CEP

CONSULTING ENGINEERS PARTNERSHIP LTD

CONCEPT
DAYRELLS ROAD
CHRIST CHURCH
BARBADOS, W I.
TEL. (809) 426-5930
FAX: (809) 426-5935
P O BOX 715, BRIDGETOWN
E-Mail CONCEPT@caribsurf.com

DIRECTORS

TONY GIBBS, BSc, DCT (Leeds), FICE, FIStructE, FASCE, MConsE, FRSA*
A E HUTCHINSON, BEng, MASc, FICE, MIStructE, MIHT, MCSCE*
P T SOBERS, MSc, DIC, MICE, MIStructE, MASCE*
A C T FARRELL, MSc, FICE, FIStructE

CONSULTANTS

D E KEY, PhD, BSc, FICE, FIStructE, MASCE
K M JOHNSON, OBE, BSc, FICE, FIWEM*
H E BROWNE, BSc(Eng), MSc, MS, MICE*

ASSOCIATE

G F HAZZARD, BSc, MBA*

40th ANNIVERSARY
1955 - 1995

Our Ref: CEP/20249

1995-09-19

Mr Jan Vermeiren
Organization of American States
17th Street & Constitution Ave NW
WASHINGTON, DC 20006
U S A

Dear Sir,

Lucelec Vulnerability Audit

In accordance with your correspondence of 23 June, 1995, we have pleasure in submitting this consolidated version of the inception and final reports for the above project.

Yours faithfully,
CONSULTING ENGINEERS PARTNERSHIP LTD

Gregory F Hazzard

Enc

GFH/acc

Caribbean Disaster Mitigation Project
Organisation of American States
Caribbean Electric Utility Services Corporation

Vulnerability Audit

St Lucia Electricity Services Ltd

September 1995

Consulting Engineers Partnership Ltd
"Concept", Dayrell's Road, Christ Church, Barbados

Caribbean Disaster Mitigation Project
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Inception Report

September 1994

Consulting Engineers Partnership Ltd
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Our Ref: CEP/20249

1994-09-13

Mr Jan Vermeiren
Organisation of American States
17th Street & Constitution Ave, NW
WASHINGTON, DC 20006
U S A

Dear Sir,

Lucelec Vulnerability Audit

In accordance with our agreement #BAC11486 under cover letter dated 7 June, 1994, we have commenced work on the above-captioned assignment.

We have met with the various other participants in the programme, carried out the first stage of field investigations and conducted a preliminary review of readily-available documents. We have identified and assessed the relevant natural hazards and provided the T & D consultant with information on the wind phenomenon.

Our Inception Report seeks to catalogue our work accomplished to date. It presents the opportunity for Lucelec, CARILEC and yourself to comment on the direction we have taken and on our broad findings. The Report invites the suggestions of the other participants with respect to areas to be emphasized during the proximate and final stages of our assignment. These could be made at the meeting scheduled for 30th September.

The undersigned wishes to acknowledge the input of Engineer Gregory Hazzard (appropriately named) in accomplishing this stage of the work.

We further wish to thank Herbert Samuel, Christopher Mitchell, yourself and others at CARILEC, Lucelec and the OAS for their valuable assistance.

Yours faithfully,
CONSULTING ENGINEERS PARTNERSHIP LTD

Tony Gibbs

CARIBBEAN DISASTER MITIGATION PROJECT

The Caribbean Disaster Mitigation Project (CDMP) is a coordinated effort to promote the adoption of natural disaster mitigation and preparedness practices by both the public and private sectors in the Caribbean region through a series of activities carried out over a five-year period. The CDMP is funded by the **USAID Office of Foreign Disaster Assistance (OFDA)** and implemented by the **Organization of American States/Department of Regional Development and Environment (OAS/DRDE)** for the **USAID Regional Housing & Urban Development Office in the Caribbean (RHUDO/CAR).**

The CDMP provides a framework for collaboration within the Caribbean region to establish sustainable public and private sector mechanisms for natural disaster mitigation that will measurably lessen loss of life, reduce the potential for physical and economic damage, and shorten the disaster recovery period over the long term. Project activities vary according to location, contents and implementation strategy, but all contribute to attainment of the overall CDMP goal: a more disaster-resistant environment for the people who live, work and invest in this hazard-prone region.

An important objective of the CDMP is to reduce the vulnerability of basic infrastructure and critical public facilities. In pursuit of this objective, CDMP has been working with the **Caribbean Electric Utility Services Corporation (CARILEC)** in assisting electrical utilities in the region in reducing the potential for losses caused by natural hazards. A Memorandum of Understanding was signed under which USAID/OAS-CDMP and CARILEC agreed to collaborate in a pilot vulnerability audit of the installations of the St. Lucia Electricity Services Ltd. (LUCELEC), and the hydro-electric installations of the Dominica Electric Services Ltd. (DOMLEC). **Consulting Engineering Partnership (CEP)** of Barbados acted as principal consultant in this project.

Lessons learned from these audits, and from a systematic evaluation of the damages to LUCELEC's installations from hurricane Debby in September 1994, and to APUA's installations from Hurricanes Luis and Marilyn in September 1995, were incorporated in this **Manual for Electrical Utilities on Mitigation of Damages caused by Natural Hazards.** The Manual provides guidelines for electrical utilities in ordering capital works and related technical services, in designing and implementing maintenance programs, and in managing natural hazard risk in general. The same Manual will help implementing engineers contracted by the utility companies in ensuring that natural hazard considerations are appropriately incorporated in the design and construction.

CARILEC's goal in promoting widespread use of this Manual among its Member Utilities is to reduce the element of surprise by providing buildings, structures and civil works of predictable performance at affordable costs.

2.0 NATURAL HAZARDS AFFECTING ST LUCIA

2.1 General

The primary natural hazards facing islands in the Caribbean are:

(i) earthquakes;
(ii) hurricanes;
(iii) torrential rains;
(iv) tsunamis;
(v) storm surges;
(vi) volcanic eruptions.

In the case of St Lucia, volcanic activity is an important consideration but falls outside the present work. The other five items are discussed generally below.

2.2 Earthquakes

Seismic events in the Eastern Caribbean, where St Lucia is located, are principally associated with a subduction zone at the junction of the Caribbean Plate and the Americas Plate. The Caribbean Plate is moving eastward relative to the Americas Plate at a rate of about 20mm per year. The Americas Plate dips from east to west beneath the Caribbean Plate along a north-south line approximately 150km east of St Lucia. This leads to a moderate level of inter-plate seismicity in the vicinity of St Lucia. The maximum historical intensities of earthquakes in St Lucia as reported by Dr John Shepherd (formerly of the Seismic Research Unit, UWI, Trinidad) are VII and VIII on the Modified Mercalli Scale. The Caribbean Uniform Building Code (CUBiC) recommends a Z-factor of 0.75 for St Lucia. However, a 1983 study by Faccioli, Taylor and Shepherd recommends a Z-factor of 0.5 and a design ground acceleration of less than or equal to 0.1g. This places St Lucia somewhere between zones 2 and 3 of the UBC and the (old) SEAOC codes of the USA. In other words, the level of seismicity in St Lucia is moderate but sufficiently important not to be ignored.

