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An Assessment of Beach Erosion Hazards in Antigua and Barbuda

OAS/USAID Post-Georges Disaster Mitigation Project

Implemented by the Organization of American States,
Unit for Sustainable Development and Environment
for USAID-Jamaica/Caribbean Regional Program

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This report was prepared under contract to the PGDM by Philmore James, Antigua

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List of Acronyms

COSALC Coast and Beach Stability Project
GIS Geographical Information Systems
OAS/USDE Organization of American States, Unit for Sustainable Development and Environment
PGDM Post-Georges Disaster Mitigation
SIDS Small Island Developing State
TS Tropical Storm
UNESCO United Nations Educational, Scientific and Cultural Organization
UPR-SGCP University of Puerto Rico Sea Grant College Program
USAID-J/CAR US Agency for International Development-Jamaica/Caribbean Regional Program

Introduction

Background

Antigua and Barbuda, a Small Island Developing State (SIDS), has a fragile economy heavily dependent on coastal tourism. In addition, the country ranks high in terms of its vulnerability to tropical storms and hurricanes. Between 1995 and 1999, Antigua and Barbuda experienced four major hurricanes, which caused severe damage and loss to the natural environment and critical changes in the social and economic fabric of the country. The severe weather conditions may be related to climate variations, climate change and possible sea level rise. It is therefore critical to analyze the changes which occur around the coastal regions of Antigua and Barbuda and where possible to predict future trends in order to determine future development policy.

On 20-22 September 1998, Hurricane Georges, a category 3 storm, struck the Eastern Caribbean islands of Antigua and Barbuda and St. Kitts and Nevis causing severe damage to the economic and social infrastructure of these islands. In Antigua, the south coast of the island suffered most of the damage, with 400 homes destroyed, major damage to a number of health facilities, and a disrupted electrical supply. The tourism sector, livestock and fisheries also suffered significant losses.

In response to the damage from Hurricane Georges, the US Agency for International Development-Jamaica/Caribbean Regional Program (USAID-J/CAR), has established a program entitled *Hurricane Georges Reconstruction and Recovery in the Eastern Caribbean* specially targeting Antigua and Barbuda and St. Kitts and Nevis. The activity entitled *Post-Georges Disaster Mitigation (PGDM) is* the disaster mitigation capacity building component of the program. *The PGDM is implemented by the* Organization of American States' Unit for Sustainable Development and Environment (OAS/USDE) for USAID-J/CAR.

The goal of the PGDM program is to reduce the vulnerability of people and economic activities in St. Kitts and Nevis and Antigua and Barbuda to natural hazards, including tropical storms and related flooding, seismic and volcanic hazards, through enhanced capacity for hazard mitigation.

The Fisheries Division, in 1991, established a beach monitoring program within the regional 'Coast and Beach Stability in the Caribbean Islands' (COSALC) Project, sponsored by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the University of Puerto Rico Sea Grant College Program (UPR-SGCP). Nineteen beaches in Antigua and six in Barbuda are monitored quarterly using standard techniques to measure beach profiles; changes in the profile cross-sectional area and profile width are then determined. These data, collected for the selected beaches, along with other related physical, social and economic information will be utilized in this project to achieve the required objectives. Additionally, it is hoped that this project could become a model for other SIDS experiencing similar conditions.

This project focuses primarily on beach changes and the various causal factors which operate within the beach zone. The impact of hurricanes, storms and different human-induced activities will also be discussed.

Project Objectives and Outline

One of the major objectives of the PGDM project of the Organization of American States, is the development of national goals, objectives and actions to reduce the vulnerability of Antigua and Barbuda to natural hazards. A prerequisite for appropriate hazard mitigation strategies is a solid understanding of the existing hazards and their effects. Under this contract, an assessment of coastal erosion hazards will be

undertaken for the islands of Antigua and Barbuda. The improved understanding of these hazards will inform national coastal development and erosion hazard vulnerability reduction policies and measures for Antigua and Barbuda.

Under this contract, a hazard assessment of coastal erosion in Antigua and Barbuda was undertaken, using current coastal erosion hazard assessment methodologies. The main outputs include the production of a technical report and a non-technical summary of the coastal erosion hazard assessment for Antigua and Barbuda. The technical report describes the structure and content of the hazard maps, the methodology employed in map preparation, including data collection, analysis and final preparation, map use and limitations, metadata and information sources and guidance on understanding coastal erosion hazards. Recommendations for future work are also included. This report also identifies key contacts in Antigua and Barbuda for coastal erosion hazards.

The non-technical summary of the erosion hazard assessment for Antigua and Barbuda has been prepared for the layman and may be distributed independent of the technical report.

Apart from the demonstration of current geographical information systems (GIS) and other techniques that may be applied in the analyses, major objectives of this project include:

- The determination of which beaches are most vulnerable to erosion.
- The development of an index for the beaches which will demonstrate the erosion hazard.

The logical framework analysis, shown in Table 1.0, gives an overview of the project. The general outline of activities and the time schedule are shown in Appendix I.

The major constraints of this project include the following:

- Availability of data: only certain beaches are monitored, and there are many gaps relating to unmonitored beaches. Furthermore, rocky and cliffed shorelines are not monitored at present.
- Limited GIS hardware and software available on island: reducing the amount of analysis that could be accomplished.
- Time: the project schedule was very short, especially in view of the time of the year (Christmas holiday period).
- Technical assistance for the project is located outside of Antigua and Barbuda: and even with modern electronic contacts this could cause some delays.

Figures 1.0 and 2.0 provide maps showing coastal erosion hazards along the beach-monitoring sites of Antigua and Barbuda. The rates of coastal change are shown graphically in Figure 3.0.

