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Beach state classification: the dissipative domain of Cocos Bay, (Manzanilla), Trinidad

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ABSTRACT. Cocos Bay on the east coast of Trinidad comprises a barrier beach system that protects the Ramsar listed freshwater Nariva Swamp from the high energy environment of the Atlantic. The Manzanilla beach with its open bay morphology, and exposure to the Atlantic Ocean presents an interesting dynamic. There have been many developments in coastal geomorphology in terms of studying beach and nearshore changes. However, most studies on beach classification overlooked the dynamics of beaches in the Caribbean exposed to the Atlantic Ocean. Attempts to classify Manzanilla beach into the existing frameworks for beach state classification has proven to be problematic. This paper evaluates the applicability of such beach state classifications on beaches exposed to the Atlantic. Results indicate that an adjustment of the original limits for the dissipative beach domain is necessary in order to classify this beach. A Manzanilla dissipative domain is also proposed as a modification of the previous limits set out by the dissipative domain.

Key words: Cocos Bay, Manzanilla, dissipative domain, beach classification, morphodynamic indices.

1. INTRODUCTION

Geomorphologists such as Wright et al. (1979), Wright and Short (1983) and Masselink and Short (1993) have identified a number of distinct morphological states or stages associated with various wave and tide regimes. Wright and Short (1983) integrated many disparate hydrodynamic and morphological factors into coherent models, with dissipative and reflective domains separated by four intermediate domains. Masselink and Short (1993) formulated a beach classification model that takes into account waves, tides and sediment. Woodroffe's (2002) summary defines the dissipative to reflective continuum in terms of wave energy.

Classification of beaches into distinct groups or types can provide a useful framework within which beach morphodynamics and morphological change can be studied (Masselink and Hughes 2003). Araya-Vergara (1986) classified profiles according to two basic data sets; morphology and genetics. Beach profiles were classified as accretional, erosional or mixed from a study in central Chile.

A number of descriptive classifications are in use to identify the type of cross-shore profile that exists at a particular location. These include equilibrium and non-equilibrium profiles, barred and non-barred profiles, and dissipative and reflective profiles. A cross-shore equilibrium profile has been described by Schwartz (1982) as a long-term bed profile produced by a particular wave climate and type of coastal sediment. Dean (1991) suggested that an equilibrium profile is an idealized profile that has adjusted to the sediment, wave, and water level fluctuations at the site of interest. As such, a profile will be in a state of (dynamic) equilibrium if the volume of sand accumulated under the profile and a chosen horizontal datum is constant in time.

The "Australian School" of coastal geomorphology has made a tremendous contribution by providing a framework for studying beach and nearshore changes. Wright et al. (1979, 1982) and Short (1979) have identified a number of distinct morphological states or stages associated with various wave and tide regimes. Additionally, they suggested that beaches may move through a temporal sequence of states in order to achieve equilibrium (i.e., regular, phased-beach changes following initial disequilibrium caused by sudden increases in wave energy). Similar ideas on phased-beach changes were put forward by Sonu and James (1973), Fox and Davies (1978), Saskia and Horikawa (1975) and Fox (1985).

The classification by Wright et al. (1979) focused on the hydrodynamic processes at work to produce dissipative and reflective profiles. In reflective profiles, most of the incident wave energy is reflected on a relatively steep beach, which most times results in a featureless profile associated with erosion. Reflective profiles predominantly occur on lower-energy ocean-fronted beaches composed of relatively coarse material, on beaches in eroding areas, and in deeply indented coastal areas. Dissipative profiles consist of a wide surf zone and a flat shallow beach that spreads most of the breaking wave energy across the beach surface. The profile has many features such as ridges and runnels, swash bars, rhythmic beach cusps and