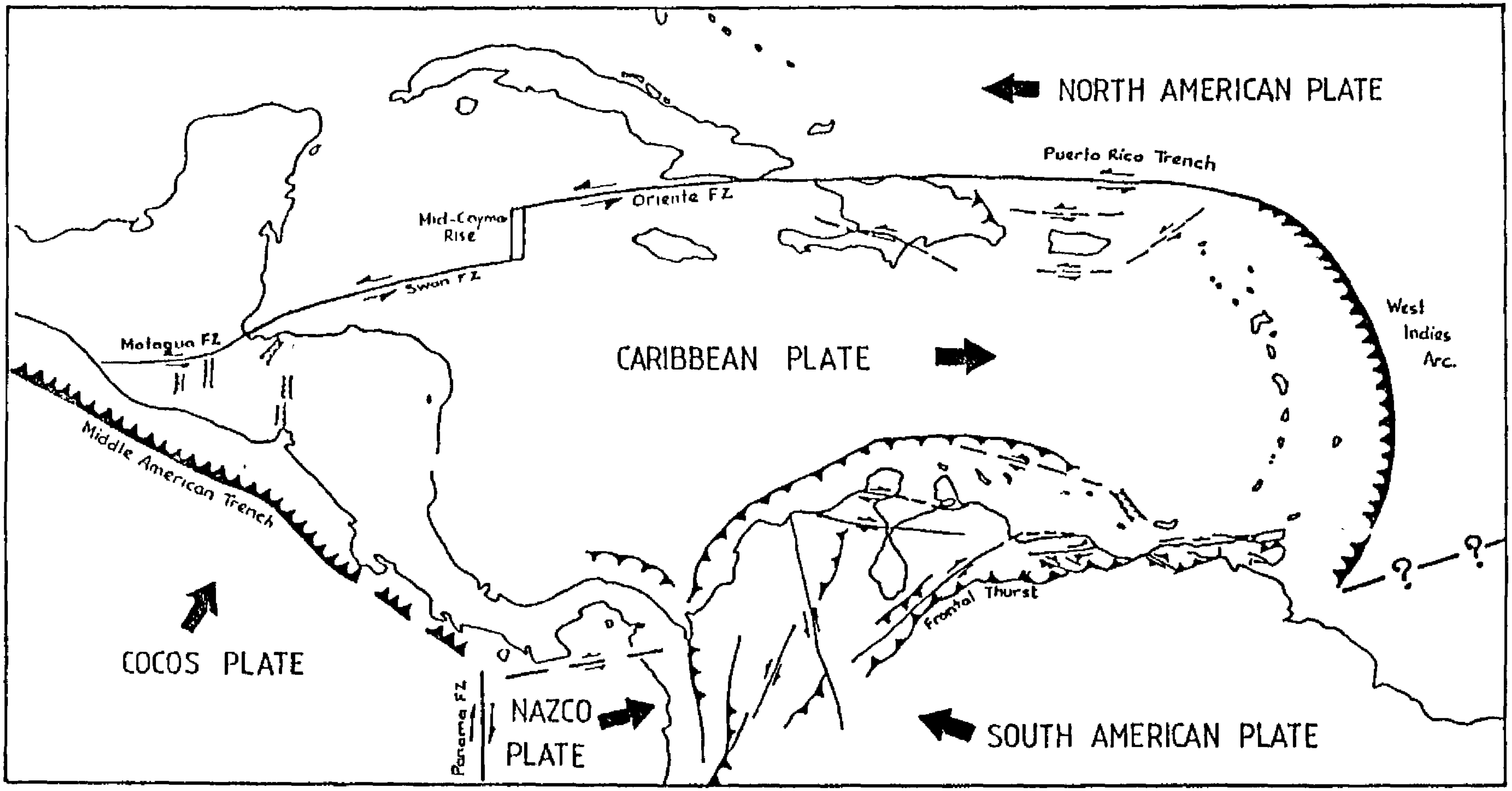
Figures 1, 2 and 3 (at the end of this sub-section) show the tectonic setting of the Caribbean, the main physical features of the Eastern Caribbean and a cross section through the island arc.

The two most recent earthquakes to have caused significant damage in St Lucia are:

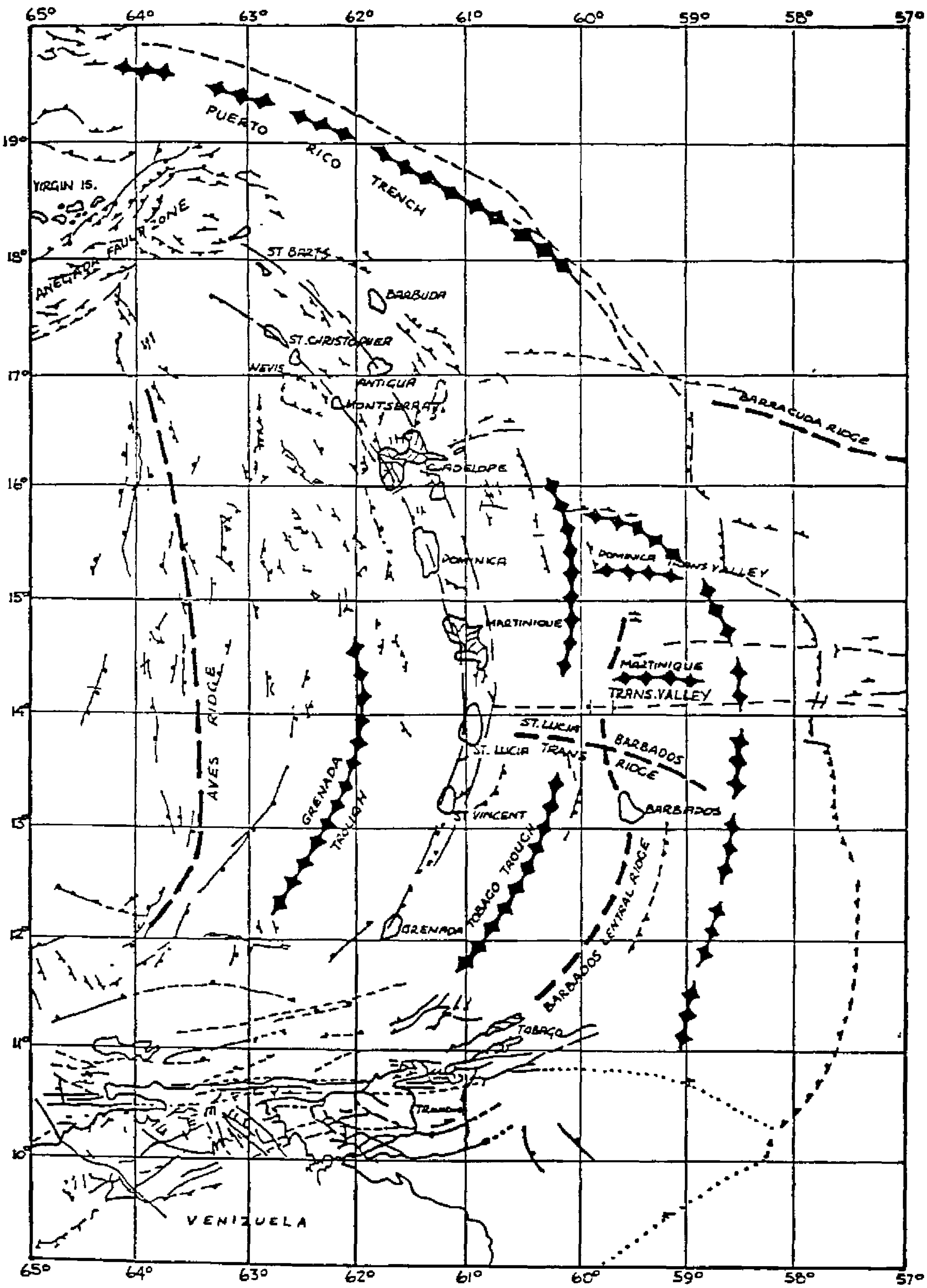
19th March 1953	-	Richter magnitude 7.5, Modified Mercalli intensity VII in St Lucia;
16th February 1906	-	Richter magnitude 7.0, Medvedev-Sponheuer-Karnik (MSK) intensity VII-VIII in St Lucia.

An isoseismic map of this latter event is reproduced in figure 4c (at the end of this sub-section).

The catastrophic Guadeloupe earthquake of 8th February 1843 produced a Medvedev-Sponheuer-Karnik (MSK) intensity of VII in St Lucia. An isoseismic map of that event is reproduced in figure 4b (also at the end of this sub-section). Other isoseismic maps (figures 4a and 4d) are presented for the events of 11th January 1839 (Richter M=7.5-7.8, MSK=VIII) and 21st May 1946 (Richter M=7.0, MSK=VII).