TABLE 1.0 LOGICAL FRAMEWORK ANALYSIS

	Objectively Verifiable Indicators	**Means of Verification**	**Important Assumptions**
GOAL: Assess beach changes around Antigua and Barbuda	Beach width Hurricanes/storms	Actual changes in beach width	Beach changes are caused by specific factors
PURPOSE: Identification of beach changes around Antigua and Barbuda	Changes in beach width Hurricane/storm occurrences Other coastal activities	Changes in relation to Storms/hurricanes and other coastal activities	Specific causes of beach changes can be identified based on periods when storms are dominant
INPUTS: Beach monitoring Data collecting Data processing Equipment and supplies Project management	Monitoring of specific beaches Actual data (beach, hurricane, sand mining) Actual equipment and supplies A successful (completed) project	Working GIs project, including equipment, personnel and a database	Apart from the data used (causes), other factors are minimal in determining beach changes
OUTPUTS: Information (coastal data) Working GIS program Maps Reports Recommendations Management 0ptions	Changes (width) due to hurricanes and storms Changes due to other activities such as sand mining and coastal development Actual report with recommendations and management options	Actual data sets Maps produced Reports written	Beach width show the major beach changes During a storm, beach changes are due only to storm effects. Other Factors dominate beach changes outside of hurricane periods.

