

CHARACTERIZING THE BEACH MORPHOLOGY OF SAN SALVADOR, BAHAMAS

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ABSTRACT: *San Salvador is a carbonate island located 640 km southeast of Miami, Florida on the eastern edge of the Great Bahamas Bank. The island is where Columbus arguably made first landfall in the New World. Given that many of the world's sandy beaches are eroding due to rising sea levels, the objective of this study was to survey a subset of island beaches to characterize their morphology and to provide a base line for future studies. This paper presents a series of maps and profiles characterizing beach morphology. It also explores the use of simple indicators such as geographic position, off-shore environments, presence/absence of beach rock, and sand grain polish to link present beach morphology to ongoing processes of beach formation. The beaches on San Salvador appear to be stable on the north and west sides of the island and prograding on the south and east sides.*

INTRODUCTION

The Bahamas Archipelago is a string of carbonate islands resting on two large bank systems (Little Bahamas Bank and Great Bahamas Bank) in the warm, shallow tropical waters southeast of Florida (Figure 1). The pod shaped island of San Salvador (11 km east-west by 19 km north-south) is located at 24° 3' N and 74° 30' W. The key topographic features found on the island are dunes (some lithified), made up of carbonate sand, and hyper saline lakes that are formed as lagoons are filled in and dunes are deposited. Much of the island's surface is that of a karst landscape. Another topographic feature is where sand is deposited by waves and currents making up San Salvador's beaches.



Figure 1. Bahamas Archipelago and location of San Salvador Island (Gerace et al., 1998)

The Bahamas is a world wide tourist attraction because of its beautiful secluded tropical beaches, and the island of San Salvador is no exception. Monument Beach, on the island of San Salvador, is arguably the place Christopher Columbus first made landfall in the New World. While extensive research has been conducted on San Salvador's geology and off-shore environments, the island's sand beaches have received little scientific scrutiny (Clark et al., 1989 and Brill et al., 1993). The study of beach morphology in the Bahamas is a growing concern as the majority of the world's sandy beaches are eroding due to rises in sea level (Bloch, 1993).

The objective of this study is to present a series of maps and profiles characterizing beach morphology for five beaches on San Salvador. The use of simple indicators such as geographic position, off-shore environments, presence/absence of beach rock, and sand grain polish are used to link present beach morphology to ongoing processes of beach formation. The survey will also provide a baseline for future studies.

LITERATURE REVIEW

Beaches may be characterized as rivers of sand flowing between the water's edge and shore, shaped by waves, turbulence and currents that stir up sediment, depositing and removing sand from this river. Coastal landforms are influenced on both a macro and micro level. While large coastal landforms are influenced by global tectonics and events on geologic time scales, smaller features, such as beaches, are influenced by waves and longshore

currents, themselves influenced by winds and storms. The beach should be seen as a small feature superimposed on larger features and subject to controls on both scales (Fox and Davis, 1976). In the case of the Bahamas, the larger features are the Bahamian Banks and the smaller features are off-shore coastal environments, currents, and winds.

Research has been conducted on the sandy beaches of San Salvador. Most studies reported in the literature focused on the grain characteristics of the sand (Hutto and Carew, 1984; Lee et al., 1986; and Clark et al., 1989). Surveys along a 1-km section of East Beach between 1990 and 1992 confirmed a prograding shoreline (Brill et al., 1993), although the beach undergoes seasonal changes with sand eroding between July and January, and re-depositing during the January to July period. Shaklee (1994) describes the building of the eastern flank of the island as occurring during the winter months. Beavers et al. (1995) concluded a four-year study of East and Sandy Point Beaches. The study concluded that changes in the East Beach morphology were seasonal, while Sandy Point Beach's changing shape could be attributed to storm events.

