

**Caribbean Planning for Adaptation to Global Climate Change
Project**

CPACC

C6: Component 6
Coastal Vulnerability and Risk Assessment
(Barbados, Grenada and Guyana)

Grenada's Coastal Vulnerability and Risk Assessment

January 2002

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Grenada's Coastal Vulnerability and Risk Assessment

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EXECUTIVE SUMMARY

INTRODUCTION

The Coastal Vulnerability and Risk Assessment Pilot Project for Grenada was undertaken as a component of the regional Caribbean Planning for Adaptation to Climate Change Project (CPACC) project which consists of nine (9) components, four (4) regional components and five (5) pilot components. The overall objective of CPACC is to support Caribbean countries in preparing to cope with the adverse impacts of climate change particularly sea level rise, in coastal and marine areas through vulnerability assessments, adaptation planning and capacity building linked to adaptation planning. The twelve (12) CARICOM countries participating in CPACC include Antigua and Barbuda, the Commonwealth of Bahamas, Barbados, Belize, the Commonwealth of Dominica, Grenada, Guyana, Jamaica, St. Christopher and Nevis, St. Lucia, St. Vincent and the Grenadines and the Republic of Trinidad and Tobago. All of the participating countries have signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC).

METHODOLOGY

The detailed methodology used by the pilot study was based on the UNEP V&A methodology and utilized a staged approach, viz:

Stage One - Identification of problems and scope of analysis.

Stage Two - Scenarios for Coastal Vulnerability Assessment.

Stage Three - Impact Assessment.

Stage Four - Autonomous and Planned Adaptation.

For the purposes of study in Grenada, the coastal zone was defined as “*the band of land and sea straddling the coastline or the area most threatened by sea storms, tsunamis and certain other natural hazards*” (Salm et al, 1984). In practice, this was demarcated at the 45m (150 ft.) contour.

Site Selection and Scenarios

Based on the results of Stage 1, three (3) sites were selected for detailed analysis, viz:

- *Southwest Peninsula* - This region bordering the coast from Point Salines in St. George’s to Elliot Point in St. George’s, including the major tourism belt and the capital city of St. George’s.
- *Northeast Coast* - The coastal corridor stretching from Marquis in St. Andrew’s to Conference in St. Andrew’s, including the town of Grenville.

- *Carriacou* - The entire coastline of the island of Carriacou.

These sites were selected based on the significant presence of the at-risk sectors and/or activities as illustrated in **Table 2.1**.

Table 2.1 – Importance of Selected Sites

| SITES | Tourism | Fishing | Human | Ports | Infra Structure | Recreation | Historic Sites |
|-----------|---------|---------|-------|-------|-----------------|------------|----------------|
| Southwest | X | X | X | X | X | X | X |
| Northeast | X | X | X | X | X | X | X |
| Carriacou | X | X | X | X | X | X | X |

It was also decided that the Vulnerability analysis would focus on the impact of sea level rise on the following sectors within these sites, viz:

- Impact on socio-economic activities.
- Impact on critical infrastructure.
- Beach erosion and inundation.
- Impact on water resources, including potential for saline intrusion of the water table.
- Impact on coastal ecosystems.
- Review of institutional arrangement for responding to sea-level rise.

Scenarios for Coastal Vulnerability Assessment

The scenarios used in the analysis were:

- ✓ Sea Level Rise
 - SLR1 = 0.2 meters for 2020
 - SLR2 = 0.5 meters for 2050
 - SLR3 = 1 meter for 2100

- ✓ 100-year storm surge levels
 - SS1 = SSpx1.2 (assumes 20% increase)
 - SS2 = SSp (assumes no changes)
 - SS3 = SSpx0.8 (assumes 20% decrease)
 - SS2 should be applied to three years into the future
 - SS1 and SS3 should be applied for the year 2050 and 2100

- ✓ Vertical movement
 - VM = 0 (assumes no vertical movement along the coast of Grenada)

These scenarios are consistent with the predictions for sea level rise in the IPCC Second Assessment Report.

Limitations

The primary limitation was the unavailability of baseline data in almost all instances, which limited the comprehensiveness of the analyses that could have been done. In some cases, this limitation was addressed through the generation of original data using field

surveys and interviews. There were a number of areas however where these options were not feasible. This included bathymetry Data, contour maps below the 25 ft. contour and geo-referenced cadastral information for households, location of coastal infrastructure and levels for groundwater wells, in a format that could have been inputted into the GIS models.

IMPACT ASSESSMENT

The analysis of the vulnerability to sea level rise showed that the sites were very vulnerable and that there was the potential for inundation and flooding at each of the sites. This flooding and inundation would significantly affect commercial activities, human settlements and infrastructural facilities. In addition, many of the beaches at the sites would be significantly eroded and some would disappear. No assessments were done of the socio-economic and infrastructural impacts for the scenarios below due to the limitations

Vulnerability to Sea Level Rise (SLR)

(a) 0.20m SLR by 2020

The *beach erosion* analysis for this scenario showed that the Grand Anse beach would lose between 20% and 31% of its current width, the northeast beaches would lose about 30% of their current widths and the Carriacou beaches would lose between 50% to 65% of their current widths under this scenario. There were no significant hydrological impacts for a 20 cm SLR.

(b) 0.5m SLR by 2050

The *beach erosion* analysis for the southwest peninsula showed that between 55% and 75% of the Grand Anse beach would disappear, while the beaches at the northeast site would lose 65% of their current widths. In Carriacou, 83% of the beaches will disappear. This will include the complete recession of the beaches at Hillsborough, Paradise, Lillette and Windward. There would also be *hydrological* impacts in Carriacou with the wells at Playfield (Hillsborough), Church and Health Center (Windward), White Man (Bellevue) and Sabazan being inundated. These wells are all within 150m of the coast.

(c) 1m SLR by 2100

The impact of inundation from a 1m SLR by 2100, on the other sectors, is summarized in **Table 3.1**.

Table 3.1 – Impact of 1 Meter Sea Level Rise

| Types of Impact | South Peninsula | West | North East Site Total | Carriacou Site |
|------------------------|---|-------------|--|--|
| <i>Area of Impact</i> | Beach areas & businesses in George's Carenage | St. on and | Roads, commercial operations, human settlements and coastal ecosystems | Commercial areas, housing areas, roads, and coastal ecosystems |

| | Lagoon Roads | | |
|---|---|------------------------------------|------------------------------------|
| Beach Erosion | 86% - 96% of Grand Anse beach would disappear | Most beaches disappear | Most beaches would disappear |
| Infrastructure | | | |
| - Buildings/Floor Space (m ²) | 4,200 | 2,300 | 1,900 |
| - Buildings/Land (ha) | 0.72 | 0.62 | 0.07 |
| - Hotels/ Rooms (no.) | - | - | 8 |
| - Hotels/Land (ha) | - | - | 0.60 |
| - Industrial Complexes (no.) | - | - | - |
| - Ports (no.) | - | - | - |
| - Recreational (no.) | 1 | 1 | - |
| - Recreational/Land (ha) | 0.21 | 0.93 | - |
| - Transportation/Road (km) | 0.70 | 0.45 | - |
| - Electricity/Line Plant (km) | 0.70 | 0.45 | - |
| - Electricity/Generation | - | 0.45 | - |
| - Telecoms/Line Plant (km) | 0.70 | - | - |
| - Telecoms/Exchange (no) | 1 | - | - |
| - Water/Sewage Mains (km) | 1.40 | 0.30 | - |
| - Sewage Pump Stations (no) | 1 | - | - |
| Infrastructure Cost (EC\$) | EC\$23.1M (3.5%) | EC\$7.47M (11.4%) | EC\$2.040M (5.7%) |
| Hydrology | Salinization of some boreholes in Bailes Bacolet and Chemin | n.a | Salinization of 80% of wells |

The majority of the beaches at all of the sites will disappear. In addition, significant infrastructure will be inundated, including an estimated 18ha of land containing all the identified exposure units on the Carenage, St. George's, which is currently less than 0.20m above mean sea-level (AMSL) - the ground floor of the Financial Complex, the Carenage Sports Complex, the Carenage Road along with related utility plant (the Cable & Wireless telephone exchange and the St. George's sewerage system pump station) located adjacent to the Carenage Sports Complex.

Vulnerability to Storm Surges

The effect of storm surge at the pilot sites was also examined

(a) 2020 Storm Surge (5 ft. Flooding)

The flooding impact of a Category 2 Storm Surge combined with SLR by 2020 is summarized in **Table 3.2**.

Table 3.2 – Impact of 5 Ft. Flooding

| Types of Impact | Southwest Peninsula | North East Site | Carriacou Site |
|-----------------------|----------------------------------|--|--|
| Area of Impact | Major beach and commercial areas | Roads, commercial operations, human settlements and coastal ecosystems | Commercial areas, housing areas, roads, and coastal ecosystems |
| Beach Erosion | Significant erosion | Significant erosion | Significant erosion |

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| | | | |
|---|----------------------------------|---|---|
| Commercial Impact | | | |
| - No. Businesses | 180 | 100 | 67 |
| - Types of businesses | Major economic activities in all | Farmers, Fishing Government, Small Business | Farming, Fishing, Government and Commercial |
| - No. Employees | 3,085 (22%) | 115 (7.3%) | 184 (30%) |
| - Employment Income (Monthly) | EC\$4.4M | EC\$0.18M | EC\$0.325M |
| - Capital Loss | - | EC\$0.20M | - |
| Human Settlement | | | |
| - No. Homes | 106 (4.5%) | 135 | 20 (1.8%) |
| - Value of Homes | EC\$9.6M | EC\$11.4M | EC\$1.16M |
| - No. People | 295 | 760 | 88 |
| Infrastructure | | | |
| - Buildings/Floor Space (m ²) | 4,200 | 2,300 | 1,900 |
| - Buildings/Land (ha) | 0.72 | 0.62 | 0.13 |
| - Hotels/ Rooms (no.) | 236 | - | 16 |
| - Hotels/Land (ha) | 10.18 | - | 1.20 |
| - Industrial Complexes (no.) | 2 | - | 1 |
| - Ports (no.) | - | 1 | 1 |
| - Recreational (no.) | 1 | 2 | - |
| - Recreational/Land (ha) | 0.21 | 1.97 | - |
| - Transportation/Road (km) | 2.24 | 0.73 | 2.10 |
| - Electricity/Line Plant (km) | 2.24 | 0.73 | 2.10 |
| - Electricity/Generation | - | - | - |
| - Telecoms/Line Plant (km) | 2.24 | 0.73 | 2.10 |
| - Telecoms/Exchange (no) | 1 | - | - |
| - Water/Sewage Mains (km) | 2.00 | 0.50 | - |
| - Sewage Pump Stations (no) | 3 | - | - |
| Infrastructure Cost (EC\$) | EC\$2.6M (0.4%) | EC\$0.798M (1.2%) | EC\$0.810M (2.3%) |
| Hydrology | None | n.a | 1 well |

There will be significant flooding impacts on homes, businesses and infrastructure in all of the sites, including major sections of the St. George’s capital, the Grand Anse tourism belt, the town of Grenville and the town of Hillsborough.

(b) 2100 Storm Surge (10 ft. Flooding)

The flooding impact of a Category 2 Storm Surge combined with SLR by 2100 is summarized in **Table 3.3**.

Table 3.3 – Impact of 10 ft. Flooding

| Types of Impact | Southwest Peninsula | Northeast Site | Carriacou Site |
|--------------------------|----------------------------------|--|--|
| Area of Impact | Major beach and commercial areas | Roads, commercial operations, human settlements and coastal ecosystems | Commercial areas, housing areas, roads, and coastal ecosystems |
| Beach Erosion | Significant erosion | Significant erosion | Significant erosion |
| Commercial Impact | | | |
| - No. Businesses | 470 | 240 | 114 |

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| | | | |
|---|---|---|---|
| - Types of Businesses | Major economic activities in all sectors | Farming, commercial, Government and small business operations | Commercial, farming, fishing and government |
| - No. Employees | 4,835 (35%) | 235 (16%) | 435 (71%) |
| - Employment Income (Monthly) | EC\$6.2M | EC\$0.32M | EC\$0.56M |
| Human Settlement | | | |
| - No. Homes | 252 (11%) | 400 | 76 (6.8%) |
| - Value of Homes | EC\$40.6M | 2,640 | EC\$6.8M |
| - No. People | 826 | EC\$25.5M | 332 |
| Infrastructure | | | |
| - Buildings/Floor Space (m ²) | 9,800 | 3,600 | 2,800 |
| - Buildings/Land (ha) | 2.10 | 0.99 | 0.25 |
| - Hotels/ Rooms (no.) | 376 | - | 16 |
| - Hotels/Land (ha) | 24.56 | - | 1.20 |
| - Industrial Complexes (no.) | 3 | - | 1 |
| - Ports (no.) | 2 | 1 | 2 |
| - Recreational (no.) | 4 | 2 | 1 |
| - Recreational/Land (ha) | 14.03 | 3.32 | 0.01 |
| - Transportation/Road (km) | 6.52 | 2.12 | 3.50 |
| - Electricity/Line Plant (km) | 6.52 | 2.12 | 3.50 |
| - Electricity/Generation | Q. Park Stn. | - | - |
| - Telecoms/Line Plant (km) | 6.52 | 2.12 | 3.50 |
| - Telecoms/Exchange (no) | 1 | - | - |
| - Water/Sewage Mains (km) | 4.41 | 1.62 | - |
| - Sewage Pump Stations (no) | 5 | - | - |
| Infrastructure Cost (EC\$) | EC\$11.75M (1.8%) | EC\$3.3M (5%) | EC\$2.33M (6.5%) |
| Hydrology | 1 monitoring borehole in BB and 2 boreholes in Grand Anse | n.a | 1 well |

There will thus be very significant flooding impacts on homes, businesses and infrastructure in all of the sites, including major sections of the St. George's capital, the Grand Anse tourism belt, the town of Grenville and the town of Hillsborough.

INSTITUTIONAL READINESS

The study revealed that apart from the CPACC project and the Initial National Communications project, there is no institution or organization dealing specifically with issues of global climate change and sea level rise. Both of these projects are limited life projects, with very specific mandates.

The analysis of the legal framework concluded that *“most of the laws that are applicable to the management of the coastal zone are sectoral and decentralized ... while they have environmental application, they were not primarily legislated to address those concerns and are mainly incidental to environmental management. However, all the legislation listed ... can be utilized for the management of the coastal zone and to prevent, control*

and mitigate loss envisaged as a result of the adverse effects of global warming and sea level rise”.

The legal framework as it obtains now could be adapted and adopted as a short-term measure. The Report identified seventeen (17) laws that, if strengthened either through amendments or proper implementation, could provide a short-term legal framework for addressing climate change and sea level rise issues.

RECOMMENDATIONS

Despite it's the limitations in this vulnerability risk assessment, it is clear that Grenada is very vulnerable to the potential negative impacts of climate change induced sea level rise. It is important therefore that measures be initiated immediately to begin the process of adaptation to climate change. A wide range of adaptation options for each of the affected sectors have been proposed and recommended that these should be given priority attention by the relevant authorities.

It also recommended a number of actions that should be implemented immediately, viz:

- Sensitisation of Policy Makers and Key Stakeholders.
- Public Awareness and Education.
- Development of an Adaptation Policy Framework, within the context of a climate change policy framework.
- Capacity Building to Enhance future V&A Analyses.
- Closing of Existing Data Gaps.
- Incorporation of the Study's Results into National Planning, including the work of National Emergency Relief Organization (NERO), the Physical Planning Unit and the Economic Affairs Division of the Ministry of Finance.

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1. INTRODUCTION

The Caribbean Planning for Adaptation to Global Climate Change (CPACC) has its genesis in the Global Conference on Sustainable Development of Small Island Developing States, which took place in Barbados in April/May 1994. During this conference, the small island states and the low-lying countries of the English speaking Caribbean approached the Organization of the American States for assistance in preparing a project on adaptation to climate change. A number of regional consultations took place within CARICOM and the GEF Council approved the project in May 1995.

1.1 THE CARIBBEAN FOR ADAPTATION TO CLIMATE CHANGE PROJECT

The overall objective of the Caribbean Planning for Adaptation to Climate Change Project (CPACC) is to support Caribbean countries in preparing to cope with the adverse impacts of climate change particularly sea level rise, in coastal and marine areas through vulnerability assessments, adaptation planning and capacity building linked to adaptation planning.

The CPACC has been designed to assist national governments and the University of the West Indies Centre for Environment to:

- Strengthen the regional capability for monitoring and analyzing climate and sea level dynamics and trends, seeking to determine the immediate and potential impacts of global climate change.
- Identify areas particularly vulnerable to the adverse effects of climate change and sea level rise.
- Develop an integrated management and planning framework for cost effective response and adaptation to the impacts of climate change on coastal and marine areas.
- Enhance regional and national capabilities for preparing for the advent of climate change through institutional strengthening and human resource development.
- Identify and assess policy options and instruments that may help initiate the implementation of a long-term programme of adaptation to climate change in vulnerable coastal areas.

The twelve (12) CARICOM countries participating in CPACC include Antigua and Barbuda, the Commonwealth of Bahamas, Barbados, Belize, the Commonwealth of Dominica, Grenada, Guyana, Jamaica, St. Christopher and Nevis, St. Lucia, St. Vincent and the Grenadines and the Republic of Trinidad and Tobago. All of the participating countries have signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC).

The CPACC project comprises of nine (9) components, four (4) regional components and five (5) pilot components. The four (4) regional components were:

- a) Design and Establishment of Sea Level Climate Data/Climate Monitoring Network.
- b) Establishment of Databases and Information Systems.
- c) Inventory of Coastal Resources and Use.
- d) Formulation of Adaptation Policy Frameworks.

The five (5) pilot projects were:

- e) Coral Reef Monitoring for Climate Change.
- f) Coastal Vulnerability and Risk Assessment.
- g) Economic Valuation of Coastal and Marine Resources.
- h) Formulation of Economic and Regulatory Proposals.
- i) Greenhouse Gas Inventory.

Guyana, Barbados and Grenada were the pilot countries for Coastal Vulnerability and Risk Assessment.

1.2 IMPORTANCE OF THE COASTAL ZONE

The Coastal Zone in many Caribbean countries is of extreme importance. In Guyana, Barbados and Grenada the majority of the populations are located within the coastal zone. The coastal zones are responsible for vast amounts of the economic activity within the countries and are vital to the economy. This includes:

- The main sources of economic activity, including tourism and agriculture.
- Critical infrastructure such as hospitals, hotels and schools.
- The seat of Government.
- Major industrial plants located.

The coastal zone also supports a wide variety of biological diversity and thus is a highly productive biological area. They often contain coral reefs, wetlands, sea grass beds, and mangroves. These ecosystems are very fragile and thus are adversely affected by the increasing economic activity, which is ongoing within the coastal zone.

With predictions of increasing sea level rise, the coastal zone with its economic activities, infrastructure, and natural ecosystems are increasingly vulnerable.

Vulnerability can be defined as ‘*the degree to which an exposure unit is disrupted or adversely affected as a result of climate effects*’, while **assessment** refers to ‘*the scientific appraisal of effects on the exposure unit*’ (IPCC 1994).

A **vulnerability assessment** can therefore be defined as ‘*a scientific appraisal of the degree to which an exposure unit is disrupted or adversely impacted as a result of climate effects*’. Vulnerability can be distinguished into natural system vulnerability to climate change and socio-economic system vulnerability. These types of vulnerability are clearly related and are interdependent, as one cannot analyze socio economic vulnerability without an understanding of how the natural system will be affected.

Adaptation refers to ‘*all those responses to climate change that may be used to reduce vulnerability*’ (UNEP 1998). Adaptation can be autonomous or planned. Autonomous adaptation represents a system’s natural response to climatic change, while planned adaptation can reduce a system’s natural vulnerability by enhancing the systems resilience and/or resistance and thus enhancing the effectiveness of autonomous adaptation (Nicholls 1998). Decision 11CP/1 of the UNFCCC refers to adaptation in the following staged process:

- **Stage I: Planning** - which includes studies of possible impacts of climate change, to identify particularly vulnerable countries or regions and policy options for adaptation and appropriate capacity building.

In the medium and long term, the following stages are envisaged for the particularly vulnerable countries or regions identified in Stage I:

- **Stage II: Measures** - including further capacity building, which may be taken to prepare for adaptation, as envisaged by Article 4.1(e) ¹.
- **Stage III: Measures** - to facilitate adequate adaptation, including insurance, and other adaptation measures as envisaged by Article 4.1(b) and 4.4 ².

1.3 METHODOLOGIES FOR VULNERABILITY ASSESSMENT

There are number of methodologies for vulnerability assessment, which have been utilized for examining the impacts of sea level rise. These include the IPCC common methodology, the US country study program methodology, the South Pacific islands methodology, the Caribbean Disaster Mitigation Project methodology, the UNEP methodology and the RIKS decision support methodology. For this assessment the UNEP methodology has been applied. A further discussion on methodologies is contained in **chapter 4**.

2. CLIMATE CHANGE AND SEA LEVEL RISE

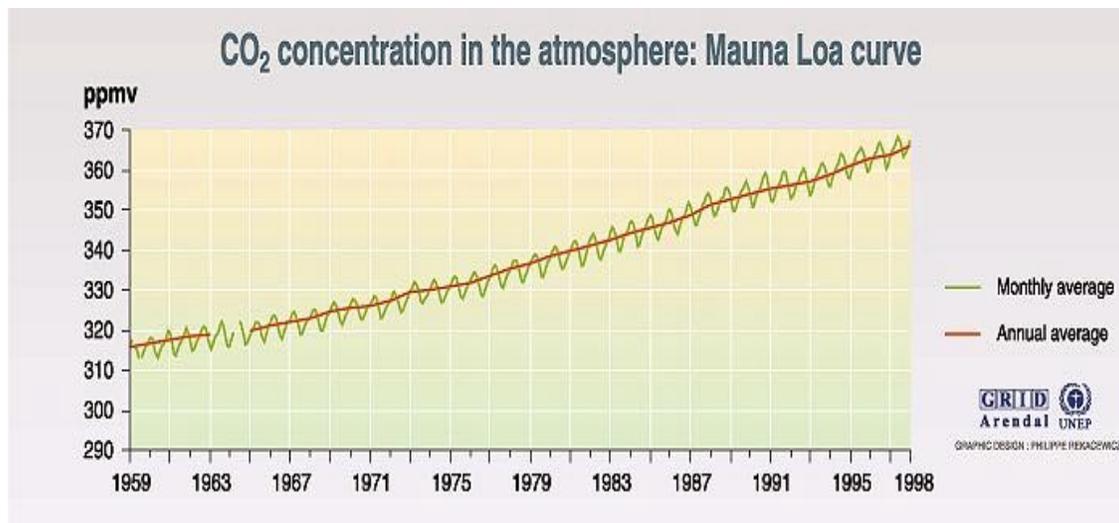
2.1. THE SCIENCE OF CLIMATE CHANGE

Changes in the earth's climate have occurred throughout the historical evolution of the earth. For example, the onset of the ice age caused the gradual decline of the dinosaurs as they could not adjust to the climate changes around them. The concept of changing climate is thus not new. However, in recent years, there has been a growing concern of the effects that the changing climate will have on human life.

In the last decade, there has been increasing scientific evidence suggesting that the continual pollution of the atmosphere with green house gases (GHG's), particularly via the combustion of fossil fuels, has been leading to global warming.

The primary cause of global warming results from the increase in the production of greenhouse gases as a result of human activity. Greenhouse gases are those gases that are important in global climate change, namely methane (CH₄), Nitrous Oxide (N₂O), Ozone (O₃), Chloroflourcarbons and Carbon Dioxide (CO₂). Increases in Nitrous Oxides (N₂O) levels have resulted from the increase in the utilization of nitrogen fertilizers, while the sources of methane (CH₄) are from the rice paddy fields, solid waste disposal sites and ruminant cattle. Ozone comes from unburnt hydrocarbons reacting with oxides of nitrogen, while chloroflourcarbons are found in aerosol propellants and refrigeration units.

