Pan American Health Organization
DIPECHO

Health Services Facilities in the Eastern Caribbean

Terms of Reference for Consultants and Standards

(with particular reference to Natural Hazards)

July 2000

Prepared for the Pan American Health Organization
under the Disaster Prevention, Mitigation and Preparedness Programme
of the European Community Humanitarian Office

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CONTENTS

1 INTRODUCTION

1.1 The Purpose of the Project

Throughout the world, including the Caribbean, natural hazards cause as much damage to health-care facilities as they do to buildings of less importance. This is both regrettable and avoidable. Health-care facilities deserve special attention because of their roles during the active periods of storms and also as post-disaster assets.

It goes without saying that the damage and destruction of hospitals would put the affected population at risk during severe storms and after all severe natural-hazard events.

It is often said that safe buildings may not be affordable, especially in relatively-poor developing countries. This is a fallacy. Particularly with respect to hurricane resistance, safe buildings are not only technically feasible but also achievable at very modest cost. This thesis has been tested and confirmed on several occasions over the years.

The Pan American Health Organization (PAHO) has been in the forefront of promoting safer buildings (including, but not limited to health-care facilities) in the Caribbean during the past two decades. In the present programme PAHO is assisted by funding from the Disaster Prevention, Mitigation and Preparedness Programme of the European Community Humanitarian Office (DIPECHO) for demonstration retrofitting sub-projects in St Lucia and Grenada. These sub-projects have as their aims:

1. Contribute to vulnerability reduction of Victoria Hospital (St Lucia) and St George's Hospital (Grenada)

2. Demonstrate the process of retrofitting for vulnerability reduction for natural hazards

3. Widen the mitigation fraternity by the exposure, involvement and training of local engineers in the processes of retrofitting

4. Document the project for use as case studies in other countries

5. Promote vulnerability reduction through retrofitting of existing facilities

The additional aim of the present project and the specific aim of this document is:

6. Promote vulnerability reduction through appropriate design criteria for new facilities

It is recognised that the suitability of health-care facilities depends on several factors other than structural safety. Some of these factors are location, water storage and supply, standby power and telecommunications within the facility and externally. Obviously the functional and administrative aspects of the facility are of paramount concern. Most of these issues are already being addressed by other agencies. The focus of this document is on the physical vulnerability of the facilities to wind forces, seismic forces and torrential rain.

1.2 Terms of Reference

The portion of the overall Terms of Reference (ToR) relevant to the subjects of the present document is:

> Prepare design criteria for mitigation to be included in the plans of Saint Lucia's Ministry of Health and the European Union for the new hospital wing.

Since the start of this project the St Lucia Ministry of Health has made a decision not to proceed with the new hospital wing at Victoria Hospital but to build a complete new hospital on another site. The design criteria in this report will therefore be for the proposed new hospital.

1.3 Issues Addressed in other Reports under this Assignment

Separate country reports have been prepared for St Lucia (by Caribbean Consulting Engineers - Roland Theobalds) and Grenada (Consulting Engineers Partnership Ltd - Selwyn Woodroffe). Those reports describe the demonstration retrofitting sub-projects mentioned in section 1.1.

1.4 An Issue not Addressed in the Terms of Reference

It is often not sufficient to specify appropriate standards for projects. There is also the need to ensure that the standards are being followed and are being interpreted correctly.

As an aid to addressing these problems there are presented in this document suggested terms of reference for consultants working on health-care facilities. These terms of reference are deliberately more detailed than usual. This would facilitate a more orderly approach to the execution of the consultants' functions and also facilitate the monitoring of these functions by the clients' representatives.

Experience shows that such an orderly approach reduces the incidence of oversights, reduces abortive work by the consultants and leads to a more efficient project overall.

2 TERMS OF REFERENCE FOR DESIGN CONSULTANTS

2.1 Briefing

The consultant will receive a brief from the client. In particular, the consultant will initiate specific discussion on natural hazards and reach agreement with the client on performance expectations for the project. The client's policy position with respect to natural hazards and the performance expectations in the event of differing levels of severity of hurricanes, earthquakes, torrential rains and other phenomena is to be clearly articulated. Decisions must be made on the appropriate levels of safety for the planned facilities. This is addressed further in Section 3 of this document.

2.2 Document Search and Interviews

The consultant will request from the client and receive all available reports related to the project and the site.

After study of the available documents the consultant will carry out interviews of the technical and other personnel of the client to supplement the information on the project obtained from the documents.

2.2.1 Inception Report

On completion of the document review and supplementary interviews the consultant will prepare an inception report including:

- the consultant's understanding and interpretation of the terms of reference;
- changes to the terms of reference since the start of the assignment;
- an appraisal of the available information and an outline of the consequential field investigations to be conducted so as to complement the information already obtained, including any special investigations which may be required;
- an outline of the programme for the remainder of the assignment.

2.3 Field Surveys and Laboratory Tests

The consultant will carry out field surveys to supplement and confirm previously-obtained information. Such field'surveys may include laboratory testing of materials taken from the site.

For the assessment of storm-water drainage provisions it may be necessary for the consultant to undertake topographic surveys of the site.

For the assessment of foundation conditions affecting anchorage and the seismic response of facilities it will be necessary for the consultant to undertake geotechnical surveys of the site and it may be necessary to undertake geophysical surveys as well.

2.4 Preliminary Appraisals, Conceptual Design and Project Definition

The consultant will interpret the brief and prepare conceptual designs for consideration by the client.

The design, analysis and detailing of buildings to be resistant to earthquakes and hurricanes are complex processes involving many issues. As an *aide-mémoire* for detailed engineering, Appendix III is included in this document. Hospital planners and architects usually dominate this phase of a project. It is important that they receive early advice from the engineers on the design team on the implications for the design concepts of natural hazards.

2.4.1 Design Stage I Report

On completion of the work described in 2.3 and 2.4 the consultant will prepare a design stage I report including:

- the design standards and codes to be used on the project;
- the agreed design criteria for the project;
- preliminary design and drawings;
- outline specification;
- procurement procedures for the construction contractors and suppliers;
- conditions of contract - general and particular;
- cost estimates;
- an outline of the programme for the remainder of the assignment.

