Beach Erosion at St. Margaret's Bay, Portland Jamaica
REPORT TO THE CITIZENS

Ridge to Reef Watershed Project

USAID Contract No. 532-C-00-00-00235-00

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

REPORT TO THE CITIZENS

August 4, 2003

Prepared for the

Government of Jamaica's
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And the

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Implemented by:

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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 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 chief investigator for the study is Professor Edward Robinson, Professor Emeritus of the Department of Geography and Geology, University of the West Indies, Mona. This popular version of the original technical report has been written by Miss Deborah-Ann C. Rowe.

Executive Summary

The citizens of St. Margaret's Bay, Portland have been greatly concerned about the rate at which the beach was eroding. Homes and other buildings along the beach were in danger of being destroyed by the sea. In fact, at least one home had already been partially destroyed with the waves breaking off the back section of the house. The residents were worried that the mining operation at the mouth of the Rio Grande was preventing the beach from being rebuilt after storms. The Ridge to Reef Watershed Project (R2RW) was contacted by the citizens association to help with the problem. As a result, a scientific study of the St. Margaret's Bay beach erosion was carried out to find out the severity of the problem, the reason the beach was eroding and to work out possible ways of dealing with the erosion. This document outlines the results of the study.

Meetings were held with relevant agencies in Kingston (Appendix 1), the St. Margaret's Bay citizens and the operators of the Rio Grande mining concern. 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. The study team visited St. Margaret's Bay to investigate the erosion and take pictures of the damaged buildings, and the mining operation. The beach was measured to note the changes over time.

The section of eroding beach from the Fisherman's Beach across the street from the St. Margaret's Bay Basic School to the Rio Grande was studied. In this report, this area will be called the "beach of concern." The road and houses behind the beach are located on a thin strip of land between the beach and a small morass. The land itself is made up of sand and gravel, which was most likely formed from sediments carried down by the Rio Grande. This material would have enclosed a lagoon in the past. The lagoon is now filled up by plants which have formed the morass.

From our investigations we conclude that significant erosion has indeed occurred along this beach, affecting buildings near the shoreline. Study of old photographs taken from planes flying above St. Margaret's Bay show that the major part of the erosion (the sea took 40 to 50 metres of land) 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 beach has been lost to the sea. This recent beach loss is mainly due to the passage of Tropical Storm Lili at the end of September 2002, and two severe storms 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. The sand that is there may well have been brought to the beach as a result of erosion of the area covered by plants and grass, on which the houses are built. The air photographs show that the beaches here and along the west side of the Rio Grande estuary have gradually disappeared. The beach at the mouth of the river does not exist now and the beach of concern is narrow (1-3 metres) and it is apparent that the beach material that is taken away by waves and storms is not being replaced.

The study also looked at similar erosion taking place at Orange Bay, Portland. Although the erosion at that beach is also significant, there is no report of sand mining nearby. As a result it cannot definitively be said that sand mining is the reason behind the beach erosion at St. Margaret's Bay. There is a possibility that the mining of sand has reduced the amount available for naturally rebuilding the beach. This is because the riverbed is made up of mostly gravel and boulders and sand may be a relatively minor constituent. A study to measure the amount of (i.e. a study to measure the amount) of the riverbed materials is needed.

The construction of the new marina at Port Antonio took large 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 Division. We believe the figure to be between 60 000 to 90 000 cubic metres. The unusually large quantity abstracted for this purpose may have temporarily stopped supplies of coarser grained material to the estuary and beach system, but we cannot confirm this, and a quantitative study of the amount of sand, pebble and boulder sized material in the river bed needs to be carried out under different river conditions.

Under normal circumstances, beaches go through a period of erosion, where the beach is taken by the sea. This period of erosion is usually followed by a period where the beach is rebuilt by natural means. We conclude that, although it is apparent that the beach of concern is in an erosive stage, in future it might be replaced by a phase of deposition and extension of the beach area. Saying whether or not this will happen would depend on the findings and recommendations of studies suggested below. However, the vegetated (grassy, planted) area behind the beach is not likely to be rebuilt enough to be considered safe for housing for many years. This is especially important if the there are building codes put in place which would for safety's sake prevent buildings from being located less than 60 metres from the beach. Most of the world's sandy beaches are currently in a state of erosion, 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 as quickly as possible for a short-term solution.

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; this section of beach should be safe for building for a much longer period of time if persons do not build too close to the shore. The residents who live and/or have businesses on the beach may be safe for another 10 years or more. It is however, not a good idea to spend money on constructing new buildings or buying land along this area of the beach.

3. A detailed quantitative study of the way the beach is naturally built up and broken down should be made. This should include measuring the water depth and sampling the sediment of the area further out to sea.

4. A similar study should be made of the kinds of sediment that make up the beach, as well as the river flow conditions under which the sediment is moved downstream 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 R2RW project activities. This river is world famous for its rafting activities. More recently sand quarrying has been taking place both upstream and downstream.

St. Margaret's Bay, Portland is a coastal town located in the northern part of the Rio Grande Watershed. 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 is rapidly eroding
- Persons are losing property 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 (rebuilding) 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, possibly installed by the Public Works Department, no longer exist or have been rendered ineffective.

2. Purpose of the Investigation

Our purpose was 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
3. Interviews were also held with members of the rafting fraternity.
4. Four survey lines were run through the affected area at St. Margaret's Bay to provide baseline information for the possible monitoring of future erosion.
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
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.

7. A visit was made to the new Marina at Port Antonio to find out the nature of dredging and construction activities last year.

8. Research was conducted to identify all possible sources of events that happened in the past that might provide additional information on the problem

9. The relevant aerial photographs and published maps of the region were acquired and examined, in order to see how the coastline of concern and the lower part of the Rio Grande has changed over the past 60 years.

10. A preliminary examination of tide, wind, wave and storm/hurricane information 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 view from the air of the coast between these two points (Figure 2), which is called the St. Margaret's Bay Beach System in this report, is sharply curved at its eastern end. The coastal area of low-lying, largely loose sands and gravels, is of variable width, and is backed by steeply sloping limestone hills. The area includes that part of the Rio Grande closest to the sea. The island shelf (section of island covered by shallow sea) is relatively narrow in this region, probably less than 2 km (although no surveys have been conducted). Seaward the sea floor steepens sharply to depths in excess of 1000 m. Previous unpublished studies indicate a deep-sea fan (a fan shaped area of sediment) offshore the Rio Grande mouth as well as an underwater canyon extending across the shelf from near the mouth of the Rio Grande. The mouth of the Rio Grande is shown as Figure 3.

