. The 1984 spring climatology from this gage shows an average spring wave direction of approximately 100 deg, 20 deg less than the May average wave direction at the slope array. Other supplemental data sources, e.g., aerial photographs and other gages, to validate this conclusion have not been found. Application of the monochromatic wave transformation model RCPWAVE (Ebersole, Cialone, and Prater 1986) with the surveyed bathymetry (Figures F9 and F10) and linear wave refraction assuming shore-parallel contours gave mean biases in wave direction similar to the STWAVE results at both the slope-array and PUV sites.

Conclusions

Comparisons were made between STWAVE numerical simulations and two nearshore gages off Cumberland and Amelia Islands to verify the use of STWAVE for wave transformation over complex bathymetry. The following conclusions were made:

a. The STWAVE model predicted transformed wave height well. The tendency to under-predict wave height may be due to the omission of local wind input to the energy spectra over the grid.

b. Systematic differences of approximately 25 deg exist between the slope array direction measurements and STWAVE results, but calculated wave directions matched directions obtained from the PUV gage to within the expected accuracy of 10 deg. The STWAVE results were reasonable at the slope-array site based on linear refraction.

c. Recent survey data could be used to check the location and shape of the complex shoal to the north of St. Marys Entrance. The shoal configuration could have strong local effects on the waves and sediment transport.

d. Tidal effects (changes in depth and wave-current interaction) are marginally significant in wave transformation. The overall effect of the tide was an increase in the scatter of wave direction. It is expected that wave estimates in the inlet, where tidal velocities are on the order of 1 m/sec, would be poorer than at the gage sites.

e. Local wind effects appear to be important for conditions of short wave period and strong winds. Local winds also contribute to the total energy level in the spectrum, regardless of peak period, and the omission of local winds may be a factor in the low wave heights predicted by STWAVE. Wind input is not presently an option in STWAVE. When wind input is included in STWAVE, the effect of local winds should be evaluated in light of these results.

f. Multiple wave trains are common and must be considered. For this application, individual wave trains were transformed separately, but nonlinear interactions between wave trains may be important in shallow water (see discussion in Smith and Vincent (1992) for nonlinear effects of transformation and breaking of multiple wave trains).

Estimation of wave transformation at Cumberland and Amelia Islands with STWAVE is accurate to within the present technology of wave measurement and analysis. The directional wave data at the project site add to the confidence in the wave-transformation model used to provide nearshore wave information to drive the shoreline-change model used in this project. Expanding our understanding of waves (both measurement and modeling) in the complex inlet environment will require additional, careful field studies.

Appendix G[1]
A Pictorial Overview of the Cumberland Island, Georgia, and Amelia Island, Florida, Coasts

This appendix consists of two sections that contain, respectively, aerial and ground photographs of major morphologic features and engineering and cultural structures along the coasts of the study sites. A baseline map is provided at the beginning of each section for orientation to the general vicinity covered by the photographs. Photographs of the same area are presented from the most recent to oldest.

The first section, aerial photographs, primarily covers the vicinity of St. Andrew Sound, St. Marys Entrance, Nassau Sound, and notable engineering or cultural coastal structures. The locations of these photographs are given on Figure G1.

The second section, ground photographs, contains photographs taken in the vicinity of many of the beach profile survey lines, in addition to other photographs of the beach and coastal structures. The locations where most of these photographs were taken can be found in Figure G13.

[1] Written by Nicholas C. Kraus and Allison Abbe.

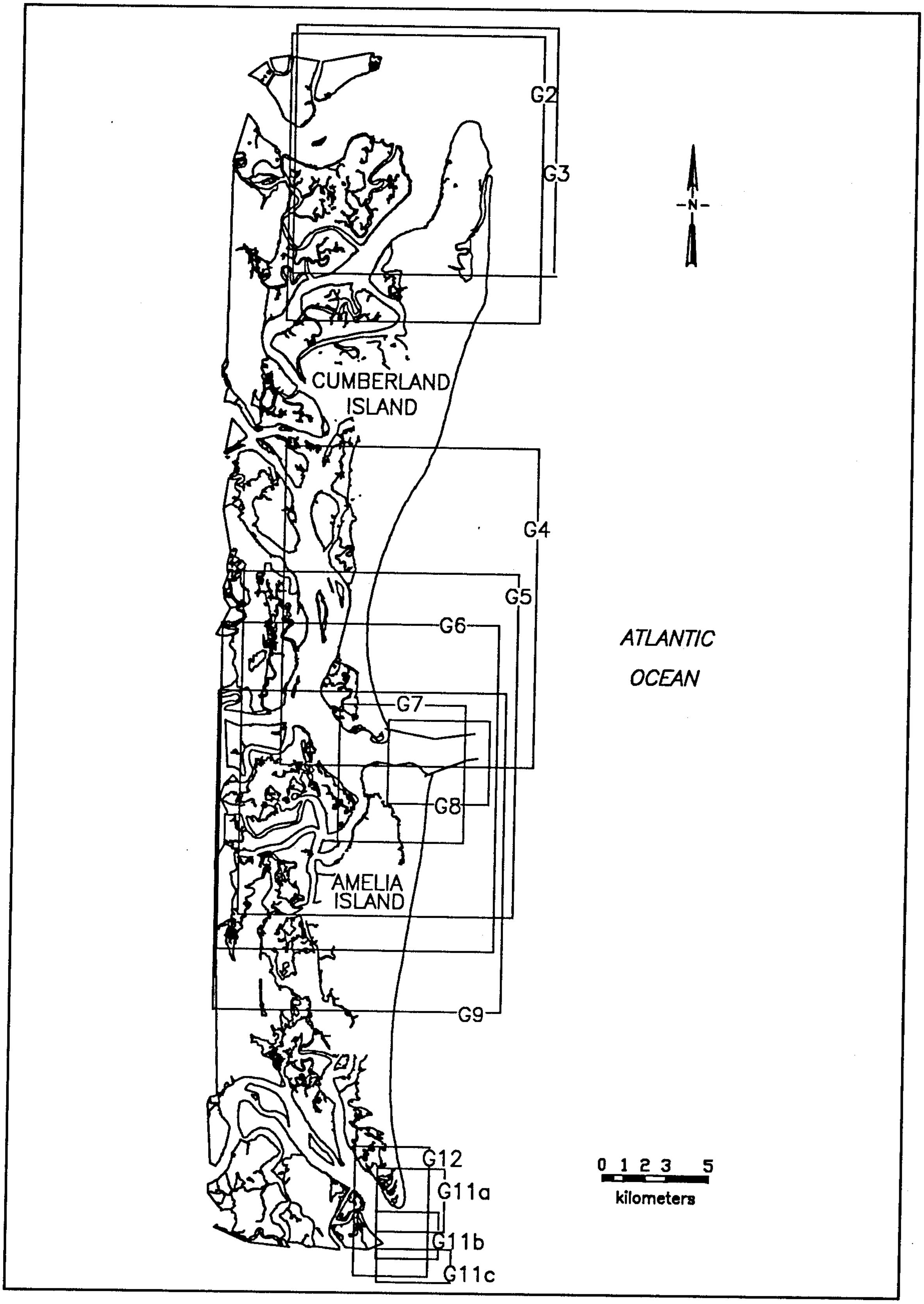


Figure G1. Approximate location of aerial photograph coverage

Aerial Photographs

Cumberland Island

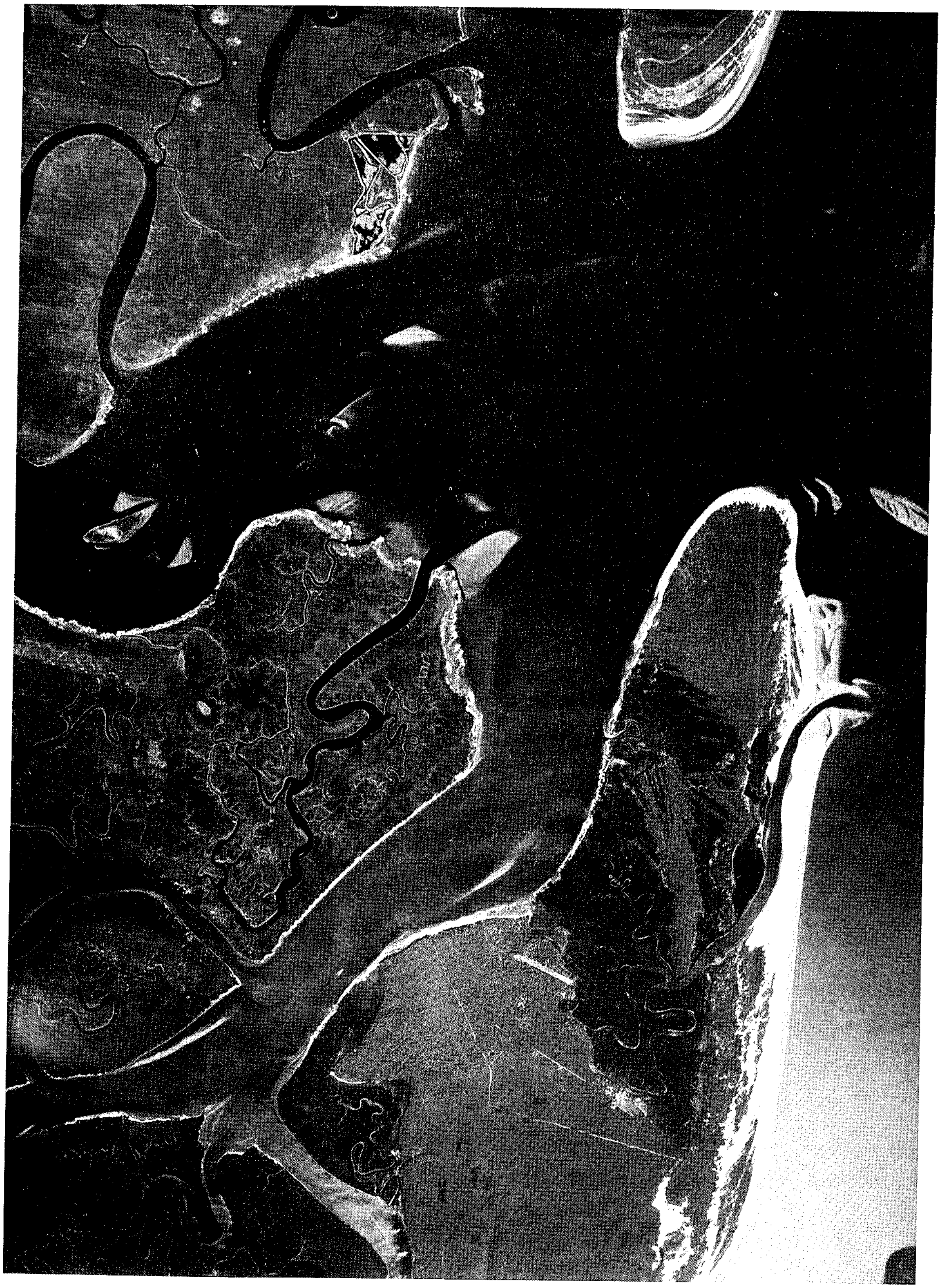


Figure G2. St. Andrew Sound, 2 April 1989, Cumberland Island (Source: NPS)

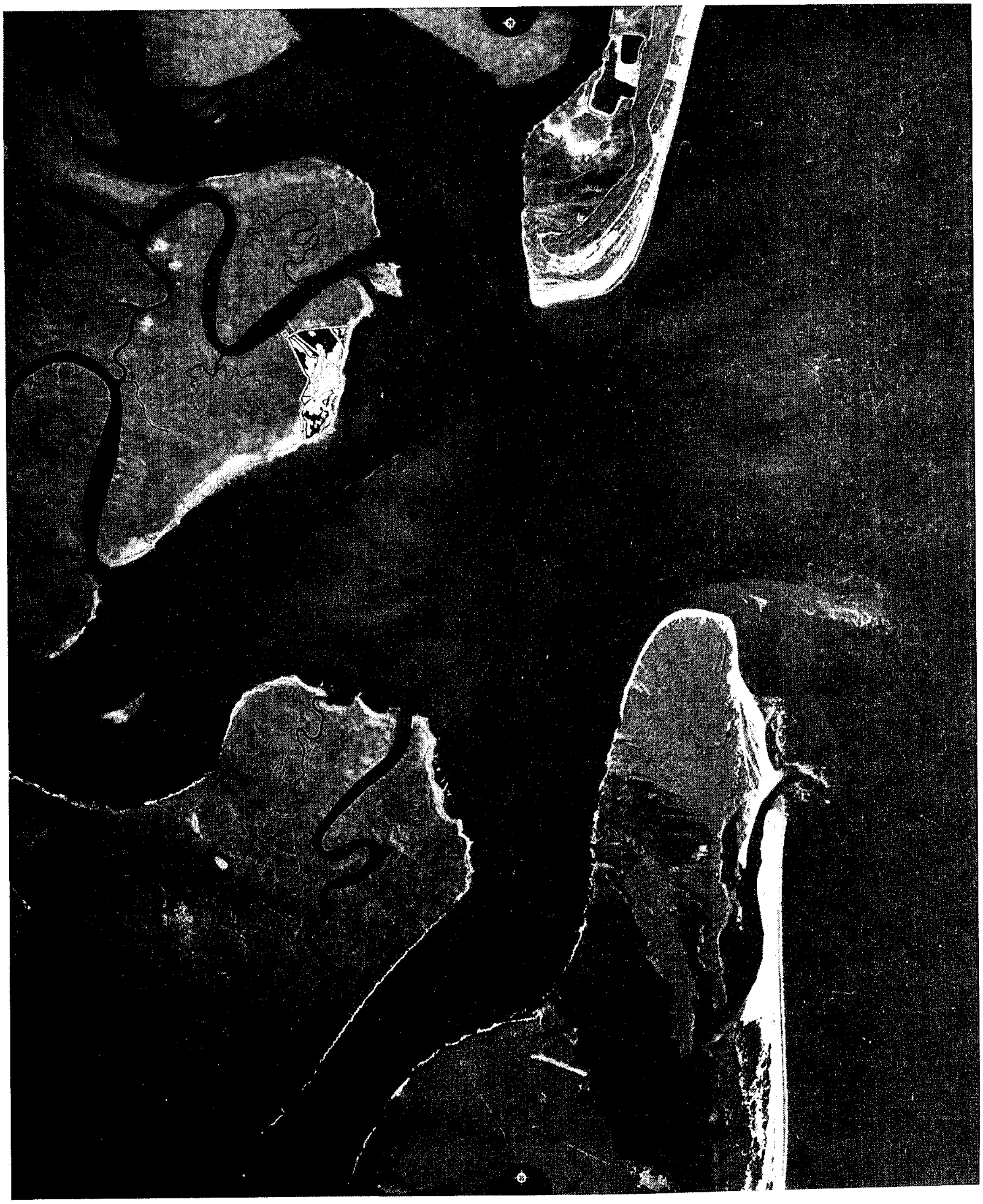


Figure G3. St. Andrew Sound, 17 January 1990, Cumberland Island (Source: NPS)