The client will review the report and hold discussions with the consultant (which may lead to revisions) and will conclude with the formal approval of the project, as defined in the report, for implementation.

The vulnerability of a building to earthquakes and hurricanes is very often associated with the non-structural components of the building. These components rarely receive the attention they deserve from the construction industry. As *aides-mémoire* Appendices I and II are included in this document addressing this issue.

In modern hospitals those elements not part of the principal load-resisting system account for approximately 80% of the cost. Traditionally, structural engineers are not consciously and directly involved with these elements. Architects, electrical engineers and mechanical engineers are usually responsible for them. These disciplines do not usually focus on wind and earthquake resistance. In most cases the relevant persons are by no means equipped for the task of providing wind-resistant and earthquake-resistant components. The solution of this problem may involve the reallocation of design responsibilities among the members of the design team with a commensurate reallocation of compensation.

This stage effectively defines the project. It is therefore most important that it be done thoroughly by the design team and be reviewed carefully by the client. The likelihood is that a satisfactory Design Stage I phase would lead to a successful project.

2.5 Design Stage II

The consultant will undertake the detailed design, analysis and detailing of all aspects of the works to be constructed. This phase of the project will include:

- the iterative process of analysis and refinement of the designs;
- construction details;
- technical specifications;
- bills of quantities.

2.6 The Tender Process

The consultant will undertake the following tasks:

- prequalification of contractors and suppliers;
- inviting tenders;
- pre-tender meeting with the bidders;
- answering questions from bidders during the tender period;
- opening of tenders, review and reporting on tenders.

The tender process culminates with the client's decision and the contract award by the consultant on behalf of the client.

2.7 Construction Stage

The consultant will undertake the following tasks:

- conduct a pre-construction meeting with the chosen contractor;
- undertake supervision-in-chief, provide resident supervision in appropriate circumstances and advise the client on the need for additional inspectors;
- conduct site meetings and prepare progress reports for issue to the client;
- check shop drawings and provide approvals when compliance with the contract documents is achieved;
- issue and administer variations and additions to the contract;
- certify payments to the contractor;
- issue the certificate of substantial completion;
- monitor latent defects during the maintenance period;
- deliver as-built drawings to the client.

At the end of the maintenance period the consultant will carry out a final inspection of the works and issue the final certificate for payment to the contractor.

3 STANDARDS FOR DESIGN

3.1 General

Codes of practice and standards should be used for new construction to achieve more consistent and predictable performance and to improve levels of safety.

Very commonly consultants use the minimum standards of codes, usually because of commercial pressures. Also, most codes are for general construction and not specific to the needs of critical infrastructure projects such as health-care facilities.

There is also the problem of building to unnecessarily high and expensive standards. Clients (in consultation with their consultants) should select, on informed and rational bases, appropriate design criteria for facilities of differing importance. Suggestions for health-care facilities are made in the following sections 3.2 to 3.5 to assist in this process, but not to preempt such consultation and selection.

Clients should recognise the need to review, on an ongoing basis, the conditions of their facilities and their standards. Standards do change as knowledge increases.

3.2 Design Criteria for Wind

3.2.1 Basic Wind Speeds and Reference Pressures

Different codes and standards define and describe wind forces and speeds differently. Since Caribbean clients have to deal with different standards regimes it is important to be able to convert from one standard to another. The main parameters used in defining wind speeds are:

- averaging period
- return period
- height above ground
- upstream ground roughness
- topography

Thus, in the commonly-used OAS/NCST/BAPE "Code of Practice for Wind Loads for Structural Design"[1] the definition reads:

> *"The basic wind speed V is the 3-second gust speed estimated to be exceeded on the average only once in 50 years ..... at a height of 10 m above the ground in an open situation ....."*

3.2.2 Caribbean Uniform Building Code (CUBiC)[2]

Figure 1 at the end of this section shows a map of the Caribbean region with isolines of reference velocity pressures taken from CUBiC for 50-year return periods.

Table 1 at the end of this section gives the CUBiC reference pressures (50-year return periods) along with corresponding wind velocities for different averaging periods.

3.2.3 Averaging Periods

Figure 2 at the end of this section presents graphs which may be used to convert wind speeds of one averaging period to speeds of another averaging period.

The OAS/NCST/BAPE "Code of Practice for Wind Loads for Structural Design" uses an averaging period of 3 seconds. CUBiC uses an averaging period of 10 minutes.

3.2.4 Return Period

[1]BNS CP28 - Code of Practice for Wind Loads for Structural Design; sponsored by the Organization of American States, the National Council for Science & Technology and the Barbados Association of Professional Engineers; prepared by Tony Gibbs, Herbert Browne and Basil Rocheford; November 1981.

[2]CUBiC Part 2 - Structural Design Requirements; Section 2 - Wind Load; 1985

The client, in consultation with (and advice from) its consultant, should make conscious decisions with respect to desired levels of safety for different facilities. These decisions can be translated into return periods. The longer the return period the greater the level of safety. Figure 3 at the end of this section presents graphs from the OAS/NCST/BAPE Code addressing this parameter. For most health-care facilities, a return period of 100 years is the suggested minimum appropriate standard.

The reference pressure for St Lucia is given in CUBiC as 0.76 kilopascals (kPa) for a 50-year return period. It is appropriate to apply an importance factor of 1.2 to this pressure (equivalent to a 10% increase in wind speed) to allow for the greater importance of a referral hospital in St Lucia.

3.3 Design Criteria for Earthquake

Much less is known about the earthquake hazard than about the wind and rainfall hazards in the Caribbean. Because of this, and because of the ongoing research in this field, there is the need for regular reviews of design criteria by the construction industry in general and consultants in particular. There may also be the justification for site-specific and project-specific studies for large or critical facilities.

For most projects, the guidance provided by existing standards and research papers would suffice. Some of these documents are listed below.

