FINAL REPORT
Preliminary Assessment of Beach Erosion at St. Margaret's Bay Portland, Jamaica

Ridge to Reef Watershed Project

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Preliminary Assessment of Beach Erosion at St. Margaret's Bay Portland, Jamaica

FINAL REPORT

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Prepared for the

Government of Jamaica's
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And the

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Preface

The Ridge to Reef Watershed Project (R2RW) is a five year (with an optional sixth year) activity contributing to the achievement of USAID/Jamaica's Strategic Objective 2 (SO2) - "improved quality of key natural resources in areas that are both environmentally and economically significant". R2RW comprises three Components contributing to the achievement of the results under SO2. Component 1 will assist targeted organizations identify and promote sustainable environmental management practices by resource users. Component 2 focuses on identifying and supporting solutions to improve the enforcement of targeted existing environmental regulations, primarily in the Great River and Rio Grande watersheds. Component 3 provides assistance to key organizations to support, coordinate, and expand watershed management efforts in Jamaica.

The Rio Grande Watershed in Portland is one of two targeted watershed areas in Jamaica for R2RW project activities. The Rio Grande River is world famous for its rafting activities. More recently sand quarrying has been taking place both upstream and down stream.

This study was commissioned by R2RW in response to reports of rapid erosion of the St. Margaret's Bay beach and a resultant loss of property to the sea. Residents claim that the beach erosion is linked to sand mining in the Lower Rio Grande.

The study brings scientific rigour to the questions surrounding the issue of beach erosion at this coastal town and attempts to answer questions regarding sustainable use of watershed resources.

The main author of study is Professor Edward Robinson, Professor Emeritus of the Department of Geography and Geology, University of the West Indies, Mona.

Executive Summary

The following document was prepared in response to a request from the Ridge to Reef Watershed Project (R2RW) to investigate reports from some of the citizens of St. Margaret's Bay, Portland, who were concerned at the extent of beach erosion in the eastern part of the township, which was leading to damage and destruction of buildings. The objectives of our investigation were to establish whether the beach erosion was significant, to determine the causes of the erosion and to develop an action plan for addressing the problem. It was the opinion of several residents that the erosion might be related to the sand and gravel mining operations in the bed of the nearby Rio Grande, so that our investigation was extended to include the mining activity.

In order to address these objectives, meetings were held with relevant agencies in Kingston (Appendix 1), the St. Margaret's Bay citizens (Appendix 2), and the operators of the Rio Grande mining concern (Appendix 5). Because of the historical significance of the rafting industry and its importance for the tourist industry, three members of the rafting community were interviewed for their opinions as to why erosion was occurring at St. Margaret's Bay (Appendix 3). The field visits included observation of the beaches of concern, including photographs of damaged structures (Appendix 2), and of the mining operations. Four lines extending from the road to the edge of the vegetated area next to the beach were measured to provide baseline information for any future monitoring that might be carried out (Appendix 4).

The beach of concern extends east from the centre of the town towards the Rio Grande. The road and houses behind the beach are sited on a thin strip of land between the beach and a small morass (see back cover photograph). The land itself is made up of semi-consolidated sand and gravel, evidently an old bar formed from sediments provided by the Rio Grande, which would initially have enclosed a lagoon, now infilled as the morass. This is the beach that is being eroded.

From our investigations we conclude that significant erosion has indeed occurred along this beach, affecting buildings near the shoreline. Study of old aerial survey photographs indicates that the major part of the erosion (up to 40 or 50 metres of shoreline retreat) occurred here immediately following the passage of Hurricane Allen in 1980. As an example, the old wooden manse, still standing at the eastern end of the strip, would have been some 60 or 70 metres from the coast before Allen, but is now quite close to the shoreline. However, the residents reported that the erosion now threatening their homes began to be more apparent about five years ago. Within the last six months about 2 metres of coastal recession has occurred. The recent retreat is mainly due to the passage of Tropical Storm Lili at the end of September 2002, and two severe northers which occurred in January and February of this year.

The present beach along this stretch of coast is composed mainly of gravel and cobbles, with very little sand. Such sand as is present may well have been derived from erosion of the vegetated area, on which the houses are built. It is evident from examination of air photographs that the beaches here and along the west side of the Rio Grande estuary have gradually disappeared. The estuary beach does not exist now and the beach of concern is narrow (1-3 metres) and it is apparent that replenishment of beach sediments is not taking place.

Although sand and gravel mining continues in the lower part of the Rio Grande, we are of the opinion that it has little direct connection with the most recent 6 months of erosion (see Appendix 6). This is because we also examined recent, similar coastal erosion that has occurred at Orange Bay, Portland, where there is no report of nearby sand and gravel mining. There remains a possibility that <u>sand</u> abstraction there has diminished the supply of sand available for possible beach replenishment. This is because the riverbed is dominated by gravel and boulders and sand may be a relatively minor constituent. A quantitative study of the river bed materials is needed.

The construction of the new marina at Port Antonio consumed considerable quantities of pebbles and small boulders, which were reported to have been taken from the lower Rio Grande about two years ago. The exact quantities reported to have been removed have not yet been ascertained, but are well in excess of the quantities of sand and crushed stone reported annually to the Mines and Geology Department. We believe the figure to be in the region of 60 000 to 90 000 cubic metres. The unusually large quantity abstracted for this purpose may have temporarily inhibited supplies of coarser grained material to the estuary and beach system, but we cannot confirm this, and a quantitative study of the transport of sand, pebble and boulder sized bedload needs to be carried out under different discharge conditions.

We conclude that, although it is apparent that the beach of concern is in an erosive phase, such phases are cyclical (or episodic), and in future might be replaced by a phase of deposition and extension of the beach area. Predicting such a reversal would depend on the findings and recommendations of studies proposed below. However, the vegetated area behind the beach is not likely to recover as an area suitable for housing for many years, especially if building codes, requiring, say, a 60 metre set back from the beach, are put into effect. Most of the world's beaches are currently in a state of recession, at least partly as a result of global sea level rise, and the beach at St. Margaret's Bay is not a special exception.

We propose that the following actions need to be taken.

1. An engineering study to determine the most appropriate kind of shore protection programme for early implementation, as the priority in the short term.

2. That some thought be given to relocation of the residents of this area in the medium to long term, as the flooding from the morass and erosion of the beach is likely to continue, unless the morass is properly drained and adequate, possibly expensive shore protection is installed. A possible alternative residential site for a fishing community might be along the beach near the Ken Jones Airport.

3. A detailed quantitative study of beach and shoreline dynamics and sediment dispersal should be made, to include bathymetric profiling and sediment sampling of the offshore area.

4. A similar study should be made of sediment composition and transport in the lower part of the Rio Grande and its estuary.

5. The Rio Grande is noted as being world famous for its rafting activities. Although not part of our project objectives, it was quite evident to us that a reconciliation of the rafting and river fishing activities with the mining activities has not yet been achieved. If the Port Antonio region is to be improved as a tourist focus then a real effort in this direction is required. Such reconciliation would also probably have spin-off for the future of the beach area at St. Margaret's Bay.

1. Background

The Rio Grande Watershed in Portland is one of two targeted watershed areas in Jamaica for the Ridge to Reef Watershed (R2RW) project activities. In its lower reaches, the Rio Grande flows through spectacular limestone scenery, and this stretch of the river has become a world famous tourist attraction as a scenic rafting trip. Towards the river mouth the floodplain widens and originally supported a flourishing agricultural industry. More recently sand quarrying has been taking place both in this part of the floodplain and upstream, just above the starting point for rafting. This has led, in some instances, to friction between the local communities and the mining concerns.

St. Margaret's Bay, Portland is a coastal town situated in the northern part of the Rio Grande Watershed on the immediate western side of the mouth of the Rio Grande (Figure 1). At the end of the 19th Century the railway from Kingston to Port Antonio was completed and the village grew around the local railway station in the early and mid 20th Century.

On December 5, 2002, staff of R2RW met with concerned residents of St. Margaret's Bay. A tour of the St. Margaret's Bay beach was conducted with residents who articulated the following:

- That the beach front along that stretch of the shoreline east of the town centre is rapidly eroding
- Persons are losing property, including buildings, to the sea
- They are convinced that the beach erosion is linked to sand mining in the lower Rio Grande. The claim is that sand mining reduces the rate of replenishment of the beach. Sand from up-river is no longer being transported by the river to the beach.
- The existing barriers (groynes) on the beach to the west of the town centre, installed and added to from the 1950s to protect the railway, no longer exist or have been rendered ineffective.

The author of the present report was asked to provide a preliminary assessment of the basis for the concerns expressed. This assessment was carried out over the months of March and April 2003. A more detailed reiteration of the concerns expressed above appears in Appendix 2 of this report.

2. Purpose of the Investigation

The purpose of the Scope of Work (SOW) is to conduct a preliminary investigation of the St. Margaret's Bay Beach to:

- Establish whether beach erosion is significant along the coastline of St. Margaret's Bay
- Determine the causes of the said beach erosion, and whether there are linkages to activities such as sand mining in the Rio Grande
- Develop an Action Plan for addressing the problem.

To achieve these goals the following activities were carried out.

1. Meetings were held with the relevant agencies and other institutions regarding the problem and identifying any information they were able to contribute (Appendix 1).
2. Meetings were held with concerned residents at St. Margaret's Bay and a guided tour of problem sites was provided by the residents to indicate the precise nature of the erosion problems being encountered (Appendix 2).
3. Interviews were also held with members of the rafting fraternity (Appendix 3).
4. Four survey lines were run through the affected area at St. Margaret's Bay to provide baseline data for the possible monitoring of future erosion (Appendix 4).
5. A visit was made to the sand and gravel extraction operations in the lower course of the Rio Grande to examine the mining procedures (Appendix 5).
6. Stops were made at Hope Bay and Orange Bay, west of St. Margaret's Bay, to determine whether or not similar evidence of recent erosion was apparent (Appendix 6).
7. A visit was made to the new Marina at Port Antonio to ascertain the nature of dredging and construction activities last year (Appendix 7).
8. Research was conducted to identify all possible sources of an historical nature that might provide additional information on the problem (Appendix 8).
9. The relevant aerial photographs and published maps of the region were acquired and examined to provide a series of geo-referenced snapshots, in order to reconstruct the historical progression of changes in the coastline of concern and in the lower reaches of the Rio Grande over the past 60 years (Appendices 9 and 10).
10. A preliminary examination of tide, wind, wave and storm/hurricane data was made, together with relevant literature on coastal processes.

3. Physical Features

Introduction

The area of concern is included in a four-kilometre stretch of coastline extending from Downer's Bluff west to Welsh Woman's Point (Figure 1). The plan view of the coast between these extremities, herein called the St. Margaret's Bay Beach System, is that of a typical zetaform beach, sharply curved at its eastern end (Davies, 1972). The coastal area of low-lying, largely unconsolidated sands and gravels, is of variable width, and is backed by steeply sloping limestone hills. The area includes the lowest reaches and the estuary of the Rio Grande. The island shelf is relatively narrow in this region, probably less than 2 km (although no bathymetric surveys have been conducted). To seaward the sea floor steepens sharply to depths in excess of 1000 m. Dredge and core samples containing coarse pebbles and cobbles recovered from these depths by the RV GOSNOLD in the 1970s (personal cruise records) indicate a deep sea fan offshore of the Rio Grande mouth. It is surmised from these data that there is probably a submarine canyon extending across the shelf from near the mouth of the Rio Grande.

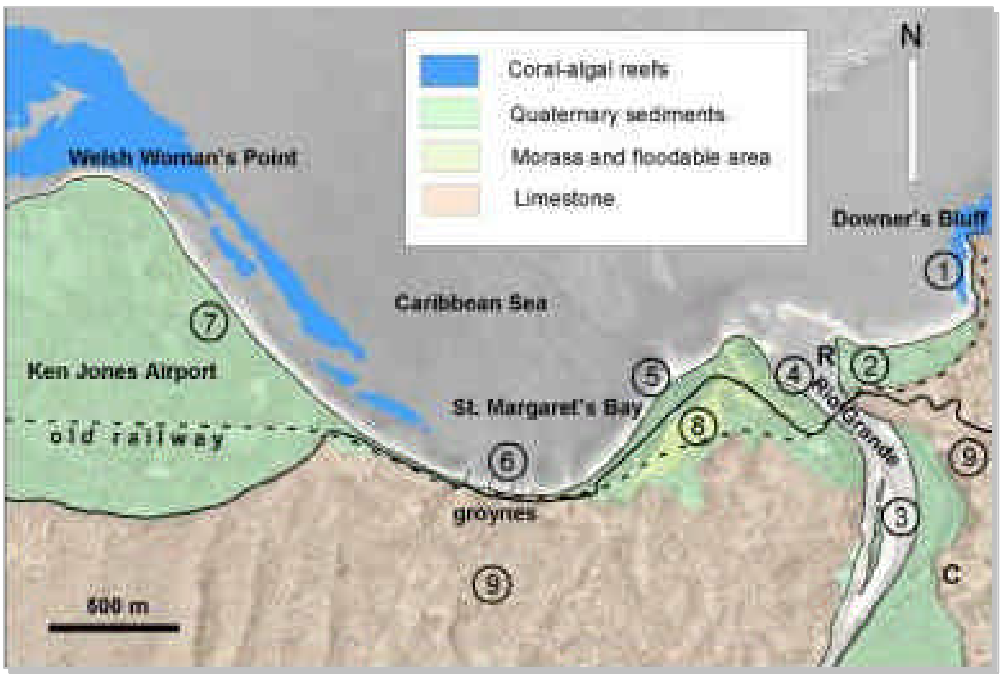

Figure 1	Location map of St. Margaret's Bay. Circled numbers refer to the physical units described in section 3. R, Rafters' Rest; C, site of sand and gravel crushing plant. The map is based on a 1961 aerial photograph.

Physical Units

For descriptive purposes the area is divided into the following nine units:

1. The rocky coast from Downer's Bluff to the Rafters' Rest beach.

2. The beach and housing area east of Rafters' Rest.

3. The lower reaches of the Rio Grande, above the main road bridge.

4. The Rio Grande estuary below the bridge.

5. The beach of main concern, fronting much of the settlement of St. Margaret's Bay.

6. The beach fronting the western part of St. Margaret's Bay, including the groyne field.

7. The beach and low-lying peninsular of Welsh Woman's Point, containing Ken Jones Airport.

8. The morass behind St. Margaret's Bay.

9. The back coast hills.

The Rocky Coast from Downer's Bluff to the Rafters' Rest Beach

The rocky coast south of Downer's Bluff is constructed of limestone belonging to the White Limestone Group of Tertiary age. Beach development is negligible and carbonate (white sand) sediments are dominant in the nearshore zone. Offshore coral-algal reefs extend south from Downer's Bluff, nearly as far as the beach at Rafter's Rest (Figure 1).

The Beach and Housing Area East of Rafters' Rest

Extending east from the estuary of the Rio Minho is a flat area (berm platform of Davies, 1972) made up of siliciclastic (non-carbonate) sediments (sand and pebbles) derived from the Rio Grande. The beach is relatively wide, swash aligned (up to 10 m) and cuspate. Cusps formed probably during stormy weather and seem to be of two generations. Grain size ranges from sand to cobble-sized particles, and increases from the swash zone (sand) to berm platform (cobble). At the western end the beach pebbles are relatively large (average size 3-4 cm, largest 10 cm). The particle sizes are arranged in layers cut by cusps which increase in size towards the berm platform. Grain-size decreases along the beach towards the east and includes sand at a distance of about 150 m from the western end. Beyond the swash zone the sea floor is made up of cobble-sized particles. The coastline along this unit appears to have remained more or less stable over the past sixty years, based on analysis of air photographs. The berm platform behind the current berm and beach consists of sand, which seems to be better sorted than that found in the swash zone.

The Lower Reaches of the Rio Grande, Above the Main Road Bridge

The Rio Grande has a sinuous course within a narrow floodplain (confined/wandering meanders of Mollard, 1973, in Selby, 1985, fig. 10.6), hemmed in by steep-sided, limestone hills. Above the main road bridge, it forms a large bend trending towards the right (west) as one looks upstream. This segment of the river forms a meander that has evolved naturally with an increasingly convex face towards the east over the past fifty years, at the expense of a formerly extensive, cultivated floodplain. The river is now eroding the right bank of the river along the road to the sand and gravel crushing plant. Point and midstream bars have developed on the west side of and within the meander (Appendix 8).