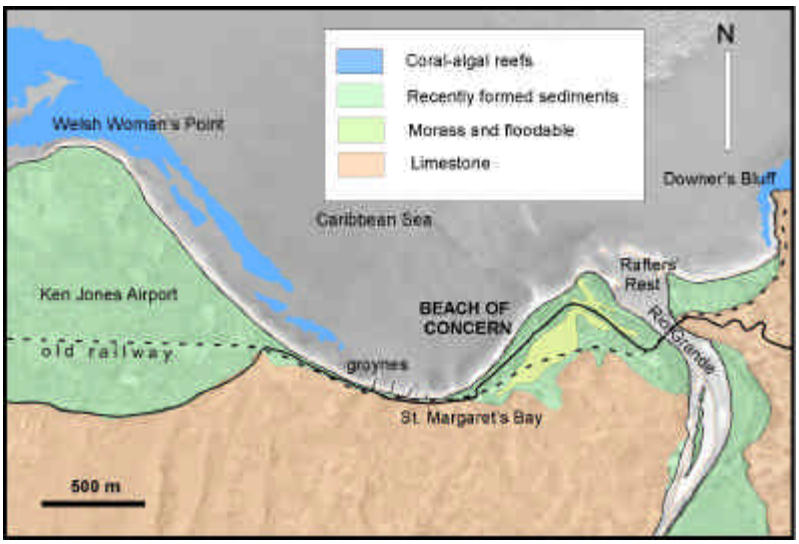


Figure 1 Location map of St. Margaret's Bay. The map is based on a 1961 aerial photograph.

Figure 2 Oblique air photograph, June 18, 1969, showing St. Margaret's Bay. The area with trees between the sea and the morass is the current coast of concern (J. Tyndale-Biscoe).

Figure 3 Oblique air photograph, August 7, 1980, taken immediately after the passage of Hurricane Allen showing large rivermouth bar. (J. Tyndale-Biscoe).

4. Beach Erosion At St. Margaret's Bay

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

From the beginning 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 a) direct observation of coastline conditions on March 3 and 4, 2003, and b) analysis of aerial and satellite photography taken at intervals from 1941 to 2002.

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. The weather conditions at the time of our visit were a calm sea and no breeze. The tide was near high.

Following our meeting we walked along the beach, starting from the area immediately across from the St. Margaret's Bay All Age School and going towards the Rio Grande Bridge. We were accompanied by residents of St. Margaret's Bay.

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 (a ridge of sand or gravel built up by waves just above the high tide area). 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. **Figure 4**.

Figure 4

Miss Moore explained that erosion extends eastwards from the beach across from the school, and that the sea seemed to have encroached more on the land as of three weeks previously. The beach height has 'fallen'. It used to be at the level of the present line of trees.

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 mainly sand but now consists of pebbles and cobbles. **Figure 5**.
- Backyards and play area have 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 have been lost due to erosion. **Figure 6**.

Figure 5

Figure 6

Mrs. Spence's Sea Wall (Figure 7)

Mrs. Spence told us that the wall was built about 5 years ago to prevent further erosion of the beach behind her house **Figure 7.** 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 have been 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 **Figure 8**.

Figure 7

Figure 8

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 centimetres 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.

At the Open Lot Beside Shop Bally Betty's House

Four drowned coconut trees…stumps visible in sea. There were approximately 6 metres of beach and berm separating the sea from the house. **Figure 9**.

Figure 9

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

Bally Betty said that 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 two months ago, heavy seas, took away the rocks. He suggested that bigger boulders were the answer to halting the erosion problems. **Figure 10**.

Figure 10

We were told that the sea floor is mostly mud offshore of this region and that trees just beyond this locality have fallen over in the past week.

On a large scale, this part of the beach is cuspate (looking like a series of crescents) and alternated from sand- to pebble- and cobble-sized particles **Figure 11**.

Figure 11

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 probably comes from recent erosion of the berm platform and may be sheltered from further transport by the large boulder field mentioned previously.

House beside the former Baptist Manse - A large old wooden building on stilts.

The foundation of the latrine is being undermined by wave action. Mrs. Cameron told us that one month ago the latrine used to be stable as the sea was further out. Undermining now takes place when the sea is at high tide. The latrine is no longer in use. **Figure 12**.

Figure 12

House Across the Road from Almond Tree Bar

The section of house facing sea being undermined with partial collapse. The owners, who still live in the house are trying to patch the crack where the back wall has now parted from the side walls. **Figure 13**.

Figure 13

The residents told us that the main damage to the house occurred between November and December, 2002 (Tropical Storm Lili) and the rough seas at Christmas. They said that within a two year period the sea has come in some 30 m onto the land, the beach used to be "way out, as far as the first line of buoys." Based on the aerial photographs, it has taken about twenty years for the sea to come in this far.

Baptist Church Backyard

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

According to the 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.

Defunct Kiddie Park

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

We were told that 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 seawater 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 railway structures here.

Spit Near Rio Grande Estuary

St. Margaret's Bay residents recalled that swamp water used to flow (across the sand) directly into the sea but the river 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.

Beneath the Rio Grande Bridge

Noel McFee reported that 10 – 15 years ago one used to be able to dive from the bridge into the river. It has now 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 for the residents as a source of nutrition and income because 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. When asked about the flood gates located near Pen, on the Rio Grande the residents said they had been 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 showed 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.

Additional comments were obtained from three of the raft captains.

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:

The 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 fallen trees 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. The road along the east bank of the river has been undermined by landslide. The riverbank was eroded by floodwaters causing a sand and gravel truck to fall into the river.

At Rafter's Rest

Raft Captain 69 Cedric Ferguson told us that: the river was being "mashed up" by sand mining operation. He said the river channel was "piled up" with material and that rafters can't use long poles under the bridge. The water was cloudy; channels blocked; rafting routes impassable because of trucks in the way; miners reluctant to make way for rafters. He also said the river course alters depending on where gravel is pushed by the miners which forces rafters to

continuously change routes. Motor oil from mining company vehicles was polluting water – tourists can't swim there. Tourists complain that sight and sound of mining operation is unpleasant.

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].

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.

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. **Figure 14**.

Figure 14

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.

Welsh Woman's Point

This beach consists of well sorted to moderately well sorted gravel beach grading to sand at the shoreline. Approximately 150 m of gravel forms the tombolo. The beach is very steep, dipping on the side facing north. **Figure 15**.

Figure 15

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. **Figure 16**.

Figure 16

The visits made on March 3 and 25 revealed that the coast has suffered further erosion since the previous year. 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. 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. Survey tape measurements made from the road to the edge of the berm platform and close inspection of the IKONOS image also support these assertions. The amount of recent retreat is estimated to have resulted from an average 1-2 m of erosion of the berm platform.

(b) Evidence from Air Photographs

Taking the evidence from the photographs first, 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 covering 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 17, and vertical survey photos, 1992 onwards) the bulge has been removed on the coast of concern. Figure 18 shows part of the topographic map of the coastline based on the 1968 air photographs covering an air photograph of the coast in 1999. The coastline receded (moved in) by up to 50m as is seen in the region of the former bulge. However, the moving in of the coastline did not affect buildings at first (although loss of land occurred) as all the dwellings along here are built near to the road.

Figure 17 Oblique air photograph, September 28, 1984, showing straightened beach (right-hand edge of photo) following Hurricane Allen (J. Tyndale-Biscoe).