3.3.1 Caribbean Uniform Building Code (CUBiC)[3]

Table 2 at the end of this section gives the CUBiC zone factors (Z) for different locations in the region. The table also shows the corresponding values for the Uniform Building Code (USA) and the Structural Engineers Association of California (SEAOC) code.

St Lucia is assigned a Z factor of 0.75 in CUBiC.

3.3.2 PAIGH[4] Research

Figure 4 at the end of this section shows a map of the Eastern Caribbean region with isolines of accelerations due to earthquakes based on a recent research programme which was completed *circa* 1994 and finally published in 1997[5]. It represents some of the latest thinking

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[3]CUBiC Part 2 - Structural Design Requirements; Section 3 - Earthquake Load; 1985

[4]Instituto Panamericano de Geografia y Historia

[5]Seismic Hazard in Latin America and the Caribbean - Final Report; Instituto Panamericano de Geografia y Historia; Volume 1 (JG Tanner, JB Shepherd); Volume 5 (JB Shepherd, JG Tanner, CM McQueen, LL Lynch); 1997

on the seismicity of the region.

It should be noted that, in comparison to the guidance in CUBiC:

- o BVI, Antigua & Barbuda and Montserrat would warrant a Zone 4 rating (CUBiC Z = 1.00, SEAOC 1990 Z = 0.4);
- o the whole of Trinidad would warrant a Zone 3 rating;
- o Dominica would warrant a Zone 2+ rating;
- o Grenada, St Lucia and St Vincent would warrant a Zone 2 rating.

Table 3 at the end of this section shows this information in comparison with the CUBiC, UBC and SEAOC factors.

3.3.4 Importance Factor

Earthquakes are not yet amenable to statistical analysis and to the determination of return periods in the same way as windstorms or rain. Nevertheless the client, in consultation with the consultant, must still make conscious decisions with respect to desired levels of safety for different facilities. These decisions are translated into importance factors in codes and standards. These factors usually vary from 1.0 to 1.5. For health-care facilities, an importance factor of 1.2 is the suggested minimum appropriate standard.

For the sole referral hospital in St Lucia the more-critical areas would warrant an importance factor of up to 1.5.

3.3.5 Concept

Satisfactory earthquake-resistant design requires more than the faithful following of the mathematical requirements of standards documents. Appropriate geometry of the overall building or structure and appropriate structural systems are critical for success.

3.3.6 Detailing

Good conceptual design and good analysis must be complemented by good detailing in order to achieve satisfactory performance of buildings and other facilities in earthquakes.

3.3.7 Moving the Goalposts

In most Caribbean islands health-care facilities operate in normal times with little or no spare capacity. In the aftermath of a major earthquake the times are certainly not normal. In such circumstances it is vital that the health-care facilities operate at close to optimum efficiency.

The conventional and traditional approach to earthquake-resistant design is to resist minor earthquakes without damage, to resist moderate earthquakes without structural damage (but tolerating non-structural damage) and to resist major earthquakes without collapse. In other words, emphasis is placed on saving lives, not on saving facilities. This would no longer do for hospitals and other health-care facilities.

There are two aspects that must be addressed in the new, proposed paradigm for health-care facilities - the improved performance of non-structural components and the mitigation of damage to load-bearing structures through the use of response-reducing devices.

Energy isolating and dissipating devices are no longer untried. Many successful installations have been completed in several countries. These devices protect buildings by limiting the energy entry at source (*eg* base isolation) or by providing energy-dissipating devices within the structure. By so doing it becomes feasible to move the goalposts with respect to performance expectations.

The aim is to design health-care facilities so that they function with little degradation in efficiency in times of major earthquakes.

It is recommended that base isolation and energy dissipating devices be investigated for feasibility at an early stage in the conceptual design of the proposed hospital.

3.4 Design Criteria for Torrential Rain

3.4.1 Design Graphs

Intensity-duration-frequency curves have been developed for several territories in the region and may be available through the Caribbean Institute for Meteorology and Hydrology in Barbados. Samples are given at Figure 5 at the end of this section.

3.4.2 Return Period

Traditionally, quite short return periods have been selected for design rain storms. It was quite common for facilities to be designed for 1-in-20-year storms. Much damage and disruption is caused with increasing frequency by torrential rains. There needs to be a reassessment of this design criterion. For health-care facilities, a return period of 50 years is the suggested minimum appropriate standard.

3.4.3 Changing Conditions

The other factor affecting rain runoff and flooding is upstream development, usually outside of the control of the client for a particular facility. It is not unlikely that well-designed drainage systems prove to be inadequate some time after they have been implemented because of greater runoff than could reasonably have been anticipated at the time of design. This typically happens when land use upstream is changed due *eg* to urban expansion. Therefore it is appropriate to adopt a conservative approach to the selection of rainfall design criteria.

For the proposed hospital in St Lucia a 10-minute intensity of 250 mm per hour is recommended.

3.5 Design Criteria for Storm Surge and Tsunami

3.5.1 Storm Surge

This complex phenomenon is of interest for coastal sites. Computer models are available for developing storm-surge scenarios for coastlines. One such model is TAOS (The Arbiter of Storms) developed by Charles C Watson and tailored for the Caribbean under the USAID/OAS-CDMP[6] programme. This model is now operational at the Caribbean Institute for Meteorology and Hydrology in Barbados.

3.5.2 Tsunami

Figure 6 at the end of this section shows a credible scenario from a likely eruption of the Kick 'em Jenny submarine volcano just north of Grenada. It is not commonly remembered that the great Lisbon (Portugal) earthquake of 1755 generated a significant tsunami in Barbados and in the 19th century many lives were lost in the (now) US Virgin Islands due to a tsunami generated by a nearby earthquake.

3.5.3 Advice

The studies of both of these hazards are highly specialised subjects for which expert advice should be sought for all low-lying, coastal developments.