Tectonic Setting of the Caribbean
(after Molnar and Sykes, 1969)
Figure 1

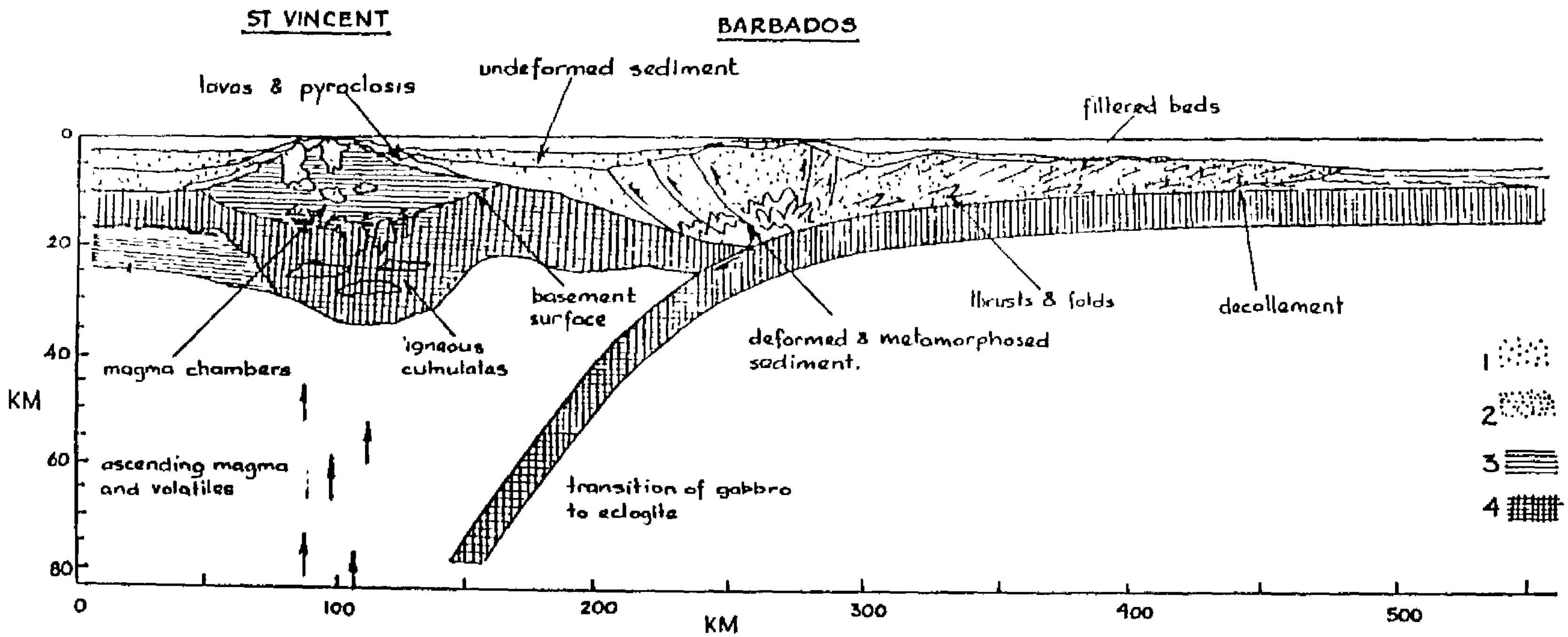


Main Features of Eastern Caribbean

(based on compilation by JE Case and TA Holcomb USNOO

and from Peter and Westbrook, 1976)

Figure 2

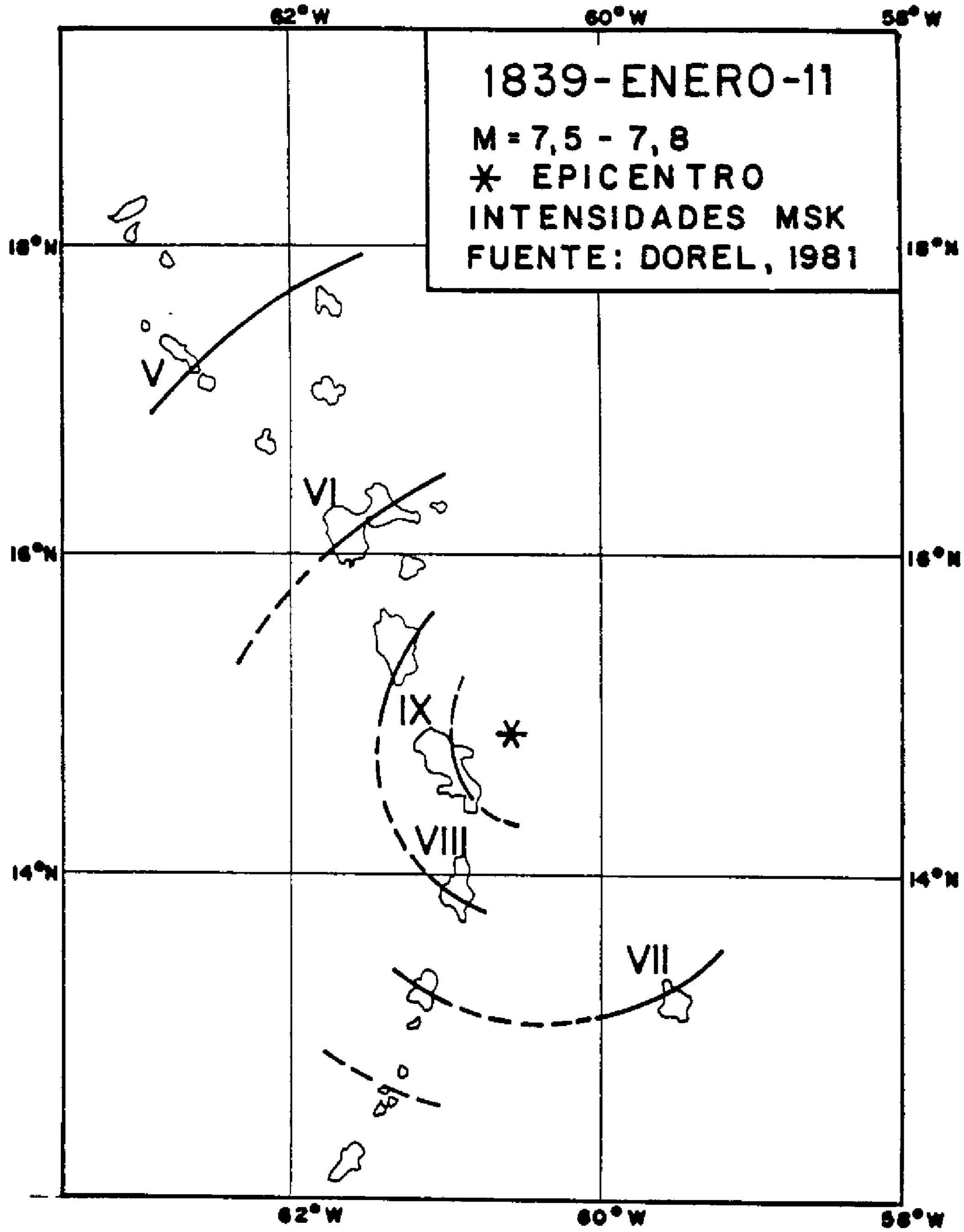


Diagrammatic cross-section of the Eastern Caribbean island arc illustrating the structure and the processes acting on it. 1. Undeformed sediment. 2. Deformed and/or consolidated sediment. 3. Igneous crust produced by the volcanic arc. 4. Main oceanic crustal layer and lower crust of arc. Vertical exaggeration 2:1.

Structure in Region of Barbados

(Westbrook, 1970)

Figure 3



62° W
60° W
58° W
1839-ENERO-11
M = 7,5 - 7,8
* EPICENTRO
INTENSIDADES MSK
FUENTE: DOREL, 1981
18° N
16° N
14° N
V
VI
IX
VIII
VII