Carbon Dioxide is the most important greenhouse gas. The increase in CO₂ arises from the combustion of substances containing carbon, namely fossil fuels such as coal, oil and natural gas, which are used to provide energy. CO₂ levels in the atmosphere are also increasing as a result of the clearance of forests for agriculture, as the forests act as a potential sink for CO₂. Atmospheric CO₂ has increased from a pre-industrial concentration of about 280 ppmv to about 367 ppmv in current times.



Source : Scripps institution of oceanography (SIO), University of California, 1998.

CO₂ concentrations in the atmosphere have been measured at an altitude of about 4,000 meters on the peak of Mauna Loa mountain in Hawaii since 1958 – **Fig.2.1**. The

measurements at this location, remote from local sources of pollution, have clearly shown that atmospheric concentrations of CO₂ are increasing. The mean concentration of approximately 316 parts per million by volume (ppmv) in 1958 rose to approximately 369 ppmv in 1998. The annual variation is due to CO₂ uptake by growing plants. The uptake is highest in the northern hemisphere springtime.

2.2. CLIMATE TRENDS IN GRENADA

Data on climate trends in Grenada have not been systematically analysed from the perspective of climate change.

At the general level, the country is characterized by humid tropical climate, with relatively constant temperatures throughout the year averaging 26 degrees centigrade. The mean maximum temperature is 31.4 degrees centigrade while the mean minimum is 24.0 degrees centigrade.

Over the last decade the annual rainfall ranged from 750 to 1400 mm. Two distinct rainfall patterns are evidenced. The dry season typically runs from January to May and the rainy season from June to December. Carriacou and Petit Martinique generally receive lower levels of rainfall and during the dry season can experience severe drought conditions.

Grenada lies in the path of the North East Trade Winds and although located south of the hurricane belt, the country is vulnerable to tropical storms, occasional hurricanes and storm surges. The hurricane season runs from June to November and Grenada was last hit by a major hurricane in 1955 (Hurricane Janet), which brought very extensive damage and resulted in the loss of over one hundred (100) lives.

In 1999, the first major storm surge, as a consequence of Hurricane Lenny, caused severe infrastructural damage to the West Coast of the Islands and to Carriacou and Petit Martinique. In the intervening years, occasional storm damage has been experienced.

3. COASTAL ASSETS AND ECONOMIC ACTIVITIES

There is no single definition of the coastal zone in Grenada and the one used for this study is “the band of land and sea straddling the coastline or the area most threatened by sea storms, tsunamis and certain other natural hazards” (Salm et al, 1984). This was deemed most appropriate in the absence of a legal definition within the laws of Grenada. This coastal area supports a vast wealth of marine resources, has some of the most biologically productive and economically valuable habitats and provides the base for a significant proportion of Grenada’s social and economic resources and activities.

3.1. MANGROVES

No recent estimates have been made of the present size of the mangroves in the tri-island state. Bacon (1991) suggested that one hundred and ninety (190) hectares of mangrove occur in Grenada. Barriteau (1998) in his study on wetlands in Grenada pointed out that mangrove forests are constantly under threat and the present estimates may well be less. Mangroves mostly occur in small pockets along the coast. Significant mangrove forest can be seen at Levera Pond, Conference Bay, La Sagesse and the bays and islands from Woburn Bay to Westerhall Bay. In Carriacou, important wetland systems occur at Petit Carenage Bay, Saline Island, Tyrrel Bay and Lauriston Point near the airport. Mangrove ecosystems are important to Grenada because they restock the offshore fishing stock; they provide income and food to rural families who purchase charcoals, crabs fish, poles and oysters that originate from mangrove areas. Mangroves are land builders and protect our coastline, reefs and beaches. They offer important opportunities for education and scientific research.

Not enough information is known about the rate of loss of wetland in Grenada. Barriteau (1998) through interviews and community meetings with users of the resources found out that a large proportion of Grenada’s mangrove forest has been lost to conversion, over harvesting and pollution. The major contributing factor is people’s perceptions and / or beliefs. The average Grenadian, he says, sees the mangrove area as “*a smelly, useless, mosquito infested swamp.*” The problem is compounded when they are converted into “something more immediately useful” by politicians for short-term economic gain (Barriteau 1998).

Some of the major threats to the mangrove ecosystems in Grenada are:

- Hotel development – This will affect La Sagesse and Levera Pond (Beacon, 1991).
- Dumpsites/landfills proposed for Conference and Telescope.
- Major infrastructural development – Carriacou airport expansion.
- Construction of artificial shrimp farms.

3.2. CORAL REEFS

Coral reefs occur mainly on the northeast and south coasts of Grenada. Large bank barrier reefs occur on the east coast of Carriacou and Petite Martinique. These reefs are strongly dominated by Elkhorn coral in shallow areas and well-developed boulder coral zones the status of these coral.

Grenada's best reef is reported to be the Moliniere reef on the west coast, north of Grand Mal Bay. This reef is proposed for an underwater park and marine reserve (GOG/OAS 1988). Moliniere reef and the reefs outside Grand Anse and Morne Rouge area seem to be under a significant degree of sediment stress presumably from upland erosion. In Grenada and the Grenadines, run-off from inland, pesticides, coral harvesting, anchor damage from boat, sewage pollution, sand mining and coastal development have reportedly caused reef damage (Environmental Profile 1991). No detailed information on the distribution effects of various "natural" stressors is available for Grenada's reef. *Goodwin, et al (1996)* studied species density and coral association at Saline Island and Jack-A-Dam Island off Carriacou. These reefs and those at Grand Anse Bay are the best-studied reef areas in Grenada in terms of community composition and species diversity.

3.3. SEA GRASSES

Little or no accurate information is available on the distribution of sea grass beds in Grenada and the Grenadines. The map developed by ENCAMP (1980) shows some areas of sea grass along the east, central and south parts of Grenada's coast and on the west coast of Carriacou.

3.4. COASTLINE FEATURES

Beaches are one of the most dynamic systems in nature and show visible changes over hours, days and years (*Cambers, 1997*). They have an intrinsic value to the coast and provide protection to the coastline, recreational opportunities to the local population and tourists, support the livelihood of the fishing communities and the fishing industry and provide nesting grounds to sea turtles. In addition to beaches, Grenada has a number of other coastal types – cliffs, offshore cays, rocky coastline and estuaries, all of which can be adversely affected by sea level rise.

3.5. FISHERIES

Grenada has the second largest shelf areas in the Organisation of Eastern Caribbean States (OECS), as well as substantial fishery resources. The major fishing centers (Victoria, Gouyave, and Melville Street, St. George's) are located on the western coast, with other important centers at Sauteurs in the north and Grenville in the east. The fishing industry is an important socio-economic activity in the coastal zone and has contributed significantly to the country's economy. In 1998, the industry contributed EC\$11.45 millions to the country's Gross Domestic Product (GDP) and was projected to contribute EC\$12.37M and EC\$ 13.32M in 1999 and 2000 (*Grenada Statistical Office, April 1999*). Fishing in Grenada and its dependent islands is artisanal and there are 1700 full time and 300 part time fishermen (*Fisheries Division, MOA, 1998*).

3.6. TOURISM

Tourism is also an important socio-economic asset in the coastal zone and is contributing significantly to the island's economy. It is presently the leading growth sector, generating more than 50% of the country's foreign exchange earnings and stimulating activity in construction and ancillary services.

In 1998 the revenue generated from stay over arrivals amounted to EC \$156M. Real GDP in tourism is projected to grow at the rate of 5 – 7% during 1998 – 2000. Total visitor arrivals are predicted to grow by 3% in 1998 and 6% in 1999 and average 8% in 1999 and 2000, based on an increase in marketing and scheduled airline services from major source market (*Medium-term Economic Strategy Paper, GOG, May 1998*).

The Master Plan for the Tourism Sector states that in 1997, 85% of the island's room stock was located in the southwestern peninsula, viz:

- Twenty-two (22) units or 40% in Grand Anse.
- Eighteen (18) units or 37% in the True Blue, Lance Aux Epines area.
- Thirteen (13) units or 8.6% in the capital city of St. George's.

There were only eight (8) accommodation units in rural Grenada accounting for 4% of the room stock. In the Levera and Bathway areas, tourist activities are increasing and with the coming to being of the proposed Levera Development Project, tourist activities will increase greatly in this area. Tourism is seen as a vital source of revenue for Government, and employment (including self-employment) for the people. The islands of Carriacou and Petite Martinique account for sixteen (16) properties, one of which is located on Petite Martinique. They represent 9% of the available room stock in Grenada. The situation has not changed since 1997.

3.7. HUMAN SETTLEMENT

According to the 1991 census, the population of Grenada and its dependencies is 95,597 persons. The population can be described as relatively young with persons under 15 years accounting for 38% and persons 65 years and over accounting for only 8%. The coastal population of Grenada, Carriacou and Petit Martinique comprise approximately twenty-nine (29) settlements inclusive of six (6) towns. These settlements account for approximately 19% of the nation's population. These communities are also host to a number of schools and other social amenities like churches, supermarkets and the like.

3.8 MAJOR PORTS

In Grenada port facilities consist of airports and marine ports.

3.7.1. Airports

The Point Saline Airport, which was opened in 1984, is located on the southwest shore of the island. The airport is of significant importance to tourism development, since it is in close proximity to the main tourist attractions in the southwest and is the main gateway into Grenada. Other airport facilities are Lauriston Airport, the only facility of its kind in Carriacou, and Pearls Airport, the former landing site on the mainland before Point Salines was commissioned. The latter is not currently in use, but plans have been announced to reopen it sometime in the future.

3.7.2. Marine Ports

There are a number of marine ports in Grenada, viz.:

- *St. George's* - The St. George's port which is the main commercial seaport is located on the southwestern side of the island. The facility is used by cruise ship visitors and by business operators for export and import of commercial goods.
- *Grenville Port* - The port of Grenville is located on the east coast of the island and is the second largest port on mainland Grenada. It functions as the main landing site for fishermen on the eastern side of the island and as a shipping facility for agricultural goods and services to and from Trinidad.
- *Gouyave Port* - This port is located on the western side of the island and is home to several fishing trawlers. Gouyave is considered as the fishing Mecca of the nation.
- *Hillsborough (Carriacou)*- This port is the main point of entry of goods and services to and from the mainland Grenada.
 - *Petite Martinique* - The port is the only connection to the outer world for Petit Martinique.

3.8. INFRASTRUCTURE

For the purpose of this study, coastal infrastructure is considered to be that related to water, electricity, telephone and roads.

3.9.1. Water

Potable water supply in Grenada comes from two sources - Ground water (wells) and surface water (river intakes). In 1998, the approximate daily production of water from ground water and surface water was 0.45 million gallons per day and 7.88 million gallons per day respectively – a total of 8.33 million gallons per day. The ground water

supply in some areas is contaminated with salt water and there are problems with maintaining salinity at acceptable levels.

3.9.2. Electricity

Electricity throughout the state of Grenada is produced by the Grenada Electricity Services Ltd. (GRENLEC). With the exception of Carriacou, the generating facilities in Grenada and Petite Martinique are very vulnerable to sea level rise. In Grenada the generating station is located in a flood prone area (Queen's Park). The facility in Petite Martinique however, is located within 75 meters from the coast where extensive sea defense work was recently completed to prevent erosion. The generating stations are not the only resources of the company that are vulnerable.

In Grenada along the distribution line at various locations there are approximately 40 switches used for isolating services. These switches are all linked via the distribution network. Thirty (30) of these are distributed throughout the interior of the island and nine (9) are located within the coastal zone and are vulnerable to sea level rise. If an area is affected within the coastal zone, the impact on the population will be minimal. Within the network, an area can receive electricity from several switch locations by methods referred to as isolating and opening an area.

3.9.3. Telecommunications

Telecommunication services in Grenada are provided by Cable and Wireless Grenada Limited and Grenada CableVision Limited. Cable and Wireless Grenada Limited hold the monopoly for the distribution of telephone and related telecommunication services. The Cable and Wireless services are distributed throughout the state via a network of cables, outside plant module (O.P.M.) and cabinets. Cables are distributed along the island roads linking O.P.M.'s and cabinets. There are approximately 18 O.P.M.'s throughout the state, four of which are coastal and are considered vulnerable to sea level rise by the company. These are located at Hillsborough, Carriacou; Petite Martinique; Victoria; and the Carenage, St. George's. Should sea level rise impact on these facilities, services to the population in Carriacou and Petit Martinique will be significantly reduced as the main services on the two islands are distributed from vulnerable locations (Hillsborough, Carriacou and Chicen, Petit Martinique).

On the mainland Grenada, the impacts on the population served by facilities, which are vulnerable, will be minimal, as a back-up system can be readily adapted to restore services. The undersea cable link to the Eastern Caribbean Fiber Optic lines on the east coast is considered very important by the company – approximately 1,500 meters of cable along the road at Grenville and St. Andrew's bay is vulnerable to possible impacts of sea level rise.

3.9.4. Roads

The island's roads can be characterized into three categories, primary, secondary and tracks. The primary roads are the main service roads linking towns and regions and can be described as low level and high level coastal roads. Low level coastal roads are roads located at beach level whereas high level coastal roads are roads constructed along the

top of coastal cliffs. Some of these roads are exposed to coastal erosion from wave action and rising sea level.

3.10. RECREATIONAL FACILITIES

Throughout the State of Grenada there are sixteen (16) major recreational facilities, which are coastal, including ALL the major facilities, viz.:

Major playing fields are:

- Tanteen Playing Field – St. George’s
- National Stadium/Queen’s Park – St. George’s
- Beausejour Playing Field – St. George’s
- Cuthbert Peters Park – St. John’s
- Alston George St. Mark’s
- Mt. Craven – St. Patrick’s
- Grenville Recreation Ground – St. Andrew’s
- La Sagesse – St. David’s
- Hillsborough – Carriacou

There are also important Hard Court facilities at:

- Tanteen Netball court – St. George’s
- Grand Anse court – St. George’s
- Grenville Hard court – St. Andrew’s
- Gouyave Hard court – St. John’s
- Victoria Hard court – St. Mark’s

3.11. HISTORIC / CULTURAL SITES

Some of the islands historical resources are distributed within 0.25 mile of the coast. These consist of historic buildings, military sites, archeological sites, geological sites and others. These sites can be divided into two main categories – National Landmark and Cultural landmarks. Many of these are used to showcase Grenada’s attraction for tourism.

Key historical sites are:

- Westerhall Rum Distillery
- St. George’s Town/Harbor
- Quarantine Point
- Fort George
- River Sallee Boiling Spring
- Lake Antoine
- Mt. Carmel Falls
- River Antoine Distillery
- Marquis Village
- Fossil Beds, Grand Bay, Carriacou
- Carib Leap / Leapers’ Hill

- Dover Ruins
- Lime Factory (Cragston, Dumfries), Carriacou
- Sandy Island

Key cultural facilities:

- National Trade Center – St. George’s
- National Youth Center – St. George’s
- Simon Pavilion – St. Andrew’s

There has been no study on possible effects of sea level rise on any of these facilities. However, it can be said that sea level rise will have negative impact on all these facilities since these are located approximately 2 meters or less above sea level.

4. METHODOLOGY FOR VULNERABILITY ASSESSMENT

4.1. METHODOLOGICAL OPTIONS

The overall objective of Component six of CPACC is to assist countries with initial adaptation planning for sea level rise through the conduct of a vulnerability assessment. Of specific concern given the pilot nature of the vulnerability assessments, is the methodology and approach, which was utilized for the vulnerability assessment.

Initially five potential vulnerability assessment methodologies and approaches were examined and critically assessed in terms of their utility for the Caribbean. The methodologies examined were:

- a) The IPCC common methodology (IPCC 1992)
- b) The US country studies program methodology (Leatherman and Yohe 1995)
- c) The South Pacific Island Methodology (Yamada et al 1995)
- d) The Research Institute for Knowledge Systems (RIKS) decision-support methodology
- e) The UNEP Handbook Methodology (Burton et al 1998)

Table 4.1.1 below examines the advantages and disadvantages of the various methodologies (*Nicholls 1998*).

It was also necessary to distinguish between a **vulnerability assessment framework** and a **vulnerability tool**. A framework could be considered as a set of fundamental questions or steps, whose answers assist the vulnerability assessment and collectively constitute some overview of coastal area's vulnerability to sea level rise. A vulnerability assessment tool is a method or a step within a vulnerability assessment framework (*Nicholls 1998*).

The vulnerability assessment methodologies were also analyzed in the context of the Klein and Nicholls (1998) definition of coastal vulnerability. Klein and Nicholls (1998) defined coastal vulnerability assessment using the conceptual framework in **Fig. 4.1.1**.

4.1.1. Assessment of Methodologies

The IPCC Common Methodology while being the first methodology, which was proposed for vulnerability studies, was found to be quite inflexible, with adaptation options insufficiently developed. The IPCC Common Methodology however is logically set out and has been utilized widely.

The South Pacific methodology, while useful, has been formulated for countries that have limited data, and thus is not suitable for Caribbean countries where there is more comprehensive data available.

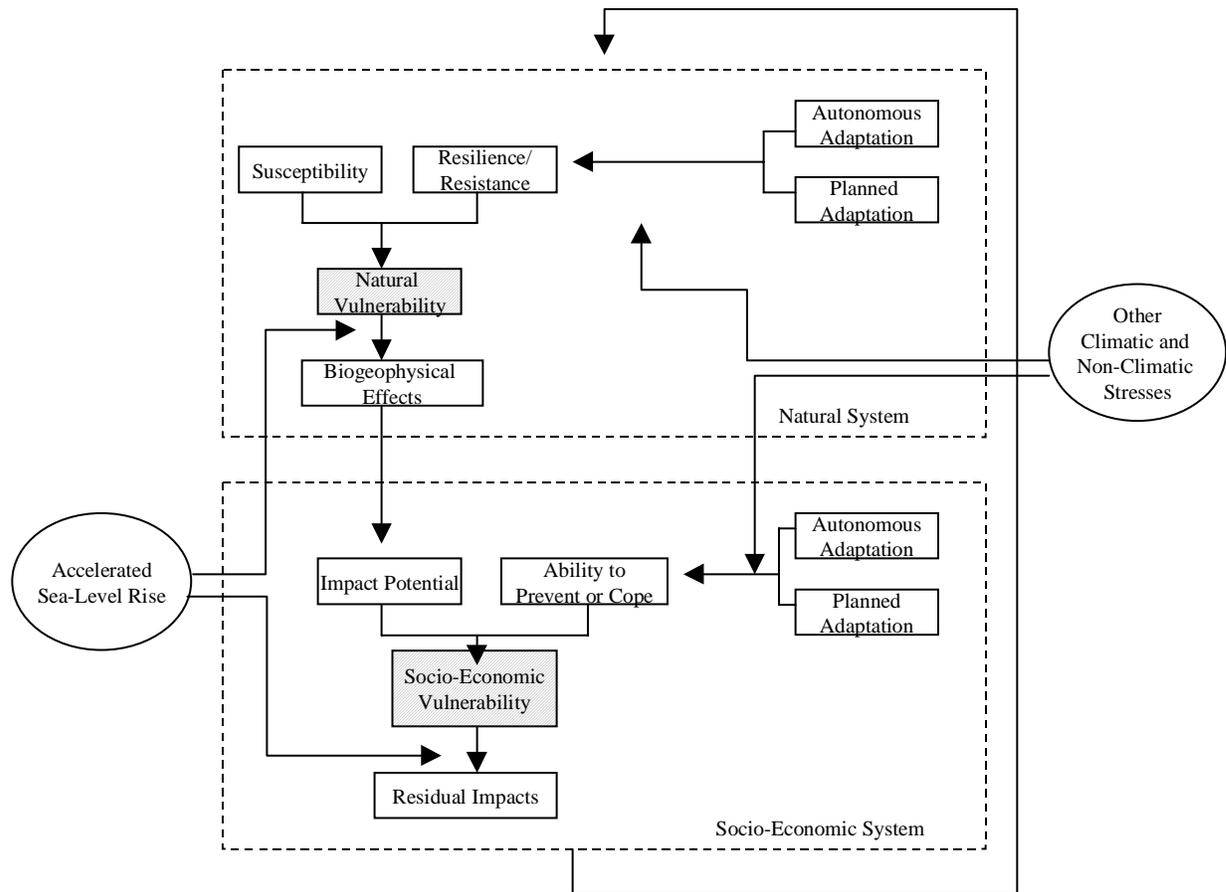
The US Country Studies, while utilizing the experience of the IPCC methodology, was found to confuse vulnerability frameworks and tools. The US Country Study programme was also found to address mainly land loss impacts.

Table 4.1.1 - Advantages and Disadvantages of the V&A Methodologies

| METHODS | V&A FRAMEWORK OR TOOL? | ADVANTAGES | DISADVANTAGES | COMMENTS |
|--|--|--|--|---|
| Common Methodology | V&A Framework | Logical prescribed structure Lends itself to producing consistent results -- useful for global aggregation Widely used | Inflexible, stressing susceptibility, not vulnerability assessment VA tools not discussed Adaptation options insufficiently developed. | Superseded by the UNEP Handbook V&A Framework |
| US Country Studies Methodology | Muddled | Some VA tools described. Workbook approach | Confuses V&A Framework and Tools Only addresses Land Loss impacts Stresses susceptibility, not vulnerability assessment | Not recommended, except the Workbook approach |
| UNEP Handbook Methodology | V&A Framework with guidance on V&A Tools | Good conceptual basis. All impacts considered. Guidance on possible V&A tools provided | Remains to be widely tested. | |
| South Pacific Islands Methodology | V&A Framework with qualitative VA Tools | Useful in areas with limited data Conceptualizes vulnerability into measurable elements | Results are qualitative to semi-quantitative | In the Caribbean, more data exists than in the South Pacific Islands. |
| Caribbean Disaster Mitigation Project | V&A Tool | Not applicable | Not applicable | Useful <u>within</u> a V&A Framework |
| RIKS Decision Support Methodology | Integrated Model | The complete coastal system is considered, and interactions can be specified as desired. | The approach can be become black box i.e. does not suit the capacity building aims of CPACC. The availability of appropriate data | Too complex for CPACC's aim of capacity building |

The Research Institute for Knowledge Systems (RIKS) Decision-support methodology proceeds in a stepwise logical manner, and comprehensively provides the framework for detailed vulnerability studies. The RIKS methodology however requires a high level of detailed data, which may not be available in the Caribbean. However with the development of capacity in the region, the RIKS decision-support system methodology could be applied in the region.

Fig 4.1.1. - A Conceptual Framework For Coastal Vulnerability Assessment (taken from Klein and Nicholls 1996)



The UNEP methodology builds upon the IPCC common methodology and the technical guidelines for assessing climate change impacts and adaptations (Carter et al 1994). The UNEP methodology for assessing vulnerability can be summarized into five (5) main stages:

- Stage 1 - Problem definition and scope of the analysis
- Stage 2 - Scenarios for Coastal Vulnerability Assessment
- Stage 3 - Impact Assessment
- Stage 4 - Autonomous Adaptation
- Stage 5 - Planned Adaptation.

The UNEP methodology has an extremely strong conceptual basis and a well developed vulnerability assessment framework, which considers all impacts of sea level rise and

climate change and provides guidance on possible vulnerability assessment tools. The UNEP methodology remains to be widely tested and it has not been widely utilized.

The UNEP guidelines while not widely used were selected as the basis for the CPACC methodology. The UNEP methodology offers the flexibility of utilization of limited data or comprehensive data. The UNEP methodology also suggests tools for vulnerability analysis.

4.2. THE CPACC METHODOLOGY FOR VULNERABILITY ASSESSMENT

The CPACC methodology focuses mainly on applying the UNEP methodology, utilizing the staged approach which was outlined in the previously, viz:

Stage One - Identification of problems and scope of analysis.

Stage Two - Scenarios for Coastal Vulnerability Assessment.

Stage Three - Impact Assessment.

Stage Four - Autonomous and Planned Adaptation.