The Rio Grande Estuary Below the Bridge

The Rio Grande estuary is funnel shaped, expanding in a seawards direction to about twice the width of the channel at the bridge. From all the photographic evidence and from personal observations over the years, a river-mouth bar has been a constant feature of the estuary, although its shape and extent varies considerably over time. The eastern part of the bar is normally evident as a spit of variable length extending out from the northwest point of the Rafters' Rest beach. On the day of our visit (March 25, 2003) no spit was visible, but there was a breaker line on a submerged bar. The western segment is normally present as a short spit or extended beach. Usually any gap in the bar is on the western, rather than the eastern side, but exceptions occur (Figure 2) and the position of the gap may have migrated over time from a more easterly position. The eastern shore of the estuary forms the beaching area for rafts and the Rafters' Rest complex. It consists of mixed sand and gravel, disturbed by rafts being drawn up on the beach, and is protected by a pebble barrier beach at the northern extremity. The western shore is forested at the present day, and without a beach, but some sixty years ago and, perhaps before, consisted of sand bars partly enclosing a lagoon complex on the estuary side of the coast road (Appendix 10; figure for 1941).

The Beach of Main Concern, Fronting Much of the Settlement of St. Margaret's Bay

The beach area fronting the eastern part of the township of St. Margaret's Bay is the zone where recent erosion by the sea has caused much concern among the residents. This is further described and discussed below. Here it is sufficient to note that, at the present day (March 2003), the beach is very narrow, dominated by shingle, and backed by a berm platform about 1.5 m above sea level showing signs of recent erosion along its seaward margin. This platform consists mainly of sand within which pebble stringers are more or less prominent. It extends from immediately behind the beach, back across the coast road to the edge of the morass behind the town (Figure 3). This low platform probably originated as a bar or spit, extending west from the mouth of the Rio Grande, eventually to enclose a former lagoon, now infilled as the morass described below at 8. The date of its formation has not yet been determined.

The Beach Fronting the Western Part of St. Margaret's Bay, Including the Groyne Field

The shingle beach just described is abruptly replaced westwards by a sand-dominated beach, passing into pebbles at the waterline. The beach widens significantly westwards and there appear to be no erosion problems here. There is a narrow berm behind the beach and this backs on to limestone bedrock along the site of the old railway. Two groynes were erected in this area in the early 1950s in positions either side of the level crossing, and two more were added by 1961. The remains of three of these groynes are visible at the present day. They appear to have been successful in inhibiting erosion here. Piling of sand on the eastern side of some of these confirms the general pattern of longshore drift in a westerly direction (Figure 3), but such drift may now be inactive among the more westerly groynes.

The Beach and low-lying Peninsular of Welsh Woman's Point, Containing Ken Jones Airport

A wide cuspate beach extends in a gradual curve from the groynes to Welsh Woman's Point. Opposite the Ken Jones Airport the beach sediments are mixed sand and moderately sorted, small pebbles. Towards the Point the sand becomes less dominant and is replaced at the Point by an extensive, steeply sloping pebble beach. This beach is fronted by completely submerged coral/algal reefs showing a well-developed groove and shute structure. The reef system becomes more extensive at the Point and large fragments of elkhorn coral break the sea surface, probably as rubble resulting from storms. At the Point a tombolo (or cusp) extends from the pebble beach to the reef crest. The wide peninsula behind the beach, on which the airport is built, is raised 1.5 to 2 m above the shoreline and appears to consist of a large berm platform (Figure 1).

The Morass Behind St. Margaret's Bay

Behind the coast road in the eastern part of St. Margaret's Bay there is a narrow zone of morass. This is permanently waterlogged and drains into an eastward flowing, probably originally canalized stream system. The drainage exits the morass beneath the coast road and turns north to flow sluggishly to the northwestern tip of the Rio Grande estuary through overgrown lagoons behind the forested western shore of the estuary. Free flow into the sea is restricted by a pebble bar. The whole drainage system is now extensively overgrown, mainly by *Hedychitium* and the morass is reported to flood over the main road whenever significant rainfall occurs. Floodwater rises by as much as 2 ft. (0.6 m) and also floods the precincts of the Baptist church. Apparently the morass was originally used for rice production, and this report is supported by examination of the early air photographs.

The Back Coast Hills

The back coast hills are steep-sided and constructed of folded rocks of the White Limestone Group of middle Tertiary (Eocene to Miocene) age. Outcropping limestone extends close to the shoreline along the area protected by groynes (figure 1).

Figure 2 Oblique air photograph, August 7, 1980, taken immediately after the passage of Hurricane Allen showing large rivermouth bar (J. Tyndale-Biscoe).

Figure 3 Oblique air photograph, June 18, 1969, showing S. Margaret's Bay. The area with trees between the sea and the morass is the current coast of concern (J. Tyndale-Biscoe).

4. Tide, Wind And Wave Data

Along this section of the coast there is a microtidal regime, the tidal range being about 30 cm. The direction of travel and the height of incoming waves to the St. Margaret's Bay coastline are primarily governed by the intensity, duration and direction of propagation of the winds that generate the waves. Over most of the year the wind is mainly coming from an easterly, even southeasterly direction. The subsequent waves also travel from a similar direction, but are refracted around the headlands in the Port Antonio region and at Downer's Bluff, so that along this part of the coast the waves come in mainly from the northeast. Figure 4 is a rose diagram of wind speeds and directions for Plumb Point on the Palisadoes. Table 1 gives data on wind speed and direction for a data recording buoy that was situated in the middle of the Caribbean Sea (near 15N, 75W, or about 350 km south east of Jamaica) and maintained by the NOAA National Data Buoy Center, USA.

Table 1 Data (mean values) from NOAA Buoy 41018 from August 1, 1994 to January 1, 1996 (adapted from Calverly et al., 2001)

Wind speed (m/s)	7.79
Wind direction (deg.)	90.93
Significant wave height (m)	1.63
Wave period (s)	5.19

The dominantly northeast origin of wave trains is supported by the direction of trend of the beach along the east side of Ken Jones Airport and Welsh Woman's Point. This is the open, swash aligned part of the zetaform beach extending from the mouth of the Rio Minho to the tip of Welsh Woman's Point. This dominance is also supported by the westerly longshore drift observed at the groyne beach (Figure 3).

However, it was noticed that the dominant wave trains on the aerial survey photographs used for this study were coming mainly from the north or northwest (Table 3 and Figure 5). For weather and visibility reasons surveys of this kind are carried out in the winter months (December to April). This would suggest that the wave trains on these particular photographs reflect the common incidence of northers at this time of the year.

Table 2 Directions of main offshore wave trains from air photographs

A) Vertical Aerial Survey Photographs And Satellite Imagery		**b) Oblique Air Photographs**	
1954, February	From the north	2001-02	Not determined
1961, April	From NNW	18-06-69	from the north-east
1968, February	From the NW	29-07-72	from the north-east
1980, February:	No data	07-08-80	(post-Allen) large swell from west; smaller waves from NNE
1992, January	From N to NNW		
1999, February	From ENE to ESE and NE		

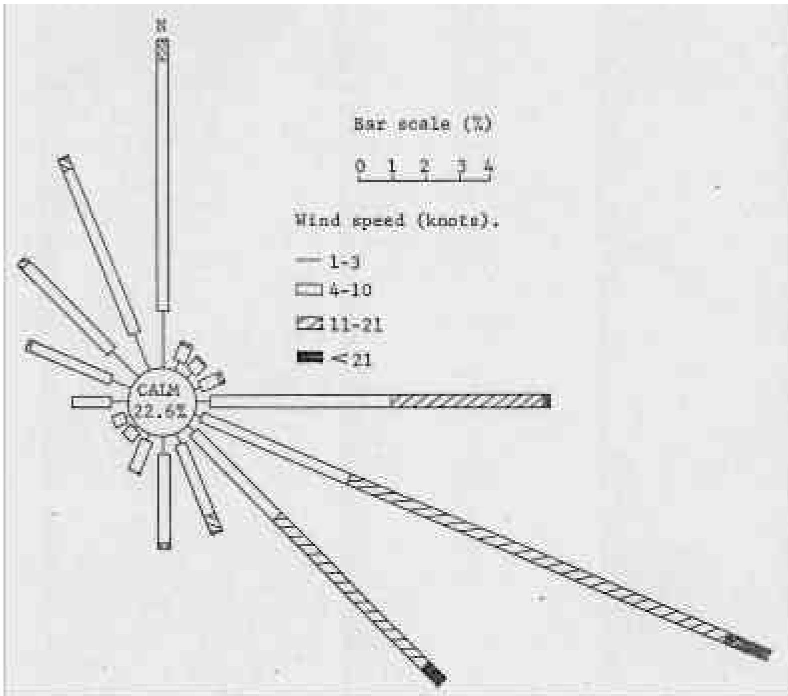

Figure 4 Palisadoes wind rose (from Hendry, 1978)

Figure 5 Air photograph taken in winter 1961, showing wave trains from the northwest.

5. Beach Erosion at St. Margaret's Bay

A meeting was held with concerned citizens at St. Margaret's Bay on March 3, 2003, under the leadership of Ms Winifred Moore, President of the St. Margaret's Bay CDC. The full text of the observations made and discussions held is given in Appendix 2. Interviews were also held with three of the raft operators, who also included their views on the erosion problem (Appendix 3). Here the first objective required by the Scope of Work (SOW) is addressed:

Establish whether beach erosion is significant along the coastline of St. Margaret's Bay

At the outset it can be confirmed that considerable erosion has occurred along that stretch of coastline extending from the Rio Grande estuary to the groynes beach. The extent of this erosion is now affecting people's property in a significant manner, including damage to and partial loss of buildings. These conclusions are drawn from evidence from a) analysis of aerial photography and satellite imagery taken at intervals from 1941 to 2002, and b) direct observation of coastline conditions on March 3 and 4, 2003.

a) Evidence from Air Photographs

To take the evidence from the photographs first, Appendix 9 shows the coastline geometry here for the winter months of the years 1954, 1992 and the present day (2001-02). Up until early 1980 the coastline here was more or less convex (bulging) towards the sea, although by early 1980 the convexity had diminished slightly, indicating some degree of marine erosion. On August 6, 1980, the eye of Hurricane Allen, one of the most severe of the 20th Century, passed within 30 miles (48 km) north of Port Antonio (Wilmot-Simpson, 1980). This hurricane caused a surge along the whole of the Jamaican north coast, estimated to be 15 feet (4.6 m) at St. Margaret's Bay and inundating the coast for about 200 m inland. The estimate probably includes the height of storm driven waves. Forty-five buildings were affected, many wooden houses being destroyed because they were not properly anchored (Wilmot-Simpson, 1980 p. 23). On all photographs examined, dated after the passage of Allen (Figure 6, and vertical survey photos, 1992 onwards) the bulge has been removed on the coast of concern. Figure 7 shows the coast of 2001-02, obtained from IKONOS imagery, superimposed on part of the topographic map of the same coastline based on the 1968 air photographs. Up to 50 m of coastal recession is evident in the region of the former bulge. However, to begin with the coastal recession did not affect buildings (although loss of land occurred) as all the dwellings along here are built near to the road.

b) Evidence from field visits of March 3-4 and March 25, 2003

The visits made in on March 3 and 25 revealed that the coast shown in the 2001-02 IKONOS image has suffered further erosion since then (Appendix 2). This was agreed by most residents to have occurred within the last few months. We concluded that this was partly a result of the passage of Tropical Storm Lili and, most recently, from at least two severe northers in January and February. The statements of the residents were supported by the evidence of recently fallen coconut trees in the swash zone of the beach, and the exposed root systems of other trees that normally grow some distance from the actual shoreline (Appendix 2). In addition, the berm platform showed extensive evidence of very recent erosion, with sand and pebbles from the platform being added to the swash zone of the beach. Close inspection of the IKONOS image also supports these assertions. Survey tape measurements were made from the road to the edge of the berm platform (Appendix 4) to provide reference points for comparison with future changes.

c) Discussion

The recent retreat is estimated to have resulted from an average 1-2 m of erosion of the berm platform over the past six to nine months. Over the last 20-25 years coastal recession on this stretch of coast has averaged about 2 metres per year. If this rate is projected uncritically into the future, it would seem that none of the present buildings or the main road would survive beyond the next 60 years, and the shoreline would be at about the northern edge of the morass behind the road. However, use of this average erosion rate as a model for future erosion ignores the fact that the rate has clearly varied, with most of the coastline loss occurring at the time of Hurricane Allen. If the loss from Allen is ignored as being a rare extreme event, then the average loss over the 20 year period would be nearer to 50 cm per year. An investigation of the nearshore currents and bottom topography should be undertaken to estimate how these might be affected by gradual changes in the geometry of the shoreline. It should also be noted that the stretches of shoreline to the east and west of the area of concern have not suffered similar changes. To the east, at the western side of the mouth of the Rio Grande, the shoreline has actually advanced by several metres (Appendix 9), while to the west the beach with the groynes is relatively wide and appears to have suffered little change over the same 20 year period (Appendix 2, photo 11).

6. Determining the Cause of Beach Erosion

The second objective of the SOW was:

Determine the causes of the said beach erosion, and whether there are linkages to activities such as sand mining in the Rio Grande

Beach Processes at St. Margaret's Bay

The St. Margaret's Bay beach system, extending from the Rio Grande estuary to Welsh Woman's Point (figure 1) is an open system, with a dominant longshore drift direction towards the west. The dynamic equilibrium of the system results from the interaction of marine wave, tide and current processes, which govern the distribution and movement of beach sediments, and the existence of a source of sediment supply. In this case the major source is sediment brought down by the Rio Grande. The beach system is open because longshore drift is moving beach sediments gradually from the mouth of the river westwards to Welsh Woman's Point and beyond. Sediments moved beyond the point are lost to the St. Margaret's Bay system and ultimately must be replaced from the Rio Grande source. If they are not replaced, then there will be progressive removal of existing beach sediment, beginning on the west side of the Rio Grande estuary and progressing west. Similar situations are present in most beach systems dominated by sediment input from rivers, and occur elsewhere in Jamaica, such as in the Annotto Bay area (Wagwater River) and the Vere coast of southern Clarendon (Rio Minho).

Because the region behind the beach at St, Margaret's Bay consists of largely unconsolidated sand and pebbles forming the berm platform, beach sediment can also be replenished through erosion of this platform. This will occur preferentially in times of heavy swells, when beach materials tend to be moved offshore to form bars, leaving the berm open to wave attack. During times of calm weather (usually the summer period) the offshore bar sediment will frequently be returned to the beach. However, sediment previously eroded from the berm platform might also be returned to the beach, but not to the platform, so that permanent loss of platform results. This is what appears to be happening to the beach of concern at this time.

Decadal or even century-long cycles of beach erosion and progradation are commonplace globally, with erosion or recession being most common (Bird, 1985). Along the east coast of North America erosion dominates some 90% of the beaches at the present day (Leatherman et al. 2003). Cooper (2002) has suggested that, for small, river-dominated estuaries in South Africa, and for the beach systems influenced by them, perhaps extreme floods are necessary to effect a reversal from recession to progradation. There may be a time lag of up to several years for such a reversal to become apparent. This suggestion is supported by observations of the beach history along the Vere coast of southern Jamaica (Robinson, submitted).

Figure 6	Oblique air photograph, September 28, 1984, showing straightened beach (right-hand edge of photo) following Hurricane Allen (J. Tyndale-Biscoe).

