STATUS OF HAZARD MAPS VULNERABILITY ASSESSMENTS AND DIGITAL MAPS IN THE CARIBBEAN

FINAL REPORT

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Preface

Hazard mapping and vulnerability assessment are the important first steps for any initiative for disaster reduction. In promoting these activities for CDERA member states on the long-term basis in future, it is essential first of all to know their current status and to compile a database of relevant information and materials.

From 2002 – 2005, the Caribbean Disaster Emergency Response Agency (CDERA) is implementing two major regional initiatives which are designed to reduce vulnerability to natural and technological hazards. These are the Japanese International Cooperation Agency (JICA) supported Caribbean Disaster Management (CADM) Project and the Canadian International Development Agency (CIDA) supported; Organization of American States executed Caribbean Hazard Mitigation Capacity Building Programme (CHAMP). The hazard mitigation planning component of the latter is being implemented in close collaboration with the Caribbean Development Bank's Disaster Mitigation Facility for the Caribbean. Hazard maps, vulnerability assessment studies, and digital maps are critical inputs to both initiatives.

The CADM project intends to establish within the project period of three years an institutional scheme for flood hazard mapping and community disaster management planning for all CDERA member states in the future. Information on hazard maps, vulnerability assessment studies and digital maps are essential for planning such future activities.

This survey conducted over the period over the period August – October 2003, reviewed the status of these thematic activities in twenty (20) countries/territories: sixteen (16) CDERA Participating States: Anguilla, Antigua and Barbuda, The Bahamas, Barbados, Belize, The British Virgin Islands, Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago, and Turks & Caicos Islands; and 4 non-participating States: Haiti, Martinique, Suriname and Puerto Rico.

The objectives of the Survey were as follows:

1. To determine the status of hazard maps and vulnerability assessment studies and their use in the socio-economic planning and management of the Caribbean.
2. To determine critical success factors, gaps and best practices in the preparation and use of hazard maps and vulnerability assessment studies in the Caribbean.
3. To compile a database of hazard maps, vulnerability assessment reports, and digital maps available in the Caribbean.

Hazards considered under the survey included natural hazards such as floods, hurricanes, landslides, coastal disasters (surge, wave, and erosion), earthquakes, and volcanic eruptions as well as technological hazards. The types of vulnerability assessment considered were structural, economic, and human assessments.

This report was prepared by Jacob Opadeyi, Shahiba Ali, and Eva Chin of the Centre for Geospatial Studies, Faculty of Engineering, the University of the West Indies, St. Augustine, Trinidad and Tobago. The study was carried out with the financial support from JICA and CIDA.

Status of Hazard Maps, Vulnerability Assessments, and Digital Maps in the Caribbean

Executive Summary

The Caribbean is highly prone to natural hazards. Climatic hazards such as strong winds and heavy rains associated with annual tropical depressions, storms and hurricanes often give rise to floods and landslides. Volcanic eruptions and earthquakes have led to loss of life and property. The emerging phenomena\on of global climate change is felt with increase in the effects of drought and fire. The experience of these hazards has caused the local, national and regional agencies of the region to embark on various forms of hazard mapping and vulnerability assessment studies aimed at reducing the impact of natural disasters.

The objectives of this study are:

1. To determine the status of hazard maps and vulnerability assessment studies and their use in the socio-economic planning and management of the Caribbean.
2. To determine critical success factors, gaps and best practices in the preparation and use of hazard maps and vulnerability assessment studies in the Caribbean.
3. To compile a database of hazard maps, vulnerability assessment reports, and digital maps available in the Caribbean.

The study was carried out in the following 20 Caribbean states:

1. Sixteen (16) CDERA Participating States: Anguilla, Antigua and Barbuda, The Bahamas, Barbados, Belize, The British Virgin Islands, Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent & the Grenadines, Trinidad & Tobago, and Turks & Caicos Islands; and
2. Four (4) non-participating States: Haiti, Martinique, Suriname and Puerto Rico.

The study was undertaken using a standardized questionnaire that was administered to relevant agencies in each of the countries/territories studied. Country visits were undertaken to collect relevant information and to confirm responses provided by respondents to the questionnaire. These were followed by the design and population of a digital database that contains data on hazard mapping, vulnerability assessment and available digital maps in each state. For each state/territory studied, a country report that captured relevant information on the status of hazard mapping, vulnerability assessment, and digital maps was produced.

