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A SEDIMENTOLOGICAL AND GRANULOMETRIC ATLAS OF THE BEACH SEDIMENTS OF FLORIDA'S EAST COAST

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ABSTRACT

This is a Florida Geological Survey (FGS) study funded by the National Oceanic and Atmospheric Administration (NOAA). This study characterizes recently sampled sediments from the beaches of Brevard, Indian River, St. Lucie, Martin, Palm Beach, Broward and Miami-Dade counties as well as those sampled previously. The prior sampling effort was part of a multi-year study titled "A Geological Investigation of the Offshore Area Along Florida's Northeast Coast, under MMS/FGS Cooperative Agreement No. 1435-0001-30757." That study included the characterization of sites in Nassau, Duval, St. Johns, Flagler and Volusia counties. In both sampling efforts, a total of 842 samples from 400 sites were collected and described. Of those samples, 609 were also granulometrically analyzed. Photographs, descriptions and the results of granulometric analyses are provided.

The study area was broken down into 18 reaches defined by geographic boundaries, such as inlets and the mouths of rivers. The study showed a frequent correlation between inlets and significant changes in mean grain size and carbonate percentage. Changes in mean grain size, both before and after removal of carbonate material, as well as the percentage of carbonate material in the samples define five regions in the study area. A moderate positive correlation between mean grain size and carbonate percentage curves was observed. The carbonate sediments present in the samples was observed to be coarser than the non-carbonate fraction. This difference in mean grain size appears to be most significant where the carbonate percentage rises above 50 percent. While the ratio of carbonate material to non-carbonate material varies substantially north of False Cape in Brevard County, the general trend from north to south shows a steady increase in the percentage of carbonate material within the samples until Government Cut in Miami-Dade County is reached. After Government Cut, there is a substantial and abrupt decline in carbonate material.

INTRODUCTION

Beach erosion is a constant concern in Florida (Clark, 1993). Shore protection options, in substantial portions of the region, are limited by extensively urbanized coastal sectors which have significant commercial and residential development proximal to the beach. Such conditions make the option of asset relocation or abandonment generally unpalatable. The shore protection measure of choice is the periodic placement of sand along the beach. A review of available records suggests that the earliest known beach replenishment projects conducted in the study area, reportedly done in the vicinity of the Lake Worth inlet on "South Beach" and on Palm Beach, were done in 1944. Such projects have continued to the present day. They have, over time, steadily increased in both volume and frequency. To facilitate such efforts, sediments to be placed on these beaches must substantially match those *in situ*. The present study provides a base line analysis of sediments on the beaches in order to facilitate such matching. The primary sedimentary parameters of concern in sediment matching are grain size and the varying ratio of non-carbonate to carbonate material. A secondary parameter of importance, generally from an aesthetic viewpoint, is color. No attempt was made in this document to distinguish between replenished beaches and those which remain in a natural state. To attempt to do so, given the history of beach development for residential and commercial purposes, replenishment projects and engineering projects related to inlet maintenance for navigation, would be problematic at best. That being said it is assumed that, in the study area, the beaches of the reach between Nassau Sound and the mouth of the St. Johns River and the beaches of the contiguous reach segment that includes the Canaveral National Seashore, Merritt Island National Wildlife Refuge and Cape Canaveral Air Force Station are in the most nearly natural condition, i.e. the most minimally impacted by activities carried out on developed segments of beach and inlets adjacent to them.

This report details the results of beach sediment sampling funded by the National Oceanographic and Atmospheric Administration (NOAA). This study characterizes recently sampled sediments from the beaches of Brevard, Indian River, St. Lucie, Martin, Palm Beach, Broward and Miami-Dade counties as well as those sampled previously as part of a multi-year study titled "A Geological Investigation of the Offshore Area Along Florida's Northeast Coast, under MMS/FGS Cooperative Agreement No. 1435-0001-30757" That previous work, as discussed in Phelps *et al.,* (2003, 2004, 2005 and 2007), included the characterization of sites in Nassau, Duval, St. Johns, Flagler and Volusia counties. The total study area encompasses the east coast of Florida commencing at the Florida/Georgia state line in the north and extending southward to Key Biscayne in central Miami-Dade County. See Figure 1 for a reference map which ties the study area to the remainder of Florida. Specific reaches of beach as defined by geographic boundaries, i.e. the mouths of rivers and inlets, are discussed in this report.

While the sampling of beaches along the east coast of Florida was done on a county by county basis, beach boundaries are delineated in this report by reaches defined by geographic features. The delineating features, river mouths and inlets, affect the natural near shore flow of sediments. They also often represent political/economic boundaries which occasionally limit the lateral extent of beach replenishment projects. The ebb tidal deltas associated with these features often serve as the sediment source for beach replenishment. The defined reaches, i.e. beach segments tied to sample site locations, are delineated in Table 1.

Grab samples of beach sediments are referred to as "beach samples". The individual sites selected for the collection of multiple beach samples are referred to as "beach sampling locations". The beach sampling locations utilized are shown in Figure 1 and listed in Table 2. Individual sampling points within those locations are specified by their place on the beach profile. Photographs of individual beach samples can be found in Appendix A. Sediment analysis conducted to characterize a beach sample's grain size distribution is referred to as "granulometric analysis". This analysis is graphically displayed on grain size distribution (GSD) curves. These curves, created from beach samples, can also be found in Appendix A. The sediment fraction referred to as "fines" is that material which will pass through a 4.00 phi, 0.0025 inch (63 micron) mesh opening (#230 sieve).

Surveyed beach monument locations, both control monuments (A monuments) and range monuments (R monuments), are established by the Bureau of Beaches and Coastal Systems (BBCS) of the Florida Department of Environmental Protection (FDEP) at approximately 1,000 foot intervals for the purposes of beach monitoring and management, and are an established reference feature in the study area. This study sampled the beach adjacent to every fifth beach monument. Table 3 ties these monument points to beach sampling locations.

Maps included in this report use either the North American Datum of 1983, herein cited as "NAD83", or the World Geodetic System of 1984, herein cited as "WGS84". Global Positioning System (GPS) instrumentation used to collect geographic global positioning fixes and/or reference points are referred to as "GPS" instrumentation, fixes or points as applicable.

All “unit conversion factors”, English to the International System of Units, i.e. Le Système International d'Unités, (SI) and SI to English, used in this report can be found listed on Table 4. These conversion factors are cited from Eshbach and Souders (1975) to four significant digits. Within the body of this report, when recourse to quantification of distance, weight or volume is required, quantifications are first expressed in English units followed, enclosed in brackets, by their expression in SI units.

PROJECT DESCRIPTION

The beach sample locations utilized are shown in Figure 1. Beach sample locations in Nassau and Duval Counties were spaced one statute mile (1.6 km) apart where practical. Sampling locations from St. Johns southward through Miami-Dade County were also located proximal to every fifth beach monument survey point (BBSC, FDEP) where practical. Table 2 and Table 3 tie beach monument survey points and latitude and longitude to beach sampling locations.

PREVIOUS WORK

Davis (1997) provides a succinct overview of the Florida east coast barrier island and tidal inlet system. Sediment transport in the study area is generally to the south, but littoral drift may be locally reversed forming closed circulation cells. Littoral cells can cause areas of convergent sand supply. Accompanying these convergent sand supply areas are divergent areas where erosion predominates. Stauble and DaCosta (1987) along with Stapor and May (1983) support the existence of local littoral circulation cells while Dean and O’Brien (1987) focus on the general southward direction of littoral transport in the study area. They provide a cogent analysis of the interaction of inlets, their ebb tidal deltas and the adjacent reaches of beaches in their statement:

> *In their natural state, inlets will achieve equilibrium with the natural sand supply and processes. This "equilibrium" may include fairly severe fluctuations of the shoreline as the channel migrates through the bar to achieve transfer of the longshore transport. The ocean bar, its connection to the adjacent shorelines and the adjacent shorelines have been termed by coastal geologists as a "sand sharing system". It is important to recognize that the form and geometry of this sand sharing system play a vital role in maintaining the continuity of longshore sand transport processes along the East Coast. In particular, the broad shallow ocean bars functioned as "sand bridges" across which the sediment transport occurred from the updrift (north) to downdrift (south) beaches. The interference with or geometric modification of this sand sharing system, particularly the ocean bar, could cause substantial interruption of the sediment supply to the downdrift shoreline.*

Proof of their assertion that channel migration can affect the shoreline is seen in the erosion of Little Talbot Island, as shown in Figure 2. The effect of "substantial interruption of sediment supply" is clearly shown by the typically seen landward offset of shorelines immediately adjacent to the downdrift sides of maintained inlets of the east coast of Florida.

Hoenstine *et al.* (1995) and Freedenberg *et al.* (1995, 1995a, 1997a, 1997b, 1999, 2000, 2000a and 2000b) in their extensive study of offshore sand sources for replenishment of the beaches of the central east coast of Florida addressed the sediments of the adjacent beaches for the purpose of sediment matching. Phelps *et al.* (2003, 2004, 2005 and 2007) addressed the beaches of northeast coast of Florida in a similar study. The samples obtained for the Phelps *et al.* studies of the northeast coast of Florida cited above have been incorporated into this report. Both studies found that beach sediments comprised a mixed lithology (quartz-carbonate sand) and barrier islands typify the coast. In those studies, indurated sediments exposed on the beaches were generically assigned to the Anastasia Formation. Although the Anastasia is regarded as Pleistocene in age, it was found to incorporate recently cemented (Holocene) beach rock. It was determined that, when examining an Anastasia specimen, it is often difficult to determine if it was cemented within the last few hundred years or lithified long before.

The Reconnaissance Offshore Data Base (ROSS), maintained by URS Corporation for BBCS, contains substantial information regarding the search for sediments suitable for beach replenishment along the east coast of Florida.

FIELD PROCEDURES AND LABORATORY ANALYSIS

Beach Sample Collection by County

As discussed in Phelps et al., (2003, 2004, 2005 and 2007), a simple alphanumeric scheme was utilized to identify loose sediment samples. All beach samples discussed in this report are identified with a two letter code for the county, followed by consecutive beach location numbers, 01, 02, 03, 04 etc., and completed by a one or two letter designation indicating the sample's placement on the beach profile. Samples collected from the swash zone, beach berm, mid-beach and back beach are designated SS, B, MB and BB, respectively. For example, a sample collected at the first sample location in Volusia County in the swash zone would be delineated as VO-01-SS.

In planning the sample protocol, it was intended that at each sampling location, samples would be collected from the swash zone, the beach berm, mid-beach and back beach. However, due to the width of the beaches visited, only swash zone, mid-beach and back beach samples were collected at many locations while at many others only swash and back beach samples could be obtained. At some locations, where the beach was extremely narrow, only a back beach sample was collected. At several locations, typically where the sea beat against a seawall, no samples were taken. GPS readings were obtained for each of the sampling points within each location. While the elevation of the sediment surface relative to mean sea level was not recorded, these elevations did not exceed 5 feet (ft) (1.5 meters (m)) above mean sea level (MSL). At each sampling point within an individual sampling location, either three or four individual duplicate samples, each totaling approximately two ounces (56.7 grams) of sediment, were obtained for sieve analysis. Samples were collected in Nassau, Duval , St. Johns, Flagler and Volusia Counties by scooping sediments from the surface to an approximate depth of one inch (25.4 millimeters) below the beach surface at each sample point using an approximately two ounce (56.7 gram) scoop, as shown in Figure 3. That procedure was subsequently modified in sampling the beaches of Brevard County and those counties south of it. In those counties, samples were collected by collecting sediments from an approximate depth of 6 to 12 inches (15.2 centimeters to 30.4 centimeters) below the surface. The intent of this change was to eliminate the influence of aeolian winnowing of fines at the sediment surface.

Cumberland Island

A single location in Georgia's Camden County on Cumberland Island's south end at the mouth of the St. Marys River was visited on January 28, 2003. Samples from the swash zone, mid-beach and back beach were collected.