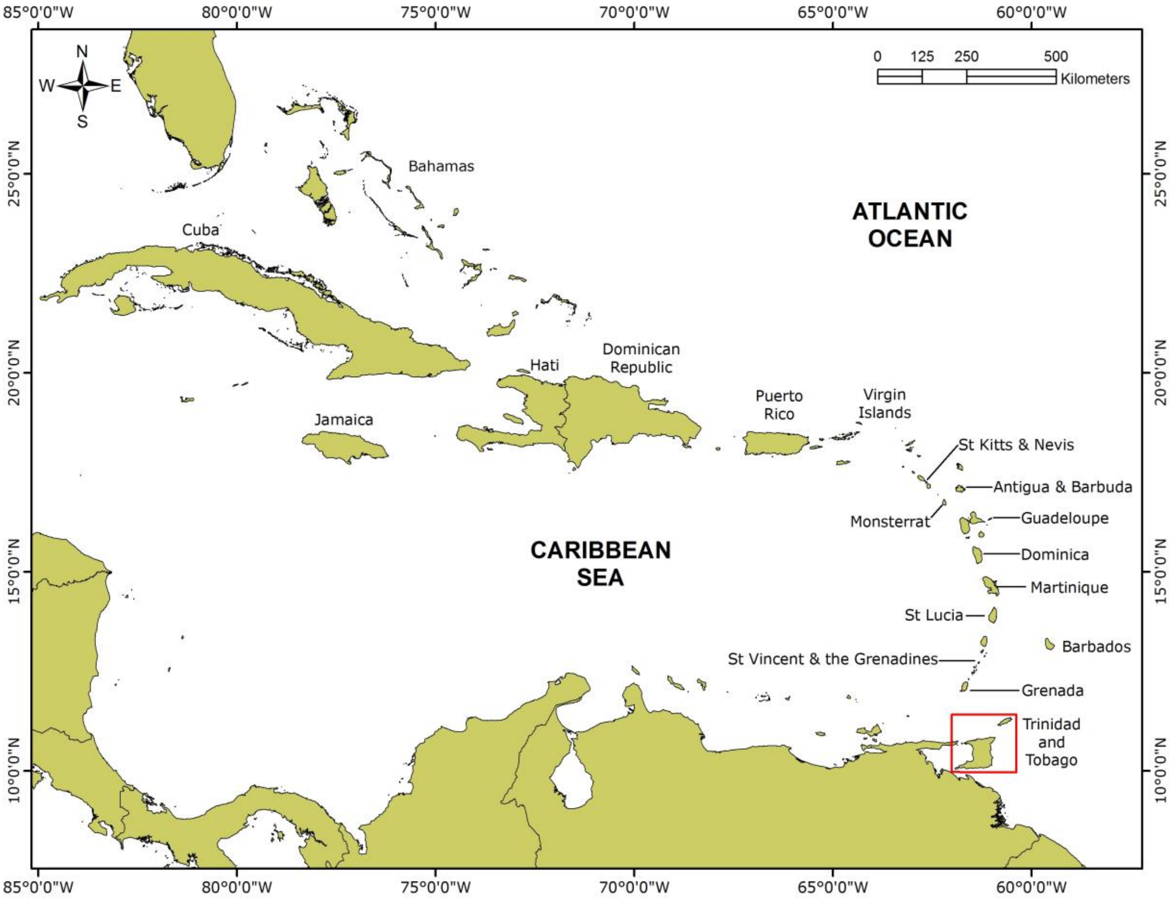

Figure 1. Map of the Caribbean Showing the Location of Trinidad and Tobago (after Darsan et al., 2012)

shoals, longshore breaker bars and troughs, and rip channels. Dissipative profiles occur mainly on exposed higher-energy beaches and composed of medium to fine grained sand.

Wright and Short (1983) were able to integrate many disparate hydrodynamic and morphological factors into coherent models which emphasize the role of antecedent conditions in determining morphological stage. Wright and Short (1983, 1984) replaced their earlier terminology with dissipative and reflective domains separated by four intermediate domains. A useful parameter utilized by Wright and Short to determine the relative importance of reflection and dissipation is the surf scaling parameter ε. Reflective conditions prevail when $\varepsilon < 2.5$, dissipative conditions when $\varepsilon > 20$ and intermediate (both reflective and dissipative) conditions occur when $\varepsilon = 2.5\text{-}20$ (Guza and Inman 1975; Guza and Bowen 1975).

The intermediate domains incorporated elements of both the reflective and dissipative domains. According to Wright and Short (1983), intermediate states may arise as a consequence of tidal changes, especially across beach profiles with separate sand and gravel elements. The four intermediate types recognized are the longshore bar-trough, rhythmic bars, transverse (welded) bars, and low-tide terrace. The beach model developed by Wright and Short (1983) is useful in explaining spatial differences in medium to high wave energy micro-tidal sandy beach environments. It is also useful in explaining how beach morphology changes under the influence of rising and falling wave conditions, however, the effect of tides is not considered.

Woodroffe (2002) summarized a classification using parameters in terms of wave energy. These parameters were used to differentiate between the dissipative, intermediate and reflective domains included breaker coefficient, surf scaling factor, phase difference, surf similarity index and dimensionless fall velocity. Masselink and Short (1993) formulated a beach classification model that takes into account the three most important environmental constraints; waves, tides and sediment. Masselink and Short's (1993) classification model of beach state contains the three main domains (reflective, intermediate, and