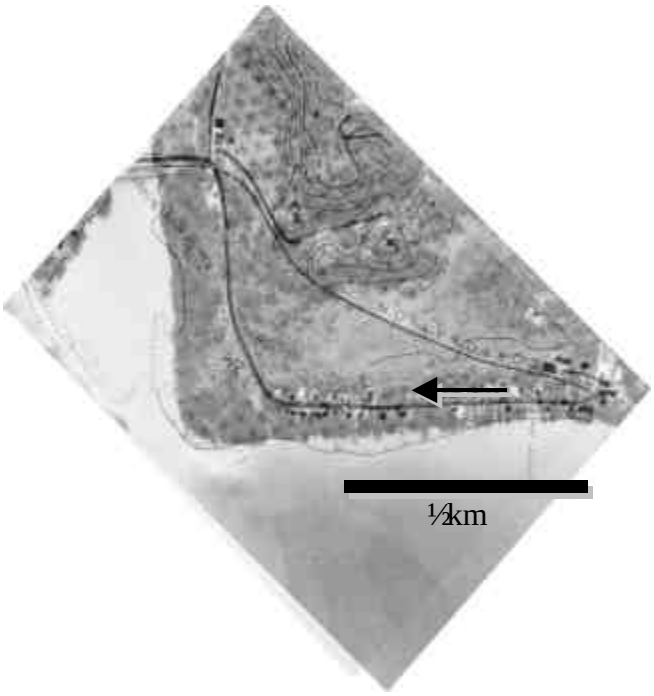


Figure 18 Shows the coast in 1999 obtained from an air photograph, overlain by part of the topographic map of the same coastline based on the 1968 air photographs. Note the large stretch of coast eroded, mainly by Hurricane Allen (arrow).

5. 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

Weather Conditions and 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. The movement of beach material along the shore, known as longshore drift, is towards the west. The naturally changing balance of the system results from the relationships among marine wave, tide and current processes, which control 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 go out of the St. Margaret's Bay system and in the end, must be replaced from the Rio Grande source. If they are not replaced, then there will be continuous removal of the beach sediment that is already there, beginning on the west side of the Rio Grande estuary and moving towards St. Margaret's Bay. Similar situations are present in most beach systems get their sediment 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 loose sand and pebbles forming the berm platform, beach sediment can also be renewed through erosion of this platform. This will most likely occur in times of heavy waves, 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.

Ten year or even hundred year cycles of beach erosion and progradation (moving of the sea further onto the land) are commonplace globally, with erosion or recession being most common (Bird, 1985). Along the east coast of North America today, about 90% of the beaches are being eroded (Leatherman et al. 2003). Cooper (2002) suggested that in Africa, beaches that get their sediments from river estuaries perhaps need very large floods from time to time, in order to change the beach system from being eroded to being rebuilt. St. Margaret's Bay may possibly need a big flood in the Rio Grande for its beach to naturally rebuild. Several years however, may have to pass before such a reversal to become apparent. This suggestion is supported by our observations of the beach history along the Vere coast of southern Jamaica.

Possible Causes of Beach Erosion

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

- Wave erosion by the onset of severe winter northers
- Wave erosion by passing tropical storms and hurricanes
- 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

The Effect of Tide, Wind and Waves

The direction of travel and the height of incoming waves to the St. Margaret's Bay coastline are primarily governed by the strength, and the direction from which the wind that creates the waves is blowing, and how long the wind blows. Over most of the year the wind is mainly coming from an easterly, even southeasterly direction. The waves made by the wind also travel from a similar direction, but are bent 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.

The direction of trend of the beach along the east side of Ken Jones Airport and Welsh Woman's Point is proof that the major direction of the waves is from the northeast. This part of the beach is the open, swash aligned (parallel to the incoming waves) section extending from the mouth of the Rio Minho to the tip of Welsh Woman's Point. This overriding wave direction is also supported by the westerly longshore drift observed at the groyne beach.

However, it was noticed that the main wave trains on the aerial survey photographs used for this study were coming mainly from the north or northwest (see Figure 19). 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 show the common occurrence of northers (storms from the north) at this time of the year. This encourages sediments to move along the airport coast towards the groynes. Along the St. Margaret's Bay coast movement is directly onshore or offshore. Heavy waves of northers erode sediments from the beaches into the offshore region. These northers may have the same effect on the beach as would a hurricane. If the following summer is mainly calm this sediment will come back onshore, but more towards the groynes area. Perhaps this is why the groynes section has sandy beaches (see Figure 20). But if no new sediment comes from the Rio Grande, the St. Margaret's Bay beach will remain eroded i.e. starved of sediment. Erosion is likely to take place during the next December to April period.

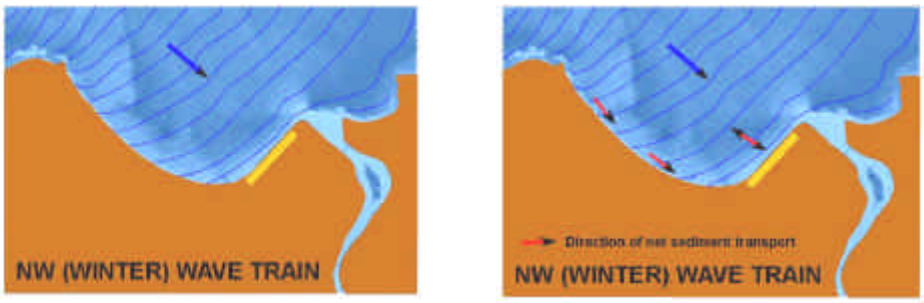


Figure 19 Diagram showing waves and sediment transport coming from the northwest into St. Margaret's Bay.

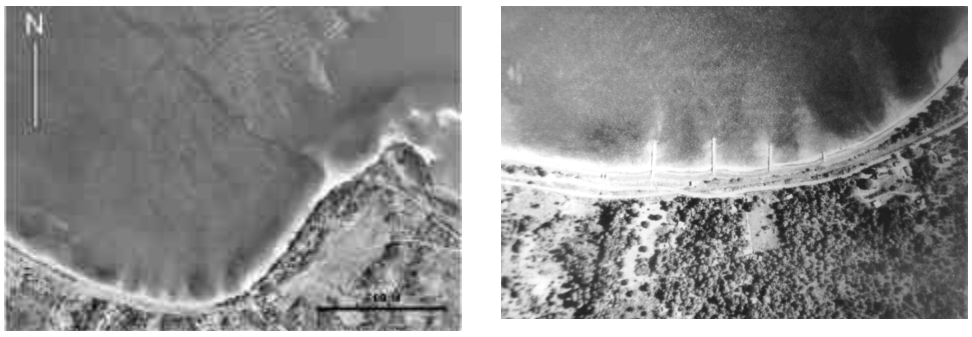


Figure 20 Air photos of the Groyne beach at St. Margaret's Bay taken in winter of 1991. Note the direction of the waves and the sandy beach.

In the summer months the direction of wave travel is usually from the northeast (See Figure 21). This movement transports the sediment which makes up the beach. Low energy summer waves promote beach growth and widening. The situation at the beach near Ken Jones Airport appears to have remained stable for the past 50 years (see Figure 22) Low energy summer waves have moved sand towards the groynes section from the stretch of present concern (see figures 23 and 24). These two influences, summer and winter, may be the reason why the groynes beach is in relatively good shape, compared with the beach section being eroded.