Two approaches to hazard mapping have been instituted in the Caribbean: region-wide hazard mapping and local hazard map. Regional hazard mapping is used for mapping hazards that are regional in extent and effects. These are mainly wind, surge, storm and seismic hazards. Local hazard mapping focus mainly on in-country flood, landslide, volcanic activities and erosion. The Seismic Research Unit of The University of the West Indies has produced two major sets of seismic hazard maps for the region. In addition to these, Puerto Rico, Martinique, the British Virgin Islands (BVI), Haiti, and Jamaica have undertaken seismic hazard maps for their respective territory/country.

The regional seismic hazard maps were produced at low resolution (0.25°) while the Martinique map has a resolution of 1:10,000.

A regional storm-related, wind, and surge [SWS] hazard mapping with a resolution of 1 km was produced for the region through the OAS/CDMP. Country/Territory focused SWS hazard mapping were produced for Belize, Jamaica, BVI, Haiti, Jamaica, Martinique, Bahamas, Montserrat, Puerto Rico and St. Kitts and Nevis. Volcanic hazard maps exist for Dominica, Grenada, Martinique, Montserrat, St. Kitts and St. Lucia. These are mainly of medium scale (1:25,000) with the exception of Martinique (1:10,000). The inadequacy of these medium scale maps for community-level planning has expressed by the end users.

Flooding is the most common and significant localized hazard in the region. Considerable amount of efforts/resources have been devoted to the production of flood hazard maps in the region. Jamaica has undertaken the most number of flood hazard maps and has developed local experts who have done these mappings for a number of the country's rivers. Landslide hazard maps take an expected second position to flood hazard maps initiatives.

The users of hazard maps cut across the spectrum of governmental agencies, NGOs, and the general public. Each uses these maps to inform public or private land use decisions.

The critical success factors of hazard mapping initiatives in the region are the following:

a. Leadership of regional organizations with commitment to serve countries in the region
b. Determination of national organizations to pursue hazard mapping recognizing this as an important initial step for disaster management
c. Effective collaboration among local agencies
d. Vested interest of the affected local communities
e. Continuous monitoring of the hazardous event
f. Use of digital methods in the preparation of the maps

The region-wide hazard maps in particular do enjoy the following critical success factors:

a. Funding that individual countries would not have been able to provide
b. Use of international experts
c. Consistency of methodology
d. Web-based dissemination of outputs
e. Ease of updates

The study found the following limitations to the flood hazard maps in the Caribbean:

a. Low level of use of digital approach to the production of flood hazard maps.
b. Lack of a standardized methodology to the production of flood hazard maps even

within a country.

c. Use of methodologies that are considered to be limiting in scope.
d. Coarse contour intervals of topographic maps.
e. Limited data on historic flood heights.
f. Inadequate input data such as cross-sections, rainfall, stream flow and land use.
g. Little use of flood hazard maps in community disaster management.
h. Existing flood hazard maps are considered to be dated and need to be updated.
i. Assumptions made in using predictive models are not valid.
j. Use of mean values instead of actual values reduced the impact of extreme events.
k. Short period of data collection due to lack of historic data.
l. Lack of current land use map to assess level of risk.

Vulnerability assessment is a logical next step after hazard identification and mapping. It involves the assessment of the degree of vulnerability of all valuable elements within the sphere of influence of the hazard that has been mapped. Over 56 vulnerability assessments have been conducted in the Caribbean for a number of purposes such as: The general purposes of Vulnerability Assessment Studies in the region are for:

- Disaster mitigation
- Identification of vulnerable elements
- Quantification of economic losses
- Improvement of structural design
- Assessment of management plans
- Location of facilities
- Response planning
- Assessment of adaptation measures
- Evacuation planning
- Establishment of community development plans
- Control of impacts
- Risk assessment
- Calculation of damage potentials

Economic vulnerability assessment is the most prevalent and these were conducted largely for coastal resources. Hazards due to the incidence of flooding and coastal erosion are the most threatening to hazards that led to the initiation of vulnerability assessment.