Seasonal cycles of progradation and erosion, from summer to winter respectively, are seen on San Salvador. The key reason for these seasonal cycles is the weather and currents. In winter the remnants of many weather systems in the United States move seaward off the coast of Florida. As the cold fronts move over warm waters they pick up moisture, contributing to a winter rainy season. These weather patterns produce northeasterly winds pushing the long-shore current, running north-south along the western shore, closer to the island and creating erosion events. The summer progradation of the beaches is in turn the result of winds shifting from a northerly to a prevailing southeasterly direction and the subsequent migration of the current farther from the shore (Gerace et al., 1998) While gentle Trade Winds grace the eastern shore, during the months of September through November these beaches may experience hurricane force winds. The frequency of these storms is not trivial, as the island is listed in the top 15 hurricane-prone areas in the Caribbean and Gulf of Mexico, averaging one hurricane every 2.86 years (NOAA).

Besides geographic position, a number of other easily identified indicators can be used to understand beach dynamics. A study of off-shore environments can reveal available energy levels. For example sand flats are open, non-vegetated areas of unconsolidated sands. They occur as off-shore extensions of beaches. Sand flats are active, high energy environments where waves and currents keep the sand mobile, and by extension, keep beaches

mobile. On the other hand, the presence of off-shore grass flats suggests an inactive, low energy environment that has a minimal impact on beach morphology. The energy level of a beach can also be determined by examining the polish of sand grains. Grains that are highly polished are suggestive of a high energy environment.

Beachrock is defined as lithified calcium carbonate sand. It is formed where sands are cemented within the beach deposit (in situ) (Bain, 1989). The Bahamas is known for the world's youngest rock. Stories abound of finding cannon balls and glass bottles encased in newly formed rock. While beach rock can act as a protective buttress, the presence of beach rock is also an indicator of beach morphology stretching back in time hundreds to thousands of years. The presence of exposed beachrock along an existing beach is a possible indicator of a stabilized beach, whereas the absence of beach rock is a possible indicator of progradation (Brill et al., 1993).

METHODOLOGY

Beach surveys were conducted on five beaches around the island of San Salvador. The beaches chosen for profiling were Graham's Harbor, Monument Beach, Grotto Beach, Sandy Point, and East Beach (Figure 2). The beaches were chosen to represent windward and leeward orientations, as well as possible effects of currents and off-shore environments.



Figure 2. Beach locations on San Salvador Island

Beach surveys were made using a series of cross-shore transects much like topographic surveys oriented perpendicular to the shoreline (Figure 3). Each profile extended from the water line, inland to a line of either vegetation or rock, characterized as a series of stations and legs. For the purpose of this study the water line (sea level at time of profiling) was characterized as a point half way between where the wave broke on shore and was swept up the beach (backwash zone). This point was given an elevation of zero.

The beach profile was conducted using a survey viewfinder (with level), stadia rod, metric tape, and an e-trex GPS unit. Each rod was two meters in length, graduated in five-centimeter increments. The distance between rods (the survey leg) was three meters. A starting point of the first profile was made at the waterline, fixed by a GPS coordinate. The coordinates were reported as Universal Transverse Mercator (UTM) units, using the San Salvador datum. The compass was used to determine the direction of each profile, as well as to determine the starting point for the next profile. Change in elevation along each leg of the profile (between stations) was recorded as changes of a reference height (145 cm) between each rod. For example, a decrease of 10 cm (reading 135 cm) indicated a rise in elevation of 10 cm. Readings and observations were recorded in a field book.

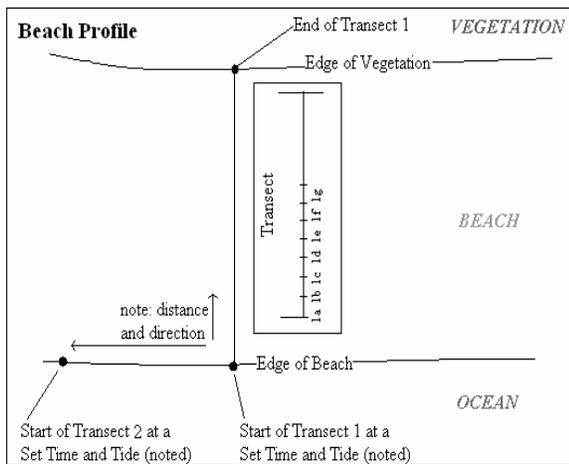


Figure 3. Construction of beach profiles

A subset of profiles (beach cross section) was drawn for each beach. The profiles were drawn in an Excel spreadsheet with distance from the water,

line expressed on the x-axis and the sum rise in elevation expressed on the y-axis. Topographic maps were drawn for each beach, using distance and elevation data collected from the survey. The maps were drawn by hand, using a protractor and a ruler to measure orientation and distance, respectively. For the purpose of this paper, the maps were scanned into Paint.