Figure 4a

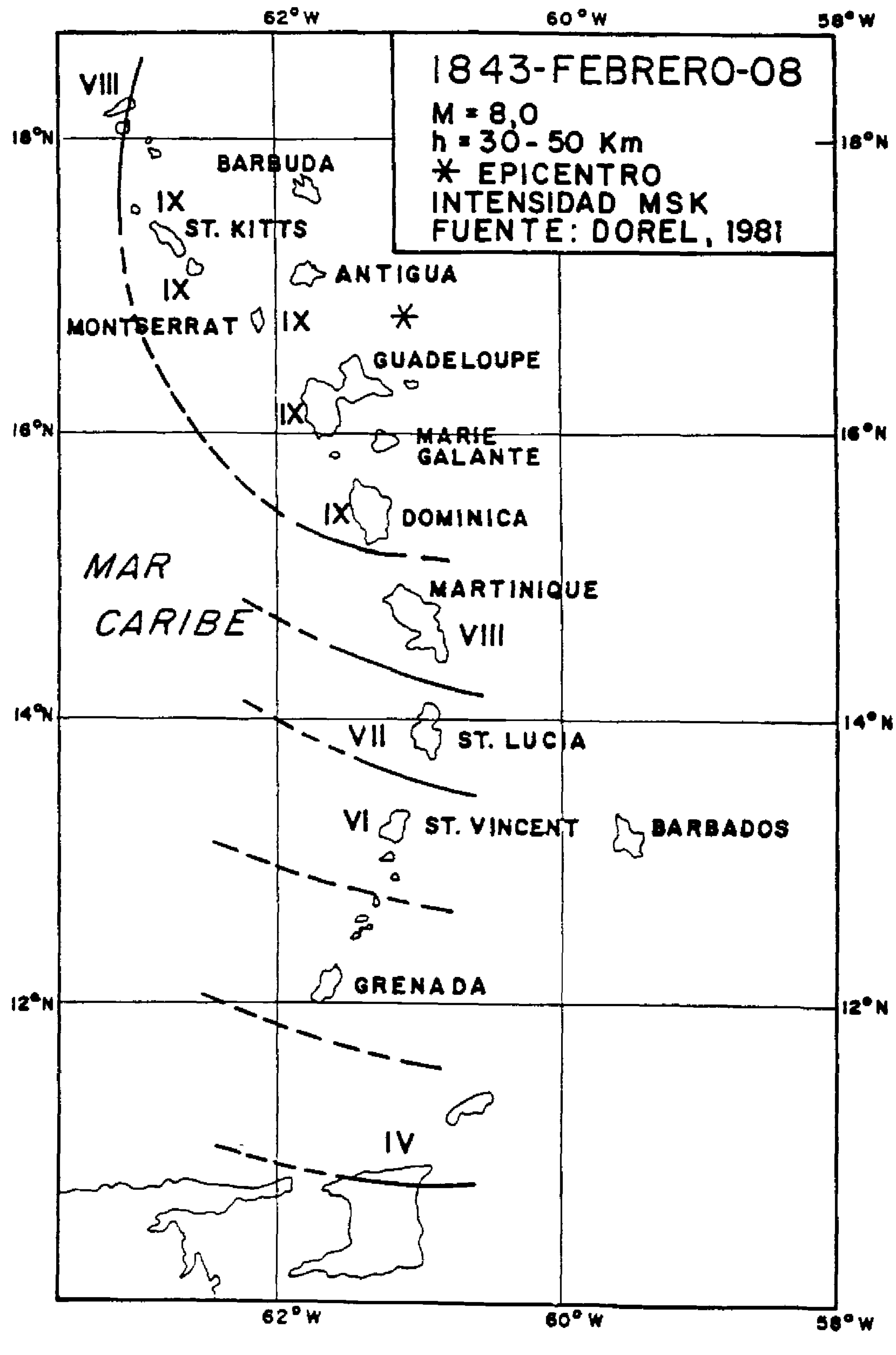

62° W
60° W
58° W
1843-FEBRERO-08
M = 8,0
h = 30 - 50 Km
✱ EPICENTRO
INTENSIDAD MSK
FUENTE: DOREL, 1981
18°N
16°N
14°N
12°N
VIII
BARBUDA
IX
ST. KITTS
IX
ANTIGUA
MONTSERRAT
IX
GUADELOUPE
IX
MARIE
GALANTE
IX
DOMINICA
MAR
CARIBE
MARTINIQUE
VIII
VII
ST. LUCIA
VI
ST. VINCENT
BARBADOS
GRENADA
IV

Figure 4b

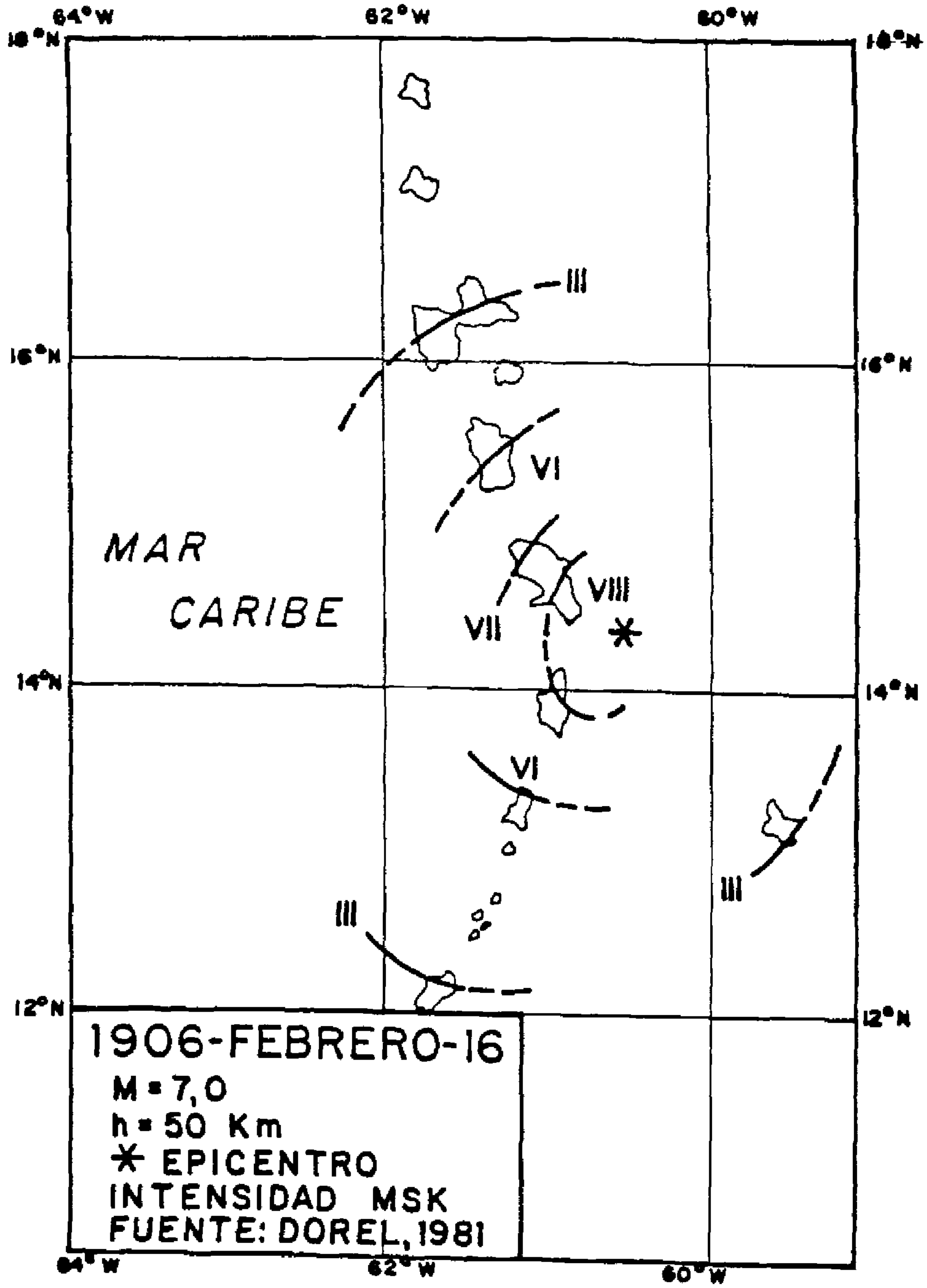

64° W
62° W
60° W
18° N
16° N
14° N
12° N
III
VI
VIII
VII
VI
III
III
MAR
CARIBE
1906-FEBRERO-16
M = 7,0
h = 50 Km
✳ EPICENTRO
INTENSIDAD MSK
FUENTE: DOREL, 1981