Nassau and Duval Counties

Beach samples from the beaches of Nassau and Duval Counties were collected from December 3 to 4, 2002, and on January 28 and 29, 2003. A total of 32 beach sampling locations were identified (14 in Nassau County and 18 in Duval County), and 100 beach samples were collected (49 in Nassau County and 51 in Duval County). Table 2 ties monument points to beach sampling locations. While it was intended that at each sampling location surface samples were to be collected from the swash zone, the beach berm, mid-beach and back beach, this was only possible at seven sites in Nassau County. At those locations, where no discernable beach berm was noted, no beach berm samples were obtained (Figure 4). There were seven such locations in Nassau County and 16 such locations in Duval County. At one location, the beach was so narrow that only samples from the swash zone and back beach were obtained (Figure 5). At one location on Talbot Island, where active erosion is taking place and no "beach" was present (Figure 2), only a single sample was obtained (Figure 6). While compiling the data for this report, it was discovered that the beach sample locations originally designated in Phelps *et al.* (2003) as NA15 through NA22 were actually located in Duval County. To be consistent with the established labeling scheme, they were therefore renamed DU11 through DU18, respectively.

St. Johns County

Samples from the beaches of St. Johns County were collected on December 4, 2002 and from December 1 to 3, 2003. A total of 110 beach samples were collected from a total of 44 sampling locations. Table 2 ties monument points to beach sampling locations. While it was intended that at each sampling location surface samples were to be collected from the swash zone, the beach berm, mid-beach and back beach, this was only possible at the northern most sampling location in St. Johns County (SJ01). At 20 locations in St. Johns County only swash zone, mid-beach and back beach samples were collected. Due to the narrowness of the beach, only swash zone and back beach samples were collected at 23 locations.

Flagler County

Samples from the beaches of Flagler County were collected December 3, 2003. A total of 41 beach samples were collected from 20 sample locations (Figure 1). Table 2 ties monument points to beach sampling locations. At only one location were swash zone, mid-beach and back beach samples collected. Due to the narrowness of the beach, only swash zone and back beach samples were collected at the remaining 19 locations.

Volusia County

Samples from the beaches of Volusia County were from November 15 to 17, 2004. A total of 107 beach samples were collected from a total of 57 sampling locations (Figure 1). Table 2 ties monument points to beach sampling locations. Due to the narrowness of the beach, only swash zone and back beach samples were collected from 52 locations in Volusia County and from three sites (VO25, VO33 and VO36) only back beach samples were collected. Additionally at two sites where no beach was present (VO34 and VO37), as illustrated in Figure 7, no samples were acquired.

Brevard County

Samples from the beaches of southern Brevard County were collected from September 23 through 26, 2008, as well as on October 28 and 29, 2008. Samples from the beaches of northern Brevard County were collected on March 17 through 19, 2009. A total of 160 beach samples were collected from 79 sampling locations (Figure 1). Table 2 ties monument points to beach sampling locations. At 13 locations swash zone, mid-beach and back beach samples were acquired. At 56 locations, due to the narrowness of the beach only swash zone and back beach samples were collected. At nine locations, where the beach was extremely narrow, only a back beach sample was collected. At one location, BV65, no samples were collected as no beach was present.

Indian River County

Samples from the beaches of Indian River County were collected on October 29 and 30, 2008. A total of 45 beach samples were collected from a total of 24 sampling locations (Figure 1). Table 2 ties monument points to beach sampling locations. At two locations swash zone, mid-beach and back beach samples were obtained. Due to the narrowness of the beach, only swash zone and back beach samples were collected at 17 locations. At five locations, where the beach was extremely narrow, only a single sample was collected.

St. Lucie County

Samples from the beaches of St. Lucie County were collected on October 30 and 31, 2008 and on December 16, 2008. A total of 32 beach samples were collected from a total of 23 sampling locations (Figure 1). Table 2 ties monument points to beach sampling locations. Due to the narrowness of the beach, only swash zone and back beach samples were collected at nine locations. At 14 locations, where the beach was extremely narrow, only a single sample was collected.

Martin County

Samples from the beaches of Martin County were collected on December 16 through December 18, 2008. A total of 44 beach samples were collected from a total of 26 sampling locations (Figure 1). Table 2 ties monument points to beach sampling locations. At two locations only swash zone, mid-beach and back beach samples were collected. Due to the narrowness of the beach, only swash zone and back beach samples were collected at 14 locations. At ten locations, where the beach was extremely narrow, only a single sample was collected.

Palm Beach County

Samples from the beaches of Palm Beach County were collected on December 18, 2008, January 6 through 8, 2008, and January 27 and 29, 2009. A total of 94 beach samples were collected from a total of 45 sampling locations (Figure 1). Table 2 ties monument points to beach sampling locations. At 13 locations, only swash zone, mid-beach and back beach samples were collected. Due to the narrowness of the beach, only swash zone and back beach samples were collected at 23 locations. At nine locations, where the beach was extremely narrow, only a single sample was collected.

Broward County

Samples from the beaches of Broward County were collected on January 27 and 28, 2009. A total of 56 beach samples were collected from a total of 26 sampling locations (Figure 1). Table 2 ties monument points to beach sampling locations. Due to the narrowness of the beach, only swash zone, mid-beach and back beach samples were collected at ten locations. At ten locations only swash zone and back beach samples were collected. At six locations, where the beach was extremely narrow, only a single sample was collected.

Miami-Dade County

Samples from the beaches of Miami-Dade County were collected on January 28, 2009, as well as on February 24 and 25, 2009. A total of 49 beach samples were collected from a total of 23 sampling locations (Figure 1). Table 2 ties monument points to beach sampling locations. At one location swash zone, berm, mid-beach and back beach samples were collected. Due to the narrowness of the beach, only swash zone, mid-beach and back beach samples were collected at seven locations. At nine locations only swash zone and back beach samples were collected. At six locations, where the beach was extremely narrow, only a single sample was collected.

Photographs of the samples collected are provided in Appendix A.

Sediment Sample Processing

The sieve nest used in sample processing by the Florida Geological Survey is delineated in Table 5 which includes a photograph (Figure 8). All grain size distribution analyses were conducted using general guidelines of the American Society for Testing and Materials (2000a, 2000b) and specific procedures advanced by the FGS sedimentology laboratory (Balsillie, 1995, 2002a, 2002b,; Balsillie and Tanner, 1999; Balsillie, Tanner and Williams, 1999; Balsillie *et.al*. 2002a; Balsillie *et.al.* 2002b; Balsillie and Dabous, 2003). Each sample was initially weighed after oven drying. The sample was then wet sieved through a #230 (0.63 mm or 4 phi) sieve, oven dried and reweighed with the weight loss being assigned to the fine fraction. The sample was then dry sieved with the portion of the pan fraction obtained during dry sieving also assigned to the fine fraction. The sample was then digested with a 4 Molar hydrochloric acid solution, rinsed with deionized water, oven dried, reweighted and resieved.

The cumulative grain size distribution curves reflect the total grain size distribution (GSD) of the sample. The weight of the fine fraction (weight loss from wet sieving and weight of the pan fraction combined) was assigned to the less than 4 phi fraction. Separate GSD's were determined for the carbonate and non-carbonate fractions of each sample along with the combined GSD of the entire sample. The grain size distribution curves are provided with analysis (Excel spreadsheet). A link is provided in the grain size analysis column on the index for beach samples.

For beach samples, sample #1 of the set was processed as described above. Sample #2, subsequent to being dried, was described and photographed. This data can be accessed via the index under the photo page column. Sample #3 of the set was dried and 10 percent of these samples were processed like sample #1, for the purpose of quality control, for granulometric analysis. The results of their granulometric analyses are provided in Appendix A. Those sample sets, collected from Brevard County and southward, not selected for processing were described, photographed and retained for processing in the future.

Grain Size Distribution (GSD) Curves

Separate GSD curves were made for the non-carbonate fractions of each sample processed by the FGS along with a combined GSD of the entire sample. These curves can be found in Appendix A.

Sediment Processing Quality Control

As a quality control check, duplicate samples were processed separately for approximately 10 percent of all beach samples processed. Twenty-five duplicate back beach samples were processed for Brevard, Indian River, St. Lucie, Martin, Palm Beach, Broward, and Miami-Dade Counties. Graphical comparisons of initial and duplicate samples can be found in Appendix B. As a result of two different sieve sets being used in the initial grain size analysis, cross analysis was also conducted. Ten duplicate samples, or approximately 4 percent, were processed in both sieve sets as well as a third. Further information and data can be found in Appendix B. In addition, 36 duplicate beach samples were previously processed for Nassau, Duval, St. Johns,

Flagler, and Volusia Counties and are also included in this report (see Appendix B). Using the Mann-Whitney Test (equivalent to the Wicoxon Test) to compare the distribution medians and Levene's Test, Conover (1999), to compare the variances, at a 95 percent confidence level, there was no significant difference found between the distributions of the first and duplicate samples for either of the two tests.

BEACH REACHES OF THE EAST COAST OF FLORIDA

Table 1 lists the beach reaches of the east coast of Florida from the Georgia/Florida border to Key Biscayne in Miami-Dade County. On that table, individual reaches are tied to their respective set of sampling locations. The following Florida Department of Environmental Protection reports produced by its Bureau of Beaches and Coastal Systems were extensively consulted and used to establish the timeline of recent beach replenishment and the construction of engineering structures on the beach reaches in the study area: Critically Eroded Beaches in Florida (2007); Strategic Beach Management Plan for the Northeast Atlantic Coast Region (2008); Strategic Beach Management Plan for the Central Atlantic Coast Region (2008); and Strategic Beach Management Plan for the Southeast Atlantic Coast Region (2008). Additionally, a historical database of beach replenishment projects, compiled by the Western Carolina University Program for the Study of Developed Shorelines (PSDS) (2009) was also consulted. Table 6 lists the limits of known metropolitan areas as well as federal, state, and county lands discussed in this report with regard to sampling locations.

Amelia Island

Geographic Setting

Amelia Island, as shown on Figure 1, lies in Nassau County and is considered to be the southern-most island in the chain of barrier islands known as the Sea Islands. This island chain extends northward from Florida to the state of South Carolina. Amelia Island is 13 mi long (21 km), approximately 4 mi (6 km) wide at its widest point and approximately 26 mi^2 (67 km^2) in area. It is separated to the north from Cumberland Island in Georgia by the St. Mary's Inlet which forms the mouth of the St. Mary's River and from Talbot Island to the south by Nassau Sound which forms the mouth of the Nassau River. It is separated from the rest of Nassau County to the west by extensive salt marshes the Intracoastal Waterway/Amelia River and the S. Amelia River. Geological evidence suggests that the island was formed during the Pleistocene and more recent Holocene ages as a result of two major fluctuations in sea level. The formation of this "Sea Island" type of barrier island is discussed in Henry (1971).

Typically, the beaches of barrier islands, such as the Sea Islands, have gentle slopes with fine-grained, well sorted sediments. The beaches on Amelia Island deviate somewhat from this due to a number of erosion control structures along the island and the periodic placement of beach fill material. The ocean front of the island, except for its north and south ends, is developed. Ongoing beach erosion occurs along much of Amelia Island's Atlantic shoreline. Approximately 2.8 mi (4.5 km) of the shoreline is either armored with stone revetment or fronted by seawalls. Beach profile measurements collected on Amelia Island are reported to have indicated beach slopes ranging from one to six degrees, with an average slope of 2.8 degrees (Raichle et al. 1997).

Beach History in Brief (from Strategic Beach Management Plan for the Northeast Atlantic Coast Region (2008))

Located within the inlet shoreline of Amelia Island fronting the St. Mary's River entrance is historic Fort Clinch and Fort Clinch State Park. Beginning in 1881, several generations of groins have been placed inside the inlet on the north end of the island to protect Fort Clinch. In 1965, a granite stone revetment was constructed at Fort Clinch and American Beach. Some of the Fernandina revetment may have been constructed later than 1965 and prior to December 1974.

Fernandina Beach consists of the segment of beach extending from the south jetty of the St. Mary's River southward to approximately the midpoint of the island. Sand dredged from the St. Mary's River Entrance has been placed principally in the northern portion of this segment.

In 1994, about 2.6 million cubic yards (cy) (2.0 million cubic meters (m^3)) of fill were placed along 3.4 mi (5.5 km) of the southern Amelia Island shoreline. Additional projects on southern Amelia Island placed approximately 300,000 cy (229,366 m^3) in both 1997 and 2001. A terminal groin field was constructed in 1995 to limit movement of fill material to Nassau Sound. The South Amelia Island Shore Stabilization, Phase I – Beach Restoration project placed about 1.9 million cy (1.5 million m^3) of sand in 2002. Another 300,000 cy (229,366 m^3) were placed in 2006.