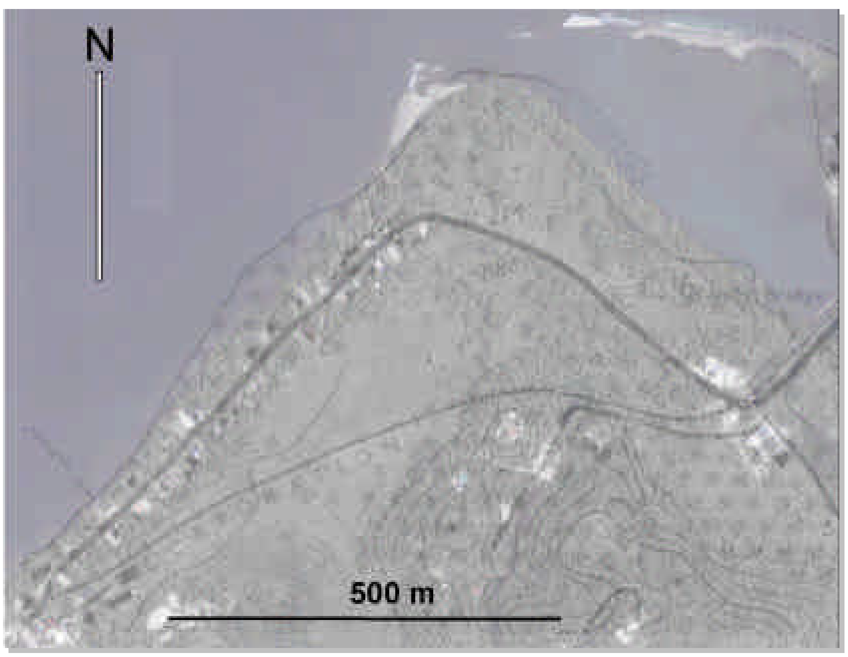

Figure 7	Shows the coast of 2001/2 obtained from IKONOS imagery, superimposed on part of the topographic map of the same coastline based on the 1968 air photographs.

Seven mechanisms are put forward for discussion as possible causes of beach erosion at St. Margaret's Bay are:

- Wave erosion by passing tropical storms and hurricanes
- Wave erosion by the onset of severe winter northers
- Interference in sediment supply from Rio Grande sand and gravel mining
- Interference in sediment supply due to marina construction at Port Antonio
- Interference in sediment supply for other reasons
- Beach recession through global sea level rise
- Beach recession through human interference other than mining

Wave Erosion by Passing Tropical Storms and Hurricanes

The effects of Hurricane Allen in 1980, when up to 40 m of recession occurred, have already been discussed. The area between the morass and the sea at St. Margaret's Bay is a berm platform, only 1-2 m above sea level, constructed, as noted above, of largely unconsolidated sand and pebbles derived from the Rio Minho. As such it is vulnerable to damage and reduction from any kind of severe storm or hurricane. The main protection is afforded by the root systems of the coastal vegetation of palm and almond trees. As the residents pointed out, the passage of Tropical Storm Lili in late September 2002 (Figure 8) caused damage to some structures near the beach (Appendix 2).

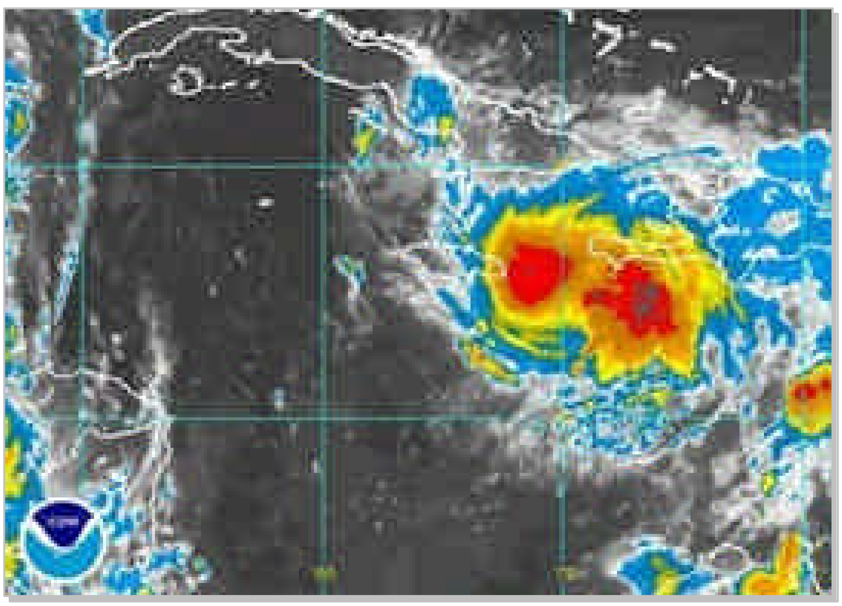

Figure 8 Satellite image of Tropical Storm Lili, 27th September 2002.

In a study carried out in the Virgin Islands (Hubbard, 1992), the passage of Hurricane Hugo on September 17th, 1989 over St. Croix, over a shelf dominated by carbonate sediments, generated wave heights of 6 to 7 m and caused wholesale flushing of sand from shelf edge areas into deep water. The sediment transport rate was eleven orders of magnitude greater than that measured during fair weather. The volume of sediment removed from the Salt River submarine canyon was approximately equivalent to a century of normal sediment accumulation. Storm surge was only 1.0 to 1.5 m because of the narrow island shelf in this area.

It is possible that a similar situation developed with the passage of Hurricane Andrew, and that sediments on the shelf, normally available for onshore fair weather replenishment, were significantly depleted. It could take many years to restore the shelf storage to its former state. Subsequent events, such as Gilbert and Lili are likely to have impeded restoration. Goldenberg et al. (2001) have discussed the recent increase in Atlantic hurricane activity and have suggested that the increase may last for several decades.

Wave Erosion by the Onset of Severe Winter Northers

Many of the aerial photographs, taken in the winter months, show wave trains originating from the northwest, rather than the northeast and east. This would suggest that these particular wave trains reflect the common incidence of northers at this time of the year (Figure 5). While the dominant wave trains of the summer months would assist in transporting any available sediments from the estuary of the Rio Grande by longshore drift, winter storm wave trains such as those in Figure 5 would impinge directly on the coast of concern, eroding finer beach sediments into the sea to form bars. They might also erode the vegetated berm platform behind the beach. As discussed above, erosion of the platform sediments represents a permanent loss of land to the sea (Figure 7). The statements by the local citizens (Appendix 2) suggest that recent loss has indeed been from at least two quite severe northers that occurred in January and February.

Interference in Sediment Supply from Rio Grande Sand and Gravel Mining

Production figures for sand and crushed stone released by the Mines and Geology Department (Table 3) indicate that mining activity on a considerable scale has been going on in the bed of the Rio Grande for several years.

Table 3 Sand and Crushed Stone Production in the Lower Rio Grande (cubic metres, Data from Mines & Geology Department)

	Grants Level	St. Margaret's Bay (Burlington)
1999 Crushed aggregate	3 070	0
Sand	12 000	14 600
2000 Crushed aggregate	3 005	0
Sand	9 850	12 000
2001 Crushed aggregate	2 817	0
Sand	12 200	18 500
2002 Crushed aggregate	2 884	6 883
Sand	11 480	16 270

The rate at which natural replenishment of mined materials takes place requires further investigation, involving developing accurate estimates of sediment transport at various discharges and a rating curve for the river, based ideally on observations at the bridge. Our discharge figures (Table 4) are based on the gauging station at Fellowship, which is some way up the river, although below the confluence with the Back Rio Grande. Such studies have not been done for this river.

It would appear, from this preliminary investigation, assuming that the production figures reflect the actual quantities removed, and that no significant illegal mining is occurring, that the present extent of <u>normal</u> mining operations at both Burlington and Grants Level should not seriously affect the quantity of sediment reaching the sea. In the past few years the Rio Grande has seen a number of abnormal flood events (Table 4). These events have probably been more than sufficient to replenish the bedload sediments of the river system. However, there is a possibility that the sand mining (as opposed to gravel/crushed stone production) may have depleted sand previously available for beach replenishment. This is because the natural sand quantities in the bed of the Rio Grande appear to be much less than the gravel-size and larger constituents. There appears to be no record of any scientific study of the actual availability of the various size fractions of raw materials in the riverbed, and it is recommended that such a study be carried out. In a Californian monitoring study of the relationship between sand mining at the mouth of a river and erosion of nearby beaches (Chester, 2000) it was discovered that beach widths started to become noticeably narrower about ten years after the commencement of mining activities.

Table 4 Notable flood events of the Rio Grande River over the period 1991-2001 (data adapted from data from the Water Resources Authority)

Peak 24hrs Discharges >200 m^3/s	Year	Duration (days)	Dates	Yearly Mean Discharge m^3/s	Maximum Monthly Mean Discharge m^3/s	Minimum Monthly Mean Discharge m^3/s
252.27	2001	4	May 9th -12th	29.29	73.63	2.64
360.37	2001	4	May 19th - 22nd			
598.69	2001	11	Oct 30th - Nov 9th			
324.06	2001	8	December 21st - 28th			
347.07	2000-2001	4	Dec 31st - Jan 3rd			
415.64	2000	1	June 1st	22.16	87.71	2.90
277.34	2000	6	Oct. 28th -Nov. 2nd			
603.16	2000	5	December 20th - 24th			
247.34	1999	2	March 17th-18th			
569.65	1999	2	October 25th -26th	28.76	66.06	5.40
281.25	1999	2	November 10th- 11th			
634.63	1998	2	January 4th-5th			
207.33	1998	1	February16th	35.70	126.48	5.68
253.62	1998	2	October 28th -29th			
789.57	1998	14	Nov 30th -Dec 12th			
462.48	1997	2	June 5th -6th			
604.63	1996	6	February 6th -11th	10.44	30.50	2.24
424.44	1996	5	November 13th -17th	29.95	86.35	8.97
265.14	1995	3	February 26th - 28th			
236.16	1995	3	November 16th -18th	29.13	59.89	4.83
432.45	1995	2	November 27th -28th			
325.28	1994	2	1 January 6th			
324.03	1994	3	January 23rd- 25th	20.24	69.84	4.95

Peak 24hrs Discharges >200 m^3/s	Year	Duration (days)	Dates	Yearly Mean Discharge m^3/s	Maximum Monthly Mean Discharge m^3/s	Minimum Monthly Mean Discharge m^3/s
371.92	1994	2	November 12th - 13th			
1524.35	1993	6	January 26th-31st			
404.66	1993	1	February 7th	49.17	125.66	7.59
635.42	1993	32	1st may -1st June			
302.87	1993	1	June 21st			
749.7	1991	3	May 21st -23rd			
298.57	1991	4	November 10th -13th	21.95	62.21	7.29

Interference in Sediment Supply due to Marina Construction at Port Antonio

Many persons at St. Margaret's Bay felt that the erosion problem at St. Margaret's Bay was directly the result of a diminution in supply of beach materials from the Rio Grande, due to the large quantities of material taken from the riverbed to construct the new marina at Port Antonio. Extraction for this phase of construction took place about two years ago. Production figures for sand and crushed stone (Table 3) do not include the oversize cobbles and small boulders abstracted from the lower part of the Rio Grande for the marina. A spokesperson at Mines and Geology Department estimated that some 40 000 cubic metres of such material may have been taken in addition to the figures given in Table 3. However, it has been estimated that the marina probably consumed more than this, at maximum perhaps 80 000 cubic metres of cobble to small boulder-size material to reclaim and fill the marina area (pers. comm. J. Aldridge, Wallace Evans Jamaica Ltd.). It is said that most of this came from the riverbed in the lower part of the Rio Grande (Burlington). The discrepancy in the figures given to us may be due to contributions to the marina project by unlicensed operators, although we have not been able to verify that such operations have occurred.

Bearing in mind the present uncertainties, some 25 000 cubic metres of sand, gravel and crushed stone were probably abstracted from the lower part of the Rio Grande in 2002. Perhaps as much as 60 000 to 90 000 cubic metres of material, including boulders, was removed in the previous year, over the period of construction of the marina. The abnormally high abstraction rate of 2001 may have temporarily upset the balance between natural sedimentation and artificial removal of sediment, but it is unlikely to lead to a long term depletion of sediment reaching the river mouth, particularly because of the flood events that have occurred recently (Table 4).

Interference in Sediment Supply for Other Reasons

Some of these reasons a speculative but all can be scientifically tested by further investigations. Flood events such as those mentioned above, associated with Hurricane Hugo in St. Croix (Hubbard, 1992) might also have the effect of discharging the finer-grained flood sediment load (sand) from the Rio Grande straight out over the edge of the shelf. Thus it would no longer be available as a possible source for beach replenishment.

If a large number of flood events occur over a comparatively short period, then the bed of the river itself may become, at least temporarily starved of sediment, particularly sand sized sediment. This is because the rate of sediment input from down slope geomorphic processes may be unable to keep up with the rate of removal of sediment, see Appendix 15.

On the other hand the shallow water now reported to be present under the Rio Grande bridge (Appendix 3) is possibly the result of deposition of sediment and aggrading of the riverbed from receding flood waters. The evolution of the Burlington meander probably also causes mid-stream shoals to migrate gradually down-river as well as cross-river, although the limestone bedrock walls of the floodplain are a constraining factor. Further work is required to sample the offshore and Rio Grande estuary area for sediment types to confirm the reports.

Another possible reason for erosion problems at St. Margaret's Bay, in particular, the loss of beach along the western shore of the Rio Grande estuary, may result from the natural changes in geometry of the lower course of the Rio Grande, summarized in Appendix 7. The progressive development of the meander at Burlington should have led to a slight diversion and reinforcement of the main flow of the river to impinge more heavily on the west bank of the estuary, possibly leading to removal of unconsolidated beach materials. As the 1941 and 1954 air photographs show, the river at that time flowed more directly northward, and there is evidence of recent (in 1941) build up of bars along the western shore of the estuary. The strong westerly swing of the river today may have altered the flow regime sufficiently to diminish, or even to erode sediments along that shore. However this speculative observation requires further investigation.

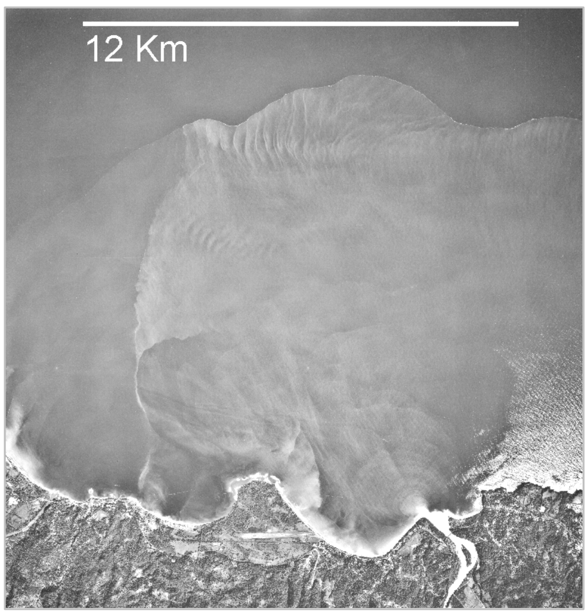

Figure 9	Sediment (mud) plume generated by the Rio Grande flood of February 13, 1999.

It has been suggested by several of the local inhabitants that the mud problems, said to be interfering with fishing offshore, result from the mining operations (Appendices 2, 3, 5). The mining company at Burlington is making serious efforts to prevent mud waste from the crushing plant from reaching the river, through the construction of a mud-settling pond (Appendix 5). Most of the mud probably originates originates from storm runoff in the valley of the Rio Grande. The valley sides are largely composed of mudrocks (Moore Town Formation of Robinson & Jiang, 1990). The gradual increase in and extension of cultivation of the valley sides in recent years has almost certainly led to an increase the acreage of denuded slopes and, hence, to increased fine grained sediment entrainment in runoff water. Figure 9 shows the 12 kilometre extent of a sediment (mud) plume from a 1999 Rio Grande flood event, smaller than the ones listed in Table

4. However local fishermen insist that, when active mining is occurring, the Rio Grande does carry noticeable quantities of mud to the sea, even under low water conditions.

Beach Recession Through Global Sea Level Rise

Sea level has been rising gradually for at least the past 100 years. Tide gauge data show that the global average sea level rose between 0.1 and 0.2 m during the 20th century. This is thought to be mainly due to thermal expansion because of an increase in global temperatures and the melting of glacial ice (Church et al. 2001). If the coastal area at a particular point is tectonically stable, any sea level rise will result in recession of the coastline. For such an historical rise the amount of expected net recession for this reason alone at, say, St. Margaret's Bay, will be small, perhaps a metre or two in a hundred years. Other factors, such as erosion from storms and replenishment of beaches from the Rio Grande are likely to have had a much greater influence over the past century, masking the effects of sea level rise. Over this period net growth rather than recession probably occurred. However, the rate of sea level rise is increasing and is expected to increase significantly in the future. The rate of increase is such that a rise of as much as 0.1 to 0.2 m may occur within the next twenty to thirty years. This rise will inevitably lead to net coastal recession. It will also make worse the already poor drainage characteristics of the morass behind the coast road. The increased water levels during flooding of the river already cause backing up of the water in the swamp (pers. comm. of local residents).