Figure 1.0 Coastal Erosion Hazard: Antigua

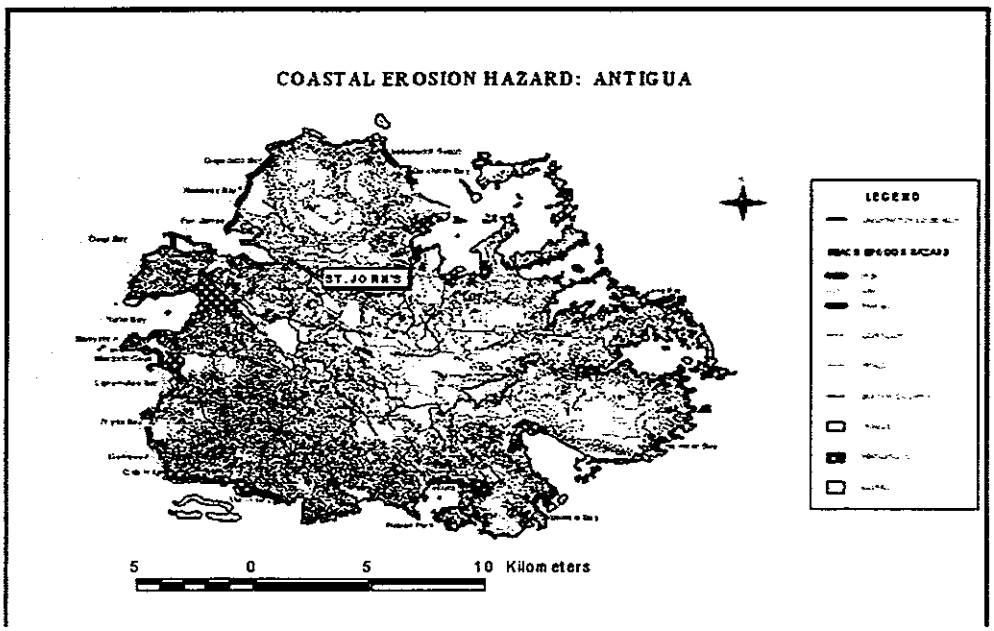


Figure 2.0 Coastal Erosion Hazard: Barbuda

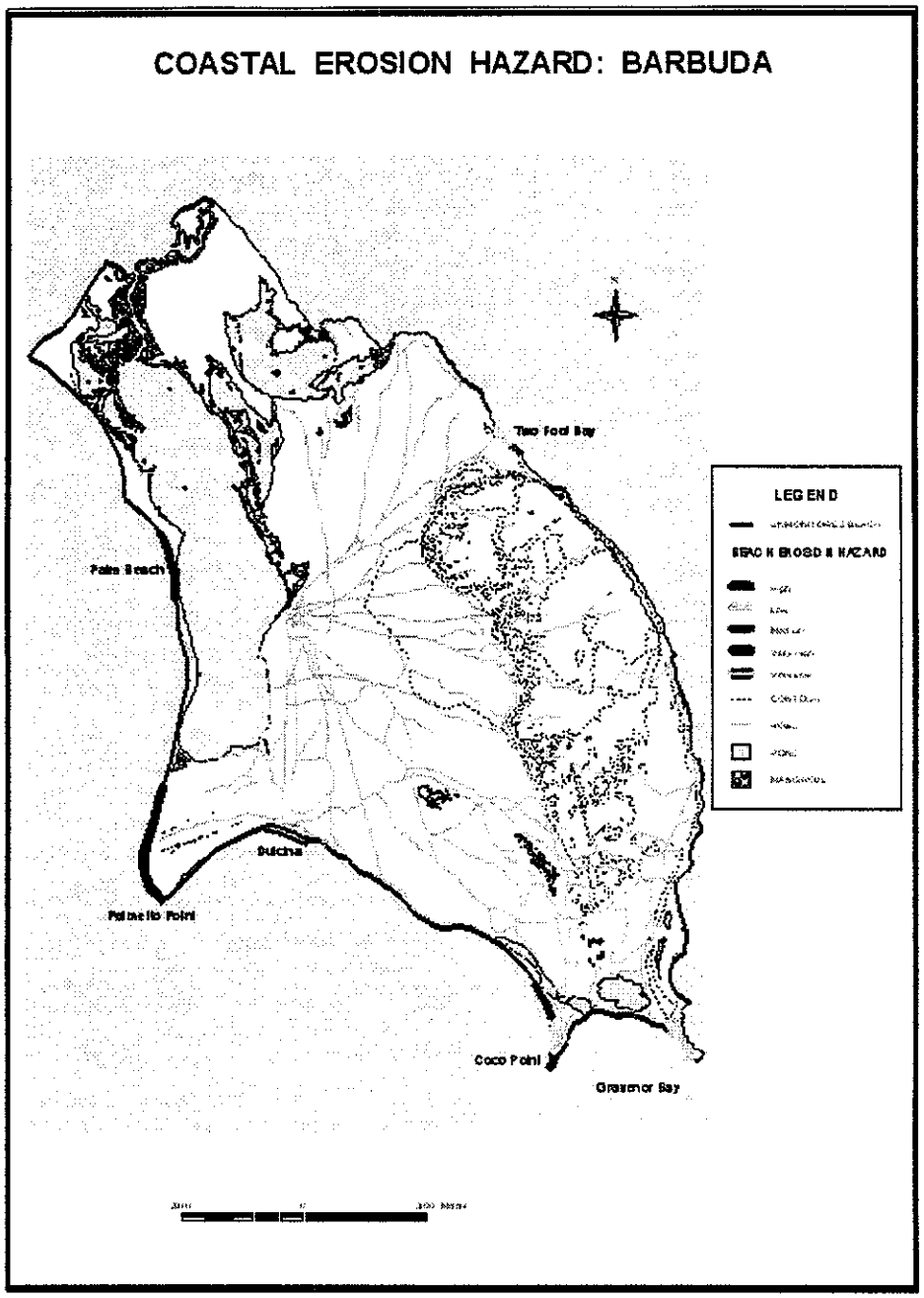
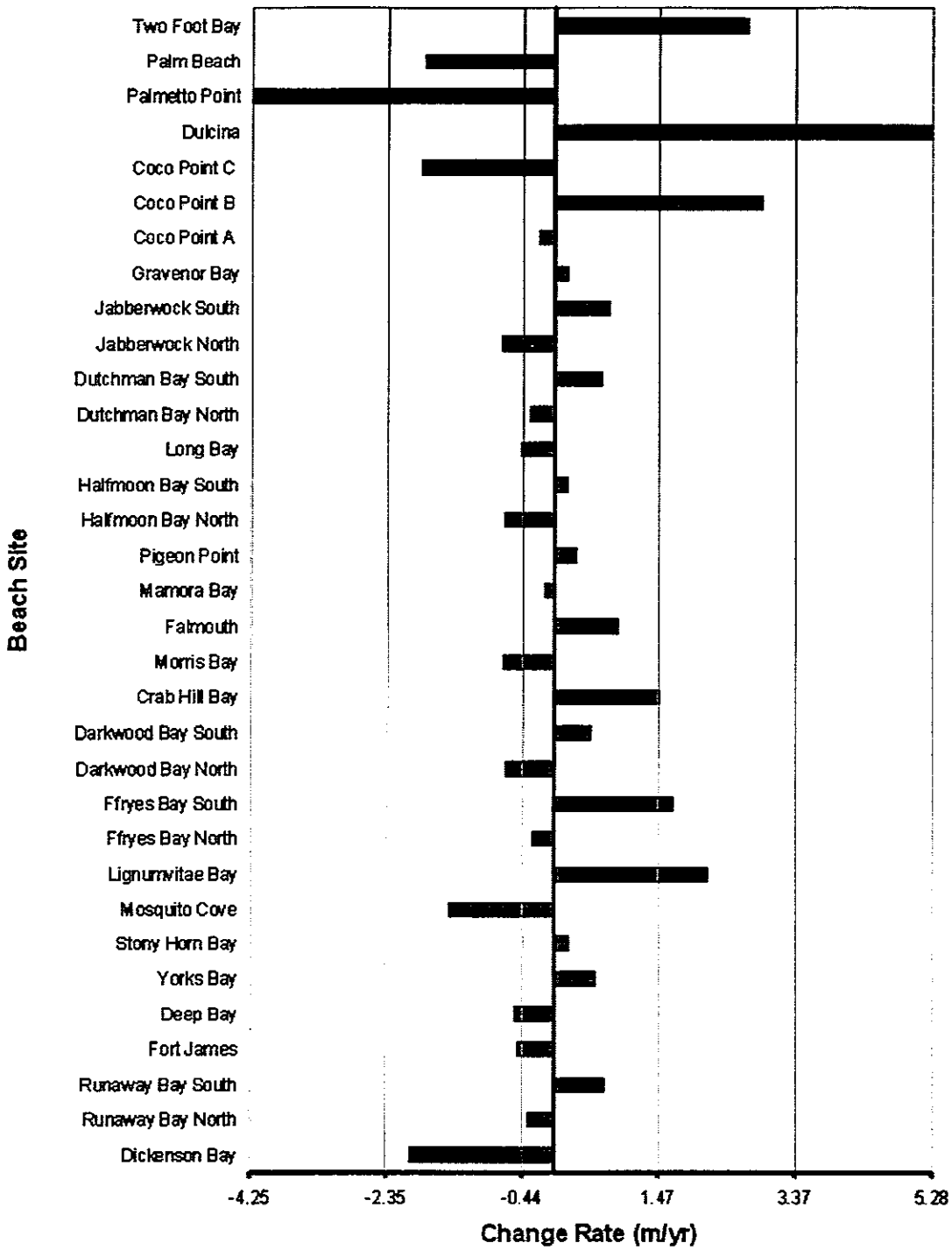


Figure 3.0 Coastal Change Rates: Antigua and Barbuda



Methodology

Several methods and techniques were used in developing this project, including surveying beach profiles, analysis of the beach data, and the use and application of various GIS computer hardware and software. The following activities are included in this hazard assessment work:

- Assembling of existing beach monitoring data for each island.
- Calculation of erosion/accretion rates for all monitored beaches.
- Assigning of coastal erosion hazard risk categories (very low, low, medium, high or very high) at the monitored beaches in each island.
- Production of island-wide geographic information system (GIS) data layers depicting the coastal erosion hazard risk zones. For each monitored beach, the layers show the calculated erosion/accretion rate. These data are in ArcView format, georeferenced to the common mapping standard for Antigua and Barbuda, and accompanied by the appropriate GIS metadata. The data dictionary is shown in Appendix II while the metadata are given in Appendix III.
- Production of island-wide coastal erosion hazard maps for Antigua and Barbuda, using the GIS data described above. These maps depict the coastal erosion hazard risk along the coastline using the following risk categories: high, medium, low and 'not monitored' for Antigua with two additional categories 'very high' and 'very low' for Barbuda. Maps include a common set of reference features that were provided by the PGDM.

Data Collection

Table 2.0 outlines the nature, format and source of data that was used in the project. The basic activities include:

- The calculation of beach width using primary beach monitoring data.
- The sourcing of other data including storm data and maps.

Beach monitoring was started in Antigua in 1991, thirteen beaches on the west, south and east coasts were selected for monitoring (Cambers, 1991). The selection included beaches showing the following characteristics:

- Varying beach dynamics between the windward and leeward coasts.
- Sites where sand mining is significant.
- Beaches important for recreation and tourism.
- Beaches impacted by development pressures and coastal reconstruction.
- Control sites where only natural changes are likely to take place

Table 2.0 Base Data for the Project

Base Data	Availability And Format		Source(s)
	Digital	Non-digital	
Beach data (width)		X	Fisheries
Hurricane data		X	Met. Office, www
Coastline, beach outline	X		PGDM Project
Hydrology: rivers, streams, watercourses, ponds	X		PGDM Project
Topography/contours	X		PGDM Project
Wetlands and other sensitive sites	X		PGDM Project
Location of major settlements	X		PGDM Project

Fisheries: Fisheries Division
Met. Office: Meteorological Office
www: World Wide Web

At most beaches, more than one profile site was established. In 1994 six additional beaches were added to the list of those monitored. Profiles are measured quarterly from fixed reference points located behind the beach, using Abney levels, ranging poles and tape measures, and the profiles terminate at the offshore step. The data are then plotted and analyzed using a custom-designed computer program; outputs include profile width and profile cross sectional area.

Beach monitoring was started in Barbuda in 1995, six beaches were selected for measurement, using similar selection characteristics as for Antigua, although in the case of Barbuda, the final selection was governed by accessibility to the site. Beach monitoring in Barbuda is undertaken with the assistance of the Coastguard, and is usually done between two and four times a year.

The Beach Profile Analysis Program was used to calculate average annual profile cross- sectional area and profile width. It was decided to use the profile width parameter as an indicator of the erosion hazard for this project, mainly because it is relatively easy to understand, e.g. if the profile width decreases over time, then the beach is eroding and the erosion hazard is greater than a profile where the width is increasing over time. For this analysis, the average profile width at a particular site for the first year of measurement was compared with the same parameter for the last year of measurement, and the difference between the two figures was divided by the number of years of measurement to provide a rate of coastal change in meters/year. However, it is recognized that more comprehensive erosion hazard indicators could be developed in the future.

The beach-monitoring program in Antigua and Barbuda concentrates on sandy beaches since these are of vital economic importance to the tourism industry. Rates of change on rocky and cliffed shorelines have

not been measured, but it is likely that they are considerably lower than those pertaining to sandy beaches in Antigua and Barbuda. Although in the case of cliffs, erosion is not usually a gradual process, but a sudden one, as large blocks collapse especially in fractured rocks such as limestone, see Cambers (1998) for a more complete discussion.

Data Automation

Using the GIS layers provided by the PGDM project as a base, new layers were created to show

beaches that are monitored/not monitored. All digitizing was done on screen. Categorization was done to show the varied beach erosion hazards throughout Antigua and Barbuda. Based on the information, maps were produced at a scale of 1:50,000.

The equipment utilized during the project include desktop computers, inkjet printers and a plotter while ArcView 3.1 was the main GIS software. MS Word 97 and MS Access 97 were used for word processing and data processing respectively.

Analysis

Using the beach monitoring and other data, major operational processes and activities were determined so that beaches affected by storms or other factors were identified. A coastal erosion hazard index was developed for the various beaches that are monitored around Antigua and Barbuda. The categories for the erosion hazard index are derived using the equal interval/class method. The rates of coastal change in Antigua and Barbuda were grouped and the range between the highest and the lowest erosion rate was determined. The range was then divided by the number of categories, which had been predetermined as five. The limits of each category were then determined as shown below:

Rate of Coastal Change Hazard category [m/yr]

+3.38 to +5.28 Very low
+1.48 to +3.37 Low
- 0.43 to +1.47 Medium or Moderate
- 2.34 to – 0.44 High
- 4.25 to – 2.35 Very high

The maps depict the hazard category for an individual beach or segment of the beach. At some beaches where there are several profile sites, it was observed that some segments of a particular beach might behave differently to others. For instance, at Runaway Bay, the northern profile site showed erosion, while the central and southern profile sites showed accretion. In cases such as this, where the particular bay was longer than 500 m, the beach was divided into two segments for the purposes of mapping. However, where a particular bay was very short, and a similar differentiation was observed, the map scale was too small to show this difference, and in such cases, an average coastal change rate was calculated for the bay and mapped. (This was the case for Stony Horn, Yorks Bay and Long Bay).