Data Analysis

On Amelia Island, 14 locations (NA01 through NA14), as shown in Table 1, were sampled from which 49 samples were collected. Swash zone, beach berm, mid-beach and back beach samples were obtained from seven locations, all but one of which lie on the southern portion of the island. Swash zone, mid-beach and back beach samples were obtained from seven locations on the northern portion of the island.

Carbonate material averaged 6 percent of the samples. The mean grain size before carbonate removal was 0.268 mm (1.899 phi). The mean grain size after carbonate removal was 0.261 mm (1.937phi). As shown in Figure 9, there is a subtle shift in grain size along the island. More specifically, grain size varies from fine grained sands at the northern and southern most points while increasing to medium grain sands in the middle of the reach. Photographs as well as granulometric analysis of the samples collected are provided in Appendix A. Curves comparing grain size north and south of the mouth of the St. Mary's River and north and south of Nassau Sound can be found in Appendix C. In the first case, the spectrum of grain sizes is shown to both coarsening and broaden southward from the mouth of the St. Mary's River. The second case, at the entrance to Nassau Sound, suggests that southward there is both a fining and a narrowing of the spectrum of grain sizes present.

Talbot Island and Wards Bank

Geographic Setting

Talbot Island and Wards Bank, as shown on Figure 1, are two barrier islands which lie on the coast of northern Duval County. Little Talbot Island, the northern-most of the pair, is separated to the north from Amelia Island by Nassau Sound and to the south from Wards Bank by Ft. George Inlet. Little Talbot Island is about 4.3 mi (7 km) in length and 0.9 mi (1.5 km) wide. It is a state park and is thus undeveloped. The southern-most of the pair, Wards Bank, is terminated to the south by the St. Johns River entrance. These islands are separated from the mainland of Duval County to the west by extensive salt marshes, the Intracoastal Waterway and in the case of Little Talbot Island by the Ft. George River.

Beach History in Brief (from Strategic Beach Management Plan for the Northeast Atlantic Coast Region (2008))

No beach nourishment projects have been conducted on either Little Talbot Island or Wards Bank. Construction began on the north St. Johns River Entrance jetty in 1882. To date, the north jetty has been extended to 2.7 mi (4.3 km) as described in the BBCS's report titled "Shoreline Change Rate Estimates, Duval County" (2000):

> *In response to Little Talbot Island's erosion problem (namely the Ft. George Inlet migration), a rubble revetment was constructed in the late 1970s along the shoreline west of the Highway A1A/SR-105 bridge spanning the Ft. George*

River. This revetment has been extended eastward over time to protect a larger portion of the road.

Figure 2 shows active erosion on Little Talbot Island in response to the southward movement of the channel in Nassau Sound.

Data Analysis

Six sample locations, NA15 through NA20 as shown in Table 1, were selected on Little Talbot Island from which 15 samples were collected. Swash zone, mid-beach and back beach samples were obtained from four locations. Swash zone and back beach samples were obtained from one location and at one location only, a single sample was collected. Figure 6 shows sample collection at that site. On Wards Bank two sample locations were selected, NA21 and NA22, from which six samples were collected. Swash zone, mid-beach and back beach samples were obtained from both locations.

Of the samples collected from Little Talbot Island, carbonate material averaged 4.2 percent of the samples. The mean grain size before carbonate removal was 0.160 mm (2.647 phi). The mean grain size after carbonate removal was 0.161 mm (2.635 phi). Of the samples collected from Wards Bank, carbonate material averaged 2.9 percent of the samples. The mean grain size before carbonate removal was 0.140 mm (2.838 phi). The mean grain size after carbonate removal was 0.140 mm (2.833 phi). As shown in Figure 9, distinct shifts were observed in both grain size and carbonate content compared to both the reach to its north and the reach to its south, with this reach being lesser in both grain size and carbonate percentage. Internal to the reach, there was seen a slight rise to a peak in carbonate material in the middle of Little Talbot Island and a corresponding slight decline across Wards Bank to its south end where it begins to increase again. Grain size remains relatively constant with shifts at Nassau Sound and the mouth of the St. Johns River. Photographs as well as granulometric analysis of the samples collected are provided in Appendix A. Curves comparing grain size north and south of the mouth of Nassau Sound, Ft. George Inlet and the mouth of the St. Johns River can be found in Appendix C. The first case, at the entrance to Nassau Sound, suggests both a fining and a narrowing of the spectrum of grain sizes present on Talbot Island and Ward Bank compared to the beaches to the north and south. The second and third cases, across Ft. George Inlet and the mouth of the St. Johns River, confirm this interpretation.

Mayport to St Augustine Inlet

Geographic Setting

This reach of beach, as shown on Figure 1, extends from the mouth of the St. Johns River southward to the St. Augustine Inlet. The island upon which it lies is separated from the mainland to the west by the Intracoastal Waterway in both Duval County and the northern portions of St. Johns County. Further south, it is separated from the mainland by the Intracoastal Waterway, the Guana River and extensive salt marshes.

Beach History in Brief (from Strategic Beach Management Plan for the Northeast Atlantic Coast Region (2008))

The Duval County Shore Protection Project was initiated in 1977 and completed in 1980 using 2,877,000 cy (2,199,000 m^3) of sand from maintenance dredging of the St. Johns River entrance and from an offshore borrow area. Beach replenishment was continued in 1985, 1986 and 1987 utilizing 1,284,000 cy (981,000 m^3), 308,700 cy (236,018 m^3) and 850,000 cy (649,871 m^3) of sand, respectively. In 1991, an additional project placed 300,000 cy (229,366 m^3) of sand. Beach replenishment was continued in 1995 with the placement of 1.2 million cy (0.9 million m^3) of sand. In 2003, renourishment was started using sand dredged from the river entrance; this work was stopped after placement of about 300,000 cy (229,366 m^3) when it was determined the

material contained excessive amounts of shell and clay and was therefore not suitable for placement on the beach. This phase of work was then restarted and completed in 2005 using 615,200 cy (470,354 m^3) of sand from an offshore borrow area; work included repair of 1.6 miles (2.6 km) of dunes.

Data Analysis

From the reach of beach extending southward from the mouth of the St. Johns River to St. Augustine Inlet, 35 sample locations, DU01 through DU10 and SJ01 through SJ25 as shown in Table 1, were selected from which 83 samples were collected. Swash zone, beach berm, mid-beach and back beach samples were obtained from one location. Swash zone, mid-beach and back beach samples were obtained from 11 locations and swash and back beach samples were obtained from 23 locations.

Along the entire reach of beach, carbonate material averaged 29.7 percent of the samples. The mean grain size before carbonate removal was 0.419 mm (1.256 phi). The mean grain size after carbonate removal was 0.282 mm (1.825 phi). Of the samples collected from location DU01 through DU10, carbonate material averaged 3.6 percent of the samples. The mean grain size before carbonate removal was 0.199 mm (2.327 phi). The mean grain size after carbonate removal was 0.201 mm (2.318 phi). Of the samples collected from SJ01 through SJ25, carbonate material averaged 40.1 percent of the samples. The mean grain size before carbonate removal was 0.564 mm (0.827 phi). The mean grain size after carbonate removal was 0.323 mm (1.628 phi). As shown on Figure 10, there was noted a distinct shift in both grain size and carbonate content at the mid-point of the reach (around location SJ06). Additional, there were changes at both the mouth of the St. Johns River (increase) and at St. Augustine Inlet (decrease). Curves comparing grain size both north and south of the mouth of the St. Johns River and St. Augustine Inlet can be found in Appendix C. The first case suggests both a coarsening and a broadening of the spectrum of grain sizes present in the reach. The second case, across St. Augustine Inlet, supports this interpretation. The shift noted at the north end of the reach, however, was more noticeable in grain size. As seen on Figure 10, the increase seen in carbonate percentage was localized to the immediate vicinity of that inlet and relatively negligible. The reaches to its north and south are finer grained and exhibit lower carbonate percentages. Photographs as well as granulometric analysis of the samples collected are provided in Appendix A.

St. Augustine Inlet to Matanzas Pass

Geographic Setting (from Strategic Beach Management Plan for the Northeast Atlantic Coast Region (2008))

This reach of beach, as shown on Figure 1, extends from the St. Augustine Inlet to Matanzas Pass, an unmaintained inlet. The island comprising this section, known on its north end as Conch Island and further south as Anastasia Island, is separated from the mainland to the west by extensive salt marshes, the Matanzas River and the Intracoastal Waterway.

Beach History in Brief (from Strategic Beach Management Plan for the Northeast Atlantic Coast Region (2008))

The Anastasia State Park and the City of St. Augustine Beach segment of beach, located south of St. Augustine Inlet, lies within the area of influence of the inlet. In 1973, a spur groin was built at Anastasia State Park and a coquina revetment was built along the south end of St. Augustine Beach. In 1988, an additional spur groin was built at the northern end of the historic seawall. Since 1996, maintenance dredging of the St. Augustine Inlet has placed sand on the beaches within this area. The St. Johns County Shore Protection Project in 2003 placed 4.2 million cy (3.2 million m^3) of sand excavated from the St. Augustine Inlet ebb shoal within this segment. Following Hurricanes Frances and Jeanne in 2004, a renourishment project completed in 2005

placed 2.8 million cy (2.1 million m^3) of sand excavated from the St. Augustine Inlet ebb shoal within this reach of beach.

Data Analysis

From the reach of beach extending southward from St. Augustine Inlet to Matanzas Pass 16 sample locations (SJ26 through SJ41), were selected from which 48 samples were collected. Swash zone, mid-beach and back beach samples were obtained from all 16 locations.

Carbonate material averaged 4.2 percent of the samples. The mean grain size before carbonate removal was 0.160 mm (2.644 phi). The mean grain size after carbonate removal was 0.158 mm (2.666 phi). As shown on Figure 10, there were seen distinct shifts in both grain size and carbonate content between both the reach to its north and the reach to its south including a decrease at St. Augustine Inlet and an increase at Matanzas Pass. Curves comparing grain size both north and south of the St. Augustine Inlet and Matanzas Pass can be found in Appendix C. The first case suggests both a fining and a narrowing of the spectrum of grain sizes present in the reach compared to the reach to the north. The second case suggests a slight fining and narrowing of the spectrum of grain sizes present compared to the reach to the south. Photographs as well as granulometric analysis of the samples collected are provided in Appendix A.

Matanzas Pass to Ponce de Leon Inlet

Geographic Setting

As shown on Figure 1, this is the longest reach of beach in the study area. Portions of it, especially in the area of the city of Daytona Beach, are substantially developed. The barrier island, upon which the reach lies, varies in width. It is separated from the mainland of St Johns, Flagler and Volusia counties by salt marshes and the Intracoastal Waterway. It is bounded to the north and south by the Matanzas Pass and Ponce de Leon Inlet.

Beach History in Brief (from Strategic Beach Management Plan for the Northeast Atlantic Coast Region (2008))

The segment of beach in the unincorporated town of Summer Haven in St. Johns County, immediately south of Matanzas Pass, is within the area of influence of that inlet. Sand from Intracoastal Waterway dredging is placed by the Florida Inland Navigation District when available. In 2002 and 2003, small emergency protective berms were constructed and some beach nourishment was accomplished. Much of the shoreline further south, at the unincorporated town of Marineland, is protected by a rock revetment and groins. Following Hurricane Floyd in 1999, the coquina revetment at Marineland, originally constructed in 1938, was reconstructed using larger granite boulders. Some of the groins were removed and some dune reconstruction work was performed. Continuing south, following severe erosion caused by tropical storm Gabrielle in 2001; wooden bulkheads were constructed at the unincorporated area of Painters Hill in Flagler County. Most of the southern portions of Flagler Beach have been armored with a rock revetment along the southern portions of Flagler Beach. In 2006, a segment of vertical seawall was constructed in this area as well.

Data Analysis

From the reach of beach extending southward from Matanzas Pass to Ponce Inlet, 53 sample locations, SJ42 through SJ44, FG01 through FG20 and VO01 through VO30 as shown in Table 1, were selected from which 109 samples were collected. Swash zone, mid-beach and back beach samples were obtained from four locations and swash and back beach samples were obtained from 48 locations. From one location, VO25, only a single sample was collected.