Beach Recession Through Human Interference Other Than Mining

There appear to be no adverse effects resulting from human interference at the beach, other than that due to continuous occupation of housing too close to the beach. Areas adjacent to housing are well used and the growth of low, protective vegetation is inhibited, thus leaving the relatively unconsolidated berm surface open to erosion. The distance of dwellings and other buildings from the shoreline is much less than that generally recommended, a criticism applying particularly to buildings constructed in the last 20 years. On the other hand, before Hurricane Allen the older buildings were as much as 60 m from the sea. In the western part of St. Margaret's Bay structures have not been affected even though they are near to the shoreline. This may be partly due to the influence of the groynes and partly due to that particular area being a zone in which erosion is not taking place because that beach is aligned neither to the wave-set from northers nor to the summer wave trains from the northeast and east. It may be receiving sand sized sediment by longshore transport from both directions.

Comparison with Orange Bay

In order to provide comparative erosion data for a beach that is almost certainly not influenced by sand and gravel mining we examined erosion reported to have occurred at Orange Bay (Mr. Mangaloo's remarks, Appendix 5), We also examined the beach at Hope Bay, where severe damage was done by the passage of Hurricane Allen (Wilmot-Simpson, 1980).

Hope Bay lies west of, (in the down-drift direction of) Daniels River and east of the larger Swift River, while Orange Bay lies west (down-drift) of the small Duncans River and just east of the much larger Spanish River. No significant sand mining has been reported in either the Spanish River or the other three rivers. Appendix 6 contains a brief report on observations carried out at Hope Bay and Orange Bay. At Hope Bay there were no signs of erosion problems affecting the wide beach there. At the eastern end Orange Bay, a situation similar to that at St. Margaret's Bay exists. Structures near the beach have been damaged, with some collapse, and the berm platform shows signs of recent erosion (Appendix 6).

7. Conclusions

Significant erosion has occurred at the beach of concern at St. Margaret's Bay, affecting buildings near the shoreline.

The trend towards erosion on this section of the coast started at the time of Hurricane Allen. The greater part of the erosion between 1941 and the present day occurred between 1980 and 1984, probably mostly due to Allen.

Up to 50 m of land was lost following the passage of Hurricane Allen.

This loss, apparently, did not immediately affect housing, which is built along the road. However it would have brought the shoreline dangerously close to such housing.

The residents generally agree that erosion affecting property has been occurring over about the past 5 years.

One to two metres of coastal recession has occurred within the last six months.

The recent recession is probably the result of the passage of Tropical storm Lili in September 2002 and the more recent incidence of severe northers in January and February 2003.

It is apparent that replenishment of beach sediments is not taking place, apart from that associated with the rivermouth bar at the entrance to the estuary.

Severe loss of beach has occurred over several years, evident on air photographs, from immediately north of the Rio Grande bridge, along the west side of the estuary and along the St. Margaret's Bay beach of concern.

We conclude that current sand and gravel mining probably has little to do with the erosion that has occurred at St. Margaret's Bay over the past six months.

In support of this conclusion, at Orange Bay, where no significant sand and gravel mining is taking place, there is similar evidence of erosion leading to the destruction of property, apparently mainly in the last six months.

It is possible that the mining of sand in a river dominated by gravel bed deposits has led to the decrease of the sand component of the beaches, but further, quantitative study of fluvial sediment components is required.

It also possible that the unusually large quantity of material abstracted from the bed of the lower Rio Grande for the marina may have temporarily inhibited supplies of coarser grained sediment to the beach system, but we cannot confirm this.

Further work is required to ascertain quantities removed and to determine the sediment budget of the river and the beach.

8. An Action Plan for Addressing the Problem

The third objective of the SOW was:

Develop an Action Plan for Addressing the Problem

We suggest that the following actions should be taken. They are listed in approximate order of priority.

1. Implement a programme to evaluate what kind of shore protection can be implemented for the shoreline of concern. There are several possibilities: constructing groynes, dumping large riprap on the shoreface, constructing gabions as suggested by one of the residents, constructing an offshore breakwater, a beach nourishment programme. Some possibilities are listed in Appendix 12. A preliminary study should be undertaken by a qualified engineer, in conjunction with a geologist with experience of coastal problems. The beach is used by fishermen, so that boat access to the sea needs to be maintained.

2. As citizens on this stretch of coast are caught, literally, "between the devil (the morass) and the deep blue sea" some thought should be given to possible relocation in the medium term to long term, perhaps near the Ken Jones airport.

3. A more detailed study should be made of beach dynamics, including, say, monthly beach profiling and monitoring over a summer and winter season, and after severe weather events. The baselines measured by us should be extended offshore, and should include sediment sampling. Current directions should also be investigated.

4. A rating curve for the Rio Grande should be established in order to estimate sediment volumes carried for various discharge figures. Evaluate annual sediment transport into the estuary and to the beach (hindcast and forecast), and develop a sediment budget for the estuary. These actions should be related to accurate figures of sand and gravel production.

5. An investigation should be made of sediment types and volumes present in the bed of the Rio Grande, and how they vary with the season and with flood events.

6. The background to the scope of work mentioned the Rio Grande as being world famous for its rafting activities. Although it does not form part of our project objectives, it was quite evident to us that a reconciliation of the rafting and river fishing activities with the mining activities has not yet been achieved. If the Port Antonio region is to be improved as a tourist focus then a real effort in this direction is required.

7. Offshore sediment sampling and bathymetry would be useful in estimating sediment reserves on the shelf, and in locating the probable submarine canyon.

8. Augering the berm platform and the morass behind the platform could be done in order to try and date (by radiocarbon) the time of formation of both zones. It could turn out to be quite recent, say, in the last 2-300 years.

9. A coastal biologist/chemist team should examine water quality and fish resources, both in the Rio Grande and adjacent offshore region, in response to expressed concerns that are not of a directly geological nature.

10. An attempt should be made to clean the drainage channels in the morass, so as to prevent flooding onto the coastal properties and highway.

9. Acknowledgments

We thank the persons and agencies listed in Appendix 1 for their assistance in providing comments and materials for this project.

Mr. Cecil Phillips, Petroleum Corporation of Jamaica, obtained a copy of Land Valuation map 115.

Dr. Trevor Yee, Natural Products Institute, UWI, identified flora.

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1941, 1954, 1968 and 1980 aerial survey photography, the Mines and Geology Department.

1961 aerial survey photography, the Department of Geography and Geology, University of the West Indies.

1992 colour aerial photography, NEPA.

1999 aerial photography, the Forestry Department (Mr. Dale Reid).

The IKONOS image, courtesy of the International Centre for Environmental and Nuclear Sciences at the University of the West Indies.

The oblique air photographs were kindly provided by J. Tyndale-Biscoe.

Revision of the draft report was greatly facilitated by feedback from the local community at a meeting of the St. Margaret's Bay Citizens Association with the consultant and members of the Ridge to Reef Watershed Project team, held on Friday May 16, and by comments from a meeting with technical personnel held at the Ministry of Lands and the Environment on Monday May 19, 2003.

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APPENDIX 1

Meetings/Visits with Relevant Agencies

February 11th	Mines & Geology: Mr. Norman Harris: aerial photos, Allen Report; Mr. Ronald Edwards: data on sand mining in Rio Grande.
February 12th	NEPA: Mr. Sean Green: Coastal Atlas of Jamaica; 1992 colour aerial photos.
February 18th &19th	University of the West Indies, Main Library West Indies Collection. Examination of Gleaner reports on Damage to St. Margaret's Bay and its environs.
February 25th	Office of Disaster Preparedness (ODPEM): Ms. Sheryl Nichols Examining reports on flood damage in the St. Margaret's Bay area.
February 26th	Wallace Evans Jamaica Ltd.: Mr. Peter Hughes Information on damage to Railroad tracks in the St. Margaret's Bay area.
March 14th & 28th	National Meteorological Service: Mr. Jeffery Spooner, Rain-fall data for the parish of Portland and Wind data from the Norman Manley international airport.
March 14th & 19th	Water Resources Authority: Mr. Dwight Smikle, Discharge data for the Rio Grande River.
March 27th	Mines and Geology Department: Mr. Godfrey Wynter and Mr. Ronald Edwards. Further information on sand and gravel extraction in the Rio Grande.

APPENDIX 2

Visit to St. Margaret's Bay, Portland, Jamaica, March 3, 2003

The following notes and records of conversations are compiled in the order in which our activities took place.

10AM Meeting with Ms Winnifred Moore, President of the St. Margaret's Bay CDC, at the St. Margaret's Bay All Age School. She took us to meet various persons with interests along the coast.

Weather conditions: Calm sea and no breeze.

Locality 1: **Walking along beach from area immediately across from the St. Margaret's Bay All Age School towards the Rio Grande Bridge.**

A sandy beach, pebbly at and below the waterline narrows from this area extending northeast along the shore. Waves (from the northeast on the day of the traverse) hit the shore at an angle. It is backed by an eroded sandy berm platform. Walking along the beach an abrupt change from sand to gravel was observed just east of the point where the road turns sharply towards the shore. The beach also becomes narrower. **Photo 1**.

Photo 1

Miss Moore:

- Erosion begins on the beach across from the school.
- Sea seemed to encroach more on land as of three weeks ago.
- Beach height has 'fallen'…used to be at the level of the present line of trees.
- Sandy part of beach probably reworked from berm platform rather than being deposited by longshore drift (Prof. Robinson).

Ira, Ena McPherson, Mrs. Spence, Bally Betty, Noel McFee (Jack) …

- Residents used to be able to play football games on the beach behind their homes. They are presently not able to do so because their playing area has been taken away by the sea.
- The area from the beach to the coast road used to be predominantly sand but now consists of pebbles and cobbles. **Photo 2**
- Backyards and play area has disappeared.
- The gully which carries water from the morass is cleaned on a regular basis but is periodically blocked by refuse supposedly from a garage upstream; bottles; household items; long logs that are washed ashore by the sea.
- Almond trees that used to line the shore lost due to erosion. **Photo 3**

Photo 2

Photo 3

Locality 2: **Mrs. Spence's Sea Wall**

Mrs. Spence:

- The wall was built about 5 years ago to prevent further erosion of the beach behind her house **Photo 4**
- Within the past month the sea has encroached on land and the waves are now at her sea wall. She estimates about 2 metres of land lost within the last month or so. Erosion has been most evident during the past 5 years.

The sea wall is made up of stacked boulder-sized blocks of limestone. It is being undermined by wave action and the mortar used to hold the rocks together has been washed away. The sand immediately behind the wall is being excavated as the water now passes through the once mortar-filled cavities in the wall. Mrs. Spence's house is approximately 3 metres behind the sea wall. Even with a calm sea, we observed that the wave action became more pronounced as we walked north eastward along the shore.

In the water there are limestone boulders which the residents say are what remain of a defensive measure against erosion, put in place by the Parish Council some 20-25 years ago **Photo 5**

Photo 4

Photo 5

Trucks used to drive out onto the beach to dump the building material. At the time we observed them, the limestone blocks were scattered in up to 60 cm of water and continued up the beach. At low tide the sea is at the level of the blocks and covers them completely at high tide.

Locality 3**:** **Open lot beside shop. Bally Betty's house**

Four drowned coconut trees…stumps visible in sea. There was approximately 6 metres of beach and berm separating the sea from the house. **Photo 6**

Photo 6

A small sandy beach on the NE side of the half-built house site

Bally Betty:

- During the heavy rains the sea covers both the beach terraces and comes to a halt immediately in front of the house.
- He placed tyres packed with rocks to create a buffer but heavy seas, two months ago, took away the rocks. He surmises that bigger boulders are the answer to halting the erosion problems. **Photo 7**
- Were told that the sea floor is mostly mud offshore of this region.
- Just beyond this locality trees have fallen over in the past week.

Photo 7

On a large scale, this part of the beach is cuspate and alternated from sand- to pebble- and cobble-sized particles **Photo 8**

Photo 8

On a smaller scale the sand-sized particles are seen in the curved sections of small cusps with larger-sized particles in the pointed sections. Again, the sand is probably derived from recent erosion of the berm platform and may be sheltered from further transport by the large boulder field mentioned previously.

Locality 4: **House beside former Baptist Manse**

A large old wooden building on stilts. Foundation of latrine being undermined by wave action.

Mrs. Cameron:

- One month ago the latrine was stable as the sea was further out.
- Undermining now takes place at high tide.
- Latrine is no longer in use. **Photo 9**

Photo 9

Locality 5: **House across the road from Almond Tree Bar**

This is a property with a bus, which backs on to the beach now. Section of house facing sea being undermined with partial collapse. There is evidence of an attempt to patch cracking where the back wall has now parted from the side walls. **Photo 10**

Photo 10

Residents:

- Main damage occurred between November and December 2002 (Tropical Storm Lili) and the rough seas at Christmas.

- Within a two year period the sea has encroached some 30 m onto the land, the beach used to be "way out, as far as the first line of buoys"

[**OUR COMMENT:** this statement seems to be an exaggeration and is not born out by examination of the air photographs. It would be nearer the truth if the words “twenty year period” were substituted for the words “two year period” above].

Locality 5b: **Baptist Church backyard**

We left the beach and crossed the road to look at problems at the Baptist Church.

Residents:

- During the last heavy rains the swamp flooded the churchyard with about 2 ft. of water.

The entire backyard of the church has been raised using cobble-sized rocks in an attempt to stave off flood damage from the swamp which borders the property.

Locality 6: **Defunct Kiddie Park**

A big blue and white building about 100 m from the sharp road bend leading towards the bridge.

Residents:

- This lot used to be an amusement park for the children of the community. The land has eroded over the last 5 years or so, and the park has been abandoned as a play area because it can no longer facilitate the large numbers of children it once did.

- The sea water used to be very clear. Since the mining operation (at just above the Rio Grande Bridge) began work it has been very cloudy.

- There used to be piles (?) for the railway here.

Locality 7: **Spit near Rio Grande Estuary**

Residents:

- Swamp water used to flow (across sand) directly into the sea but channel area is now blocked by pebble beach.

- The present spit was formed by Tropical Storm Lili, when it was more extensive than now and was a complete bar across the estuary to Rafter’s Rest. [We have air photographs, taken in January 2003 that seem to support this statement]. Spit area used to be a wider beach (see Jan. 30, 1992 photos).

From here the party walked along the west side of the Rio Grande estuary to the bridge. There was no beach along this shore.

Locality 8: **Beneath the Rio Grande Bridge**

Noel McFee:

- 10 – 15 years ago one used to be able to dive from the bridge into the river. Now it has become too shallow (siltation) to do so without the risk of breaking ones neck.

- The river is muddier than it used to be.

- Fishing in the river is no longer a reliable option as a source of nutrition and income for residents as the fish have gone away. Residents suggested the water is now too shallow for them to exist in any great quantities; the water is rendered uninhabitable by the sand mining operation nearby; the water is too muddy now and fish traps get filled with mud instead of fish.

- The floodgates, located near Pen, on the Rio Grande were dug up by the sand mining operation about 1½ years ago [we have not confirmed this statement].

Inspection of both the old railway bridge and the road bridge revealed no evidence of any damage. The eastern abutments are on limestone bedrock. The western abutments are on alluvium but sited well back (100 m+) from the active river channel.

Summary Remarks by Residents:

- The residents of St. Margaret's Bay are of the general opinion that the problems they now face with erosion are as a result of the sand mining operation on the Rio Grande.

- They say that because the sand is not being allowed to travel out to sea, the beach which comprises their backyards is not being replenished.

- They believe that halting the mining operation will halt the erosion problems.

- They suggest that a sea wall consisting of large boulders be placed along the beach to form a barrier against coastal erosion. The boulders should be encased in gabion baskets to prevent them being washed away by the sea.