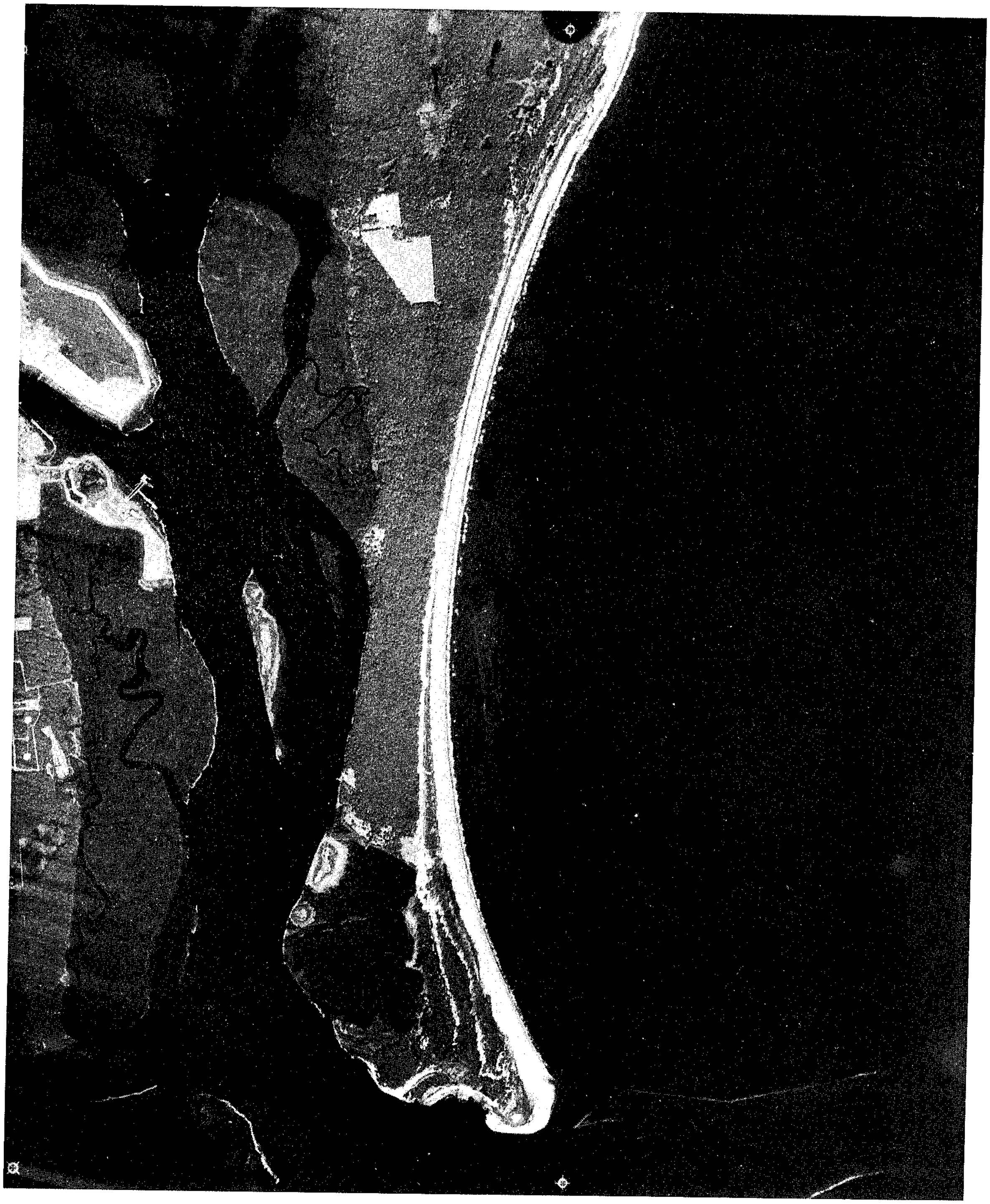


Figure G4. Southern Cumberland Island and jetty, 17 January 1990 (Source: NPS)

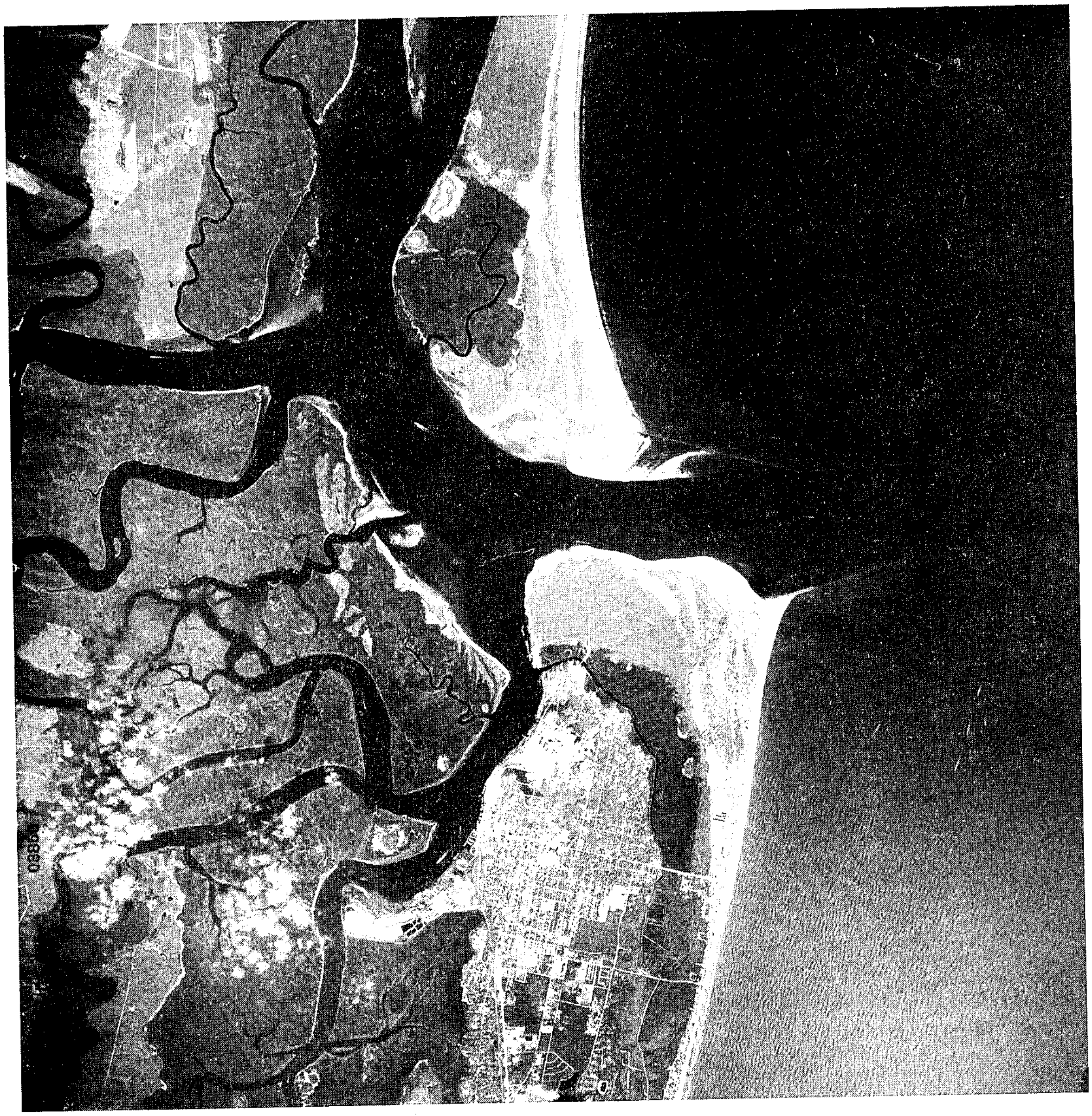


Figure G5. St. Marys Entrance, 17 January 1990 (Source: NPS)

Figure G6. St. Marys Entrance, 2 April 1989 (Source: NPS)

St. Marys Entrance

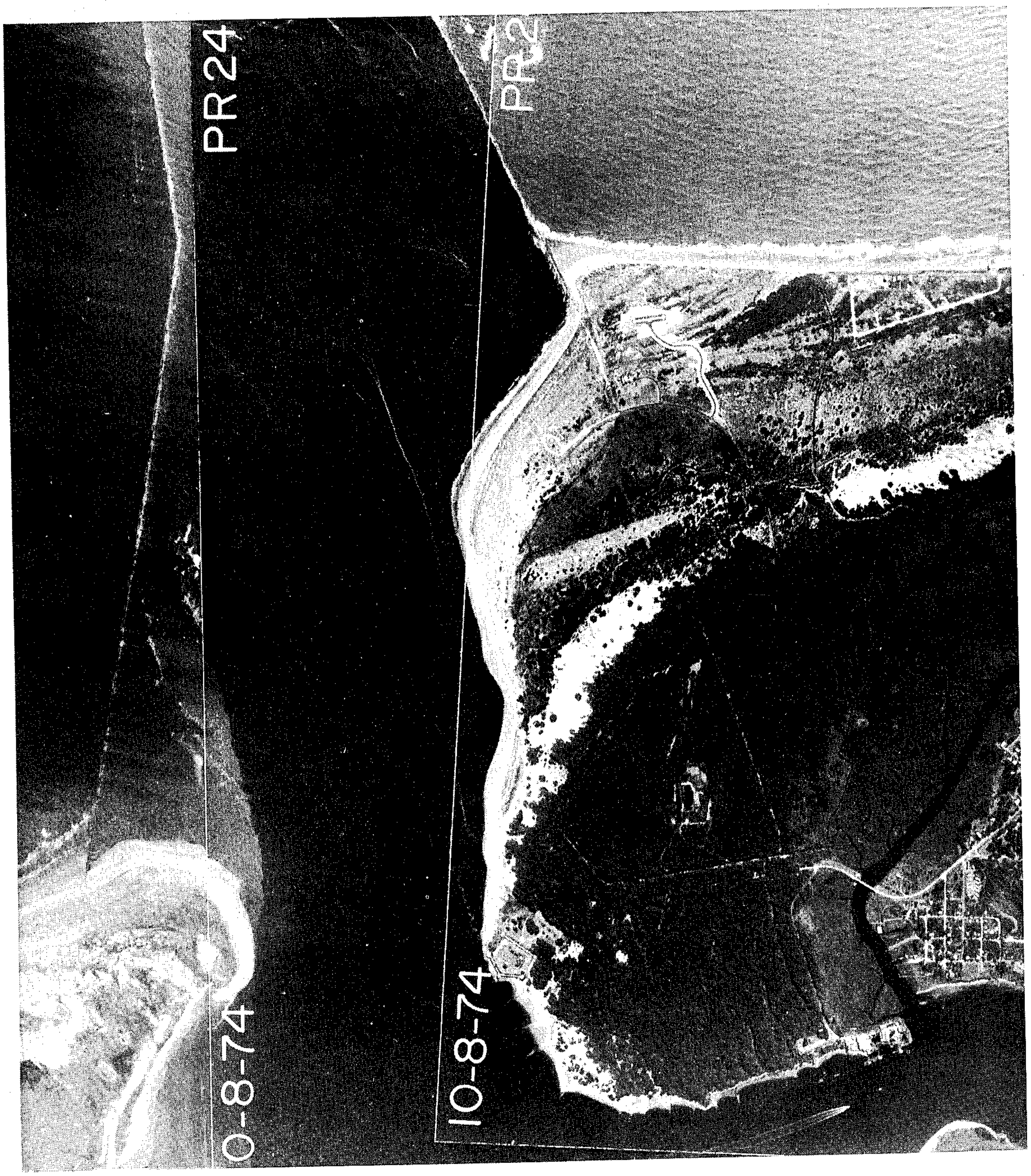


Figure G7. St. Marys Entrance, prior to Amelia Island pier construction, 8 October 1974