Along the entire reach of beach, carbonate material averaged 22.1 percent of the samples. The mean grain size before carbonate removal was 0.282 mm (1.827 phi). The mean grain size after carbonate removal was 0.243 mm (2.040 phi). As shown on Figure 11, there were noted distinct shifts in both grain size and carbonate with grain size and the percentage of carbonate material both abruptly increasing and then gradually declined southward. That decline is interrupted by a peak in both proximal to the inlet. The reach to its north is finer grained and exhibits lower carbonate percentages. Of the samples collected from location SJ42 through SJ44, carbonate material averaged 12.4 percent. The mean grain size before carbonate removal was 0.236 mm (2.086 phi). The mean grain size after carbonate removal was 0.212 mm (2.236 phi). Of the samples collected from FG01 through VO08, carbonate material averaged 34.4 percent of the samples. The mean grain size before carbonate removal was 0.445 mm (1.169 phi). The mean grain size after carbonate removal was 0.326 mm (1.616 phi). Of the samples collected from VO09 through VO30, carbonate material averaged 7.7 percent of the samples. The mean grain size before carbonate removal was 0.212 mm (2.240 phi). The mean grain size after carbonate removal was 0.203 mm (2.304 phi). Curves comparing grain size both north and south of Matanzas Pass and Ponce de Leon Inlet can be found in Appendix C. The first case suggests a slight coarsening and broadening of the spectrum of grain sizes present compared to the reach to the north. In the second case, the grain size curves north and south of Ponce de Leon Inlet show virtually no difference. Photographs as well as granulometric analysis of the samples collected are provided in Appendix A.

Ponce de Leon Inlet to Port Canaveral

Geographic Setting

Within this reach of beach only the segment immediately south of Ponce de Leon Inlet (a.k.a. Ponce Inlet), consisting of the city of New Smyrna Beach and the unincorporated town of Bethune Beach in southern Volusia County, has been developed. The remainder of this reach lies in Smyrna Dunes Park immediately south of Ponce de Leon Inlet, Canaveral National Seashore, Merritt Island National Wildlife Refuge and Cape Canaveral Air Force Station. As shown on Figure 1, the barrier island upon which the reach lies varies in width and is locally quite narrow at Canaveral National Seashore. It is separated from the mainland of Volusia and Brevard counties by extensive salt marshes, the Intracoastal Waterway and at Canaveral National Seashore by Mosquito Lagoon and the Banana River. It is bounded to the north and south by the Ponce de Leon Inlet and the cut at Port Canaveral, respectively.

Beach History in Brief (from Strategic Beach Management Plan for the Northeast Atlantic Coast Region (2008) and Strategic Beach Management Plan for the Central Atlantic Coast Region (2008))

The developed segment of beach south of Ponce Inlet lies adjacent to New Smyrna Beach and Bethune Beach. Much of New Smyrna Beach has vertical seawalls and bulkheads and much of Bethune Beach has rock revetments. Hurricanes Frances and Jeanne (2004) destroyed 5,145 ft (1,568 m) of seawalls and inflicted severe beach and dune erosion leaving much of this area with little recreational beach. Hurricane Wilma (2005) caused additional cumulative erosion and wall damage. In 2006, dune restoration activities were conducted as an interim measure to provide limited temporary protection as a result of storm impacts.

Data Analysis

From the reach of beach extending southward from Ponce Inlet to Port Canaveral, 61 sample locations, VO31 through BV34, as shown in Table 1, were selected from which 116 samples were collected. Swash zone, mid-beach and back beach samples were obtained from one location. Swash and back beach samples were obtained from 55 locations. Only back beach samples were collected from three locations, and there were two locations (VO34 and VO37) from which no samples were collected, as no beach was present.

The mean grain size in the reach before carbonate removal was 0.402 mm (1.314 phi). The mean grain size after carbonate removal was 0.351 mm (1.509 phi). The samples collected from this reach of beach carbonate material averaged 31.2 percent. Curves comparing grain size north and south of Ponce de Leon Inlet can be found in Appendix C. The grain size curves north and south of Ponce de Leon Inlet show virtually no difference. Of the samples collected from locations VO31 through VO57 carbonate material averaged 41.9 percent of the samples. The mean grain size before carbonate removal was 0.427 mm (1.226 phi). The mean grain size after carbonate removal was 0.346 mm (1.531 phi). As shown in Figure 12, there were noted distinct shifts in both mean grain size and carbonate in this portion of the reach with mean grain size and the percentage of carbonate material both abruptly increasing approximately 8 miles (12.9 kms) south of Ponce Inlet. Both mean grain size and carbonate percentage decrease around the Volusia/Brevard County Line and then continue to decrease until False Cape (BV18), where they both increase. Then, near Cape Canaveral, both mean grain size and carbonate percentage decrease after which they incrementally increase until dropping, once again, at Port Canaveral. Curves comparing grain size both north and south of Port Canaveral, which can be found in Appendix C, suggest a coarsening and broadening of the spectrum of grain sizes north of Port Canaveral compared to those to the south. Of the samples collected from locations VO31 through VO39, carbonate material averaged 12.8 percent. The mean grain size before carbonate removal was 0.173 mm (2.527 phi). The mean grain size after carbonate removal was 0.178 mm (2.492 phi). Of the samples collected from locations VO40 through VO57, carbonate material averaged 53.2 percent. The mean grain size before carbonate removal was 0.607 mm (0.720 phi). The mean grain size after carbonate removal was 0.448 mm (1.158 phi). Of the samples collected from locations BV01 through BV34, carbonate material averaged 25 percent. The mean grain size before carbonate removal was 0.384 mm (1.379 phi). The mean grain size after carbonate removal was 0.355 mm (1.493 phi). Photographs as well as granulometric analysis of these samples are provided in these web pages and can be accessed via Appendix A.

Port Canaveral to Sebastian Inlet

Geographic Setting

As shown on Figure 1, the island upon which this reach of beach is located varies substantially in width. It is separated from the mainland of Brevard County by the Banana River to the north and Intracoastal Waterway to the south and the Indian River. Segments of this reach of beach are developed while others, at for example Patrick Air Force Base and Sebastian Inlet State Park, are in a more natural state.

Beach History in Brief (from Strategic Beach Management Plan for the Central Atlantic Coast Region (2008))

The section of beach designated by BBCS as North Reach in Brevard County runs from the south jetty at Port Canaveral to the south limits of Cocoa Beach. Within this segment, the Brevard County Shore Protection Project was implemented in 2001 with the placement of 3.14 million cy (2.4 million m^3) of sand. The project involved work on a beach berm. Following the effects of the 2004 hurricane season, nourishment was accelerated and 754,600 cy (576,933 m^3) of sand were placed during the spring of 2005.

Further south, the Patrick Air Force Base Beach Restoration Project was constructed between December of 2000 and April of 2001 with 600,000 cy (458,732 m^3) of sand being placed. Following the effects of the 2004 hurricane season, nourishment was accomplished during the spring of 2005 with 321,500 cy (245,804 m^3) of sand placed.

The section of beach designated by BBCS as Mid-Reach in Brevard County begins at the southern boundary of Patrick Air Force Base and extends to just north of the town of Indialantic.

Following the effects of the 2004 hurricane season, dune restoration projects were implemented in 2005 and 2008. This work supplemented emergency protective berms.

The section of beach designated by BBCS as South-Reach in Brevard County begins at Indialantic and extends to Spessard Holland Park. Beach restoration was initially conducted in 1980. A subsequent beach restoration project was completed in two segments in 2002 and 2003 with 1.431 million cy (1.094 million m^3) of sand, respectively, placed. Following the effects of the 2004 hurricane season, additional renourishment was necessary and 578,910 cy (442,608 m^3) of sand were placed in 2005. Further south in southern Brevard County, following the effects of the 2004 hurricane season, emergency protective berms and dune restoration projects were constructed in 2005 and 2008.

Data Analysis

From the reach of beach extending southward from Port Canaveral to Sebastian Inlet, 45 sample locations, BV35 through BV79 as shown in Table 1, were selected from which 94 samples were collected. Swash zone, mid-beach and back beach samples were obtained from 12 locations. Swash zone and back beach samples were obtained from 25 locations. A single sample was obtained from eight locations and at one site, where no beach was present, no sample was collected.

Carbonate material averaged 25.1 percent of the samples. The mean grain size before carbonate removal was 0.354 mm (1.499 phi). The mean grain size after carbonate removal was 0.323 mm (1.631 phi). Curves comparing grain size north and south Port Canaveral can be found in Appendix C. The grain size curves north and south of Port Canaveral suggest a fining and a narrowing of the spectrum of grain sizes. As shown on Figure 13, There is a shift in mean grain size and carbonate percentage north and south of the cut at Port Canaveral and north and south of Sebastian Inlet. South of the cut both mean grain size and carbonate percentage abruptly decline. The mean grain size curves then recover and slightly increase near the middle of the reach as well as on the southern end of the reach just north of Sebastian Inlet. As seen in the grain size comparison curves which can be found in Appendix C, there is a coarsening of the spectrum of grain sizes immediately at and north of Sebastian Inlet compared to the sediments to its south.

With regard to the carbonate percentage curve, south of the Port Canaveral Cut, after an initial decrease, it abruptly rises then gradually decreases until just north of Sebastian Inlet. The carbonate curve shown on Figure 13, discounting localized excursions, indicates a general incremental increase in carbonate percentage from Port Canaveral Cut southward until just before the Sebastian Inlet where it peaks for the reach. Photographs as well as granulometric analysis of these samples are provided in Appendix A.

Sebastian Inlet to Ft. Pierce Inlet

Geographic Setting

This reach of beach consists of North Hutchinson Island. North Hutchinson Island is a barrier island which, on its northern end in Indian River County, is called Orchid Island. On its south end in St. Lucie County lies the Indian River Aquatic Preserve. It is separated to the west from the mainland of Indian River and St. Lucie Counties by the Indian River Lagoon, the Indian River, Spratt Creek, the Indian River Narrows, Johns Island Creek, multiple other creeks and coves and the Intracoastal Waterway. It is bounded to the north and south by the Sebastian and Fort Pierce Inlets respectively.

Beach History in Brief (from Strategic Beach Management Plan for the Central Atlantic Coast Region (2008))

The beach segment, which lies immediately south of Sebastian Inlet, includes Sebastian Inlet State Park and unincorporated Ambersand Beach. Sand from inlet bypassing has been placed within the northern portion of this segment. The Ambersand Beach Restoration Project was implemented in 2003 with the construction of a beach berm with the placement of approximately 590,000 cy (451,087 m^3) of sand. During the spring of 2007, approximately 80,000 cy (61,164 m^3) of sand were placed on the beach. In the winter of 2007, an additional 173,116 cy (132,356 m^3) of sand from an offshore borrow site were placed.

Further south, Orchid Island (in Indian River County) was severely impacted by Hurricanes Floyd and Irene (1999) and Hurricanes Frances and Jeanne (2004). Dune restoration was conducted at the county parks of Treasure Shores and Golden Sands following each of these major storms.

Continuing south, following the effects of the 2004 hurricane season, the construction of emergency protective berms was completed at the unincorporated town of Wabasso Beach in Indian River County. A dune restoration project consisting of additional sand and vegetation at Wabasso Beach County Park was implemented in 2005 to supplement the emergency protective berms.

Further south at Vero Beach in Indian River County, seawall construction, dune restoration, and small dune restoration projects conducted routinely by the City of Vero Beach have been carried out. Following the effects of the 2004 hurricane season, emergency protective berms were constructed. A dune restoration project, consisting of additional sand and vegetation, was implemented in 2005 to supplement the emergency protective berms. Additional dune restoration was conducted in 2008.

Finally, at unincorporated town of South Beach in Indian River County, seawalls have been constructed along much of the area. Following the effects of the 2004 hurricane season, emergency protective berms were constructed. A dune restoration project, consisting of additional sand and vegetation was implemented in 2005 to supplement the emergency protective berms. The Indian River County Sector Seven Beach Restoration Project was completed in the spring of 2007 and involved the placement of approximately 363,000 cy (277,533 m^3) of beach quality sand on the beach.

Data Analysis

From the reach of beach extending southward from Sebastian Inlet to Ft. Pierce Inlet, 31 sample locations, IR01 through IR24 and SL01 through SL07 as shown in Table 1, were selected from which 53 samples were collected. Swash zone, mid-beach and back beach samples were obtained from two locations. Swash zone and back beach samples were obtained from 18 locations. Only back beach samples were obtained from 11 locations.