- They encourage a speedy resolution to the problem as their homes are in danger of being destroyed.

- They imply that the people who live further up the coast are not concerned about the problem they are facing as their beach there is not being eroded.

Locality 9: **St. Margaret's Bay Groynes**

Miss Moore then took us to look at the beach occupied by the groynes.
Marley and Plant built the original groynes. The groynes are in a state of disrepair and the fourth, easternmost groyne seems to have disappeared. **Photo 11**

Photo 11

They seem to have done their job as the beach on which they are located shows no significant sign of erosion. The beach here is much wider than that along the region of concern reported on above. The beach here is mostly sand with pebbles along the shoreline.

Locality 10: **Welsh Woman's Point**

Well-sorted to moderately well-sorted gravel beach grading to sand at the shoreline. Approximately 150 m of gravel forming the tombolo. Beach very steeply dipping on side facing north. **Photo 12**

Photo 12

Locality 11: **Beach in line with Ken Jones Aerodrome Hangar**

Sandy beach widens towards airport.

Prof. Robinson:

- Perhaps there is sand offshore Welsh Woman's Point [later insert: No, but there is a well-developed reef with sand patches in between].

Grain size of larger beach material increases along the shore, from Welsh Woman's Point towards the aerodrome. Cuspate pebble bar forms edge of terrace closest to water. Wind system produces a ridge of sand behind the pebble bar. Low-lying dunes formed on aerodrome terrace, which seems to be an extended berm platform. **Photo 13**

Photo 13

Interviews Held with Three of the Raft Captains at the Rio Grande Bridge and at Rafters' Rest

At Rio Grande Bridge

(The railway bridge was erected in February 1931 for the Jamaica Government Railway by the Canadian Bridge Co. Ltd., Walkerville Ontario).

Comments made by Rio Grande rafters, Garfield and Roy:

- Mining operations cause heavy siltation of the area leading from the mining operation out to the sea. The areas just before and immediately under the bridge are especially shallow.
- Fish have disappeared supposedly because of cloudy water and oil from trucks loading sand.
- The trees downed on the banks of the river (left bank facing the sea) were as a result of flooding in September 2001. The coast road was flooded during this event, from the bridge back into the town of St. Margaret's Bay.
- Road along the east bank of the river undermined by landslide: river bank eroded by flood; sand and gravel truck fell into river.

At Rafter's Rest

Raft Captain 69: Cedric Ferguson:

- River being "mashed up" by sand mining operation.
- River channel "piled up" with material; rafters can't use long poles under the bridge, water cloudy.
- Channels blocked; rafting routes impassable because of trucks in the way; miners reluctant to make way for rafters.
- River course alters depending on where gravel is pushed by the miners, forces rafters to continuously change routes.
- Motor oil from mining company vehicles polluting water – tourists can't swim there.
- Tourists complain that sight and sound of mining operation is aesthetically unappealing.
- Another sand mining operation exists upstream at Grant's Level (same size as company downstream), just above the location where the rafting begins. Operations therefore are at the beginning and end of tour and not good for business. [We did not visit the sand mining operation at Grant's Level].

APPENDIX 4

Survey Tape Measurements from the Seaward Edge of the Road to the Eroded Edge of the Berm Platform (see Appendix 4, Figure 1 for Traverse Locations)

Traverse # 1 **Across the road from the Campari Bar**

Reference Point: Front edge of side-wall of unfinished garage

Distance from Road to Reference Point:	8.55m
Distance from Reference Point to Edge of Berm Platform:	27.6m
Distance from Reference Point to Swash Zone:	32.0m

Southern end of Traverse 1

Northern end of Traverse 1

Traverse # 2 **Across the Street from Carpenter's Shop**

Reference Point: Pillar at south end of wall of incomplete garage

Distance from Road to Reference Point:	0.7m
Distance from Reference Point to Edge of Berm Platform:	33.9m
Distance from Reference Point to Centre of Modern Berm:	37.8m
Distance from Reference Point to Swash Zone:	42.6m

Northern end of Traverse 2

Southern end of Traverse 2

For scale:

Distance from Reference Point to Back of Main House next door: 15.6m

Traverse # 3 Open Lot about 30 m from bend in Road

Reference Point: Light Post

Distance from Road to Reference Point:	0.7m
Distance from Reference Point to Edge of Berm Platform:	47.1m

For scale:

Distance from Reference Point to front of house on the right:	6.43m
Distance from Reference Point to back of house on the right:	19.10m

Southern end of Traverse 3

Traverse # 4 Garage Across the Street from St. Margaret's Bay Basic School

Reference Point: Front Wall of building on right

Distance from Road to Reference Point:	6.4m
Distance from Road to Edge of Berm Platform:	18.6m
Distance from Reference Point to Edge of Berm Platform:	12.2m
Distance from Road to Sea Wall:	19.6m
Distance from Reference Point to Sea Wall:	13.2m

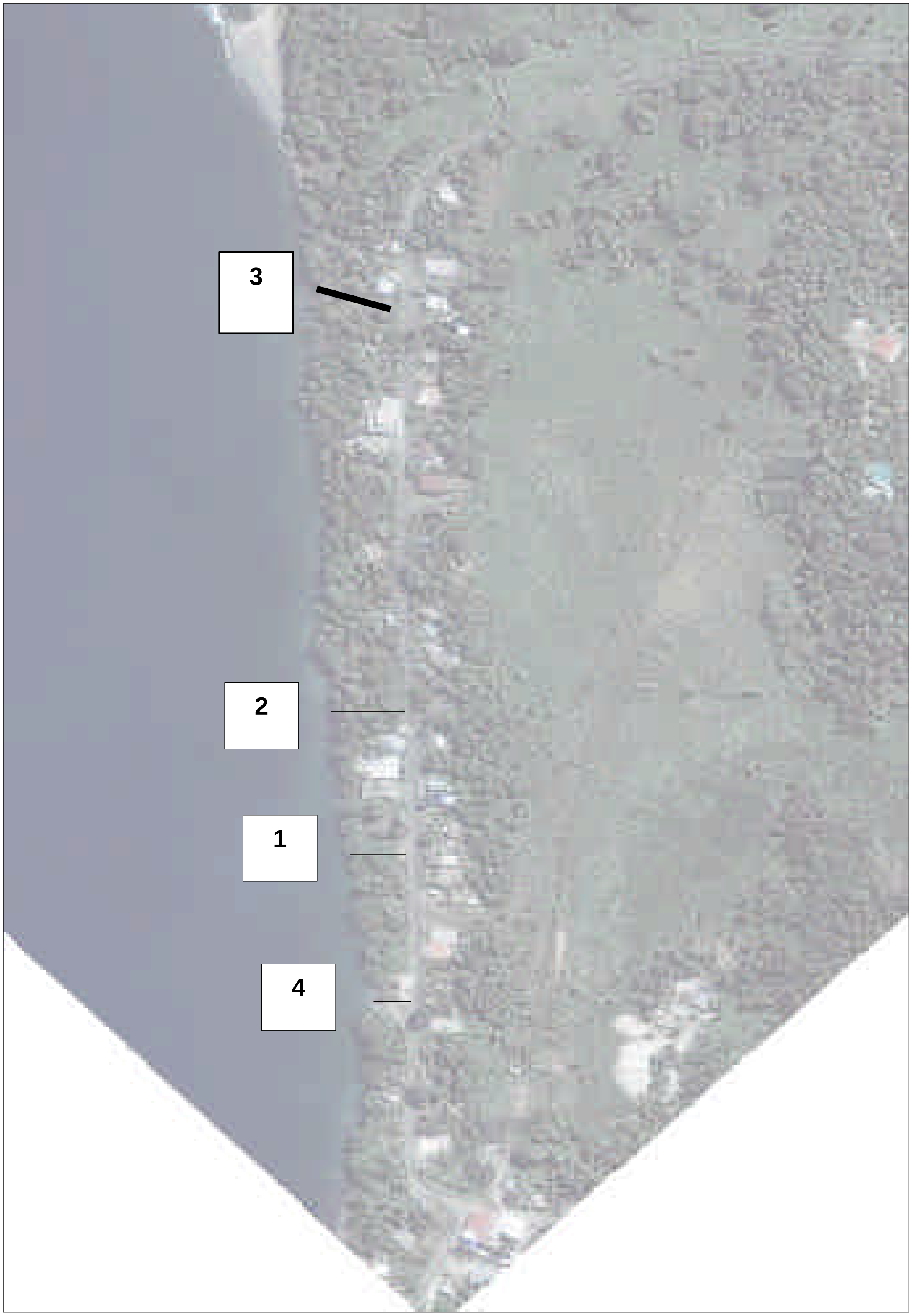
Southern end of Traverse 4

Northern end of Traverse 4

For scale:

Distance from Road to front of building on the right: 6.4m
Distance from Road to back of building on the right: 15.75m

Traverse #	Distance From Coast Road to Reference Point (m)	Distance From Reference Point to Edge of Berm Platform (m)	Distance From Coast Road to Edge of Berm Platform (m)
1	8.55	27.6	36.15
2	0.7	33.9	34.6
3	0.7	47.1	47.8
4	6.4	12.2	18.6


3
2
1
4

Visit to the Mining Operation, at Agro Expo Ltd., Owned and Operated by Mr. David Phillipson, March 4, 2003

In the absence of Mr. Phillipson we were conducted on a tour by Mr. Shaw, later joined by Mr. Mangaloo.

Locality 1: **Road along Rio Grande from their office to the crushing plant**

Water clear, shoal visible. River channel deeper here than under the bridge. **Photo 14**

Photo 14

Mr Shaw:

- There were 2 events of flooding in January and February 2003 which brought a halt to production.
- River tends to flood on the bank on which the mining operation is located.
- The Rio Grande has been progressively "eating away" at the eastern bank and subsequently the road. This road is used to transport mined material from areas of mining to main processing area.
- To stave off further undercutting of the road the company have opened another channel in the river, through a sand bar, to divert the flow of the water.
- Mining began 1994/95. Sand mined using a crane and sifted.
- Machine crushing of mined material began in 2000.
- After heavy rains the entire upper terrace (the floodplain) is flooded

- The company used to be involved in fish farming and had ponds on the upper terrace. This was discontinued after the floods of October 2000 flooded the upper terrace on which the ponds were located and the fish escaped.

- The company's farming activities have also been reduced due to flooding. Banana crops on both sides of the river flooded on a regular basis.

- River is at its lowest level in April/May.

Locality 2: **Bend in Rio Grande opposite Tourist Shops**

This is the area where most recent extraction has been taking place. The site is a flood channel of pebbles to small boulders, with scattered pockets of sand.

Based on the plastic bags stuck in the trees on the opposite bank, the river is approximately 3m higher when in spate. This is also about the height of the floodplain on the eastern side of the river. **Photo 15**

Photo 15

Banana farm being eroded by river. **Photo 16**

Photo 16

Shaw:

- The floodgate (just around the bend) is still in existence.

- The entire area was once entirely given over to agriculture (bananas for export) but the periodic flooding and erosion has changed the economic focus to sand mining.

Locality 3: **Sand and Gravel Processing Plant**

Mr. Shaw:

- 1/2" and 3/8" gravel produced by sifting and crushing. **Photo 17**

- Crusher capable of producing 300 cubic yards of sand in a 10 hr day.

- Stockpile of washed sand seen in yard was approximately 1000 cubic yards and represented 2 days work. **Photo 18**

Photo 17

Photo18

Mr. Mangaloo:

- Muddy water from production is passed through a U-shaped mud-settling pond (~1m deep). Gravity filtered water is allowed to flow back into the river. **Photo 19, Photo 20**

- Mr Mangaloo suggests that last years dredging/dumping operations in Portland to create the new marina has contributed significantly to the coastal erosion.

- His father in Orange Bay has lost approximately 2m of beach as a result of erosion. The Public Beach in Orange Bay has disappeared.

- He does not think the sand mining activities have brought about the coastal erosion problems.

- Entire operation consists of the mining and production of sand and gravel and agriculture on a reduced scale. The company employs 30 persons including security.

Photo 19

Photo 20

Locality 4: **Old road (alongside Rio Grande) leading from Rio Grande Bridge to Sand Mining Headquarters**

The road has been undercut by erosion; now reduced to footpath; used to extend to point where a tractor (property of the mining company) now lies submerged in the river. Trees submerged. **Photo 21**

Photo 21

APPENDIX 6

Field Observations at Hope Bay and Orange Bay

On the return journey to Kingston, March 4, 2003, brief stops were made at Hope Bay and Orange Bay to see if there were any similar signs of erosion. Hope Bay lies west of, (in the down-drift direction of) Daniels River and east of the larger Swift River, while Orange Bay lies west (down-drift) of the small Duncans River and just east of the much larger Spanish River. No significant sand mining occurs either in the Spanish River or the other two rivers.

Locality 1: **Hope Bay – Black Stuff Beach Bar**

No signs of erosion; very wide beach in comparison to St. Margaret's Bay. **Photo 22**

Photo 22

Sand beach changes to gravel-pebble beach towards St. Margaret's Bay end.

Locality 2: **Orange Bay (Public) Bathing Beach**

Open 9am-5pm daily, Orange Bay Hopewell Citizens Association and NRCA

(Savannah Point to the East)

Pebble and sand beach. Water clear. Waves coming in from the north-east. Drowned coconut trees. In what seems to have been a recent event, the beach has been eroded right up to the lawn. **Photo 23**

Photo 23

The sanitary conveniences are ~2m away from becoming undermined. Almond tree toppled but still growing. One beach structure now in the tidal zone.

Orange Bay Resident:

- Public Beach has not been used in a year
- Used to be filled with people on public holidays
- Beach area used to be wider; sea “way out”
- People say the construction of the marina in Port Antonio caused the destruction of the sea.

Next door the sea wall has been destroyed and the front porch of the building it was protecting demolished. The foundation is still being undermined. **Photo 24**

Photo 24

APPENDIX 7

Visit to the New Marina at Port Antonio, March 25, 2003

Interview with Mr. Tracy Prows, Manager

Mr. Prows made the following points:

- Harbour was dredged to allow cruise ships access to the marina.
- Dredging took place in either July or August 2002 and lasted 3 days.
- Dredging operator reportedly dredged 10 feet of what was described as "wet slimy sludge and scandal bags."
- The dredged material was dumped 10 miles out to sea.
- Dredging activities reached no closer than 100 m from Navy Island.
- Silk screens were placed over the mud bar extending from Navy Island for environmental purposes.
- There is a mud bar extending at an increasing rate from a stream emptying into West Harbour.
- He does not know where the white sand for the new beach at the marina came from but says that NEPA issued a permit for the sand.
- He indicated that a public stakeholders meeting was held in Port Antonio in 2002, prior to the dredging, in connection with an EIA carried out by Environmental Solutions.

Sand in this area is a mixture of carbonate and non-carbonate material. The new beach at the Marina, mentioned above, was created by dumping white marine carbonate sand (*Halimeda*, echinoid spines, mollusk shells, *Homotrema*, *Archaias*) in the area behind the shoreline and along the shore.

Historical Research on Factors Affecting Weather Conditions at and Near St. Margaret's Bay

Introduction

Most of the natural disasters that affect the coastline in St. Margaret's Bay, Portland are associated with large influxes of water usually associated with heavy rainfall resulting from hurricanes or tropical depressions affecting the northeastern section of the island. Hurricanes, which affect the islands in the Caribbean, are usually formed in the Atlantic Ocean or the Caribbean Sea (Gray, 1990). They meander their way around both the Atlantic Ocean and the Caribbean Sea progressing northerly into the Gulf of Mexico. This journey usually takes these hurricanes and/or tropical depressions in close enough proximity to land to affect the weather in these areas or they may make a direct landfall. In the last two hundred and eighty years, thirty (Table I) of these cyclonic systems have affected the northeastern section of Jamaica. June to November, referred to as the "hurricanes season", is the period of the year noted for the highest incidence of hurricane formation in the Atlantic Ocean (Gray 1990).

Year 1815

The earliest reports of hurricane damage sustained in the northeastern section of the island were obtained from the Office of Disaster Preparedness Emergency Management (ODPEM) website[1]. Here there are records, which date as far back as 1815. Their records show that the hurricane that hit the island, October 18-19, 1815, brought strong winds and caused rivers to over flow their banks. This resulted in the loss of buildings, bridges and property. However the report does not list specific rivers in the area.