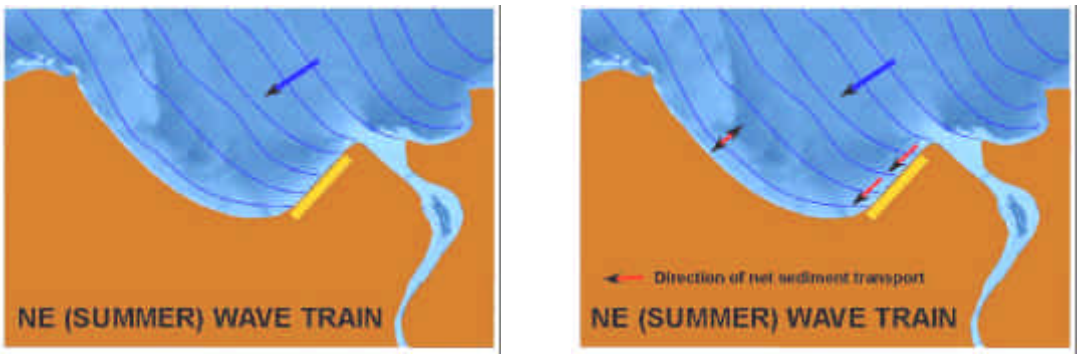


Figure 21 Diagram showing waves and sediment coming from the northeast. The rectangular strip shows the beach area being eroded in St. Margaret's Bay.

Figure 22 Beach near Ken Jones Airport.

Figure 23 Beach at Groyne area

Figure 24 Beach eroded in area of concern

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 25) caused damage to some structures near the beach (Appendix 2).

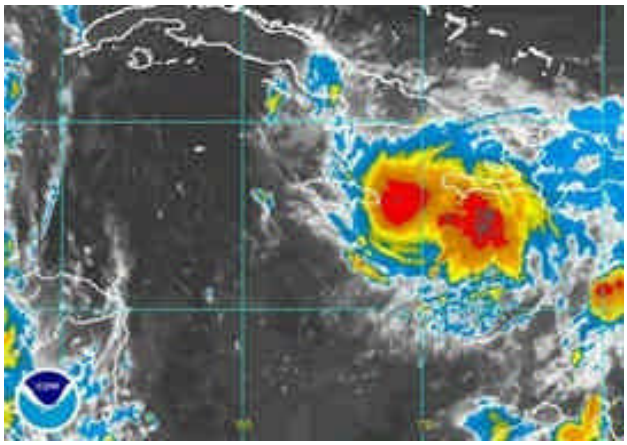


Figure 25 Satellite image of Tropical Storm Lili, 27th September 2002.

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 white sand, generated wave heights of 6 to 7 m and caused wholesale flushing of sand from shelf edge areas into deep water. Eleven times the amount of sediment as is usually moved in fair weather was transported. The volume of sediment removed from the Salt River submarine canyon was roughly equivalent to the amount of sediment that would have built up in a hundred years. 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 in St. Margaret's Bay with the passage of Hurricane Andrew, and that sediments on the shelf, normally available rebuild the beach during fair weather, 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 slowed down 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.

An account of the more severe storms to have affected this part of Jamaica is given in Table 1.

Table 1 Occurrence of Severe Storms Affecting the Northeastern Part of Jamaica

Year	Occurrence
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.
1903	On August 11, 1903 the effects of another hurricane, origination south east of Jamaica traveling in a north westerly direction, 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	Occurrence
1909	Although this hurricane hit western Jamaica on the November 18th, 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]).
1915	This hurricane passed north of the island 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])
1916	A severe hurricane passed just south of the island 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.
1917	1917 brought the third hurricane in as many years. 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 north eastern section of the island.
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 information 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]).
1944	This severe hurricane swept from the east on a west-north-west track 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]).
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 where most of the damage was caused by sea and wind (ODPEM[1]).

Year	Occurrence
1980	Hurricane Allen moving on a west-northwesterly course skirted the north coast of Jamaica on August 5th 1980. Travelling 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.
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 travelled 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]).
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	Occurrence
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]).
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.

Most of the natural disasters that affect the coastline in St. Margaret's Bay, Portland are associated with large amounts of water usually being brought in by heavy rainfall resulting from hurricanes or tropical depressions affecting the northeastern section of the island. In the past one hundred and eighty-six years, thirty (Table I) such storms 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).

Interference in Sediment Supply from Rio Grande Sand and Gravel Mining

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**

The water is clear, with a shoal visible. The river channel is deeper here than under the bridge. **Figure 26**.

Figure 26

Mr Shaw told us that there were 2 events of flooding in January and February 2003 which brought a halt to production. He said the 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 has opened another channel in the river, through a sand bar, to divert the flow of the water. Mr. Shaw said that mining began 1994/95. Sand is 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. The 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. **Figure 27**.

Figure 27

Banana farm being eroded by river. **Figure 28**

Figure 28

Mr. 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. **Figure 29**.
- 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. **Figure 30**.

Figure 29

Figure 30

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. **Figure 31, Figure 32**.
- 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.

Figure 31

Figure 32

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. **Figure 33**.

Figure 33

Production figures for sand and crushed stone released by the Mines and Geology Department (Table 2) indicate that mining activity on a considerable scale has been going on in the bed of the Rio Grande for several years.

Table 2 Sand and Crushed Stone Production in the Lower Rio Grande (in cubic metres, information from Mines & Geology Division)

		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 the amount of sediment being carried at various discharges, based ideally on observations at the bridge. Our discharge figures (Table 3) are based on the gauging station at Fellowship, which is some way up the river, although below the confluence with the Back Rio Grande, but no measurements of the amount of sediment being carried appear to have been carried out 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 normal 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 notable flood events (Table 3). These events have probably been more than sufficient to replenish the sediments in the bed of the river. 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 different size ranges of raw materials in the river bed, and such a study should 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 3 Notable flood events of the Rio Grande River over the period 1991-2001 (information adapted from the Water Resources Authority). Peak one-day discharges are the average quantity of water in cubic metres passing the gauging station every second for that particular day. Averages are also given for the daily discharge over each whole year, and figures for the months with the highest and lowest discharges for that particular year.

Peak One Day 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	Dec 21st - 28th			
347.07	2000-01	4	Dec 31st - Jan 3rd			
415.64	2000	1	Jun 1st	22.16	87.71	2.90
277.34	2000	6	Oct 28th -Nov. 2nd			
603.16	2000	5	Dec 20th - 24th			
247.34	1999	2	Mar 17th - 18th			
569.65	1999	2	Oct 25th -26th	28.76	66.06	5.40
281.25	1999	2	Nov 10th - 11th			
634.63	1998	2	Jan 4th - 5th			
207.33	1998	1	Feb 16th	35.70	126.48	5.68
253.62	1998	2	Oct 28th - 29th			
789.57	1998	14	Nov 30th - Dec 12th			
462.48	1997	2	Jun 5th - 6th			
604.63	1996	6	Feb 6th - 11th	10.44	30.50	2.24
424.44	1996	5	Nov 13th - 17th	29.95	86.35	8.97
265.14	1995	3	Feb 26th - 28th			
236.16	1995	3	Nov 16th - 18th	29.13	59.89	4.83
432.45	1995	2	Nov 27th - 28th			
325.28	1994	2	1 Jan 6th			

Peak One Day 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
324.03	1994	3	Jan 23rd - 25th	20.24	69.84	4.95
371.92	1994	2	Nov 12th - 13th			
1524.35	1993	6	Jan 26th - 31st			
404.66	1993	1	Feb 7th	49.17	125.66	7.59
635.42	1993	32	1st May - 1st Jun			
302.87	1993	1	Jun 21st			
749.7	1991	3	May 21st - 23rd			
298.57	1991	4	Nov 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 falling off 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 2) 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 Division estimated that some 40 000 cubic metres of such material may have been taken in addition to the figures given in Table 2. However, another person involved in that project thought that the marina probably consumed more than this, maybe as much as 80 000 cubic metres of cobble to small boulder-size material to reclaim and fill the marina area. It is said that most of this came from the river bed 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 unusually 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 3). However, if such extraction rates were to be repeated frequently then there would probably be serious interference with sediment supplies to the coastal region.

