ACKNOWLEDGMENTS

The British Overseas Development Agency (now DFID) and the Government of the British Virgin Islands funded this project. I wish to express my deep appreciation to both entities for their support.

I am indebted to a large number of counterparts, experts, researchers, friends and colleagues who have made important contributions towards this project. My gratitude to the Deputy Governor, Mr. Elton Georges, OBE who leads a very professional and committed disaster organisation at the hub of which is the Office of Disaster Preparedness headed by the National Disaster Coordinator, Mr. Donovan Gentles. Without their strong support, understanding and patience the Project may have floundered and not achieved its objectives.

Special thanks to the numerous public and private sector agencies that willingly participated and provided information to the process. In particular to the Town and Country Planning Department that provided the data set, which gave the Project such a successful start.

To the other consultants which conducted the component studies, I say thanks for your expert input which has greatly enhanced the quality of this report and also to the Technical Advisory Committee for their guidance.

Finally, to Ms. Leann Hill of the Office of Disaster Preparedness for her formatting and graphic design contributions in the final report, I say thanks.

Thanks to all who made my stay in the BVI enjoyable.

Aedan Earle, Msc
Project Manager
Hazard and Risk Assessment Project
November 1997

TABLE OF CONTENTS

OPD BVI

#3 Wailing Road
MacNamara
Tortola
British Virgin Islands

Tel: (284) 494-4499 or
(284) 494-4979
Fax: (284) 494-2024

E-Mail Address:-
bviodp@caribsurf.com

Project Team

Project Manager
Mr. Aedan Earle

Tropical Cyclone Hazards
Mr. Chuck Watson

Inland Flooding
Mr. Hernan Solis

Seismic Hazards
Dr. William Ambeh

Loss Estimation
Prof. Norris Stubbs

Vulnerability Assessment
Mr. Aedan Earle

Editing done by:
Mr. Donovan Gentles
National Disaster Co.

Cover designed by:
Ms. Leann Hill

Technical Advisory Committee

Mr. Jeremy Collymore
Mrs. Jennifer Campbell
Mr. Keith Ford

CHAPTER 1 INTRODUCTION

1.1 GENERAL

The British Virgin Islands' (BVI), Hazard and Risk Assessment Project (HRAP), is a major part of the Hazard Mitigation Programme being conducted by the Office of Disaster Preparedness (ODP). The HRAP was conceived by Jennifer Worrell whilst National Disaster Coordinator in 1993 as a means of establishing the nature of hazards both natural and manmade to which the BVI is exposed.

Funding for the management of the Project was provided by the British Government through the Overseas Development Agency (ODA) and the Government of the BVI provided funds for the project activities. The duration of the project was twenty three months from April 1995 to March 1997 and the total budget was US$90,000. The project was coordinated by Aedan Earle, a consultant recruited from Jamaica.

The main objective of the project was to characterise the natural and man-made hazards to which the BVI is exposed with an emphasis on natural hazards since they were perceived to be, based on past experience, the greatest threat. The idea then was to systematically determine the nature of the hazardous phenomena that have the potential of affecting the BVI and to evaluate the possible impacts that might result. In this respect the project could be seen to consist of three broad aspects, hazard assessment, impact evaluation and the development of loss reduction recommendations. The project was designed to consist of four main activities;

1) Hazard Mapping
2) Production of an inventory of the elements at risk
3) Vulnerability Analysis and Loss estimation
4) Development of Mitigation or loss reduction strategies.

The hazard mapping component included an assessment of the following hazards:- Hurricanes, Land-borne flooding, Seismicity, and Landslides.

In this report, the term **HAZARD** represents the latent danger associated with a physical phenomenon of natural or technological origin that may occur in a specific place and at a given time producing adverse effects on people, property, and the environment.

RISK is defined as the damage, destruction or expected loss resulting from a combination of the probability of hazardous events occurring and the vulnerability of elements to those hazards. The term **VULNERABILITY** is used to indicate the intrinsic predisposition of elements to suffer damage from possible hazardous phenomena.