Amelia Island

Figure G8. Northern Amelia Island and jetty, 17 January 1990 (Source: NPS)

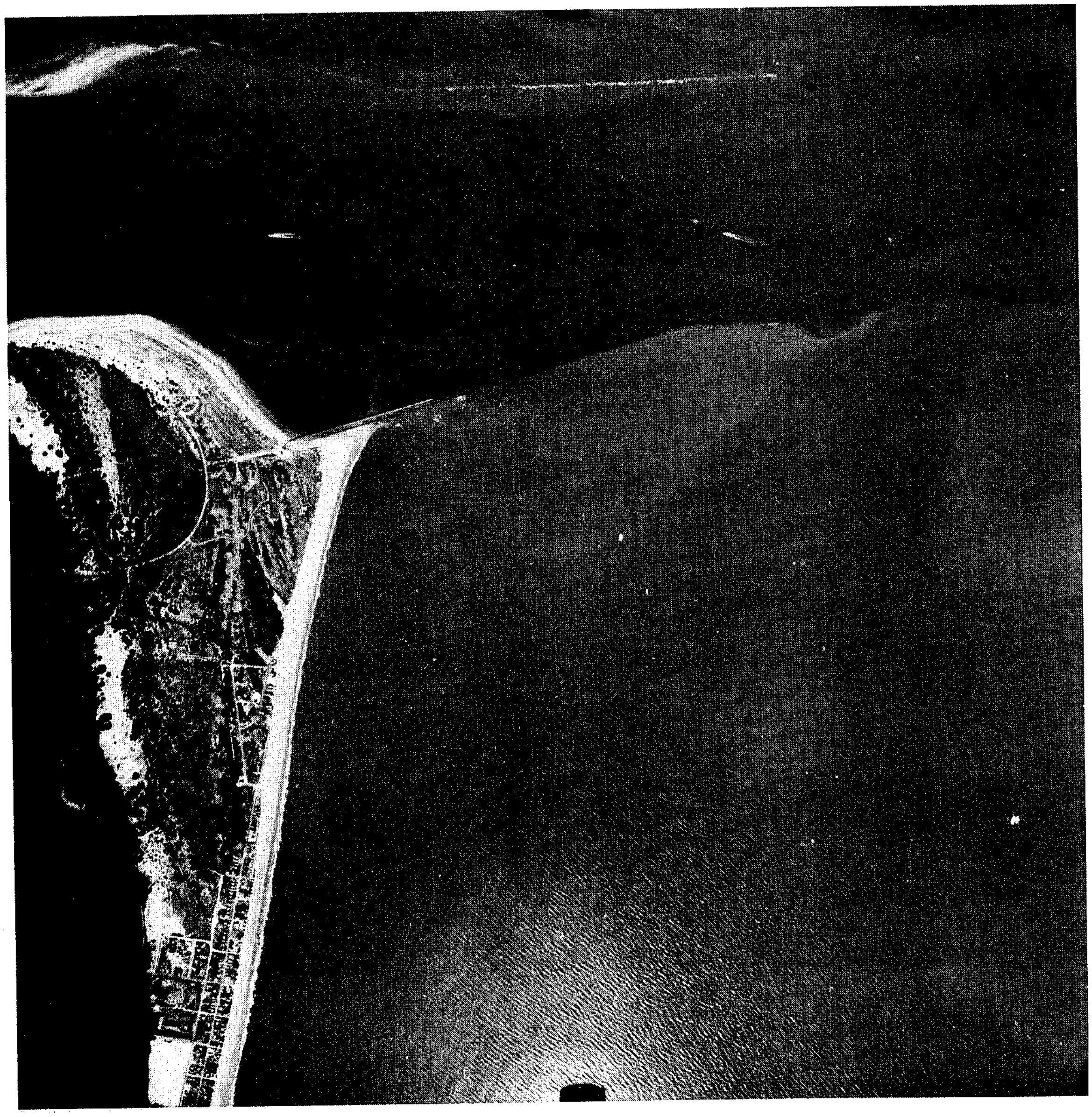


Figure G9. Northern Amelia Island and jetty, 2 January 1981

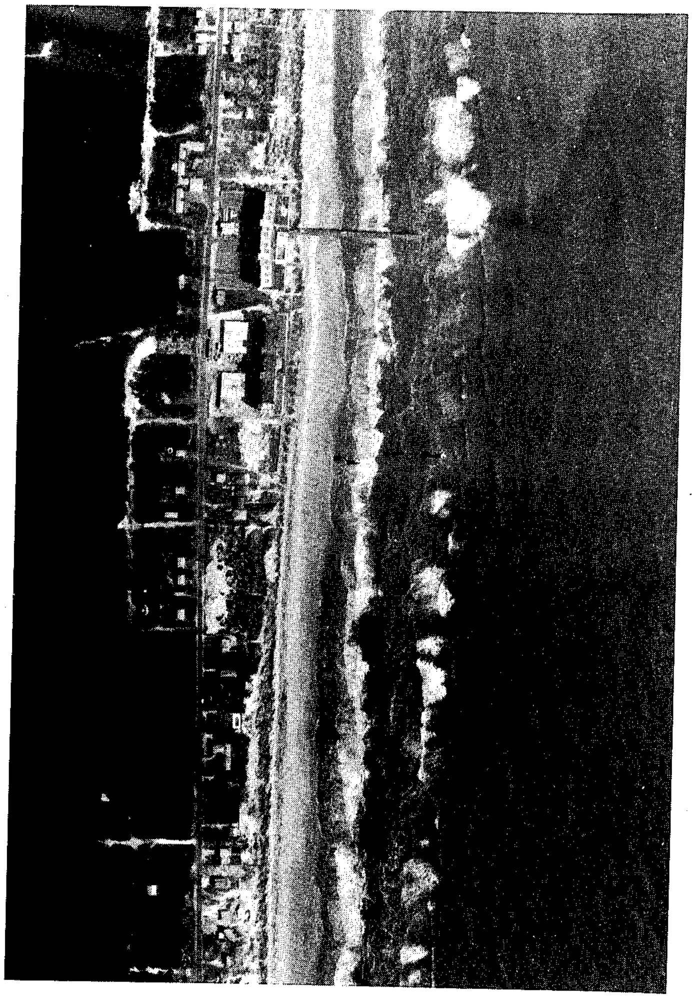


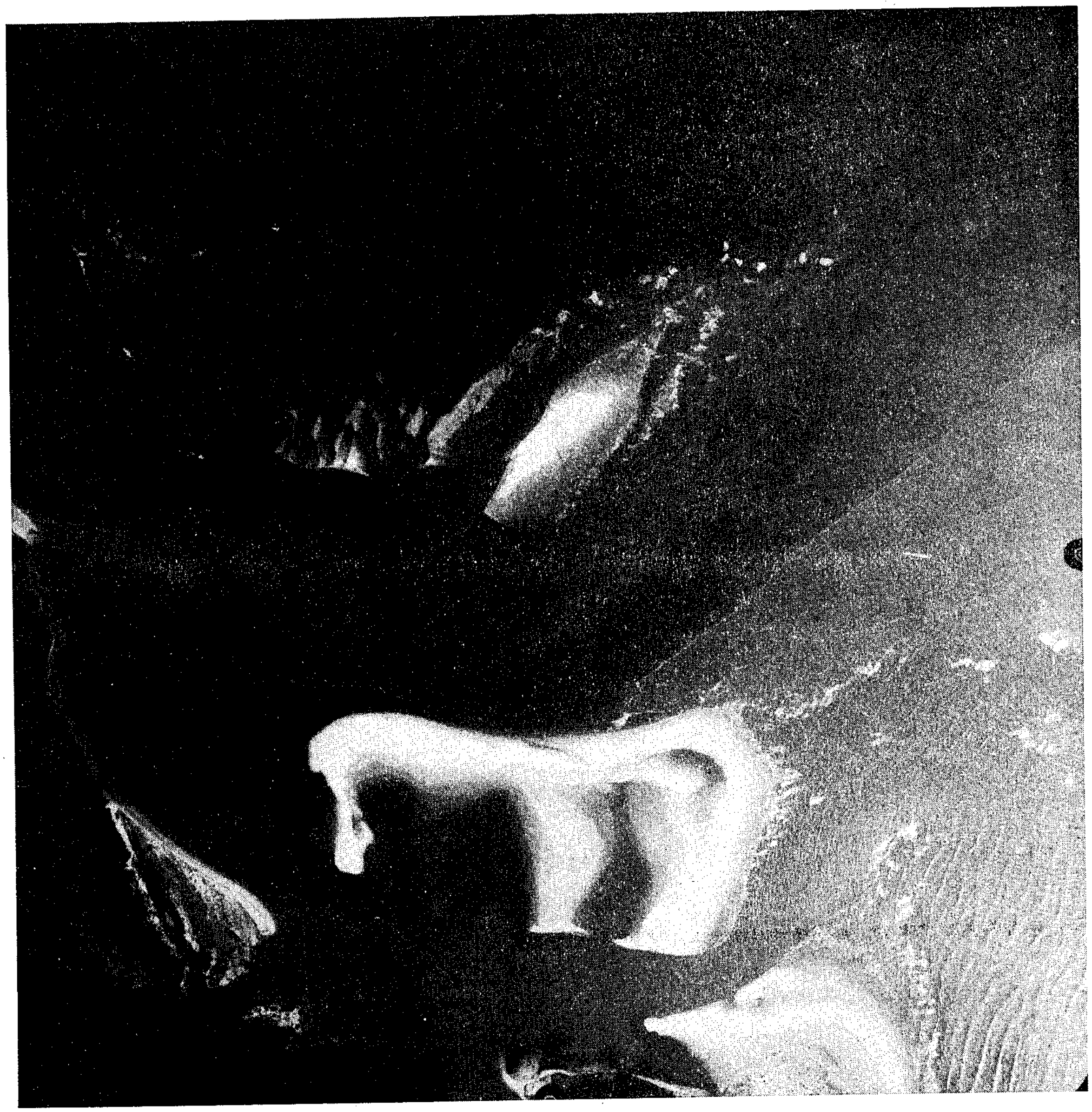
Figure G10. Amelia Island Profile Line 40 and fishing pier at Fernandina Beach, 8 October 1974

a. Southern Amelia Island

Figure G11. Nassau Sound and vicinity, October 1991 (Sheet 1 of 3)

b. Middle of Sound

Figure G11. (Sheet 2 of 3)



c. Nassau Sound and Little Talbot Island

Figure G11. (Sheet 3 of 3)