Year 1903

On August 11, 1903 the effects of another hurricane, origination south east of Jamaica traveling in a north westerly direction (MAPS), devastated the Parish of Portland. Reports from the ODPEM website[1] state that "All eastern and northern parishes were severely hit with Port Antonio devastated". Winds in the worst hit areas were estimated at 120 miles per hour. The destruction of towns and villages along the eastern coast was due to some extent to storm surge, which washed away some houses.

Year 1909

Although this hurricane hit western Jamaica on the November 18th (MAPS), its effects were felt on the island as early as the 11th when heavy rains began to pummel eastern sections of the island. Severe damage had been done to roads and banana plantations in eastern Jamaica and many sections of the island and many, from St. Catherine and St. Mary, eastward had recorded over 30 inches of rainfall by the 14th of November.ODPEM[1]).

Year 1915

This hurricane passed north of the island (MAPS) in early August of 1915 causing damage along the north coast. Many of the coastal towns of St. Mary and Portland were inundated by powerful storm surges. Considerable damage was due to flooding a result of the heavy rains generated by this sever hurricane (ODPEM[1])

Year 1916

A severe hurricane passed just south of the island (MAPS) August 15-17 1916. Most of the damage from the hurricane was focused along the south coast; however the northern parishes of Portland and St. Mary were affected by strong winds which destroyed crops (ODPEM[1]) on a northwestward track with dire consequences for the whole island especially the south coast.

Year 1917

1917 brought the third hurricane in as many years (MAPS). Considerable damage was sustained in the north eastern sections of the island but the extent of the devastation of the hurricane was reduced, as effects were only felt for four hours, as the eye moved between Kingston and Port Antonio on September 23rd (ODPEM[1]). This said, the towns in the northeastern section of the island were "left in shambles" as a combination of wind, water and wave destroyed or damaged villages and induced vigorous storm surges which inundated parts of Port Antonio (ODPEM[1]). The heavy rain resulted in rivers flooding and more than 9 inches of rain was recorded in the northeastern section of the island.

Year 1940

The ODPEM reported flooding in the Swift River area of Portland in 1940, however there is no reference to the source of the rainfall which caused the flooding. The damage to roads and bridges were described as "colossal" (ODPEM[1]). Rainfall data from the area shows that Greenvale in Portland recorded 27.15 inches in 24 hours and Richmond in St. Mary 11 inches in 12 hours with 8 inches in the same time at Buff Bay; 16 inches in 24 hours were recorded at the latter locality with the gauge having overflowed for a long time (ODPEM[1]).

Year 1944

This severe hurricane swept from the east on a west-north-west track (MAPS) on August 20th and dealt a devastating blow to the island. The parishes hardest hit were Portland, St. Mary and St. Thomas, however all north coast parishes and the northern parts of the southern parishes were very badly hit. Port Antonio was completely wrecked and many villages in Portland were almost completely wiped out. The sea did considerable damage along the north coast, invading and causing damage in many towns and villages (ODPEM[1]).

Year 1951

Hurricane Charlie struck Jamaica on August 17th with winds as high as 125 miles per hour and is described as "The worst modern day strike by a hurricane on the shores of Jamaica". The hurricane's path was along the south coast of the island (MAPS) where most of the damage was caused by sea and wind (ODPEM[1]).

Year 1980

Hurricane Allen moving on a west-northwesterly course (MAPS) skirted the north coast of Jamaica on August 5th 1980. Traveling at 20 miles per hour, the hurricane, with maximum winds at 170 miles per hour passed Jamaica just 20 miles offshore Galina Point, St. Mary (Wilmot-Simpson). The proximity to the island resulted in much damage occurring as a result of storm surge along the North coast. In St. Margaret's Bay, the storm surge associated with this event achieved a maximum height of 15ft and had a maximum surge distance inland of 200 yards (Wilmot-Simpson).

Structural damage and coastal alteration reported by Wilmot-Simpson show that along the coast, several buildings were affected both east and west of the Rio Grande by storm surge, extensive relocation of sand to the back beach area and that the main road east of the Ken Jones airstrip was undercut in sections. His report noted that 3/4 of a mile of the main road going north along the coast as well as 1/4 mile of railway were buried by sand and a 5/8 mile stretch of coastline immediately north often air strip was covered with an average of 3 inches of sand up to 100 yards inshore.

Year 1988

The twelfth tropical depression of the hurricane season became tropical storm Gilbert on September 10 and was upgraded to Hurricane Gilbert on the morning of September 11. The hurricane traveled across the island from Morant Point to south of Negril. Its centre reached Morant Point on the morning of September 12. Hurricane force winds extended outwards 75 miles (120 km) from the centre in all directions (ODPEM[1]).

Strong winds, flooding and to a lesser degree landslides was responsible for the widespread destruction. Estimates showed that a least 70% of major buildings were damage, these included schools, hospitals, parish council offices and hotels. Damage to crops and livestock was reported in all agricultural areas. The fisheries industry also suffered substantial losses. Public utilities and communication were also severely affected. A total of forty-five lives were lost in various incidents related to the hurricane (ODPEM[2]).

Year 1993

Portland experienced heavy rains through out the year with two flooding events occurring in January and May. These were the result of heavy rainfall experienced over approximately seven days in January and again for the entire month of May.

The heavy rains occurring in January caused the Rio Grande and its tributaries to swell and overflow their banks. Rafts had been swept down river and destroyed and damaged was also sustained at the Rafter's Rest at Berrydale which was also flooded (The Daily Gleaner). Reports from the Meteorological office state that the accumulated average of rain fall in Portland in the first five days, in the month of May, was 636 mm compared to the accumulated average for the four month period January – April of 1854 mm. Witnesses described that they watched the Rio Grande as it "frothed and swirled its muddy waters racing by, taking sections of land with it" (The Daily Gleaner).

Year 2000

A frontal system which hovered over Jamaica resulted in continuous rain fall from 29th December 2000 to 4th January 2001. The damage that occurred in the parishes during this event, as a result of surface drainage was intensified because of intense rains that affected the island in November and December of 2000. This prior event had diminished the absorptive capacity of the soil and therefore an increase in surface drainage was experienced in January 2001. This increase in surface run-off caused what were considered "gentle meandering streams" to become destructive rivers e.g. Pencar River, St. Mary (ODPEM[2]).

Year 2001

Heavy rainfall experienced in the northeastern parishes of Jamaica during the period October 28th and November 5th 2001 was a direct result of the formation of Hurricane Michelle. Of the seven rain gauges in Portland the only one located on the coast was at Port Antonio, and it measured a total of 94.4 mm (Table 1) over the four-day period. The most intense rainfall over this period in the parish was experienced at Bellevue, which received a total of 698mm (ECLAC 2002). Reports to the Daily Gleaner by the National Works Agency (NWA) indicate that the road leading to the Swift River Bridge was cut off, and The Office of Disaster Preparedness and Emergency Management (ODPEM) reported that the Spanish River, Swift River, Back Rio Grande, Mabess and the Rio Grande were in spate. Further reports by the Daily Gleaner (December 2001) state that sections of the Spanish River Bridge in Orange Bay, Portland that were badly damaged in November had now experienced further destruction as a section of the reinforcing wall being along the Spanish River Bridge was washed away, while the foundation of the reinforcing wall for the Swift River Bridge had shifted.

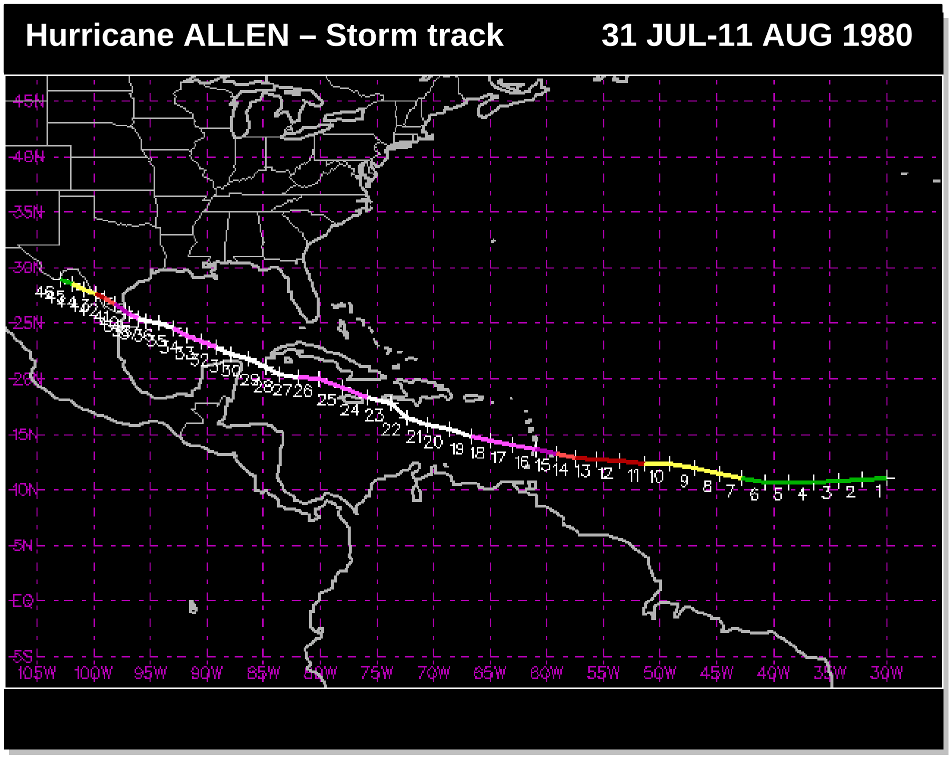
Preliminary Rainfall Report for October 27-30 2001 (in mm)

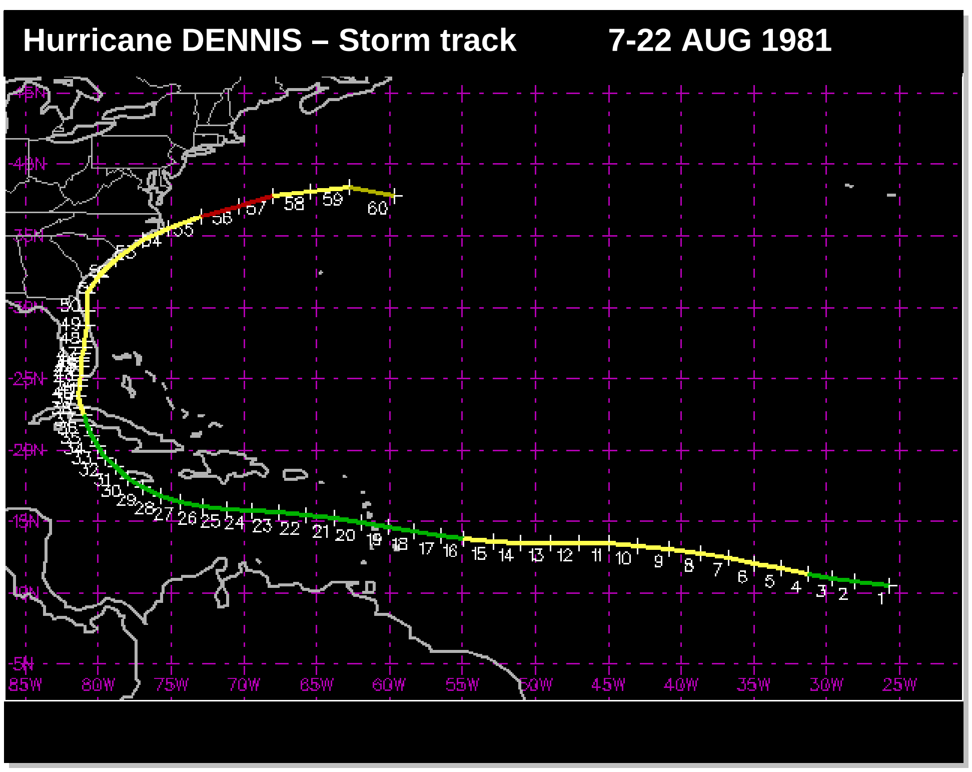
Station	Parish	October			
		27	28	29	30
Orange River	St. Mary	-	142.0	300.0	33.3
Brimmer Hall		-	107.8	208.4	13.7
Industry		9.8	96.0	230.0	32.0
Boscobel		39.4	96.5	162.8	38.1
Agualta Vale		-	47.4	345.9	19.6
Passley Gardens	Portland	-	19.6	137.7	49.9
Moore Town		0.0	186.6	300.1	31.3
Bellevue		29.0	11.0	622.0	36.0
West Retreat		16.0	11.0	217.1	55.4
Comfort Castle		0.0	244.8	27.1	55.4
Spring Garden		2.5	0.0	428.2	92.6
Port Antonio		0.0	20.0	62.0	12.4

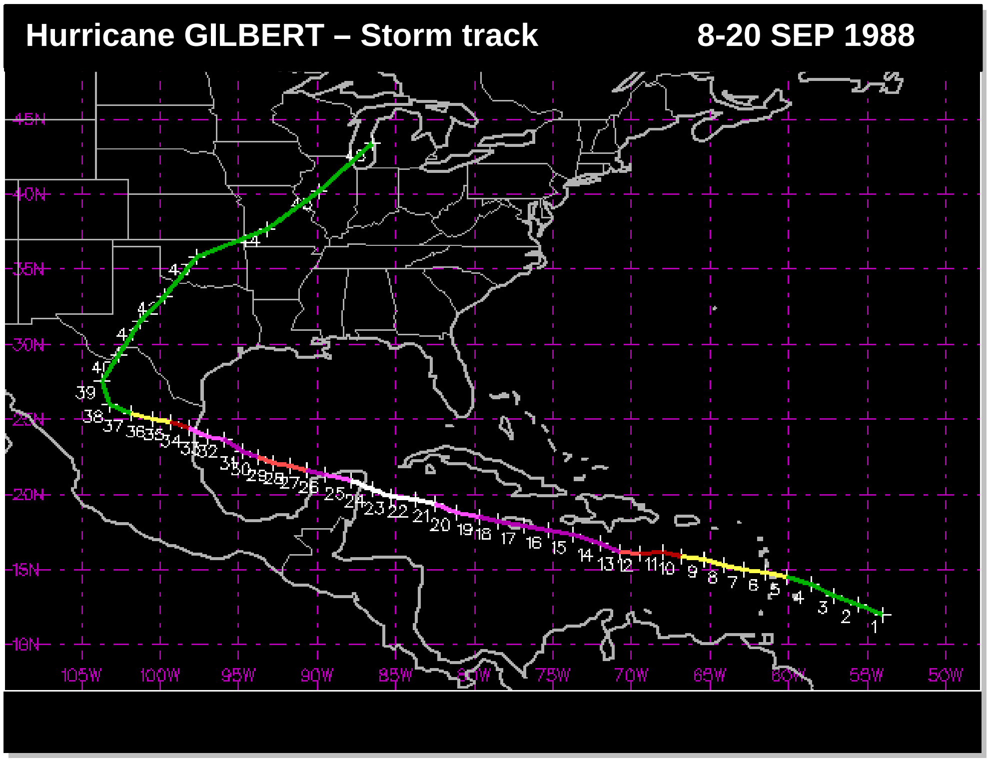
Figures represent amounts in millimeters. Source: Modified from ECLAC 2002