A variety of methods were used to conduct the vulnerability assessment. This in itself reduces the opportunity for local and regional capacity building. The study came across the following limitations expressed by users of vulnerability assessment studies in the region:

a. Assessment is mostly qualitative
b. Inadequacy of input data: profile and elevation data, for example

c. Lack of water level data during severe storm events.
d. Changes to original methodology due to inadequate input data
e. Limited field data
f. Prolonged delays in start up
g. Non-availability of high resolution and current data
h. Multiple assessment did not assess vulnerability of specific elements
i. High level of generality in the methodology used
j. Non- incorporation of local knowledge
k. Short time frame of the study
l. Lacking continuity

These limitations where present, reduce the effectiveness of the studies and efforts should be made to avoid these limitations in future works. The study identifies the following other issues critical to the effectiveness of VAS in the region:

a. Very little use of hazard maps in the conduct of vulnerability assessment.
b. No measure of effectiveness of the studies when disasters do occur.
c. Vulnerability assessment studies are mostly event driven and not legally enforced as in Martinique and Puerto Rico.
d. The National Disaster Coordinators do not have access to the outputs of the studies and may not be informed or involved in the early stages of the studies.
e. Outputs of the studies are generally poorly disseminated to end-user. In fact dissemination of outputs is mostly not considered as an essential part of the studies and not properly included in the budget.
f. Little involvement of indigenous knowledge.
g. No budgetary allocation for follow-up studies or updating of dated studies.
h. The lack of documented and published methodology.

The development of GIS-based digital map in the Caribbean has passed its infancy stage. All the countries studied have digital maps. Puerto Rico, Martinique, Haiti, The Bahamas, Belize, BVI have well-established national digital base maps and the institutional mechanisms for the dissemination of these maps. Apart from the low-resolution regional seismic and storm hazard maps, some countries have digital hazard maps. These are mostly for flood and landslide hazards. The issues of concern in the development of digital maps in support of hazard mapping and vulnerability assessment are:

- Lack of high-resolution maps
- Lack of a common map datum, ellipsoid and map projection
- Currency of existing maps
- Accessibility of existing digital maps
- Lack of metadata for existing digital maps

The best practice in the preparation of hazard mapping, vulnerability assessment, digital maps in the Caribbean were found in Martinique. The island; a French Territory benefited from an institutionalized approach developed in France. The main highlights

of the Martinique practice are:

- The use of collaborative and consultative approach.
- Institutionalization of the process (it is mandatory)
- Legislative support to back the process and products
- Community focus via the use of large-scale maps (1:10,000)
- Open dissemination of the products
- Regular financial support.

This study revealed that a number of hazard maps were available which had already been produced with considerable resources and time in the past. Regional, national, and community organizations should make maximum use of these maps for disaster management and any other purposes. In order to reduce the impacts of these deficiencies, the following recommendations are offered.

Production, Dissemination, Use, and Updating

a. There is a need to institutionalize hazard mapping in the region to develop a standardized methodology, to review/improve hazard maps produced, to disseminate to users, to monitor the impacts of hazard maps and to develop regional capacity for hazard mapping and their uses. The most practical way will be to establish a partnership of existing regional organizations as pursued by CADM project for flood hazard mapping. Establishment of new agencies such as the Seismic Research Unit will also be considered as an alternative way.

b. Copies of the database and other products generated by regional or externally funded projects should be provided to local agencies charged with the responsibility of producing and maintaining hazard maps, vulnerability assessments and digital maps.

c. The use of hazard mapping, vulnerability assessment studies in development-related activities should be actively encouraged.

d. The production and dissemination of hazard maps should be mandated by law if the reduction of vulnerability to hazard through the building of more resilient society is to be achieved.

e. A more user-centred approach to the production and dissemination of hazard maps should be pursued as a matter of urgency.

f. The designated national agencies should be provided with the resources needed for effective dissemination of the outputs of the hazard mapping, vulnerability assessment studies and digital mapping data in the country/territory.

g. Adequate funding should be provided for the building of capacity in disaster mitigation. This would ensure a reduction of loss of life, property and the

biophysical environment. The current disaster-trigger approach and reliance on external funding cannot adequately be used to support the long-term nature of the effects of natural hazards in the region.

h. There is a need to obtain feedback from the project stakeholders before the final reports of hazard mapping and vulnerability assessment studies are published.

i. A national record of users and uses of hazard maps and vulnerability assessment results should be maintained.

Role of National Agencies

a. There is urgent need to upgrade the infrastructure of National Disaster Offices so as to ensure that the use of hazard maps is fully integrated into their routine activities.

b. In each country, a national agency should be designated as the repository of hazard mapping, vulnerability assessment studies and digital mapping data.

c. A national coordinating body should be designated with the responsibility to specify, monitor and coordinate activities relating to hazard mapping, vulnerability assessment studies and digital mapping data production in the country/territory.

d. A national clearinghouse should be established with responsibility to specify, monitor, evaluate, and disseminate digital mapping in the country/territory.

e. National Disaster Offices should be adequately informed and involved in every hazard mapping and vulnerability assessment study to be undertaken in each country/territory.