Off-shore environments were characterized as sand flats, grass flats, hard ground, or patch reefs. The characterization was made by snorkeling for a distance of about 100 meters off shore. The polish of collected sand grains was determined by viewing the grains through a dissecting microscope.

RESULTS AND DISCUSSION

Graham's Harbor

Graham's Harbor is located along the northern end of the island (north facing) (see Figure 2). The beach is relatively long and (concave) crescent shaped. The total survey length is 280 meters (14 transects) with an average surveyed depth of 13.5 meters (Figures 4 and 5). This beach is the narrowest of the surveyed beaches. The UTM coordinates of the first transect's start point are 2667389N 554258E and the last transect's start point is 2667426N 554514E.

The off-shore environment is made up of grass flats, indicating a low-energy environment. In addition, sections of the beach include beachrock. Beachrock acts as a natural break wall, further decreasing the beach's energy. The sand grains show little polish. Due to its low energy environment, the morphology of the beach likely does not vary with seasonal changes in current or weather, even though it would be exposed to northerly winds associated with winter cyclonic storms coming off of the continent. The presence and angle of beachrock (Figure 6) suggests that the low energy character of the beach has persisted, as the position and slope of the beach rock is similar to that of the present day beach.

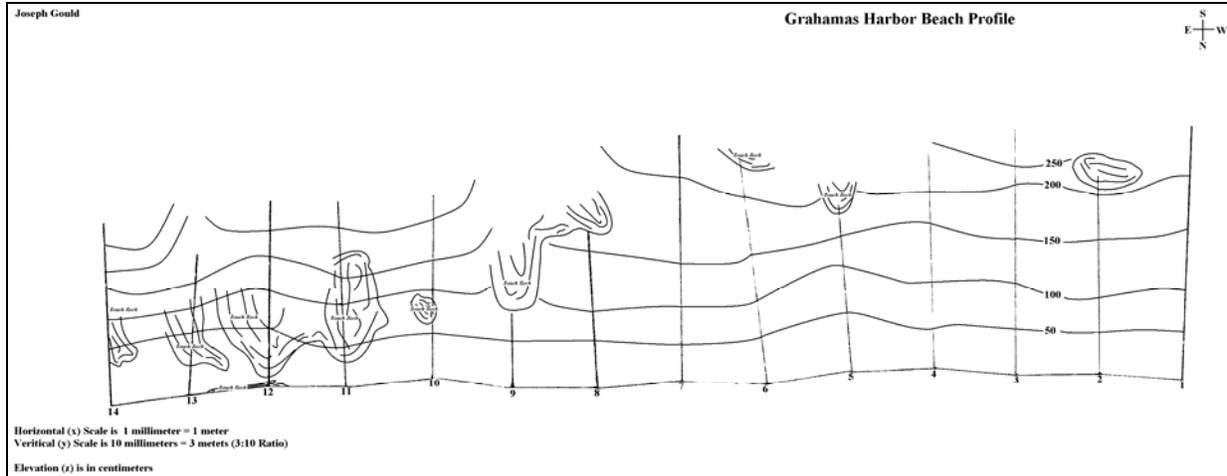


Figure 4. Survey map of Graham's Harbor beach. Surveyed on March 27, 2005

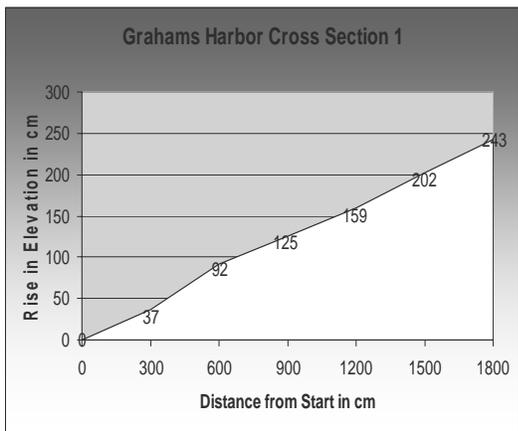


Figure 5. Profile of Transect 1 (2.7x vertical exaggeration, slope = 15 degrees)