Structure and Content of the Hazard Maps

Together with the reports the hazard maps for Antigua and Barbuda form the main output of this project. The maps show erosion hazards for the various monitored beaches around Antigua and Barbuda. The base map was produced from overlays provided by the PGDM project. These include contours, roads, settlements and critical coastal habitats. The maps are drawn at a scale of 1:50,000.

The maps are entitled: Coastal Erosion Hazard: Antigua/Barbuda and the hazard categories are shown in color for easy reference and contrast. For Antigua the relative hazards are shown as low, moderate or high, while for Barbuda, where there is a greater range in the data, there are two additional categories: very low and very high, these show relatively extreme conditions.

Most of the map sheet is covered by the actual map which is accompanied by an illustrated legend. Apart from the various established symbols shown on the map the legend seeks to explain the meaning of the relative rankings in both quantitative and qualitative terms.

There is a caption indicating the suggested usage and limitations of the maps. These maps should only be used for the purpose of coastal erosion hazard analysis and not for all hazards since there are major limitations. The information is based only on changes in beach width. Using the given erosion rates, predictions regarding the erosion hazard can be made, although a longer time series would produce more accurate results. Without scientific evidence and reliable data, unmonitored beaches have not been ranked for erosion hazard, although various qualitative observations exist for some of these unmonitored beaches. The maps therefore do not indicate the erosion risk for beaches that are not monitored.

For up to date information on the state of the coastal areas of Antigua and Barbuda contact:

Fisheries Division
Ministry of Agriculture, Lands, Fisheries
Perry Bay
St. John's
Antigua W.I.
Tel./Fax: 1-268-462-1372
Email: fisheries@candw.ag

The logos of the sponsors or implementing agencies (USAID and OAS) are also placed on the maps. For additional information the PGDM website is given as the main contact for the project. This is shown as http://www.oas.org/pgdm.

Results and Discussion

Available data show that the number and intensity of tropical storms is on the increase. Table 3.0 clearly shows that the number of named storms has increased over the last five year period (55 %) as compared with the previous five year period (1990-1994), and the number of hurricanes per year has increased by 78 %. For the same period the number of hurricane days per year trebled while the number of category 3, 4 or 5 hurricanes quadrupled. Antigua and Barbuda experienced four major tropical systems during the past five years. Several beaches have changed their shape and character as a result.

Table 3.0 Hurricane Frequency Between 1990 and 1999 in the Atlantic Basin

Five Year Period	No. Named Storms	No. Hurricanes Per Year	No. Hurricane Days Per Year	No. Category 3, 4, 5 Hurricanes Per Year
1990 – 1994	8.4	4.6	13.6	1
1995 – 1999	13.0	8.2	41.4	4.0

Source: http://typhoon.atmos.colostate.edu/forecasts/1999/nov99/

Table 4.0 shows the major tropical systems that affected Antigua and Barbuda between 1995 and 1999. Four of the systems made landfall. Apart from the direct effects of hurricane winds, storm surges also impacted the coastline. At the monitored beaches, the changes in beach area and width result from a combination of factors including hurricane impacts.

Table 4.0 Tropical Systems which affected Antigua and Barbuda between 1995 and 1999

Name	Category	Wind Speed (km/hr)	Track Location Location	Date
Iris	TS	93	South	27-Jul-95
Luis	4	222	Landfall	09-Sep-95
Marilyn	1	148	North	15-Sep-95
Bertha	1	139	South	07-Aug-96
Hortense	1	130	North	09-Oct-96
Erika	1	130	North	09-Jun-97
Georges	3	185	Landfall	21-Sep-98
Jose	2	157	Landfall	20-Oct-99
Lenny	TS	102	Landfall	20-Nov-99

Note: Wind speeds are for the direct time of passage over Antigua and Barbuda

Analysis of the coastal change rates along the monitored beaches of Antigua (see Table 5.0) indicates that erosion is the dominant process on nine beaches while the other nine show accretion. Six of these beaches show marked variations along their length, in that erosion and accretion dominate on different segments of the beach. (As discussed in the Methodology section, a similar

variation was seen in three very short beaches: Stony Horn, Yorks Bay and Long Bay, but this variation could not be mapped because of scale limitations). Where there is variation between the different beach segments, erosion tends to dominate along the northern end of the beach, and accretion at the southern end.

As shown in *Table 5.0, most of the monitored beaches on Antigua (16) fall between the medium to high hazard category with one* in the medium to low (Ffryes) and two that are fully low (Crab Hill Bay and Lignumvitae Bay).

Table 5.0 Antigua – Mean Annual Rates of Coastal Change 1992 - 1999

Beach	Mean annual coastal change rate (m/yr)	Hazard category
Dickenson Bay	-2.01	High
Runaway Bay North	-0.37	Medium
Runaway Bay South	0.71	Medium
Fort James	-0.50	High
Deep Bay	-0.55	High
Yorks Bay	0.59	Medium
Stony Horn Bay	0.21	Medium
Mosquito Cove	-1.47	High
Lignumvitae Bay	2.16	Low
Ffryes Bay North	-0.31	Medium
Ffryes Bay South	1.68	Low
Darkwood Bay North	-0.67	High
Darkwood Bay South	0.52	Medium
Crabhill Bay	1.49	Low
Morris Bay	-0.71	High
Falmouth	0.90	Medium
Mamora Bay	-0.14	Medium
Pigeon Point	0.30	Medium
Halfmoon Bay North	-0.70	High
Halfmoon Bay South	0.19	Medium
Long Bay	-0.47	High
Dutchman Bay North	-0.34	Medium