4.2.1. Stage One - Identification of Problems and Scope of Analysis

The stage requires the identification of the study area, potential problems in the area and the selection of the level of analysis that is required. This stage requires an assessment of the likely magnitude of sea level rise and the likely impacts of sea level rise. A screening assessment is then performed.

This screening assessment is primarily an extremely quick way of assessing the coastline vulnerability, identifying areas for detailed study, identifying priority socioeconomic impacts, as well as identifying data requirements for the vulnerability assessment. The screening assessment aids in focusing the study particularly when there are limited resources. The screening assessment is thus used to plan how the vulnerability assessment could be effectively implemented.

The screening assessment utilizes prior knowledge (e.g. previous studies) and expert judgment, is carried out over a short period of time such as 2 -3 months and generally considers the impact of a 1-metre rise in sea level. A Screening Assessment matrix is then completed using a ranking system noting where there would be major, significant or minor. **Table 4.2.1** shows the completed Screening Assessment matrix for Grenada.

Table 4.2.1 – Grenada Screening Assessment Matrix

| Biophysical Impact | Human Settlements | Water Resources | Tourism | Recreation | Infrastructure | Fishing | Ports | Historic Cultural |
|--------------------|-------------------|-----------------|---------|------------|----------------|---------|-------|-------------------|
| Erosion | 1 | 2 | 1 | 2 | 2 | 1 | 2 | 3 |
| Inundation | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 |
| Eco-system Loss | 2 | None | 2 | None | None | 1 | None | 3 |
| Salinization | 2 | 2 | 3 | None | 3 | None | 3 | 3 |

1 = Major Impact; 2 = Significant Impact; 3 = Minor Impact

Based on the Screening Assessment, initial areas for consideration for complete vulnerability assessments are identified.

The criteria used for site selection in Grenada was:

- Elevation, topography and susceptibility to sea level rise
- Existence of human settlements
- Economic importance including presence of tourism facilities
- Presence of critical infrastructure
- Historical and cultural value
- Data requirements for conducting the vulnerability analysis.

Using these criteria, three (3) sites were selected, viz:

- *Southwest Peninsula* - This region bordering the coast from Point Salines in St. George's to Eliot Point in St. George's, including the major tourism belt and the capital city of St. George's.
- *Northeast Coast* - The coastal corridor stretching from Marquis in St. Andrew's to Conference in St. Andrew's, including the town of Grenville.
- *Carriacou* - The entire coastline of the island of Carriacou.

These sites were selected based on the significant presence of the at-risk sectors and/or activities as illustrated in **Table 4.2.2**.

Table 4.2.2 – Importance of Selected Sites

| SITES | Tourism | Fishing | Human | Ports | Infra Structure | Recreation | Historic Sites |
|-----------|---------|---------|-------|-------|-----------------|------------|----------------|
| SouthWest | X | X | X | X | X | X | X |
| NorthEast | X | X | X | X | X | X | X |
| Carriacou | X | X | X | X | X | X | X |

It was also decided that the Vulnerability analysis would focus on the impact of sea level rise on the following sectors within these sites, viz:

- Impact on socio-economic activities.
- Impact on critical infrastructure.
- Beach erosion and inundation.

- Impact on water resources, including potential for saline intrusion of the water table.
- Impact on coastal ecosystems.
- Review of institutional arrangement for responding to sea-level rise.

4.2.2. Stage Two - Scenarios for Coastal Vulnerability Assessment

The CPACC Methodology required the use of the following climate change scenarios:

- ✓ Sea Level Rise
 - SLR1 = 0.2 meters for 2020
 - SLR2 = 0.5 meters for 2050
 - SLR3 = 1 meter for 2100
- ✓ 100-year storm surge levels
 - SS1 = SSpx1.2 (assumes 20% increase)
 - SS2 = SSp (assumes no changes)
 - SS3 = SSpx0.8 (assumes 20% decrease)
 - SS2 should be applied to three years into the future
 - SS1 and SS3 should be applied for the year 2050 and 2100
- ✓ Vertical movement
 - VM = 0 (assumes no vertical movement along the coast of Grenada)

These scenarios are consistent with the predictions for sea level rise in the IPCC Second Assessment Report.

4.2.3. Stage Three - Impact Assessment

(a) Data Collection

The Screening Assessment aided in understanding what data was needed to be acquired. **Table 4.2.3** below gives an idea of the type of data that was required for the vulnerability assessment.

The data on the specific sites was collected using a variety of methods, viz:

- Review of existing reports and studies.
- Analysis of existing data from a vulnerability perspective.
- Conduct of field surveys to generate new data.
- Field visits to each of the sites.
- Expert interviews with knowledgeable persons

Table 4.2.3. – Examples of Data Requirements for Vulnerability Analysis

| |
|--|
| The best topographic data, including regular contours; |
| Evidence for subsidence/uplift, including the methods used to determine; |
| Bathymetric charts and maps, particularly for shallow water areas (<10-m depth); |
| Coastal geomorphology (i.e., hard unerodible cliffs, erodible cliffs, beaches, wetlands, etc.) to select appropriate impact models; |
| Wave data, or wave hindcasts to define the wave climate; |
| Tide gauge data to define tidal characteristics and flood elevations (Note that 50 years of data is required to confidently extract long-term sea-level trends (Douglas, 1991; Nicholls and Leatherman, 1996) so this is unlikely); |
| Estimates of flood return periods, from tide gauges and/or hindcasts; |
| Historical storm and flood damage from major storms, including physical changes and socio-economic costs; |
| Present status of coastal ecosystems, particularly coral reefs and wetlands. How much degradation and destruction has occurred, and what is the prognosis for the future without climate change? |
| Scientific research on ecosystem response to climate change, particularly examples in the Caribbean. |
| Present coastal problems, including (1) beach erosion, (2) cliff erosion, (3) coastal flooding by storm surge, (4) coastal flooding by run-off, (5) saltwater intrusion, (6) others? Information should be as quantitative as possible and put as much emphasis on the long-term rather than the short-term; |
| Any response to these problems, including both hard and soft engineering (seawalls, nourishment, etc.) and institutional changes (building setbacks, coastal zone management programs, etc.); |
| Human influence on sediment availability at the coast. List areas where dams have been built on rivers, coastal erosion has been stopped, and littoral drift has been impeded; |
| Coastal land use and historical changes in coastal land use; |
| Plans for major future infrastructure development such as ports, airports, etc. which will be close to present sea levels; |
| Development of coastal tourism, if appropriate and plans for future development; |
| Coastal population distribution and historical changes in coastal population distribution; |
| Forecasts of coastal population distribution. |

Table 4.2.4 summarises the data collection methodologies utilised for the various sectors. Wherever feasible, all data collected was geo-referenced and entered into a Geographic Information System (GIS) database to facilitate modeling.

Table 4.2.4 - Summary of Data Collection Methodologies

| SECTORS | Review Existing Reports | Analysis of Existing Data | Field Surveys to generate new data | Field Visits/Ground Truthing | Expert Interviews |
|----------------|-------------------------|---------------------------|------------------------------------|------------------------------|-------------------|
| Beach Erosion | √ | √ | - | √ | √ |
| Socio-economic | √ | √ | √ | √ | √ |
| Infrastructure | √ | √ | √ | √ | √ |
| Hydrology | √ | √ | √ | √ | √ |
| Coral Reefs | √ | √ | √ | √ | √ |
| Legal Review | √ | √ | - | √ | - |

(b) Techniques Used in Impact Assessment

A variety of techniques were used in conducting the impact assessment, viz:

- (i) *Sea Level Rise*: It was not possible to conduct a rigorous analysis of the impact of each of the sea level rise scenarios. This was due to the fact that the available contour maps did not have any contour lines below the twenty-five foot contour and the DEM's created by the GIS were not able to generate scenarios below 5 ft. Alternative models were not made available to the technical team.

The SLR socio-economic impacts that were derived were therefore done using expert judgment and ground truthing and are based on the technical team's identification and assessment of the areas that are clearly less than 1 m below sea level. The assumption was made that all of these areas would become inundated with a 1m sea level rise.

SLR socio-economic impacts below 1m were not considered, as it was felt that the methodology was not sufficiently accurate to generate any useful results.

Other methods were utilized to assess the impact on beach erosion and salt-water intrusion.

- (ii) *Storm Surge Analysis*: The 100 year storm surge was taken to be that from Hurricane Janet which hit Grenada in 1955. This was used, as Hurricane Janet is on record as being "the worst" hurricane ever to have hit Grenada. The available record shows that Hurricane Janet was a Category 2 Hurricane when it hit Grenada.

In developing the storm surge impact models to be used in the GIS analysis, it was necessary to convert the storm surge scenarios into flooding and inundation scenarios. This was done using the relationships in **Table 4.2.5** obtained from the National Hurricane Center in Miami.

Table 4.2.5 - Storm Surge/Flooding Impacts Associated with Hurricanes

| HURRICANE STRENGTH | WIND SPEED (mph) | PRESSURE (mb) | STORM SURGE | FLOODING IMPACT |
|--------------------|------------------|------------------|-----------------|-------------------------|
| Category 1 | 74 – 95 | > 980 | 4 – 5 ft | |
| Category 2 | 96 – 110 | 965 – 979 | 6 – 8 ft | 3 ft¹ |
| Category 3 | 111 – 130 | 945 – 964 | 9 – 12 ft | 5 ft |
| Category 4 | 131 – 155 | 920 – 944 | 12 – 18 ft | 10 ft |
| Category 5 | >155 | < 920 | > 18 ft | 15 ft |

Source: National Hurricane Center

Hurricane Janet was a high Category 2 hurricane (almost Category 3) when it hit Grenada – winds of 105 mph, pressure of 979 mb. The related storm surge was therefore 8 ft – 12ft² and the expected flooding impact would have been approximately 3 ft to 5 ft. This was used as the base case scenario for the storm surge impact analysis. **Tables 4.2.6 and 4.2.7** contain the derived flooding impacts for all of the recommended CPACC scenarios for each of the two boundary points – 8 ft storm surge and 12 ft storm surge.

Table 4.2.6 – Flooding Impacts under CPACC Scenarios for 8 ft. Storm Surge (3 ft Flooding)

| Year | SLR (m) | SS1 (m) | SS2 (m) | SS3 (m) | Net storm surge level (m) | Flood Imp |
|--------|---------|---------|---------|---------|---------------------------|-----------|
| 2020 | 0.20 | - | 1 | - | 1.2 | 3.94 |
| 2050-1 | 0.50 | 1.2 | - | - | 1.7 | 5.58 |
| 2050-2 | 0.50 | - | 1 | - | 1.5 | 4.92 |
| 2050-3 | 0.50 | - | - | 0.8 | 1.3 | 4.27 |
| 2100-1 | 1.00 | 1.2 | - | - | 2.2 | 7.22 |
| 2100-2 | 1.00 | - | 1 | - | 2 | 6.56 |
| 2100-3 | 1.00 | - | - | 0.8 | 1.8 | 5.91 |

¹ Assumption made by technical team

² This has been verified by the expert interviews

Table 4.2.7 – Flooding Impacts under CPACC Scenarios for 12 ft. Historical Storm Surge (5 ft Flooding)

| Year | SLR (m) | SS1(m) | SS2 (m) | SS3 (m) | Net storm surge level (m) | Flood Impact (ft) |
|--------|---------|--------|---------|---------|---------------------------|-------------------|
| 2020 | 0.20 | - | 1.52 | - | 1.72 | 5.64 |
| 2050-1 | 0.50 | 1.82 | - | - | 2.32 | 7.61 |
| 2050-2 | 0.50 | - | 1.52 | - | 2.02 | 6.63 |
| 2050-3 | 0.50 | - | - | 1.22 | 1.72 | 5.64 |
| 2100-1 | 1.00 | 1.82 | - | - | 2.82 | 9.25 |
| 2100-2 | 1.00 | - | 1.52 | - | 2.52 | 8.27 |
| 2100-3 | 1.00 | - | - | 1.22 | 2.22 | 7.28 |

The scenarios in **Tables 4.2.6 and 4.2.7** show that the flooding and inundation impacts would range from 3.94 ft at the low end to 9.25 ft at the upper end, viz:

| Year | Potential Storm Surge Impact |
|------|------------------------------|
| 2020 | 3.94 – 5.64 ft |
| 2050 | 4.27 – 7.61 ft |
| 2100 | 5.91 - 9.25 ft |

This data was inputted into the GIS model, which was used to identify the key impact areas, using a 5 ft. contour impact (low end) and a 10 ft contour impact (high end).

(c) GIS Modeling

Sea level rise scenario layers were created using 5ft and 10ft contours from the contour layers to generate polygons representing the bound of these SLR. In preparation for the spatial analyses and scenario modeling, as required by the project, a number of thematic layers were used. **Fig. 4.2.1** is a schema of the cartographic model used by the application.

The following layers used by the application were obtained from the Land Use Division, viz:

- Contours
- Roads and Rivers
- Buildings
- Mangroves
- Beaches
- Commercial properties
- Sea walls and Jetties
- Wells

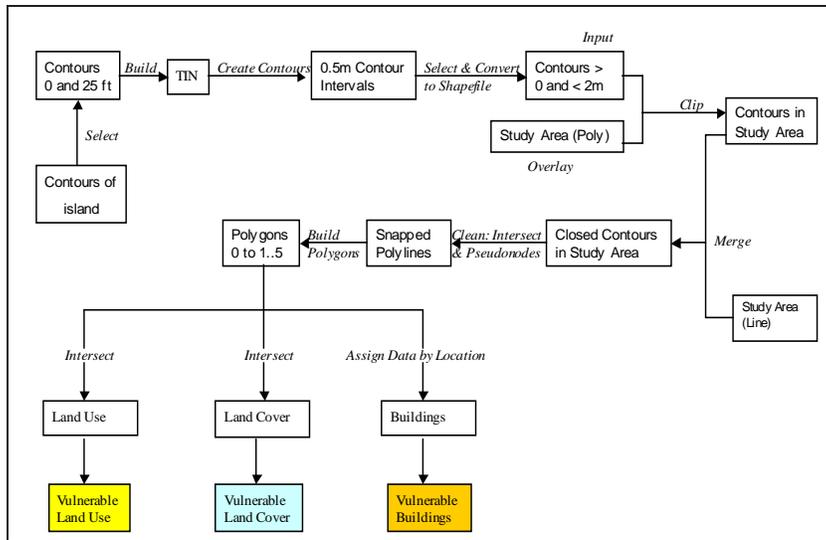
The 25ft contour lines for the study area were obtained by clipping the project site boundary theme, unto the contour theme for each of the sites. The resulting theme (clipped 25ft contour) was used to generate a digital elevation model (DEM) theme of

the area. From the resulting DEM, contours were generated with a vertical interval of 5ft. The undesirable records were removed from the database and the 0-5, 5-10 and 10-15ft contours were used to generate the polygon theme representing the corresponding SLR.

The polygon themes representing the 5ft and 10ft were used as the overlays polygons to determine the entities vulnerable to coastal inundation. The Geo-processing was conducted stepwise with the vulnerability scenario of various infrastructural and natural resource entities considered.

The databases of the theme that resulted from the geo-processing were updated using the ‘K-12 School Tools’, ‘update theme Geometry’ function. The database tables for the themes were used to quantify each vulnerable entity.

Fig 4.2.1 – The Cartographic Model of the GIS Application



(d) Biophysical/Sectoral Impact Analysis

The beach erosion was modeled using the Bruun Rule (1962), while the hydrological analysis of seawater intrusion into unconfined aquifers was done using the Ghyben-Herzberg relation (Driscoll 1986). The socio-economic and infrastructure impact analysis was done by combining the data generated from the field surveys with the results of the GIS impact analysis. Data on transportation infrastructure consisted of road dimensions, materials of construction, engineering design, sea defense works and year of (re) construction.

The electricity plant was described by the lengths of the various distribution lines, number of transformers and poles and, with respect to the Queen’s Park power station the generating capacity, fuel storage and building parameters. Telecoms infrastructure was similarly described by the lengths of aerial and underground cable, exchanges, outside plant modules (OPM) and outside plant interfaces (OPI).

Water and sewerage parameters were length, diameter, material, joint type and depth of cover of pipelines, sewage lift stations, and year of construction. In analyzing the physical damage imparted by floods and inundation to the coastal infrastructure elements under consideration in this study – buildings, roads and utility facilities, both aerial and buried – the following was considered:

- *Buildings and Recreational Facilities* - undercutting of structural foundations and playing surfaces by erosion; battering of structural members such as walls by floating debris (during hurricanes).
- *Roads* - undercutting of road pavement, base and sub-base by erosion resulting from wave action; partial or total destruction of sections of roadway by flood-related landslides.
- *Pipelines and Appurtenances* - uncovering, displacement or complete removal of sections of pipe due to soil erosion; displacement and flotation of pipes and chambers, causing ruptures in the installations, as groundwater levels rise; in the case of underground pump stations, damage to pumping equipment and electrical installations through submergence when flood levels exceed the height of dry-well access manholes; and
- *Electricity and Telecoms Line Plant* - erosion at the base of utility poles from flood and landslide action, causing collapse and line breakage.

The cost of the potential infrastructure damage to each exposure unit was estimated in accordance with the following assumptions and guidelines:

- The cost of flood damage to buildings and hotels would generally be computed as a proportion of the cost of the buildings.
- The magnitude of damage suffered by a structure could depend on the following factors, *inter alia*:
 - The proximity of the structure to the coastline.
 - The relative shelter afforded by other structures.
 - The type and extent, if any, of coastal protection works in the vicinity of the structure.
 - The extent of damage suffered as a result of wave action resulting from Hurricane Lenny on November 1999 - this determined from observation of the damages, results of the coastal vulnerability survey (Thomas 2000; Smith 2001) and actual costs of damage reported by building owners.
- Once a significant proportion of an urban road is inundated, then the entire road would have to be abandoned.

- Main roads subject to inundation would have to be re-routed where possible at a unit cost 25% greater than the investment cost.
- The extent of damage, or risk factor (%), applied to utility infrastructure would be of the same order of magnitude as that applied to roads.

(e) Coral Reefs

The raw data collected was inserted into the CPACC Component 5 Excel spreadsheet. This software calculates percent abundance for individual hard corals and collective gorgonians (soft coral), sponges, zooanthids, macroalgae, dead coral with algae, calcareous algae and sand, pavement and rubble, in terms of percent abundance of the five transects. A results summary chart was generated for each transect. From these summary charts were generated tables, which showed the mean percentage abundance of the categories, the standard deviation from the means, and the number of points per transect for each category. For the fish, species data was input into Excel spreadsheets, and tables generated on the number of reef fish over a 100 m² area.

4.2.4. Stage Four - Autonomous and Planned Adaptation

Stage Four involves an assessment of adaptation options, which are feasible.

- *Autonomous Adaptation* refers to responses that will happen spontaneously without policy intervention for example the moving inland of coastal wetlands.
- *Planned Adaptation* refers to policy suggestions, which could be put in place as a result of the outputs vulnerability studies, for example setbacks for buildings or new building codes.

4.3. LIMITATIONS

The Vulnerability analysis was constrained by a number of factors:

4.3.1. Data Limitations

The unavailability of baseline data in almost all instances, limited the comprehensiveness of the analyses that could have been done. In some cases, this limitation was addressed through the generation of original data using field surveys and interviews. There were a number of areas however where these options were not feasible:

- *Bathymetry Data* – The unavailability of bathymetry data made it impossible to assess the full impacts of either sea level rise, or storm surges. This data on wave dynamics and wave energy was important to facilitate analysis of the erosion potential, and the run-off potential of the waves, under the different scenarios. Its unavailability meant that the analysis that was done was a static flooding and inundation analysis.

It also meant that the impacts of the various reefs and headlands that protect Grenada's coasts on wave action and energy were not taken into consideration. In

the Southeast peninsula, for example, the *Environmental Impact Statement for Port Expansion Project, St. George's Port, Grenada* states that the Wave refraction analysis carried out by IMA (1995) for the Environmental Impact Analysis for the St. George's Port Expansion Project indicated that westerly waves approaching St. George's Harbour show strong convergence at Ballast Ground (a headland south of the harbour entrance) and lesser convergence at Fort George Point, with very few waves reaching the inner reaches of the harbour. This wave refraction was ignored on the project analysis. In this regard, it is significant to note however, that the same report states that "*observed or measured deep water wave characteristics are generally lacking in most of the Caribbean Islands*" (pg.37). A similar decision was made with regards to the northeast site, where, although the town of Grenville is located behind a reef that extends across the entire mouth of the Grenville harbour, the analysis was conducted under the assumption that the reef had no effect on the impact of sea level rise and/or storm surges.

- *Contour Maps* – The unavailability of contour maps below the 25 ft. contour made it impossible to model any impacts within the 0 – 1 m range.
- *Geo-referenced Cadastral Information* – The unavailability of census or cadastral information for households, location of coastal infrastructure and levels for groundwater wells, in a format that could have been inputted into the GIS models limited the ability to assess socio-economic impacts. This was overcome for the St. George's site by accessing similar information from another source. However, the absence of such information for the Northeast Peninsula and Carriacou, meant that the impact assessments for those sites were not as rigorous or as detailed as for the St. George's site.

4.3.2. Unavailability of Relevant Models

The technical team did not have many sea-level rise models to work with. It therefore had to conduct most of its analyses from first principles, relying on the technical capacities of the sectoral consultants and their abilities to incorporate climate change considerations into their technical analyses.

5. IMPACTS OF SEA LEVEL RISE

The three sites selected were:

- *The Southwest Peninsula* - The region bordering the coast from Point Salines, northwards to Eliot Point in St. George's, including the major tourism belt and the capital city of St. George's.
- *The Northeast Coast* - The coastal corridor stretching from Marquis, northwards to Conference in St. Andrew's, including the town of Grenville.
- *Carriacou* - The entire coastline of the island of Carriacou.

For each of the sites, the study area was demarcated as being the area between the coastline and the 45m (150 ft.) contour.

5.1. SOUTHWEST PENINSULA

5.1.1. Site Characteristics

The study area consisted of 12 km of coastline containing beaches, commercial areas and national port and airport facilities

(a) Beaches

There are five (5) beaches within this site – Morne Rouge, Pandy, Grand Anse, Queen's Park and Grand Mal – **Table 5.1.1.**

Table 5.1.1 – Characteristics of Beaches in Southwest Peninsula

| Site | Length of Beach (Km) | Sand Type | Sand Color | Level of Development along beach |
|--------------------|----------------------|-----------|------------|----------------------------------|
| Morne Rouge | 1.20 | fine | white | 80% |
| Pandy | 0.45 | Coarse | White | 0% |
| Grand Anse | 2.70 | fine | | 30% |
| Queens Park | 0.30 | fine | | 100% ^s |
| Grand Mal | 1.50 | fine | | 70% |

Of these, the world famous Grand Anse beach is the most important. It is approximately 2.7 km long with the width varying alongshore from 8 m to 45 m (*Cambers 1986*).

Although there are small coral reefs outside this beach, most of the beach is exposed to the Caribbean Sea. All of the beaches in this site are partially or wholly compartmentalized in terms of littoral drift, by rocky headlands forming littoral cells and sub-cells. Cambers (1996) identified four (4) such cells on the Grand Anse Beach. The beach material found on the southwest beaches comes from the volcanic parent material

and the remains of some of the dead coral from the reefs offshore. The Lands and Surveys and Land Use departments in the Ministry of Agriculture have aerial photos for most of Grenada for the years 1966, 1970, 1982 and 1992. In addition, for Grand Anse, some detailed survey plans are available for some sections for an earlier period. A study of these maps gives an indication of the beach erosion at three sites for the past 35 years at Grand Anse. By using unchanged landmarks along the Morne Rouge main road, distances to high watermark were obtained.

Survey plans at two locations (the Camerhogne Park and the Old Aquatic Beach Club) were compared for 1962 and 1964 and 2000 respectively. Along Camerhogne Park the beach receded about 3.3m over 38 years, while at the Old Aquatic Beach Club beach recession ranged from 5.65m to 7.75m over 36 years. Further evidence of the erosion at Grand Anse is the disappearance of some structures from the 1960s, including the Governor's Beach house and an access road, evident on the 1960's aerial photos.