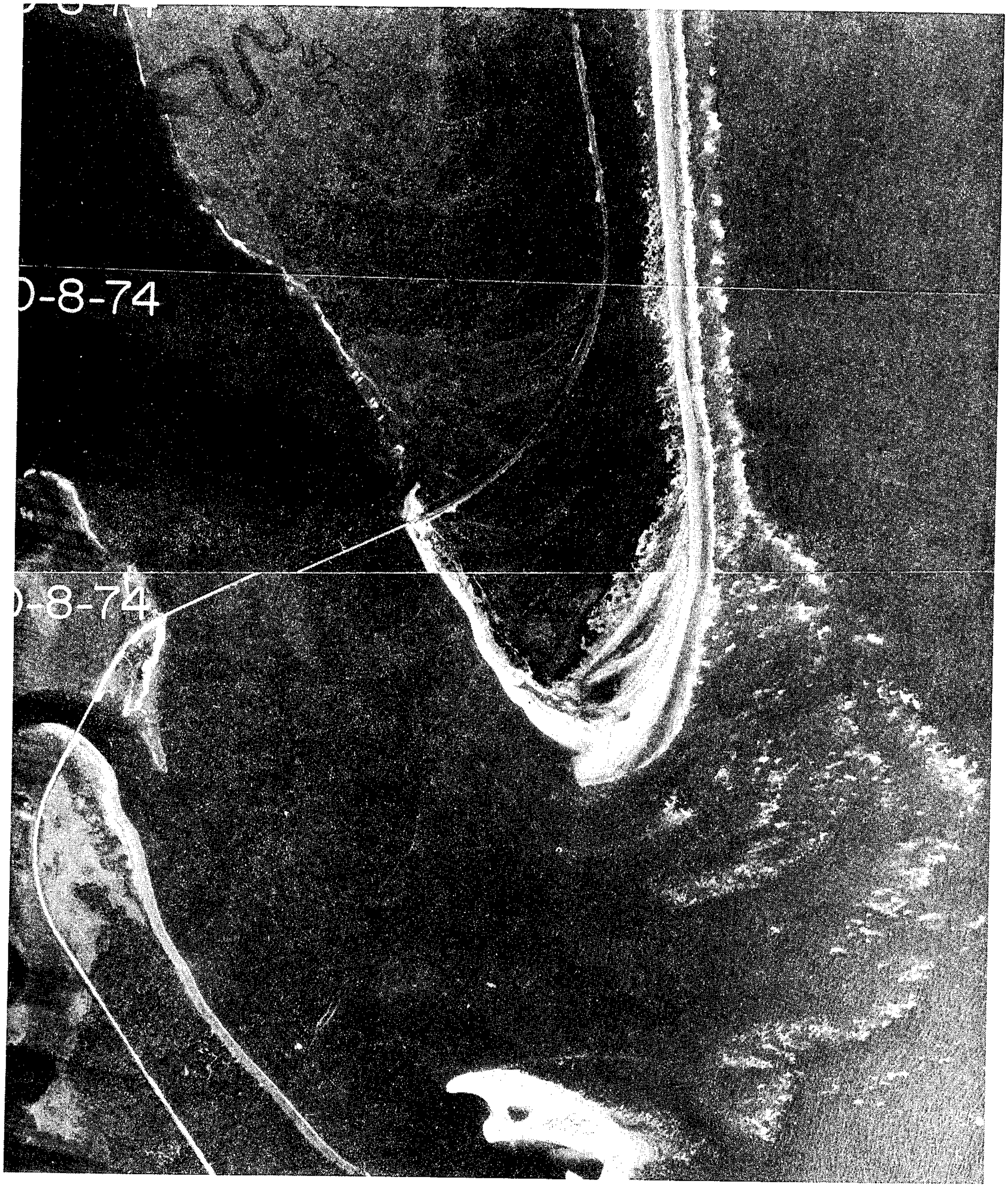


Figure G12. Southern Amelia Island and Nassau Sound, 8 October 1974

Ground Photographs

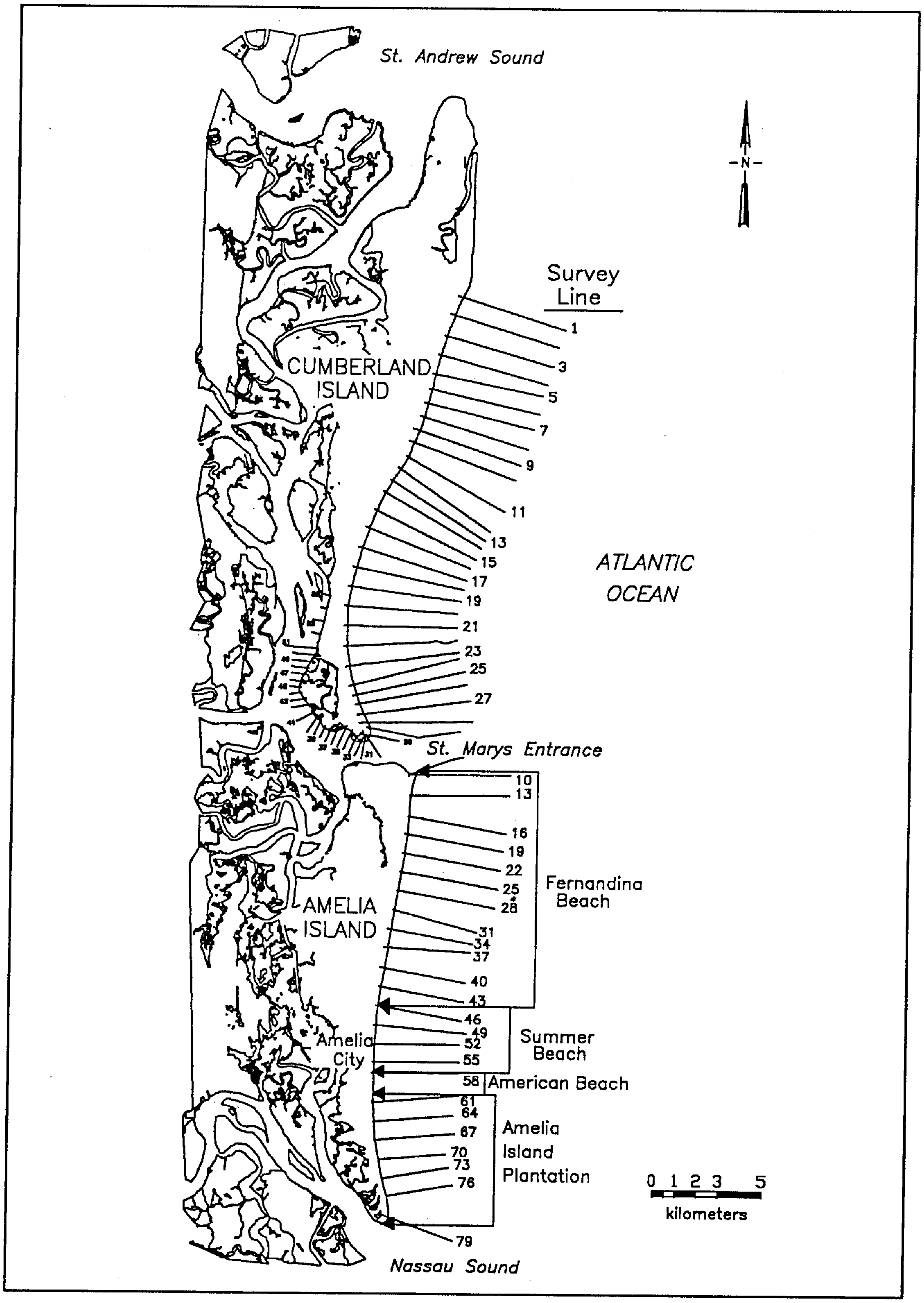


Figure G13. Location of profile survey lines

Figure G14. Profile Line 1, looking south, May 1992, Cumberland Island

Figure G15. Profile Line 2, looking east, May 1992, Cumberland Island

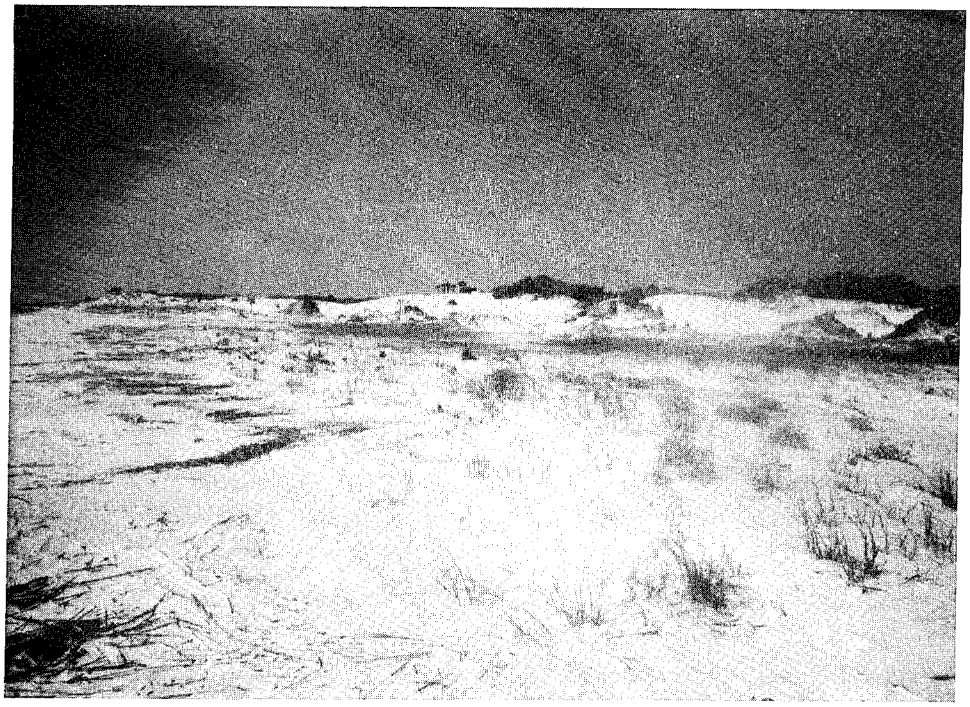


Figure G16. Profile Line 2, looking south along dunes, May 1992, Cumberland Island

Figure G17. Profile Line 3, looking south, May 1992, Cumberland Island

Figure G18. Profile Line 3, looking west, May 1992, Cumberland Island

Figure G19. Profile Line 4, looking west, May 1992, Cumberland Island

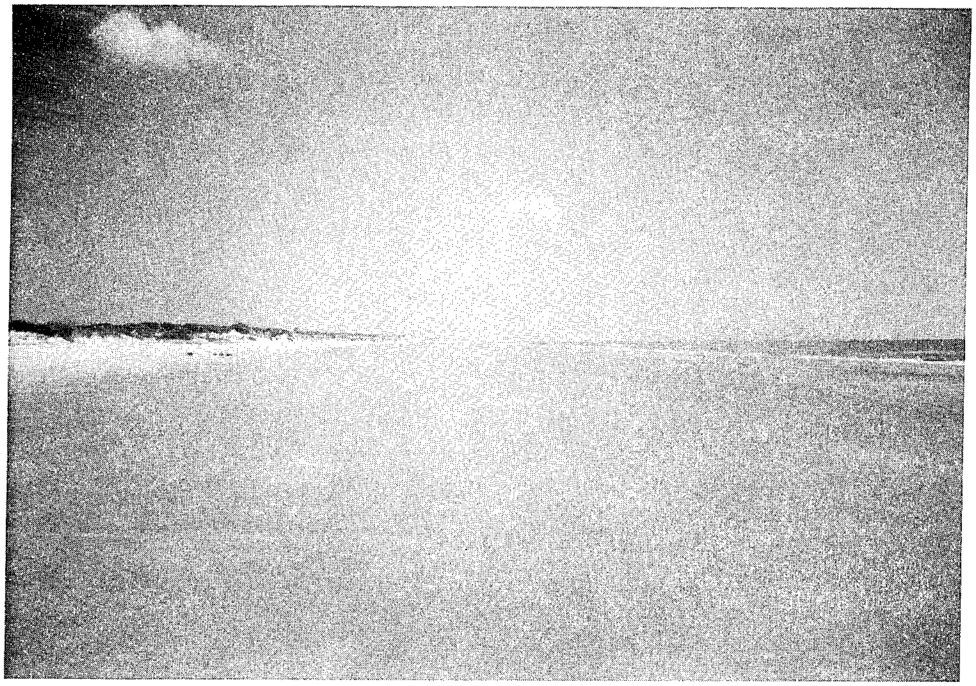
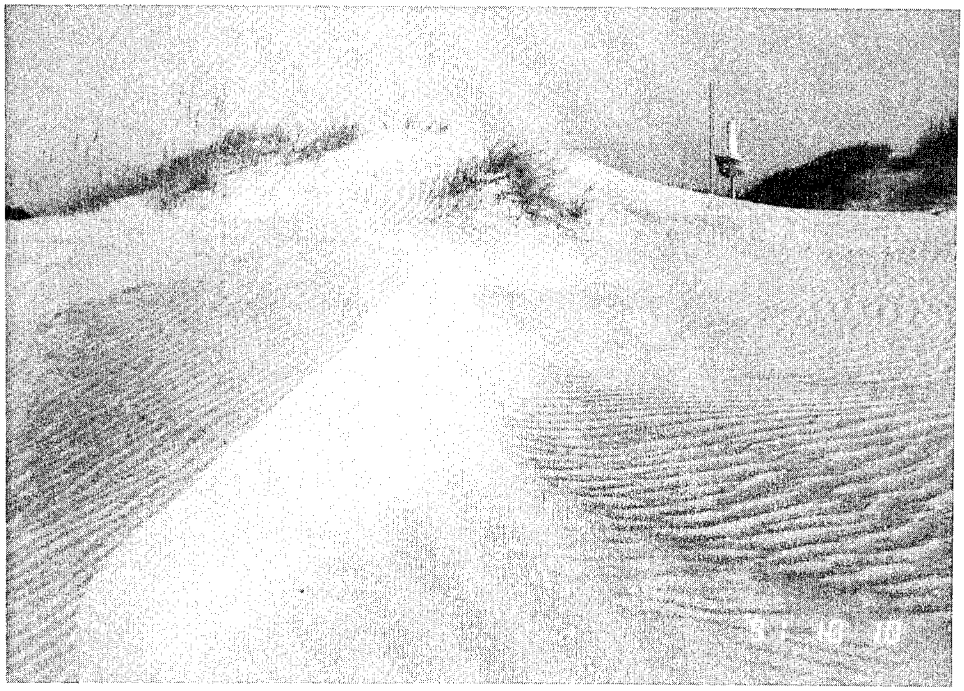