This study has created the infrastructure needed to ensure that information on hazard mapping, vulnerability assessment studies and digital mapping can be easily collected and disseminated. It is necessary therefore that this infrastructure be maintained.

Status of Hazard Maps, Vulnerability Assessments, and Digital Maps in the Caribbean

1.0 Introduction

The people and fragile economies of Caribbean territories are vulnerable to the regular occurrence of hazards that often result in disasters crippling their economies. Efforts to map and assess these hazards and the elements that are vulnerable to them have been done at different scales, times, costs, and by different funding agencies. To reduce the vulnerability of the Caribbean to the devastating effects of hazards in an effective and efficient manner, there is need for comprehensive documentation on the nature of the hazards, their spatial extent, frequency of occurrence and their effects. Such an undertaking is being led by the Caribbean Disaster and Emergency Response Agency (CDERA) via two major initiatives: the Caribbean Disaster Management (CADM) Project and the Caribbean Hazard Mitigation Capacity Building Programme (CHAMP).

1.1 Objectives

The objectives of the study were as follows:

a. To determine the status of hazard maps and vulnerability assessment studies and their use in the socio-economic planning and management of the Caribbean.
b. To determine critical success factors, gaps and best practices in the preparation and use of hazard maps and vulnerability assessment studies in the Caribbean.
c. To compile a database of hazard maps, vulnerability assessment reports, and digital maps available in the Caribbean.

The study was carried out in the following 20 Caribbean States:

CDERA Participating States:

Anguilla, Antigua and Barbuda, The Bahamas, Barbados, Belize, The British Virgin Islands (BVI), Dominica, Grenada, Guyana, Jamaica, Montserrat, St. Kitts and Nevis, Saint Lucia, St. Vincent & the Grenadines, Trinidad & Tobago, and Turks & Caicos Islands.

Non-CDERA Participating States:

Haiti, Suriname, Martinique, Puerto Rico.

1.2 Rationale for the study

Since the Caribbean is highly prone to natural hazards, it is imperative that efforts to mitigate the impact of these hazards be recorded, reviewed, and improved upon. The

absence of such records could lead to duplication of efforts, and lack of a knowledge base. The record of hazard mapping and vulnerability assessment studies in the region would provide the infrastructure for learning more about the likely extent and magnitude of potential hazards and its potential impacts on the vulnerable elements. It provides the opportunity for improving on previous efforts through a review of limitations, extent of uses and users, and effectiveness in time of disaster. The record will also provide the opportunity for identifying gaps in the extent of coverage, data collection, strengths and weaknesses of methodologies used.

The record of past hazard mapping, vulnerability assessment studies, and digital maps (HMVASDM) is not a static document. Hence, this study includes the development of an information system using a relational database. This system will provide the architecture for updating the information collected on the status of hazard mapping, vulnerability assessment studies, and digital maps in the Caribbean. The data querying functionalities of the relational database will help its user to obtain relevant information with relative ease. The study also attempts to develop a record of GIS digital data existing in the region. This record is meant to facilitate data sharing and to reduce duplication in the generation of spatial data.

This final report contains only the summary of findings and issues of the study. More detailed information on each of the 20 countries/territories can be found in the individual country reports submitted as part of this study.

The output of this study will first be used by CADM project for the preparation of its sustainability plan. CADM is currently carrying out pilot projects in three countries with the objective to establish a partnership among CDERA, regional and national institutions, which will carry out flood hazard mapping and community disaster management planning in all member countries, sustainably following the CADM project in the future. This study provides key information required for the preparation of the sustainability plan and at the implementation stage thereafter

1.3 Methodology

The study was conducted using an eight-step approach as shown in Table 1.1.

Table 1.1: Methodological Steps of the Study

Step #	Activity
1	Design of questionnaire
2	Design of relational database
3	Distribution of questionnaire to prospective respondents
4	In-country collection of information
5	Preparation of country reports
6	Data entry into the relational database
7	Preparation of customized reports
8	Preparation of final regional report

In step 1, a questionnaire was designed and approved by the CDERA. The approved questionnaire was translated into French for the benefit of respondents from Haiti and Martinique, and to Dutch for the benefit of respondents from Suriname. The questionnaire comprised 4 sections. Section I solicited personal and contact information on the respondents. Section II focused on Hazard Mapping initiatives that have been undertaken in the country. Critical information solicited included: purpose of the mapping, methodology used, uses and users of the hazard map produced, and limitations in the use of the hazard map. Section III of the questionnaire was on Vulnerability Assessment Studies initiated for the country. As in Section II, information on purpose, method, uses and users, and limitations were also solicited. Section IV was designed to obtain information on GIS digital maps existing in the country. Apart from the list of digital maps, information on map datum and map projection, and map scale were also solicited. A copy of the questionnaire is in Appendix I.