(b) Socio-Economic Characteristics

The main socio economic establishments and activities in this site include:

- Residential housing and small businesses
- Gasoline storage and receiving station
- Small scale and subsistence farming
- Recreation and sea bathing areas
- Large fish storage and processing plant
- Fishing vessels and fishing paraphernalia
- The national stadium
- The main power generating facilities
- Major utility and transportation facility
- Site of the fish market under construction
- The capital city
- The major seaport and airport
- The seat of government
- The major hotel plants and facilities
- The major yachting facilities and marinas
- The major financial and banking facilities
- The major manufacturing plants and equipment
- St. George's University
- Several heritage sites
- Coral reefs
- Natural break water
- Major communication infrastructure
- Site of proposed bus terminal and cruise ship facility

The area constitutes the greatest concentration of property and people on the island. In fact, it is the nerve center of the economy. The estimated number of households within the site based on data from the 1991 population census was 2,343. The estimated population density in the city of St. George's is 4,261 persons per square kilometer. The

density for the rest of the parish is estimated at 428 persons per square kilometer (Grenada 1991 Census).

It is envisaged that the site will undergo massive transformation within the project time frames. This transformation will include movement from small businesses to large businesses, from small-scale low technology agriculture and fishing to highly modernized and technology-intensive farming and fishing. It is envisaged that the city center will be expanded with movement along the coast both north and south, and that residential housing will move further than the center (*Preliminary Report – National Physical Development Plan*). There are also plans for the development of a cruise ship terminal and a bus terminal in the close vicinity of the city center. A more intensive concentration of commercial and residential activities is the most likely outcome and the population is therefore expected to rise significantly within the project time frames.

The results of the socio-economic survey highlighted the following additional characteristics, viz:

- The weighted average household size was 2.85 persons. The average size of households of the national population is 3.9.
- The average monthly household income was \$1,361.
- The estimated of the number of people employed was 13,850.
- The weighted average sales generated were \$455,000.
- 62 percent of the properties were concrete structures. 23 percent of the properties were constructed after 1990 and 55 percent after 1980.
- The weighted average property value was \$152,000.
- 10 percent of the respondents had experienced flooding. Poor drain maintenance, heavy rainfall, sea level rise and high tides were listed as the most important factors.
- The weighted average of the cost of flood damage was \$22,000.

(c) Critical Infrastructure

The critical infrastructural facilities located within this site are:

- Six (6) - public sector buildings, including the National Insurance Scheme (NIS) building on Melville Street, the Financial Complex on the Carenage, a wing of the General Hospital currently undergoing reconstruction and the Grenada Trade Center in Morne Rouge;
- Six (6) - hotels, including the four (4) largest in Grenada: Grenada Grand Beach Resort and Spice Island Beach Resort on Grand Anse Beach, and the Rex Grenadian and La Source at Point Salines.
- Three (3) - industrial complexes: the Grenada Commercial Fisheries complex and Texaco bulk terminal at Grand Mal, and the newly constructed Melville Street fish market;
- Two (2) - ports: the port of St. George's and the Point Salines International airport (PSIA);
- Four (4) - major recreational facilities, including the Queen's Park Stadium, Tanteen Recreation Ground and Grand Anse Sports Complex;

- Five (5) - major elements of the transportation infrastructure, including the Western Main Road (WMR), Melville Street, the Wharf Road or Carenage and the Grand Anse Main Road;
- Electricity plant of the privately-owned provider Grenada Electricity Services Ltd. (GRENLEC);
- Telecommunications (telecoms) plant of the privately-owned provider Cable & Wireless Grenada Ltd. (C&W); and
- Water and sewerage plant of the statutory corporation National Water & Sewerage Authority (NAWASA).

The investment cost of this infrastructure is EC\$652.5 million.

The characteristics of these facilities are summarized in **Appendix 1**.

(d) Hydrology

All public water treatment plants and distribution reservoirs lie outside of the study areas. The study therefore decided to assess as proxies, public sources outside of the study area, which were located in areas with similar characteristics to the study area.

* To avoid screen dewatering *Source:* adapted from DIWI 1996, 1997a

Table 5.1.2 Summary of Boreholes in Southwest Peninsula

| Area/wellfield | Borehole | Year of constrn. | Type | Depth (m) | Prodn. cap.* (m3/day) | Status/comment |
|-------------------|----------|------------------|-------------|-----------|-----------------------|---|
| Chemin Valley | Ch-1 | 1960 | Production | 61.00 | 1,000 | Productive |
| | Ch-2 | 1982 | Production | 61.00 | 720 | Productive |
| | Ch-4 | 1990 | Production | 48.77 | 240 | Prodn. Stopped 1995: saline intrusion |
| | C1-OB | 1997 | Observation | 27.75 | - | 2" dia. piezometer |
| | C2-OB | 1997 | Observation | 57.98 | - | 2" dia. piezometer |
| | C4-MB | 1997 | Monitoring | 94.64 | - | 2x2" dia. piezometers screened 60, 90 m |
| Baillie's Bacolet | BB-1 | 1990 | Production | 57.91 | 360 | Productive |
| | BB-2 | 1990 | Production | 57.91 | 540 | Productive |
| | BB-3 | 1997 | Production | 59.52 | 1,400 | Productive |
| | BB1-OB | 1997 | Observation | 52.90 | - | 2" dia. piezometer |
| | BB2-MB | 1997 | Monitoring | 92.20 | - | 3x2" dia. piezometers screened 30, 60, 90 m |
| | BB3-OB | 1997 | Observation | 59.70 | - | 2" dia. piezometer |

Six (6) production boreholes at Chemin Valley and Baillie's Bacolet near the southern coastline were selected in this regard. The main parameters of these boreholes, along with nearby monitoring boreholes, are shown in **Table 5.1.2**.

The analysis conducted for this project concluded that the seawater interface is encroaching on the groundwater in Chemin Valley and Baillie's Bacolet due to overpumping of the boreholes, and that the production boreholes Ch-4 and BB-2 – and

to a lesser extent BB-1– are directly threatened by seawater intrusion during production and have no future as production wells.

There are also several private boreholes supplying brackish water for desalination at on-site reverse osmosis (RO) desalination plants that are used for commercial purposes. These operations are summarised in **Table 5.1.3**.

There are no reliable data available on the groundwater levels or aquifer characteristics of the 7 privately owned brackish water boreholes in the study area. However, with the exception of the Grenada Breweries borehole, the wells are all located on the relatively dry southwest peninsula within 250m of the sea and are most likely under threat from seawater intrusion. This would be manifested by increased salinity (conductivity) of the extracted water thereby placing greater demand on the RO desalination plants.

Table 5.1.3 Private Brackish Water Boreholes in Southwest Peninsula

| Owner | Location | No. wells | Approx. yield (m3/day) |
|---------------------------|-----------------------|------------------|-------------------------------|
| Spice Island Beach Resort | Grand Anse Beach | 1 | 55 |
| Flamboyant Hotel | Grand Anse Beach | 1 | 45 |
| Grenada Breweries | Maurice Bishop H'way. | 1 | 327 |
| Rex Grenadian Resort | Point Salines | 2 | 109 |
| La Source Hotel | Point Salines | 2 | 182 |

(e) Coral Reefs

Three (3) Reefs within this site were included in the project, viz:

- *Red Buoy Reef (GPS coordinates: N 12° 02' 48.4 W 61° 45' 35.2; Average depth: 41 ft (12.5 m))*

This reef, located at the entry of the St. George’s harbour is an almost oval bank reef, with a reef crest approximately 41 ft (12.5m) deep. Along the northern and the deepest section, the reef terminates at the top of a steep wall that drops to approximately 105 ft (32 m). It was comprised primarily of hard corals, and was rather cohesive i.e. there were not many sand channels at the site.

The Red Buoy site, which is approximately 500m from the mouth of St. George’s harbour, is transversed by numerous vessels on a daily basis. All stakeholders interviewed believed that Red Buoy was the reef with the highest potential for anthropogenic impacts off Grenada. Based on this local knowledge, diver observation and Red Buoy’s proximity, the reef was classified as being heavily stressed. Its location at the mouth of the harbour also makes the reef susceptible to hydrocarbon spills, bilge discharges and discarded solid waste from moored vessels. Additionally, the harbour basin is a sink for surface water runoff from

the greater St. George's area, therefore Red Buoy reef may be further stressed by land based sources of pollution. The degree of impacts linked to land-based sources of pollution is directly dependant on the amount of rainfall (surface water) flowing into St George's from inland sources. Visibility at this site was poor and significantly lower than at any other site assessed. There were also signs of anchor damage. As it was expected that polluted waters, if present, would flow from shore outwards, the 20 m X 10 m monitoring site was established along the north eastern section of the reef i.e. the section closest to St George's.

- *Boss Reef - GPS coordinates (N 12° 02' 24.0 W 61° 46' 19.5; Average depth: 32 ft (10 m).*

Boss Reef is a section of a low lying and gently sloping bank reef that runs along the southern section of the West Coast of Grenada. It appears that this barrier reef is rather extensive, as consistent information regarding the extremities of Boss Reef could not be gathered from the main stakeholders. Boss Reef is situated in close proximity to Grand Anse, which is the area with the highest concentration of dive shops on the island. The site is therefore visited regularly by dive boats carrying large numbers of recreational divers. It is widely accepted that boaters who visit the site often try to drop their anchors on one of the many sand patches when anchoring, however, unfortunately, anchor damage was still very common at the site. Diver damage, which is the main cause of coral mortality at heavily dived sites, (*Medio et al, 1996*) was also witnessed at Boss Reef. Despite these physical impacts, the site was rated healthy due to the high number of live hard corals.

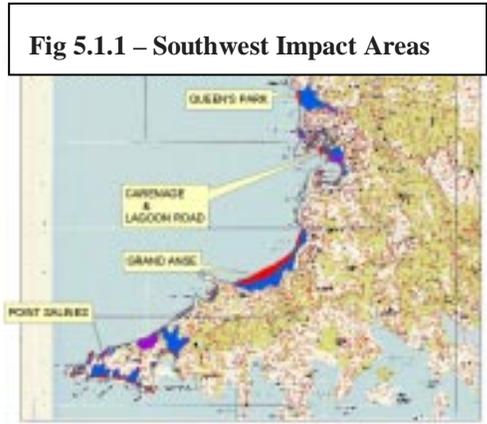
- *Northern Exposure (GPS coordinates: N 12° 02' 21.3 W 61° 46' 14.2; Average depth: 23 ft (7 m))*

Northern Exposure is situated landward, in relatively close proximity to Boss Reef, and has a very similar topography. Despite these similarities however, there was a greater abundance of soft corals at Northern Exposure, some of which reached 8ft in height, and lesser abundance of hard corals per unit area. Local dive operators rated Northern Exposure as heavily stressed, however this rating was based primarily on its lack of hard corals (reef building corals). Such community shifts are however natural, especially in such shallow areas where the effects of wave energy are exacerbated (*Hubbard, 1997*). Very few fish were observed on this reef, and this may be the result of over fishing as several small fishing boats were *anchored* in the area.

5.1.2. Vulnerability Analysis

(a) Major Impact Areas

The major impact areas in this site are the Point Salines area in the extreme southwest, the Grand Anse area, the Carenage and Lagoon Road areas of the capital city – St. George’s and the Queen’s Park area of the Capital City – St. George’s – **Fig. 5.1.1.**



(b) Vulnerability to Sea Level Rise

The vulnerability to sea level rise (SLR) under the different scenarios could not be rigorously assessed for all parameters because of the limitations of the methodology.

- *SLR – 0.2m to 2020*

The **Beach Erosion** results for Grand Anse suggest that between 20% and 31% of the beach would disappear for a 20 cm rise in sea level.

- *SLR – 0.5m to 2050*

The **Beach Erosion** results for Grand Anse suggest that between 55% and 75% of the beach would disappear for a 50 cm rise in sea level.

It must be noted that the estimated erosions are due solely to sea-level rise and do not include other naturally occurring coastal processes which would be important in determining eventual shoreline position.

If the combination of the present erosion rates and the impact of sea level rise are considered jointly, then the rate of disappearance of many of the beaches would be more dramatic.

- *SLR – 1.0m to 2100*

The vulnerability of this site to the impact of a 1-meter sea level rise by 2100 is summarised in **Table 5.1.4.**

The table shows that there will be a number of adverse consequences at this site:

Table 5.1.4 – Impact of 1 Meter Sea Level Rise in Southwest Peninsula

| Types of Impact | Point Salines | Grand Anse | Carenage & Lagoon Road | Queen’s Park | Site Total |
|-----------------------|---------------|-------------|------------------------|--------------|-------------|
| <i>Area of Impact</i> | Most | Beach areas | Carenage | None | Beach areas |

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| | beach areas | and all land, hotels and businesses up to main road | Road and Lagoon Road, and businesses located on these roads | | & businesses in St. George's on Carenage and Lagoon Roads |
|---|-------------|---|---|---------|---|
| Beach Erosion | No data | 86% - 96% of beach would disappear | No data | No data | 86% - 96% of Grand Anse beach would disappear |
| Infrastructure | | | | | |
| - Buildings/Floor Space (m ²) | - | - | 4,200 | - | 4,200 |
| - Buildings/Land (ha) | - | - | 0.72 | - | 0.72 |
| - Hotels/ Rooms (no.) | - | - | - | - | - |
| - Hotels/Land (ha) | - | - | - | - | - |
| - Industrial Complexes (no.) | - | - | - | - | - |
| - Ports (no.) | - | - | - | - | - |
| - Recreational (no.) | - | - | 1 | - | 1 |
| - Recreational/Land (ha) | - | - | 0.21 | - | 0.21 |
| - Transportation/Road (km) | - | - | 0.70 | - | 0.70 |
| - Electricity/Line Plant (km) | - | - | 0.70 | - | 0.70 |
| - Electricity/Generation | - | - | - | - | - |
| - Telecoms/Line Plant (km) | - | - | 0.7 | - | 0.70 |
| - Telecoms/Exchange (no) | - | - | 1 | - | 1 |
| - Water/Sewage Mains (km) | - | - | 1.40 | - | 1.40 |
| - Sewage Pump Stations (no) | - | - | 1 | - | 1 |
| Infrastructure Cost (EC\$) | - | - | - | - | EC\$23.1M |
| Hydrology | | | | | Salinization of some boreholes in Bailes Bacolet and Chemin |

- ✓ *Beach Erosion* - Between 86% and 96% of the Grand Anse beach will disappear under this scenario.
- ✓ *Infrastructure Impact* - The likely impacts of a 1m SLR by the year 2100 is the inundation of an estimated 18ha of land containing all the identified exposure units on the Carenage, St. George's, which is currently less than 0.20m above mean sea-level (AMSL).

These are:

- the ground floor of the Financial Complex
- the Carenage Sports Complex
- the Wharf Road along with related utility plant – including the Cable & Wireless telephone exchange and the St. George's

sewerage system pump station located adjacent to the Carenage Sports Complex.

The investment cost of this infrastructure is EC\$23.1M (3.5% of the value of the exposure units).

- ✓ *Hydrology* - Assuming that a 1m SLR in year 2100 resulted in a similar rise in the water table in the study area in Grenada, then application of the Ghyben-Herzberg analysis would indicate a 1m reduction in the seawater rise reserve for the Baillie's Bacolet boreholes to -0.10m (BB-1), -3.36m (BB-2) and 40.69m (BB-3). A similar rise in the seawater interface would be expected at Chemin Valley. *This adverse impact is clearly minor when compared with the threat posed by overpumping of the aquifers.*

(c) Vulnerability to Storm Surges

- *2020 Storm Surge*

The vulnerability to a Category 2 storm surge combined with a 0.2-meter sea level rise resulting in waves of 8 – 12 ft and flooding of 5 ft, is summarized in **Table 5.1.5**. The table shows that there will be a number of adverse consequences at this site:

- ✓ *Beach Erosion* – based on the experience of Hurricane Lenny in 1999, it is expected that significant erosion will result. This could not be quantified in the absence of bathymetry data.
- ✓ *Socio-economic Impact* – The impacts here will be on commercial activities as well as human settlements, viz:
 - 180 businesses operating in all sectors of the economy and employing 3085 will be affected. The monthly value of the employment income is EC\$4.4M. The contribution to GDP could not be quantified due to data limitations. **It is recommended that a separate study to determine the GDP contribution of this site be commissioned as it is the one of the primary hub of national economic activity.**
 - 295 persons, living in 106 homes will be temporarily (or permanently) displaced. The value of these homes is EC\$9.6M.
- ✓ *Infrastructure Impact* - Approximately 60ha of land could be vulnerable to flooding under this scenario. This includes:
 - The fisheries and fuel complexes in Grand Mal and all land areas up to 80m on the coastal plain.

The table shows that there will be a number of adverse consequences at this site:

- ✓ *Beach Erosion* – based on the experience of Hurricane Lenny in 1999, it is expected that significant erosion will result. This could not be quantified in the absence of bathymetry data.
- ✓ *Socio-economic Impact* - The impacts here will be on commercial activities as well as human settlements, viz:
 - 470 businesses operating in all sectors of the economy and employing 4,835 persons will be affected. The monthly value of the employment income is EC\$6.2M. The contribution to GDP could not be quantified due to data limitations. **It is recommended that a separate study to determine the GDP contribution of this site be commissioned as it is the one of the primary hubs of national economic activity.**
 - 826 persons, living in 252 homes will be temporarily (or permanently) displaced. The current value of these homes is EC\$40.6M.
- ✓ *Infrastructure Impact* - Approximately 188 ha of land could be vulnerable to flooding under this scenario. This includes:
 - Between 600 m – 700 m of the Western Main Road in the Grand Mal/Fontenoy area could be impacted. This could also adversely impact aerial electricity and telecommunications plant and buried water mains.
 - Approximately 300m of the Western Main Road, related utilities in the Queen’s Park area along with the power station and stadium could be impacted by 10ft. floods, which could encroach 800m inland – up to the vicinity of Steele’s Auto complex in River Road.
 - Approximately 75% of the ‘downtown’ area west of Grenville Street, with floodwaters encroaching 150m inland – to within 30m of the foot of Market Hill as well as the Port Authority complex, Tanteen Recreation Ground and Tanteen Road.
 - All land and buildings in the Grand Anse area as far inland as the Grenada Trade Centre, Youth Development Centre, South St. George Police Station, the Morne Rouge Main Road and about 300m of the Grand Anse Main Road – including utility infrastructure.
 - The Rex Grenadian and La Source hotels and the PSIA sewage treatment ponds in the Point Salines area.

The investment cost of the infrastructure at risk is EC\$11.75M.

- ✓ *Hydrology* – the monitoring borehole BB2-MB and 2 brackish water boreholes at hotels on Grand Anse Beach are vulnerable to wave overtopping under this scenario.

5.2. NORTHEAST COAST

5.2.1. Site Characteristics

The study area consisted of 10 km of coastline containing many of Grenada’s marine ecosystems – beaches, mangroves, river estuaries, offshore reefs. It is located within 15 miles of Grenada’s most active volcano “*Kick ‘em Jenny*”.

(a) Beaches

There are four (4) beaches within this site – Conference, Paradise, Telescope and Grenville – **Table 5.2.1**.

Table 5.2.1 – Characteristics of Beaches in the Northeast Site

| Site | Length of Beach (Km) | Sand Type | Sand Color | Level of Development along beach |
|------------|----------------------|--------------|------------|----------------------------------|
| Conference | 1.5 | Fine | Black | 0 |
| Paradise | 1.88 | Fine | White | 0 |
| Telescope | 1.5 | Medium | White | 0 |
| Grenville | 1.5 | Fine & muddy | Black | 50% |

The east coast beaches from Conference to Marquis are largely unprotected from the Atlantic Ocean. These beaches border the Meadows-Middle Lake mangrove swamps and the Pearls-Paradise plains. At Meadows and Middle Lake an 8 m recession would expose the mangrove swamps to direct action of the sea. The Telescope to Marquis beaches are protected by coral reefs. The importance of the reefs’ protection is evident along the Grenville beaches, which are at sea level in some parts.

The Conference-Marquis beaches are made up of Lake Antoine volcanics in the north, alluvial and superficial deposits in the middle and Great River Beds to the South. The beach material tends to be fine-grey in the north, fine-white along Pearls and Paradise, white coral along Telescope and fine and muddy from Grenville to Marquis.

For the East Coast, aerial photographs were used to analyze beach erosion at two sites. At the Pearls beach on the foot of the old Pearls Airport, aerial photographs are available for 1951,1966, 1982 and 1992. The analysis showed that:

- Between 1951 and 1966 the beach accreted 11.3m.

- Between 1966 and 1982 beach erosion probably accelerated due to sand mining. Between 1966 and 1982 the beach receded 3.3 m and a further 3.7 m over the next ten years.

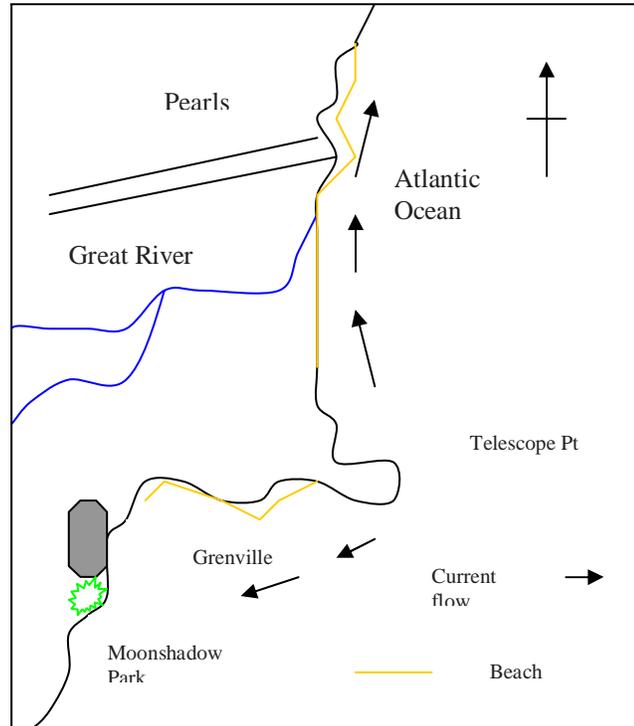
The steady beach recession during the 1990s may be explained by the continued practice of sand mining, reduction of riverine sediment supply to the beaches along the Great River due to sand and gravel mining from the river and the construction of small dams on the tributaries of the Great River.

Fig 5.2.1 - Beach accretion at Pearls

The accretion at Pearls beach prior to the mid-1960s resulted from movement of eroded material from the Telescope point and silt deposits from the Great River - **Figure 5.2.1**.

The rate of erosion at the Telescope-Grenville Bay observed from field data appears to be underestimated as compared to that from aerial photographs.

Mangrove, manchineel and sea grape trees - **Fig. 5.2.2 (a) and 5.2.2 (b)** - evident during the mid-1960s have disappeared by the 1990s. This is further supported from discussions with the older residents of the area who put beach recession in the region of 11m in the past 40 years.



The high level of erosion may be explained by changes in the water quality in the bay from the rapid and high rate of residential development above the beach, losses of coral outside the beach due to coral harvesting for white lime during the 1960s and 1970s. White lime was an important input for the St. Andrew's agricultural activities of this period.