Figure G20. Profile Line 5, looking north, May 1992, Cumberland Island

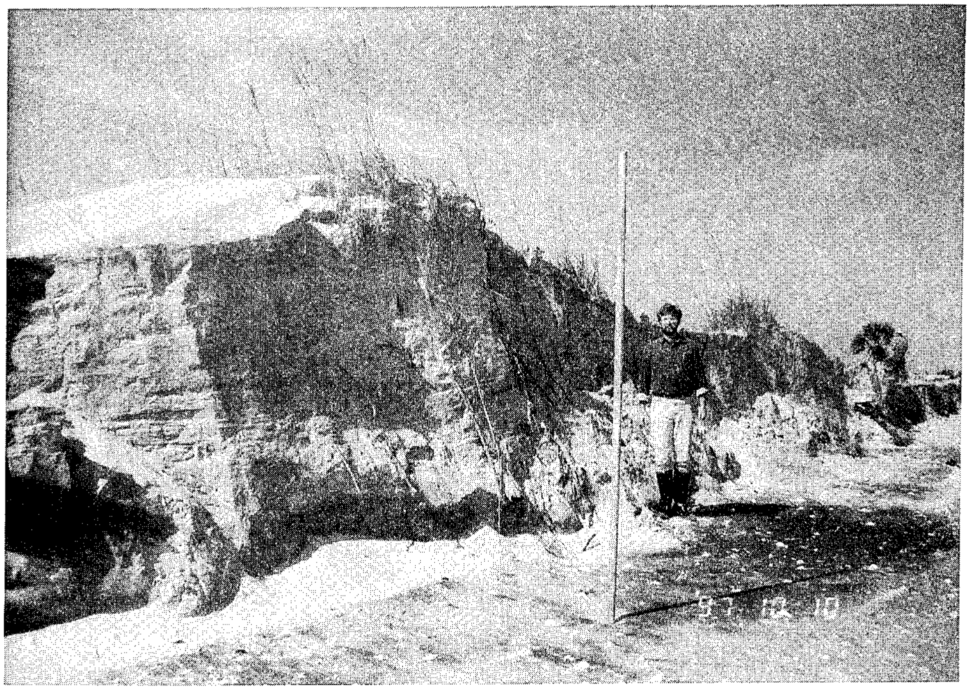
Figure G21. Profile Line 6, looking south, May 1992, Cumberland Island



a. Looking south

b. Looking northeast

Figure G22. Dunes on north Cumberland Island, 10 October 1991



a. Front monument post

b. Looking north

Figure G23. Profile Line 10, 10 October 1991, Cumberland Island

Figure G24. Beach near Stafford Shoal, 30 July 1990, Cumberland Island

Figure G25. Profile Line 13, looking north, May 1992, Cumberland Island

Figure G26. Profile Line 17, looking south, May 1992, Cumberland Island

Figure G27. Profile Line 18, looking south, May 1992, Cumberland Island

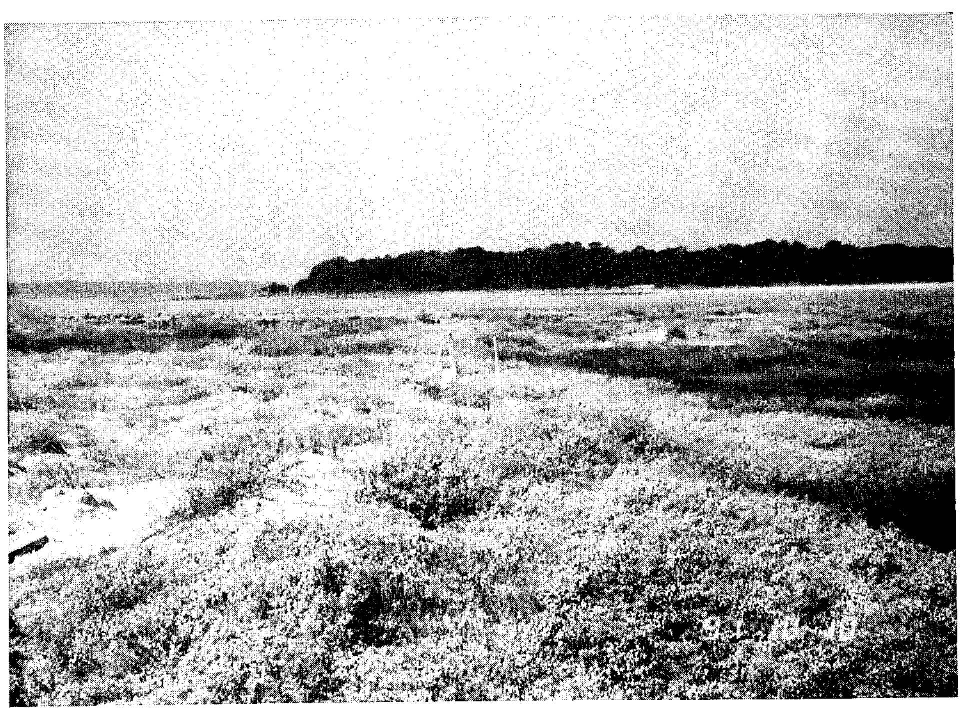
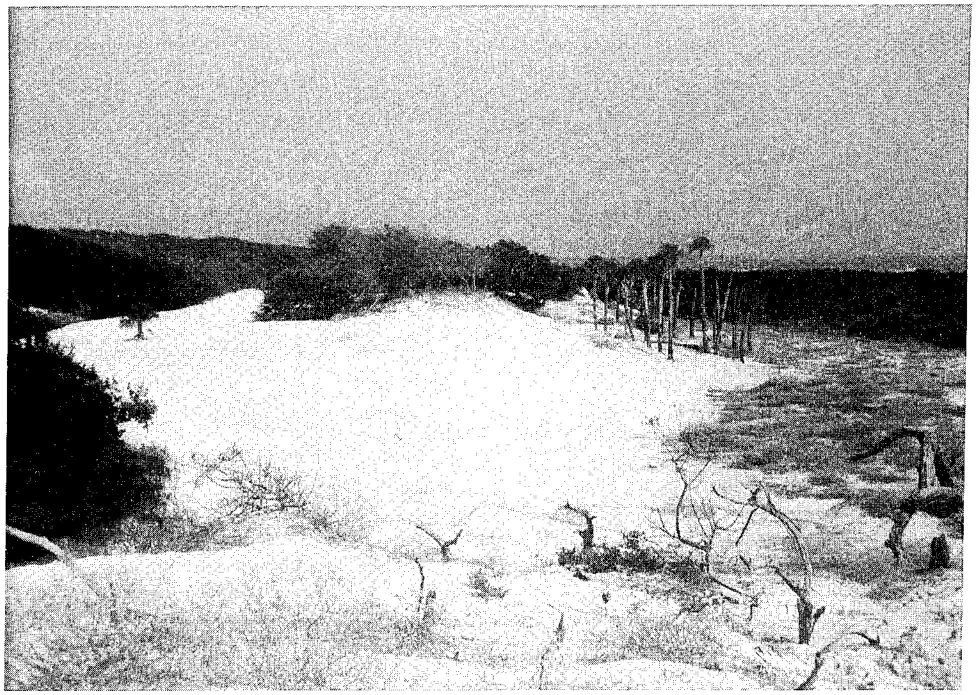
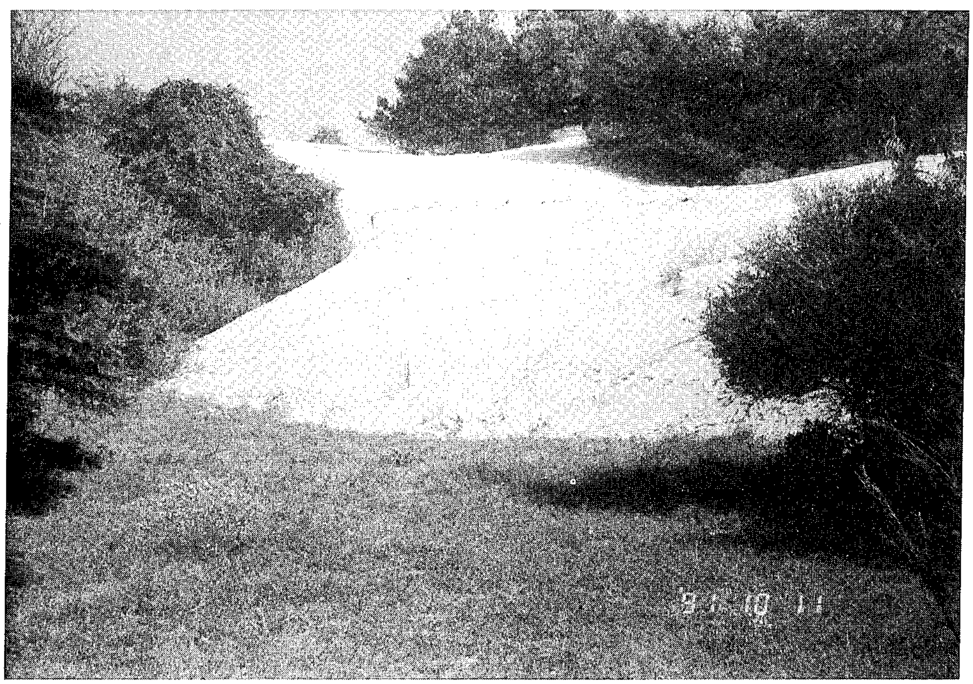


Figure G28. Profile Line 19, looking south, Amelia Island paper plant in background, 10 October 1991, Cumberland Island



a. Looking north



b. Landward of dune line, looking north from beach access road

Figure G29. Taken between Profile Lines 23 and 27, 10 October 1991, Cumberland Island

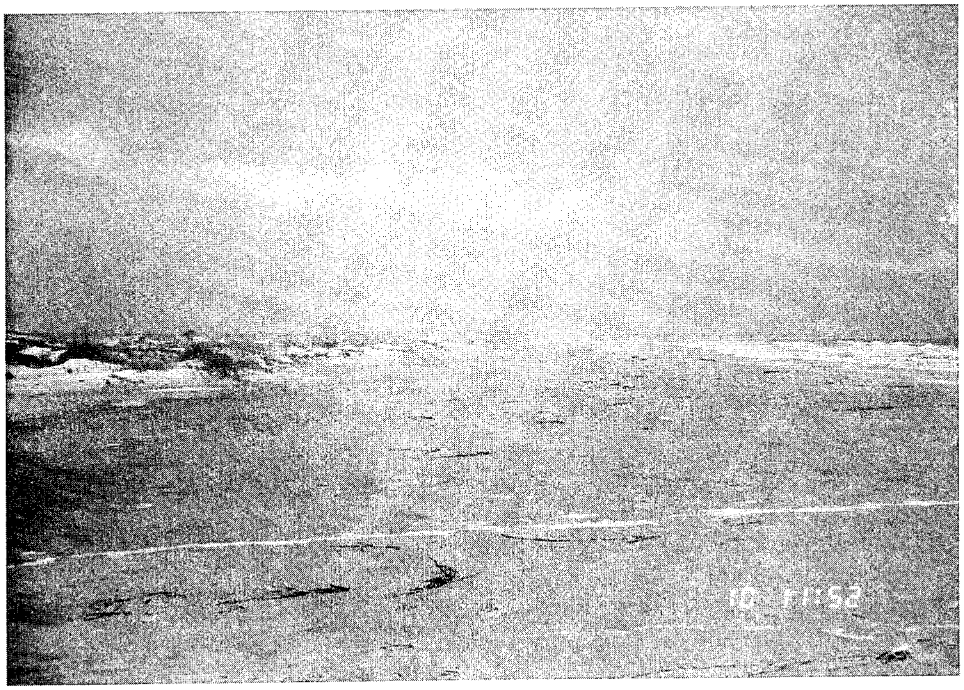


Figure G30. Profile Line 28, looking north from jetty, 10 October 1991, Cumberland Island

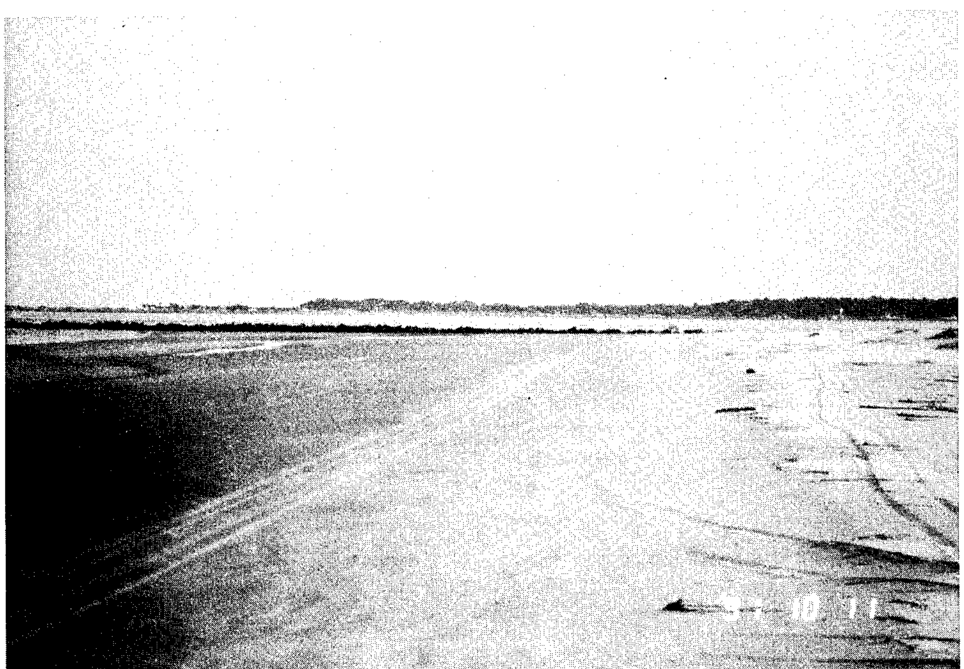


Figure G31. Profile Line 28, looking south from jetty, 11 October 1991, Cumberland Island

Figure G32. Profile Line 29, looking east towards jetty at high tide, 10 October 1991, Cumberland Island