The project as conceived was therefore multifaceted as it sought to evaluate all aspects of hazards as an integrated whole. In addition the project also aimed at addressing the full range of natural hazards which maintained the natural interconnection and interaction between natural phenomena which pose a threat to the BVI. Therefore the project as designed, aimed at providing a comprehensive picture of the hazards of the BVI.

1.2 APPROACH

The HRAP was conducted as a series of sub-projects consisting of the four main activities outlined above. Each sub-project involved scientific studies which were conducted by experts in that particular area. These activities were coordinated by the project manager who was also responsible for the compilation of the final reports and products of the various studies.

The hazard mapping studies were carried out by local and overseas consultants in collaboration with government agencies. These studies involved fieldwork, utilized existing reports, and baseline data, aerial photographs, topographic and bathymetric maps and existing baseline data and digital databases.

The project manager determined that an appropriate framework for the project was the Geographic Information System (GIS) platform. This system consists of a combination of computer software and hardware capable of capturing, storing, manipulating and presenting spatial information in the digital domain. In this system therefore all information is converted and transformed into digital maps. Once in this digital domain analysis can be carried out by the software which is designed to establish relationships between layers of digital maps. The system is also capable of producing high quality hard copy maps.

In this respect the adaption of the GIS framework for the project would result in the creation of a digital database of spatial information. The presence of a central GIS in the Town and Country Planning Department (TCPD) of the BVI Government, meant that the data produced by the project could be easily used, stored, maintained and updated. The digital data also allowed for ease of electronic transfer via such media as the Internet. Therefore the GIS framework shifted the project toward the production of information as a dynamic database of spatial data in digital format.

The GIS database was developed with the industry standard ArcInfo GIS package. Data was digitized in AutoCad and the final datasets were finished and presented in ArcView. This software is also used by the TCPD. The TCPD GIS which has been operational for the past four years provided many essential datasets. The HRAP therefore also produced a GIS and a database which can be utilized for disaster management and long term development planning by the TCPD.

The ultimate aim of the project was to provide information which could be used to mitigate the losses which might result from the occurrence of hazardous events. This report is therefore specifically geared towards supplying the agencies responsible for development planning and disaster management with information that can assist in decision making that will contribute to a reduction of losses from potential hazards . ***The overall format and pitch of the report is therefore of a technical nature and in some respects may not be a layman's document.***

The project was guided by a Technical Advisory Committee (TAC), which consisted of Jennifer Worrell, Jeremy Collymore, Keith Ford and the Project Manager. The National Disaster Coordinator of the ODP, Donovan Gentles served as secretary to the Committee. The TAC met once and was kept up to date through regular telephone contacts and through two interim progress reports which were produced. Throughout the course of the project a concerted effort was made to involve local agencies. The project benefitted from considerable assistance from the Departments of Town and Country Planning, Conservation and Fisheries, Public Works, Water and Sewerage, Agriculture and Survey.

1.3 LIMITATIONS

The science contained in this report represents the state of the art in the respective areas of study and the results of the scientific studies conducted in the course of the project can stand alone as reliable bodies of scientific work. In those areas of the project where this was achieved I believe the project was very successful. In this respect the hazard mapping component was most successful within the limits of time and resources. However there were many unexpected and prolonged delays in carrying out these studies.

As a result of these delays and the inventory of the elements at risk, the vulnerability/cost estimation analysis and the development of Mitigation strategies components were carried out by the project manager who also undertook the development of the GIS. The vulnerability of structures in the BVI to hurricane force winds was carried out by an expert in the field.

1.4 REPORT FORMAT

This final report has been compiled after a lengthy review by government and non government concerns of the draft report. In addition the findings contained in this report were presented at a public forum to allow for additional feedback and discussion of issues.

The findings of the various component studies have been extracted and compiled here from the final reports submitted to the project manager by the consultants. The complete reports are available at the Office of Disaster preparedness.