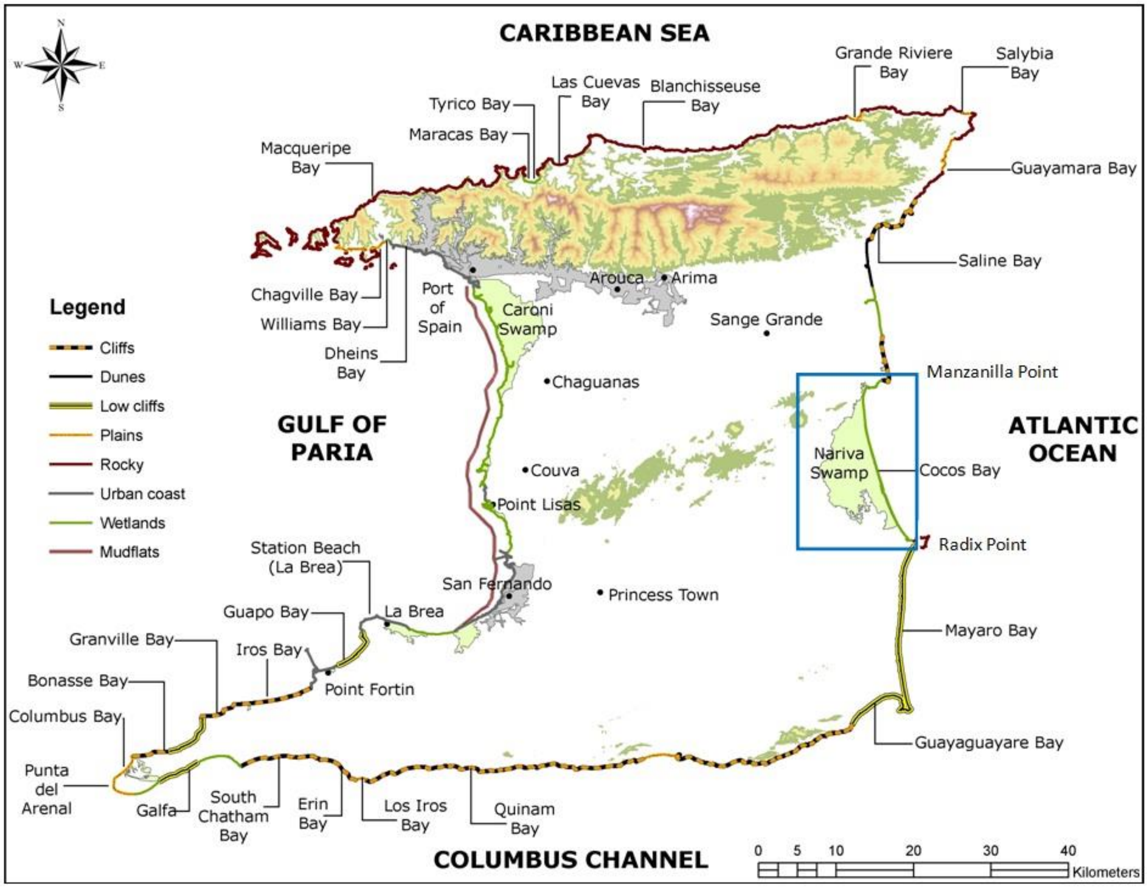

Figure 2. Map of Trinidad Showing the Location of the Study Area (after Darsan et al., 2012)

dissipative), but also includes additional states under these existing domains.

The objective of this study is to evaluate the extent to which the Manzanilla beach at Cocos Bay fits into the existing frameworks for beach state classification by Wright and Short (1983), Woodroffe (2002) and Masselink and Short (1993). This will involve a comparison of hydrodynamic indices and morphological characteristics.

2. STUDY AREA

Trinidad and Tobago, the most southerly of the Caribbean islands, is situated between 10º 02’ to 10º 50’ N (latitude) and 60º 55’ to 61º 56’ W (longitude). It is located on the continental shelf of South America and immediately adjacent to the outflow of the Orinoco River, and this determines to a great extent the nature and form of its coastal and marine environment (**Figure 1**). Trinidad’s coasts are influenced by the discharge of the Orinoco River, and the Guiana current that flows along the east coast of South America (Andel, 1967).

The variations in direction and strength of the wave attack along with the variations in geologic structure have produced a wide range of coastal landforms on the beaches in Trinidad. Cocos Bay has been classified as an open sea beach (Georges, 1983). The east coast of Trinidad is rugged in its northern section where the rocks of the Northern Range outcrop. Further south the coastline becomes gentler, where in the central regions the Nariva wetlands are found (Bertrand et al., 1992). The east coast morphology of Trinidad is extremely varied with three stretches of low coast separated by prominent headlands. Manzanilla beach is a barrier beach system found in Cocos Bay, embraced by two prominent headlands at Manzanilla Point and Radix Point (**Figure 2**).

The Cocal area includes the Manzanilla beach in Cocos Bay and the Nariva Swamp. The Cocal sand bar known locally as Manzanilla beach, has a relationship with the Nariva Swamp whereby the freshwater swamp is protected from the marine environment by the barrier beach. The barrier beach provides a low energy environment for fine sediment deposition, allowing wetland vegetation colonization. The barrier beach also protects the swamp from salt water intrusion, helping to