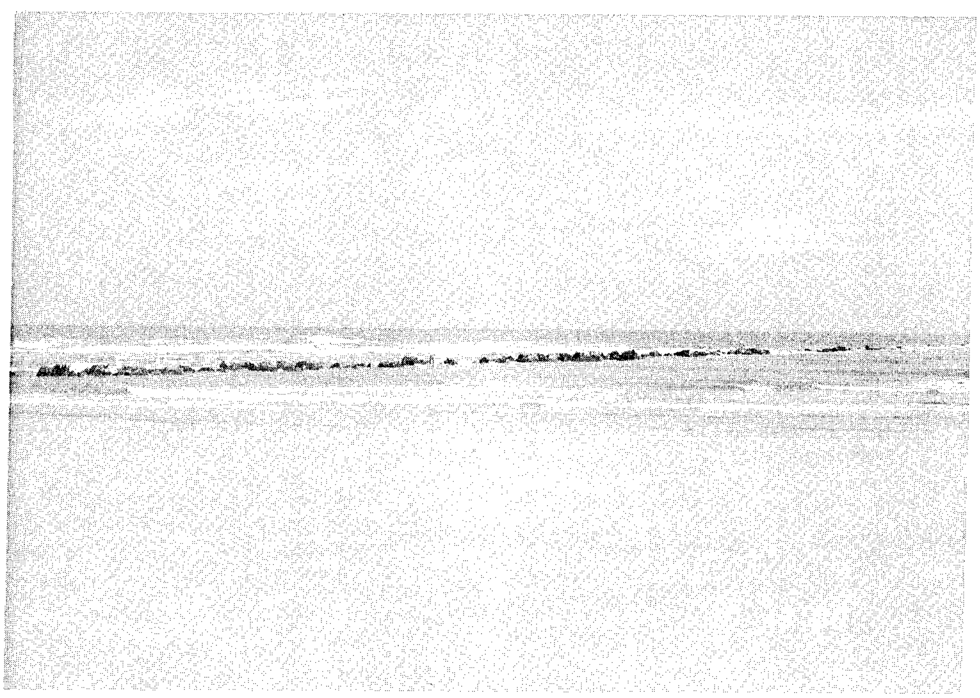
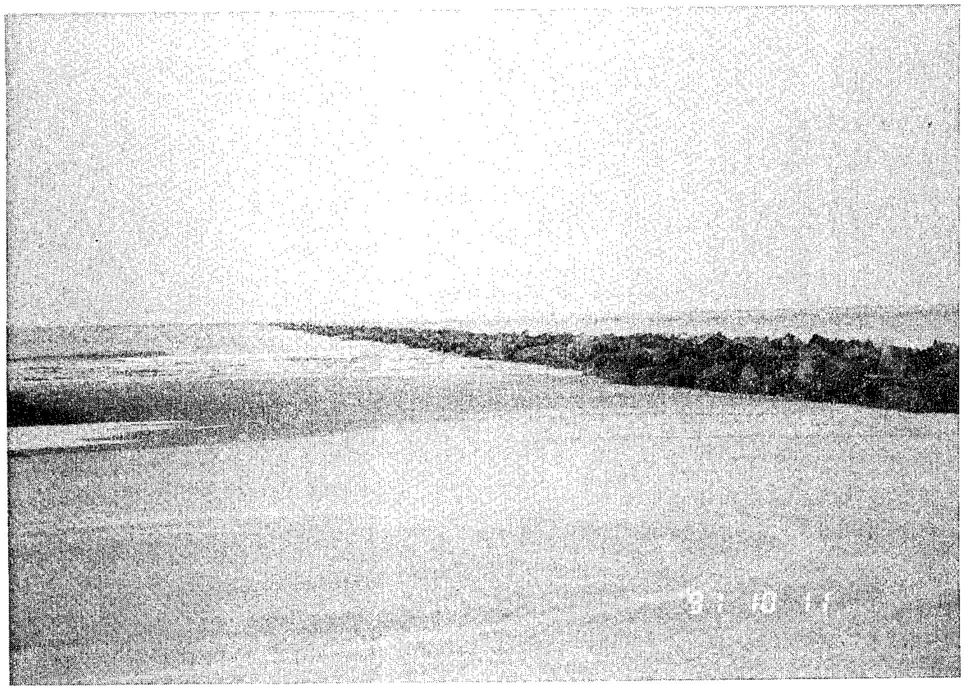


Figure G33. Profile Line 29, looking east, 10 October 1991, Cumberland Island



a. Looking east

b. Scour holes

Figure G34. Jetty at low tide, 11 October 1991, Cumberland Island

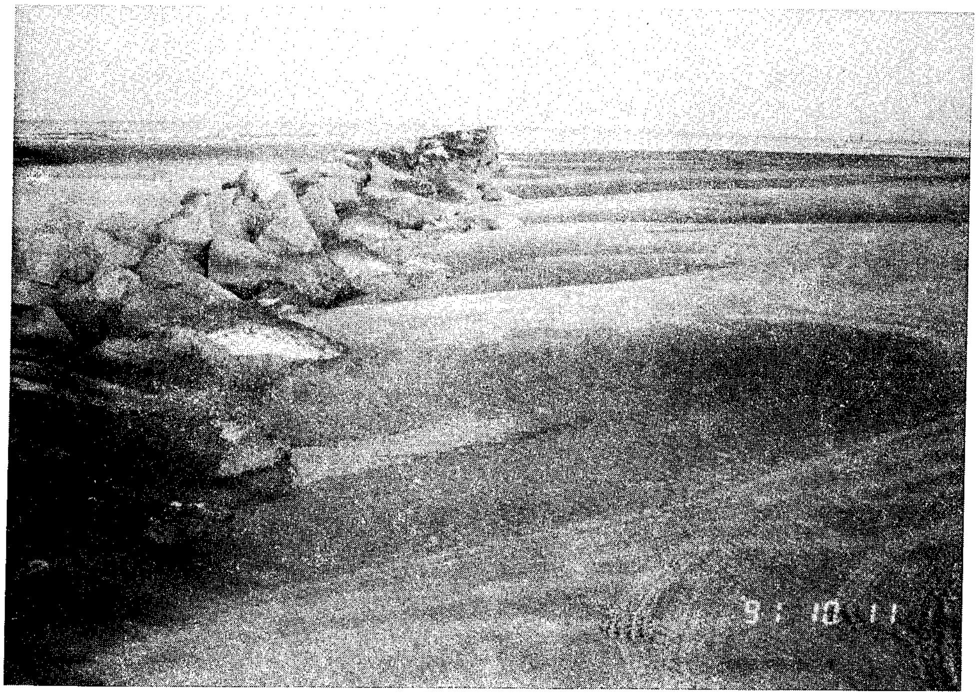


Figure G35. Jetty, looking east, 11 October 1991, Cumberland Island

Figure G36. Jetty, looking northeast, 11 October 1991, Cumberland Island

Amelia Island

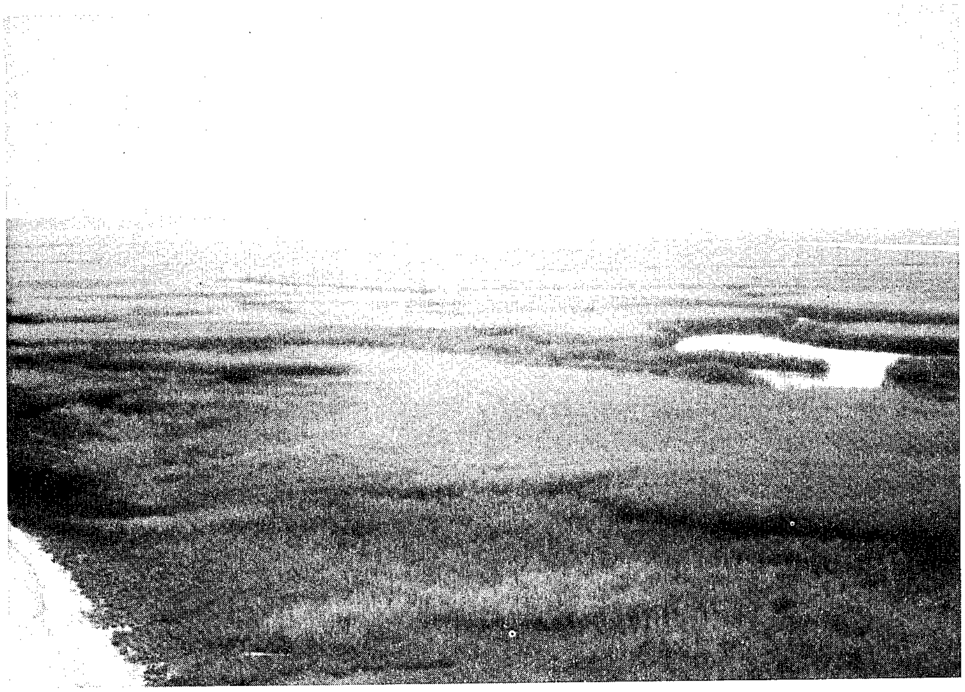


Figure G37. St. Marys Inlet marshes, 30 July 1990, Amelia Island

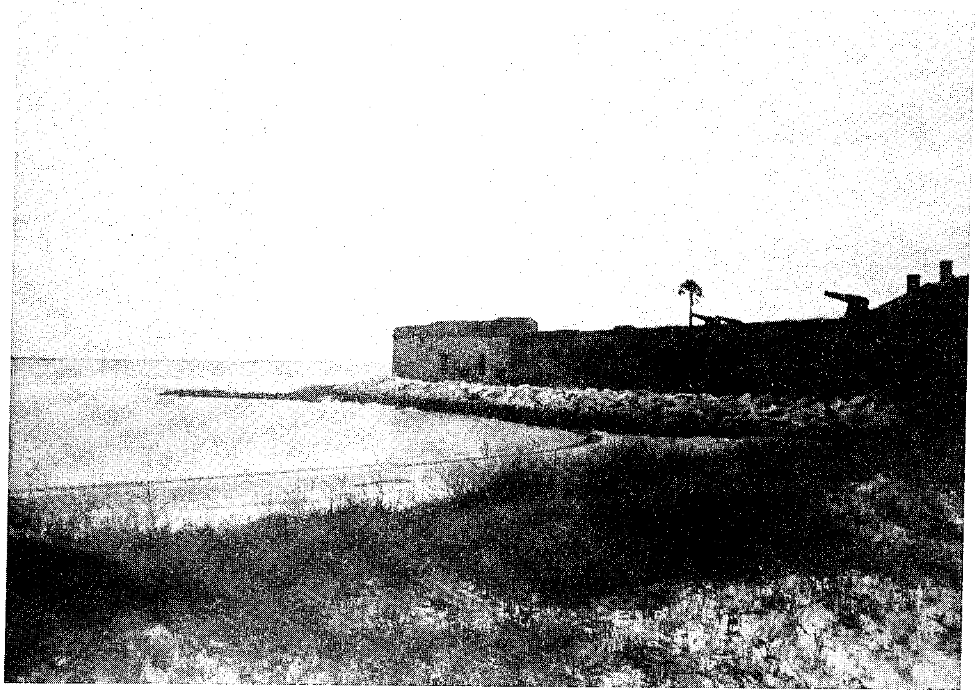


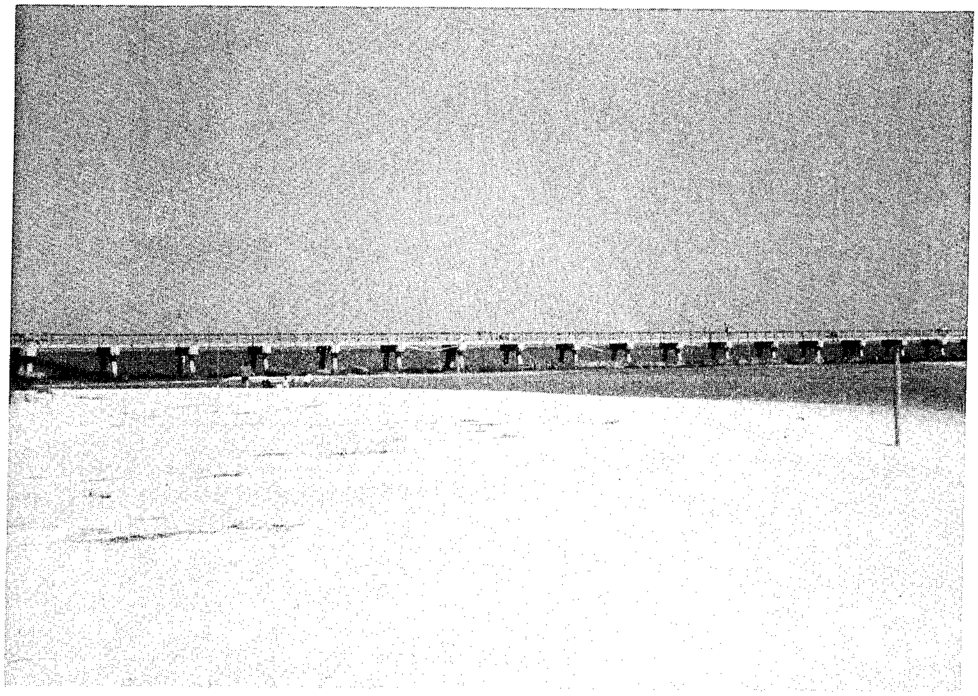
Figure G38. Fort Clinch, looking east, January 1992, Amelia Island