CHAPTER 2 BACKGROUND

2.1 PHYSICAL CHARACTERISTICS

2.1.1 PHYSIOGRAPHY

The British Virgin Islands (BVI) consists of over forty islands, islets and rocks which belong to the Virgin Islands archipelago, of which the largest islands are the United States Virgin Islands of St. Thomas and St. Croix, Figure 1.1. The islands are about 60 miles east of Puerto Rico and 140 miles north-west of St. Kitts, located near latitude 18.3° N, and longitude 64.5° W. They rest on the Greater Antilles submarine ridge at its eastern extremity and are separated from the Lesser Antilles by the deeper water of the Anegada Passage.

The islands which make up the British Virgin Islands can be placed into four groups . To the south extending for about 20 miles are a series of islands including Peter Island, Norman Island, Ginger Island, Cooper Island terminating in the island, of Virgin Gorda. The second group is parallel to the first group and extends for about 15 miles and consists of Tortola, Beef Island, Great Thatch, Great Camanoe and Guana Island.

The shallow, three to four mile wide Sir Francis Drake Channel separates the two groups. To the north-west of the Tortola group lies the third group consisting of Jost Van Dyke, Little Jost Van Dyke, and the Tobago Cays, which are separated from the second group by a shallow channel. Anegada forms a fourth unit about 30 miles north of Virgin Gorda to the north-east of Tortola. The total area of the British Virgin Islands is about 59 square miles. This study focuses on the four larger inhabited islands of the BVI - Tortola, Virgin Gorda, Anegada, and Jost Van Dyke, Tortola is the largest and most developed island and the center of government. It is an elongated island oriented roughly east-west, about twelve miles long and three miles wide with a total area of about 24 square miles.