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[6]Caribbean Disaster Mitigation Project; funded by the United States Agency for International Development; implemented by the Organization of American States

Reference Wind Velocity Pressures
and
Wind Speeds
(50-year return period)
(taken from CUBiC)

Location	q_{ref} CUBiC	10 min CUBiC	1 hr	1 min (or "fastest mile")	3 sec
Antigua	0.82	37	35	45	56
Barbados	0.70	34	32	41	51
Belize - N	0.78	36	34	43	54
Belize - S	0.55	30	29	37	45
Dominica	0.85	38	36	46	57
Grenada	0.60	32	30	38	47
Guyana	0.20	18	17	22	27
Jamaica	0.80	37	35	44	55
Montserrat	0.83	37	36	48	59
St Kitts/Nevis	0.83	37	36	48	59
St Lucia	0.76	36	34	43	57
St Vincent	0.73	35	33	42	56
Tobago	0.47	28	26	38	42
Trinidad - N	0.40	26	25	31	39
Trinidad - S	0.25	20	19	25	30
Notes	q_{ref} = pressures in kilopascals (kPa)	wind speeds in metres per second (ms^{-1})			

Table 1

Z Values
(taken from CUBiC)
and Equivalent Seismic Zone Factors and Numbers

Territory	Z Value CUBiC & UBC 85	Z Factor UBC 1988 & SEAOC 1990	Zone Number SEAOC
Antigua	0.75	0.3	3
Barbados	0.375	0.15 - 0.2	2
Belize - (areas within 100km of southern border, ie including San Antonio and Punta Gorda but excluding Middlesex, Pomona and Stann Creek)	0.75	0.3	3
Belize - (rest of)	0.50	0.2	2+
Dominica	0.75	0.3	3
Grenada	0.50	0.2	2+
Guyana - (Essequibo)	0.25	0.1	1+
Guyana - (rest of)	0.00		
Jamaica	0.75	0.3	3
Montserrat	0.75	0.3	3
St Kitts/Nevis	0.75	0.3	3
St Lucia	0.75	0.3	3
St Vincent	0.50	0.2	2+
Tobago	0.50	0.2	2+
Trinidad - (NW)	0.75	0.3	3
Trinidad - (rest of)	0.50	0.2	2+

Table 2

Seismic Hazard Values for Structural Design Purposes in the Commonwealth Caribbean

(Compiled by Tony Gibbs)

Country	CUBiC Z values 1985	equivalent Zone No (SEAOC 80)	equivalent Z factor (UBC 88)	PAIGH isoacceleration lines max	PAIGH isoacceleration lines min	PAIGH/TG Z factor 1993/94	PAIGH/TG Zones 1993/94	equivalent Zone No (SEAOC 80)	equivalent Z factor (UBC 88)	conservative Zone No (SEAOC 80)	conservative Z factor (UBC 88)
Anguilla				300	250	0.500	2.5	2.5	0.20	3	0.30
Antigua & Barbuda	0.750	3	0.30	850	450	1.000	4	4	0.40	4	0.40
Bahamas - southern				115	70					1	0.15
Barbados	0.375	2	0.15	225	175	0.375	2	2	0.15	3	0.25
Belize - north	0.500	2.5	0.20	200	120					2	0.20
Belize - south	0.750	3	0.30	240	200					3	0.25
British Virgin Islands				550	450	1.000	4	4	0.40	4	0.40
Cayman Islands				160	80	0.375	2	2	0.15	2	0.20
Cuba				250	80					3	0.25
Dominica	0.750	3	0.30	300	250	0.500	2.5	2.5	0.20	3	0.30
Dominican Republic				425	225					4	0.40
Grenada	0.500	2.5	0.20	175	125	0.375	2	2	0.15	2	0.20
Guyana - Essequibo	0.250	1.5	0.10	130	90					1	0.15
Guyana - remainder	0.000	0	0.00	90	80					1	0.10
Haiti				250	125					3	0.25
Jamaica	0.750	3	0.30	260	150					3	0.30
Montserrat	0.750	3	0.30	600	400	1.000	4	4	0.40	4	0.40
Puerto Rico				350	240			4	0.40	4	0.35
St Kitts & Nevis	0.750	3	0.30	450	300	0.750	3	3	0.30	4	0.40
St Lucia	0.750	3	0.30	175	150	0.375	2	2	0.15	2	0.20
St Vincent & the Grenadin	0.500	2.5	0.20	175	100	0.375	2	2	0.15	2	0.20
Trinidad - NW	0.750	3	0.30	370	300	0.750	3	3	0.30	4	0.40
Trinidad - remainder	0.500	2.5	0.20	370	300	0.750	3	3	0.30	4	0.40
Tobago	0.500	2.5	0.20	300	270	0.500	2.5	2.5	0.20	3	0.30
Turks & Caicos Islands				160	80					2	0.20

Notes
In the Zone columns 1.5 means between 1 and 2
In the Zone columns 2.5 means between 2 and 3
CUBiC = Caribbean Uniform Building Code
SEAOC = Structural Engineers Association of California
UBC = Uniform Building Code (ICBO)
ICBO = International Conference of Building Officials
PAIGH = Pan American Institute of Geography and History
PAIGH/TG = PAIGH's research (by Dr Shepherd) interpreted by Tony Gibbs

Seismic Hazard Values for Structural Design Purposes
Commonwealth Caribbean
Compiled by Tony Gibbs
22-Jan-99