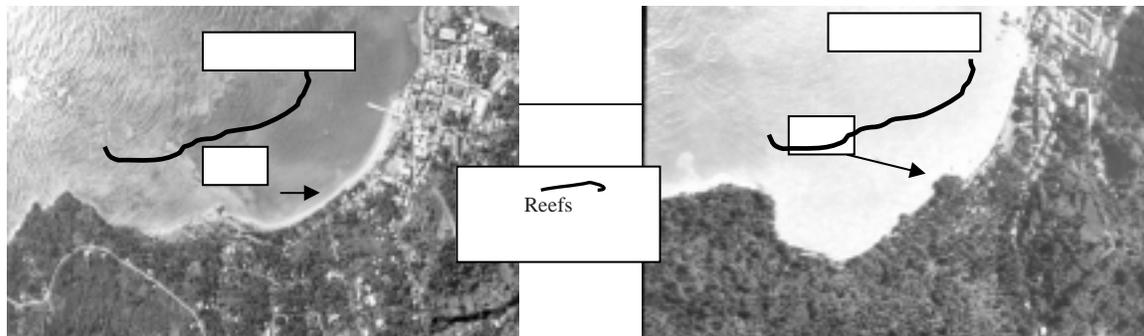


Fig 5.2.2 (a) Aerial photo of Grenville/Telescope 1962

Fig. 5.2.2 (b): Aerial photo of Grenville/Telescope 1992

The dynamics of the erosion on the Telescope-Grenville beach is also evident by the change in beach material from its black granite origin in the earlier periods to a current white coral eroded material. The influence of the original solid waste site and the eventual land reclamation on the southern side of the town of Grenville is not clear. This reclaimed land now known as Moon Shadow Park is at high risk to erosion and land subsidence as the land settles.

The eroded materials from the Telescope-Grenville beach are transported southwards along the shore and deposited in the vicinity of the Grenville jetty and the Anglican Church.

(b) Socio-economic Characteristics

The main socio-economic activities in this site include:

- Residential housing and small businesses
- Small scale subsistence farming include small ruminant husbandry
- Recreation and sea bathing areas
- Small scale fishing activities
- Small scale manufacturing enterprises
- A major information center (Simon)
- Pearls Airport (now out of service)
- Several heritage sites
- Second major town (Grenville)
- Mangrove swamps and wetlands
- Rivers and tributaries
- Amerindian archeological sites
- Coral reefs
- Seaport facility primarily for coastwise and inter-island trading
- Sand mining activity
- Utility infrastructure
- Boat building activities
- Charcoal burning
- Poaching

The dominant occupation in the area was small-scale farming and fishing, and micro enterprises. There were large tracts of undeveloped land owned by the government and large landowners.

The major development prospects for the area includes the provision of enabling infrastructure to support the construction of a 300-room hotel facility in the Levera /Chambord area located within 10 km of the site. This infrastructure development calls for the construction and rehabilitation of approximately 16 kilometers of coastal roads and reconstruction of the Pearls Airport facility.

Other potential developments include the expansion of the Simon Information Park, residential low-income housing development and the accompanying utility infrastructure.

The anticipated population growth in the area will be high, mainly as a result of internal migration associated with hotel development in Levera and the expansion of the manufacturing and information plant at Simon.

A large section of the coastal areas on this site is not developed and the potential for the establishment of large developmental project on the site is high. The USA Government, as an example, owns 133 acres of beachfront on this site, which was earmarked for the Construction of a communication facility. The status of this project is not available.

The beaches at Pearls and Telescope have been used extensively for sand mining. This has undermined their resistance to rising tides.

The major commercial area in the town of Grenville is below sea level.

The results of the socio-economic survey highlighted the following additional characteristics, viz:

- The weighted average household size was 4.03. The average household size of the national population is 3.9.
- The average monthly household income was \$1,053.
- The estimated number of people employed was 1570.
- The weighted average sales generated in the three sites was \$72,000.
- 32 percent of the buildings were made of concrete. 23 percent of the properties were constructed after 1990 and 55 percent after 1980.
- The weighted average property value was \$63,000.
- 84 percent of the properties were not insured. 37 percent of the respondents indicated that costs were the major inhibiting factor. 46 percent indicated that they never thought of insurance for their properties. 11 percent indicated that they never insured their properties because of apprehension about insurance policies. It is also significant to note that 2 percent of the respondents indicated that insurance companies refused to insure properties on the coast. In sum, therefore, the respondents are susceptible to significant financial losses resulting from property damage due to sea level rise.
- 97 percent of the respondents experienced flooding. Poor drain maintenance, heavy rainfall, sea level rise and high tides were listed as the most important factors.
- The weighted average of the cost of flood damage was \$40,000.

(c) Critical Infrastructure

The critical infrastructural facilities located within this site are:

- Five (5) - public buildings on Victoria Street on the coast of Grenville, including the Police Station and Magistrate’s Court.
- The port of Grenville.
- Four (4) - recreational/cultural facilities including Victoria Park and Simon Cultural Center.
- The Eastern Main Road (EMR).
- Victoria Street and Ben Jones Street in Grenville.
- Electricity, telecoms and water plant along EMR.

The investment cost of this infrastructure is EC\$65.8 million.

The characteristics of these facilities are detailed in **Appendix 2**.

(d) Hydrology

There are no sources of domestic and commercial freshwater supply within this site.

(e) Coral Reefs

The town of Grenville is protected by a reef that extends across most of the Grenville harbour. This reef was not studied in this project due to time constraints.

5.2.2. Vulnerability Analysis

(a) Major Impact Areas

The major impact areas are the Conference Bay area on the north of the site, the town of Grenville and the Soubise/Marquis area in the south of the site. – **Fig 5.2.3 (a) and 5.2.3 (b)**.

Fig 5.2.3 (b) – Northeast Impact



Fig 5.2.3 (a) – Northeast Impact



(b) Vulnerability to Sea Level Rise

The vulnerability to sea level rise (SLR) under the different scenarios could not be rigorously assessed for all parameters because of the limitations of the methodology.

- *SLR – 0.2m to 2020*

The **Beach Erosion** results for this site show that under this scenario, the beaches would lose about 30% of their current widths.

- *SLR – 0.5m to 2050*

The **Beach Erosion** results for this site show that under this scenario, the beaches would lose about 65% of their current widths

- *SLR – 1.0m to 2100*

The vulnerability of this site to the impact of a 1-meter sea level rise by 2100 is summarised in **Table 5.2.2**.

The table shows that there will be a number of adverse consequences at this site, viz:

- ✓ *Beach Erosion* - The results for this site show that under this scenario, most of the beaches would disappear. The beach at Grenville, which is slightly below sea level, could be lost by both a combination of inundation from higher sea levels and the erosion process. Under an increasingly rising sea, the rate of beach loss from Grenville and Telescope south would be more dramatic than is estimated from sea level rise beach loss simulation. At Telescope North to Pearls there is room for beach recession. The rate of beach erosion on the east coast along Grenville-Pearls would be influenced by whether sand mining at Pearls and Telescope is continued.
- ✓ *Infrastructure Impact* - data gathered during ground-truthing and the coastal vulnerability survey conducted under other sub-components of Grenada's case study (*Thomas 2000; Smith 2001*), suggest that approximately 10 ha of land could be inundated under this scenario. This includes:
 - The ground floor of all buildings and infrastructure facilities in Grenville within about 30m of the shoreline. This could include the Police Station, Fish Market, Anglican Church and School and Moonshadow Park.
 - Approximately 50m of Victoria Street and 400m of the Eastern Main Road in the Soubise/Marquis area.

The investment value of the affected infrastructure is EC\$7.47M.

Table 5.2.2 – Impact of 1 Meter Sea Level Rise in North East Site

| Types of Impact | Conference Bay | Grenville Town | Soubise/Marquis | Site Total |
|---|--|--|---|--|
| <i>Area of Impact</i> | Wetlands migrate inland; farming along the coast and Great River estuary | Victoria Street including Police Station, Post Office, commercial buildings, fisheries building, Anglican church | All building between eastern main road and coast for a distance of 1 km as well as 500 m of Eastern Main Road within the same 1km area. | Roads, commercial operations, human settlements and coastal ecosystems |
| <i>Beach Erosion</i> | Most beaches disappear | Most beaches disappear | Most beaches disappear | Most beaches disappear |
| <i>Infrastructure</i> | | | | |
| - Buildings/Floor Space (m ²) | - | - | - | 2,300 |
| - Buildings/Land (ha) | - | - | - | 0.62 |
| - Ports (no.) | - | - | - | - |
| - Recreational (no.) | - | - | - | 1 |
| - Recreational/Land (ha) | - | - | - | 0.93 |
| - Transportation/Road (km) | - | - | - | 0.45 |
| - Electricity/Line Plant (km) | - | - | - | 0.45 |
| - Telecoms/Line Plant (km) | - | - | - | 0.45 |
| - Water Mains (km) | - | - | - | 0.30 |
| Infrastructure Cost (EC\$) | - | - | - | EC\$7.47M |
| <i>Hydrology</i> | n.a | n.a | n.a | n.a |

(c) Vulnerability to Storm Surges

▪ *2020 Storm Surge*

The vulnerability to a Category 2 storm surge combined with a 0.2-meter sea level rise, with waves of 8 – 12 ft and a flooding impact of 5 ft is summarized in **Table 5.2.3**.

The table shows that there will be a number of adverse consequences at this site:

- ✓ *Beach Erosion* – based on the experience of Hurricane Lenny in 1999, it is expected that significant erosion will result. This could not be quantified in the absence of bathymetry data.
- ✓ *Socio-economic Impact* - The impacts here will be on commercial activities as well as human settlements, viz:
 - 100 businesses operating in the farming, fishing, small business and government sectors of the economy and employing 115 persons will be affected. The monthly value of the employment income is EC\$0.18M. In addition, the small farmers and fishermen in the area

are vulnerable to capital loss of EC\$0.20M in the form of agricultural equipment and fishing boats.

- 760 persons, living in 135 homes will be temporarily (or permanently) displaced. The current value of these homes is EC\$11.4M.

Table 5.2.3 – Impact of 5 ft Flooding in Northeast Site

| Types of Impact | Conference Bay | Grenville Town | Soubise/Marquis | Site Total |
|--|--|--|---|---|
| <i>Area of Impact</i> | Wetlands migrate inland; farming along the coast and Great River estuary | Victoria Street including Police Station, Post Office, commercial buildings, fisheries building, Anglican church | All building between eastern main road and coast for a distance of 1 km as well as 500 m of Eastern Main Road within the same 1km area. | Roads, commercial operations, human settlements and coastal ecosystems |
| <i>Beach Erosion</i> | Significant erosion | Significant erosion | Significant erosion | Significant erosion |
| <i>Commercial Impact</i> - No. Businesses - Type of Business - No. Employees - Value of Employment Income (monthly) - Capital Loss | 30 Small farmers who own relatively large tracts of land - EC\$0.030M | 50 Police Station, Port, Church, School, Fisheries, small retail operations 90 EC\$0.090M | 20 Fishermen and small retail 25 EC\$0.060M EC\$0.20M | 100 Farmers, Fishing Government, Small Business 115 EC\$0.18M EC\$0.20M |
| <i>Human Settlement</i> - No. Homes - Value of Homes - No. People | 5 EC\$0.3M 20 | 25 EC\$1.5M 100 | 105 EC\$6.6M 640 | 135 EC\$11.4M 760 |
| <i>Infrastructure</i> - Buildings/Floor Space (m ²) - Buildings/Land (ha) - Ports (no.) - Recreational (no.) - Recreational/Land (ha) - Transportation/Road (km) - Electricity/Line Plant (km) - Telecoms/Line Plant (km) - Water Mains (km) Infrastructure Cost (EC\$) | | | | 2,300 0.62 1 2 1.97 0.73 0.73 0.73 0.50 EC\$0.798M |
| Hydrology | n.a. | n.a | n.a | n.a |

- ✓ *Infrastructure Impact* - Approximately 28 ha of land could be vulnerable to flooding under this scenario. This includes:
 - The airstrip of the former Pearls Airport, which could be impacted by 5ft. floods encroaching up to 150m inland.
 - Approximately 300m of Victoria Street in the town of Grenville and all infrastructure to the east, including the Police Station, Fish Market, Anglican Church and Primary School and Port Authority complex, could be impacted by 5ft. floods.
 - 700 m of the Eastern Main Road and related utility infrastructure, in the Soubise / Marquis area.

The investment cost of the affected infrastructure is EC\$0.798M.

- *2100 Storm Surge*

The vulnerability to a Category 2 storm surge, combined with a 1-meter sea level rise, with waves of 8 – 12 ft and a flooding impact of 10 ft is summarized in **Table 5.2.4**.

The table shows that there will be a number of adverse consequences at this site:

- ✓ *Beach Erosion* – based on the experience of Hurricane Lenny in 1999, it is expected that significant erosion will result. This could not be quantified in the absence of bathymetry data.
- ✓ *Socio-economic Impact* - The impacts here will be on commercial activities as well as human settlements, viz:
 - 240 businesses operating in the farming, fishing, small business and government sectors of the economy and employing 235 persons will be affected. The monthly value of the employment income is EC\$0.32M. The contribution to GDP could not be quantified due to data limitations.
 - 2640 persons, living in 400 homes will be temporarily (or permanently) displaced. The current value of these homes is EC\$25.5M.
- ✓ *Infrastructure Impact* - Approximately 108 ha of land could be vulnerable to flooding under this scenario. This includes:
 - The airstrip of the former Pearls Airport, which could be impacted by 10ft. floods encroaching 300m inland.
 - Approximately 30% of the 'downtown' area in Grenville town, including 100m of Ben Jones Street and the Magistrate's Court.

- Approximately 420m of the Eastern Main Road in and around Grenville town, along with utility infrastructure.
- Approximately 1300m of the Eastern Main Road in the Soubise/Marquis area.

The investment cost of the infrastructure at risk is EC\$3.3M.

Table 5.2.4 – Impact of 10 ft. Flooding in Northeast Site

| Types of Impact | Conference Bay | Grenville Town | Soubise/Marquis | Site Total |
|--|---|--|---|--|
| Area of Impact | Wetlands migrate inland; farming along the coast and Great River estuary | Victoria Street including Police Station, Post Office, commercial buildings, fisheries building, Anglican church | All building between eastern main road and coast for a distance of 1 km as well as 500 m of Eastern Main Road within the same 1km area. | Roads, commercial operations, human settlements and coastal ecosystems |
| Beach Erosion | Significant erosion | Significant erosion | Significant erosion | Significant erosion |
| Commercial Impact - No. Businesses - Type of business - No. Employees - Value of Employment Income | 30 Farming activities and part of Pearls Airstrip - EC\$0.050M | 190 Retail operations, banks, market square, school, church, Police Station 210 EC\$0.210M | 20 Fishing and retail 25 EC\$0.06M | 240 Farming, commercial, Government and small business operations 235 EC\$0.32M |
| Human Settlement - No. Homes - No. People - Value of Homes | 15 60 EC\$0.9M | 85 340 EC\$5.0M | 300 2,240 EC\$19.6M | 400 2,640 EC\$25.5M |
| Infrastructure - Buildings/Floor Space (m ²) - Buildings/Land (ha) - Ports (no.) - Recreational (no.) - Recreational/Land (ha) - Transportation/Road (km) - Electricity/Line Plant (km) - Telecoms/Line Plant (km) - Water Mains (km) Infrastructure Cost (EC\$) | - - - - - - - - - - | - - - - - - - - - | - - - - - - - - - | 3,600 0.99 1 2 3.32 2.12 2.12 2.12 1.62 EC\$3.3M |
| Hydrology | n.a | n.a | n.a | n.a |

5.3. CARRIACOU

The study area consisted of 40 km of coastline surrounding the entire island of Carriacou. It contains beaches, mangroves, turtle nestling grounds, commercial areas and commercial ports.

5.3.1. Site Characteristics

(a) Beaches

Carriacou has many beaches, most of them on the Caribbean Sea (western) side of the island. The main beaches are at Harvey Vale, Paradise, Lauriston, Bogles, Petite Carenage-Lillette and Windward – **Table 5.3.1.**

Table 5.3.1 – Characteristics of Beaches in Carriacou

| Site | Length of Beach (Km) | Sand Type | Sand Color | Level of Development along beach |
|-------------------------|----------------------|-----------|------------|----------------------------------|
| Harvey Vale | 1.63 | Fine | | 30% |
| Paradise | 1.50 | Fine | White | ≅ 5% |
| Lauriston | 0.88 | Medium | White | 0 |
| Hillsborough | 2.0 | Fine | White | ≅ 70% |
| Bogles | 0.37 | Coarse | White | 0 |
| Petit Carenage-Lillette | 0.95 | Medium | White | 0 |
| Windward | 1.70 | Fine | Black | ≅ 15% |

The Harvey Vale Beach is found within the Tyrrel Bay is made of a white-gold fine-grain textured sand. The Beach is well protected by the Southwest and Jack Iron point peninsulas. All of the eroded materials remain within Tyrrel Bay. Similarly, Paradise and Lauriston Beaches are sheltered by head rocks at Point Cistern and Lauriston Point. These two beaches are flat Eroded material from these two beaches drift towards Sandy Island about 1km from shore.

Hillsborough Beach is less well protected than Harvey Vale Paradise or Lauriston and is particularly vulnerable to the winter storm surges. Bogles Beach is unprotected with very coarse beach materials. This beach is steeper than the other beaches and is vulnerable to tropical storms and winter surges. Recession for this beach is restricted by 5m cliffs.

Petite Carenage-Lillette is the only beach on the northern side of the island. The beach has been undisturbed by human activity, partly because of inaccessibility. Material for this beach is supplied from dead corals from the Eastern Coast reefs.

The beaches at Windward and along Watering Bay are comprised of predominantly fine black sands with occasional pockets of coarser white sand. Although these beaches are located on the rougher Atlantic Coast, they are fully protected by coral reefs.

Organized beach erosion data for Carriacou is not available. Using a combination of expert judgment (experts include fishermen, boat builders, beach property owners and local environmental activists), beach surveys conducted during 3 days in July 2000 and aerial surveys for 1958, 1966, 1982 and 1992, some estimates of the historic erosion was possible. Using expert judgment based on knowledge of the lands, loss foot-paths and roads, coastline and beach recession along some parts of Harvey Vale Paradise, and Hillsborough (west coast) is put at a maximum of 10 m over 45 to 50 years.

At Harvey Vale, the aerial photographs indicate that there was significant beach erosion from Hurricane Janet. At the Harvey Vale-Hermitage Junction, the 1958 photograph indicates that the beach was eroded to such an extent, that the road went through the beach. There was some recovery by 1966 with well-established manchineel and seagrape trees by 1982. In the vicinity of the Jetty however, there are signs of continued erosion. In 1958, there was about a 12m vegetative strip between the road and the beach. There are negligible changes seen in the 1966 aerial photograph. Significant beach recessions are observed from the 1982 and 1992 photographs. In 2000, virtually all of this 12m vegetative strip has disappeared and is now occupied by the beach.

At Hillsborough, beach erosion has had a significant impact. The combination of 1966, 1982 and 1992 aerial photographs with the field visits in 2000 show that the original Esplanade on a 10m vegetative strip prior to 1966, had disappeared by 2000. Most of the erosion occurred during severe events, particularly winter storm surges. Along the Lauriston Road, road protection became necessary during the 1980s as the beach was eroded about 12m in some places over the past 25 years. Flooding of this strip of road is a common occurrence during the winter storm surges.

On the beaches at Bogles (East Coast) and Black Bay (East coast) erosion is more difficult to quantify. Best estimates are about 6 m to 8 m in the past 40 years (15cm to 20cm per year). The material on the beach at Bogles is made up of coarse coral remains and stones. There is evidence of small collapsing caves, undermined by wave action. However, the evidence of erosion is not so obvious on aerial photographs. At Black Bay, there is evidence of coastal erosion probably more from onshore weathering activities than from the action of waves.

In the case of Lillette-Petite Carenage, during field visits during 2000 a 2 m strip of dead sea grape along 50% of the beach was observed. It is not clear whether the sea grape dieback is a result of erosion alone, or a combination of erosion and saltwater intrusion. It is evident however that the width of the die-back has been almost constant over at least the past 30 years and that the die-back recedes at about 1.2 m in 15 years (8 cm/yr.). The relatively low rate of erosion at Lillette-Petite Carenage is supported by aerial photographs for 1966, 1982 and 1992 in which little change in the position of the beach line is evident. This low erosion may be explained by the sheltered nature of the beach and the absence of human development on the beach.

At Windward on Watering Bay, which is protected by offshore reefs, beach erosion, while evident has been low. Some parts of the beach have been damaged from illegal dumping of waste and the presence of three large shipwrecks in the Bay. The Windward coastal road, which during the 1950s was 4m to 5m from the high-water mark, had to be

protected during the 1990s as high-water mark is now against the protected walls. During the hurricane season, this coastal road is frequently flooded. The once popular beach north of the Windward jetty has been reduced to mud banks. The coastline in this area has receded about 10m over the past 50 years. This is supported by comparison of aerial photos from 1966, 1982 and 1992.

(b) Socio-economic Characteristics

The main socioeconomic activities and establishments within this site are:

- Residential housing and small business
- Small scale subsistence farming
- Small ruminants husbandry
- Recreational and sea bathing facilities
- Small scale fishing
- Small scale manufacturing
- Boat building facilities and marinas
- Utility and transportation infrastructure
- Heritage sites
- Government facilities
- Water catchments, wells, water desalination plant
- Airport and seaports
- Mangrove swamps, coral reefs, oyster beds and scrub lands
- Hotel facilities and yachting activities

The estimated number of households within the site is 1125. The population of Carriacou is expected to rise much slower than the national average within the sea level time frames.

The major development activities earmarked for the area are road rehabilitation including sea defenses, low income housing development, development of a mini stadium and other recreational facilities and expansion of the coastal tourism plant.

It is envisaged that development and human settlement activities will be concentrated in Hillsborough and Harvey vale areas (both coastal communities). Population growth is therefore expected to concentrate along the coastal zone.

It is also envisaged that airport and ports expansion activities will take place. A water distribution system and solid waste management system will also be constructed.

The results of the socio-economic survey highlighted the following additional characteristics, viz:

- The weighted average household size was 4.37. The average size of households of the national population is 3.9.
- The average monthly household income was \$1,603.
- The estimated of the number of people employed in Carriacou was 610.
- The weighted average sales generated in Carriacou was \$235,000.

- 32 percent of the properties were constructed form concrete. 23 percent of the properties were constructed after 1990 and 55 percent after 1980.
- The weighted average property value was \$90,000.
- 70 percent of the properties in Carriacou were not insured. 37 percent of the respondents indicated that costs were the major inhabiting factor. 46 percent indicated that they never thought of insurance for their properties. 11 percent indicated that they never insured their properties because of apprehension about insurance policies. It is also significant to note that 2 percent of the respondents indicated that insurance companies refused to insure properties on the coast. In sum, therefore, the respondents are susceptible to significant financial losses resulting from property damage due to sea level rise.
- 30 percent of the respondents had experienced flooding. Poor drain maintenance, heavy rainfall, sea level rise and high tides were listed as the most important factors.
- The weighted average of the cost of flood damage was \$100,000. It must be noted here that Carriacou received significant damage as a result of Hurricane Lenny.

(c) Critical Infrastructure

The critical infrastructural facilities located within this site are:

- Eight (8) - public buildings including the Government Administration Offices and Police Station on main Street, Hillsborough and several schools.
- Two (2) - hotels in Hillsborough.
- The Shell fuel depot at Harvey Vale.
- The port of Hillsborough and Lauriston Airport.
- Two (2) - recreation grounds.
- Roads in and between Hillsborough, L'Esterre, Harvey Vale, Windward and Petite Carenage.
- Electricity and telecoms plant along the various roads and NAWASA's Seaview desalination plant.

The investment cost of this infrastructure is EC\$35.6 million.

The characteristics of these facilities are detailed in **Appendix 3**.

(d) Hydrology

The principal freshwater resources in use in Carriacou comprise the following (*DIWI 1996*):

- Private rainwater roof catchments, with underground cisterns.
- Public rainwater catchments, with underground cisterns and tanks.
- One (1) production borehole (no. H1) located at Beausejour, Hillsborough, with an approximate yield of 5.2 m³/hr, which serves a very limited distribution line in part of Hillsborough.

- Twenty eight (28) - dug wells with a combined yield of 27-36 m³/day, used mainly for livestock watering.
- Five (5) - springs.