Figure 4c

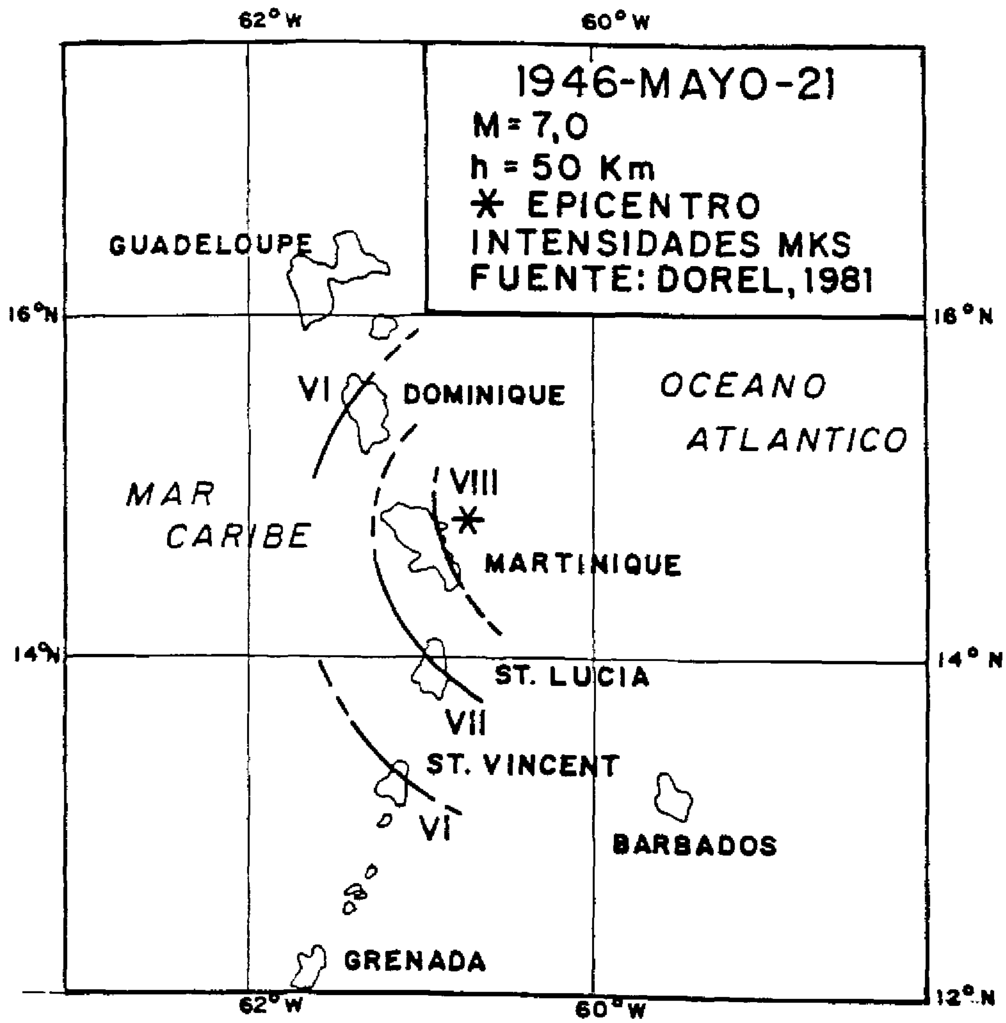

62° W
60° W
1946-MAYO-21
M = 7,0
h = 50 Km
* EPICENTRO
INTENSIDADES MKS
FUENTE: DOREL, 1981
GUADELOUPE
16° N
16° N
VI
DOMINIQUE
OCEANO
ATLANTICO
MAR
CARIBE
VIII
MARTINIQUE
14° N
14° N
ST. LUCIA
VII
ST. VINCENT
VI
BARBADOS
GRENADA
62° W
60° W
12° N

Figure 4d

2.3 Hurricanes

St Lucia lies in the North Atlantic Ocean, one of the six main tropical areas of the earth where hurricanes may develop every year. In its April 1991 Information Bulletin, the Caribbean Cyclone-Resistant Housing Project (CCRHP-UWI) states that over 4000 tropical storms have occurred in the region within the past 500 years, half of which developed into hurricanes. A general historical record of those hurricanes affecting St Lucia from the seventeenth century to 1980 is given in Table 1 (at the end of this sub-section)

Cyclones are formed when an organised system of revolving winds, clockwise in the Southern Hemisphere and anti-clockwise in the Northern Hemisphere, develop over tropical waters. The classification of a cyclone is based on the average speed of the wind near the centre of the system. In the North Atlantic they are called tropical depressions for wind speeds up to 17 metres per second (m/s). Tropical storms have wind speeds in the range 18 m/s to 32 m/s. When the wind speeds exceed 32 m/s the system is called a hurricane

A hurricane is a large-scale, low-pressure weather system. It derives its energy from the latent heat of condensation of water vapour over warm tropical seas. In order to develop, a hurricane requires a sea temperature of at least 26°C which must be maintained for several days for the system to sustain itself A large expanse of sea surface is required for the formation of a hurricane, about 400 kilometers (km) in diameter A mature hurricane may have a diameter anywhere from 150 km to 1000 km with sustained wind speeds often exceeding 52 m/s near the centre with still higher gusts

A unique feature of a hurricane is the eye. The system of revolving winds does not converge to a point, but becomes tangential to the wall of the eye at a radius of 8 to 12 km from the geometric centre of the disturbance The eye is an area of light winds, thin cloud cover and the lowest barometric pressure The eye provides a convenient frame of reference for the system and can be tracked with radar, aircraft or satellite Figure 5 (at the end of this sub-section) shows the variations of wind speed and barometric pressure with distance from the eye of the hurricane.

In Figure 6 (at the end of this sub-section) a probability chart and table (CCRHP-UWI) are presented depicting the cyclone hazard in a 2-degree square (approximately 220 km x 220 km) centred on Barbados. The statistics for St Lucia are not readily available but are likely to be very similar to those for Barbados It is estimated that the probability of a direct hit on St Lucia is about 65% of the probability of a passage through the 2-degree square as shown on figure 6

As part of the OAS Caribbean Disaster Mitigation Project wind hazard maps have been produced by TAOS Output System (A full description of this system is provided in the paper "The Arbiter Of Storms A High Resolution, GIS Based System for Integrated Storm Hazard Modelling" by Charles C Watson, Jr. The 100-year Wind Hazard Map for St Lucia is reproduced as figure 7 in this report It shows the influence of topography on the wind speed

The destructive potential of a hurricane is significant due to high wind speeds, potential torrential rains which produce flooding and occasional storm surges with heights of several metres above normal sea level.

The Saffir-Simpson scale is often used to categorize hurricanes based on wind speed and damage potential. The following five categories of hurricanes are recognized:

	Wind Speed		
Category	**m/s**	**mph**	**Damage**
HC1	33 - 42	74 - 95	Minimal
HC2	43 - 49	96 - 110	Moderate
HC3	50 - 58	111 - 130	Extensive
HC4	59 - 69	131 - 155	Extreme
HC5	>69	>155	Catastrophic

The Caribbean Uniform Building Code and the BNSI/NCST/OAS/BAPE Wind Code set out the basic wind parameters for the design of buildings in St Lucia. The normal requirement is the 1-in-50-year wind, ie a wind speed which on average is not expected to be exceeded more than once in 50 years. In St Lucia this produces a basic 3-second gust wind speed of 58 m/s. This represents a category 3 hurricane. For a category 4 hurricane, a wind speed is experienced which on average is not expected to be exceeded more than once in 100 years. The 1-in-200-year wind is experienced in a category 5 hurricane.

ST LUCIA CYCLONE CATALOGUE

1600-1700

October 23 or 24, 1694

1700-1800

June 12-14, 1780
October 10-18, 1780 - "Great Hurricane"