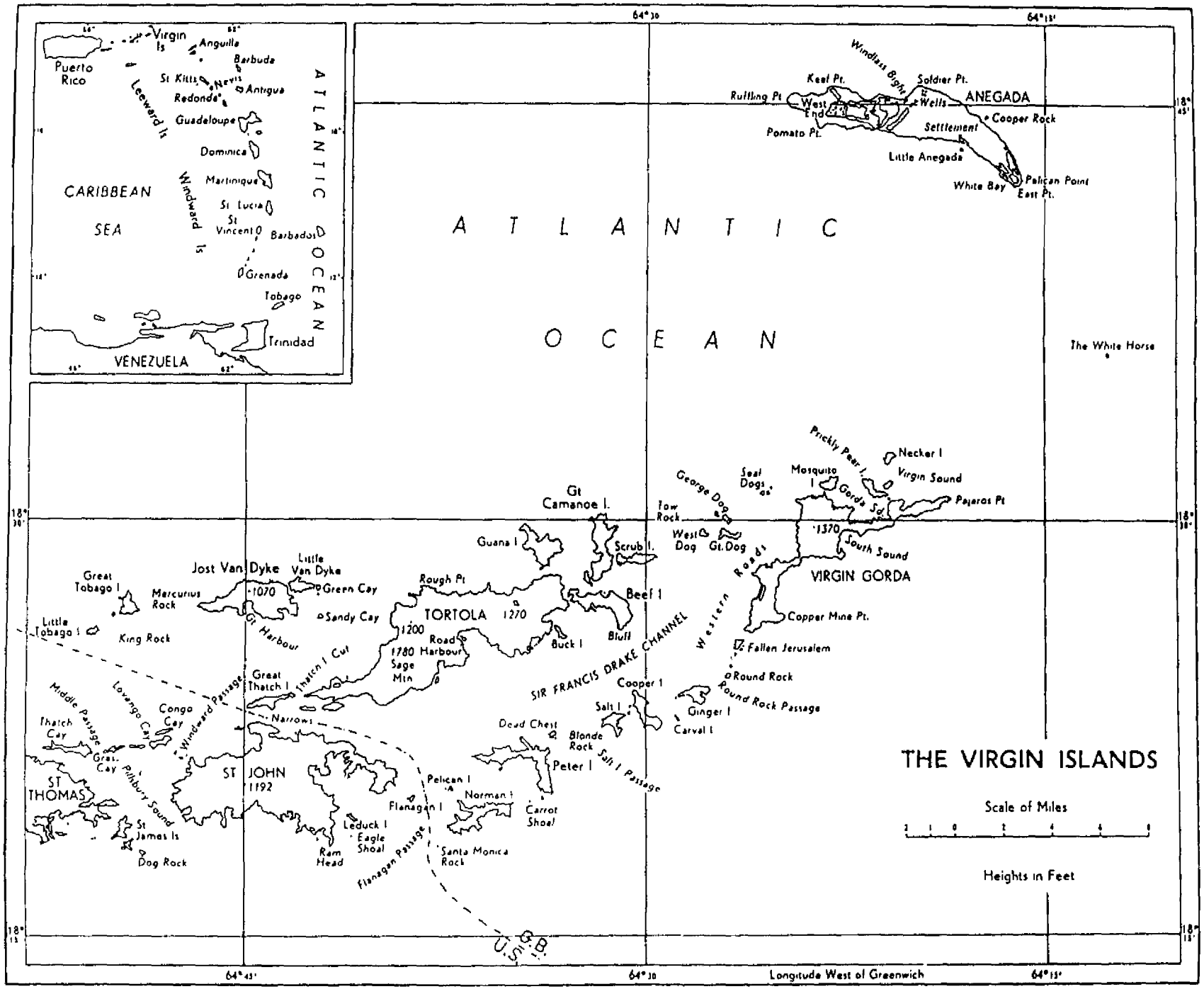
Virgin Is
Anguilla
Barbuda
Puerto Rico
St Kitts
Nevis
Antigua
Redonda
Leeward Is
Guadeloupe
Dominica
Martinique
CARIBBEAN SEA
Windward Is
St Lucia
St Vincent
Barbados
Grenada
Tobago
Trinidad
VENEZUELA
ATLANTIC OCEAN
ATLANTIC OCEAN
Windlass Bight
Soldier Pt.
Keal Pt.
Ruffling Pt
West End
Wells
ANEGADA
Cooper Rock
Settlement
Pomato Pt.
Little Anegada
White Bay
Pelican Point
East Pt.
The White Horse
Prickly Pear I.
Necker I
Virgin Sound
Mosquito I
Seal Dogs
George Dog
Gorda Sd.
Pajaros Pt
Tow Rock
West Dog
Gt. Dog
1370
South Sound
VIRGIN GORDA
Western Road
Copper Mine Pt.
Fallen Jerusalem
Round Rock
Round Rock Passage
Ginger I
Carval I
Cooper I
Salt I
Gt Camanoe I.
Guana I
Scrub I.
Beef I
Buck I
Bluff
Rough Pt
TORTOLA
1270
1200
Road Harbour
1780 Sage Mtn
Jost Van Dyke
Little Van Dyke
Green Cay
1070
Sandy Cay
Gt Harbour
Great Tobago I
Marcurius Rock
Little Tobago I
King Rock
Thatch I Cut
Great Thatch I
Middle Passage
Lovango Cay
Congo Cay
Thatch Cay
Windward Passage
Narrows
Great Cay
Pillsbury Sound
ST THOMAS
ST JOHN
1192
St James Is
Dog Rock
Ram Head
Leduck I
Eagle Shoal
Flanagan I
Pelican I
Norman I
Carrot Shoal
Flanagan Passage
Santa Monica Rock
Dead Chest
Blonde Rock
Salt I Passage
Peter I
SIR FRANCIS DRAKE CHANNEL
U.S.
G.B.
THE VIRGIN ISLANDS
Scale of Miles
Heights in Feet
64°30
64°15'
64°45'
64°30
Longitude West of Greenwich
64°15'
18°45'
18°30'
18°15'

FIGURE 1.1

The highest point is Sage Mountain with an altitude of 1,780 feet. The capital Road Town, has developed around Road Harbor which is a large south-facing bay on the south coast of Tortola. For the purposes of this study, Beef Island a small island off the eastern tip of Tortola is regarded as part of Tortola. They are connected by a bridge which spans the narrow Beef Island Channel .

Virgin Gorda is the second most developed island with a total area of about 9 square miles. It consists of a central rectangular landmass with two peninsulas, one to northeast and the other to the southeast. The length from end to end is about 10 miles and the greatest width about 2 miles. The main settlement on Virgin Gorda is Spanish Town which occupies the low plateau of the southern peninsula. The highest point is 1359 feet at Gorda Peak.