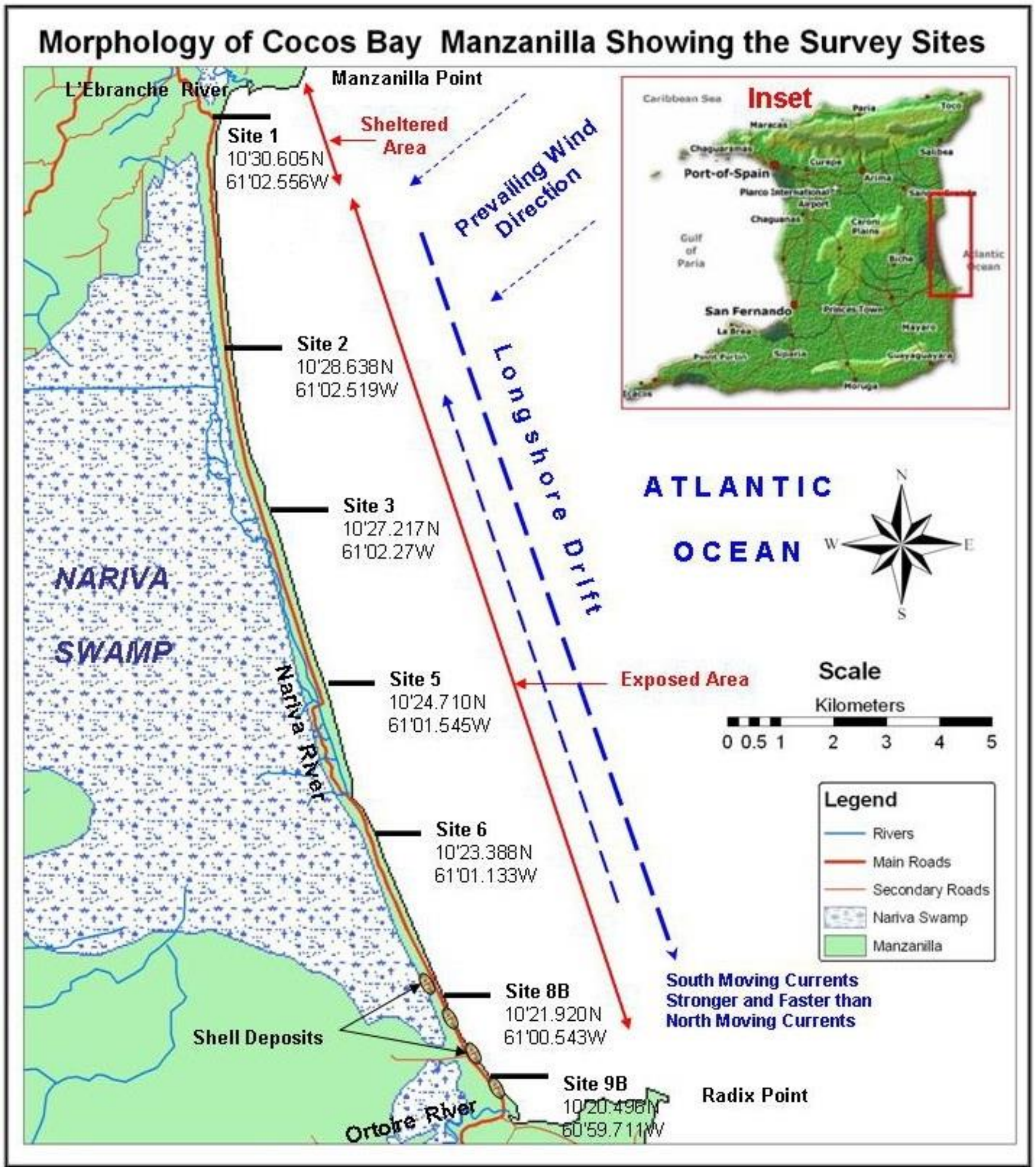

Figure 3. Morphology of Cocos Bay, Manzanilla Showing Study Sites

maintain the correct salinity levels that promote life in this wetland ecosystem (Darsan, 2005). Without the Cocal Sand Bar (the Manzanilla beach), the Nariva Swamp would not exist in its present condition. The characteristics (including the geology and hydro-geology) of the sand bar are not well known having not received much research (Environmental Management Authority, 2001). The Cocal sand bar has a fairly low topography with some sections below sea level (Williams, 2000).

There is also significant erosion along several parts of the Manzanilla beach (Singh, 1997), particularly near the Nariva River mouth; attributable to fresh water outflow and tidal inflow dynamics. The Manzanilla beach located along the Manzanilla/Mayaro Main Road, is about 20 km long, and borders the landward edge of the Nariva Swamp. The back of the barrier beach has not been driven inland with coastal retreat, and as such, sections of the barrier are becoming progressively narrower.

The Nariva River also carries large quantities of particulates and nutrients to Cocos Bay which has implications for marine biota and productivity (Bacon et al., 1979). At several points along Manzanilla beach, the sand bar has been eroded from fresh water outflow and sea water inflow; creating points where salt water is able to directly penetrate and alter salinity in the Nariva Swamp (Environmental Management Authority, 2001).

3. METHODS

Data collection included beach profiling, littoral data (coastal processes) and sediment data. Data were collected on a diurnal, lunar (tidal), monthly and seasonal basis to reveal the changes that occur diurnally, from spring to neap tides, seasonally from winter to summer periods and monthly over a year period. Data for the winter period (dry season) was collected from December 2005 to January 2006 at 9 sites along the beach (**Figure 3**). Data for the summer period (wet season) was collected from June to July 2006 respectively, to compare results with the surveys from the winter period. Data was subsequently collected monthly over a 14 month period from August 2006 to September 2007. The hydrographic survey was conducted on the 7th of August, 2007 where the marine weather conditions were satisfactory.

Beach Profiling

Beach Profiles were collected using a Topcon survey level, compass, 30 m tape and graduated staff. The uneven ground surface interval method was employed, where the beach slope is measured over uneven distances, corresponding to breaks or changes in slope (Goudie, 1990).

Nearshore Bathymetry

A hydrographic survey was also conducted to investigate the offshore bathymetry of the bay. A dual-frequency hydrographic echo sounder was mounted on the side of the vessel (7 m fishing boat), with its transducer (probe) immersed in the water. The survey was carried out as an extension of the beach profiles done up to wading depth (1.5 m water depth) into the offshore region to 10 m water depth. During the hydrographic survey, the vessel followed a bearing that corresponded with that of the land-based beach profile, so that a continuation of the profile into the offshore region was obtained. The boat was guided using GPS positioning, and specialty surveying software. The offshore profiles generated have Universal Transverse Mercator (UTM) positions and are relative to the Naparima 1955 Datum. Data from a tide gauge at Guayaguayare Bay were input into the Admiralty Tide Program to predict the tides at Nariva River mouth. These tides produced for Nariva were then input into the surveying software to calculate the mean sea level while conducting the hydrographic survey.