Step 2 involved the design of a relational database for storing and analyzing data will be collected. Microsoft Access™ database software was chosen for this purpose. Using the approved questionnaire, primary and relate tables were designed as well as a user interface for data entry into the system. The database is composed of the following flat data and linked tables:

1. Respondent
2. Hazards maps
   2.1 Categories
   2.2 Users-uses
3. Vulnerability Assessment
   2.1 Categories
   2.2 Users-uses
4. Digital maps

A data dictionary of the database can be found in the project Database Report (a separate document).

In step 3, CDERA contacted the National Disaster Coordinators (NDCs) of each state, informed them of the need for the study and provided them with digital copies of the questionnaire. The NDCs in turn sent copies of the questionnaires to relevant agencies in their countries. In countries where the consultants have established personal contacts with relevant agencies, copies of the questionnaires were sent to these persons directly. Appendix II contains the contact information on respondents and the NDCs contacted for this study. The NDCs provided the in-country support needed for the study. The distribution of the questionnaire was followed by scheduling of dates for country visits.

Step 4 is in-country data collection. Country visits were arranged with the objectives to:

a. articulate the objectives of the survey and seek information on hazard and disaster issues confronting the countries,
b. conduct interviews with prospective respondents, and
c. collect copies of relevant information (if made available).

The country visits normally involved meeting the key persons in the relevant agencies, conducting interviews that would yield responses to the questionnaire, and conducting site visits where resources permitted.

Step 5 addressed the preparation of country reports using a standardized template. This was followed by compilation of the completed questionnaire and other supporting documentation collected during the visits. The draft country reports were sent by CDERA to the respective countries for review and feedback. The final country reports were prepared using comments and feedback received.

Step 6 focused on the entry of responses obtained from the questionnaire into the database designed in Step 2. The advantage of entering the responses in a database as opposed to a spreadsheet is the ability to query the database and produce reports based on the needs of the user. The user-interface designed for data entry is in the user manual which can be found in the project Database Report.

In step 7, a verification of the data entered into the database was undertaken. This was followed by the generation of customized reports. The following reports were created:

a. Hazard map reports
b. Users-uses of hazard maps reports
c. Vulnerability assessments reports
d. Users-uses of vulnerability assessment reports
e. Respondents report

Copies of these reports can be found in the project Database Report. With training, NDCs would be able to use the database to obtain information on HMVASDM activities in the Caribbean.

Step 8 was the preparation of a final regional report that captures key issues on HMVASDM in the Caribbean (this report).

The strength of this methodology lies in the following:

a. Willingness of respondents to provide the relevant information.
b. Personal and informal interaction between the NDC, respondents and the consultants.
c. Adequacy of time for respondents to review and prepare responses before the country visits took place.
d. Use of database software that allows for easy updating of information collected.
e. Knowledge of the Consulting Team of key persons and agencies in the 20 states visited.

The methodology, however, suffers from the following weaknesses:

a. Unavailability of some critical information.
b. Short time frame for the completion of the study.
c. Newness of some of the responses requested from the respondents e.g.

: Users and uses
: Limitations of the outputs

d. Inadequate feedback from some respondents
e. Responses reflected respondent's individual knowledge and not documented information or collective knowledge of the agency.

2.0 Major hazards confronting the Region

The territories surveyed in the Caribbean are located from Suriname, just 2º above the Equator to the Bahamas, whose northward extension is roughly 5º north of the Tropic of Cancer, the same latitudinal extent that provides the conditions of warm, moist air and clockwise Coriolis Force required for the formation of tropical depressions, storms and hurricanes; and from Belize to the West at 89º longitude to Barbados in the Eastern Caribbean located at 59º West longitude. The islands in the Eastern Caribbean, arranged in a distinct arc, mark the leading edge of the Caribbean plate to the east, while the islands of the Greater Antilles mark its northern edge. This tectonic setting adds seismic, tsunamigenic and volcanic hazards to the region. This broad geographic extent of the Caribbean provides the environment for a number of natural hazards, that either cannot be avoided or whose effects cannot easily be reduced.