Table 3

Regional Map of Wind-pressure Contours
(from CUBiC)
Figure 1

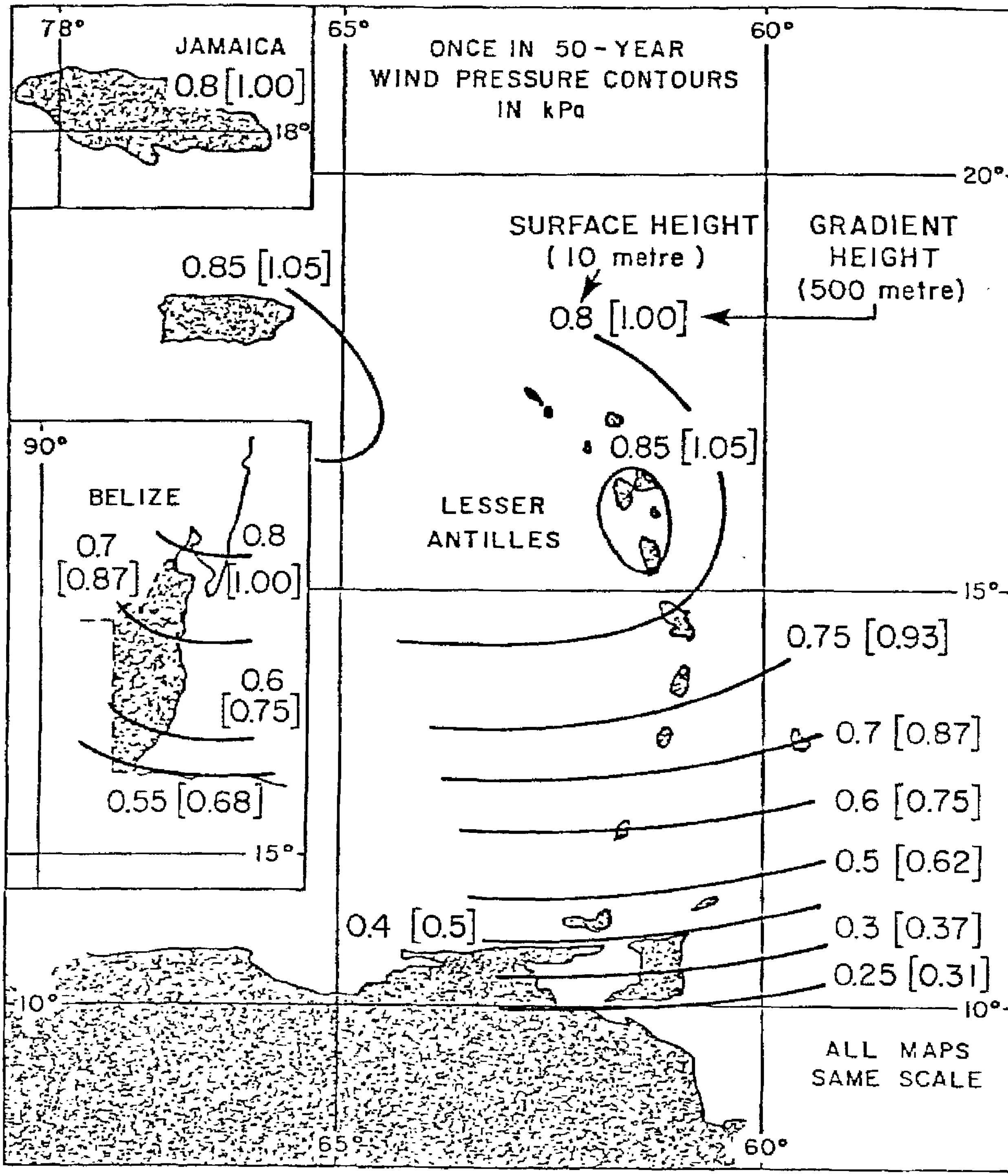
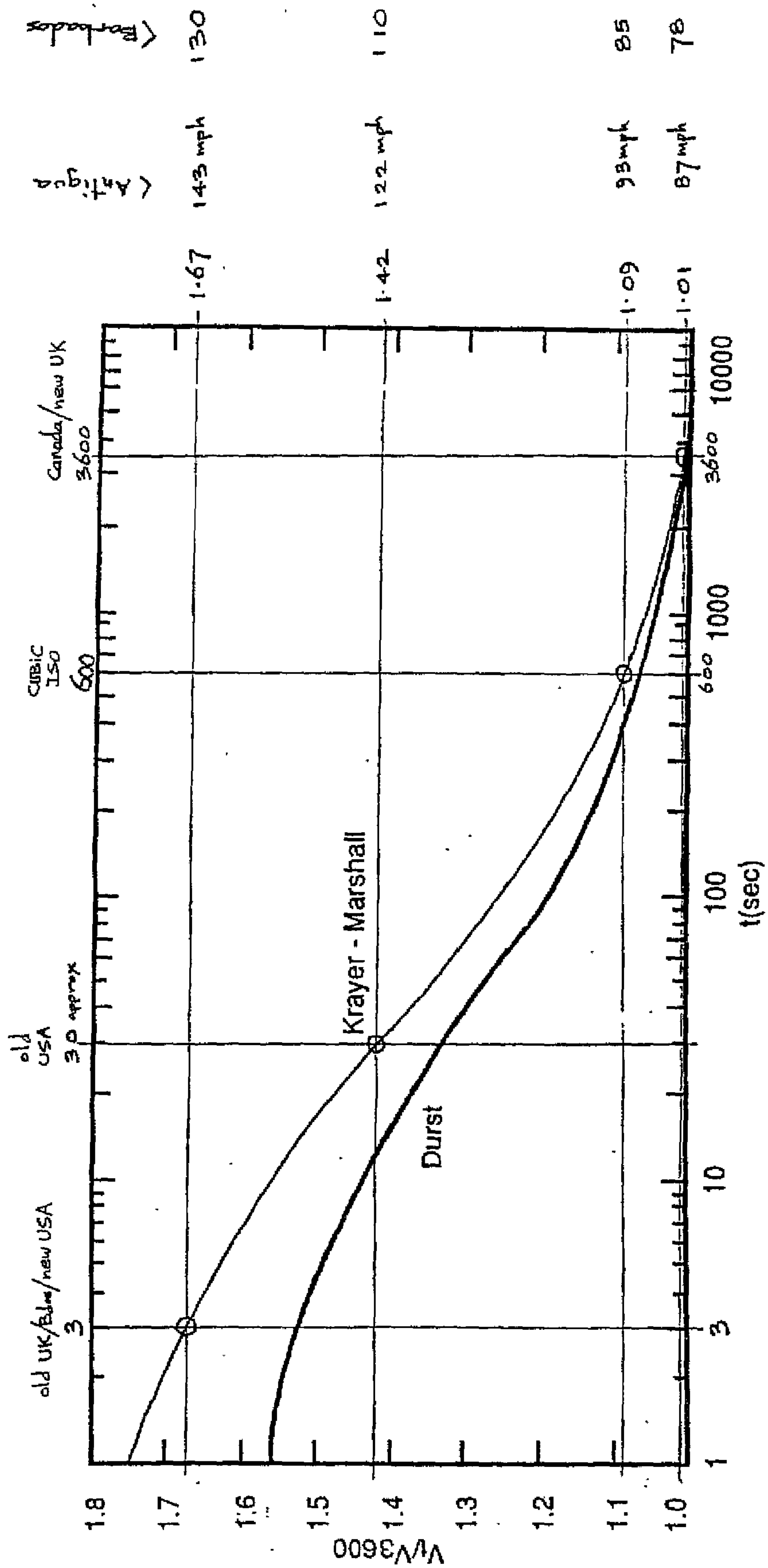