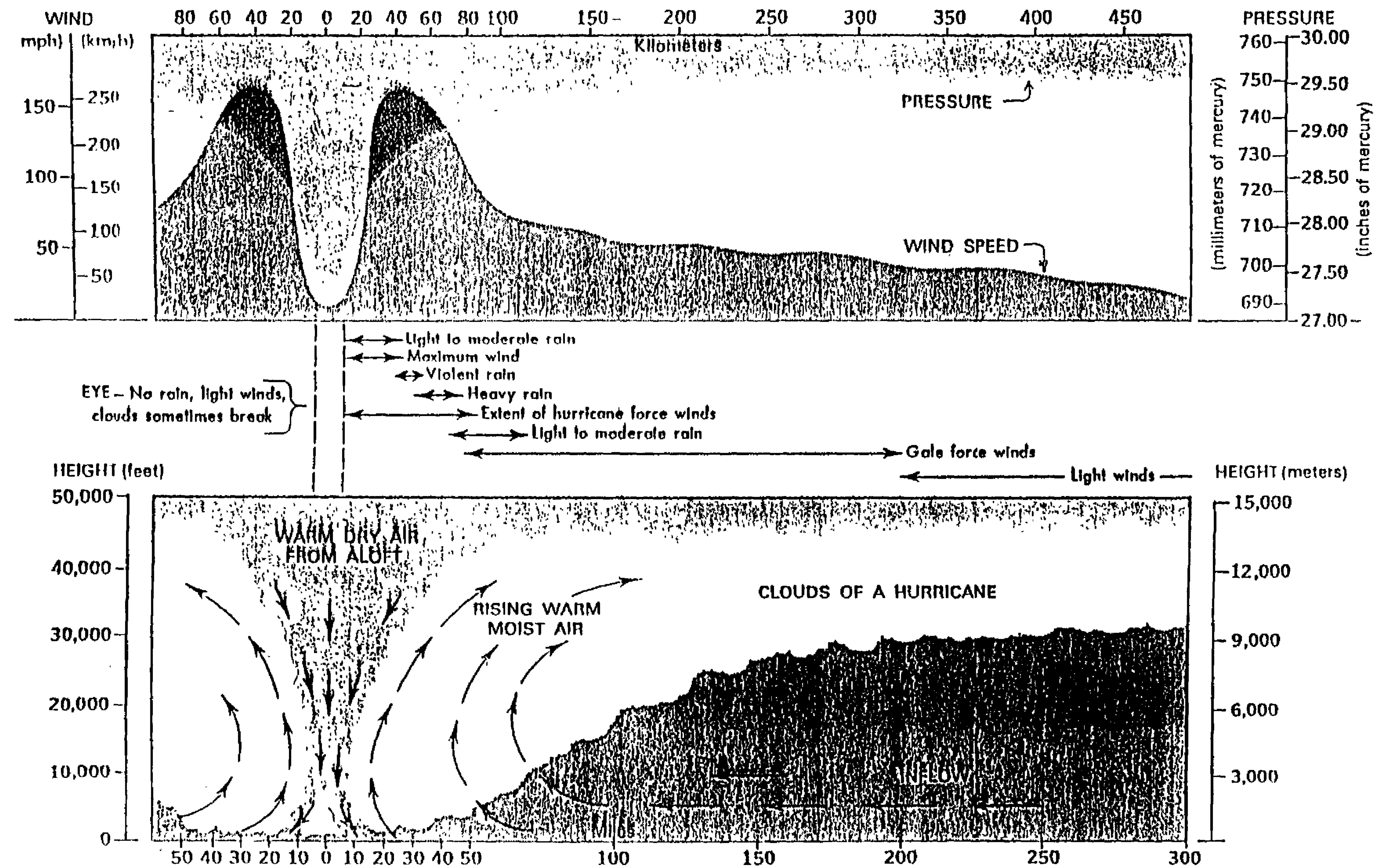
1800-1900

October 23, 1817
October 21, 1818
September 21-22, 1819
October 13-15, 1819
July 9, 1837
October 6, 1841

1900-1980

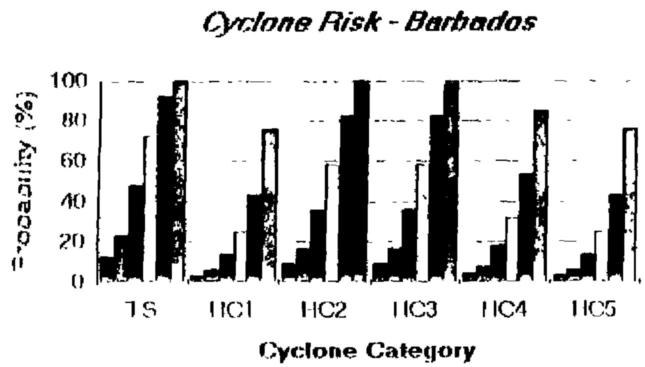
September 2-5, 1951	
October 30 - November 6, 1956	- heavy swells from "Greta" to west-northwest
July 10, 1960 - "Abby"	- destruction most severe in memory
September 25, 1963 - "Edith"	- $3,465,000 in damages
September 5-22, 1967 - "Beulah"	- torrential rains; $3 million in damages
August 4, 1980 - Hurricane "Allen"	

Table 1



upper chart shows:
.Variations of Wind Speed and Barometric Pressure with distance from the eye of the hurricane

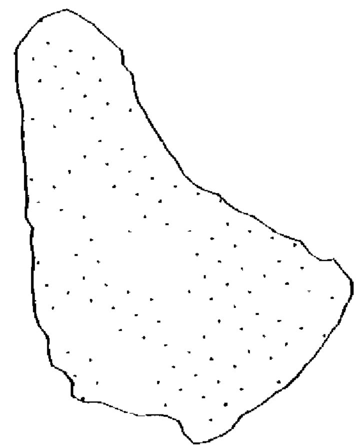
Figure 5



Key

TS - Tropical Storm
HC - Hurricane Category

Every Year · Once in 2 Yrs · Once in 5 Yrs · Once in 10 Yrs · Once in 20 Yrs · Once in 50 Yrs



Number of Years	Probability of Cyclone (%)					
	TS	HC1	HC2	HC3	HC4	HC5
1	12	3	8	8	4	3
2	23	6	16	16	7	6
5	48	13	36	36	17	13
10	73	25	58	58	32	25
20	93	43	83	83	53	43
50	100	76	99	99	85	76

Cyclone Hazard in 2-Degree Square Centred on Barbados

Figure 6

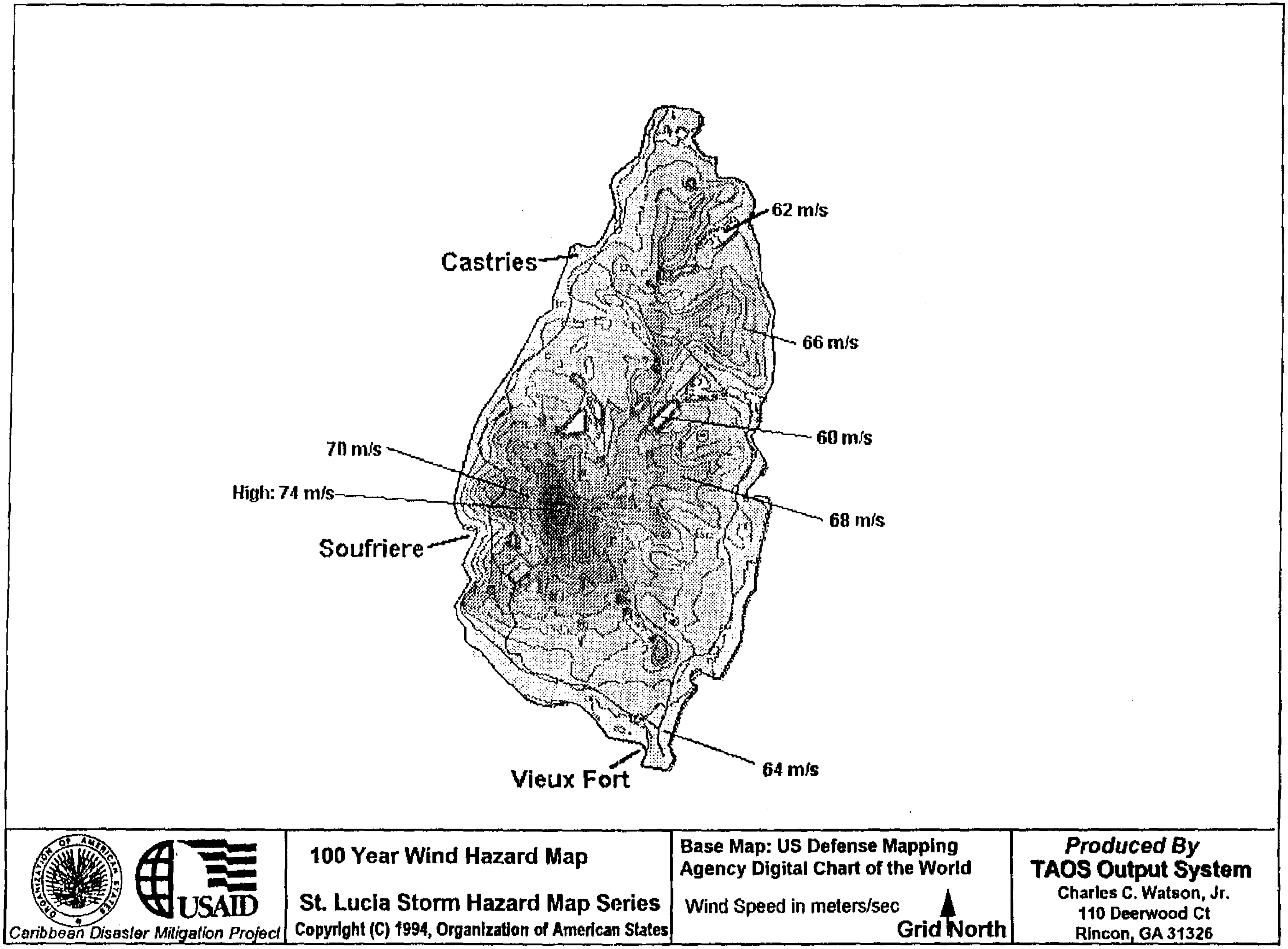

62 m/s
Castries
66 m/s
60 m/s
70 m/s
High: 74 m/s
68 m/s
Soufriere
64 m/s
Vieux Fort
Caribbean Disaster Mitigation Project
USAID
100 Year Wind Hazard Map
St. Lucia Storm Hazard Map Series
Copyright (C) 1994, Organization of American States
Base Map: US Defense Mapping Agency Digital Chart of the World
Wind Speed in meters/sec
Grid North
Produced By
TAOS Output System
Charles C. Watson, Jr.
110 Deerwood Ct
Rincon, GA 31326