Figure 6. Beachrock Along Graham's Harbor beach (looking east from dock)

Monument Beach

Monument Beach is located on the western side of the island (see Figure 2). This is the beach where Christopher Columbus arguably made first landfall in the New World. This beach is relatively long (320 meters of its length was surveyed) and shallow (average surveyed depth of 17 meters) (Figures 7 and 8). The UTM coordinates of the first transect's start point are 2655398N 547899E and the last transect's start point is 2655625N 548108E.

The off-shore environment is made up of grass flats, patch reefs, and sand flats near the shore

and between some patch reefs – indicating a low to medium energy environment. The beach sand grains show little polish. Beach rock is present on the beach (Figure 9), but unlike Graham's Harbor, the rock is located on the backshore of the beach, offering no protection to the present day beach. Exposed to northerly winds associated with winter cyclonic storms, the beach is likely susceptible to moderate seasonal modifications. The beach rock was measured at a slope of 5 to 10 degrees, similar to that of the present day beach (9.5 degrees), indicating little overall change in beach morphology or slight degradation over the years.

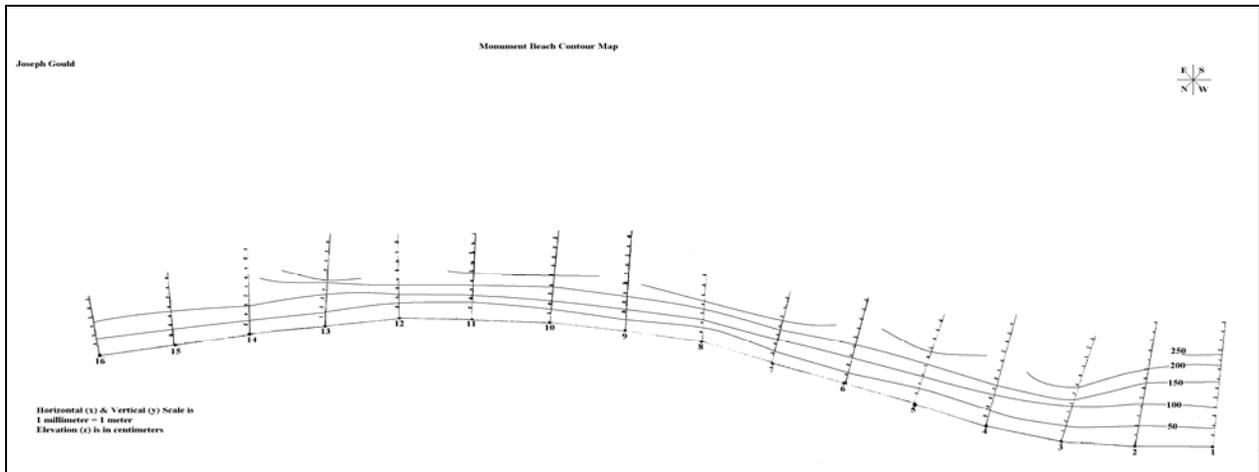


Figure 7. Survey map of Monument beach. Surveyed on March 31, 2005

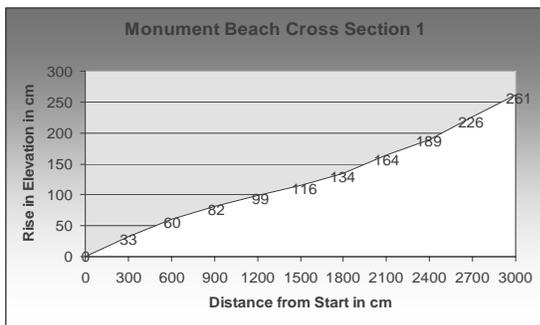


Figure 8. Profile of Transect 1 (4.5x vertical exaggeration, beach slope = 9.5 degrees)