Beach	Mean annual coastal change rate (m/yr)	Hazard category
Dutchman Bay South	0.66	Medium
Jabberwock North	-0.74	High
Jabberwock South	0.77	Medium

There was no clear pattern between the rate of beach change and the coastline orientation. The beaches on the northeastern side of the island tend to show overall accretion. This is noticeable for Jabberwock and Dutchman Bay. Although these beaches are open to winds directly off the Atlantic Ocean the effects are minimized by the presence of offshore reef systems. Furthermore at Dutchman Bay, an offshore breakwater provides additional protection. Similar reef protection exists at Halfmoon Bay and Mamora Bay, however, these beaches show overall accretion. On the south coast, Pigeon Point and Falmouth Beach show some accretion, this may be due to their sheltered nature within Falmouth Harbour. Morris Bay falls within the high hazard category, possibly a result of the open nature of the bay combined with the narrow shelf providing deep water conditions close inshore, which will increase exposure during storm events.

Along western Antigua, accretion dominates at Crab Hill Bay, Ffryes Bay, Lignumvitae Bay, Stony Horn and Yorks Bay. Most of these beaches are relatively open, although in the case of Lignumvitae Bay, T-shaped groynes may be playing a role in the accretion process. The more sheltered Mosquito Cove differs markedly in that like Darkwood Beach erosion tends to dominate. At Darkwood this may be due to the long-term effect of sand mining, while at Mosquito Cove it could be the combined impact of sand mining and harbour dredging.

The northwestern shore of Antigua has one of the highest levels of coastal tourism development. Beaches here show relatively high rates of erosion particularly along Dickenson Bay, which together with Deep Bay and Fort James show high erosion hazard. Runaway Bay falls within the moderate erosion hazard category, although it should be noted that the northern end of this beach showed very severe erosion, which started the year after Hurricane Luis (1996).

Although storm impacts are emphasized in this report, other factors play major roles in determining the erosion/accretion rates along the beaches around Antigua. The role of development too close to the coastline, sand-mining, dredging, coastal protection structures, beach orientation, and relief of nearby landscape should never be underestimated. The average annual width of monitored beaches over the period 1992-1999 on Antigua is shown in Appendix IV, and for Barbuda over the period 1995-1999 in Appendix III. An increase in the number of sites as well as the number of beaches monitored, in Antigua and Barbuda, would increase the database and the accuracy of the analysis.

In the case of Barbuda with its flat, low-lying landscape there is an even greater contrast in the rates. Of the six beaches monitored on Barbuda two (Two-Foot Bay and Dulcina) clearly show accretion as the dominant process while erosion is more significant for two others (Palm Beach and Palmetto Point). The different sectors of Coco Point, a long spit, tend to vary, with accretion dominant in the north whereas the peninsular in the south is eroding.

As depicted in Table 6.0, the hazard categories for Barbuda range from the extreme of very low (Dulcina) to very high (Palmetto Point). Palmetto Point is a large sandy promontory with an extensive array of sand dunes. Such promontories, like spits, are unstable and tend to move, sometimes dramatically. On the other hand the presence of an extended jetty at the River (near to Dulcina) could cause a build-up of sediments along the adjoining coastline. Palm Beach is located on a narrow sand bar enclosing the Codrington Lagoon, storms and hurricanes frequently

Table 6.0 Barbuda – Mean Annual Rates of Coastal Change 1995 - 1999

Site	Mean annual coastal change rate (m/yr)	Hazard Category
Gravenor Bay	0.189	Medium
Cocoa Point A	-0.211	Medium
Cocoa Point B	2.916	Low
Cocoa Point C	-1.862	High
Dulcina	5.278	Very Low
Palmetto Point	-4.25	Very High
Palm Bay	-1.816	High
Two Foot Bay	2.689	Low

cut through this bar. In spite of surrounding coral reefs, Coco Point is changing rapidly, the southern end of the spit is eroding, and accretion is occurring at the northern end. In the northeast, Two Foot Bay, which is exposed to the Atlantic Ocean, shows accretion and a low erosion hazard rate. This may be partly due to the fringing reefs along the northeastern coast of Barbuda.

In reference to the effects of tropical systems on the coastal areas of Antigua and Barbuda, various reports have shown that with the passage of a tropical storm or hurricane the rate at which coastal activity occurs tend to increase. (Black et. Al, 1996a, 1996b; Cambers 1993, 1996a, 1996b). Beaches therefore may show both seasonal and long-term changes as winds interact with waves, tides and currents. Erosion and deposition are the basic manifestations of beach change. The impact of hurricanes on beaches is significant since wind speed and direction are critical controlling variables of wave action.

While the relationship between the proximity of a hurricane center and the amount of beach erosion is essential, other factors that influence the severity of erosion must be analyzed. These include the characteristics of the particular hurricane, coastline shape, width of the offshore shelf and the presence of local features such as coral reefs. A more broad-based study may be needed to show a comparison between the effects of these factors and that of tropical systems on the coastline of Antigua and Barbuda.

Recommendations and Conclusions

Based on the nature and importance of the coastal landscape of Antigua and Barbuda, especially the beaches, there is a need to develop strategies to cope with the erosion hazard vulnerability. The following measures should be considered for the future:

- Increasing the number of monitored sites on individual beaches that are already monitored. This will improve the accuracy of analysis and interpretation. The frequency of monitoring could also be increased from quarterly to once every two months. Additional technical monitoring staff would be required.

- Increasing the number of monitored beaches: The beaches monitored should not only include beaches directly under threat because of misuse or overuse, but also more beaches which are close to their 'natural state'. This should give an indication of the relative effects of human related impacts on the coastal landscape.

- A team from Barbuda should be trained so as to ensure more frequent monitoring of beaches on the island.