Figure A200.1 Map of Region of Application

Wind-speed Variation with Averaging Period

(from Durst and Krayer-Marshall)

Figure 2



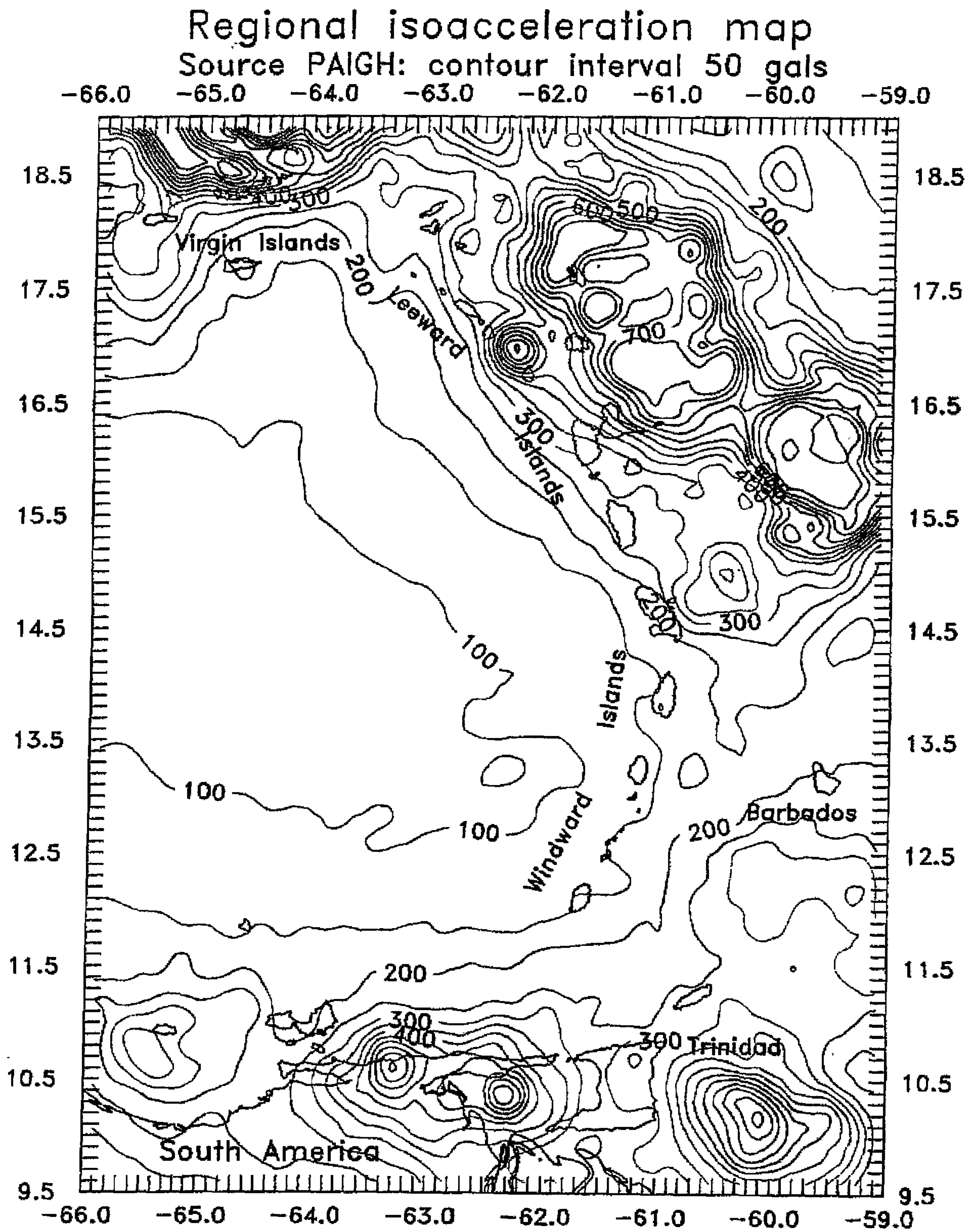
Ratio of Probable Maximum Speed Averaged over *t* Seconds to Hourly Mean Speed

Source: Ref. 4

Isoacceleration Map of the Eastern Caribbean

(from John Shepherd - PAIGH)