Figure 9. Beachrock on Monument Beach (looking north)

Grotto Beach

Grotto Beach is located on the western side of the island, but unlike Monument Beach it is positioned with a north-facing orientation (see Figure 2). Grotto Beach is a short beach with an estimated length of about 300 meters and average surveyed depth of about 32 meters (Figures 10 and 11). About 80% of the beach was mapped, in total about 240 meters in length. The UTM coordinates of the first transect's start point are 2649070N 544708E and the last transect's start point is 2649074N 544502E.

There is only one rock outcrop on the beach, with no exposed beach rock along the shoreline. The off-shore environment is made up of sand flats and a few patch reefs, indicating a high energy environment. The sand grains are well polished. This beach is also exposed to northerly winds associated with winter cyclonic storms. Grotto Beach is likely susceptible to substantial seasonal changes in morphology. These changes are reinforced by the presence of a sand escarpment and steep profile, and the absence of beach rock.

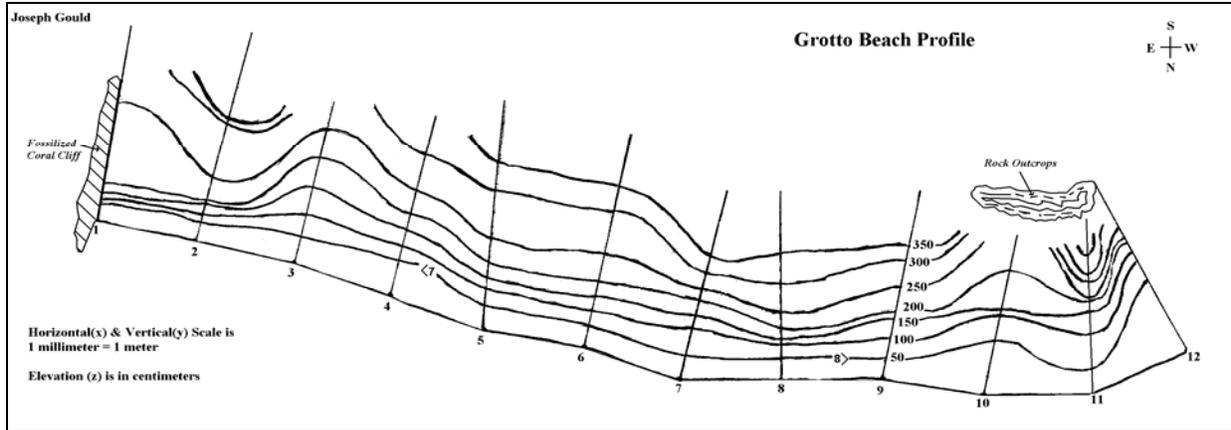


Figure 10. Survey Map of Grotto beach. Surveyed on March 26, 2005

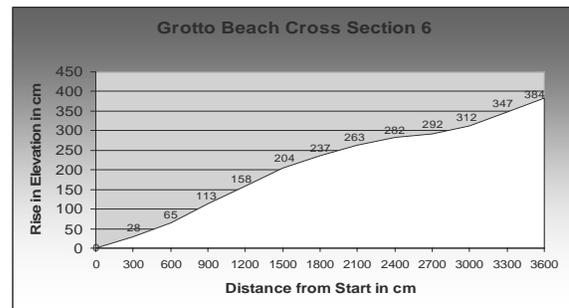
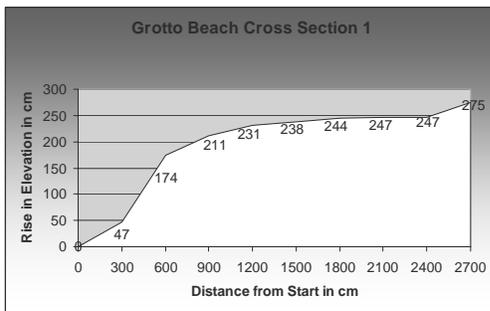