Of the public facilities, five (5) catchments, twelve (12) dug wells and the production borehole fall within the study area. The characteristics of these facilities are detailed in **Table 5.3.2.**

Table 5.3.2. Inventory of Coastal Groundwater in Carriacou

| Well name (location) | No. | Depth (m) GL | Diameter (m) | SWL (m) GL | Dist. to coast (m) | Comment |
|----------------------------|-----|--------------|--------------|------------|--------------------|--------------------|
| <i>Dug wells</i> | | | | | | |
| Botany (Hillsborough) | H10 | 4.90 | - | - | 360 | Abandoned |
| Brunswick | H7 | 3.19 | 3.20 | - | 600 | Well dry |
| Church (Windward) | L3 | 5.43 | 4.75 | 4.24 | 60 | - |
| Dumfries | D1 | 3.00 | 3.30 | 1.45 | 250 | Fairly clean |
| Harveyvale | HA3 | 4.28 | 2.74 | 2.39 | 240 | - |
| Health Centre (Windward) | L2 | 3.85 | 3.80 | 3.46 | 40 | - |
| Maway (Brunswick) | H5 | 8.05 | 3.05 | 5.61 | 950 | Fairly clean |
| Petit Carenage | L4 | 4.00 | 2.30 | 3.71 | 200 | - |
| Playfield (Hillsborough) | H4 | 2.67 | 3.00 x 3.05 | 2.31 | 130 | Polluted |
| Sabazan | S1 | - | 4.10 | 4.93 | 150 | Fairly clean |
| Spring (Hillsborough) | H3 | 4.28 | 2.00 x 2.25 | 3.22 | 380 | - |
| White Man (Bellevue) | D2 | 3.55 | 4.30 | 2.28 | 50 | - |
| <i>Production borehole</i> | | | | | | |
| Beausejour | H1 | 30.50 | 0.34 | 5.24 | 500 | Serves part Hills. |

Source: adapted from Barragne-Bigot 1987a, with field observations made 2000.07.07

Carriacou is divided into 15 watersheds of which the following, shown with their respective areas and estimated groundwater recharge, are of particular relevance to this study; there are no perennial streams on Carriacou.

- Harvey Vale – 181.3 ha; 0.330 Mm³/year.
- Dumfries/Grande Breteche – 202.5 ha; 0.368 Mm³/year.
- La Resource/Sabazan – 152.5 ha; 0.277 Mm³/year.
- Hillsborough – 186.3 ha; 0.339 Mm³/year.

There are inadequate ground level and water quality data available to enable precise determination of the current threat of seawater intrusion into the groundwater and wells in Carriacou, however due to the hydrogeological constraints and small volume of the aquifers it can be concluded that the threat is significant.

(e) Coral Reefs

- *Jack - A - Dan Reef (North West Coast)(GPS coordinates: N 12° 29' 39 W 61° 28' 01 Average depth: 23 ft (7 m)).*

This is a shallow patch reef, just off Jack -A- Dan island approximately 1 km NW of Hillsborough. The small island is volcanic in origin and is comprised of a rocky outcrop, with a small lagoon and sandy beach, surrounded by coral reefs. The western section of the island was exposed with a 10 m wide fringing reef, the southern end consisted primarily of coralline algae, the eastern end was shallow (3-4 m) with reef rubble and sand patches, whereas the northern portion was composed primarily of hard corals (Price, 1998). The area surveyed in this study was on the eastern side of the island, that is, the section closest to the capital town of Hillsborough.

Local stakeholders considered Jack- A- Dan the most negatively impacted site off Carriacou, and diver observations classified the reef as moderately stressed.

Two significant impacts were identified at this site:

- ✓ the lambi (conch) processing business was centered on Jack-A-Dan and discarded shells with rotting meat were often left on the island by fishermen. This could act as a potential source of nutrient enrichment (Price, 1998), which generally promotes the growth of algae.
 - ✓ Hurricane Lenny, which impacted the islands in 1999, significantly damaged the reef system, and large stands of toppled *Montastrea annularis* colonies were observed scattered across the reef face. It should be noted that this section of reef was not monitored. In addition to this hurricane damage, some recent anchor damage was also observed as evidenced by its localised nature and the fact that the broken stubs were as yet uncolonised by algae.
- *Sandy Island* (GPS coordinates: N 12° 29.13 W 61° 28.14; Average depth: 22 ft (6 m)).

Sandy Island is one of the westerly outlying barrier islands and was described as “ephemeral”. It is comprised of an accumulation of sand, which is protected by the reef to the west of the island and sea grass beds to the southeast. Dive surveys were carried out on the northwestern sections of the island, and primarily hard corals colonized this, the most robust section of reef.

The reef crest of Sandy Island was primarily composed of *Acropora palamata* most of which was destroyed by Hurricane Lenny (Nagel pers com). With the collapse of these reef building corals, erosion of the island set in until all that is now left is an approximately 150 m long sand spit, with a few palm trees. It is possible that in the future another hurricane may cause all sediment to be washed away, and the island will disappear altogether. Although Sandy Island is frequently visited by boaters, anchor damage was not observed, and it was speculated that the large sand reserves on the eastern side of the island provided adequate anchoring. There were also several signs on the island, which prohibited many forms of environmental hazardous activities, such as littering. This site was considered moderately stressed.

- *Frigate Island Reef* (GPS coordinates: N 12° 24' 36 W 61° 28' 56; Average depth: 43 ft (13 m)).

Frigate Island is a rocky, volcanic outcrop located south of Carriacou and surrounded by an extensive reef system. The site surveyed was approximately 43 ft (13 m) deep, and at the edge of a moderate wall that dropped down to 75 ft. (23 m). The reef lacked the fissures and sand channels characteristic of other sites monitored, and exhibited 100% coral abundance in some areas.

During the dives at Frigate Island, there were no signs of physical damage, either from natural or anthropogenic sources. The site was categorised as healthy based primarily on the high abundance, diversity and robustness of its corals. The high algal coverage in some areas where coral abundance decreased and the occasional presence of black band disease prevented the classification of pristine. Very little particulate matter or suspended solids were observed in the water column, and visibility was more than 100 ft (30 m), the best observed at any site.

- *Sister Rocks Reef* (GPS coordinates: N 12° 28' 36.1 W 61° 30' 34.5; Average depth: 40 ft (12 m)).

Sister Rocks are two volcanic islets covered with guano and separated by a narrow channel, approximately 30 m (9ft.) wide and 5 m (1.5 ft) deep. The islets are located to the west of Carriacou. Currents between the islets were extremely strong and formed complex eddying systems around the islands. The reef itself was a narrow and steeply sloping shelf that extended no more than 20 m (6ft) from the islets in all directions prior to sloping steeply down to 110ft (33 m). Diver observations at the time of monitoring were in keeping with those of Price (1998), who described atypical organisms such as the elephant ear sponges and anemones. The site was characterised primarily by soft corals and sponges, whereas hard corals were uncommon and generally in small colonies.

Due to its relatively isolated location approximately 1.2 km west of Pt. Cistern, this site was only visited by dive operators, however its small size and steep slope meant that anchors were not often dropped on the reef. This site was categorised as moderately stressed.

- *Diamond Point Reef* (GPS coordinates: N 12° 20' 16.1 W 61° 34.5' 38; Depth 25- 110ft (8-37m)).

All the reefs in this area are termed “*Kick Em Jenny*” Reefs due to the close proximity to the submarine volcano and are the sites expected to “bare the brunt”, of any impacts linked to the eruption of the volcano. This specific reef is located at an approximate midpoint between Grenada and Carriacou. The area was characterised by a narrow reef flat with an extremely steep wall, which dropped off to 100 ft

Transects were not laid on this reef due to extremely strong currents experienced at the time of the dive, as well as its topography which consisted mainly of

vertical walls with numerous overhangs and crevices. This site was not demarcated, nor was a wand utilised to keep a consistent height above the reef. Instead, during the dive an ongoing video was taken in order to obtain information about the type of organisms found and coral health.

This was the first reef monitored which showed no signs of bleaching or of coral diseases. It is important to note that turf and macroalgae were still present on the reef, albeit not in the quantities observed on the other reefs that were situated closer to either of the two mainlands. No physical impacts such as anchor or hurricane damage were observed either. This site was given a classification of pristine.

5.3.2. Vulnerability Analysis

(a) Major Impact Areas

The major impact areas are the Harvey Vale area in the south, the Hillsborough town (capital) in the west, the Petite Carenage area in the north and the Mt. Pleasant area in the east – **Fig 5.3.1.**

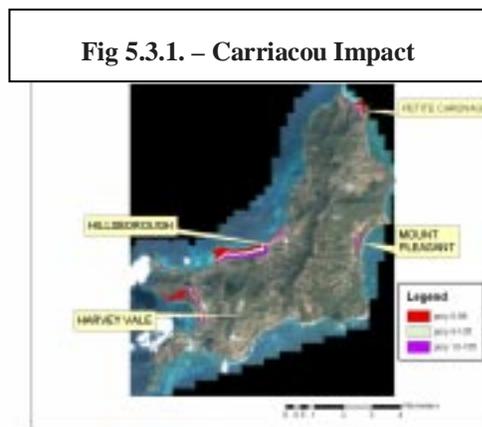
(b) Vulnerability to Sea Level Rise

The vulnerability to sea level rise (SLR) under the different scenarios could not be rigorously assessed for all parameters because of the limitations of the methodology.

- *SLR – 0.2m to 2020*

The analysis shows that the beaches in Carriacou will lose between 50% and 65% of their current widths for a 20 cm SLR.

- *SLR – 0.5m to 2050*
 - ✓ *Beach Erosion* - The analysis shows that 83% of the beaches in Carriacou will disappear. This will include the complete recession of the beaches at Hillsborough, Paradise, Lillette and Windward.
 - ✓ *Hydrology* – the wells at Playfield (Hillsborough), Church and Health Centre (Windward), White Man (Bellevue) and Sabazan will be inundated under this scenario. These wells are all within 150m of the coast.
- *SLR – 1.0m to 2100*



The vulnerability of this site to the impact of a 1- meter sea level rise by 2100 is summarised in **Table 5.3.3**.

Table 5.3.3 – Impact of 1 Meter Sea Level Rise in Carriacou

| Types of Impact | Harvey Vale | Hillsborough | Petit Carenage | Mt. Pleasant | Site Total |
|---|---|---|---|------------------------------|--|
| Area of Impact | Main Road and all buildings Beach area Fuel Storage Tanks Oyster beds & adjoining road | Commercial buildings next to jetty and all buildings between beach and main road (700 meters) Silver Beach Hotel | Beach will be inundated Mangroves at L'Apelle will disappear | Beach inundated | Commercial areas, housing areas, roads, and coastal ecosystems |
| Beach Erosion | Most beaches would disappear | Most beaches would disappear | Most beaches would disappear | Most beaches would disappear | Most beaches would disappear |
| Infrastructure | | | | | |
| - Buildings/Floor Space (m ²) | - | - | - | - | 1,900 |
| - Buildings/Land (ha) | - | - | - | - | 0.07 |
| - Hotels/ Rooms (no.) | - | - | - | - | 8 |
| - Hotels/Land (ha) | - | - | - | - | 0.60 |
| - Industrial Complexes (no.) | - | - | - | - | - |
| - Ports (no.) | - | - | - | - | - |
| - Recreational (no.) | - | - | - | - | - |
| - Recreational/Land (ha) | - | - | - | - | - |
| - Transportation/Road (km) | - | - | - | - | - |
| - Electricity/Line Plant (km) | - | - | - | - | - |
| - Telecoms/Line Plant (km) | - | - | - | - | - |
| Infrastructure Cost (EC\$) | - | - | - | - | EC\$2.040M |
| Hydrology | | | | | Salinization of 80% of wells |

The table shows that there will be a number of adverse impacts under this scenario, viz:

- ✓ *Beach Erosion* – Most beaches in this site will completely disappear under this scenario.
- ✓ *Infrastructure Impact* - Data gathered during ground truthing, and interpolation of the 1m contour of land inundation, suggest the likelihood that a 1m SLR could impact the foundation of exposure units along the Hillsborough waterfront, and that a total of about 30ha of land in Carriacou could be inundated.

The investment cost of this affected infrastructure is EC\$2.040M.

- ✓ *Hydrology* – the wells at Dumfries, Harvey Vale, and Petit Carenage - all within 250m of the coast – will also be inundated under this scenario.

(c) Vulnerability to Storm Surges

- *2020 Storm Surge*

The vulnerability to a Category 2 storm surge combined with a 0.2-meter sea level rise, with waves of 8 – 12 ft and a flooding impact of 5 ft is summarized in **Table 5.3.4.**

The Table shows that there will be a number of adverse consequences at this site.

- ✓ *Beach Erosion* – based on the experience of Hurricane Lenny in 1999, it is expected that significant erosion will result. This could not be quantified in the absence of bathymetry data.
- ✓ *Socio-economic Impact* - The impacts here will be on commercial activities as well as human settlements, viz:
 - 67 businesses operating in all sectors of the economy and employing 184 persons will be affected. The monthly value of the employment income is EC\$0.325M. The contribution to GDP could not be quantified due to data limitations.
 - 88 persons, living in 20 homes will be temporarily (or permanently) displaced. The current value of these homes is EC\$1.16M.
- ✓ *Infrastructure Impact* - Approximately 99 ha of land could be vulnerable to flooding under this scenario. This includes:
 - The Port Authority complex and Government Administration Offices on Main Street in Hillsborough, Silver Beach Hotel, about 300m of Main Street and 1.0Km of the Hillsborough/L'Esterre Road along with utility infrastructure.
 - The Shell fuel depot in the L'Esterre/Harvey Vale area and about 600m of the L'Esterre/Harvey Vale Road
 - Approximately 200 m of main road in the Windward/Petit Carenage area.

The investment cost of the affected infrastructure is EC\$0.810M.

- ✓ *Hydrology* – One (1) public freshwater facility, the Playground dug well located in Hillsborough about 130m inland, is potentially vulnerable to inundation under this scenario.

Table 5.3.4 – Impact of 5 ft. Flooding in Carriacou Site

| Types of Impact | Harvey Vale | Hillsborough | Petit Carenage | Mt. Pleasant | Site Total |
|---|--|---|---|--|--|
| <i>Area of Impact</i> | Main Road & buildings on road, Beach, Fuel Storage Tanks, Oyster beds & road | Commercial buildings next to jetty and all buildings between beach and main road (700 meters) Silver Beach Hotel | Beach will be inundated Mangroves at L'Apelle will disappear | Beach inundated | Commercial areas, housing areas, roads, and coastal ecosystems |
| <i>Beach Erosion</i> | Significant erosion | Significant erosion | Significant erosion | Significant erosion | Significant erosion |
| <i>Commercial Impact</i> - No. Businesses - Type of Business - No. Employees - Value of Employment Income (Monthly) | 14 Shipping and fishing activities 35 EC\$0.06M | 38 Port, government buildings, police station, small hotels, fishing, retail and airport 149 EC\$0.24M | 15 Farming and Fishing - EC\$0.025M | None - - | 67 184 EC\$0.325M |
| <i>Human Settlement</i> - No. Homes - Value of Homes - No. People | 7 EC\$0.06M 31 | 13 EC\$1.1M 57 | 0 0 0 | 0 0 0 | 20 EC\$1.16M 88 |
| <i>Infrastructure</i> - Buildings/Floor Space (m ²) - Buildings/Land (ha) - Hotels/ Rooms (no.) - Hotels/Land (ha) - Industrial Complexes (no.) - Ports (no.) - Recreational (no.) - Recreational/Land (ha) - Transportation/Road (km) - Electricity/Line Plant (km) - Telecoms/Line Plant (km) Infrastructure Cost (EC\$) | - - - - - - - - - - - - | - - - - - - - - - - - - | - - - - - - - - - - - - | - - - - - - - - - - - - | 1,900 0.13 16 1.20 1 1 - - 2.10 2.10 2.10 EC\$0.810M |
| Hydrology | | | | | 1 well |

- *2100 Storm Surge*

The vulnerability to a Category 2 storm surge, combined with a 1-meter sea level rise, with waves of 8 – 12 ft and flooding of 10 ft is summarized in **Table 5.3.5**.

Table 5.3.5 – Impact of 10 ft. Flooding in Carriacou Site

| Types of Impact | Harvey Vale | Hillsborough | Petit Carenage | Mt. Pleasant | Site Total |
|---|---|--|---|---------------------|--|
| <i>Area of Impact</i> | Main Road and all buildings on road; beach area; fuel storage tanks; oyster beds and adjoining road | Commercial buildings next to jetty on Main Street and all buildings between beach and main road (700 meters) Silver Beach Hotel | Beach will be inundated Mangroves at L'Apelle will disappear | Beach inundated | Commercial areas, housing areas, roads, and coastal ecosystems |
| <i>Beach Erosion</i> | Significant erosion | Significant erosion | Significant erosion | Significant erosion | Significant erosion |
| <i>Commercial Impact</i> | | | | | |
| - No. Businesses | 16 | 98 | None | None | 114 |
| - Type of Business | | | | | |
| - Value of Business | | | | | |
| - No. Employees | 37 | 298 | - | - | 435 |
| - Value of Employment Income (Monthly) | EC\$0.06M | EC\$0.5M | | | EC\$0.56M |
| <i>Human Settlement</i> | | | | | |
| - No. Homes | 21 | 55 | None | None | 76 |
| - Value of Homes | EC\$1.9M | EC\$4.9M | - | - | EC\$6.8M |
| - No. People | 92 | 240 | - | - | 332 |
| <i>Infrastructure</i> | | | | | |
| - Buildings/Floor Space (m ²) | - | - | - | - | 2,800 |
| - Buildings/Land (ha) | - | - | - | - | 0.25 |
| - Hotels/ Rooms (no.) | - | - | - | - | 16 |
| - Hotels/Land (ha) | - | - | - | - | 1.20 |
| - Industrial Complexes (no.) | - | - | - | - | 1 |
| - Ports (no.) | - | - | - | - | 2 |
| - Recreational (no.) | - | - | - | - | 1 |
| - Recreational/Land (ha) | - | - | - | - | 0.01 |
| - Transportation/Road (km) | - | - | - | - | 3.50 |
| - Electricity/Line Plant (km) | - | - | - | - | 3.50 |
| - Telecoms/Line Plant (km) | - | - | - | - | 3.50 |
| <i>Infrastructure Cost (EC\$)</i> | - | - | - | - | EC\$2.33M |
| <i>Hydrology</i> | | | | | 1 well |

The table shows that there will be a number of adverse consequences at this site:

- ✓ *Beach Erosion* – based on the experience of Hurricane Lenny in 1999, it is expected that significant erosion will result. This could not be quantified in the absence of bathymetry data.

- ✓ *Socio-economic Impact* - The impacts here will be on commercial activities as well as human settlements, viz:
 - 114 businesses operating in all sectors of the economy and employing 435 persons will be affected. The monthly value of the employment income is EC\$0.56M. The contribution to GDP could not be quantified due to data limitations.
 - 332 persons, living in 76 homes will be temporarily (or permanently) displaced. The current value of these homes is EC\$6.8M.
- ✓ *Infrastructure Impact* - Approximately 171 ha of land could be vulnerable to flooding under this scenario. This includes:
 - Land areas in Hillsborough as far inland as the Police Station, 1.0Km of main road and about 0.75ha at the western end of the Lauriston Airport runway.
 - Land areas in the L’Esterre/Harvey Vale area to include 50m² of the Harvey Vale playing field and an additional 200m of main road.
 - 400m of main road in the Windward/Petit Carenage area.

The investment cost of the affected infrastructure is EC\$2.33M.

- ✓ *Hydrology* – there will be no additional hydrology facilities affected under this scenario.

5.4. CORAL REEFS

5.4.1. Reef Status

(a) Corals

The reefs off Grenada and Carriacou ranged from heavily stressed to pristine, with most reefs being classified as moderately stressed. Coral abundance ranged from 12.4% – 35.2% for Grenada’s bank reefs and 16% – 40% for Carriacou’s fringing reefs.

However, the overall mean coral abundance for Grenada was 26.4%, which was higher than Carriacou’s overall mean of 21.65%. Although it was initially expected that due to its lower population density, Carriacou’s reefs would have exhibited fewer impacts, this was not the case. Hurricane Lenny was identified as one of the most significant stresses detected in the program. Though a natural impact, the hurricane that destroyed large stands of Carriacou’s coral reefs and left behind a barren substrate, also made the reef more susceptible to human impacts. While these barren areas could easily be recolonised with new coral recruits, the prevailing water quality conditions apparently favored the growth of algae.

(b) Algal Abundance

The presence of algae does not necessarily mean that a reef is stressed or unhealthy, and some scientists believe the term coral reef is a misnomer, as it does not incorporate the menagerie of other organisms, including algae that help to maintain a functioning ecosystem (Brylske, 1997). The consistently high levels of turf algae (20.5% – 47.7%) and macroalgae (4.5% - 35.6%) observed were still of some concern however, as excessive algal coverage usually indicates eutrophic conditions.

Dive operators at both islands indicated that the macroalgae was seasonal and often linked with turbid, discoloured water (possibly from the South American mainland). They further reported that these events occurred around the summer months. This seasonal variation highlights the need to re-survey the sites, in order to determine the veracity of these statements.

It should be noted that turf and macroalgae, though less common, were also observed at Diamond Point, the only reef classified as pristine. Their presence also lent strength to the theory that some quantities of algae form part of the natural reef ecosystem. The algae can however proliferate as a result of nutrient enrichment, easily out competing adult corals for valuable space on the reef, and prohibiting settlement of new larvae (Birkeland, 1997 and Tomascik, 1991).

(c) Coral Diseases and Bleaching

Black Band Disease (BBD) and Yellow Band Disease (YBD), though not quantified, were observed on all of the reefs monitored, with the exception of Diamond Point. The absence of diseases at this pristine site, which was several miles from the nearest inhabited island, adds strength to the theory that the impacts of coral disease can be exacerbated by land based activities. Coral bleaching was also observed at several of the sites monitored, but its abundance and intensity were much lower than disease occurrence.

5.4.2. Impacts Related to Global Climate Change

Without the benefits of water quality sampling, and after one round of sampling, it is difficult to conclusively quantify the impacts of GCC specifically on Grenada and Carriacou's coral reef communities, at the present time. However, generalised predictions were made regarding likely impacts, viz:

- The expected increase in the intensity and frequency of storms may cause further physical damage to both islands' reefs, especially to the near shore fringing reefs of Carriacou.
- The associated increase in rainfall will further increase surface and groundwater runoff, which could result in the introduction of more sediment and nutrients into the marine environment.
- Finally, should sea surface temperatures continue to increase, it is also likely that corals will be chronically stressed and bleached. The increases in "natural" stress

levels coupled with anthropogenic impacts will possibly render many reefs incapable of keeping pace with sea level rise.

6. INSTITUTIONAL READINESS

6.1. INSTITUTIONAL COORDINATION

The study revealed that apart from the CPACC project and the Initial National Communications project, there is no institution or organisation dealing specifically with issues of global climate change and sea level rise. Both of these projects are limited life projects, with very specific mandates.

It has been learnt that there were several attempts in the recent past to establish a broad base multi sectoral committee to deal with issues of the environment.

The Sustainable Development Council has been functioning as a clearinghouse to air issues of global climate change and sea level rise and other environmental related subjects. In fact, the Council is the official Steering Committee for the Convention on Biodiversity and the Convention to Combat Desertification. The Council can continue to function as a medium for discussion of environmental issues but there is a dire need for the establishment of a structured framework to continually address issues of sea level rise due to global climate change.

6.2. LEGAL FRAMEWORK

A analysis of the legal framework, conducted for this analysis (Alexis 2000), concluded that *“most of the laws that are applicable to the management of the coastal zone are sectoral and decentralized ...while they have environmental application, they were not primarily legislated to address those concerns and are mainly incidental to environmental management. However, all the legislation listed ... can be utilized for the management of the coastal zone and to prevent, control and mitigate loss envisaged as a result of the adverse effects of global warming and sea level rise”*.