- An inventory of coastal resources and uses needs to be prepared and regularly updated for Antigua and Barbuda. This would provide valuable information for future analyses of coastal hazards. To some extent, this process has already been initiated through the Caribbean Planning for Adaptation to Climate Change project (CPACC).

- With more time and resources, a broad-based approach should be developed to analyze coastal erosion hazards, incorporating additional parameters besides beach width.

Following the completion of this project, some useful suggestions were received from Dr. Cassandra Rogers of the University of the West Indies, relating to ways to enhance the coastal hazard mapping in St. Kitts and Nevis, and in Antigua and Barbuda, as well as in other such studies in different islands in the future. It was pointed out that the maps show the beach erosion hazard only, not the coastal erosion hazard, which would include other factors such as cliff erosion and changes in low rocky shores. However, quantitative data are not available for these sections of coastline. While additional information relating to the nature of the un-monitored coast, e.g. whether it consist of cliffs, beaches or other coastal forms, would be useful to the map user, this should be produced as an additional map, since it would complicate the beach erosion hazard maps. It was recommended that in future studies in other islands, alternatives to the equal interval method for determining the hazard categories should be considered. The beach change data sets are very small (25 beaches measured over 7 years in Antigua and 8 beaches measured over 4 years in Barbuda), and not sufficiently robust for this method, since adding one new beach with an extreme erosion/accretion rate would change the hazard rating dramatically. Furthermore, the beach erosion hazard categories of high, medium, low etc. determined by the equal interval method, have different ranges in each island thereby reducing the opportunity for inter-island comparison.

However, despite its obvious limitations, this present analysis can be used to inform the development of national coastal development policies and measures to reduce the vulnerability to coastal erosion hazards.

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APPENDICES

Appendix I: The Activity Timetable: November 2000 – January 2001

[The activity timetable is not included in this version of the report.]

Appendix II: Data Dictionary

FolderName	FileName / Type	Content /Attribute	Feature Type
Antigua	Shape Files		
	Beach.shp	Beaches	Point
	Coast.shp	Coastlines	Polygon
	Contour.shp	Contours	Line
	Corals.shp	Coral Reefs	Polygon
	Watercourse.shp	Drainage	Line
	Ponds.shp	Water Bodies	Polygon
	Mangrove.shp	Mangroves	Polygon
	Beach_Ant.shp	Monitored Beaches	Line
	Road.shp	Roads	Line
	Settlement.shp	Settlements	Polygon
	An_unmon.shp	Unmonitored Beaches	Line
	Arcview Project Files		
Antigua	antigua_pgdm.apr	(Antigua PGDM)	
	bmon.apr	Arcview Project (Antigua Beach monitoring Sites)	
	Documents,database, Spreadsheets		
Other	Beach	Beach Database	
	PGDM.doc	Final Project Document	

	FileName / Type	Content /Attribute	Feature Type

FolderName			
Barbuda	Shape Files		
	Beach.shp	Beaches	Point
	Barcoast.shp	Coastlines	Polygon
	Barconto.shp	Contours	Line
	Barponds.shp	Water Bodies	Polygon
	Barmangr.shp	Mangroves	Polygon
	Beach_Bar.shp	Monitored Beaches	Line
	Barroad.shp	Roads	Line
	Bar_unmon.shp	Unmonitored Beaches	Line
Barbuda	**Arcview Project Files**		
	barbuda_pgdm.apr	Arcview Project (Antigua PGDM)	
	barmon.apr	Arcview Project (Antigua Beach monitoring Sites)	

Most of the information were received as secondary data. However, the following information refers to the original Source Map:

Scale 1:25,000
Number of sheets 2
Contour interval 25ft and 100ft
Grid British West Indies
Projection Transverse Mercator
Spheroid Clarke 1880 (Modified)
Unit of Measurement Metre
Meridian of Origin 62 West of Greenwich
Latitude of Origin Equator
Scale factor at Origin 0.9995
False Coordinates of Origin 400,000 m Easting; Nil m Northing
Year published 1962

Appendix III: Metadata for Maps

Metadata for Coastal Erosion Hazard Data is available on the PGDM web site at http://www.oas.org/pgdm

Appendix IV: Barbuda Mean Annual Beach Width 1995-1999

Site	1995 (m)	1996 (m)	1997 (m)	1998 (m)	1999 (m)	Coastal change rate m/yr
Governor Bay	14.389	10.038	14.746	12.467	15.144	**0.189**
Cocoa Point A (K Club)	34.945	29.422	29.588	32.993	34.1	**-0.211**
Cocoa Point B (Hotel Cottage Wall)		48.044	56.314	60.716	56.793	**2.916**
Cocoa Point C (Hotel)		65.889	62.891	46.12	60.302	**-1.862**
Dulcina	38.163	50.288	49.352	48.221	59.275	**5.278**
Palmetto Point		52.011	109.302	114.235	39.261	**-4.25**
Palm Bay	34.372	28.294	25.814	26.052	27.107	**-1.816**
Two Foot Bay	39.415		42.799	45.947 61.31	62.845	**2.689**

Hazard Categories:

Rate of Hazard category Coastal Change (m/yr)

+3.38 to +5.28 Very low
+1.48 to +3.37 Low
- 0.43 to +1.47 Medium/Moderate
- 2.34 to – 0.44 High
- 4.25 to – 2.35 Very high