The major climatic hazards of the region are strong winds and heavy rains associated with the annual formation of tropical depressions, storms and hurricanes, during the rainy season, often giving rise to floods to a greater extent in the northern territories, such as Jamaica, than in the southern territories of the Caribbean; and droughts during the dry season, particularly in territories that have limestone formations. Storm surges often linked to the passage of storms and hurricanes result in coastal flooding. Guyana, though not in the hurricane path, experiences heavy rains that can result in inland and coastal flooding from the passage of the Inter Tropical Convergence Zone, and occasional, yet severe, drought that may be influenced by La Niña.

Tropical storms and hurricanes, floods and drought affect the Greater Antilles to a greater extent than the Lesser Antilles, while volcanic eruptions and earthquakes are added concerns for the islands of the Lesser Antilles. Soufrière Hills in Montserrat is the region's longest erupting volcano that started in 1995 and continues to the present. The active submarine volcano, Kick 'em Jenny, off the northwest coast of Grenada poses the threat of tsunamis whose effects are likely to be felt throughout the Caribbean. Tectonic and volcanic earthquakes are a common occurrence in the Caribbean region having magnitudes ranging from 3 to 8 on the Richter scale. The threat of sea level rise related to global climate change is an additional hazard that Caribbean territories must plan for. Coastal erosion slowly yet inexorably threatens the human and economic activities of the heavily populated coastal zones of Caribbean territories.

The occurrence of landslides, debris flows, and rock falls are largely affected by heavy

rains accompanying storms and hurricanes. Territories that possess steep and rugged topography, such as Dominica, are particularly prone to landslides, which are often exacerbated by road cuttings and land clearance for settlement.

On-shore and off-shore oil spills, transport of nuclear waste in Caribbean waters, storage and transport of hazardous chemicals, and toxic release of chemicals are some of the major technological hazards Caribbean countries are likely to face. Overall, the Caribbean region is prone to climatic, tectonic, and technological hazards.

3.0 Hazard Mapping Initiatives

The hazards that are confronting the Caribbean can be classified into two: region-wide hazards and local hazards. Region-wide hazards are those in which the area of impact has wider spatial extent that crosses national boundaries such as storm, wind, surge, seismic, and volcanic hazards. On the other hand, the sphere of influence of local hazards is usually limited to the boundaries of a state or a specific locale in the state. The treatment of these two classes has been different in the region. Region-wide hazards tend to attract external funding compared to local hazards. In the following sections, a summary of the both the region-wide and local hazards is provided.

3.1 Region-wide Hazards Maps

At the regional level, two seismic hazard mapping and one storm hazard mapping initiatives have been undertaken in the Caribbean. One of the seismic hazard map initiatives was produced as part of the routine work of the Seismic Research Unit (SRU) at the University of the West Indies (UWI), while the other was produced for the Organization of American States (OAS) as part of the Caribbean Disaster Mitigation Project (CDMP). The regional storm hazard maps were also produced by the OAS/CDMP.

3.1.1 Seismic Hazard Maps

Two sets of seismic hazard maps were produced for the region, as shown in Tables 3.1a and 3.1b. Both were produced by the SRU for the engineering community at a resolution of 0.25 degrees. The first set of seismic hazard maps (Figures 3.1, 3.2, and 3.3) was produced for the OAS/CDMP Regional Seismic Hazard Assessment Project in 1998. They were generalized hazard maps, showing ground acceleration, ground velocity and Modified Mercalli Intensities (MMI). The second set of seismic hazard maps produced in 1999 showed Modified Mercalli Scale (MMS), the Peak Ground Acceleration (PGA) and the Secondary Ground Acceleration (SGA) values. The methodology used to produce the hazard maps was the outcome of a collaborative effort in 1997 that improved upon previous methodologies used, resulting in the 1999 maps being an improvement on the 1998 maps.