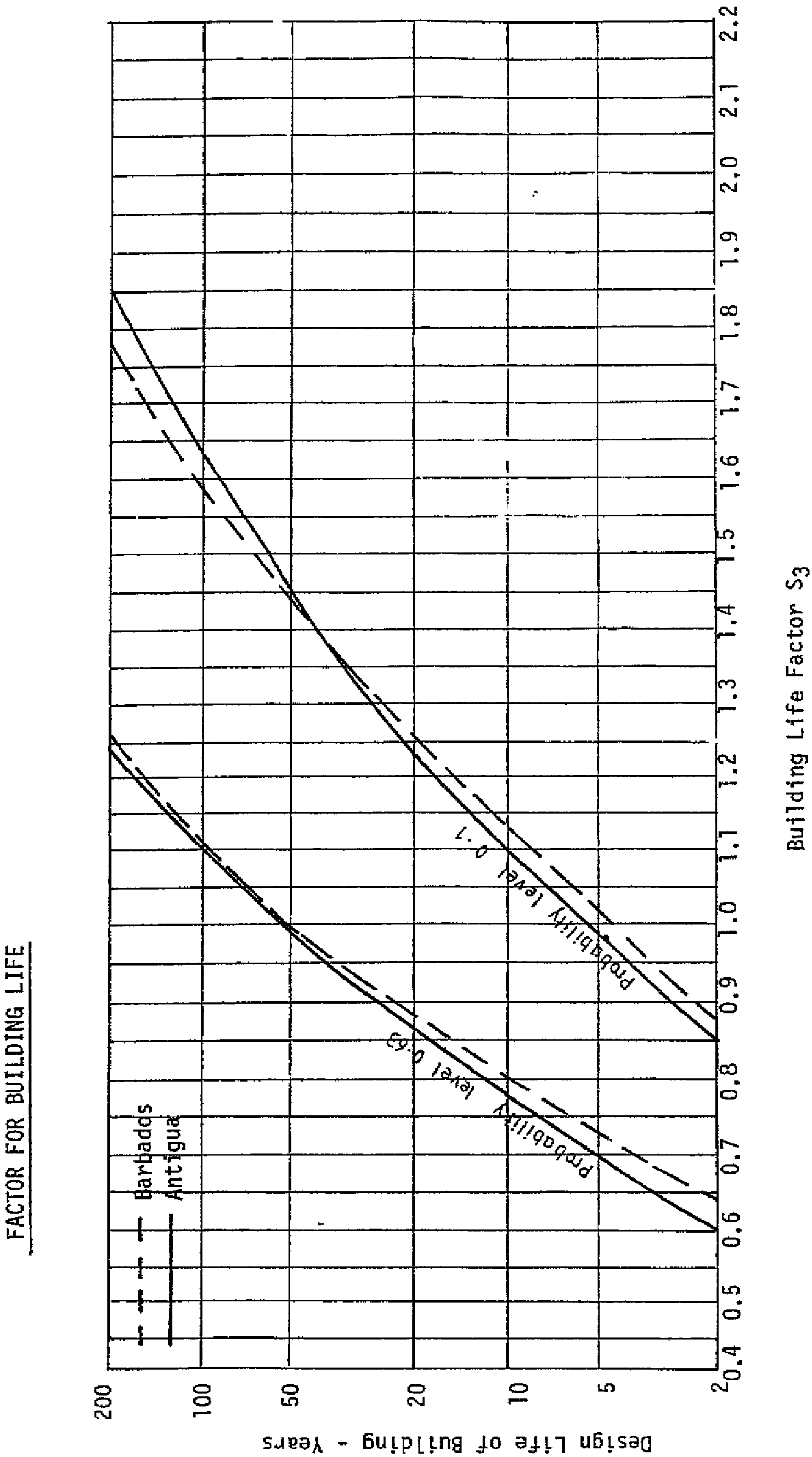
Figure 4



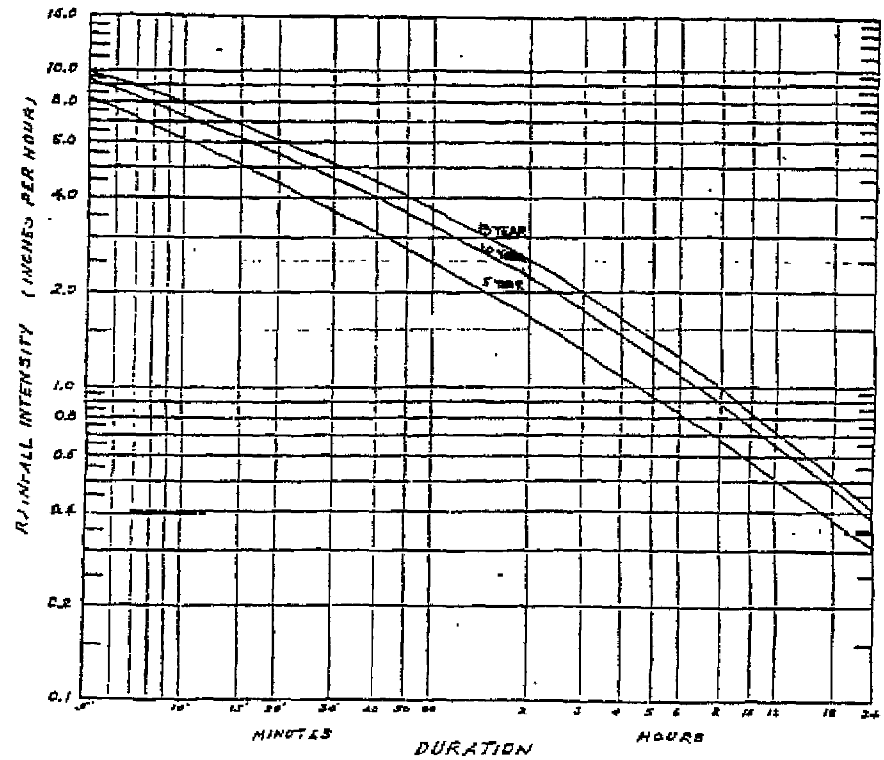
S_3 Factor for Return Period and Probabilities

(from OAS/NCST/BAPE Code)