Appendix V: Antigua Mean Annual Beach Width 1992-1999

Site	1992 (m)	1993 (m)	1994 (m)	1995 (m)	1996 (m)	1997 (m)	1998 (m)	1999 (m)	Coastal change rate (m/yr)
Dickenson Bay A (North)	32.827	30.159	30.359	32.714	28.344	25.531	29.791	26.576	**-0.314**
Dickenson Bay B	18.192	14.933	17.945	18.251	33.409	26.077	31.116	24.876	**-1.412**
Dickenson Bay C	13.457	12.108	10.839	11.452	26.874	22.788	18.091	24.164	**-2.157**
Dickenson Bay D	22.889	10/054	20.959	15.164	18.674	12.375	8.934		**-3.241**
Dickenson Bay E (South)	29.922	26.073	24.052	26.371	16.577	15.188			**-2.947**
Runaway Bay A (North)	19.192	16.768	17.708	21.257	19.699*	14.399	17.060	15.035	**-0.371**
Runaway Bay B	26.455	24.488	25.265	23.644	30.147	31.592	31.187	29.78	**0.475**
Runaway Bay C (South)	30.311	25.394	26.211	30.106	35.308	40.014	39.399	36.961	**0.950**
Fort James A (North)	27.988	21.999	27.363	25.716	62.544	57.196	63.656	59.523	**-0.877**
Fort James B (South)	22.719	20.851	25.419	23.185	48.368	48.672	47.882	47.214	**-0.115**
Deep Bay A (North)	18.647	17.483	18.417	18.193	50.929	43.759	43.039	45.134	**-1.042**
Deep Bay B (South)	29.296	28.042	29.157	29.641	48.118	45.185	45.789	47.479	**-0.049**
Stony Horn A			18.617	16.923	12.993	15.198	15.016	15.149	**-0/694**
Stony Horn B			19.060	18.588	26.57	29.257	27.260	32.590	**1.110**
Yorks Bay A			27.680	30.286	32.663	31.865	34.001	35.938	**1.652**
Yorks Bay B			23.480	25.064	24.135	21.068	18.002 40.112	43.235	**-0.471**

* Some estimation involved at this site because the reference point was lost several times in 1996 due to erosion.

Site	1992 (m)	1993 (m)	1994 (m)	1995 (m)	1996 (m)	1997 (m)	1998 (m)	1999 (m)	Coastal change rate (m/yr)
Mosquito Cove			35.140	31.408	31.988	30.885	31.313	27.782	**-1.472**
Lignumvitae Bay A (North)			63.159	63.401	72.856	72.113	69.685	75.390	**2.446**
Lignumvitae Bay B			18.699	21.519	29.460	32.641	39.52	48.947	**6.056**
Lignumvitae Bay C		13.890	10.747	11.071					**-1.410**
Lignumvitae Bay D (South)				20.383	30.956	21.557	27.322	26.528	**1.536**
Ffryes Bay A (North)	33.497	31.593	28.418	28.612 76.298	67.499	71.617	71.684		**-0.347**
Ffryes Bay B	20.711	18.049	19.667	24.273 65.513	66.203	63.043	58.792	60.009	**-0.277**
Ffryes Bay C (South)	50.901	49.039	50.787	44.809	66.507	59.431	51.638	62.67	**1.680**
Darkwood Bay A (North)	39.395	34.224	35.280	30.510	23.262	22.299	23.919	30.244	**-0.730**
Darkwood Bay B	17.467	19.778	19.665	16.634 40.249	28.485	35.075	38.800	36.769	**-0.616**
Darkwood Bay C (South)	28.914	29.473	29.688	30.903	39.210	32.605	32.480	32.554	**0.520**
Crab Hill Bay	23.369	25.399	27.698	24.162	30.228	27.429	29.663	29.521	**1.490**
Morris Bay	19.950	17.513	19.502	17.414	12.726	14.160	13.676	15.014	**-0.705**
Falmouth Bay	24.522	28.704	29.021	30.013	33.341	34.070	32.752	30.829	**0.901**
Mamora Bay		10.728	12.197	10.519	10.552	10.085	9.876	9.884	**-0.141**
Pigeon Point A	31.020	30.662	30.976	28.097	34.077	33.981	33.894	32.206	**0.169**
Pigeon Point B	19.520	22.760	21.638	22.290	21.423	23.787	19.595	22.577	**0.437**

Site	1992 (m)	1993 (m)	1994 (m)	1995 (m)	1996 (m)	1997 (m)	1998 (m)	1999 (m)	Coastal change rate (m/yr)
Halfmoon Bay A (North)	44.555	34.015	38.429	40.231	38.997	39.912	31.222	39.560	**-0.713**
Halfmoon Bay B (Central)	33.909	30.863	30.983	36.193	35.797	35.448	36.551	34.826	**0.131**
Halfmoon Bay C (South – Hotel)	24.676	17.419	25.019	26.621	26.152	24.698	23.551	26.448	**0.253**
Long Bay A (East)	18.921	16.207	18.223	19.283	27.485	19.997	20.743 31.528	 29.681	**-1.371**
Long Bay B (West)	23.017	22.529	24.009	24.533	27.883	28.214	24.686	26.054	**0.434**
Dutchman Bay A (North)			27.015	23.276 23.622	26.380	29.274	26.831	27.774	**0.083**
Dutchman Bay B			25.234	26.414	37.264	22.925	23.048	21.414	**-0.764**
Dutchman Bay C (South)			16.776	21.489	17.649	17.242	14.730	20.049	**0.655**
Jabberwock A (North)	29.794	27.447	38.157	32.986	35.056	37.625	31.933 47.753	40.380	**-0.744**
Jabberwock B (South)	27.653	24.529	30.336	27.399	36.348	37.030	32.435	33.057	**0.772**

Hazard Categories:

Rate of Hazard category Coastal Change (m/yr)

+1.48 to +3.37 Low
- 0.43 to +1.47 Medium/Moderate
- 2.34 to – 0.44 High