Jost Van Dyke is the next most developed island. It is irregularly shaped with a maximum length of 4.2 miles and width of about 0.75 miles and a total area of about 4 square miles. The main settlement on Jost Van Dyke is Great Harbor around the south facing bay of the same name. The highest point on Jost Van Dyke is Majohny Peak at 1054 feet. Anegada is a very flat relatively large elongated island oriented roughly east-west with a total area of about 13 square miles. It is 10 miles long and 2 miles wide with a maximum elevation of only 26 feet. The only, developed area is a small town known as The Settlement found on the south coast.

With the exception of Anegada the islands are hilly with most of the landmass consisting of steep slopes which rise precipitously from the sea. Tortola is composed of a series of hills forming a central spinal ridge along the length of the island. Most of the ridge is above 1000 feet in elevation. Hillslopes are uniform and steep, often in excess of 40° and cut extensively with drainage lines. Well developed steep drainage channels called ghuts run from the ridges to the coastline producing a series of small coastal valleys separated by spurs which extend to the coastline. Narrow relatively flat coastal strips composed of alluvium form the flood plains of the larger ghuts which are adjacent to the larger bays.

The topography of Jost Van Dyke is very similar to that of Tortola on a smaller scale. Virgin Gorda has a central peak 1,370 feet high which is part of a ridge oriented north south. A lateral ridge projects from the eastern side of the central landmass forming a long narrow peninsula. A relatively flat plateau known as 'The Valley' is connected to the southern end of the central landmass. The coastline of the islands with the exception of Anegada, are generally rugged with steep rocky headlands indented with bays.

Wide sandy beaches have developed in the larger bays especially those associated with the largest watersheds. Anegada is very a flat limestone island with one quarter of its surface area occupied by salt ponds. The western part of the island and the northern coastline is mantled by carbonate sands, with a well developed dunes complex. The rest of the islands' surface consists of exposed limestone bedrock with abundant sink holes and solution pits typical of karst limestone land forms.

2.1.2 CLIMATE

The islands lie within the northeasterly trade wind belt and possess a moderate, subtropical climate with average daily temperatures of 87°F varying from highs of 92°F and winter lows of 67°F. Daytime summer temperatures are tempered by a steady sea breeze and usually there is a fall of about 10°F at night.

Rainfall occurs usually as showers of short duration resulting from the lifting and cooling of humid air as it passes over the islands. Average annual rainfall is 50 inches varying from about 35 inches along the coast and on to about 80 inches on Mt. Sage per year. The heaviest showers occur during the periods September-December when over 50% of annual rainfall occurs. The driest period is between January and April.

A detailed rainfall analysis is presented in Chapter 4. Extreme rainfall events are associated with cold fronts which occur during the winter months and with tropical waves, depressions, storms and

hurricanes during the summer months from June to November. A detailed analysis on hurricanes is presented in Chapter 3. The dominant wind direction is NE with the other main direction being SE with an average speed of 20 Km/h.

2.1.3 GEOLOGY

The British Virgin Islands, Puerto Rico, and the US Virgin Islands are part of a relatively small crustal block on the northeastern corner of the Caribbean plate. The block is bounded by the Puerto Rico Trench in the north, the Anegada Trough in the southeast, the Martes Trough to the south, and Mona Canyon to the west. The Anegada Trough is a major crustal feature, known as an intraplate rupture and extends from the Caribbean Plate boundary in the northeast in a southwesterly direction.

The British Virgin Islands, Puerto Rico, and the US Virgin Islands are the exposed high points of a relatively flat submarine shelf resting on this crustal block known as the Puerto Rico-Virgin Island Platform which lies submerged at a depth of about 100 feet below current sea level. During the Pleistocene age this platform formed a single subaerial landmass or super-island.

The geology of Puerto Rico and the Virgin Islands is similar consisting of a series of volcanic and igneous rocks typical of island arc plate boundary settings, with associated sedimentary sequences and igneous intrusives. The rocks have been regionally metamorphosed, deformed and hydrothermally altered as a result of several phases of intense tectonic activity.