The Report concluded that the legal framework as it obtains now could be adapted and adopted as a short-term measure. This combined with proper administrative direction and control could provide the legal framework for environmental management in the short to medium term. The adaptation would only require minor but important amendments in the short term. Once the structure is properly coordinated and comprehensive data is collected, then the issues would be much clearer, facilitating the development of new guidelines, management structures and legal framework.

The Report identified seventeen (17) laws that, if strengthened either through amendments or proper implementation, could provide a short-term legal framework for addressing climate change and sea level rise issues. These laws and the proposed amendments are detailed in **Appendix 5**.

6.3. AWARENESS LEVELS

The socio-economic survey conducted for this analysis found that 83 percent of the respondents (across the three sites) indicated previous knowledge of the issue of climate change and 84 percent indicated knowledge of sea level rise associated with climate change.

This relatively high awareness came about primarily as a result of radio and television communications, viz:

- 39 percent of the respondents indicated hearing mention of the issues on radio.
- 14 percent read about the issues on newspapers.
- 33 percent were exposed to the issue via television.

- 8 percent via book and magazines.
- 3 percent of the respondents were exposed to the issues via the Internet.

Radio communication is more significant in St. Andrew, where over 50 percent became aware of these issues through that medium. Many respondents indicated that they heard about the issue within recent times as a consequence of the Climate Change Project.

In response to a question on the importance of sea level rise in Grenada, 44 percent of the respondents indicated that sea level rise is very important for Grenada. An additional 43 percent indicated some level of importance. 13 percent indicated that sea level rise is not important for Grenada.

No assessment of the awareness and readiness of business and/or political leaders was available, or had been done by this analysis.

7. ADAPTATION OPTIONS

The conceptual frameworks developed in the last decade for climate/vulnerability assessment (*Parry and Carter 1998, Klein and Nicholls 1999*) draw a basic distinction between responses to climate change that are *autonomous* or spontaneous (e.g. the accretion of mangroves in response to SLR), and those that require deliberate policy decisions, referred to as *adaptation strategies* or *planned adaptation*.

Planned adaptation options to SLR are usually classified into the following three broad categories (*Nurse 1997, Nicholls and Klein 2000*):

- *Planned Retreat* - a relocation of human activities away from threatened coasts, allowing all natural system effects to occur;
- *Accommodation* - in which all natural system effects are allowed to occur and human use of the coast is adjusted so as to minimize impacts; and
- *Protection* - which involves defense of vulnerable areas, populations and economic activities by application of ‘soft’ or ‘hard’ engineering options.

7.1. AUTONOMOUS ADAPTATION

7.1.1. Beaches

Historic observations indicate that there have been both accretion and erosion going on in different cells of the beaches, allowing eroded material from one cell to be deposited on other cells. There is therefore a high likelihood that many beaches would disappear in part or completely where there is limited space due to lack of land, or restriction from permanent development. It is also likely that some that disappear would be replaced by others close by, while others would be pushed inland.

Additional work in this area is needed to determine the extent to which autonomous adaptation will play a significant role on the preservation of the beaches that are vulnerable to climate change.

7.1.2. Socio-economic

This is not a relevant option for the location of human settlements or facilities for commercial and recreational activities.

7.1.3. Infrastructure

This is not a relevant option for the location of infrastructural facilities.

7.1.4. Hydrology

This is not a relevant option for the location of public freshwater facilities.

7.1.5. Coral Reefs

There was insufficient data to analyse the dynamics of the coral ecosystems. Additional data collection and analysis are needed in this area.

It was therefore recommended that, due to seasonal fluctuations, a second reef survey should be completed within a year of the initial survey, and during another period of the year (possibly staggered at a six-month interval). This re-survey will provide the first quantitative information regarding the *rate and direction of change* in Grenada’s coral

reef communities as they relate to the impacts of GCC. Dependant on the results of this re-survey, it may be advisable to either expand the size of each monitoring site, or to monitor certain critical sites more frequently.

In addition to the implementation of a water quality programme that encompasses temperature, salinity, pH, nitrates, phosphates and turbidity, a comprehensive monitoring programme aimed at detecting changes induced by GCC should also identify the frequency and type of coral diseases, as well as the percentage bleaching. Such an approach will allow the direct effects of GCC to be tracked over time, and may provide an early warning system for GCC impacts throughout the region.

This coral reef monitoring programme is aimed at determining the impacts of Global Climate Change on coral reefs. It is however important not to lose sight of the fact that GCC and anthropogenic impacts are inextricably linked. Without the latter stressors, it is entirely possible that the former stressors might not be as severe. Mitigative steps, therefore, taken towards improving the health of marine ecosystems with respect to GCC, must begin with reducing the human impacts.

7.2. PLANNED ADAPTATION

7.2.1. Beaches

Planned adaptation to the threat of additional beach erosion could take many forms.

(a) Planned Retreat

Planned retreat is a viable option. This could be achieved through enforcement of the building setback of 50 meters proposed by Cambers and others and already enshrined in the Grenada Building Code.

(b) Accommodation

The removal of non-climate stressors on the beach processes is a critical element of any strategy of accommodation.

In this regard, the elimination of the practice of sand mining for construction is critical and the Government should move swiftly to ensure that other sources of construction sand are available to the local construction industry to enable it to outlaw sand mining in the shortest possible time.

Other policy responses could include the building piers, docks and other buildings high enough to compensate for the future rise in sea level.

It is also important that a comprehensive study to quantify the potential economic losses from inundation and beach erosion from sea level rise should be undertaken. The use of appropriate computer models to simulate the impact of sea level rise and extreme storm events on all of the affected areas will be a useful component of such a study.

The results will assist in informing the analysis of additional accommodation options.

(a) Protection

The building of sea walls, revetments and the like is also a viable option that can be pursued.

The implementation of all of the above will be dependent on the existence of up-to-date and reliable data on the beach processes – erosion, sediment transport and the like - and the impact of climate change on them.

As Grenada is a small country, excessive efforts are not required in setting up a comprehensive beach erosion monitoring and measurement program. A sustainable program would need to involve the widest participation to reduce the concentration of required personnel while at the same time ensuring that there is wide ownership of the program. The use of students from the upper forms of secondary schools in a five to seven year program could be advantageous. In this regard, the following is recommended:

- A review of the existing beach monitoring program supported by UNESCO and the University of Puerto Rico during the nineteen eighties and early nineteen nineties.
- The development of a program for collecting data on beach erosion using secondary schools. This program should include appropriate incentives.
- The geo-referencing of all data collection/beach-monitoring locations.
- The establishment of three storm surge data collection sites at Grand Anse, Harvey Vale and Hillsborough. Measurements should be intensified during the periods of storm surges.
- Regular comparative analysis between observed data and satellite imagery.

7.2.2. Socio-economic

(a) Planned Retreat

The primary option here is the establishment of alternative settlement plans with respect to vulnerable coastal vulnerable.

It is important to note here however that 78 percent of the respondents to the socio-economic survey indicated that they were unwilling to relocate. The persons who indicated willingness to move stated that proximity to basic utilities is a prerequisite.

(b) Accommodation

This is the most viable option from a socio-economic perspective. Implementation will require that the following receive priority in the policy formulation process:

- The institutionalization of a Climate Change Monitoring Committee.
- Establishment of a public awareness and public information and education programmes on the issues related to sea level rise and global climate change.
- Issues of sea level rise to be given higher priorities in economic and social planning framework.
- Review of relevant environmental laws and institutionalization of enforcement mechanisms.
- Specific allocations targeted for environmental management in the National Budget.
- Promotion of the involvement of stakeholders and the public at large in the management of the environment.
- Development of a National Land Use policy with special emphasis on coastal activities.
- Review of the Solid Waste Management Programme taking into account issues of coastal pollution, flooding and garbage disposal.
- The establishment of a National Housing Plan.
- The development of human capital and research capacity for climate change issues.
- The establishment of an information database on climate change.

(c) Protection

Actions under this option will include:

- Review of relevant environmental laws and institutionalization of enforcement mechanisms.

- Construction of breakwaters and sea defense walls.
- Protection of mangroves, swamps and wetland areas through collaboration with the activities recommended in the National Biodiversity Action Plan.

7.2.3. Infrastructure

(a) Planned Retreat

Implementation of the retreat option on Grenada would involve, *inter alia*:

- Abandonment of the Wharf Road (Carenage) and the Grenville and Hillsborough waterfronts.
- Loss of functionality of a significant part of the St. George's sewerage system.
- The realignment and re-construction of sections of the Western Main Road and Eastern Main Road along with utility infrastructure.
- Loss – through erosion – of Grand Anse Beach.

The cost and implications of this option would clearly be prohibitive and highly unattractive, therefore retreat is not proposed.

(b) Accommodation

Accommodation options include:

- *Building Code* - the Grenada Building Code (1999) should be enforced as part of the country's regulatory mechanisms for ensuring adequate building standards. Future amendments of the Code could include more detailed standards for sea-defense structures.
- *Public Education* - timely public information about the danger of living in low-lying coastal areas that are at risk from SLR could be a cost-effective means of reducing future expenditure. The science of GCC should also be introduced, appropriately, into the schools.
- *Land Use Planning and Legislation* - existing land use legislation should be more stringently enforced by PPU in coastal areas, in particular the requirement for building setbacks. Siting of large infrastructure facilities should not be permitted in high-risk coastal areas and should be encouraged in less vulnerable areas. Further, the recent draft bill promulgated as the *Physical Planning and Development Control Bill and Environmental Impact Assessment Regulations*, which seeks to harmonize the existing legislation for planning and land development, should be enacted into law. The provisions for environmental impact assessment could be expanded to include climate impact assessment.

- *Increased Height of Coastal Infrastructure* - in cases where the construction of a coastal infrastructure element is considered essential to the national economy and is approved, the developer, funding agency and PPU should ensure that SLR is incorporated in design considerations and a marginal increase in the height of the structure is included.

(c) Protection

Protection options include:

- *Breakwaters* - these are hard structures, usually large boulders, used to reduce the impact of waves on the shoreline. They may be constructed several meters offshore as ‘submerged breakwaters’, or along the shore as ‘riprap’. This engineering option, although relatively expensive, was considered the best available tool for protection of lowland areas along the Mediterranean coast of Egypt (El Raey *et al* 1999). According to DIWI (1994), due to the steep foreshore and the relatively long period swell waves experienced along Grenada’s west coast, offshore breakwaters would need to be relatively substantial to create a reasonable reduction in wave energy to prevent coastal erosion; they could be an option for the east coast of Grenada and for Carriacou.
- *Coastal Revetments* - these may consist of rubble mound structures with carefully placed layers of armour stone of varying sizes; scour protection to existing seawalls in which a rubble-mound structure is placed in front (at the toe) of the existing structure; vertical RC seawalls; or a combination of RC retaining walls protected by armour stone. These response strategies are also expensive, but the latter design has been widely employed for coastal road sea defense in Grenada and Carriacou during the past 5-6 years. The most appropriate and cost-effective option for the Carenage could be an RC seawall with appropriately sized parapet to reduce wave overtopping.
- *Beach Nourishment and Groynes* - this could include the ‘soft’ engineering option of depositing sand onto the beach; this could be used in conjunction with groynes – hard structures built perpendicular to the coastline – to trap sand in the longshore sediment transport system. Groynes are easily constructed and fairly cost effective (El Raey *et al* 1999). This option could be employed for Grand Anse Beach and other beaches.

(d) Cost of Adaptation

Application of the proposed protection measures to the vulnerable exposure units using unit construction costs obtained from the literature (El Raey *et al* 1999; DIWI 1994) and the Ministry of Works, indicates that the estimated cost of protecting these facilities from 5 - 10ft. floods and a 1m SLR in 100 years is approximately EC\$111M – composed of the following:

- *Breakwaters* – 1.8Km; cost EC\$18.0M;
- *Seawall/rubble Mound Revetment* – 3.4Km; cost EC\$44.2M;
- *RC Seawall* – 3.0Km; cost EC\$24.0M;
- *Beach Nourishment* – 500,000 m³; cost EC\$22.5M; and
- *Groynes* – 0.45Km; cost EC\$2.25M.

It should be noted that the above computation is based on current costs, and does not include annual maintenance costs. The estimate also does not account for the value of ecosystems that could be lost due to protection.

7.2.4. Hydrology

(a) Planned Retreat

Viable retreat options for this sector include:

- *Abandonment of Boreholes* - production boreholes Chemin Ch-4, and Baillie's Bacolet BB-2 and BB-1, all located within 900m of the coastline, should no longer be used as production wells, but should be used as observation boreholes. Strict adherence to this practice should reduce the rate of seawater encroachment on the coastal groundwater and contribute to sustainability of the aquifers well into this century.
- *Siting of future Boreholes* - wherever possible future production boreholes should be located inland at a distance greater than 2,000m from the sea, away from the seawater interface, and should be no deeper than 60m. DIWI (1997b) suggest that the higher valleys of Baillie's Bacolet, Beausejour (St. George) and Great River (St. Andrew) may be of interest in this regard, and that further geological mapping of Grenada would significantly help in the location of the most promising layers for borehole drilling.

(b) Accommodation

There are many accommodation options that could be effective in this sector. These include:

- *Rehabilitation of Existing Boreholes* - as suggested by DIWI (1997b), the older production boreholes such as Chemin Ch-1 and Ch-2 should be chemically treated against clogging of the slotted casing and redeveloped to recover the initial well characteristics and reduce total aquifer drawdown during pumping.
- *Redesign of Wells* - NAWASA could examine the feasibility of redesign of existing production boreholes to incorporate horizontal adits that would reduce drawdown. This option, however, is likely to be costly.

- *Pumping Tests* - these are conducted to determine the performance characteristics of a well and the hydraulic parameters of the aquifer, and should be carried out on production wells at least every other year. The resulting information would facilitate efficient groundwater exploitation and reduced risk of wellfield overpumping, as well as more accurate application of the Ghyben-Herzberg relation to determine the approximate seawater interface elevation.
- *Groundwater Monitoring Programme* - monitoring and observation boreholes in the Chemin and Baillie's Bacolet wellfields should be monitored on a monthly basis (Chapman 1996) to determine static water levels and salinity profiles. The *in situ* measurement of conductivity is probably the most practical and cost-effective measure for monitoring seawater encroachment on the groundwater. Data generated from this activity – as well as other relevant wellfield data - should be shared with the Physical Planning Unit of the Ministry of Finance (PPU) and LUD, for input into the Coastal Resource Information System (CRIS) provided by the CPACC Project.
- *Equipment Procurement* - in order to enable data collection under the proposed groundwater monitoring programme, NAWASA's field personnel would require access to an electronic probe/sampler of the type provided by CPACC for the Project. The following would also be indispensable: a basic water level indicator with a ½" diameter probe (to enable SWL and DWL measurements in the producing boreholes), and an electronic field conductivity meter – to allow regular (weekly) verification of the quality of the groundwater being abstracted.
- *Borehole Elevations* - the ground level elevations of all boreholes should be determined with survey-grade accuracy to facilitate accurate hydraulic computations.
- *Enforcement of Legislation* - NAWASA should more stringently enforce the provisions of the *National Water and Sewerage Authority Act 1990*, Cap. 208 of the Revised Laws (Section 44), pertaining to the conservation, control and exploitation of underground sources of water by private entities. The resulting information would enable computation of the seawater interface elevation and could be input to the CRIS database.
- *Public Awareness* - timely public education about SLR impacts on Grenada's water resources could be a cost-effective means of reducing future expenditure, and would assist the operators of private boreholes to implement timely adaptation measures.
- *Staff Training* - this would increase the competence of field personnel in the implementation of pumping tests and the proposed groundwater monitoring programme, and analysis of the ensuing data.
- *Water Conservation and Improved Efficiency* - this demand-side management option, which Nurse (1997) suggests is a major option for use by the Caribbean region, would promote reduction of potable water demand through measures

such as universal metering, reduction of unaccounted-for water and public education.

- *Creation of Buffer Zones* - in the future, when municipal wastewater would be subject to at least secondary treatment, NAWASA could consider the feasibility of creating buffer zones to assist in preventing seawater encroachment - by injecting treated wastewater into one or other of the abandoned boreholes.

The following additional accommodation actions are recommended for Carriacou:

- *Rainwater Harvesting* - this relatively low-cost resource is the principal source of domestic water supply, and the use of individual private roof catchments and cisterns has acquired a significant socio-cultural importance. Continued and expanded use of private and public rainwater catchments and storage facilities is suggested as the most cost-effective adaptation measure for Carriacou.
- *Groundwater Investigation* - consideration should be given to the implementation of the exploratory well drilling programme recommended by Barrage-Bigot (1987a) and endorsed by DIWI (1996), which comprised the drilling of 12 new boreholes over the entire island.
- *Rehabilitation of Traditional Dug Wells* - several of these should be cleaned, fenced and protected.
- *Induced Aquifer Recharge* - the proposal by Barragne-Bigot (1987a) for construction of a micro-dam in Petit Carenage to induce recharge to the aquifer could be addressed.
- *Desalination* - further use of seawater or brackish water for desalination could be examined (NAWASA recently commissioned a 450m³/day RO plant in Carriacou). *This option, however, should not take precedence over the less costly rainwater harvesting and groundwater exploitation options.*

(c) Protection

Protection options include:

- *Erection of Seawater Barriers and Sea Walls* - the first of these 'hard' engineering options would involve the driving of metal sheet piles beyond the toe of the seawater interface to physically block the encroachment of seawater on the aquifer; while the second consists of construction of a revetment/sea wall along the coastline to prevent flooding and inundation caused by SLR. Both of these options could be relatively very costly.

- *Rock Armour* - the hotels on Grand Anse Beach and Point Salines could utilize gabion baskets or other rock armour to protect brackish water wellheads from the potential impacts of inundation and erosion. Further, the accommodation options of adapting RO plants to treat increasingly saline water could be considered.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1. NEXT STEPS

Despite its limitations, this Pilot Study has demonstrated that Grenada is very vulnerable to the potential negative impacts of climate change. It is important therefore that measures be initiated immediately to begin the process of adaptation to climate change.

This should be initiated at the same time as efforts are being made to improve Grenada's capacity to further analyse the potential impacts of climate change, not only for the sites used in this Pilot Study, but for the entire island.

The next steps in this process should therefore include the following:

8.1.1. Sensitisation of Policy Makers and Key Stakeholders

It is important that the policy-makers and key stakeholders be sensitized to the potential consequences of climate change at the earliest opportunity. This is necessary, as the implementation of any response measures will require their approval and support.

8.1.2. Public Awareness and Education

It is also important that the general public be made aware of the potential consequences of climate change. This is necessary for two reasons:

- It will facilitate their participation in the process of developing a national response strategy; and
- It will provide a supportive basis for the implementation of national policies and measures initiated in response to the threat of climate change.

8.1.3. Development of an Adaptation Framework

It is necessary that the response to climate change be initiated within a structured framework. Failure to develop such a framework could result in the initiation of uncoordinated responses by individual stakeholders. Such an approach will not optimize the use of the scarce resources that are available.

The development of an Adaptation Framework, within the context of a National Climate Change Policy Framework, is therefore a necessary first step. This policy development process should include all key stakeholders and members of the general public, given that climate change is expected to impact on the lives of everyone in the country.

8.1.4. Capacity Building to Enhance future V&A Analyses

It is also necessary that the Vulnerability and Adaptation (V&A) analysis started by this Pilot Study be further refined to improve its accuracy. It should also be extended to encompass the entire state of Grenada.

This will require a strengthening of the capacity of the current national technical team in the short run and a broadening of the skill base to include other technical personnel in the medium to long term. Such capacity building should include:

- Training in the use of modeling techniques relevant to the respective sectors.
- Training in the establishment and use of systematic monitoring and observation processes to enhance data collection for their respective sectors.

- Training in the assessment and analysis of climate change impacts, including the analysis of climate variability to assess its implications for understanding the longer-term impacts of climate change.

8.1.5. Closing Data Gaps

Efforts should be made to immediately address the data gaps identified, as failure to do this would subject V&A future work to similar limitations. The two priority areas are:

- The development of GIS base maps for the entire island. The IKONOS imagery provided by CPACC for Carriacou was extremely useful in the analysis. Acquisition of similar maps for the entire island would go a long way in resolving the problems created by the contour resolution of the maps that are currently available.
- The sourcing of bathymetry data, or the initiation of data collection in that area.

8.1.6. Report Incorporation into National Planning

The findings of this Pilot Study should be immediately incorporated into the work of at least three departments in Grenada, viz:

- The *National Emergency Relief Organization* (NERO) could use the results of this Pilot Study to assist in developing contingency plans for flooding under various storm surge scenarios.
- The *Physical Planning Unit*, which is presently preparing a national Physical Development Plan for Grenada. These findings would prevent decisions being made that would prove costly to rectify at a later stage.
- The *Economic Planning Unit*, which is responsible for project preparation and negotiation with international funding agencies. It is imperative that the climate change considerations raised by this report be incorporated into their work to ensure that due consideration is given to climate change impacts in the preparation of future project proposals.

8.2. TECHNICAL AND HUMAN RESOURCE NEEDS

The short-term technical and human resource needs to implement the next steps include:

8.2.1. Technical Needs

The immediate technical needs include:

- An identification of the available models that can be used to further enhance the various components of the vulnerability and adaptation analysis.
- An identification of the data needs required for the utilization of these models.

- An identification and initiation of the systematic observation and monitoring processes required for the collection of the required data on a systematic basis.
- An identification of all relevant equipment required for the data collection and analyses.
- The establishment of an institutional framework for the management of the overall Vulnerability and Adaptation process.

8.2.2. Human Resource Needs

The human resource needs revolve around the need for capacity building at two levels – among the members of the technical team and among the managerial and technical personnel in all of the relevant institutions that will have to respond to the challenges of climate change on a day-to-day basis.

The capacity building needs for the members of the technical team include:

- Further training in the V&A methodologies that are relevant to their respective sectors.
- Training in appropriate V&A modeling techniques relevant to their respective sectors.
- Training in data collection and analysis techniques relevant to their respective sectors.

The capacity building for the managerial and technical personnel in the affected institutions include:

- Understanding the causes and effects of climate change in general.
- Understanding the potential impacts of climate change on their respective sectors, the causes of the specific impacts and the options available for responding.
- Training in techniques for monitoring and analysis of the impact of climate change on their sectors, including data collection and modeling techniques.
- Training in implementing options for responding to climate change, including monitoring the impact of response measures that have been initiated.
- Support for integrating climate change considerations into the day-to-day management of their institutions and sectors.

8.3. FUTURE STEPS

The medium to long-term actions will revolve around the implementation of the Adaptation Framework, within the context of an overall Climate Change policy framework.

Central to this has to be the implementation of an institutional framework for environmental management in Grenada. This framework has to include:

- The passage of the legislative amendments identified by this study, in order to provide the legal framework for responding to climate change.
- The establishment of an organizational focus for the management of climate change – either as an independent National Climate Change Unit or as a Climate Change Unit within an Environmental Management Authority or some other institution responsible for the overall management of the environment in Grenada.

This institutional framework will be responsible for the development and implementation of climate change-related initiatives and projects. These will be developed in response to the vulnerabilities and response options identified through the work of the technical personnel in the various institutions and sectors.

8.4 CONCLUSIONS

This study shows that Grenada has the potential to be significantly affected by the negative impacts of climate change, especially sea level rise and more intense extreme events (storm surges).

These negative impacts will affect Grenada's infrastructure, beaches, tourism sector, commercial activities, water supply, recreational activities and human settlements. The physical cost of the damage to the coastal assets as a result of these impacts will be significant in terms of Gross National Product (GDP), as will be the impact on economic activity. The human displacement as a result of the need for temporary and/or permanent relocation and lost or interrupted employment and household earnings, will disrupt day-to-day life, as it presently exists.

It is therefore imperative that Grenada's policymakers and population immediately begin the process of planning response measures. An early start will increase the likelihood that the costs of the necessary adaptation will be minimized. It will also increase the likelihood that these measures will be in place before the full impact of climate change begins to affect Grenada, thus minimizing the negative impacts that will result.