Figure G39. Fort Clinch, looking west, 12 October 1991, Amelia Island

a. Looking southeast

b. Looking east

Figure G40. Pier and jetty, 12 October 1991, Amelia Island



a. Looking north

b. Looking north

Figure G41. Pier and jetty, 12 October 1991, Amelia Island

Figure G42. Jetty, looking south, January 1992, Amelia Island

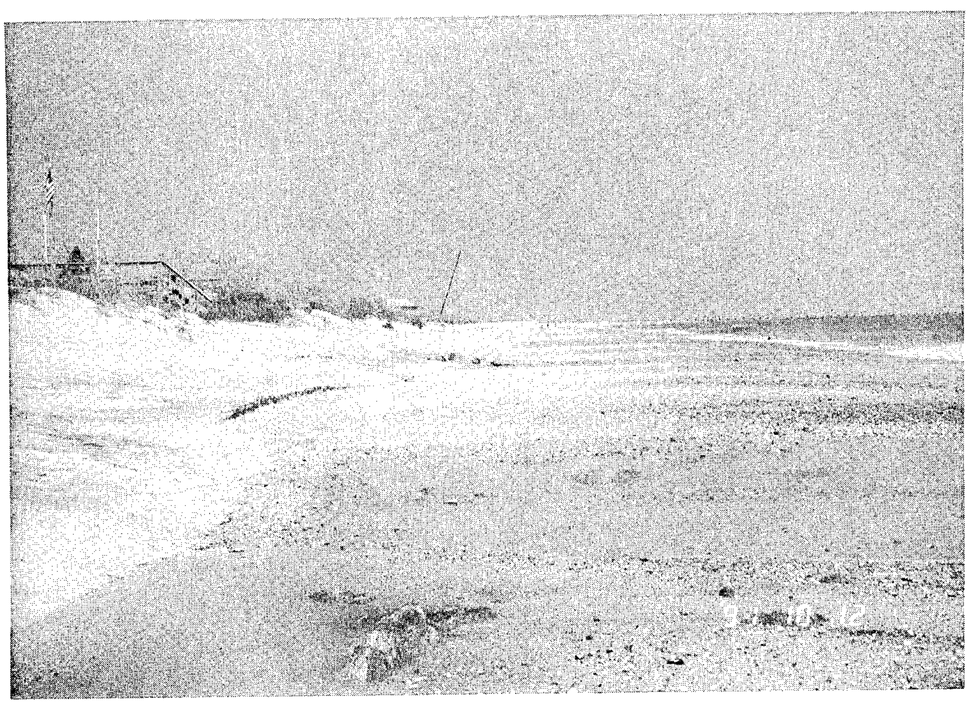


Figure G43. Profile Line 13, looking north, pier in background,
12 October 1991, Amelia Island

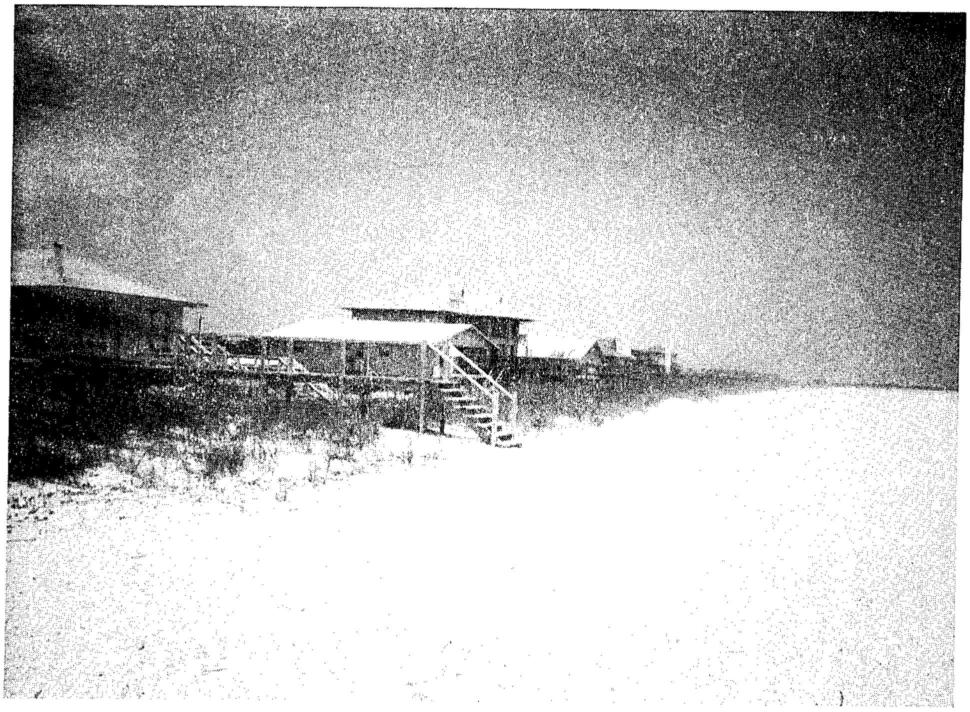


Figure G44. Profile Line 13, looking north, May 1992, Amelia Island

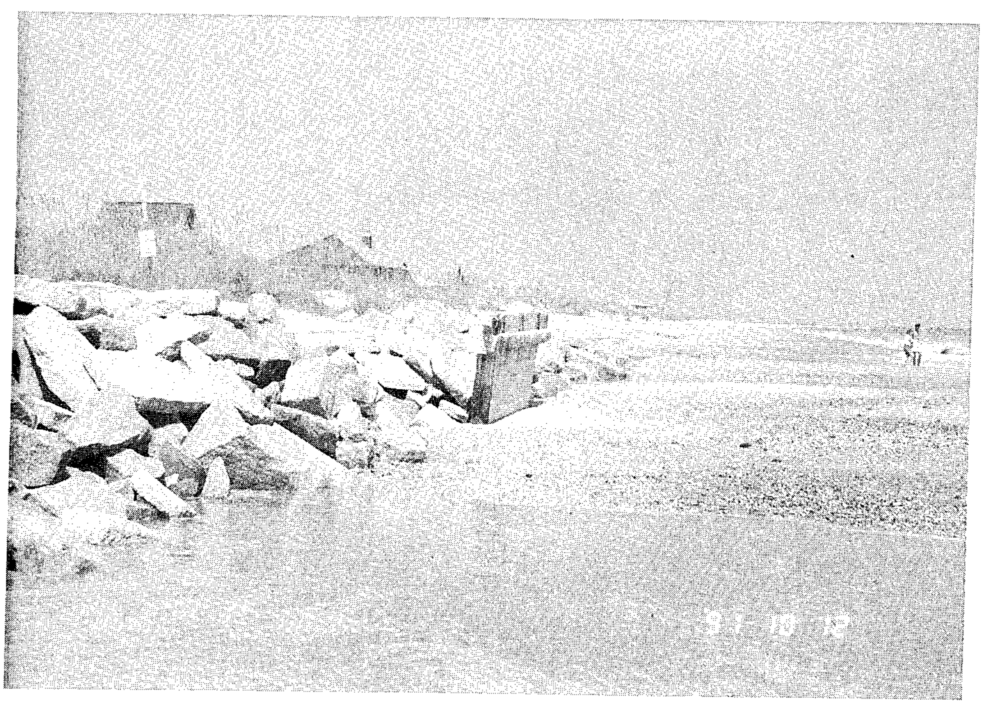


Figure G45. Profile Line 16, looking north, 12 October 1991, Amelia Island

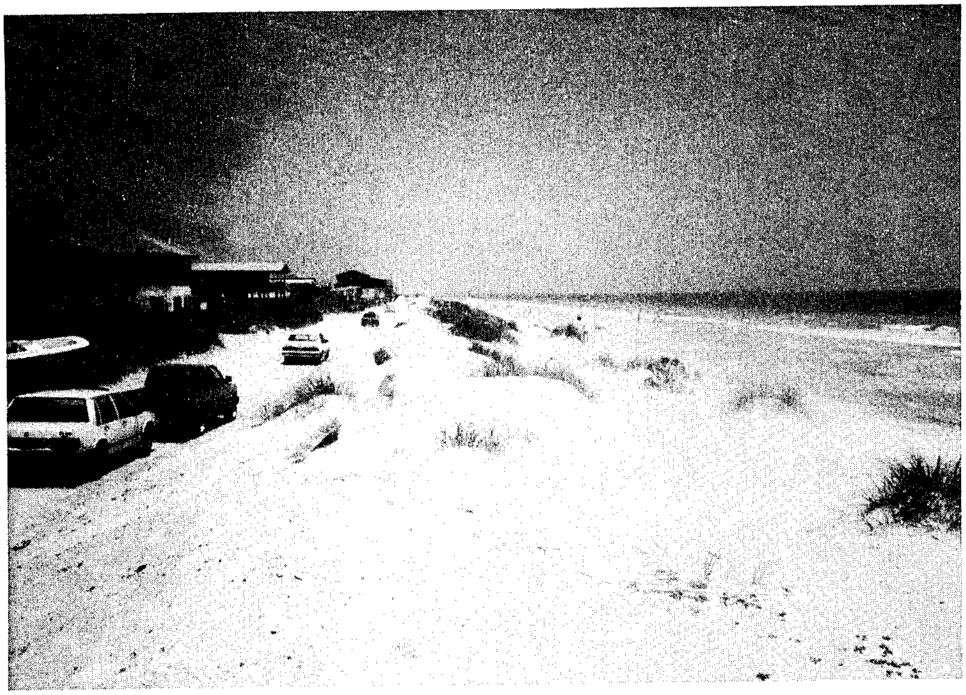


Figure G46. Profile Line 19, looking north, May 1992, Amelia Island

Figure G47. Profile Line 25, looking south, May 1992, Amelia Island

Figure G48. Profile Line 37, looking north, May 1992, Amelia Island

Figure G49. Profile Line 37, looking south, 12 October 1991, Amelia Island

a. Looking north, including development

b. Looking north, including foreshore

Figure G50. Profile Line 40, Fernandina Beach fishing pier in background, May 1992, Amelia Island

Figure G51. Profile Line 40, looking northeast, 12 October 1991, Amelia Island

Figure G52. Profile Line 49, looking south, May 1992, Amelia Island

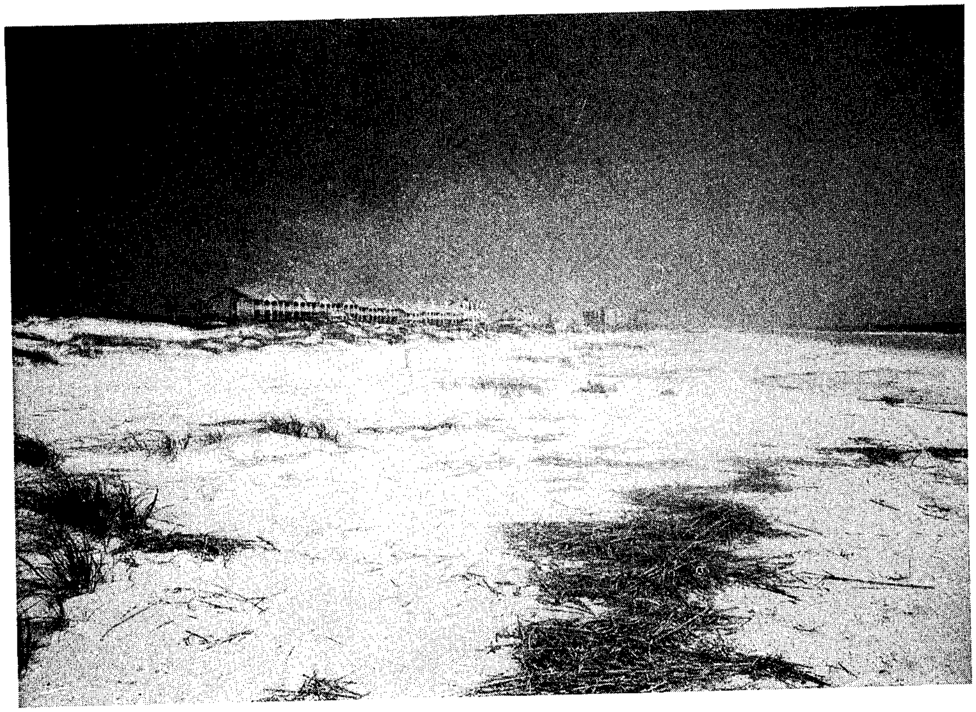


Figure G53. Profile Line 55, looking north, May 1992, Amelia Island

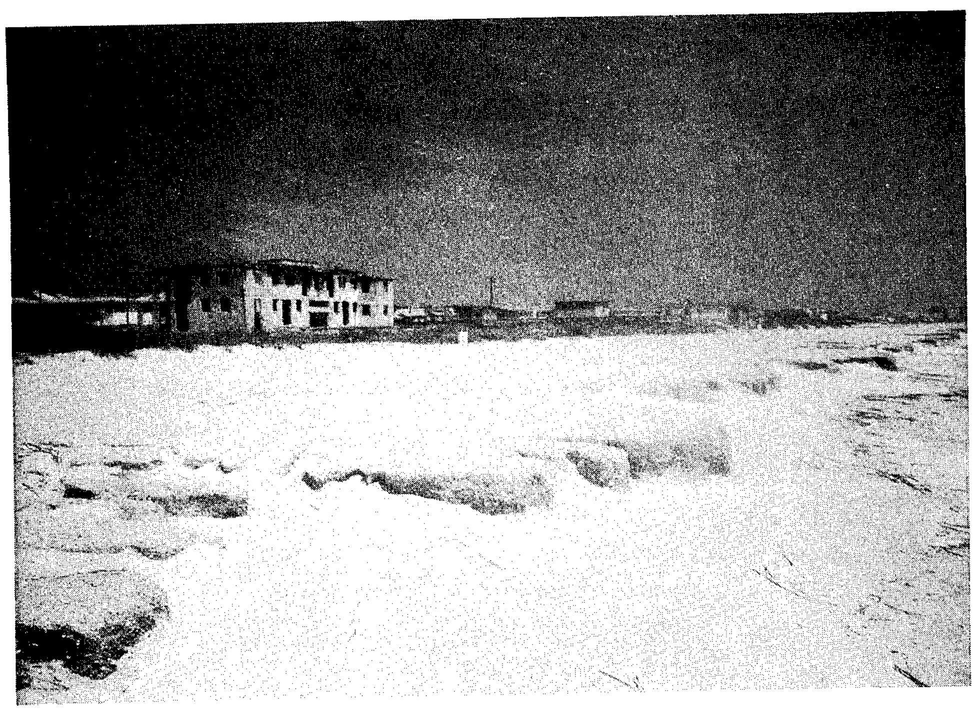


Figure G54. Profile Line 58, calcified sediments from beach fill, looking northwest, May 1992, Amelia Island