Littoral Data

Littoral data were collected on each survey date (wind strength and direction, wave height, wave period, wavelength and breaker angle, breaker type, and longshore currents) using standard geomorphological techniques as outlined by Goudie (1990). The Beaufort Scale was used to estimate wind speed at each site. Wind direction was recorded as a compass point, using a flag to assess the compass direction. Three averaged readings were taken of breaker height, wave period, wavelength and longshore currents. Breaker height was measured directly using a graduated staff as the distance from water level to wave crest. Wave period was obtained as the time (in seconds) for 10 wave crests to pass a stationary object. Wavelengths were measured directly using a measuring tape as the distance between two successive wave crests. Longshore currents were obtained as the distance moved by a float over sixty seconds. The current direction was recorded using a compass.

Wave velocity, wave steepness, wave energy, surf scaling factor and surf similarity parameter were calculated using the following formulae:

$$\textit{Wave Velocity} = \textit{Wavelength/Wave Period} \qquad \ldots (1)$$

$$\textit{Wave Steepness} = \textit{Wave Height/Wavelength} \ldots (2)$$

$$\textit{Wavelength in Deep Water} = gT^2/2\pi \qquad \ldots (3)$$

$$\textit{Wave Energy } (E) = 1/8\, pg\, H^2 \qquad \ldots (4)$$

(Dyer's (1986) Wave Energy Equation)

$$E = a.2\pi / g.T.\ \tan^2\beta \qquad \ldots (5)$$

(Guza and Inman's (1974) Surf Scaling Factor)

$$\epsilon = \tan\beta / (H/L)\ 0.5 \qquad \ldots (6)$$

(Battje's (1974) Surf Similarity Parameters)

Where a = Wave Height
β = Beach Slope
g = Acceleration due to Gravity (9.81 m/s)
H = Wave Height
L = Wavelength
p = Water Density (sea water - 10.25 kg/m)
T = Wave Period

Beach Sediments

Beach sediments were collected from the upper foreshore (mean high water mark), lower foreshore (mean low water mark), and surf zone (15 m seaward of the lower foreshore sample) at each site along the profiling transect. Beach sediment grain-size analysis was conducted using a nest of standard sieves at 0.5 ø intervals (with sizes ranging from 4 mm to < 0.0625 mm) using the standard method for dry-sieving by the British Standard Institute (BSI) as outlined by Tucker (1995). Gradistat-v5

Table 1: Folk and Ward Parameter Averages for Nearshore Sediment

	Site 1 UF	Site 1 LF	Site 1 SZ	Site 2 UF	Site 2 LF	Site 2 SZ	Site 3 UF	Site 3 LF	Site 3 SZ	Site 5 UF	Site 5 LF	Site 5 SZ	Site 6 UF	Site 6 LF	Site 6 SZ	Site 8B UF	Site 8B LF	Site 8B SZ	Site 9B UF	Site 9B LF	Site 9B SZ
Mean (ϕ)	2.28	2.87	2.72	2.47	2.67	2.46	2.66	2.86	2.76	2.77	2.80	2.80	2.64	2.63	2.57	1.85	0.73	1.55	2.25	2.10	2.41
Sorting	0.49	0.56	0.85	0.44	0.51	0.67	0.41	0.38	0.47	0.39	0.40	0.42	0.40	0.42	0.56	0.58	1.40	1.50	0.60	1.00	1.09
Skewness	0.08	-0.32	-0.55	0.15	-0.05	-0.15	0.02	-0.01	-0.10	0.04	-0.01	-0.06	0.05	0.03	-0.06	0.16	0.42	-0.38	0.13	-0.08	-0.41
Kurtosis	1.16	1.11	1.59	1.03	0.85	0.86	0.97	0.95	1.01	1.02	0.98	0.95	0.98	0.99	1.28	1.27	0.65	1.04	1.13	0.86	1.34

Table 2. Folk and Ward Parameter Averages for Offshore Sediment

	Site 3 – 10m	Site 5 – 10m	Site 6 – 10m	Site 8B – 10m	Site 9B – 10m	Site 9B – 5m	Site 9B – 3m
MEAN:	Very Fine Sand 3.969	Very Fine Sand 3.685	Very Fine Sand 3.597	Very Fine Sand 3.786	Very Fine Sand 3.932	Very Coarse Silt 4.252	Very Fine Sand 3.417
SORTING:	Poorly Sorted 1.033	Moderately Sorted 0.902	Moderately Sorted 0.768	Moderately Sorted 0.906	Poorly Sorted 1.109	Poorly Sorted 1.403	Well Sorted 0.493
SKEWNESS:	Very Fine Skewed 0.577	Very Fine Skewed 0.352	Fine Skewed 0.254	Very Fine Skewed 0.452	Very Fine Skewed 0.522	Very Fine Skewed 0.503	Very Fine Skewed 0.427
KURTOSIS:	Extremely Leptokurtic 3.097	Very Leptokurtic 2.775	Very Leptokurtic 2.684	Extremely Leptokurtic 3.028	Very Leptokurtic 2.754	Very Leptokurtic 1.880	Very Leptokurtic 1.678

was used to compute Folk and Ward (1957) statistical grain size distribution analysis, using the graphical method.