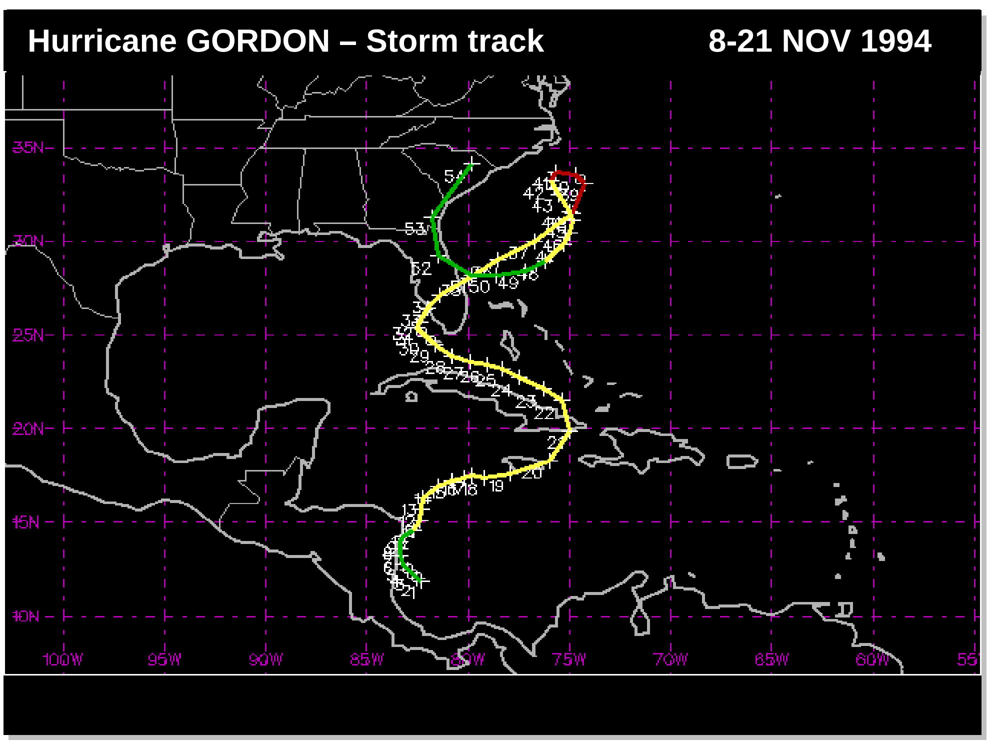
MAPS

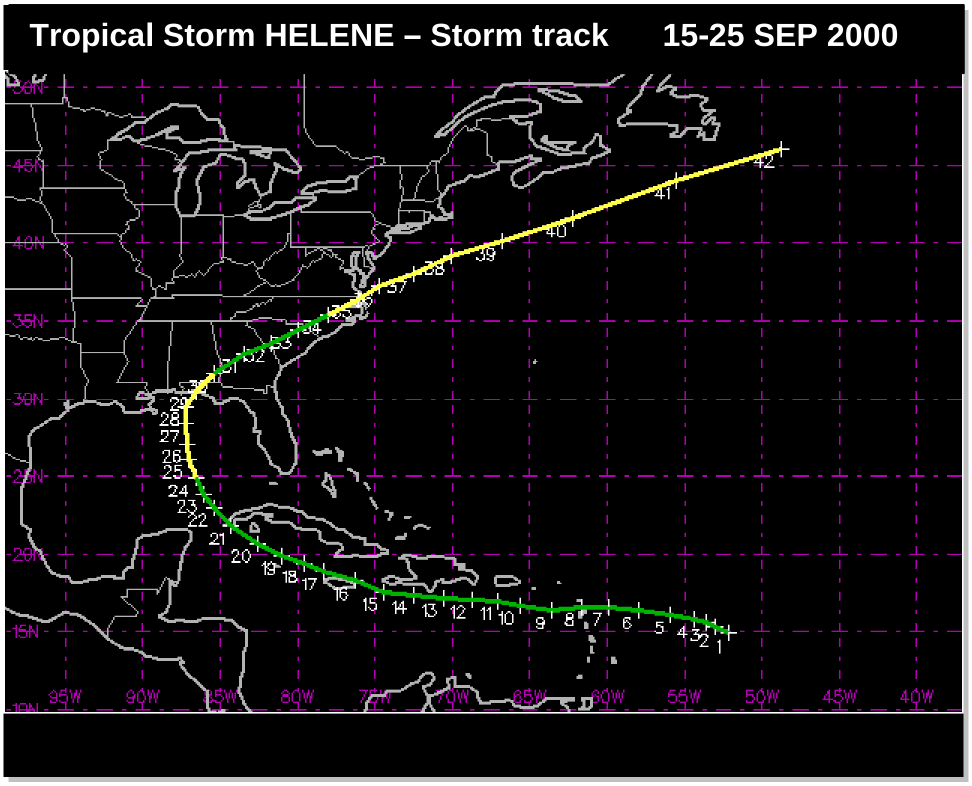
Maps 1 to 5 were obtained from http://weather.unisys.com/hurricane/atlantic/

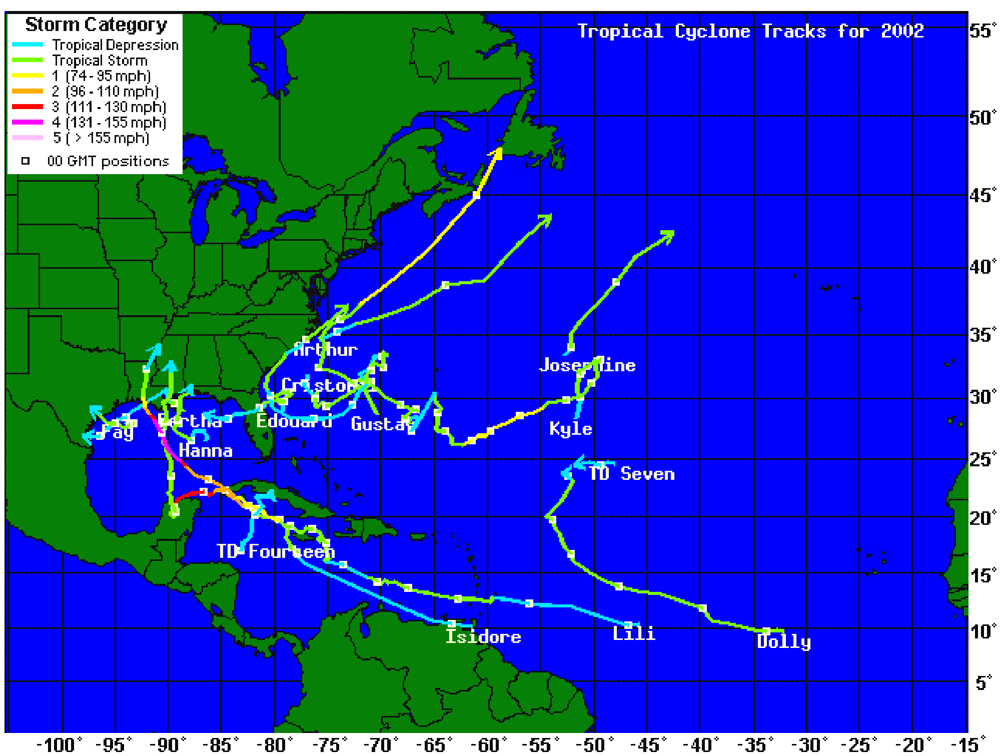





Hurricane GILBERT – Storm track
8-20 SEP 1988
45N
40N
35N
30N
25N
20N
15N
10N
105W
100W
95W
90W
85W
80W
75W
70W
65W
60W
55W
50W


Hurricane GORDON – Storm track
8-21 NOV 1994
35N
30N
25N
20N
15N
10N
100W
95W
90W
85W
80W
75W
70W
65W
60W


Tropical Storm HELENE – Storm track 15-25 SEP 2000
45N
40N
35N
30N
25N
20N
15N
95W
90W
85W
80W
75W
70W
65W
60W
55W
50W
45W
40W


Storm Category
Tropical Depression
Tropical Storm
1 (74 - 95 mph)
2 (96 - 110 mph)
3 (111 - 130 mph)
4 (131 - 155 mph)
5 (> 155 mph)
00 GMT positions
Tropical Cyclone Tracks for 2002
Arthur
Cristobal
Bertha
Edouard
Gustav
Fay
Hanna
Josephine
Kyle
TD Seven
TD Fourteen
Isidore
Lili
Dolly
55°
50°
45°
40°
35°
30°
25°
20°
15°
10°
5°
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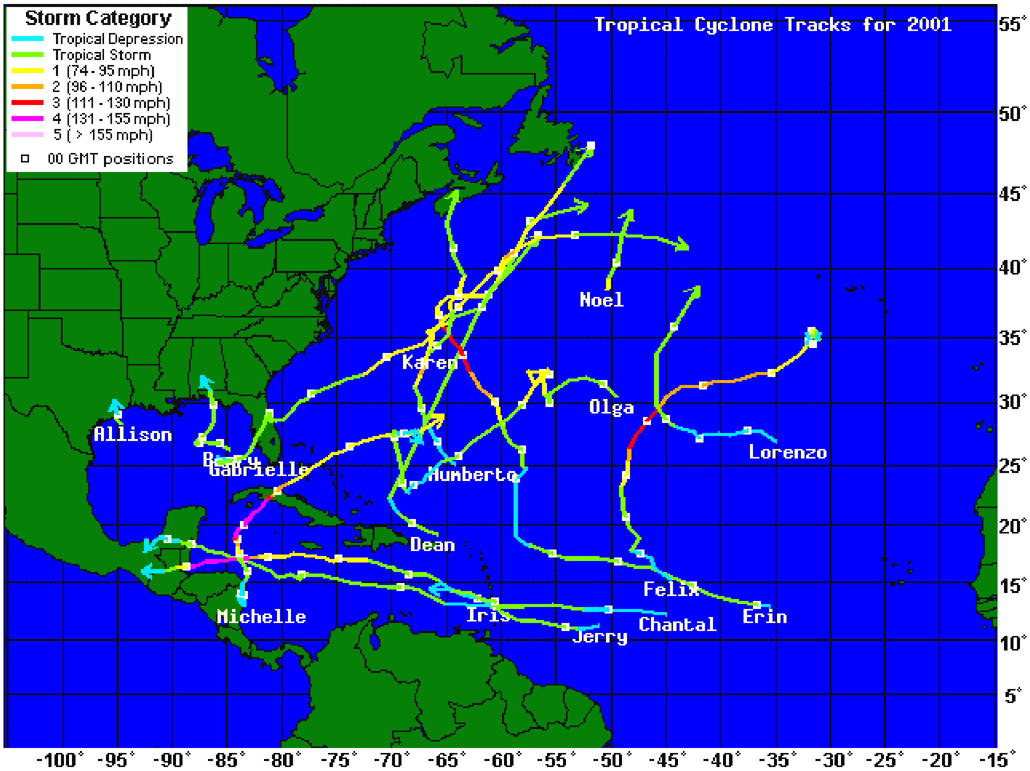


Maps 6 and 7 of storm/ hurricane tracks for 2001 and 2002 were obtained from wunderground.com.

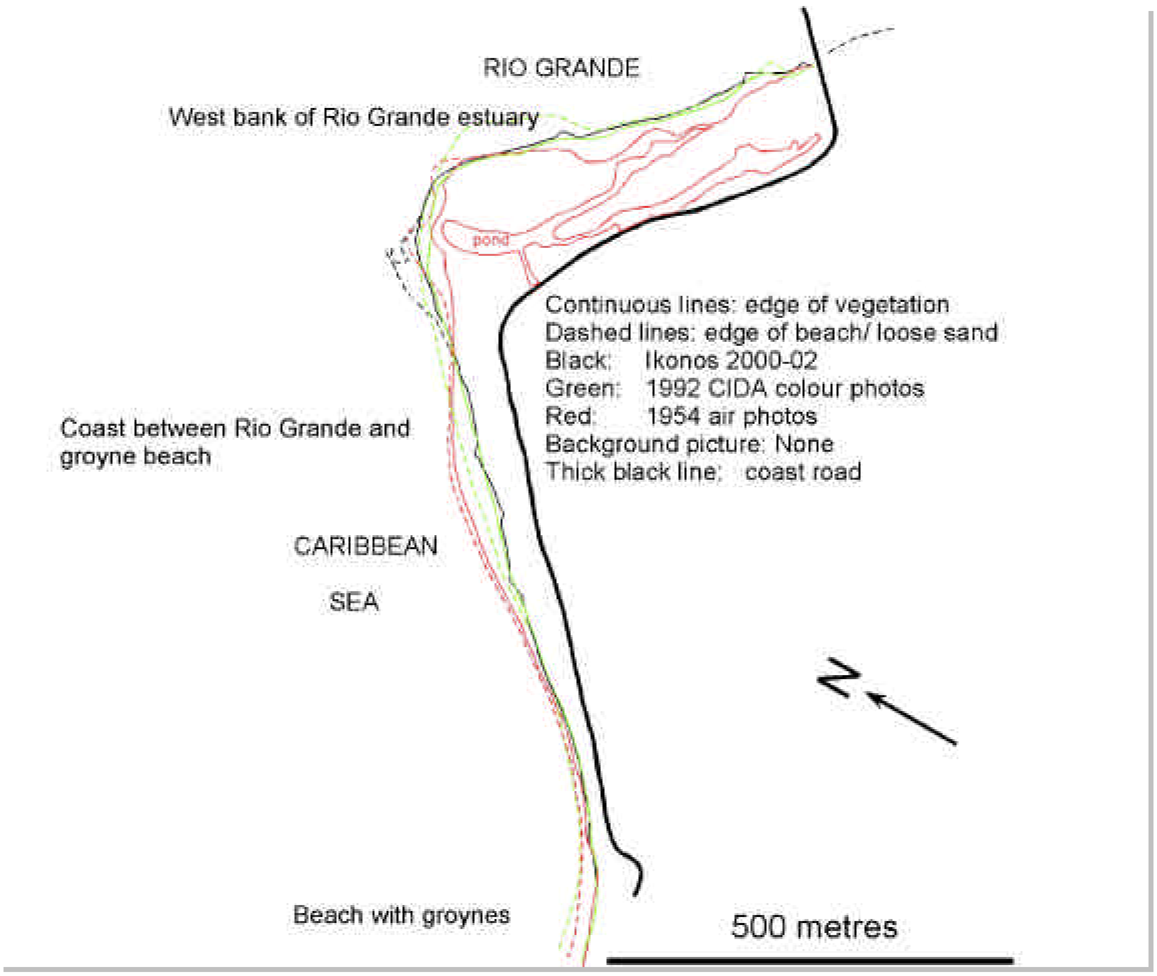
Table 1 **Dates and names of hurricanes which have affected north-eastern Jamaica between 1712 and 2002.**

1712	28 August	**Hurricane**	All Island
1714	29 August	**Hurricane**	
1722	28 August	**Hurricane**	All Island
1726	22 October	**Storm**	
1903	11 August	**Hurricane**	North Eastern, Jamaica
1909	November	**Hurricane**	St Mary
1915	12-13 August	**Hurricane**	St. Mary & Portland
1916	15-16 August	**Hurricane**	All Jamaica
1917	23 September	**Hurricane**	NE
1944	20 August	**Disastrous Hurricane**	Portland & St. Mary
1951	17 August	**Hurricane Charlie**	Kingston/Port Royal/Morant Bay damaged