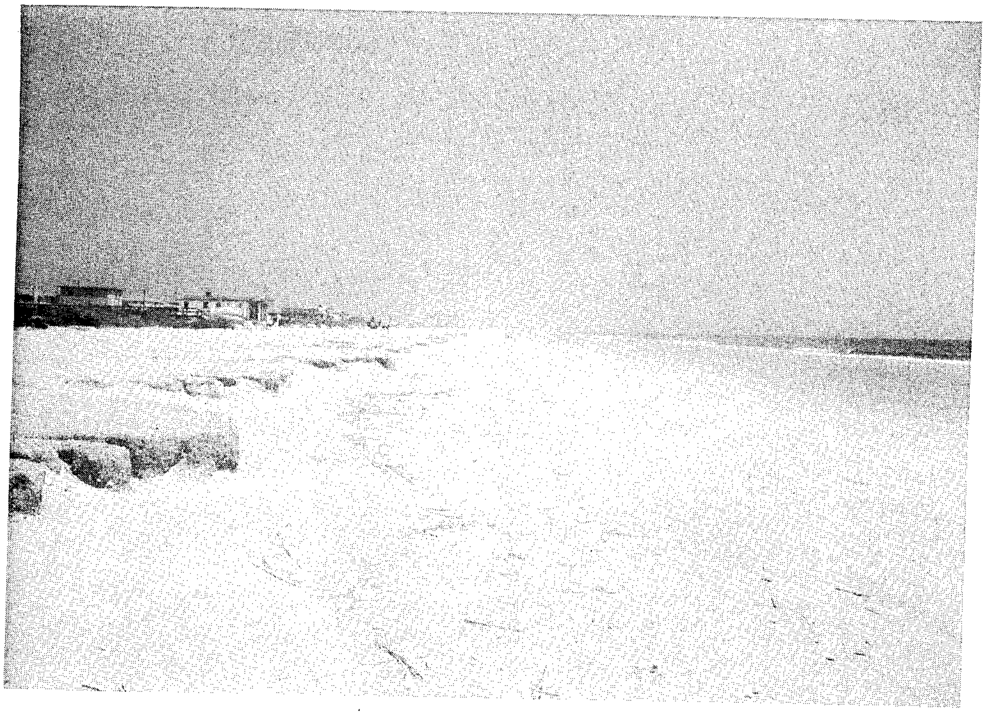


Figure G55. Profile Line 58, looking north, May 1992, Amelia Island

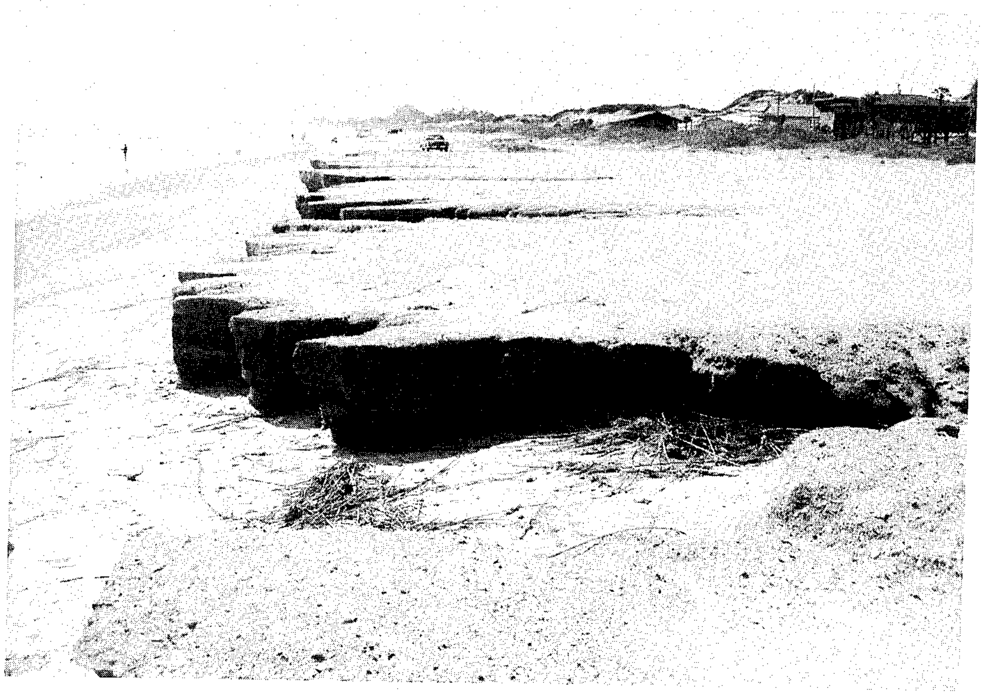


Figure G56. Near profile 58, looking south, 12 October 1991, Amelia Island

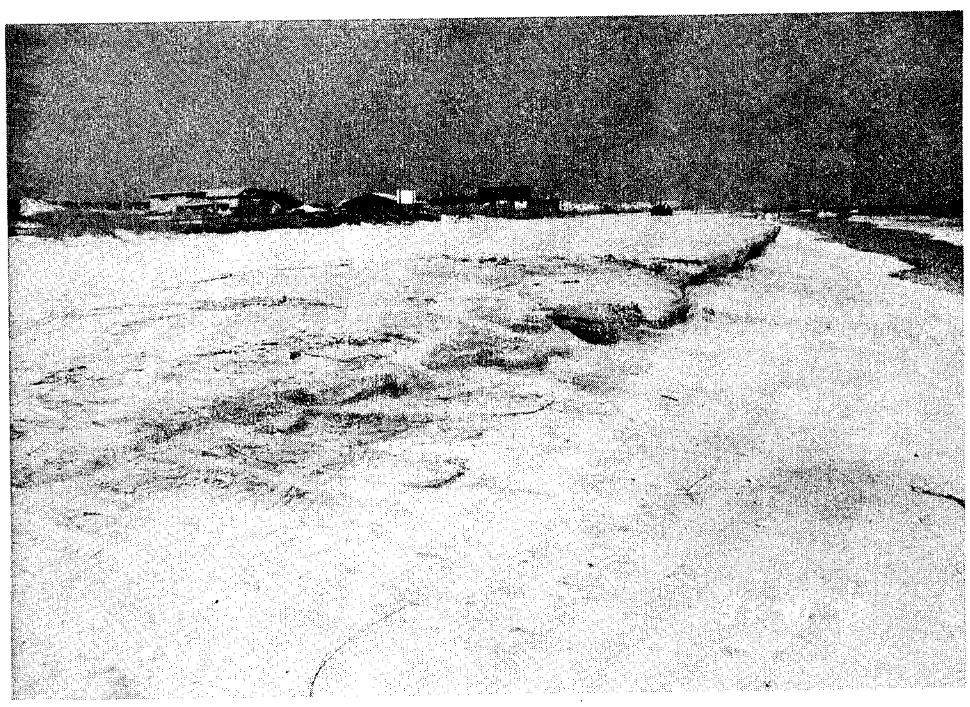


Figure G57. Near Profile Line 58, 12 October 1991, Amelia Island

Figure G58. Near Profile Line 58, looking north, 12 October 1991, Amelia Island

Figure G59. Profile Line 61, looking south, May 1992, Amelia Island

Figure G60. Profile Line 64, looking north, May 1992, Amelia Island

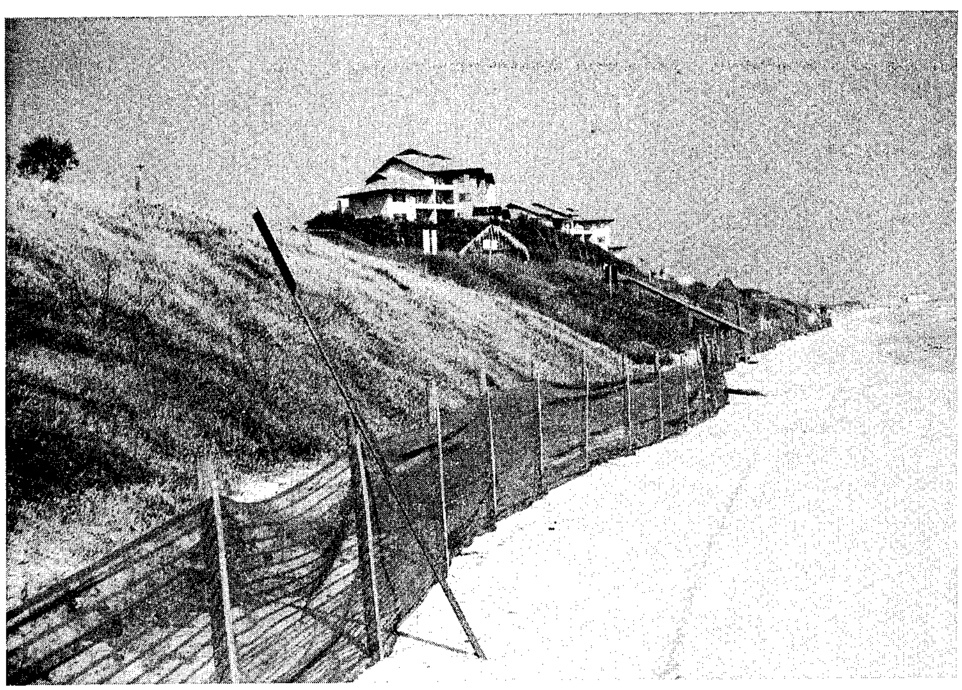


Figure G61. Profile Line 64, looking north, 12 October 1991, Amelia Island

Figure G62. Profile Line 67, looking south over golf course, May 1992, Amelia Island

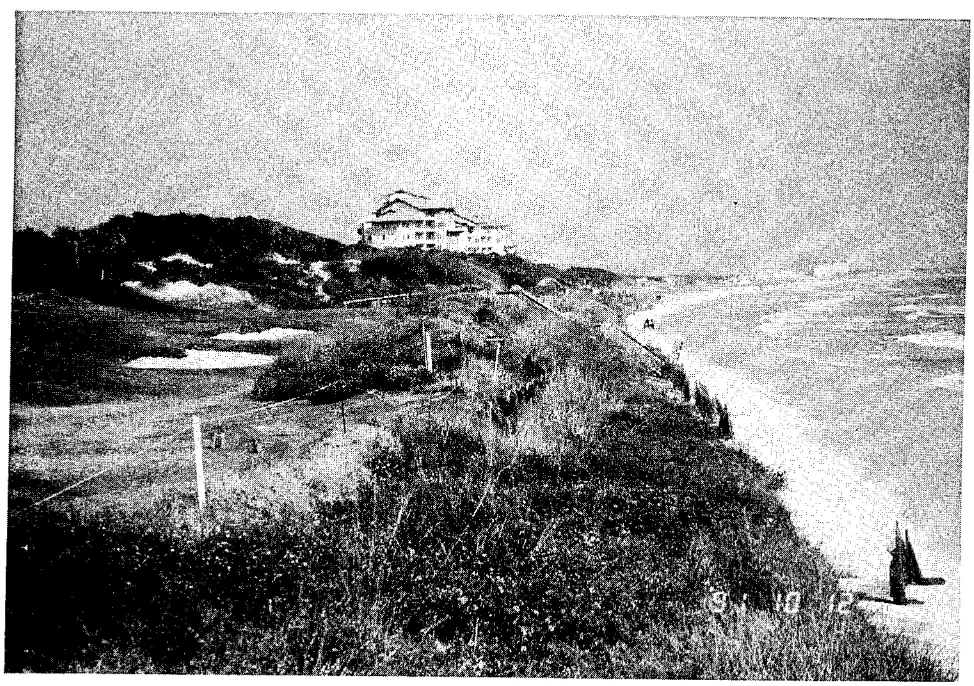


Figure G63. Profile Line 67, looking north over golf course, 12 October 1991, Amelia Island

Figure G64. Profile Line 70, looking south, May 1992, Amelia Island

Figure G65. Profile Line 73, looking south, May 1992, Amelia Island

Figure G66. Profile Line 73, looking southwest, May 1992, Amelia Island

Figure G67. Profile Line 76, looking north, May 1992, Amelia Island

Figure G68. Profile Line 79, looking south to Nassau Sound, 12 October 1991, Amelia Island

Figure G69. Looking south to Nassau Sound, May 1992, Amelia Island

a. Looking south

b. Looking southwest

Figure G70. Nassau Sound, 30 July 1990

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12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The objective of this study was to assess the impacts of U.S. Navy-sponsored navigation channel modification and maintenance activities conducted from 1985-1992 on the shoreline in the vicinity of the traditionally called St. Marys Entrance. This inlet, separating Cumberland Island, Georgia, to the north and Amelia Island, Florida, to the south, contains a large estuary, a commercial and recreational port, Fernandina Harbor, Florida, and, since the 1970s, a U.S. Navy submarine base located at Kings Bay, Georgia. A study of the coastal area included the following components:

a. Review of historical data and previous studies.
b. Numerical simulation of waves and shoreline change.
c. Monitoring of waves, water level, shoreline position, beach profile and sediments, and ebb-tidal bathymetry over the period 1988-1992.

No adverse impact on the beaches of Cumberland Island and Amelia Island by U.S. Navy navigation channel modification and maintenance at St. Marys Entrance could be detected in any of the analyses or monitoring performed in this study.

14. SUBJECT TERMS
See reverse.

15. NUMBER OF PAGES
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