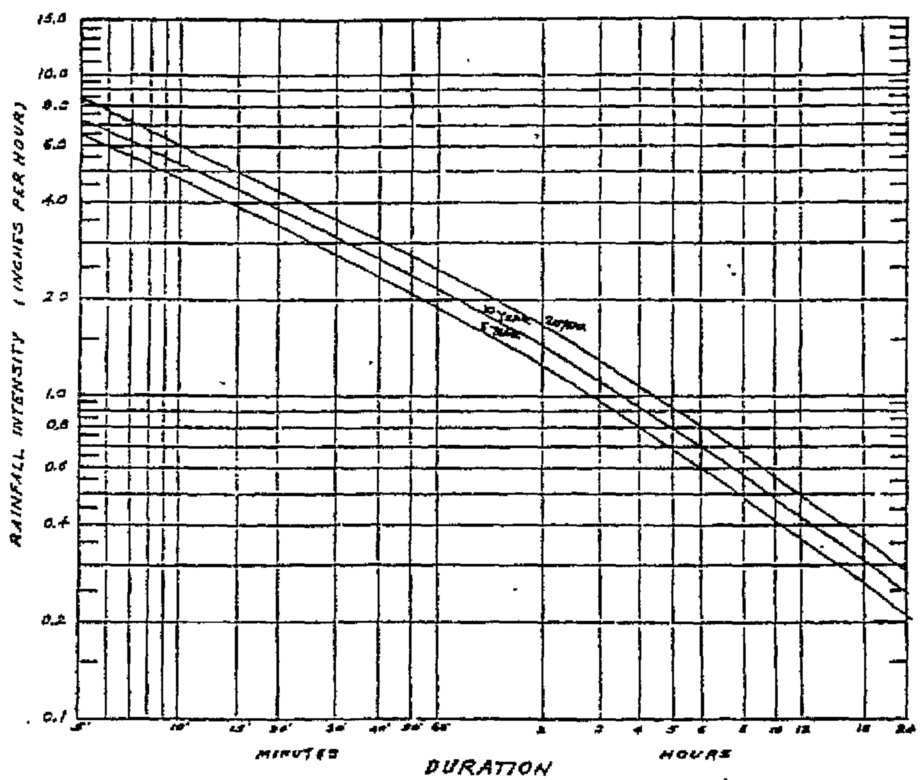
Figure 3



Rainfall-Duration-Frequency Curves for St Lucia
Figure 5



Union (north)

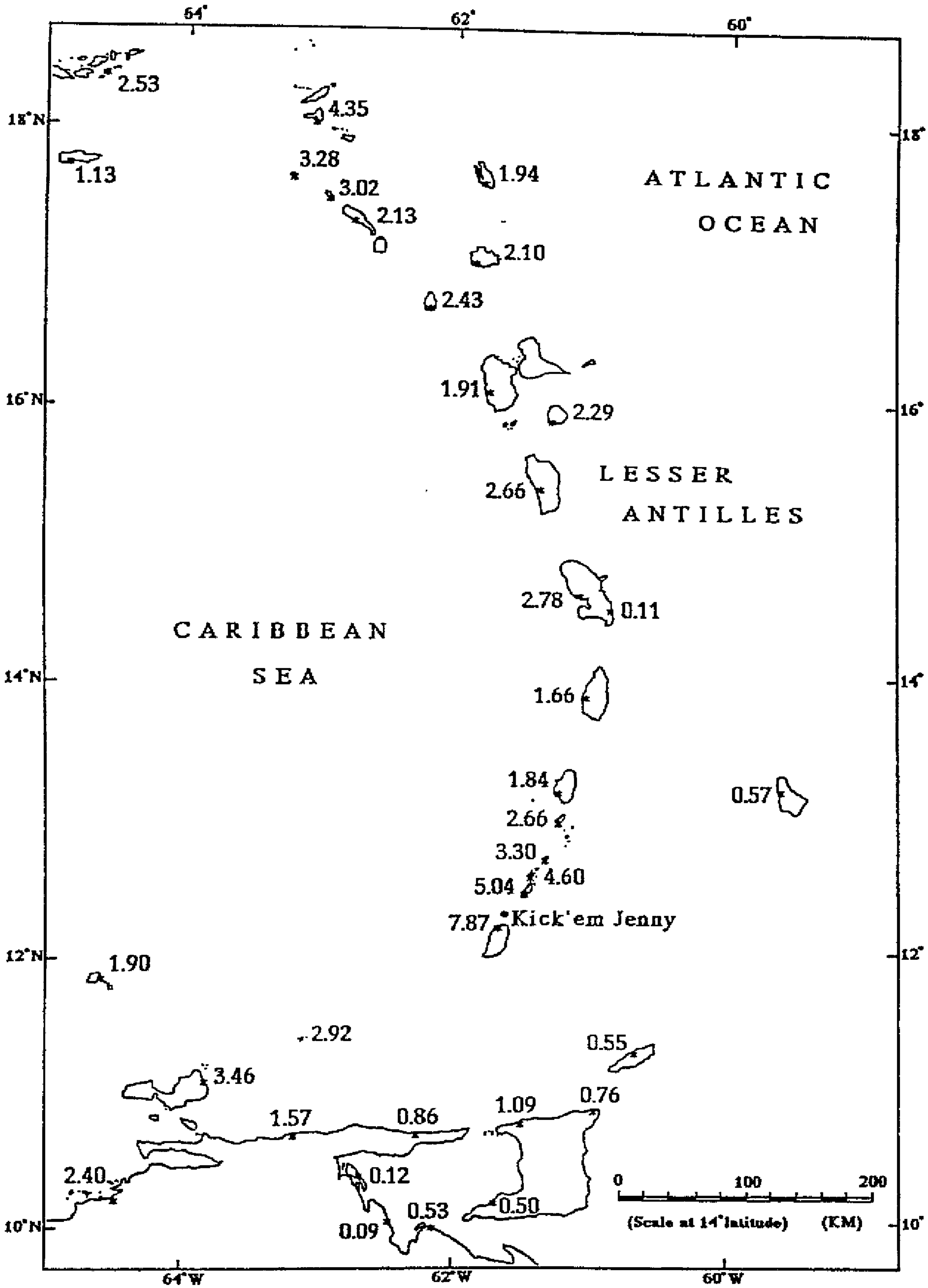


La Perle, Soufrière (south)

Tsunami Heights for Realistic Kick 'em Jenny Eruption

(from Martin Smith & John Shepherd - 1992 VEI = volcanic explosive index)

Figure 6



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