Of the islands being examined all except Anegada are underlain by a series of well stratified, steeply dipping, marine-lain volcanics and associated sedimentary rocks of Cretaceous age. The rocks exposed in Tortola consists largely of well stratified metamorphosed volcanics interlayered with sedimentary rocks with smaller outcrops of pyroclastic volcanics in the north, stratified metamorphosed marine sediments in the west and plutonic igneous rocks in the east.

Jost Van Dyke is underlain entirely by pyroclastic volcanics, while Virgin Gorda and Beef Island are composed almost entirely of plutonic intrusives. Anegada is composed entirely of reef limestone deposited in Pleistocene time. The volcanics consist of a series of tuffs, breccias, lava flows and shallow intrusives, which are andesitic in composition. They have all undergone regional metamorphism. These rocks are hard, medium grained, highly fractured rocks which form beds ranging from a few centimeters to a meter thick. The beds are oriented with a pervasive east-west strike and dip steeply to the south at angles greater than 45°.

The pyroclastic volcanic rocks range from fine grained tuffs to coarse grained agglomerates with boulders of breccia which are less stratified but also have an east-west strike. The metamorphosed marine sediments consist of well stratified fine to medium grained terrigenous sediments and limestones with a pervasive east-west strike. Plutonic igneous rocks consist of intrusive diorites which are coarse grained, hard, massive rocks, which are extensively jointed. In Virgin Gorda significant metalliferous deposits are associated with these rocks. Metalliferous ore which has been extracted in the past include copper, chalcopyrite, malachite, native copper, hematite, pyrites and molybdenite.

The surficial deposits consist of alluvium, beach deposits, littoral deposits boulders, and artificial fill. Alluvial deposits are confined to the lower reaches of the valleys where they form relatively flat alluvial lowlands adjacent to the sea. The alluvium exposed along the stream courses is a poorly sorted mixture of sediments, ranging from clay to boulders with occasional lenses of sand and gravel from 1-5 feet thick. In St. Thomas where the depositional environment is similar, beds of sand and gravel up to 3 feet thick have been found lying on or near underlying bedrock surface are the remnants of former stream channels now buried by more recent alluvium.

The alluvium has been estimated between 60-100 feet deep. In some areas there are littoral deposits intermixed with fine decomposed coral silts and sands. Beach deposits consists of unconsolidated, loose, medium grained carbonate sands. The most extensive beach deposits are found on western side of Anegada where a well developed beach ridge complex has developed with stabilized sand

dunes. Soils throughout the islands are shallow, friable, immature, residual soils generally less than 18 inches thick. These soils are medium to coarse grained, well graded, sandy silts generally with a dark yellow brown color. There are extensive areas of reclaimed land in Road Town and along sections of the south coast of Tortola which have been developed over the last 25 years.

Large boulders form significant surficial deposits especially in southern Virgin Gorda where large boulders up to 10 meters it diameter form an expansive boulder field. Smaller boulders are also found on Beef Island and along some ridge tops in Tortola. These boulders are the products of long term subaerial and marine spheroidal weathering of plutonic igneous rocks.

2.1.4 SURFACE DRAINAGE

Surface drainage on the islands is controlled to a large extent by the topographic and geologic features of the watersheds. Most runoff takes place through steep gullies called ghuts, except Anegada where surface runoff occurs as very shallow sheet flow. The ghuts are temporary streams with significant runoff occurring as storm discharge following rains of 1 inch or more. A detailed drainage analysis is presented in Chapter 4.

2.1.5 GROUND WATER

The alluvium and the bedrock aquifers found on the islands occur as small individual, hydraulically interconnected water-bearing units with boundaries coinciding with the watershed divides. Each valley is essentially a self-sustaining hydrologic unit. Alluvial deposits in the valleys are recharged by any rainfall which results in storm runoff generally occurring in varying amounts about 6 times in a year of average rainfall in Tortola.