Figure 7

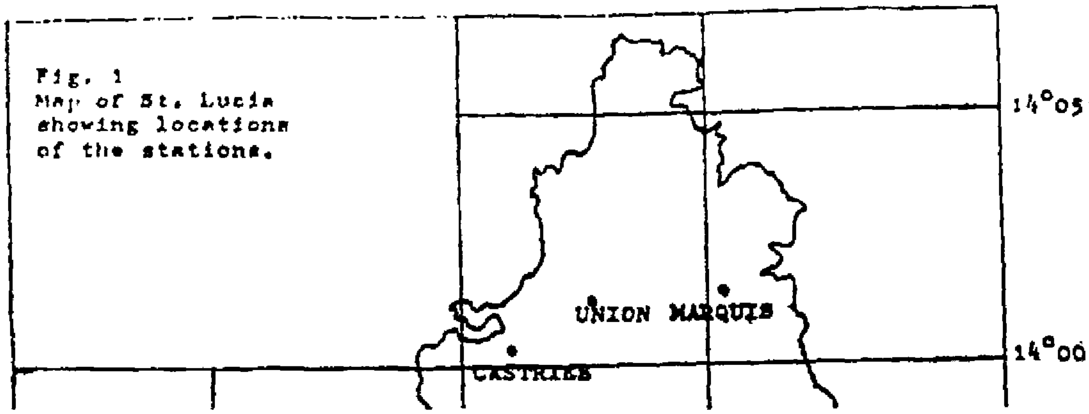
2.4 Torrential Rains

Although hurricanes are often accompanied by heavy rains, severe rainfall events resulting in flooding in St Lucia are also, and frequently, associated with troughs and tropical depressions. The risk of flooding is therefore not restricted to, nor more likely to occur, during hurricane events.

Drainage systems and structures in St Lucia are generally designed for rainfall events having return periods of 20 years. This means that such systems are likely to become overloaded and cause some degree of flooding when rainstorms are experienced with return periods greater than 20 years. Figure 8 and 9 (at the end of this sub-section) show the rainfall intensity-duration-frequency curves for two locations in St Lucia.

Generally, lower lying areas will be more susceptible to flooding than higher and sloping ground.

The damage caused by flooding depends on the type and elevation of facilities in the location. The results of flooding may range from the inconvenience of temporarily submerged driveways to the loss of equipment and finishes inside flooded buildings and consequential disruption of the functions.