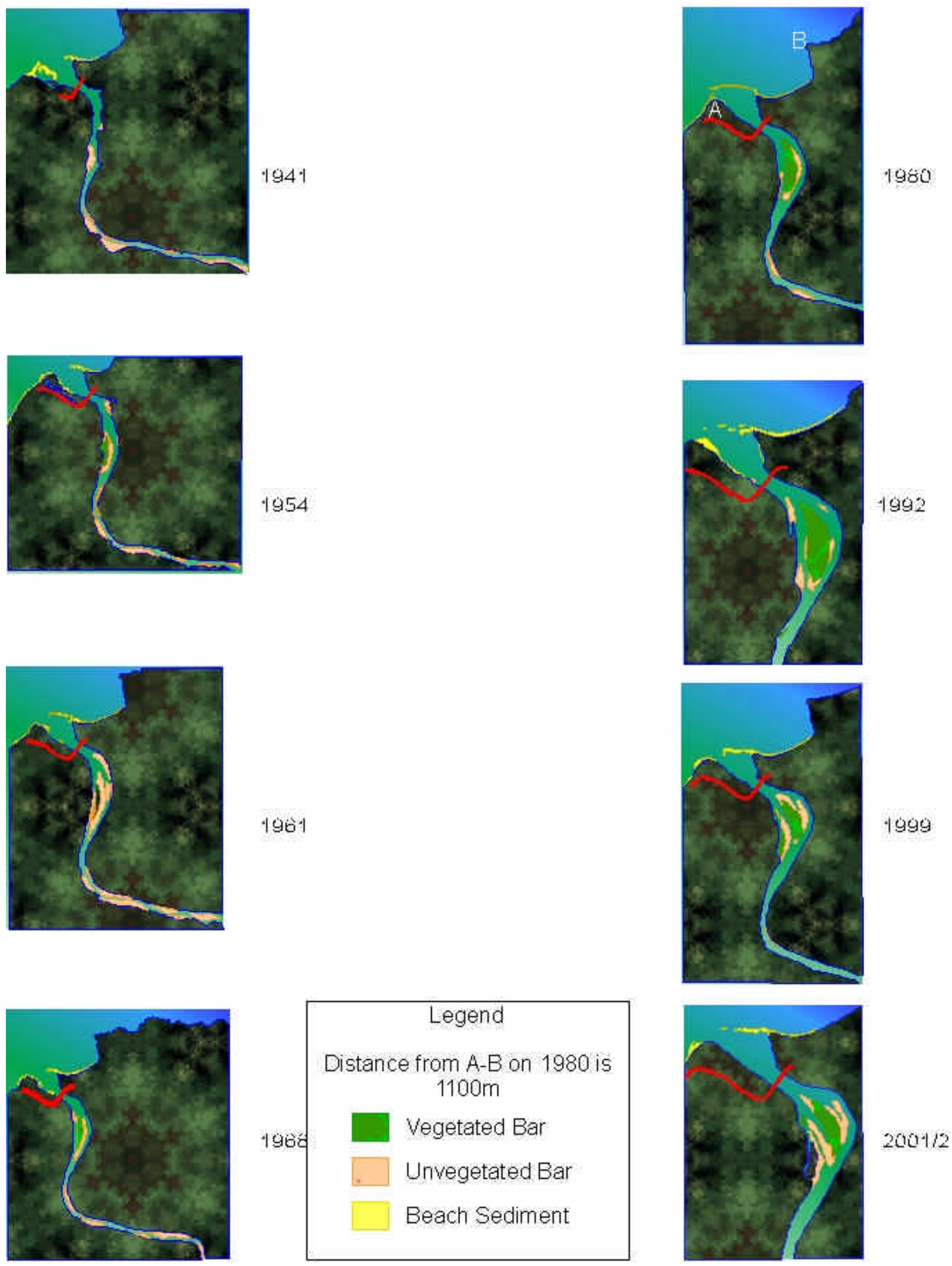
1954		**Hurricane Hazel**	Caused widespread rains in eastern Jamaica.
1955		**Hurricane Janet**	Unleashed island wide rains that caused flooding.
1958		**Tropical Storm Gerda**	Caused flooding on the north coast.
1963	5-7 October	**Hurricane Flora**	Affecting the eastern section
1964		**Hurricane Cleo**	Affected northeastern coast of the island.
1966		**Hurricane Inez**	Affected northeastern coast of island.
1969		**A Tropical Storm**	Caused extensive damage in eastern and northern parishes
1970		**Tropical Storm Alma**	Caused widespread showers in eastern parishes
1974		**A Frontal System**	Caused flooding on northcoast, resulting in extensive damage
1978		**Hurricane David**	Caused flooding in eastern section of the island.
1980	August	**Hurricane Allen**	Missed Jamaica but winds and heavy rains generated by the hurricane ravaged the island.
1981		**Hurricane Katrina**	Caused torrential rains island wide and flooding in the eastern section of the island
1988	12 September	**Hurricane Gilbert**	All island
1998	October	**Hurricane Mitch**	
2001	October & November	**Hurricanes Iris & Michelle**	Rains from both Hurricanes affected Jamaica
2002	18 September	**Hurricane Isidore**	All island
2002	October	**Tropical Storm Lili**	All island
2002	14 October	**Tropical Depression 14**	

APPENDIX 9

Coastal Changes, 1954-1992 – 2000



Changes in the Course of the Lower Part of the Rio Grande Between 1942 and 2002



Maps, Air Photographs and Satellite Imagery

Maps

Jamaica 1:50 000 (Imperial Series) Sheet M, 1st Edition, 1955. Air photography flown December 1941.

Jamaica Land Valuation Index, 1:12 500 scale, Sheet 115, 1959 Edition. Air photography flown 1954.

Jamaica 1:12 500 scale topographic map Preliminary Edition (1970) Sheet 114B.
Air photography flown by Spartan Air Services Ltd. 1968.

Jamaica 1:50 000 (metric edition) Series 1 (1984), Sheet 13, Blue Mountains. Coastal air photography flown Dec. 1979 to Feb. 1980 by BKS Surveys Ltd. Interior lines flown partly in 1979-1980 (BKS) and partly in 1968 (Spartan).

Jamaica 1:50 000 (metric edition) Series 1 (1984), Sheet 14, Port Antonio.
Coastal air photography flown Dec. 1979 to Feb. 1980 by BKS Surveys Ltd. Interior lines flown 1968 by Spartan Air Services Ltd. BKS photo numbers covering St. Margaret's Bay would be in the range 7/072 – 7/077.

Air Photographs

1941	J28: 349, 350; J29: 352, 353. December 1941.
1954	Film 31: 087, 088; Film 32, 001, 002, 003. February 1954.
1961	55 JA 25: 079, 080, 081, 082. 5 April 1961.
1968	Line 86: 001, 002; Line 87: 001, 002. 10 February 1968.
1980	Line 25: 072. December 1979 - February 1980.
1992	JAM92-007: 81, 82, 87, 88. 30 January 1992.
1999	JAM99-11: 178, 179. 13 February 1999.

Satellite Imagery

IKONOS Tile 24a. Information on the exact date has not yet been received, but it is within the period 24 January, 2001 to 30 July, 2002.

NOTES The 1980 BKS photography was flown in Dec. 1979-Feb. 1980, i.e. before Hurricane Allen, according to the footnotes on the topographic maps.

The USAF flight of Aug. 7, 1980 (immediately post-Allen) had photo numbers 191-194 for St. Margaret's Bay area, but these had not been accessed at the time of completion of the draft report.

Combating Beach and Coastal Erosion

Basically there are four alternatives:

- Do nothing, but plan for designing and enforcing setbacks and possible relocation of citizens living in threatened buildings. Institute a setback regulatory system for any future development.
- Armour the shoreline (sea walls, revetments or other barriers of various types, including vegetation).
- Build structures to control the rate and intensity of erosion (groynes, offshore barriers etc.).
- Use beach nourishment to promote beach widening.

1. If a decision is made to forego active shoreline protection, then a system of setbacks must be implemented to allow for future development. With the right kind of research and investigative procedures, setback planning can be made more or less site specific. On coastlines subject to erosion, the amount of setback should be related to the expected life of nearshore structures, and whether or not they are 'hard' (difficult to relocate) or 'soft' (easily transportable) (University of Hawaii Sea Grant Extension Service, 1997).

   At St. Margaret's Bay, for example, where coastal recession over the past 20 years has averaged about 2 metres per year. If this rate is projected into the future, a building expected to last 60 years, ideally, should not be built closer than 120 m from the shoreline. Unfortunately, this would locate such a building in the morass behind the main road. In general, if the current recession rate continues, it would appear that <u>any</u> building on the present coastal strip would not survive beyond the next 50 years. Also, the coast road would not survive in its present location.

   Use of the present average erosion rate, as a model for future erosion should not be accepted uncritically. An investigation of sediments and currents in the shore zone should be undertaken to estimate how these might be affected by gradual changes in the geometry of the shoreline.

2. Amouring a shoreline that is undergoing long-term retreat will halt the retreat for as long as the armouring remains more or less intact. But it will usually cause narrowing of the beach, as any supply of sediment originating in the area behind the shoreline will be cut off. As this particular beach is not geared towards the tourist industry, armouring of the shoreline might be the most effective way to go.

   Shoreline protection at St. Margaret's Bay would not necessarily involve construction of a seawall. Relatively cheap, short-term protection could be achieved using sand bags or sand-filled geo-textile tubes, or cobble and boulder-filled gabions. However, bearing in mind that the un-treated, and admittedly episodic coastal recession rate averaged over the past 25 years, is about 2 m/yr it might make good sense to build more substantial structures to protect the future of the highway if nothing else.

3. The rate and intensity of erosion may be controlled in different ways. Longshore transport of sediment may be controlled by constructing groynes or breakwaters, or by introducing new sediment on a regular basis up shore of the affected area.

   Groynes similar to those at the western end of St. Margaret's Bay will help to retain sediments along the coast of present concern, but would inhibit supply of beach materials to down shore regions, thus promoting erosion there instead of at the place being protected.

   Construction of a breakwater or artificial reef a short distance offshore is another way of promoting sediment accumulation along the coast of concern. Such structures would decrease the wave energy impinging on the shoreline, allowing sediments to accumulate there.

   Supplying sand and gravel at the up shore end (that is, at the junction of the coast with the Rio Grande estuary) might be a better alternative, but this would need to be done on a regular basis. This approach is related to beach nourishment, discussed below.

4. Sand nourishment is probably the most widely accepted method of preserving beaches (Committee on Beach Nourishment and Protection, 1995). Although artificial replenishment of beach sand will temporarily halt or delay future erosion, sand is sacrificed in the process, so that a beach nourishment scheme needs to incorporate provision for periodic replenishment. A successful scheme of this sort will halt coastal recession as well as maintain a wide beach. Choice of sand for nourishment is important. The more closely matched the new sand is to the existing beach sand, the more stable will be the nourishment exercise. Therefore a beach nourishment programme must include a careful survey of existing sediment types on the coast and offshore, and their directions of transport. The sediment characteristics of the possible sources of new sand must also be evaluated.

   In the context of St. Margaret's Bay, existing short and long-term natural sediment sources are, a) the offshore area, b) the berm platform, c) the Rio Grande. Thus the Rio Grande sand may be a suitable source of new sand for artificial nourishment. However, it should not develop into a "borrowing from Peter to pay Paul" kind of situation. If Rio Grande sand mining is affecting sand supplies to the beach, as seems possible, then it would seem that the initial nourishment and the regular re-nourishment exercises involved would be a price the mining companies would have to pay to continue operations.

APPENDIX 13

Comments from the Community of St. Margaret's Bay at a Meeting Held on May 16th 2003

- Effect of mud on the coral reef St. Margaret's Bay
- Coral Reef swamped with mud (Fisherman)
- Erosion of beach due to mining operation. They dug up the river mouth and changed the course of the river
- Should not allow outsiders to destroy such an important resource (river and reef)
- How many people benefit from mining? How many people suffer due to it (mining)
- Not a simple matter. A lot more research into the problem is needed
- What of other mining operations on the river e.g. at Berridale?
- Are the other mining operations taking precautions with mud disposal?
- Agencies of the state are overly sensitive and protective of the issue
- Smell from the mud, a foul smell emanates from the mud
- Has any water quality testing been done? Some was done through CWIP. What were the results?
- Need to do some water quality testing on the river
- Only mullet coming from the river. Many types of fish seemed to have migrated or died (river /mouth of river)
- One of the four groynes has disappeared. The remaining three are in poor condition. All were in place in 1969
- Having lost these protective structures there would be some effect
- Wave regime may have changed. There is a need to evaluate if repairing groynes would make any positive change
- Swamp needs cleaning, it is over grown and stagnant with mosquitoes

Next Steps

- Meeting of agencies May 19th
- Coastal zone division: request pollution control division (NEPA) to look at mining operations
- Further work needs to be done, they will bring those needs to the table

- Community needs to review the information they now have
- Will get back to the community with results/feed-back from the agencies meeting on May 19th
- SDC has a responsibility to work with the community organizations. Getting similar complaints from other costal communities e.g. Snow Hill. Should invite these persons to meeting such as this one (Falloon)
- Citizens should open their minds to causes of problem outside of mining (Falloon)

<u>What does the community want to see next?</u>

- Examine options put forward to stabilize the beach, i.e. engineered structures
- Education of the community on care of shoreline. Burning of shrubs on shoreline should stop – a public education programme
- Need 15 more copies of the report
- Community will get together to read and better understand what is presented
- Technical persons to be invited to clarify any questions community might have
- The rafts men in Snow Hill were invited but did not show.

APPENDIX 14

Comments from the Meeting of Agencies Held on May 19th 2003

Next Steps

1. Expand the scope of the study

   - Prepare Rio Grande sediment budget (over one year or more) to understand full cyclic impacts also for extreme events.

   - Study socio-economic activities occurring in the river and the impact on the river.
     - Land use changes
     - Agriculture, forestry, quarrying

   - Monitor Water Quality (can coincide with socio-economic study)

   - Examine engineering/relocation options to reduce erosion on beach
     - Bathymetry
     - Current and wave regimes
     - Sediment transportation

   - Drainage engineer to look at flooding potential of the blocked and overgrown swamp drainage channel and outlet

   - Explore issue of reconciliation: Mining vs. Tourism

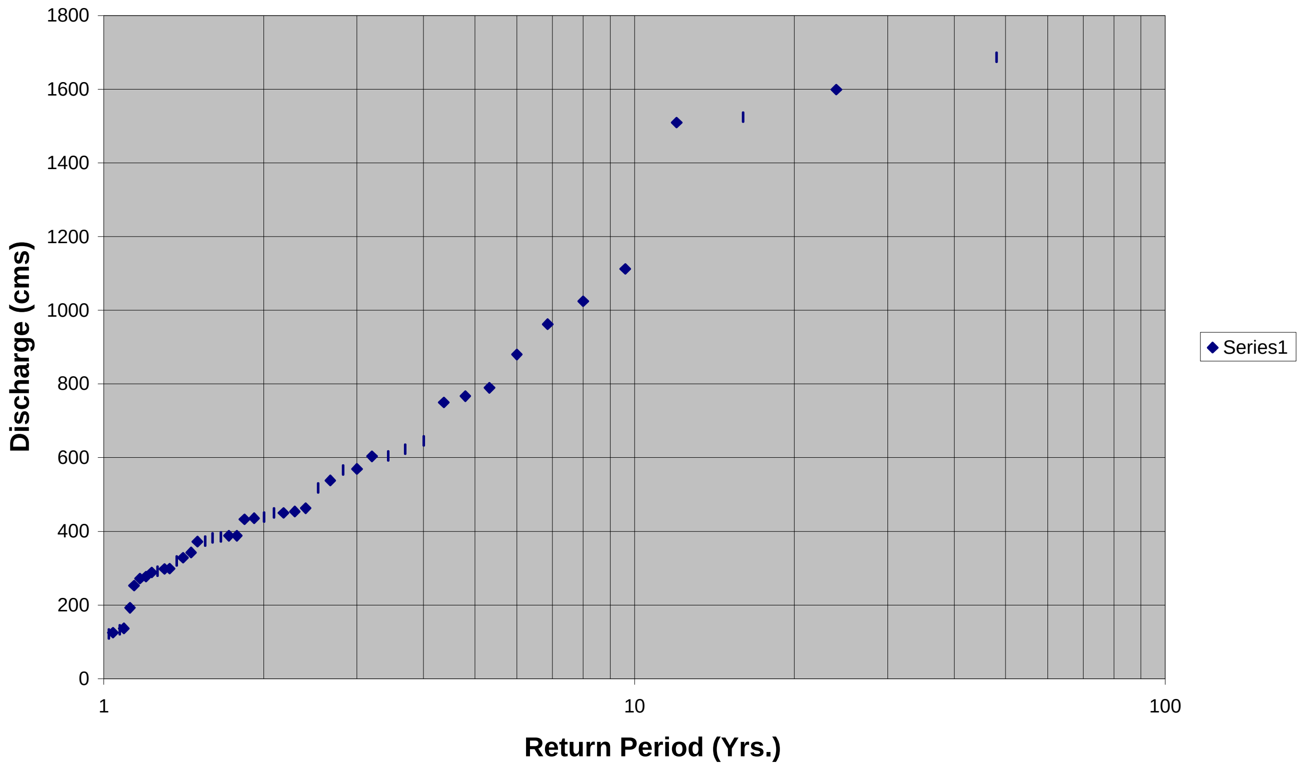
     Key to informed decision

     1. Socio –economic study
     2. Sediment budget

     * An educational component
       - Focusing on the communities
       - Compliance issues etc.

APPENDIX 15

Flood Frequency Graph for the Rio Grande



Ridge to Reef Watershed Project