4. RESULTS

Grain Size Analysis

The Folk and Ward (1957) parameters revealed that the mean grain size ranges from coarse-sand ($\phi = 0.73$) at site 8B to fine-sand ($\phi = 2.87$) at site 1 lower foreshore. Beach sediment comprised of fine-sand at all sites except at site 8B, which had medium-sand predominating due to a more permanent shell deposit that coarsened the sediment. Most sediments were well-sorted except for sites 8B and 9B where moderate-sorting existed as a result of the bimodal distributions.

The upper foreshore sediments were either near-symmetrical or fine-skewed. Some sediments were strongly fine-skewed ($\phi = 0.42$), such as the lower foreshore sediments at site 8B. The lower foreshore and surf zone sediments of sites 1, 8B and 9B differed in that they were generally coarse-skewed, while those at sites 2, 3, 5 and 6 were generally near-symmetrical.

The average kurtosis for site 1 was leptokurtic (where the centre of the grain-size distribution is better sorted than the ends). The sediments at sites, 2, 3, 5, and 6 were mesokurtic (normal and possess a normal bell shaped curve) with the exception of the surf zone sediment at site 6 which was leptokurtic. The upper foreshore and surf zone sediments at sites 8B and 9B were generally leptokurtic, while their respective lower foreshore sediments were platykurtic (where the ends of the grain-size distribution are better sorted than the centre) (**Table 1**).

The Folk and Ward Parameters for the offshore

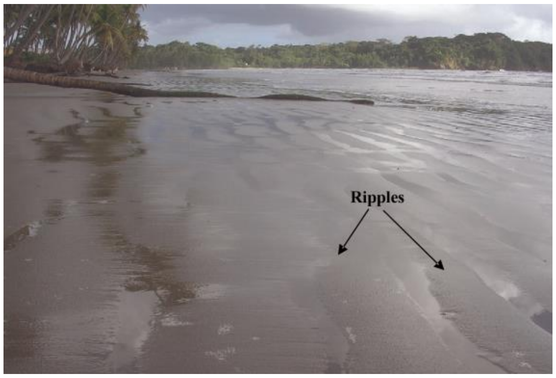

Figure 4. Ripples on the lower foreshore at Site 1

Figure 5. Spilling breakers at Manzanilla

sediments showed that the sediments are all very fine grained sands, with the exception of the 5 m depth sediment at Site 9B, which is a coarse grained silt. Sorting ranged from poorly-moderately-sorted in the 10 m and 5 m depth sediments, while at the 3 m depth sediment was well-sorted, probably because of its higher energy contact with the wave base that was able to influence its sorting. The sediments were generally very fine-skewed and very leptokurtic (**Table 2**).

Morphology

A typical beach profile at Manzanilla shows a flat shoaling beachface with a beach angle ranging between 3° to 6°, and composed of fine sand. The lower foreshore contains ripples with a wavelength of 20-30 cm (**Figure 4**). The surf zone is extensive ranging from 100-250 m and contains several lines of spilling breakers (3-5 in the surf zone) (**Figure 5**). The widest surf zones are found in the middle of the bay, decreasing in width towards each end.

The surf zone contains multiple offshore bars that migrate cross-shore with wavelengths of 10-30 m. These offshore bars are found at a distance of 75-150 m based on the land-based surveys. The land-based surveys did not go beyond the 150 m mark, however, it is suggested by Wright and Short (1983) and Masselink and Short (1993) that extensive surf zones as at Manzanilla would contain multiple offshore bars. Beyond the surf zone, large-scale bedforms are found and included mega ripples and sandwaves. The mega ripples are found at a distance of 350-500 m at a depth of 4-5 m with wavelengths of 25-60 m. Further seaward, sandwaves are found with ripples superimposed comprising very fine sand (**Figure 6**).

Coastal Processes

The Manzanilla beach has a Surf Scaling Factor ranging between 4-94, and a Surf Similarity Parameter ranging between 0.25-0.60. Wave energy varies between 3800-9500 J/m^2 and wave steepness between 0.04-0.06 under normal wave conditions (**Tables 3-4**).

5. DISCUSSION

Based on beach classification by Wright and Short (1983), Woodroffe (2002) and Masselink and Short (1993) (**Table 5**), not all sites along Cocos Bay