Figure 11. Grotto Beach profiles for Transect 1 (foreshore slope = 26 degrees, backshore slope = 3 degrees) and Transect 6 (beach slope = 10 degrees) (both profiles: 4x vertical exaggeration)

Sandy Point

Sandy Point is located on the very southern tip of the island, with a southern orientation (see Figure 2). This relatively straight beach is the second longest on the island with an average surveyed depth of 63 meters making it the deepest beach on the island. Due to its length, the distance between transects was doubled so that a larger section of the beach could be surveyed. With this adjustment, 240 meters of the beach were surveyed using 6 transects (Figures 12 and 13). The UTM coordinates of the first transect's start point are 2647835N 543795E and the last transect's start point is 2647713N 543955E.

The off-shore environment is made up of sand flats and a few patch reefs – suggesting a high energy environment. In addition, the sand grains

appear highly polished. This beach has a sand escarpment at its face giving it a steep slope which then levels off and dips in the middle.

On top of this escarpment Sargasso weed and other organic matter was deposited which helps hold the sand in place. The dip in the beach profile suggests aeolian scouring as a removal mechanism. This mechanism is reinforced by the presence of beach pavement (uniform shell fragments) on the backshore and presence of inland dunes. There is no beachrock or rock outcrops along the beach. Sandy Point Beach is likely susceptible to substantial seasonal changes in morphology, although the depth of the beach and presence of sand dunes inland suggest that the changes in beach morphology are likely confined to the foreshore. The low beach slope (with the exception of the area nearest the shoreline) suggests a prograding beach.

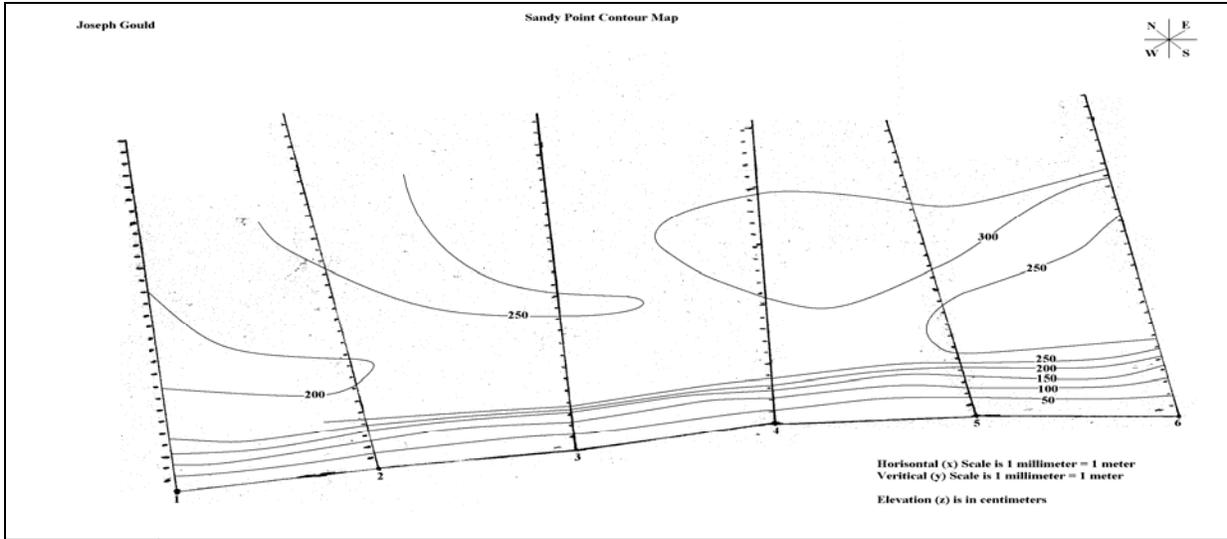


Figure 12. Survey map of Sandy Point beach. Surveyed on April 1, 2005

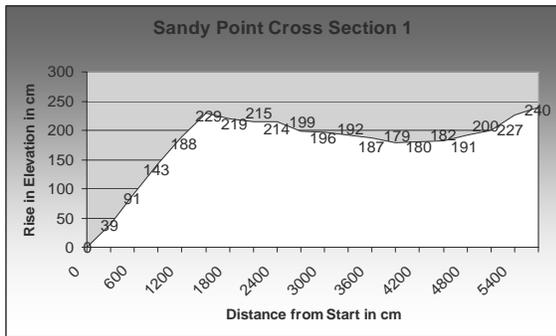


Figure 13. Sandy Point profile of Transect 1 (11x vertical exaggeration)