Mr. Tracy Prows, Manager of the Marina, made the following points in an interview with us on March 25.

- The 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.

Interference in Sediment Supply for Other Reasons

Some of these reasons are speculative but all can be scientifically tested by further investigations.

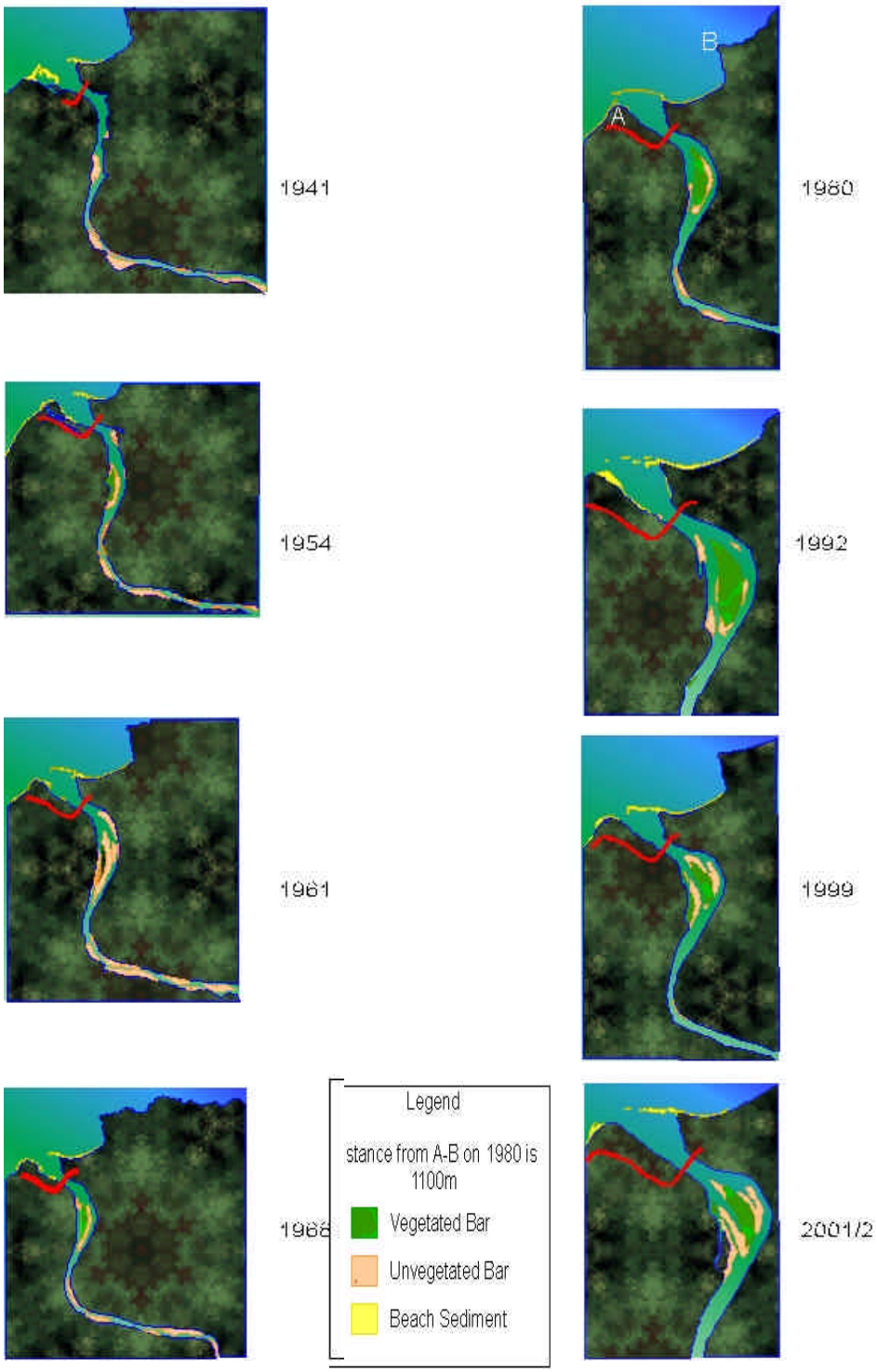
Flood events such as those mentioned above, associated with Hurricane Hugo in St. Croix (Hubbard, 1992) might also have the effect of discharging the finer-grained flood sediment load (sand) from the Rio Grande straight out over the edge of the shelf. Thus it would no longer be available as a possible 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.

On the other hand the shallow water now reported to be present under the Rio Grande bridge is possibly the result of deposition of sediment and aggrading (shallowing) of the river bed from receding flood waters. The evolution of the Burlington meander (the bend in the Rio Grande just before the mouth bridge) 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 shape of the lower course of the Rio Grande, summarized in Figure 34. 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 (see Figure 34).

Figure 34 Diagrams showing changes in the course of the lower part of the Rio Grande between 1942 and 2002



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.

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. 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 (Figures 31 & 32). Most of the mud probably originates from storm runoff in the valley of the Rio Grande. The valley sides are largely composed of shale and mudrocks. The gradual increase in and extension of cultivation of the valley sides in recent years has almost certainly led to an increase in the acreage of slopes stripped of vegetation and, which leads to more mud and gravel being removed by the river. Figure 35 shows the 12 kilometre extent of a sediment (mud) plume from a 1999 Rio Grande flood event, smaller than the ones listed in Table 3. However local fishermen insist that, when active mining is occurring, the Rio Grande still carries noticeable quantities of mud to the sea, even under low water conditions.