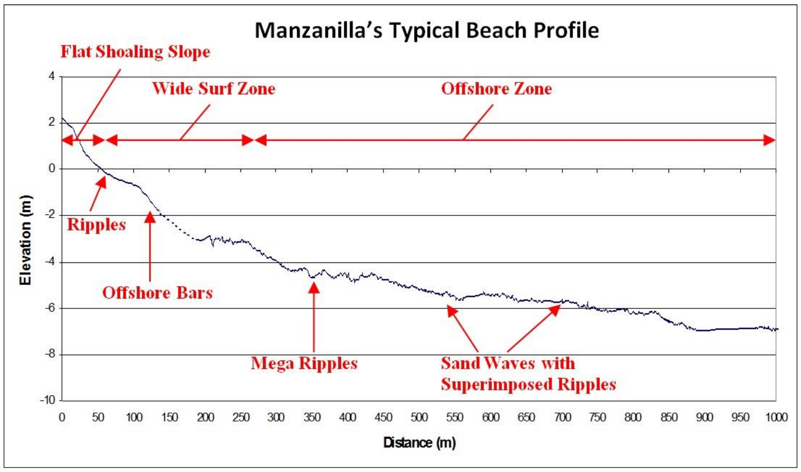

Figure 6. Manzanilla's typical beach profile

Table 3. Summary of coastal processes winter 2005 to summer 2006

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
Wave Period (secs)	**7.0**	**7.6**	**7.1**	**6.7**	**7.9**	**9.0**	**6.9**	**8.0**	**6.9**
Wave Height (m)	**0.6**	**0.6**	**0.7**	**0.7**	**0.6**	**0.6**	**0.8**	**0.8**	**0.8**
Wavelength (m)	**16.2**	**18.2**	**16.4**	**18.0**	**17.0**	**15.9**	**18.4**	**15.7**	**17.8**
Wave Velocity (m/s)	**2.41**	**2.55**	**2.33**	**2.74**	**2.15**	**1.85**	**2.79**	**1.98**	**2.58**
Wave Steepness	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**
Wave Energy (J/m^2)	**5388.99**	**5595.20**	**6418.08**	**5646.34**	**4933.36**	**4776.24**	**7101.52**	**7894.94**	**7635.71**
Mean Beach Angle (º)	**6.36**	**4.87**	**3.68**	**3.44**	**3.17**	**3.64**	**5.60**	**4.97**	**3.20**
Surf Scaling Factor	**4.82**	**7.47**	**15.73**	**19.70**	**16.77**	**11.30**	**8.20**	**8.66**	**26.98**
Surf Similarity Parameter	**0.60**	**0.47**	**0.31**	**0.32**	**0.29**	**0.33**	**0.48**	**0.39**	**0.27**

Table 4. Summary of coastal processes over a 14 month period

	Site 1	Site 2	Site 3	Site 5	Site 6	Site 8B	Site 9B
Wave Period (secs)	**7.3**	**7.3**	**8.1**	**7.0**	**7.4**	**7.1**	**7.2**
Wave Height (m)	**0.5**	**0.6**	**0.5**	**0.6**	**0.5**	**0.8**	**0.8**
Wavelength (m)	**14.5**	**15.5**	**14.7**	**16.0**	**13.0**	**13.3**	**13.6**
Wave Velocity (m/s)	**2.0**	**2.2**	**1.8**	**2.4**	**1.8**	**1.9**	**1.9**
Wave Steepness	**0.04**	**0.04**	**0.04**	**0.04**	**0.04**	**0.06**	**0.06**
Wave Energy (J/m^2)	**3838.05**	**4892.96**	**4004.14**	**4812.16**	**4132.08**	**7759.15**	**9543.51**
Mean Beach Angle (º)	**5.3**	**4.6**	**3.7**	**3.3**	**3.3**	**4.5**	**3.4**
Surf Scaling Factor	**5.65**	**9.19**	**10.77**	**18.39**	**93.57**	**12.30**	**24.89**
Surf Similarity Parameter	**0.50**	**0.40**	**0.34**	**0.31**	**0.28**	**0.34**	**0.25**

Table 5. Dissipative Domain Parameters outlined by Wright and Short (1983), Woodroofe (2002), and Masselink and Short (1993)

Attribute	**Parameter**	**Wright & Short (1983)**	**Woodroffe (2002)**	**Masselink & Short (1993)**
		Dissipative Domain	**Dissipative Domain**	**Barred Dissipative Domain**
Morphodynamic	Surf Scaling Factor	20-200	>20 (after Guza & Inman, 1975)	
Indices	Surf Similarity Parameter	<0.23	<0.64 (after Battjes, 1974)	
Waves	No. of waves in the surf zone	3		
	Approximate surf zone width (m)	100->1000		
	Breaker Type	Spilling		Spilling
	Angle of Breaker Approach	Shore normal 0°		
Morphology	Nearshore Bars in Surf Zone	Multiple shore parallel		Multiple shore parallel
	Slope Degrees	<1°		
	Beach Profile Form	Rectilinear		
Sediment	Mean Sediment	Silt to Fine Sand		
	(Phi) Size	>+2		

Table 6. Comparison of the Manzanilla Dissipative Domain with Wright and Short (1983)

Attribute	Parameter	Wright & Short (1983) Dissipative Domain	Manzanilla Dissipative Domain
Morphodynamic Indices	Surf Scaling Factor	20-200	4-94
	Surf Similarity Parameter	<0.23	0.25-0.60
Waves	No. of waves in the surf zone	3	3-5
	Approximate surf zone width (m)	100->1000	100-250
	Breaker Type	Spilling	Spilling
	Angle of Breaker Approach	Shore normal 0°	Shore normal-Slightly Oblique 0°-10°
	Wave Energy (J/m2)	-	3800-9500
	Wave Steepness	-	0.04-0.06
Morphology	Ripples on Lower Foreshore	-	wavelength 20-30cm
	Nearshore Bars in Surf Zone	Multiple shore parallel	Multiple shore parallel
	Megaripples Offshore	-	wavelength 25-60m
	Slope Degrees	<1°	3°-6°
	Beach Profile Form	Rectilinear	Flat Shoaling
Sediment	Mean Sediment	Silt to Fine Sand	Fine Sand
	(Phi) Size	>+2	>+2

Note: Additional parameters included in red

would fit into the dissipative domain. A consideration of some of the descriptive criteria outlined by Wright and Short (1983) such as width of the surf zone, number of waves in the surf zone, breaker type, presence of nearshore bars and sediment would support placing Manzanilla beach into the dissipative domain.