East Beach (aka Junk Beach)

East Beach is located along four miles of the eastern side of the island (see Figure 2). It is the longest beach on the island and the second deepest beach surveyed (mean depth of 36 meters). A 160-meter section of the beach was surveyed using 8 transects. The UTM coordinates of the first transect's start point are 2664222N 556926E and the last transect's start point is 2664371N 556913E.

The near-shore environment of the beach is predominately grass flats and patch reefs - classified as a low energy environment. The sand grains appear the least polished of all five beaches studied. The position of the beach on the east side of the island protects it from the northerly winds associated with cyclonic winter storms, leaving the beach exposed to

gentler trade winds. Exceptions would occur with the approach of a hurricane.

No beach rock or rock outcrops are found along this beach. The prevailing easterly winds and off-shore current deposit a large amount of flotsam and Sargasso weed along the beach, likely securing sand in place. As with Sandy Point, the depth of the beach and presence of sand dunes inland suggest that the changes in beach morphology are likely confined to areas near the shore. The low beach slope suggests a prograding beach.

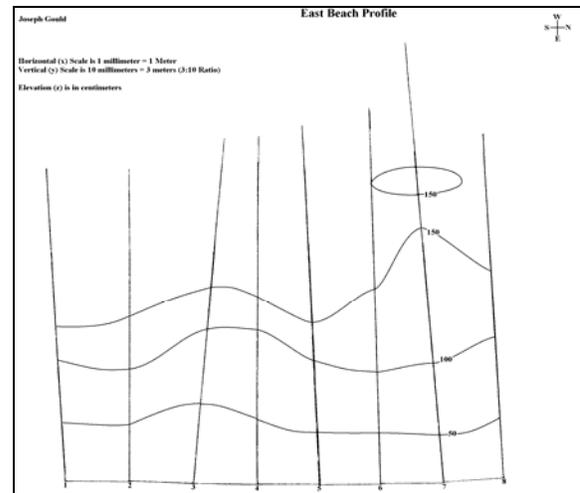


Figure 14. Survey map of East beach. Surveyed on March 29, 2005

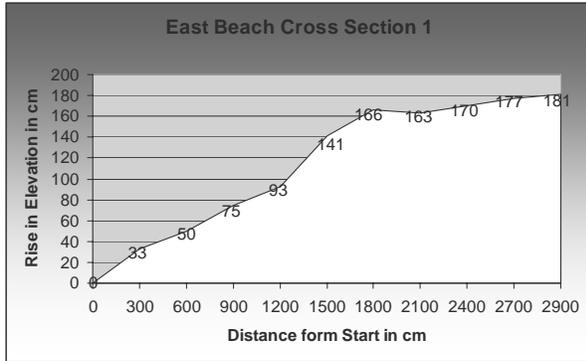


Figure 15. East beach profile of Transect 1 (foreshore slope = 9 degrees, and backshore slope = 1 degree) (7x vertical exaggeration)

CONCLUSIONS

A series of maps and profiles, characterizing beach morphology, was produced for five beaches located on the island of San Salvador, Bahamas. Simple indicators such as geographic position, off-shore environments, presence/absence of beach rock, and sand grain polish successfully linked present beach morphology to ongoing processes of beach formation. While the maps and profiles provide a baseline for future work, the beaches on San Salvador appear to be stable on the north and west side of the island and prograding on the south and east sides.

While use of GPS coordinates will enable replication of these surveys in future research, efforts are needed to incorporate these and future survey results into the existing San Salvador Geographic Information System (GIS) data base.

ACKNOWLEDGEMENT

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