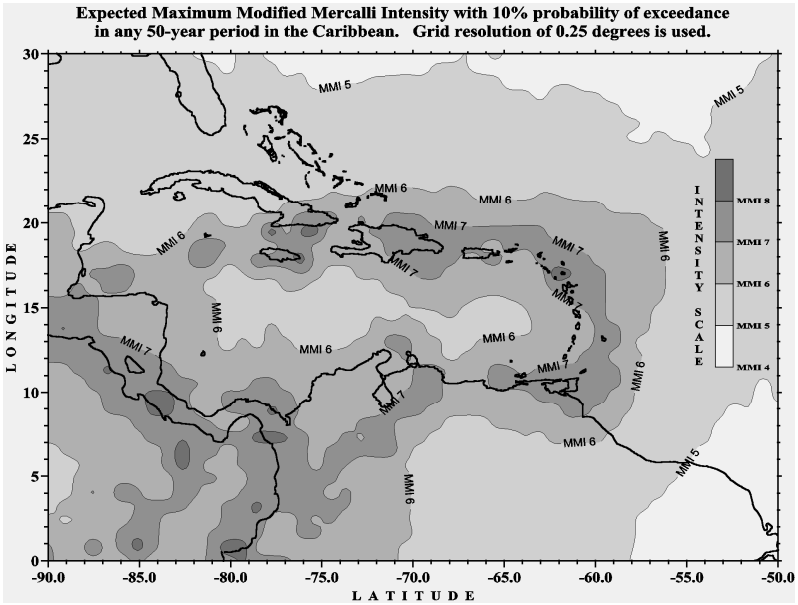


Figure 3.1: Expected Modified Mercalli Intensity map produced by SRU, 1998

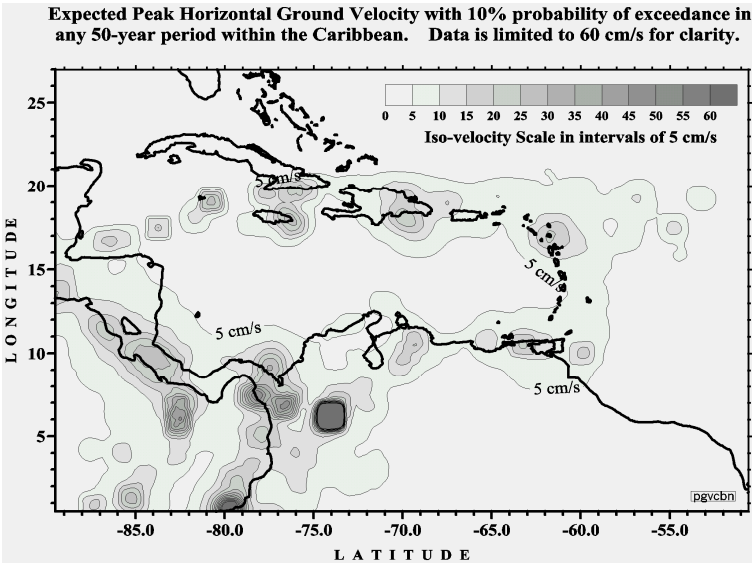


Figure 3.2: Expected Peak Ground Velocity map produced by SRU, 1998

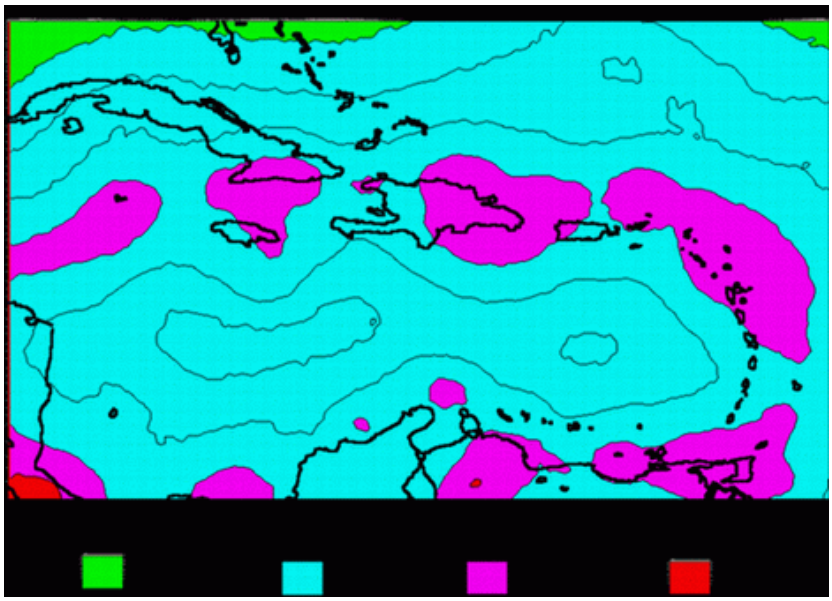


Figure 3.3: Modified Mercalli Intensities for the Caribbean produced by SRU, 1998