Application of the morphodynamic indices such as Surf Scaling Factor and Surf Similarity Parameter however, placed the sites at Manzanilla into the dissipative and intermediate domains as outlined by Wright and Short (1983). Using the Surf Scaling Factor on the coastal processes from winter 2005 to summer 2006 (in **Table 3**), only site 9 fell within the dissipative domain with site 4 coming close the value of >20 to classify it as belonging to the dissipative domain; with the other sites fitting into the intermediate domain.

Using the Surf Similarity Parameter, none of the sites fitted into the requirement of <0.23 for the dissipative domain, but rather fell within the intermediate domain. Only site 9 with a value of 0.27 came close to the criteria for the dissipative domain by Wright and Short (1983) over the period winter 2005 to summer 2006. The data for the 14 month period also showed that only site 9B came close to the required <0.23 in the surf similarity parameter required to belong to the dissipative domain. However, all the sites belonged to the dissipative domain as outlined by Woodroofe (2002) summary after Battjes (1974).

According to the classification outlined by Masselink and Short (1993) barred dissipative beaches have spilling breakers in the surf zone, a bar and trough morphology, and rips may be present. These criteria would place the sites at Manzanilla into the barred dissipative domain outlined by Masselink and Short (1993).

A consideration of both parameters (Surf Scaling Factor and Surf Similarity Parameter) would therefore place the sites at Manzanilla within either the dissipative or intermediate domains of beach stage classification by Wright and Short (1983). The dissipative sites were found at site 9 and to some extent site 5, while the intermediate sites were at sites 1, 2, 3, 4, 6 and 8. However, a consideration of other criteria outlined by Wright and Short (1983) and Masselink and Short (1993), such as width of the surf zone, number of waves in the surf zone, breaker type, presence of nearshore bars and sediment would support placing Manzanilla beach into the dissipative domain.

The beach at Manzanilla clearly belongs to the dissipative domain having considered most of the criteria, since the beach does not possess the criteria outlined for the intermediate domains based on breaker type and morphological characteristics. The attempt to classify the beach using only the Surf

Scaling Factor and Surf Similarity Parameter has proven to be problematic.

An attempt to classify Manzanilla beach into the existing models of beach state has highlighted the problems associated with such models. It should also be noted that the classification done by Wright and Short (1983) was based on the study of Australian beaches and the beach at Manzanilla would have slightly different environmental controls that affect its morphology, being exposed to the high energy environment of the Atlantic. This highlights the need for more studies to undertaken in the Caribbean region on open beaches so that beach states can be properly classified according to their unique environmental setting.

Having considered all of the criteria used in beach domain classifications, the Manzanilla beach belongs to the dissipative domain, however a different range of values for existing morphodynamic indices are presented. This classification therefore builds on the existing classification parameters outlined by Wright and Short (1983), Woodroofe (2002) and Masselink and Short (1993), with slight modifications to their morphodynamic indices. The classification by Wright and Short (1983) is most comprehensive, and therefore more suitable for comparison with the Manzanilla attributes. In addition to attributes provided by Wright and Short (1983): wave energy, wave steepness, lower foreshore ripples, and offshore megaripples, are also included (**Table 6**).

Finkl (2004) in his work on integrated and systematic approaches to coastal classification, proposed that a new system be applied to coastal classification, where the new system should classify more than the shore or coastline and should apply to a "zone" and not a line. The classification procedure should allow for "across-the-shore" variation as well as "along-the-shore" extent. The new classification system should be open ended so that new information can be added as required (Finkl, 2004). Fairbridge (2004) argues that coastal classification has been needlessly complicated in the past by failure to concentrate on directly observable attributes. Fairbridge (2004) is therefore suggesting that a more appropriate method for classification should first focus on the observed descriptive attributes of the system, which includes the environmental and historical setting.

The environmental controls on the morphology of Manzanilla beach include geographical location and its microtidal conditions, being exposed to the Atlantic Ocean, and the associated tropical storms and hurricanes that help shape the beach morphology seasonally. To this end, it would be better to offer a classification for this beach based on the physical attributes present at different sections of a typical beach profile. The most important parameters in beach classification at Manzanilla are breaker type, number of waves in the surf zone, width of the surf zone, presence of nearshore bars and sediment grain size.

6. CONCLUSIONS

Attempting to classify Manzanilla beach into the existing models of beach state classification has proved problematic. The lack of related research on Caribbean beaches exposed to the Atlantic has added to the poor understanding of beach states in the region. While extensive studies have been conducted and classifications made on North American and Australian beaches, their application to this beach system highlights some issues related to extrapolation of results.

As such, a dissipative model was designed for Manzanilla adapting from previous classifications. This classification builds on the existing classification parameters outlined by Wright and Short (1983), Woodroofe (2002) and Masselink and Short (1993), with slight modifications to their morphodynamic indices. As such the morphodynamic indices as well as the observable attributes of the beach have been discussed. A typical Manzanilla dissipative profile is also presented based on the physical attributes present on the profile.

The typical dissipative profile model of Manzanilla displays most of the attributes which defines a dissipative domain, such as, a flat shoaling beach slope, multiple offshore bars, and an extensive surf zone (>100 m). Additionally, the profile model presents the offshore morphology up to 10 m water depth which shows the presence of megaripples and sandwaves.

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