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6. LEGAL REVIEW

Government of Grenada (1990) Laws of Grenada 1990 (Continuous Revised Laws of Grenada 1990 Volume II – Volume X)

| | | |
|-------------------------|---|-------------|
| Volume II | - | CAP 1-66 |
| Volume III | - | CAP 67-108 |
| Volume IV | - | CAP 109-162 |
| Volume V | - | CAP 163-218 |
| Volume VI | - | CAP 219-284 |
| Volume VII | - | CAP 285-344 |
| Volume VIII(Subsidiary) | - | CAP 1-184 |
| Volume IX (Subsidiary) | - | CAP 188-313 |
| Volume X (Subsidiary) | - | CAP 314-344 |

Government of Grenada: Laws of Grenada 1991 – 1999, individual years published by the Government printer containing: -

- Principal legislation (ordinances) Acts
- Subsidiary legislation (orders, proclamations, rules, regulations)
- Imperial legislation (applicable to the State passed during the year)

Appendix 1 Summary of Critical Infrastructure Facilities in Southwest Peninsula

| # | Infrastructure facility/ general location | Technical description |
|-----------------------------|--|--|
| <i>Buildings</i> | | |
| 1 | NIS Building Melville/Hillsborough Streets | 3- storey RC framed office bldg. 2,300 m ² floor space; land area 1,450m ² ; constr. 1992; bldg. protected by 38m x 12m rock armour revetment |
| 2 | General Hospital Fort George Point | 2/4- storey RC framed bldg; 231 + 270 beds; land area 3.78 ha; Ph. 1 project completion Jan. 2002 |
| 3 | Financial Complex South-west Wharf Road | 3- storey RC framed office bldg; HCB external walls with clay block cladding; 4,180 m ² floor space; land area 0.72 ha; re-constructed 1995 |
| 4 | Grenada Trade Centre Morne Rouge | Single storey/mezzanine RC industrial-type bldg. 1,200 m ² floor space; land area 0.42 ha; constructed 1994 |
| 5 | Youth Development Centre Morne Rouge | RC sports hall 1,185 m ² floor space; land area 0.61 ha; constructed 1996 |
| 6 | South St. George Police Stn. Morne Rouge | 2- storey RC framed bldg. 900 m ² floor space; land area 0.20 ha; constructed 1994 |
| <i>Hotels</i> | | |
| 7 | Grenada Grand Beach Resort Grand Anse Beach | 2- storey RC framed bldgs. comprising 188 rooms on 8.09 ha landscaped property; constr. 1986; 4- storey RC framed wing (52 rooms) under constr. |
| 8 | Coyaba Beach Resort Grand Anse Beach | 2- storey RC framed bldgs. comprising 70 rooms with 50m setback from high water mark on 2.23 ha landscaped property; constructed 1987 |
| 9 | Spice Island Beach Resort Grand Anse Beach | Single/2- storey RC bldgs; 66 rooms on 3.24 ha landscaped property; constr. 1961/1985/2000; brackish water borehole for 55 m ³ /day desal. plant |
| 10 | Flamboyant Hotel Grand Anse Beach | Single/2- storey RC bldgs. comprising 61 rooms on 1.62 ha landscaped property; constr. 1966/1996; 12m brackish water borehole for 45 m ³ /day desal. plant |
| 11 | Rex Grenadian Hotel Point Salines | 2- storey RC bldgs. comprising 212 rooms on 14.57 ha landscaped property; constr. 1993; 2 x 30m brackish water boreholes for 109 m ³ /day desal. plant |
| 12 | La Source Hotel Point Salines | 2- storey RC bldgs. comprising 100 rooms on 7.08 ha landscaped property; constr. 1993; 2 brackish water boreholes for 182 m ³ /day desal. plant |
| <i>Industrial complexes</i> | | |
| 13 | Gda. Commercial Fisheries complex Grand Mal | Single storey RC industrial bldg. 977 m ² ; land area 1,530 m ² protected by 100m rock armour; RC piled fishing jetty 90m x 5m; constructed 1997 |
| 14 | Texaco bulk terminal Grand mal | Eleven (11) steel tanks containing 3,640 m ³ gasoline, diesel, avjet and LPG located on 0.62 ha land; constr. 1934; tank farm protected by 1m RC bund walls |
| 15 | Melville Street fish market complex Mid Melville Street | 2- storey RC industrial bldg. 676 m ² ; reclaimed land area 0.36 ha protected by RC gravity revetment; RC gravity landing wharf & breakwater jetty, ea. 35m; const. 2001 |
| <i>Ports</i> | | |
| 16 | Port Authority Complex East Carenage | Steel framed, aluminum clad industrial warehouses 7,042 m ² ; land area 3.24 ha; main quay 335m x 12m; schooner wharf 82m x 12m; constructed 1959 / 2000 |
| 17 | Point Salines International Airport Point Salines | 1-storey/mezz. steel framed bldgs. 3,000 m ² ; asphalt r'way. 2,743m x 45m ; 50m ³ /day facultative sewage ponds; constr. 1984; rock armour revetment installed 2000 |

Appendix 1 (cont'd) Summary of Critical Infrastructure Facilities in Southwest Peninsula

| # | Infrastructure facility/ general location | Technical description |
|---------------------------|---|---|
| Recreation | | |
| 18 | Queen's Park Stadium Queen's Park | 12.04 ha football/athletics and cricket fields; steel framed stadia with pre-stressed RC slabs; seating capacity 15,000x2; sewerage; constructed 2000 |
| 19 | Carenage Sports Complex North-west Carenage | 0.21 ha multi-use hardcourt; 2- storey RC framed bldg. 304 m ² floor space; sewerage; constructed 1972 |
| 20 | Tanteen Recreation Ground Tanteen | 1.58 ha sports complex incl. cricket/football field, netball courts, bleachers and pavilion; sanitary facilities; constructed 1990 |
| 21 | Grand Anse Sports Complex Grand Anse Beach | 0.2ha multi-use hardcourt; sanitary facilities; constructed 1972 |
| Transportation | | |
| 22 | Western Main Rd. (WMR) Grand Mal-Queen's Park | 2.6Km x5.5m; 50mm asphaltic concrete surface on 150mm base; cumulative 400m RC and masonry retaining sea defence walls |
| 23 | Melville St. St. George's | 650mx5.5m; 50mm asphaltic concrete on 150mm base; 550m RC and masonry retaining sea defence walls |
| 24 | Sendall Tunnel Bruce/Monckton Streets | 107mx3.66m arch; providing an important link between the east and west sectors of the Town of St. George's; constructed 1895 |
| 25 | Wharf Road Carenage | 700mx5.6m; 50mm asphaltic concrete on 150mm base; entire road protected from the sea by 1.5-2.5m masonry stone wall - sections under severe erosion attack |
| 26 | Grand Anse Main Road Port St. George's-Point Salines | 9.2Km x6.7m; 90mm asphaltic concrete on 200mm base; lined drains; 300m rock armour sea defense near Falege; re-constructed 1998 |
| Electricity | | |
| 27 | Transmission system Grand Mal- Point Salines | 17.4Km high voltage lines (3-phase); 16.5Km low voltage lines (1-/3-phase); 54 transformers (10-50 kVA); approx. 320 timber poles |
| 28 | Queen's Park power station Queen's Park | 14- generating units (1.0-5.5 MW), total capacity 32MW; 2- steel framed power plant bldgs. 2,200m ² ; 3- fuel tanks ea. 1,900m ³ ; land area 2.75 ha |
| Telecommunications | | |
| 29 | C & W plant - WMR Grand Mal- St. George's | 4Km 18 optic fibre cable ; Grand Mal outside plant module; St. George's exchange; |
| 30 | C & W plant - G. Anse Grand Anse Main Road | 6Km 12 optic fibre cable; Mt. Hartman exchange; 11Km Eastern Caribbean Fibre System; Frequent earth station |
| Water/Sewerage | | |
| 31 | Western Main Road water mains Grand Mal-Queen's Park | 1.16Km - 200mm dia. ductile iron bell-and-spigot pipeline; approx. 0.9m depth of cover; installed 2001 |
| 32 | Grand Anse water mains Grand Anse | Ductile iron: 1.01Km - 75mm dia; 700m - 100mm dia; 340m - 300mm dia. PVC: 250m - 200mm dia.; 600m - 150mm dia; installed 1974/1984 |
| 33 | St. George's sewerage system Town of St. George's | Gravity mains: 700m - 175mm dia. clay (few lengths of cast iron); inst. 1939; Force mains: 650m - 200mm dia. high density polyethylene fused pipe; inst. 1992; 2- submersible pump stations; rehabilitated 1992 |
| 34 | Grand Anse sewerage system Grand Anse-Point Salines | 5.5Km - 200mm dia. PVC force main; gasketed push-fit/mechanical joints; 0.9-1.2m cover; 4- wet/dry well pump stations; constr. 1993 |

Appendix 2 Summary of Critical Infrastructure Facilities in Northeast Site

| # | Infrastructure facility/ general location | Technical description |
|-----------------------------------|--|--|
| <i>Buildings</i> | | |
| 1 | Grenville Police Station Victoria Street | 2- storey RC framed bldg; 960 m ² floor space; land area 820 m ² |
| 2 | Grenville fish market Victoria Street | Single storey RC industrial bldg. 230m ² ; land area 0.36 ha |
| 3 | Grenville Magistrates Court Ben Jones Street | 2- storey RC framed bldg; 1,330 m ² floor space; land area 0.37 ha |
| 4 | Anglican church Victoria Street | Masonry stone bldg; 360 m ² floor space; land area 800m ² |
| 5 | Anglican primary school Victoria Street | 2- storey masonry stone bldg; student capacity 400; 720 m ² floor space; land area 1,000 m ² |
| <i>Ports</i> | | |
| 6 | Port Authority Complex Grenville | RC industrial warehouse 350 m ² ; land area 0.30 ha; jetty 100m x 7.3m |
| <i>Recreation/cultural</i> | | |
| 7 | Victoria Park Grenville | 1.17 ha football field; RC pavilion; sanitary facilities |
| 8 | Moonshadow Park Grenville | 0.93 ha multi-use hard court |
| 9 | Simon Cultural Centre Simon | 1.2 ha cultural facility; RC pavilion; timber bleachers; seating capacity 1,000 |
| 10 | Former Pearls airport runway Pearls | Runway used for motor sports; asphalt surface 1,600 x 35m |
| 11 | 'Old' Catholic Church Grenville | Masonry stone bldg; 670 m ² floor space; land area 0.21ha; historical/cultural facility |
| <i>Transportation</i> | | |
| 12 | Eastern Main Road Conference - Marquis | 9.5Km x 5.5m; 50mm asphaltic concrete surface on 150mm base; 250m RC retaining sea defense wall; re-constructed 1989-1996 |
| 13 | Vicoria Street Grenville | 400m x 5.5m; 50mm asphaltic concrete surface |
| 14 | Ben Jones Street Grenville | 400m x 5.5m; 50mm asphaltic concrete surface |
| <i>Electricity</i> | | |
| 15 | Transmission system - EMR EMR: Conference-Marquis | 13.7Km high voltage lines (3-phase); 18.9Km low voltage lines (1-/3-phase); 62 transformers (10-50 kVA); approx. 250 timber poles |
| <i>Telecommunications</i> | | |
| 16 | C & W plant - EMR Conference-Marquis | 6Km aerial 18 optic fibre cable; 3.5Km underground 18 optic fibre cable; Grenville exchange; 10 outside plant interfaces; 25Km main cables |
| <i>Water/Sewerage</i> | | |
| 17 | Eastern Main Road water mains Grenville-Battle Hill | 1.8Km - 100mm dia. PVC gravity main; gasketed push-fit joints; 0.9m depth of cover; installed 1988 |

Appendix 3 Summary of Critical Infrastructure Facilities in Carriacou

| # | Infrastructure facility/ general location | Technical description |
|-------------------|---|---|
| Buildings | | |
| 1 | Hillsborough Police Station Main Street | 2- storey RC framed bldg; 900 m ² floor space; land area 1,200 m ² |
| 2 | Govt. Administration Offices Main Street, Hillsborough | 2- storey RC framed bldgs; 1,900 m ² floor space; land area 1,330 m ² |
| 3 | Community Centre Hillsborough | Single storey RC bldg; 300 m ² floor space; land area 0.4 ha |
| 4 | Hillsborough Secondary School | 2- storey RC bldg; student capacity 350; 950 m ² floor space; land area 1ha |
| 5 | Hillsborough Govt.School | 2- storey RC bldg; student capacity 300; 900 m ² floor space; land area 0.73ha |
| 6 | Hillsborough Health Centre | Single storey RC bldg; 200 m ² floor space; land area 0.27 ha |
| 7 | Harvey Vale Govt. School | Single storey RC bldg; student capacity 250; 700 m ² floor space; land area 0.97ha |
| 8 | Mt. Pleasant Govt. School | 2- storey RC bldg; student capacity 200; 650 m ² floor space; land area 1.62ha |
| Hotels | | |
| 9 | Silver Beach Hotel Beausejour Bay | Single/2-storey RC bldgs; 16 rooms; land area 1.2ha |
| 10 | John's Unique Resort Main Street, Hillsborough | 2-storey RC framed bldgs; 17 rooms |
| Industrial | | |
| 11 | Shell fuel depot Harvey Vale | Three (3) steel tanks containing 477m ³ gasoline and diesel located on 1,000m ² land; tank farm protected by 1m RC bund walls |
| Ports | | |
| 12 | Port Authority Complex Hillsborough | Steel framed industrial warehouse 250 m ² ; jetty 97m x 7.3m |
| 13 | Lauriston Airport | Single storey RC bldg. 210m ² ; asphalt runway 800m; constr. 1966/1994; rock armour revetment installed 1994 |
| Recreation | | |
| 14 | Hillsborough Recreation Ground | 1.33 ha football/cricket field |

Appendix 3 (cont'd) Summary of Critical Infrastructure Facilities in Carriacou

| # | Infrastructure facility/ general location | Technical description |
|---------------------------|---|--|
| <i>Recreation contd.</i> | | |
| 15 | Harvey Vale playing field | 1.09 ha football/cricket field |
| <i>Transportation</i> | | |
| 16 | Hillsborough-L'Esterre Road | 3.2Km x 5.5m; 150mm conc. pavement; constr. 1994; 20m mass conc. retaining wall with armour stone & 84m gabion wall constr. 2000 |
| 17 | L'Esterre-Harvey Vale Road | 1.6Km x 5.5m; 125mm concrete pavement; constructed 2001 |
| 18 | Windward-Petit Carenage Road | 2.6Km x 5.5m; 125mm concrete pavement; constructed 1994 |
| <i>Electricity</i> | | |
| 19 | Transmission system Hillsborough/L'Esterre/H' Vale | 6.5Km high voltage lines (3-phase); 11.9Km low voltage lines (1-/3-phase); 14 transformers (10-50 kVA); approx. 120 timber poles |
| <i>Telecommunications</i> | | |
| 20 | C & W plant Hillsborough | 200m aerial main cable; exchange (1st Ave.); 1 outside plant interface |
| <i>Water</i> | | |
| 21 | Desalination plant Seaview | Seawater reverse osmosis plant; capacity 450 m ³ /day |

APPENDIX 4

RECOMMENDED LEGISLATIVE AMENDMENTS

It is recommended that an Environmental Board or Council be established to coordinate the management of environmental issues as a short-term measure, until an institution to manage the environment is established.

That Council should include some of the key administrators who have responsibility for the administration of the existing laws. The Council would be responsible for advising on the enforcement of the legislation, amending legislation, data collection and the overall direction of the administrative functions relating to environmental legislation. In addition, the Council should be able to identify vulnerable areas and advise Government on the necessary action which should be taken in those areas.

One of the priority tasks of the Council would be to advise on the implementation of the following recommendations with respect to the legal framework for managing the impacts climate change.

1. Beach Protection Act

This is specific to the concerns of coastal erosion, salt water intrusion, and the protection and preservation of coastal infrastructure.

Recommendation:

The Act should expressly bind the Crown. Also, there should be better coordination between the line Ministry and the Council, which should be able to identify vulnerable areas and advise and implement preventative measures. The Council should also be allowed to advise on alternatives that will divert from heavy sand mining. There should therefore be a provision for the advice of the Council generally as it relates to environmental concerns.

2. Carriacou Land Settlement Act

This Act has specific application to the prevention of coastal erosion, the prevention of landslides and the protection and preservation of sensitive mangrove areas from indiscriminate destruction by the makers of charcoal.

Recommendation:

The Board should be given the expanded authority to acquire land for the conservation of natural resources and expressly to take into account the issues raised by global warming.

Any decision to take those measures and make regulations should be with the advice of the Council.

3. Crown Lands Act

The Act provides the Governor-General with the power to make rules for the management of Crown lands. This Act relates only to Government lands and there is some overlap with Forest Legislation.

4. The Grenada Building Code

The Grenada Building Code was updated in 1999 and establishes safety standards for building and building construction. The code addresses adequately the standards required for buildings that can effectively withstand the adverse effects of hurricanes, floods and heavy seas.

The code is administered by the Land Development Control Authority and thus ties in with the regulatory aspects of that Authority. This cross-sectoral responsibility puts the Control Authority in a good position to monitor and enforce the approved standards. The Act also provides ideally for the prevention of loss through the enforcing of adherence to the requirements of the Code.

Recommendation:

All large building projects should, in addition to meeting the required engineering standards, should also be required to meet approved environmental impact assessment under Land Development Control Act.

5. Civil Liability for Oil Pollution Damage

This is legislation putting into force an international convention for providing compensation for oil pollution damage. The Act therefore is a useful tool for preventing and mitigating loss due to oil pollution damage.

The Act requires contributions from ship owners to be put into a special fund, which is used to compensate the measures taken to mitigate and minimize oil pollution damage.

6. Fisheries Act

This Act is a good example of the incidental application of environment law. The Act was passed primarily to regulate the conduct and management of fisheries. At the same time, it makes provision for the protection of marine areas and the adjacent or surrounding land. These provisions are relevant to the management of the coastal zone with respect to coastal erosion, the protection of reefs, aquatic and marine plants and animals, oil pollution and mangrove forest on the near shore.

Recommendation:

The Minister should be given the power to declare marine areas specifically with regard to environmental concerns in the fishing waters and the near shore. There should also be coordination between the administrators in areas that share similar responsibilities.

7. Forest Soil and Water

The Act speaks primarily to the protection of forests on Government-owned and Crown lands. These provisions provide an ideal opportunity for the protection of hillsides from inundation and slides, the protection of watersheds and the prevention of flooding.

Recommendation:

The Minister should be given the power to declare any forest area on private land as a protected forest area if it becomes necessary for the protection of water supplies and the associated effects of sea level rise.

8. Land Development Control Act

The Act controls and manages development and land use activities in conformity with approved environmental standards. This makes this Act one of the more important tools for determining where and what type of development could be carried out in Grenada.

This Act properly administered could be applied generally for the prevention, mitigation, relocation and change in user activity envisaged under the project. For example, development could be prohibited in areas vulnerable to flooding or the effects of storm surges and heavy wave action.

Recommendation:

The legislation should as a matter of course require an environmental impact assessment for any development or large building which is likely to have a significant environmental impact or is to be carried out in areas determined to be a vulnerable or high-risk area.

9. National Parks and Protected Areas Act

Like the Crown Lands Act, this Act regulates conduct on government-controlled land declared as a National Park. The Act thus provides a good regulatory framework for the control and management compatible with the objectives of prevention and mitigation loss envisaged by the project. The Act speaks to the prevention of water supplies, the prevention of landslips and the formation of torrents and ravines. Thus the Act is important for the prevention and mitigation of floods and ensuring that there is an adequate and safe water supply.

Recommendation:

The Minister is empowered to make regulations for carrying out the purposes of the Act; however, it would be useful to have a coordinating agency. The agency should advise the Minister on measures that may be required to manage these parks. That agency should also advise the Minister on areas which should be declared as National Parks.

10. National Trust Act

The Act has some relevance to the management of the environment with specific reference to submarine areas. As such, it could be a useful tool for the protection of coral reefs, other marine plants and marine life in those areas. The Act demonstrates the multi-sectoral application of environmental law. Thus while the Act is primarily one for the preservation of historic and other areas including submarine areas of natural beauty, properly coordinated, it could be utilized for the management of the coastal zone.

Coral reefs are the first line of defense and these help to prevent or mitigate damage caused by wave action. Thus the Act can be effective to prevent such losses in adverse weather caused by storm surge.

Recommendation:

There is a need for spelling out the importance of coordinating with agencies that share similar responsibilities. This becomes important because of the overlap with the Crown Lands Act and the Forest Soil and Water Act. Areas in need of special protection could also be included here. Secondly, the membership of the Council could be amended to make provision for a member of the coordinating agency.

11. National Water and Sewerage Authority

The Act gives the Authority overall responsibility for water supplies throughout the State of Grenada as well as for the control, disposal and treatment of sewage. The Act is therefore a useful tool for preserving potable water supplies and for the prevention of coastal pollution.

Recommendation:

Because of the incidence of overlapping responsibilities shared with other agencies for the preservation of water catchment areas and the prevention of coastal pollution, the need for a coordinating agency is emphasized. Such an agency will assign responsibilities to be shared among the relevant agencies.

12. Oil in Navigable Waters

The Act provides for the protection of the coastal waters from pollution associated with the transport, delivery and transfer of petroleum products. The Act is thus primarily one for dealing with preventative and mitigation measures for protecting the coastal and inland waters of Grenada.

Recommendation:

Responsibility for the administration of the Act falls under the Permanent Secretary, Ministry of Finance. It may be that the Harbour Master or the Manager of the Port Authority might be better placed to administer this legislation.

13. Pesticides Control Act

The Act is a useful tool for regulating the use of hazardous substances. Thus, the Act ensures that those substances are properly labeled, used and disposed off. The Act thus speaks to the preservation and protection of ground water supplies and the promotion of human health through safe practices.

Recommendation:

The Act should make provision for alternative methods of pest control. It may be useful to allow the Minister to be advised by the coordinating agency when regulations are to be made under the Act.

14. Public Health Act

This Act governs all matters relating to human health and is thus of universal application in the management of the effects of global warming and sea level rise. The Act also has a cross-sectoral application with respect to flooding through the enforcement of proper drainage throughout the State.

15. Roads Act

The Act is primarily for the management and the protection of roads and bridges for the proper maintenance of rivers and watercourses. As such, this Act provides an ideal legal framework for the prevention of floods and the maintenance of coastal infrastructure. Like most of the other legislation, proper coordination is required to ensure the sharing of responsibility and information.

16. Territorial and Maritime Boundaries Act

The Act defines the extent of Grenada's Sovereignty but it also provides for the protection of the marine environment. This Act therefore can be utilized to assist in the management of the coastal zone. Section 34 (1) provides the Minister with the power to make rules for among other things, the preservation of the marine environment.

Recommendation:

Section 9 (3) gives the State the power to punish for the infringement of any law within Grenada. However, specific mention is made of Customs, Health and Immigration Laws. For the removal of any doubt, preservation of the marine environment and resources and the prevention of pollution should be spelt out in the legislation. Secondly, regulations made by the Minister under the Act should be made with the advice of the coordinating agency with respect to the prevention of marine pollution and preservation of the marine environment.

17. Town and Country Planning Act

The Act makes provision for the orderly development of land throughout Grenada. The Act is administered by a Central Authority, which prepares schemes or adopts schemes

for development purposes. This Act properly administered could be used extensively for defining land use on the island. The Act thus has application for the prevention and mitigating of the effects of adverse weather. This is especially so in restricting development in vulnerable or high-risk areas.

Recommendation:

There appears to be some overlap between the responsibilities under this Act and those of the Land Development Control Authority and to a lesser extent, the Carriacou Land Settlement Act. This overlap emphasizes the need for a coordinating agency to ensure the paramountcy of environmental concerns.

Like the Land Development Control Act, any application for the approval of a scheme should be accompanied by an environmental impact assessment under the terms of the Land Development Control Authority Act. The terms of any such assessment should contain a provision for public approval.