Carbonate material averaged 31.5 percent of the samples. The mean grain size before carbonate removal was 0.343 mm (1.543 phi). The mean grain size after carbonate removal was 0.309 mm (1.697 phi). As shown on Figure 14 there is a shift in mean grain size and carbonate percentage north and south of the Sebastian Inlet that does not exactly coincide with the inlet but appears to be shifted one sample point to the south of it. For grain size this is illustrated by grain size curves, which can be found in Appendix C, comparing grain size north and south Sebastian Inlet. This shift may be a result of sand bypassing. South of that point, as shown on Figure 14, both mean grain size and carbonate percentage abruptly decline. The mean grain size curves then recover but indicate that the sediments remain finer than those on the south end of the reach to the north. The mean grain size curves indicate a subtle incremental increase in mean grain size southward until just before Ft. Pierce Inlet where they decline. The carbonate percentage curve south of that point abruptly rises only to fall to a low point in the middle of the reach, after

which it gradually rises on the southern end of the reach. The carbonate curve indicates an incremental increase in carbonate percentage southward until just before the Ft. Pierce Inlet where it declines as well. Finally there was a distinct shift in both mean grain size and carbonate percentage north and south of the Ft. Pierce Inlet with mean grain size and the percentage of carbonate material both increasing in the reach to the south. This is also illustrated by grain size curves, which can be found in Appendix C, comparing grain size north and south Ft. Pierce Inlet. Photographs as well as granulometric analysis of the samples collected in this reach are provided in Appendix A.

Ft. Pierce Inlet to St. Lucie Inlet (Hutchinson Island)

Geographic Setting

This reach of beach, as shown on Figure 1, is generally known as Hutchinson Island. Hutchinson Island is a barrier island separated from Martin and St. Lucie Counties by the Indian River/Intracoastal Waterway which forms the Jensen Beach to Jupiter Inlet Aquatic Preserve. The southern third of the island is in Martin County while the northern remainder is in St Lucie County. It is bounded to the north and south by the Ft. Pierce and St. Lucie Inlets respectively.

Beach History in Brief (from Strategic Beach Management Plan for the Central Atlantic Coast Region (2008))

In 1971, the Fort Pierce Shore Protection Project restored shoreline immediately south of the Fort Pierce Inlet using 718,000 cy (548,950 m^3) of sand from a borrow area located 2,000 ft (610 m) offshore of the project area. Nourishment has also been conducted using dredged material from maintenance of the Fort Pierce Inlet navigation channel. Additionally, nourishment was conducted in 1980 using 346,000 cy (264,535 m^3) of sand from a borrow area located 2,500 ft (762 m) offshore of the project area. In 1997, a spur jetty was constructed on the south jetty to accumulate sand south of the south jetty. In 1999, the shoreline was renourished using 830,000 cy (634,580 m^3) of sand from a borrow area located three nautical miles (4.8 km) offshore at Capron Shoal, with subsequent renourishment utilizing the same source in 2003, and again in 2004 with 336,000 cy (256,890 m^3) and 406,000 cy (310,409 m^3) of sand, respectively. Maintenance renourishment was conducted in 2005 with the placement of approximately 700,000 cy (535,188 m^3) of beach quality sand. Additional renourishment in 2007 consisted of the placement of approximately 500,000 cy (382,277 m^3) of sand from Capron Shoal.

Further south in 2005 and 2006, an emergency dune restoration project was implemented in the southern end of St. Lucie County's portion of the island using 160,000 cy (122,328 m^3) of sand. The material originally placed was determined incompatible, removed, and then replaced with compatible sand. Dune restoration was further conducted in the vicinity of Walton Rocks in St. Lucie County in 2007.

In Martin County, beach restoration was conducted through the Martin County Shore Protection Project in 1996, 2001, and 2002 with the placement of 1.34 million cy (1.02 million m^3), 178,000 cy (136.090 m^3) and 126,000 cy (96,333 m^3) of sand, respectively, on the south end of the island. Following the effects of the 2004 hurricane season, nourishment was accelerated, and in 2005, a restoration project was implemented including dune restoration and construction of emergency protective berms. A total of 1.32 million cy (1.01 million m^3) was used in the 2005 efforts.

Data Analysis

From the reach of beach comprising Hutchinson Island, which extends southward from Ft. Pierce Inlet to St. Lucie Inlet, 25 sample locations, SL08 through SL23 and MT01 through MT09 as shown in Table 1, were selected from which 40 samples were collected. Swash zone, mid-beach and back beach samples were obtained from one location. Swash zone and back beach samples were obtained from 13 locations. Only back beach samples were obtained from 11 locations.

Carbonate material averaged 62.2 percent of the samples. The mean grain size before carbonate removal was 0.473 mm (1.080 phi). The mean grain size after carbonate removal was 0.372 mm (1.428 phi). The mean grain size after carbonate removal was calculated from only 24 samples as there was too little sediment remaining in one sample to process. As shown on Figure 14, there were shifts in both mean grain size and carbonate percentage north and south of the Ft. Pierce Inlet and north and south of St. Lucie Inlet. North and south of Ft. Pierce Inlet the shift in grain size is illustrated by curves which can be found in Appendix C. Similar to the reach to the north, as seen on Figure 14, carbonate percentage dips in the middle of the reach, after which it increases on the south end until just north of St. Lucie Inlet where it starts to decrease. Within this reach, however, overall mean grain size slightly increases while the mean grain size of non-carbonate fraction remains relatively constant. Photographs as well as granulometric analysis of these samples are provided in Appendix A.

St. Lucie Inlet to Jupiter Inlet (Jupiter Island)

Geographic Setting

As shown on Figure 1, this reach of beach consists of Jupiter Island. On its northern end adjacent to the St. Lucie Inlet lies the St. Lucie Inlet Preserve State Park and Hobe Sound National Wildlife Refuge. Jupiter Island is a barrier island separated from the rest of Martin and Palm Beach Counties by the Indian River, the Intracoastal Waterway, Peck Lake, the south Jupiter Narrows and Hobe Sound. It is bounded on the north by the St. Lucie Inlet where the St. Lucie and Indian Rivers meet and on the south by Jupiter Inlet, which is at the mouth of the Loxahatchee River. It was once two islands separated by an inlet.

Beach History in Brief (from Strategic Beach Management Plan for the Central Atlantic Coast Region (2008))

In 1973 and 1974, the Jupiter Island Beach Restoration Project placed sand along a portion of the town of Jupiter Island's shoreline in Martin County using an offshore borrow source. Nourishment of discrete segments of the town's shoreline using offshore borrow areas has been conducted on a three to four year basis with 625,000 cy (477,846 m^3) placed in 1997. In 1999, the St. Lucie Inlet flood shoal sand transfer project bypassed 714,000 cy (545,892 m^3) of sand to the Hobe Sound National Wildlife Refuge segment of shoreline north of the town of Jupiter Island. An additional 221,000 cy (168,966 m^3) and 292,000 cy (223,250 m^3) of sand were placed in 2000 and 2002 respectively. Following the effects of the 2004 hurricane season, renourishment was initiated in the spring of 2006 and completed in 2007 with the placement of 2.3 million cy (1.8 million m^3) of sand.

South of the Blowing Rocks Preserve in Martin County, a dune restoration project was implemented in 2008. In 1993, a dune restoration project was completed in Coral Cove Park on southern Jupiter Island. Following the effects of the 2004 hurricane season, emergency protective berms were constructed in 2005.

Data Analysis

From the reach of beach comprising Jupiter Island, which extends southward from St. Lucie Inlet to Jupiter Inlet, 19 sample locations, MT10 through MT26 and PB 01 and PB02 as shown in Table 1, were selected from which 30 samples were collected. Swash zone, mid-beach and back beach samples were obtained from one location. Swash zone and back beach samples were obtained from nine locations. Only back beach samples were obtained from nine locations.

Carbonate material averaged 69.9 percent of the samples. The mean grain size before carbonate removal was 0.542 mm (0.884 phi). The mean grain size after carbonate removal was 0.410 mm (1.285 phi). The mean grain size after carbonate removal was calculated from only 18

samples as there was too little sediment remaining to process in one sample. As shown on Figure 15, there are downward shifts in both mean grain size and carbonate percentages localized in the northern and southern ends of the reach. Through a majority of the reach, however, both mean grain size and carbonate percentage increase southward. Aside from the sample obtained immediately before Jupiter Inlet, on the south end of the reach, mean grain size and the percentage of carbonate material are both higher within the reach's southern end as compared to the north end of the reach to its south. For grain size this is illustrated by curves, which can be found in Appendix C, comparing grain size north and south Jupiter Inlet. That curve set shows the sample furthest north of the inlet to be both coarser and narrower in its spectrum of grain sizes present compared to both the sample immediately north of the inlet and those to its south. The changes in carbonate percentage, as shown in Figure 15, are substantial with a range of carbonate percentages from below 40 percent to over 90 percent. Photographs as well as granulometric analysis of these samples are provided in Appendix A.

Jupiter Inlet to Lake Worth Inlet (Singer Island)

Geographic Setting

As shown on Figure 1, Singer Island, upon whose south end lies the town of Palm Beach Shores, as well as part of the city of Riviera Beach, and John D. McArthur Beach State Park, is separated from the mainland of Palm Beach County by the Intracoastal Waterway, Lake Worth Creek and Lake Worth.

Beach History in Brief (from Strategic Beach Management Plan for the Southeast Atlantic Coast Region (2008))

In 1995, the Jupiter-Carlin Park Beach Restoration Project was completed using 604,000 cy (461,791 m^3) of sand from the ebb tidal shoal of Jupiter Inlet. After the 1995 restoration project, periodic placement of sand in the area coincided with maintenance dredging of Jupiter Inlet and the Intracoastal Waterway. In March 2002, beach nourishment was conducted using 625,000 cy (477,846 m^3) of sand from an offshore borrow site. In 2001, the Juno Beach Restoration Project was completed using 1.0 million cy (0.8 million m^3) of sand obtained from an offshore borrow area. Dune restoration projects throughout much of the area in the vicinity of Ocean Reef Park were also performed in 2001, 2004, 2005, and 2006.

Data Analysis

From the reach of beach extending southward from Jupiter Inlet to Lake Worth Inlet, 13 sample locations, PB03 through PB15 as shown in Table 1, were selected from which 29 samples were collected. Swash zone, mid-beach and back beach samples were obtained from four locations. Swash and back beach samples were obtained from eight locations. Only back beach samples were collected from one location.

Carbonate material averaged 56 percent of the samples. The mean grain size before carbonate removal was 0.457 mm (1.131 phi). The mean grain size after carbonate removal was 0.377 mm (1.406 phi). As shown on Figure 15, mean grain size increases southward through the reach. Mean grain size and the percentage of carbonate material are both lower within the reach's northern end compared to the reach to its north and higher on the reaches southern end compared to the reach to its south. For the north end of the reach this is illustrated by curves, which can be found in Appendix C, comparing grain size north and south of Jupiter Inlet. That curve set shows the sample furthest north of the inlet to be both coarser and narrower in its spectrum of grain sizes present compared to both the sample immediately north of the inlet and those to its south. The most distinct difference is in the change in carbonate percentage on the north end of Jupiter Inlet. Photographs as well as granulometric analysis of these samples are provided in Appendix A.

Lake Worth Inlet to Boynton Inlet (Palm Beach Island)

Geographic Setting

As shown on Figure 1, this reach of beach consists of Palm Beach Island. This barrier island is separated from the mainland by Lake Worth/Intracoastal Waterway. On the island are the towns of Palm Beach, South Palm Beach, and Manalapan, as well as a small part of the city of Lake Worth.

Beach History in Brief (from Strategic Beach Management Plan for the Southeast Atlantic Coast Region (2008))

Most of the shoreline of Palm Beach Island is armored with seawalls, bulkheads, and revetments. There are also numerous relict and functional groins.

In 1995, the Town of Palm Beach Mid-Town Beach Restoration Project was completed using 880,000 cy (672,802 m^3) of sand from an offshore borrow site located south of Lake Worth Inlet ebb shoal. The project included construction of 11 groins that were completed in 1996. In 2003, beach nourishment and restoration using 1.4 million cy (1.1 million m^3) of sand was completed. Further nourishment was performed in 2006 using 893,000 cy (882,747 m^3) of sand.