Water in the volcanic and associated sedimentary rocks is confined to open fractures and joints. Recharge to the bedrock occurs once or twice a year from rainfall that exceed 2 to 3 inches in 24 hours.

2.2 SOCIO-ECONOMIC SETTING

2.2.1 DEMOGRAPHICS

The population of the BVI is 16,115 (1991 census). Of the total 13,200 live in Tortola, 4000 in Virgin Gorda, 162 in Anegada, and 140 in Jost Van Dyke and 144 in the other islands. There has been a doubling of the population between 1984 and 1994 due to a large influx of migrants who currently reside and work in the BVI. Expatriates account for over 45% of the present population, most of whom are from the other Caribbean countries.

2.2.2 ECONOMY

The British Virgin Islands has a small open but stable economy in which the currency is the US dollar. Most goods are imported through ports of entry including sea ports and airports, while there are no significant visible exports. The major shipping port is Port Purcell in Road Town, Tortola which handles containers and break bulk cargo. The Beef Island airport handles most air freight including the services of three major courier companies. The major commercial sectors include international financial services, tourism, agriculture, construction, general commerce and trade, The government employs over 2000 persons.

The international finance services industry which largely involves off-shore company registration is currently the largest earner of foreign exchange. It is a major employer of professionals and medium skilled persons. The industry provides important linkages with accounting, legal and banking services. This industry which has grown rapidly since 1985 presently offers an important service to a predominantly international clientele.

Tourism is the second largest earner of foreign exchange generating yearly receipts of over US$ 250 million and is the largest single employer in the private sector. There are over 40 small hotels, most

of which are in Tortola as well about 10 guest houses and over 650 charter boats. The charter boat aspect of tourism in the BVI is very significant. It contributes a major portion of accommodation, trade, in terms of provisioning as well as important service linkages in areas such as boat repair and servicing. The BVI receives over 200,000 stop-over visitors and over 80,000 cruise ship passengers per annum.

2.3 HAZARDS AFFECTING THE BRITISH VIRGIN ISLANDS

The British Virgin Islands is exposed to natural and man-made hazards which have the potential to cause significant loss of life and property, as well as serious damage to the environment, and the economy. The natural hazards to which the BVI is exposed consist primarily of the effects of tropical systems and related weather systems that includes land borne flooding, wind damage, and coastal flooding and the ground shaking effects of earthquakes. Landslides also pose a minor threat.

Man-made hazards largely consist of the potential accidental exposure of the environment to hazardous chemicals, large explosions, and accidents related to mass transportation of people. In this respect oil spills represents the greatest man-made or technological hazard to the BVI.

The damage potential and the high probability of occurrence of these natural hazards makes them far more significant than man-made hazards. This report therefore focuses on natural hazards which were studied in detail, while the man-made hazards are only briefly described.

Hurricanes and earthquakes are the natural hazards that pose greatest threat to the BVI. It is the opinion of the author that hazard mitigation activities in the BVI, be concentrated on reducing the potential impact of these two hazards.

In the following chapters tropical cyclone systems that produce hurricanes, and their effects are described, followed by a description of the nature of earthquake hazards in the BVI. Since weather systems other than tropical cyclone systems have the potential to cause major flooding, this hazard is treated in a separate chapter. In all cases the possible distribution and magnitude of the hazardous phenomenon is assessed to determine the degree of exposure or susceptibility of locations in the BVI.

To arrive at a determination of the risk posed by a particular phenomenon, requires that the elements at risk be established. For this project therefore, an inventory of the elements at risk in the BVI was carried out to identify the entities which can be affected by particular hazards. This largely consisted of the mapping of most buildings and other significant structures such as roads, utility distribution networks, and jetties.

The vulnerability or intrinsic predisposition to damage from hurricane force winds of the main structural types in the BVI was evaluated. Some general statements are made regarding, the vulnerability to storm surge, inland flooding, and ground shaking due to earthquakes. Based on the degree of vulnerability established, estimates of potential damage were calculated.

Finally some approaches to loss reduction are recommended in the form of mitigation strategies. These include both structural and nonstructural measures which address mitigation for existing and future development, and highlight the importance of incorporating mitigation issues into the planning process.