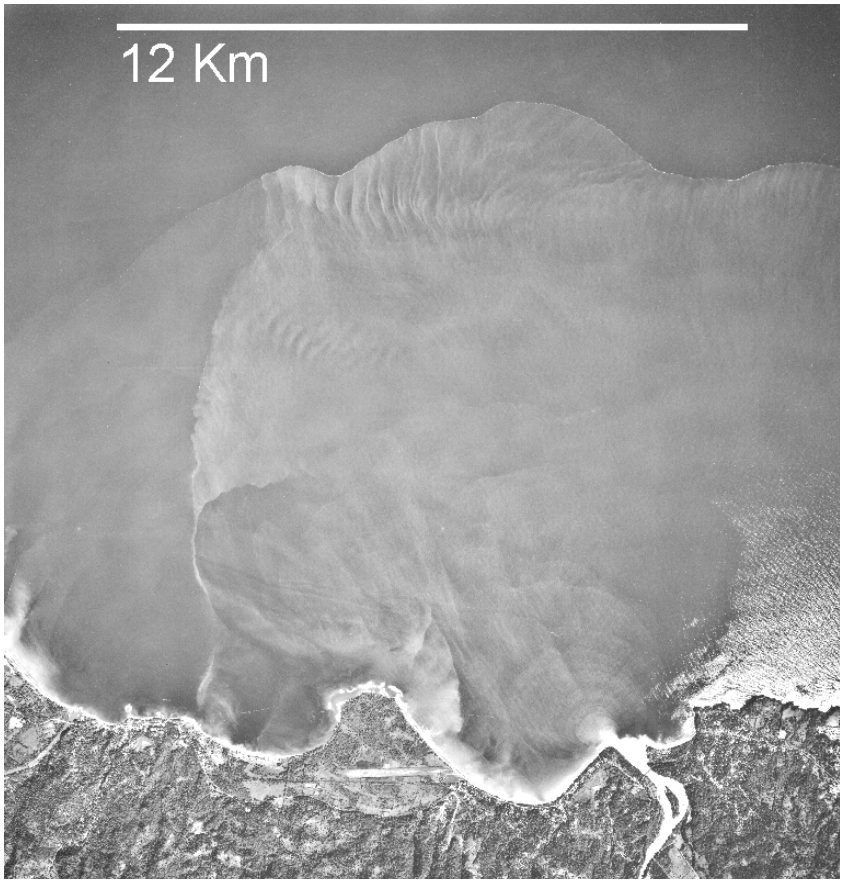


Figure 35 Sediment (mud) plume developed as a result of the Rio Grande flood of February 13, 1999.

Beach Recession Through Global Sea Level Rise

Sea level has been rising gradually for at least the past 100 years. Tide gauge information show that the global average sea level rose between ten and twenty centimeters during the 20th century. This is thought to be mainly due to ocean waters expanding as they get warmer

because of an increase in global temperatures as well as the melting of glacial ice (Church et al. 2001). If the coastal area at a particular point not undergoing earth movements, any sea level rise will result in retreat of the coastline. For such a historical rise, the amount of expected retreat for this reason alone at 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, growth rather than retreat 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 further coastal retreat. It will also make worse the already poor drainage characteristics of the morass behind the coast road. As the residents have pointed out, the increased water levels during flooding of the river already causes backing up of the water in the swamp.

Beach Erosion 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 trains 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 Hope Bay and Orange Bay

In order provide comparative erosion information for a beach that is almost certainly not influenced by sand and gravel mining we examined erosion on, March 4, 2003, reported to have occurred at Orange Bay. 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. 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.

Hope Bay – Black Stuff Beach Bar

This beach shows no signs of erosion, it is very wide in comparison to St. Margaret's Bay. **Figure 36**.

Figure 36

Orange Bay (Public) Bathing Beach

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

(Savannah Point to the East)

This is a pebble and sand beach. The water is clear. Waves come in from the north-east. There are drowned coconut trees. In what seems to have been a recent event, the beach has been eroded right up to the lawn. **Figure 37**.

Figure 37

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

According to one Orange Bay resident, the Public Beach has not been used in a year. It used to be filled with people on public holidays. The beach area used to be wider, the sea "way out". She reported that some people said 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. **Figure 38**.

Figure 38

6. 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 Hurricane 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 river mouth 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 (amount of sediment carried) of the river and the beach.

7. 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 used for the shoreline of concern. There are several possibilities: constructing groynes, dumping large riprap on the shore face, constructing gabions as suggested by one of the residents, constructing an offshore breakwater, a beach nourishment programme. Some possibilities are listed on pages 43-47. 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. This relocation may be necessary in the next 10 years.

3. A more detailed study should be made of changing beach processes including, say, monthly measurements of the beach 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. Measurements for the Rio Grande should be made in order to estimate sediment volumes carried for various discharge figures. Evaluate annual sediment transport into the estuary and to the beach (for the past and the future). A sediment budget for the estuary i.e. a measurement of the gain and loss of sediment) should be carried out. 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 (measurement of distance from sea level to sea floor) would be useful in estimating sediment reserves on the shelf, and in locating the probable submarine canyon.

8. Augering (taking samples by boring holes) the berm platform and the morass behind the platform could be done in order to try and date 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 geologist/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.

8. Combating Beach and Coastal Erosion

Basically there are four alternatives:

1. 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.

2. Armour the shoreline (sea walls, revetments or other barriers of various types, including vegetation).

3. Build structures to control the rate and intensity of erosion (groynes, offshore barriers etc.).

4. 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, the rate of 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 will 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. As noted previously, the rate of erosion seems to vary greatly through time and the present rate is probably low, less than a metre per year. 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 (see Figure 39).

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 geotextile tubes, or cobble and boulder-filled gabions (Figure 40) or the boulder seawall in Figure 41. 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.