In 2006, the Phipps Ocean Park Beach Restoration Project was completed using 1.1 million cy (800,000 m^3) of sand from two borrow sites located approximately 3,500 ft (1067 m) offshore and approximately 1.5 and 2.6 mi (2.4 and 4.2 km) south of the fill area. In conjunction with the Phipps Ocean Park Beach Restoration Project in the spring of 2006, the Town of Palm Beach implemented a dune restoration project using approximately 724,200 cy (553,690 m^3) of sand from offshore sources.

A portion of South Palm Beach is armored. Palm Beach County has initiated a feasibility study to assess beach management alternatives. A beach replenishment and dune restoration project was completed in the beach segment at South Palm Beach in 2008. The volumes of sand utilized are not available.

Data Analysis

From the reach of beach extending southward from Lake Worth Inlet to Boynton Inlet, also known as South Lake Worth Inlet, 15 sample locations, PB16 through PB30 as shown in Table 1, were selected from which 26 samples were collected. Swash, mid-beach and back beach samples were obtained from two locations. Swash and back beach samples were obtained from seven locations. Only back beach samples were collected from six locations.

Carbonate material averaged 51.1 percent of the samples. The mean grain size before carbonate removal was 0.398 mm (1.330 phi). The mean grain size after carbonate removal was 0.353 mm (1.504 phi). As shown on Figure 15, mean grain size is locally lower within the reach's north end and higher on its south end compared to the reaches to its north and south. Both mean grain size and carbonate percentage declines slightly southward through the reach. In addition, mean grain size decreases at Boynton Inlet while carbonate percentage increases. Photographs as well as granulometric analysis of these samples are provided in Appendix A. Grain size curves of samples immediately north and south of Lake Worth and Boynton Inlets are provided in Appendix C.

Boynton Inlet (South Lake Worth Inlet) to Boca Raton Inlet

Geographic Setting

The reach of beach includes the towns of Ocean Ridge, Briny Breezes, Gulf Stream and Highland Beach as well as the cities of Boynton Beach, Delray Beach, and Boca Raton. As shown on

Figure 1, the barrier island upon which the reach lies varies substantially in width. It is separated from the mainland of Palm Beach County by the Intracoastal Waterway, Lake Roger, Lake Wyman and Lake Boca Raton.

Beach History in Brief (from Strategic Beach Management Plan for the Southeast Atlantic Coast Region (2008))

In April 1998, the Ocean Ridge Beach Restoration Project was completed along 1.6 m (2.6 km) of beach using 784,000 cy (599,411 m^3) of sand from a borrow site located 2,100 ft (640 m) offshore of the project area. The project included construction of eight groins. The beach is nourished by an inlet sand transfer plant from which, it is estimated, a minimum of 60,000 cy (45,873 m^3) of sand are bypassed annually. An additional nourishment project was completed in 2005 using 550,000 cy (420,505 m^3) of sand from the previously used borrow site.

In 1973 and 1978, the Delray Beach Restoration Project was completed using 1,635,000 cy (1,250,047 m^3) and 701,000 cy (535,952 m^3) of sand, respectively, from an offshore borrow area. Beach renourishment was conducted twice in 1992 using 1.2 million cy (0.9 million m^3) of sand for each effort. An additional renourishment project was completed in 2005 using 412,000 cy (314,996 m^3) of sand.

In August 1988, the Boca Raton (North) Beach Restoration Project was completed using 1.1 million cy (.8 million m^3) of sand from an offshore borrow site. The project included construction of a rock groin. In April 1998, beach nourishment was accomplished using 680,000 cy (519,897 m^3) of sand. In 2004, the Boca Raton (Central) Beach Restoration Project was accomplished using 480,000 cy (366,986 m^3) of sand from a borrow site located 2,500 ft (762 m) offshore. The project included construction of a groin 1,500 ft (457 m) north of the Boca Raton Inlet north jetty and modifications to the north jetty. An additional replenishment project was implemented in 2006 using 340,000 cy (259,948 m^3) of sand.

Data Analysis

From the reach of beach extending southward from Boynton Inlet, also known as South Lake Worth Inlet, to Boca Raton Inlet, 14 sample locations, PB31 through PB44 as shown in Table 1, were selected from which 34 samples were collected. Swash zone, mid-beach and back beach samples were obtained from six locations. Swash zone and back beach samples were obtained from eight locations.

Carbonate material averaged 51.5 percent of the samples. The mean grain size before carbonate removal was 0.359 mm (1.478 phi). The mean grain size after carbonate removal was 0.324 mm (1.626 phi). As shown on Figure 16, both mean grain size and carbonate percentage are relatively lower than the reaches to its north or south. The only exception is a spike in carbonate percentage at Boynton Inlet. Both mean grain size and carbonate percentage increase southward through the reach. Photographs as well as granulometric analysis of these samples are provided in Appendix A. Grain size curves of samples immediately north and south of Boynton and Boca Raton inlets are provided in Appendix C.

Boca Raton Inlet to Hillsboro Inlet

Geographic Setting

The barrier island upon which this reach lies is separated from the mainland of southern Palm Beach County and Broward County by the Intracoastal Waterway and the Hillsboro River. The reach is heavily developed.

Beach History in Brief (from Strategic Beach Management Plan for the Southeast Atlantic Coast Region (2008))

This reach of beach includes a one mile segment of beach in the City of Boca Raton in Palm Beach County. In July 1985, the Boca Raton (South) Beach Restoration Project was completed using 220,000 cy (168,202 m^3) of sand from the ebb tidal shoal of Boca Raton Inlet. Subsequent nourishment in 1996 and 2002 used 220,000 cy (168,202 m^3) and 300,000 cy (229,366 m^3) of sand, respectively, also from the ebb tidal shoal. The length of the 2002 project was extended south to the Palm Beach / Broward County line.

This reach of beach also includes the cities of Deerfield Beach and Hillsboro Beach in Broward County. Some armoring exists on Hillsboro Beach and a boulder mound groin exists on Deerfield Beach. Beach restoration and nourishment has been conducted at Hillsboro Beach. Additional restoration activities include inlet sand bypassing activity at Boca Raton Inlet and material placement for the South Boca Raton project. In 1972, a nourishment project at Hillsboro Beach was implemented using 360,000 cy (275,239 m^3) of sand from an offshore borrow site. In 1998, the Hillsboro Beach Restoration Project was completed using 555,000 cy (424,237 m^3) of sand.

Data Analysis

From the reach of beach extending southward from Boca Raton Inlet to Hillsboro Inlet, six sample locations, PB45 and BW01 through BW05 as shown in Table 1, were selected from which 11 samples were collected. Swash zone, mid-beach and back beach samples were obtained from one location. Swash zone and back beach samples were obtained from three locations and back beach samples were obtained from two locations.

Carbonate material averaged 58 percent of the samples. The mean grain size before carbonate removal was 0.445 mm (1.169 phi). The mean grain size after carbonate removal was 0.389 mm (1.362 phi). As shown on Figure 16, mean grain size and carbonate percentage increase at Boca Raton Inlet and Hillsboro Inlet. Grain size curves of samples immediately north and south of Boca Raton and Hillsboro inlets, provided in Appendix C, show the samples collected immediately north and south to be coarser than those further away. In addition, the trend (from the reach to the north) of increasing mean grain size and carbonate percentage continues through this reach. Photographs as well as granulometric analysis of these samples are provided in Appendix A.

Hillsboro Inlet to Port Everglades

Geographic Setting

This reach of beach includes the communities of Pompano Beach, Sea Ranch Lakes, Lauderdale-By-The-Sea, and Ft. Lauderdale. As shown on Figure 1, it is located on a barrier island separated from the mainland of Broward County by the Intracoastal Waterway and on the south end by the New River Sound, Lake Sylvia and the Stranahan River. It is heavily developed.

Beach History in Brief (from Strategic Beach Management Plan for the Southeast Atlantic Coast Region (2008))

Numerous bulkheads and retaining walls exist along this stretch of coast. In 1970, restoration of Pompano Beach was completed using 1.08 million cy (0.83 million m^3) of sand from an offshore borrow site. In 1983, restoration and nourishment of Pompano Beach and Lauderdale-By-The-Sea was conducted using 1.9 million cy (1.5 million m^3) sand from offshore borrow sites. In 2004, renourishment of Pompano Beach and restoration of Lauderdale-By-The-Sea and northern Fort Lauderdale was competed using 935,000 cy (714,858 m^3) of sand from offshore borrow sites.

Data Analysis

From the reach of beach extending southward from Hillsboro Inlet to Port Everglades, 12 sample locations, BW06 through BW17, were selected from which 31 samples were collected. Swash zone, mid-beach and back beach samples were obtained from seven locations. Swash zone and back beach samples were obtained from five locations.

Carbonate material averaged 57.7 percent of the samples. The mean grain size before carbonate removal was 0.402 mm (1.316 phi). The mean grain size after carbonate removal was .335 mm (1.576 phi). As shown on Figure 16, both mean grain size and carbonate percentage vary through the length of the reach. After increasing at Hillsboro Inlet, both mean grain size and carbonate percentage decrease, reaching a low mid-reach, and then increase. The change in carbonate percentage is more distinct than mean grain size. Photographs as well as granulometric analysis of these samples are provided in Appendix A. Grain size curves of samples immediately north and south of Hillsboro inlet and Port Everglades are provided in Appendix C.

Port Everglades to Baker's Haulover Inlet

Geographic Setting

This reach of beach includes John U. Lloyd State Park and the communities of Dania, Hollywood, Hallandale Beach in Broward County In addition, the communities of Sunny Isles and Golden Beach as well as Haulover Beach Park in Dade County are also along this reach of beach. It is located on a barrier island separated by the Intracoastal Waterway and Dumfoundling Bay from the mainland of Broward County and northern Miami-Dade County. It is heavily developed in many areas.

Beach History in Brief (from Strategic Beach Management Plan for the Southeast Atlantic Coast Region (2008))

In 1971, the City of Hallandale Beach restored the southernmost 4,000 ft (1,219 m) of Broward County shoreline with 350,000 cy (267,594 m^3) of sand from an offshore borrow site. In 1976, beach restoration of John U. Lloyd State Park was completed using 1.09 million cy (.83 million m^3 of sand from offshore borrow sites. A beach berm was also constructed. In 1989, renourishment and sand tightening of the south jetty was conducted, and a beach berm constructed using 603,400 cy (461,332 m^3) of sand.

In 1979, restoration of the Hollywood-Hallandale Beach was accomplished using 1.98 million cy (1.51 million m^3) of sand from offshore borrow sites. A beach berm was also constructed at that time. In 1991, renourishment using 1.1 million cy (0.8 million m^3) of sand was conducted, and a beach berm constructed. Renourishment of John U. Lloyd State Park and Hollywood-Hallandale Beach segments was completed in 2006 using 1.54 million cy (1.18 million m^3) of sand from offshore borrow sites. Additionally, a spur groin attached to the south jetty and two T-head groins located on the shore south of the inlet were constructed to retain the beach fill within the park project area.

Between 1955 and 1984, 976,000 cy (746,200 m^3) of sand were placed on the beaches of Golden Beach, Sunny Isles and Haulover Beach Park. In 1987, restoration of the 1.3 mi (2.1 km) long Haulover Beach Park was conducted using 240,000 cy (183,493 m^3) of sand from an offshore borrow area. In 1988, restoration of Sunny Isles beaches was accomplished using 1.32 million cy (1.01 million m^3) of sand from an offshore borrow area. The loss of fill material spreading into Golden Beach required renourishment of northern Sunny Isles' beaches with 80,000 cy (61,164 m^3) of sand in 1997. In 2001, an additional 922,000 cy (701,919 m^3) of sand was placed.

Data Analysis

From the reach of beach extending southward from Port Everglades to Baker's Haulover Inlet, 14 sample locations, BW18 through BW26 and DD01 through DD05 as shown in Table 1, were selected from which 28 samples were collected. Swash zone, mid-beach and back beach samples were obtained from four locations. Swash zone and back beach samples were obtained from six locations and back beach samples were obtained from four locations.