RAINFALL INTENSITY-DURATION FREQUENCY CURVES

UNION

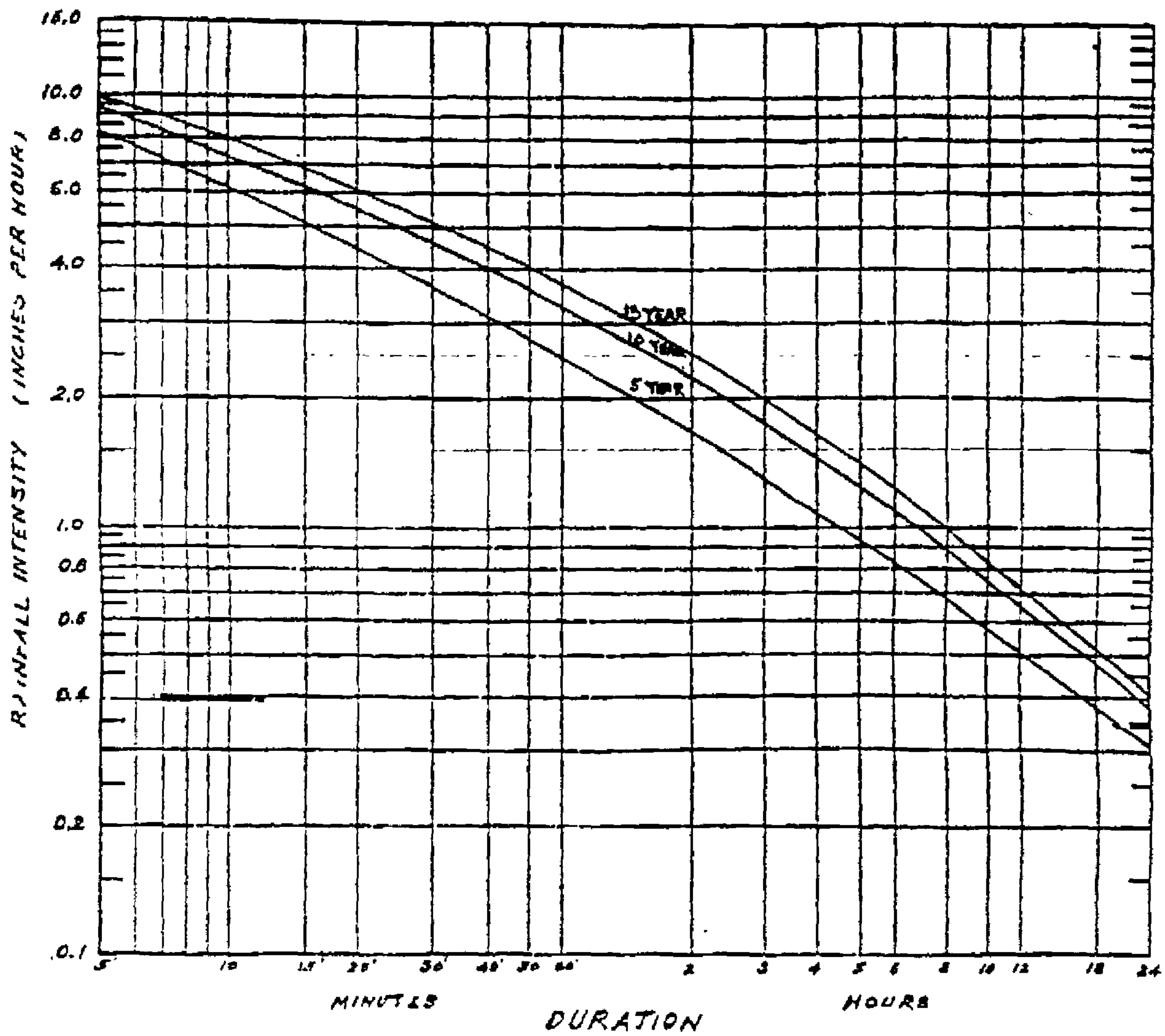


Figure 8

RAINFALL INTENSITY-DURATION FREQUENCY CURVES

LA PERLE, SOUFRIERE,
ST. LUCIA

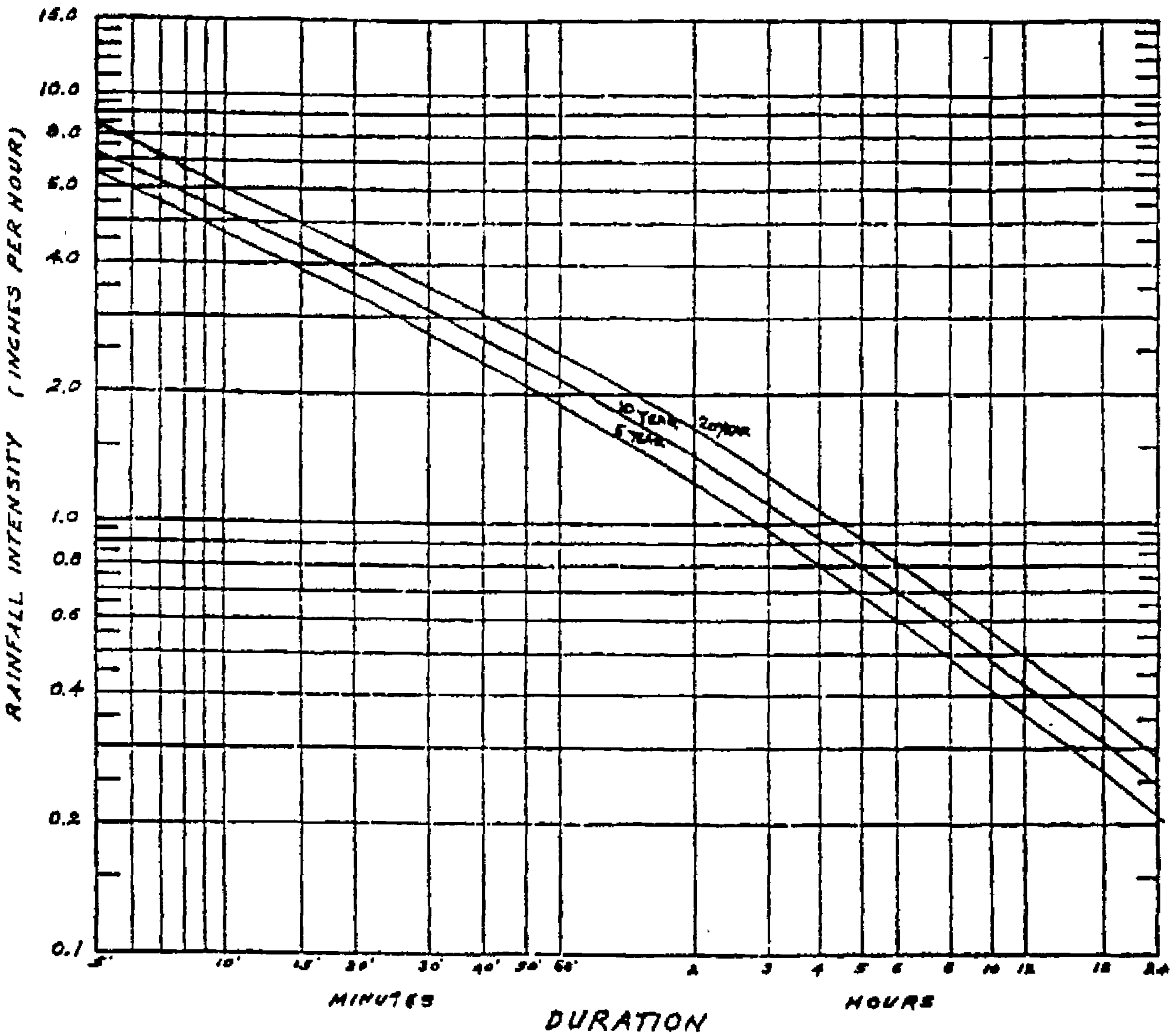


Figure 9

2.5 Tsunamis

Tsunamis (sometimes colloquially called tidal waves) are usually caused by tectonic earthquakes and volcanic eruptions. Landslides and underwater explosions have also been known to cause tsunamis. There are few historical records of tsunamis in the Caribbean. However, recent studies by Martin Smith and John Shepherd have identified future eruptions of the Kick 'em Jenny volcano as a potential tsunami hazard to St Lucia. The travel time would be about 30 minutes from eruption at source to Castries and the final run-up value on the St Lucia west coast would be about 1.8 metres for a realistic scenario. The 1755 Lisbon earthquake produced tsunami waves in Barbados and, probably, in St Lucia as well. Such an event, with a return period of a few hundred years, could produce tsunami waves on St Lucia's east coast of between 2 and 5 metres. Figure 10 at the end of this section shows the tsunami hazard in the Eastern Caribbean.

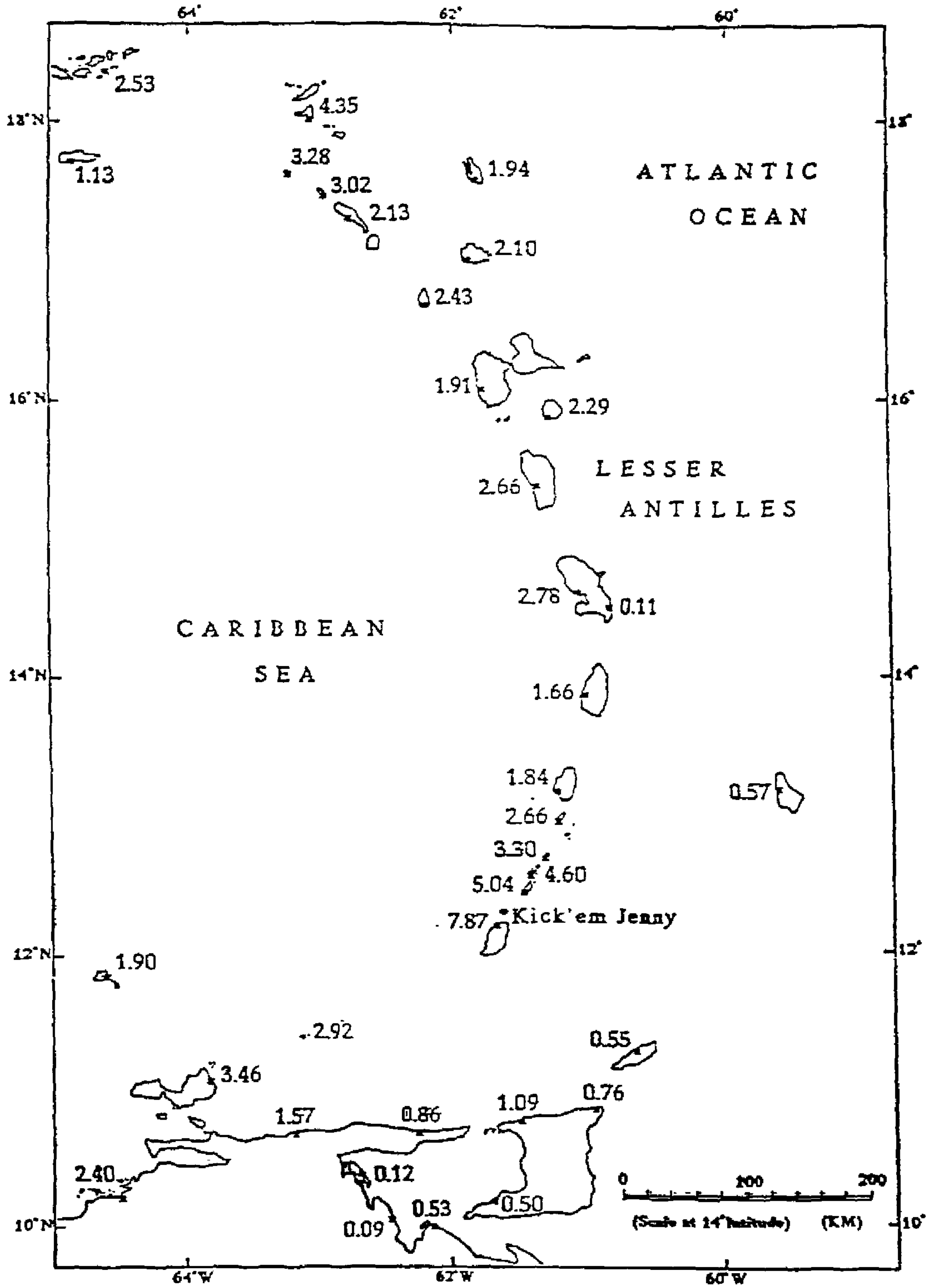


Fig. 10 Final run-up values in metres for a 'realistic' scenario event at Kick'em Jenny (VEI = 3).

2.6 Storm Surges

Storm surges are associated with hurricanes and consist of unusual volumes of water flowing onto shorelines. Such surges have been responsible for much of the damage caused by hurricanes, especially in large, low-lying coastal settlements.

Storm surges are complex phenomena which behave quite differently from one shoreline to another. The several main components governing their behaviour are:

Astronomical Tide:	water levels due to tidal variation;
Initial Water Level.	elevated basin-wide water levels caused by larger storms,
Pressure Deficit:	elevated water levels caused by low pressure systems;
Inland Runoff	raised water levels in rivers and sea outfalls due to prolonged rainfall,
Current Surge:	ocean currents caused by high winds leading to the "piling up" of shallow waters;
Wave Setup:	water accumulating from continuous trains of waves on breaking on shoreline,
Wave Action & Runup:	effect of actual waves superimposed on the above factors.

As well as causing flooding and damage to coastal structures, storm surges may also precipitate flooding further inland through the blockage of the outfalls of drainage systems

The information in this sub-section has been taken from OAS/CDMP documents