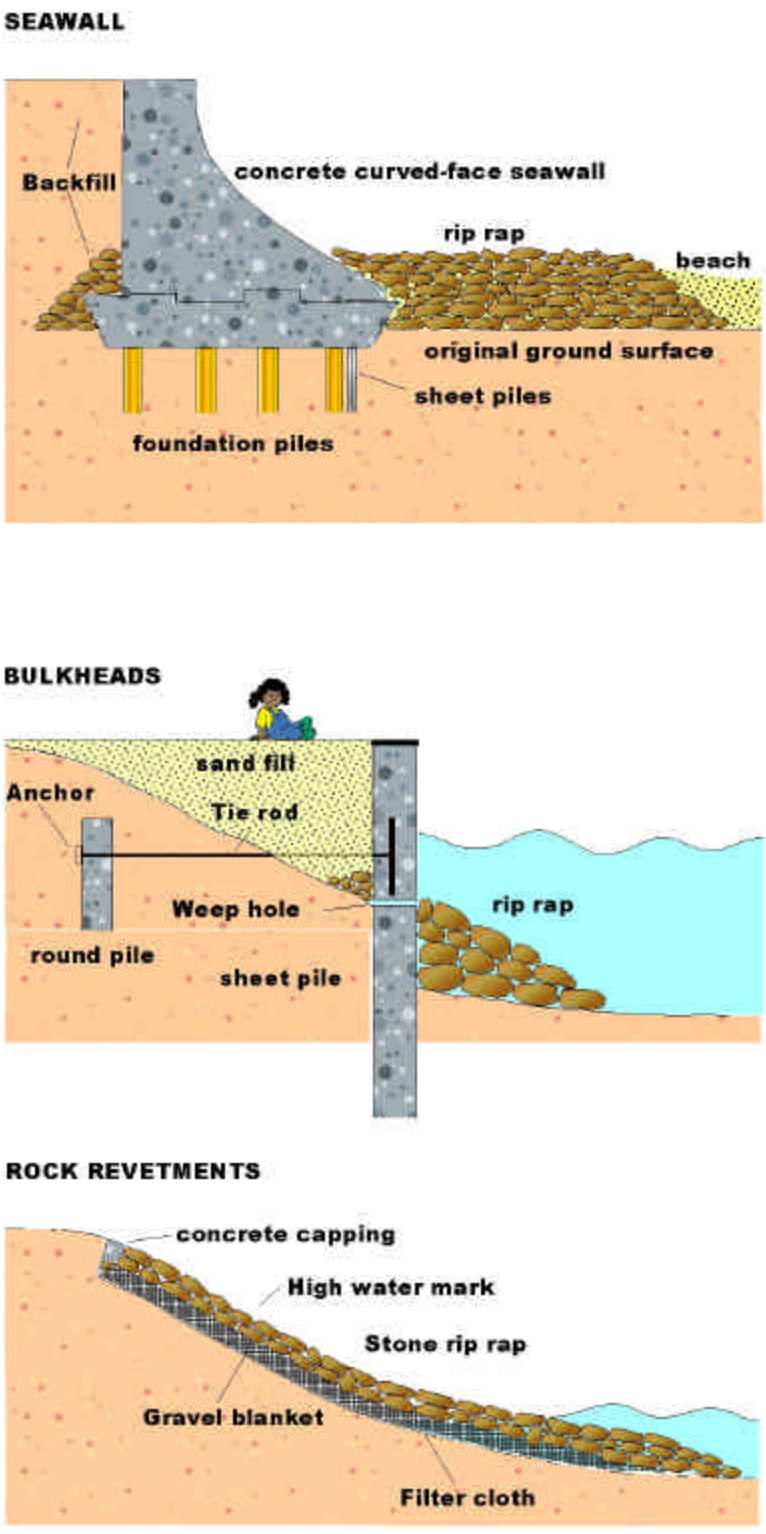


Figure 39 Three kinds of built structures for shoreline protection (armouring).

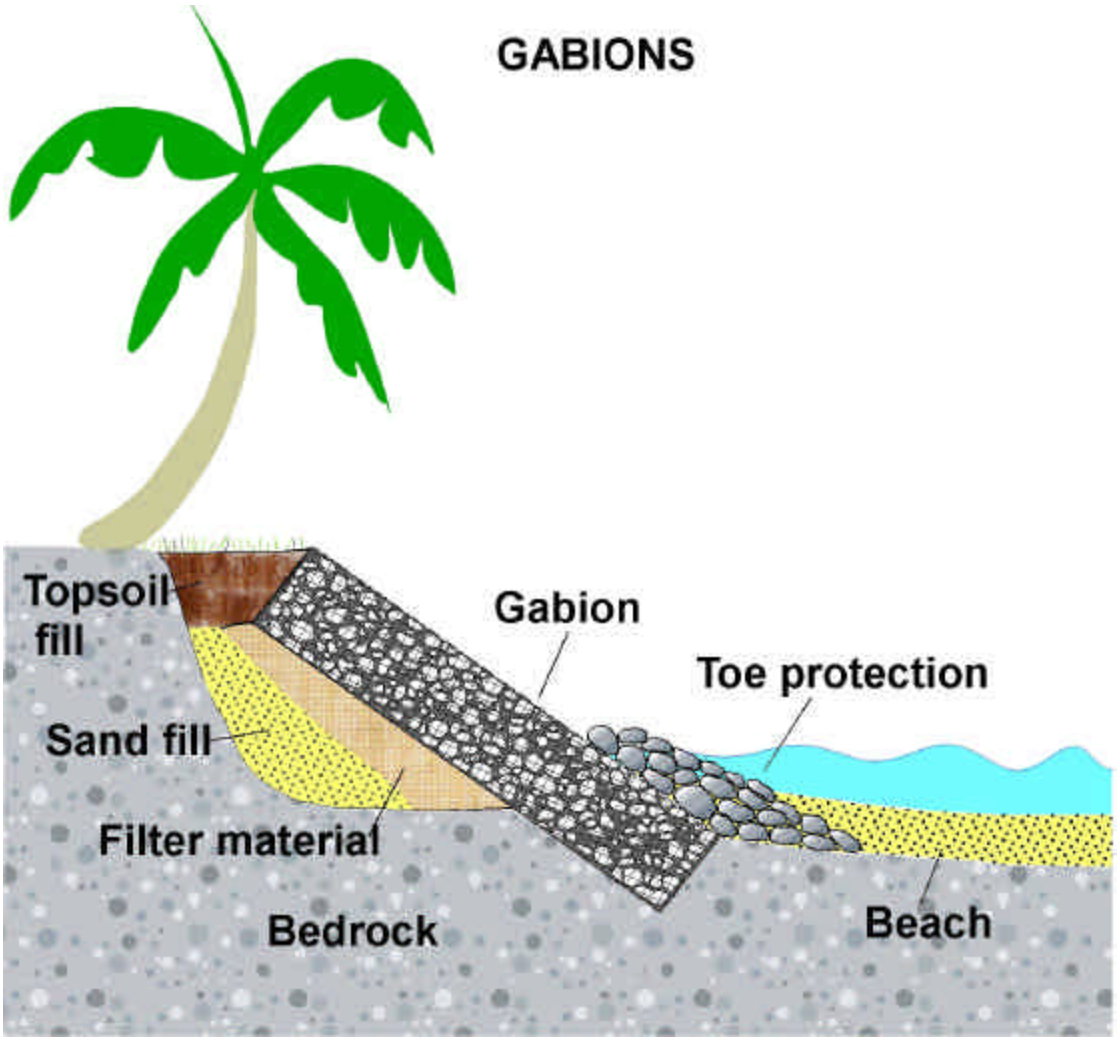


Figure 40 Gabion method of protecting beach

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 upshore 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 areas immediately on the other side of the groynes, thus promoting erosion there instead of at the place being protected (see Figure 42).