Carbonate material averaged 74.2 percent of the samples. The mean grain size before carbonate removal was 0.480 mm (1.058 phi). The mean grain size after carbonate removal was 0.350 mm (1.514 phi). The mean grain size after carbonate removal was calculated from only ten samples as there was too little sediment remaining to process in the other four samples. As shown in Figure 16, both mean grain size and carbonate percentage decrease at Port Everglades. Mean grain size and carbonate percentage then increase from north to south across the reach. Photographs as well as granulometric analysis of these samples are provided in these web pages and can be accessed via Appendix A. Grain size curves of samples immediately north and south of Port Everglades and Baker's Haulover Inlet are provided in Appendix C. The pre-carbonate digestion grain size curves for samples north and south of Baker's Haulover Inlet suggest that the sediments immediately north of the inlet are coarser than those immediately to its south.

Baker's Haulover Inlet to Government Cut

Geographic Setting

As shown on Figure 1, this is a 9.4 mile (15.1 kilometer) reach of beach from Baker's Haulover Inlet to Government Cut in Dade County. It includes the communities of Bal Harbour, Surfside, and Miami Beach. It lies on a barrier island that is separated from the mainland by the waters of the North Bay of Biscayne Bay and Indian Creek. It is extensively and quite heavily developed.

Beach History in Brief (from Strategic Beach Management Plan for the Southeast Atlantic Coast Region (2008))

Beach restoration has been accomplished for the entire reach. From 1960 to 1969, 305,000 cy (233,189 m^3) were placed at Bal Harbour. In 1975, an additional 1.63 million cy (1.25 million m^3) were placed. This was followed by the placement of 225,000 cy (172,024 m^3), 142,000 cy (108,566 m^3), 35,000 cy (26,759 m^3), and 230,000 cy (174,847 m^3) in 1990, 1998, 2002, and 2003, respectively.

The restoration of Surfside and Miami Beach began with the placement of 2.94 million cy (2.25 million m^3) in 1978, and continued with the placement of 1.53 million cy (1.17 million m^3) in 1979, the placement of 3.18 million cy (2.43 million m^3) in 1980, the placement of 2.2 million cy (1.7 million m^3) in 1981 and the placement of 2.4 million cy (1.83 million m^3) in 1982. This multi-year project included restoration of a 20 ft (6 m) wide dune and a 50 ft (15 m) wide berm. Additional fill material was placed seaward of the berm and renourishment of several areas was conducted with the placement of 110,000 cy (84,101 m^3) and 50,000 cy (38,228 m^3) in two areas in 1985.

Due to the poor performance of the beach fill along a segment of shore at Miami Beach, the beach has been eroded by storm waves and tides and, therefore, has not maintained the designed beach width. The implementation of a 1994 nourishment project resulted in the placement of 120,000 cy (91,746 m^3), which was followed up with the placement of 432,000 cy (330,287 m^3) and 85,000 cy (64,987 m^3) in two segments in 1997, the placement of 18,000 cy (13,762 m^3) in 1998, the placement of 627,700 cy (479,911 m^3) and 211,500 cy (161,700 m^3) in two segments in 1999, and the placement of 200,000 cy (152,911 m^3) in 2001. Three shore-attached breakwaters were constructed during 2002. As part of this project, 110,000 cy (84,101 m^3) of beach sand were placed at the breakwater site and 50,000 cy (38,228 m^3) of beach sand

were placed in an adjacent erosional area. In 2005 and 2006, approximately 40,000 cy (30,582 m^3) and 30,000 cy (22,937 m^3) of sand respectively were placed down drift of the structures. Also during 2006, approximately 30,000 cy (22,937 m^3) of sand and approximately 50,000 cy (38,228 m^3) of sand were placed on two segments of beach.

Data Analysis

From the reach of beach extending southward from Baker's Haulover Inlet to Government Cut, ten sample locations, DD06 through DD15 as shown in Table 1, were selected from which 25 samples were collected. Swash zone, beach berm, mid-beach and back beach samples were obtained from one location. Swash zone, mid-beach and back beach samples were obtained from four locations and swash and back beach samples were obtained from four locations. A single sample was obtained from one location.

Carbonate material averaged 87.6 percent of the samples. The mean grain size before carbonate removal was 0.469 mm (1.093 phi). The mean grain size after carbonate removal was 0.433 mm (1.207 phi). The mean grain size after carbonate removal was calculated from only three samples, as there was too little sediment remaining to process in the other seven samples. As shown in Figure 17, both mean grain size and carbonate percentage decrease at Baker's Haulover Inlet but then increase before trending downward. Carbonate percentage, however, spikes once more on the south end of the reach after a substantial local decline. Mean grain size is coarser and carbonate percentages significantly higher in this reach that in the reach to the south. Photographs as well as granulometric analysis of these samples are provided in Appendix A. Grain size curves of samples immediately north and south Baker's Haulover Inlet and Government/Norris Cut are provided in Appendix C. The pre-carbonate digestion grain size curves for samples north and south of Baker's Haulover Inlet suggest that the sediments immediately north of the inlet are coarser than those immediately to its south. The grain size curves for sample shown furthest north Government Cut/Bear Cut suggest that the sediments to the north are coarser than those to the south.

Virginia Key and Key Biscayne

Geographic Setting

As shown on Figure 1, Virginia Key and Key Biscayne are islands that lie off shore of the north end of Biscayne Bay. Norris Cut separates Virginia Key from Fisher Island to the north. Fisher Island is a small, privately owned and developed, manmade island. Fisher Island is separated from Miami Beach to the north by Government Cut, a man-made inlet providing entrance to the Port of Miami. Bear Cut separates Virginia Key from Key Biscayne to the south. Norris Cut and Bear Cut are stable, natural coastal inlets. Key Biscayne is separated from the Florida Keys to the south by an expanse of water that forms the mouth of Biscayne Bay.

Beach History in Brief (from Strategic Beach Management Plan for the Southeast Atlantic Coast Region (2008))

Concerning Government Cut, in 1983, the sand tightening of 1,200 ft (366 m) of the seaward end of the north jetty was completed. In 1999, the remainder of the north jetty was sand tightened. The inlet channel and jetties act as a barrier to littoral sand transport to the down drift beaches south of the inlet by trapping sand in the channel or deflecting it offshore.

As of 2008, navigational dredging has not been conducted at Norris Cut and Bear Cut. Terminal groins have been constructed on Norris Cut to stabilize beaches on Fisher Island and Virginia Key. In 1948 and 1956, groin fields were installed along the Bear Cut shoreline of Virginia Key. In 1965, concrete piling and wood panel groins were installed on the inlet shore of southern Virginia Key fronting Bear Cut. In 1974, groins were constructed and 110,000 cy (84,101 m^3) of beach compatible dredged material were placed. In 2003, the rehabilitation of the existing

groins, construction of three additional groins, and placement of a small amount of beach fill placed by truck from an existing stockpile were completed. In 1969, on Virginia Key a 50 ft (15 m) wide beach berm along 1.3 miles (2.1 km) of the beach using 177,000 cy (135,326 m^3) of sand was constructed.

In 1991, a privately funded beach erosion control project on Fisher Island north of Virginia Key was constructed. The project consisted of the placement of 25,000 cy (19,114 m^3) of imported oolitic aragonite sand and the construction of eight rock T-head groins.

In 1969, a 50 ft (15 m) wide berm along two segments of shore, using 196,000 cy (149,852 m^3) of sand from a borrow area located immediately offshore, was constructed on Key Biscayne. In 1987, 2.4 miles (3.9 km) of beaches were restored on Key Biscayne using 420,000 cy (321,113 m^3) of sand from an offshore borrow area. The project restored a 25 ft (7.5 km) wide berm at the Village of Key Biscayne and a 20 ft (6 m) wide berm at Cape Florida State Park as well as provided additional beach fill. A terminal groin was also constructed at the south end of Bill Baggs-Cape Florida State Recreation Area. In 1994, damage caused by Hurricane Andrew to the terminal groin and adjacent revetment protecting the Cape Florida Lighthouse was repaired. In August 2002, a beach nourishment project at the Village of Key Biscayne was completed along 1.3 miles (2.1 km) of beaches using 121,000 cy (92,511 m^3) of sand from an offshore borrow site approximately 4,000 ft (1219 m) offshore from the southern tip of Key Biscayne.

Data Analysis

From the reaches of beach extending southward along Virginia Key and Key Biscayne, two sample locations (DD16 and DD17), and six sample locations (DD18 through DD23) were selected, respectively, as shown in Table 1. Two samples were collected from Virginia Key and ten samples were collected from Key Biscayne. Out of all eight locations, swash zone, mid-beach and back beach samples were obtained from one location. Swash zone and back beach samples were obtained from two locations. Only back beach samples were obtained from five locations.

Carbonate material averaged 46.6 percent of the samples collected on Virginia Key. The mean grain size before carbonate removal was 0.326 mm (1.618 phi). The mean grain size after carbonate removal was 0.297 mm (1.751 phi). Carbonate material averaged 39.3 percent of the samples collected on Key Biscayne. The mean grain size before carbonate removal was 0.301 mm (1.731 phi). The mean grain size after carbonate removal was 0.288 mm (1.793 phi). As shown on Figure 17, both mean grain size and carbonate percentage are lower on Virginia Key compared to the reach to the north. Mean grain size and carbonate percentages are both higher on Virginia Key compared to Key Biscayne to the south. Additionally, carbonate percentage spikes in the middle of Key Biscayne. Photographs as well as granulometric analysis of these samples are provided in Appendix A. Grain size curves of samples immediately north and south Government/Norris Cut and Bear Cut are provided in Appendix C.

SUMMARY AND CONCLUSIONS

Appendix A, in addition to providing photographs of beach conditions and descriptions, photographs and granulometric analysis of samples, also provides analysis of their color via the use of Munsell values. Color, generally from an aesthetic view point, is considered a secondary parameter of importance. History has shown, however, that the political/economic ramifications of beach replenishment sediment color mismatches with *in situ* sediments can be considerable. Table 7 provides a summary of beach sediment descriptions. Table 8 provides a summary of the average carbonate percentages and mean grain size for the various reaches. Note that the statistics for the reaches of Mayport to St. Augustine Inlet, Matanzas Pass to Ponce de Leon Inlet, and Ponce de Leon to Port Canaveral are parsed out into segments in order to better analyze changes north and south of Cape Canaveral. In addition, Appendix C provides comparative GSD curves across the individual inlets. As can been seen in several of these curve sets the carbonate fraction present in the samples

has a component that is coarser than what is present in the non-carbonate fraction. Photomicrographs of 17 samples illustrating variability in grain size and carbonate content are provided in Appendix D. A power point presentation illustrating the study area and our findings is provided as Appendix E.

Figure 18 graphically displays changes in mean grain size, both before and after removal of carbonate material, as well as the percentage of carbonate material in the samples through the length of the East Coast. The nature of the changes in these curves define five distinct regions.

The first region is defined by the area bounded by sample locations NA01 and SJ06. It includes the reaches of beaches from the mouth of the St. Marys River to the Nassau Sound, from Nassau Sound to the mouth of the St. Johns River, and the northern portion of the reach extending from the mouth of the St. Johns River to St. Augustine Inlet. Proceeding south from the mouth of the St. Marys River at the Georgia/Florida border, the carbonate fraction is low and the mean grain size is relatively fine. Lateral changes in mean grain size occur at the inlets that define the reaches in this region. The reach comprising Little Talbot Island and Wards Bank displays the minimum mean grain size for the region. There is little to no separation between the pre and post carbonate curves. These conditions continue to a point just south of the Duval/St. Johns County line in the middle of the Mayport to St. Augustine Inlet reach. At that point, carbonate percentages spike laterally from less than 10 percent to more than 90 percent.

The second region is defined by the area bounded by sample locations SJ06 and BV18. This region includes the southern portion of the reach extending from the mouth of the St. Johns River to St. Augustine Inlet, the full extent of the reaches from St. Augustine Inlet to Matanzas Pass and from Matanzas Pass to Ponce de Leon Inlet, as well as the portion north of False Cape of the reach from Ponce de Leon Inlet to Port Canaveral. In this region, mean grain size and carbonate percentages both periodically spike in tandem and then decline southward. Where mean grain size and carbonate percentages spike, there is a strong separation between the pre and post carbonate curves. This separation suggests that the carbonate fraction is coarser. Rapid lateral changes in mean grain size and carbonate percentage are strongly associated with St. Augustine Inlet and Matanzas Pass. The sediments of the reach between St. Augustine Inlet and Matanzas Pass are finer grained and lower in carbonate material compared to the reaches to its north and south. South of Matanzas Pass the mean grain size and carbonate percentage curves spike again. Carbonate percentages at that point go from less than 10 percent to over 80 percent. From that spike the curves gradually decline to a point south of Ponce de Leon Inlet where they spike once more. Carbonate percentages at that point go from 10 percent or less to over 60 percent. From that spike, both sets of curves again decline with the decline in the carbonate curve the more apparent. The location where there is a dip in the carbonate curve begins the third region. Geographically, this point corresponds with a feature know as False Cape. As shown on Figure 1, False Cape lies approximately 12.4 miles (mi) (20 kilometers (km)) north of Cape Canaveral.