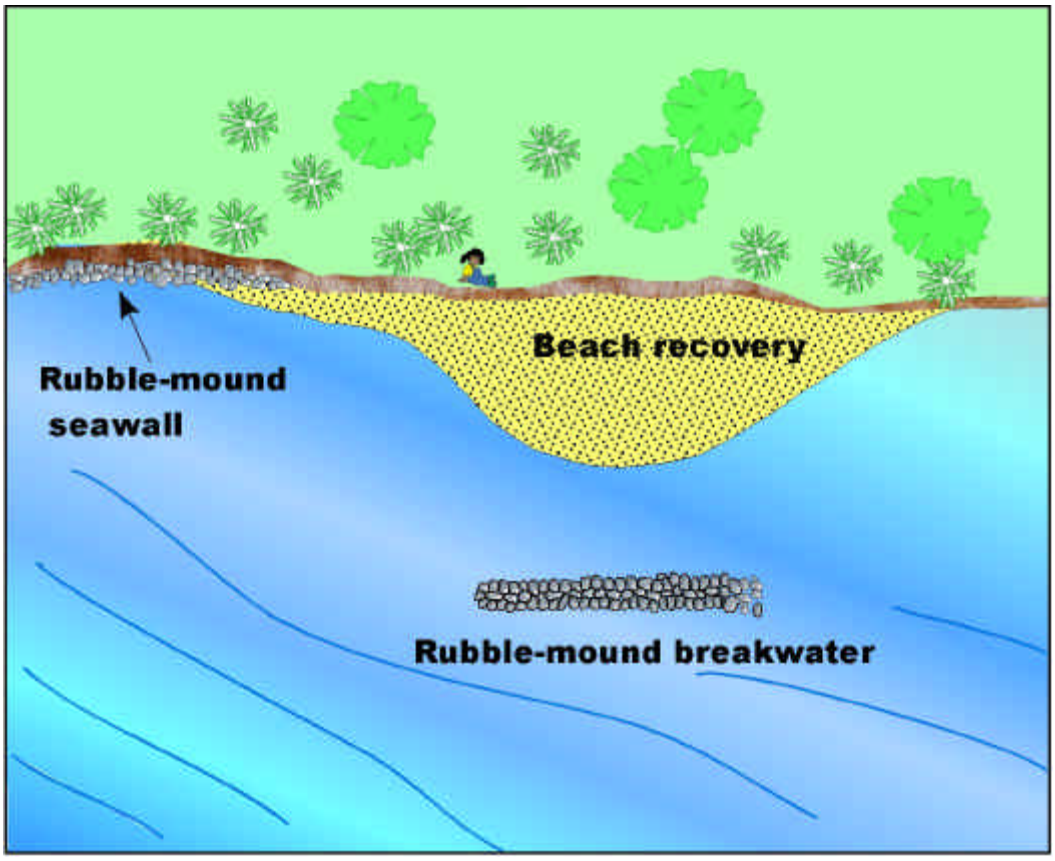


Figure 41 Breakwater to protect shoreline

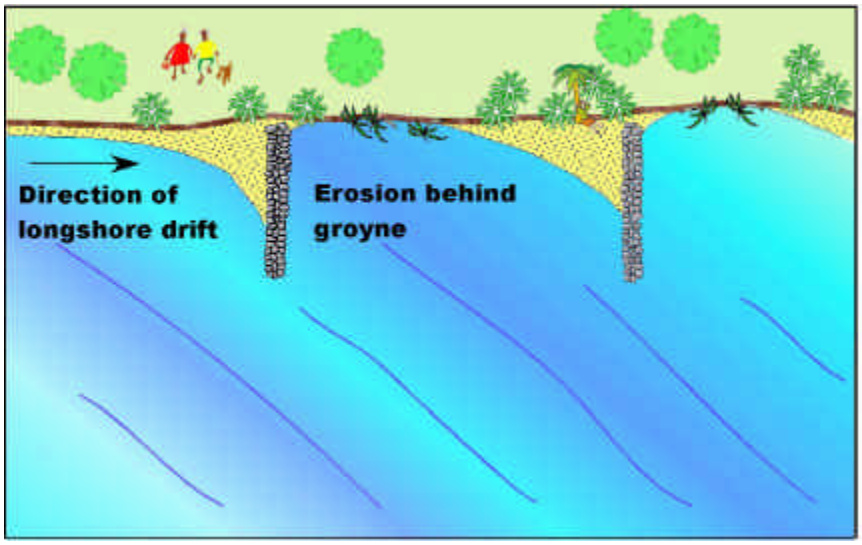


Figure 42 Groyne method of protecting shoreline. Note area behind groyne is eroded.

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 (see Figure 41).

Supplying sand and gravel at the upshore 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. See Figure 43.

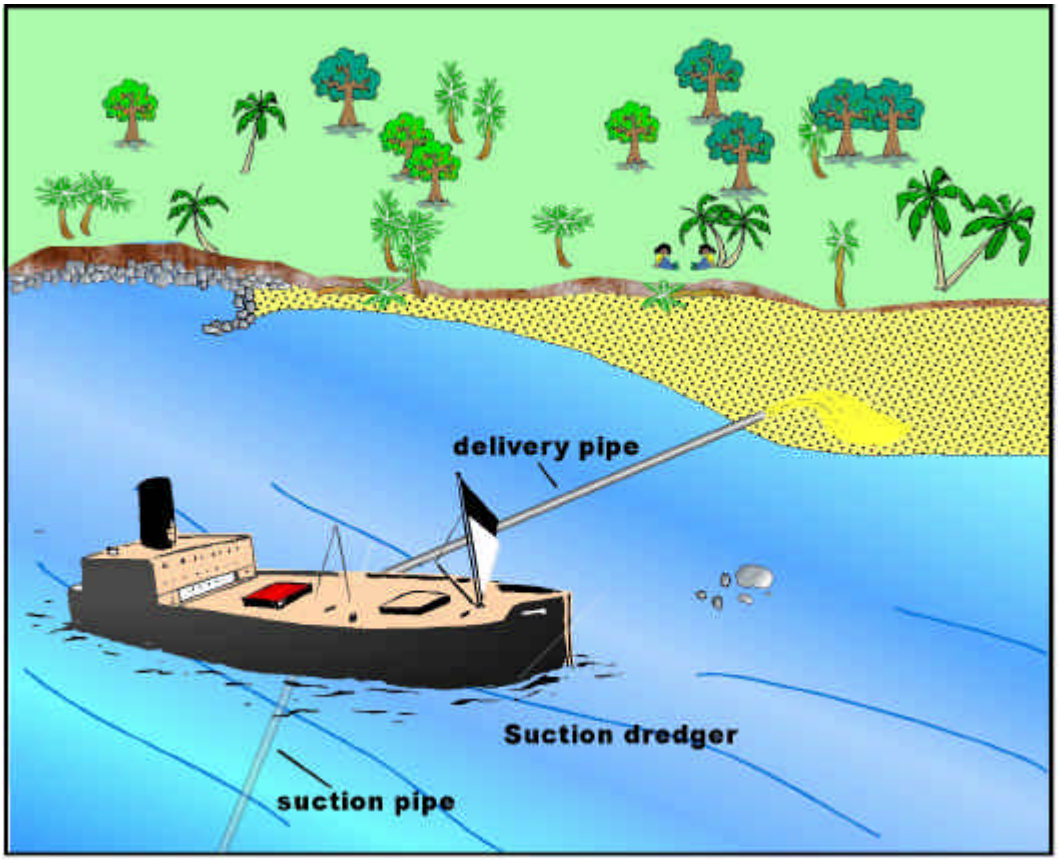


Figure 43 Beach nourishment activities

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 replenishment exercises involved would be a price the mining companies would have to pay to continue operations.

9. Response from the Residents

Comments From the Community of St. Margaret's Bay at Meetings Held on May 16th 2003 and July 3rd 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.
- Engineers needed to build beach-saving structures.
- Believe mining is the cause of erosion.
- Main concern is saving homes.

- Possibility of erosion at suggested relocation area.
- Public awareness campaign needed.
- Counsellors for community members needed.
- Downer's Bluff is called Bluff Point.
- Pictures in report should be in colour.
- Do not think structural measures suggested would work.
- Culverts with six-foot pipes should be used to drain swamp area as in Buff Bay.
- Any seawall built should have a gap to allow for passage of fishermen.
- Concern about taxes being demanded for land which no longer exists.
- Effects of tides and storms on the shoreline need to be controlled.

Next Steps

- Meeting of agencies to be scheduled for May 19th, 2003.
- 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).

What does the community want to see next?

- 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 raftsmen in Snow Hill were invited but did not show.

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

Next Steps

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.

10. 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.

Aerial photographs and satellite imagery were kindly loaned by the following agencies:

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).

2001/2 IKONOS imagery, ICENS.

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

We thank the members of the St. Margaret's Bay Citizens Association for their comments, suggestions and hospitality. This popular version of the report was also facilitated by a meeting with residents, held on July 3, 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: information 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 information for the parish of Portland and Wind information from the Norman Manley international airport.
March 14th & 19th	Water Resources Authority: Mr. Dwight Smikle, Discharge information 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

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.

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 located at the time of completion of this report.

Ridge to Reef Watershed Project