The third region, which begins south of False Cape, is defined by the area bounded by sample location BV18 and SL07. It includes the southern portion of the reach from Ponce de Leon Inlet to Port Canaveral, the reach from Port Canaveral to Sebastian Inlet, and finally the reach from Sebastian Inlet to Ft. Pierce Inlet. South of False Cape, the mean grain size curves are relatively constant throughout regions 3 and 4. Those regions are defined by changes in the carbonate percentage curve. With the exception of occasional dips and spikes, the carbonate curve north of Ft. Pierce Inlet generally remains between 20 percent and 40 percent.

The fourth region, which begins south of Fort Pierce Inlet, is defined by the area bounded by sample locations SL08 and DD15. It includes the reach from Fort Pierce Inlet to St. Lucie Inlet, the reach from St. Lucie Inlet to Jupiter inlet, the reach from Jupiter Inlet to Lake Worth Inlet, the reach from Lake Worth Inlet to Boynton Inlet, the reach from Boynton Inlet to Boca Raton Inlet, the reach from Boca Raton Inlet to Hillsboro Inlet, the reach from Hillsboro Inlet to Port Everglades, the reach from Port Everglades to Baker's Haulover Inlet, and finally the reach from Baker's Haulover Inlet to Government Cut.

North of Fort Pierce Inlet carbonate percentage is less than 30 percent while south of the inlet abruptly it rises to over 70 percent. With occasional dips, the carbonate percentage curve builds southward to a peak of over 90 percent on the north side of Jupiter Inlet. Progressing south of Jupiter Inlet, the carbonate percentage drops to below 55 percent. From there, the carbonate curve dips slightly to between 40 percent and 60 percent and then builds to a peak north of Government Cut of over 90 percent. In the two reaches north of Government Cut, the carbonate percentages exceed 80 percent, and there is often too little non-carbonate material left after carbonate extraction to process.

The fifth region consists of a two reaches defined by the area bounded by sample location DD16 and DD23. It extends south of Government Cut to the south end of Key Biscayne. South of Government Cut, on Virginia Key and Key Biscayne, both sets of curves abruptly decline. The carbonate percentage curve falls to between 20 percent and 40 percent.

Additionally, from Figure 18, several general observations can be made. The mean grain size and carbonate percentage curves track well (where carbonate percentages increase so does mean grain size). Significant separation between the pre and post carbonate curves is noted where the carbonate percentage curve rises above 50 percent. While the ratio of carbonate material to non-carbonate material varies substantially north of False Cape, the general trend from north to south show a steady increase in the percentage of carbonate material within the samples until Government Cut is reached. After Government Cut, there is a substantial and abrupt decline in carbonate material.

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REFERENCES CITED

American Society for Testing and Materials, 2000a, Standard test method for particle-size analysis of soils: West Conshohocken, Annual Book of ASTM Standards, American Society of Testing and Materials International, v. 4.08, p. 10-16.

American Society for Testing and Materials, 2000b, Standard guide for statistical procedures to use in developing and applying test methods: West Conshohocken, Annual Book of ASTM Standards, American Society of Testing and Materials International, v.14.02, p. 583-588.

Balsillie, J. H.,1995, William F. Tanner on environmental clastic granulometry: Florida Geological Survey Special Publication No. 40, 145 p.

Balsillie, J. H., 2002a, Analytic granulometry tools: Florida Geological Survey Web site: http://www.dep.state.fl.us/geology/geologictopics/analytic_gran_tools/analytic_gran.htm, (June 2009).

Balsillie, J. H., 2002b, Red flags on the beach, part III: Journal of Coastal Research, v. 18, p. iii-vi.

Balsillie, J. H., and Dabous, A. A., 2003, A new type of sieve shaker; the Meinzer II~, comparative study with Rotap technology: Florida Geological Survey Open File Report No. 87, 93 p.

Balsillie, J. H., and Tanner, W. F., 1999, Suite versus composite statistics: Sedimentary Geology, v. 125, p. 225-234.

Balsillie, J. H., Tanner, W. F., and Williams, H. K., 1999, Sticky grain occurrences in sieving: Florida Geological Survey Open File Report No. 79, 15 p.

Balsillie, J. H., Dabous, A. A., and Fischler, C. T., 2002a, Moment versus graphic measures in granulometry: Florida Geological Survey Open File Report No. 84 , 85 p.

Balsillie, J. H., Donoghue, J. F., Butler, K. M., and Koch, J. L., 2002b, Plotting equation for Gaussian percentiles and a spreadsheet program application for generating probability plots: Journal of Sedimentary Research, v. 72, p. 929-933.

Clark, R. R., 1993, Beach conditions in Florida: a statewide inventory and identification of the beach erosion problem areas in Florida: Florida Department of Environmental Protection, Beaches and Shores Technical and Design Memorandum No. 89-1: 202 p.

Conover, W.L., 1999 Practical nonparametric statistics, 3rd Edition: New York, John Wiley & Sons, 584 p

Davis, R. A., 1997, Geology of the Florida Coast: *in* Randazzo, A.F. and Jones, D.S., eds. The Geology of Florida, Gainesville, University Press of Florida, p.155-168.

Dean, R.G. and M.P. O'Brien, 1987, Florida's East Coast Inlets, Shoreline Effects and Recommendations for Action: Report No. 87-17, Coast and Ocean Engineering Department, University of Florida, Gainesville, 65 pp.

Eshbach, O.W., and Souders, M., eds., 1975, Handbook of Engineering Fundamentals, 3rd. Edition: New York, John Wiley & Sons, 1562 p

Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems, 2000, Shoreline change rate estimates Duval County, Florida: ftp://ftp.dep.state.fl.us/pub/water/beaches/HSSD/reports/duvsre.pdf, (June, 2009).

Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems, 2007, Critically eroded beaches in Florida: http://bcs.dep.state.fl.us/reports/crit_ero.pdf, (June 2009).

Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems, 2008, Strategic Beach Management Plan for the Northeast Atlantic Coast Region: http://www.dep.state.fl.us/beaches/publications/pdf/SBMP/Northeast%20Atlantic%20Coast%20Region.pdf, (June, 2009).

Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems, 2008, Strategic Beach Management Plan for the Central Atlantic Coast Region: http://www.dep.state.fl.us/beaches/publications/pdf/SBMP/Central%20Atlantic%20Coast%20Region.pdf, (June, 2009).

Florida Department of Environmental Protection Bureau of Beaches and Coastal Systems, 2008, Strategic Beach Management Plan for the Southeast Atlantic Coast Region: http://www.dep.state.fl.us/beaches/publications/pdf/SBMP/Southeast%20Atlantic%20Coast%20Region.pdf, (June, 2009).

Freedenberg, H., A.B. Highley, R. Hoenstine and H. Williams, 1995, A Geological Investigation of the Offshore Area Along Florida's Central East Coast-Interim Report to the U.S. Department of Interior, Minerals Management Service: Year 1: Tallahassee, Florida Geological Survey unpublished report, 8 p. and Appendices.

Freedenberg, H., R. Hoenstine, Z. Chen and H. Williams, 1995a, A Geological Investigation of the Offshore Area Along Florida's Central East Coast, Year 1: Tallahassee, Florida Geological Survey Open File Report No. 69, 97 p.

Freedenberg, H., Hoenstine, R., Strong, N., Trimble, C., Chen, Z. and Dabous, A., 1997a, A Geological Investigation of the Offshore Area Along Florida's Central East Coast, Annual Report to the MMS-Year 2: Tallahassee, Florida Geological Survey unpublished report, 31 p. and Appendices.

Freedenberg, H., Dabous, A., Trimble, C., and Williams, H., 1997b, New Perspectives in Locating Sand for Beach Restoration in Florida – An Interim Report; Geological Society of America, Southeastern Section, Abstracts with Program, v29, no 3, p. 181.

Freedenberg, H., Hoenstine, R., Dabous, A., Cross, B., Willett, A., Lachance M., Chen, Z. and Strong, N., 1999, A Geological Investigation of the Offshore Areas Along Florida's Central East Coast, Annual Report to the MMS-Year 3: Tallahassee, Florida Geological Survey unpublished report, 19 p. and Appendices.

Freedenberg, H., Hoenstine, R., Dabous, A., Cross, B., Willett, A., Lachance, M., Fischler, C., and Stern, G., 2000a, A Geological Investigation of the Offshore Areas Along Florida's Central East Coast, Annual Report to the MMS-Year 4: Tallahassee, Florida Geological Survey unpublished report, 9 p. and Appendices.

Freedenberg, H., Hoenstine, R., and Dabous, A., 2000b, Preliminary Identification of Sand Resources in Federal Waters Along the Central Florida East Coast, Proceedings: 2000 National Conference on Beach Preservation Technology, February 2–4, 2000, Melbourne, Florida. p. 247-257.

Henry Jr., V. J. 1971. Geology, history and development of Amelia Island. in McCormick, J., & Associates. 1971. Amelia Island, Nassau County, Florida: a preliminary ecological inventory, A report to the Amelia Island Development Company.

Hoenstine, R., H. Freedenberg, Z. Chen and H. Williams, 1995, A Geological Investigation of the Offshore Area Along Florida's Central East Coast – Annual Report to the MMS-Year 1: Tallahassee, Florida Geological Survey unpublished report,, 99 p.

MyFlorida.com, 2009, The Reconnaissance Offshore Data Base, URS Corporation: Bureau of Beaches and Coastal Systems of the Florida Department of Environmental Protection: MyFlorida.com website: http://ross.urs-tally.com/, June, 2009.

Phelps, D.C., Hoenstine, R.W., Balsillie, J.H., Dabous A., Lachance M., and Fischler C., 2003, A geological investigation of the offshore area along Florida's northeast coast, Year One annual report to the United States Department of Interior, Minerals Management Service: 2002-2003: Florida Geological Survey unpublished report. (on CD).

Phelps, D.C., Hoenstine, R.W., Balsillie, J.H., Ladner, L.J., Dabous A., Lachance M., Bailey K., and Fischler C., 2004, A geological investigation of the offshore area along Florida's northeast coast, Year Two annual report to the United States Department of Interior, Minerals Management Service: 2003-2004: Florida Geological Survey unpublished report (on DVD).

Phelps, D.C., Hoenstine, R.W., Ladner, Balsillie, J.H., L.J., Dabous A., Sparr, J., and Lachance M., 2005, A geological investigation of the offshore area along Florida's northeast coast, Year Three annual report to the United States Department of Interior, Minerals Management Service: 2004-2005: Florida Geological Survey unpublished report (on DVD).

Phelps, D.C., Sparr, J., Lachance M., and Dabous A., 2007, A geological investigation of the offshore area along Florida's northeast coast, Year Four annual report to the United States Department of Interior, Minerals Management Service: 2005-2006: Florida Geological Survey unpublished report (on DVD).

Raichle, A.W., Bodge, K.R. and Olsen, E.J., 1997, St. Marys Entrance Inlet Management Study: unpublished report prepared for Nassau Soil and Water Conservation District. 486 p and appendices.

Stauble, D.K. and Da Costa, S.L., 1987. Evaluation of backshore protection techniques: Proceedings of the Fifth Symposium on Coastal and Ocean Management, Coastal Zone '87, Seattle, WA, p. 3233-3247.

Stapor, F.W. and J.P. May, 1983, The Cellular Nature of Littoral Drift along the Northeast Florida Coast: Marine Geology, v.51, p. 217-237.

Western Carolina University Program for the Study of Developed Shorelines (PSDS), 2009, The U.S. Beach nourishment experience including New England, east coast barrier islands, Pacific coast, and Gulf of Mexico shorelines, Western Carolina University website: http://www.wcu.edu/1038.asp (June, 2009).