Table 3.1a: Seismic Hazard Maps produced for Caribbean Disaster Mitigation Project (CDMP) Regional Seismic Hazard Assessment Project

Country/Territory	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Anguilla	To produce page-size maps of ground acceleration, ground velocity and Modified Mercalli Intensities	0.25º grid resolution	1998	OAS	No information was available
Antigua & Barbuda					
Bahamas					
Barbados					
Belize					
BVI					
Dominica					
Grenada					
Guyana					
Haiti					
Jamaica					
Montserrat					
St. Kitts and Nevis					
Saint Lucia					
St. Vincent					
Suriname					
Turks and Caicos Is.					
Trinidad & Tobago					

Table 3.1b: Seismic Hazard Maps produced by Seismic Research Unit

Country/Territory	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Anguilla	To map general level of earthquake hazard in the Caribbean in the terms of the Modified Mercalli Scale and PGA and SGA values	0.25º grid resolution	1999	Seismic Research Unit	No information was available
Antigua & Barbuda					
Bahamas					
Barbados					
BVI					
Dominica					
Grenada					
Guyana					
Jamaica					
Montserrat					
St. Kits and Nevis					
Saint Lucia					
St. Vincent					
Turks and Caicos Is.					
Trinidad & Tobago					

At a national level, seismic hazard maps have been produced for the BVI, Haiti, Jamaica, Martinique and Puerto Rico. Some details of those national initiatives are shown in Table 3.1c.

Table 3.1c: Other Seismic Hazard Maps

Country/ Territory	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
BVI	Identify areas vulnerable to liquefaction	1:25,000	1997	Seismic Research Unit, UWI	No information was provided
Haiti	To assess the capacity of the country to respond to natural and human induced disaster	1:300,000	2002	Le Bureau D´Oxfam-GB, Haiti	No information was provided
Jamaica	To identify areas prone to earthquakes, KMA	***unknown***	July 1999	The University of the West Indies [UWI], Mona.	No information was provided

Country/ Territory	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Jamaica	To guide land use planning and development, South coast of Jamaica	1:500,000	1998	***unknown***	No information was provided
	Preliminary hazard assessment for Jamaica	1:250,00	1987	Mines and Geology Division	No information was provided
Martinique	To show areas prone to earthquakes	1:10,000	Sept 2002	Préfecture de la Région Martinique; Direction Départemental de l'équipement (DDE)	No information was provided
Puerto Rico	Ground shaking	unknown	2002	URS Corporation; *Universidad Metropolitana (UMET)*	No limitations were given
	To map expected seismic ground motions for 500 & 2500 year periods	1:450,000	2002	US Geological Survey, CGHT	No limitations were given
	To map areas prone to liquefaction	1:450,000	2002	URS Corporation; *Universidad Metropolitana (UMET)*	No limitations were given

Sample copies of Caribbean regional seismic hazards maps as well as that of Puerto Rico and Martinique are shown in Appendix III-1.

3.1.2 Storm-related Wind, Wave and Surge Hazard Maps

One set of regional storm-related wind, wave and surge [SWS] hazard maps was produced by the OAS/CDMP for the entire Caribbean. In addition to this, several countries have undertaken country-focused SWS hazard maps. The OAS/PGDM project produced medium scale 1:50,000 SWS hazard maps for Antigua and Barbuda, and St. Kitts and Nevis in 2001. Tables 3.2a and 3.2b show the SWS hazard maps prepared through the OAS/CDMP and other initiatives.

Table 3. 2a: OAS/CDMP- Storm-related wind, wave and surge hazard maps

Country/ Territory	*Purpose*	*Scale*	*Date produced*	*Limitations*
Regional[1]	Preparation of an atlas of probable storm effects	1km^2 grid	2000	No information provided
Belize	Assessment of potential hazards generated by tropical storms (SWS hazard)	1:50,000	1995	Use of 20 metres contour, which is too small a scale to be effective
Jamaica	To estimate the level of surge for any given return period and produce flood return period maps - Montego Bay	***unknown***	1997	No information provided

Note 1: List of Countries/Territories: Antigua & Barbuda, Barbados, Belize, BVI, Dominica, Grenada, Haiti, Jamaica, Montserrat, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines, Tobago

Table 3. 2b: Other- Storm-related wind, wave and surge hazard maps

Country/ Territory	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Antigua & Barbuda	Hazard mitigation plan development (SWS hazards)	1:50,000	2001	National Office of Disaster Services	Maps in need of updating; lack of current digital data
BVI	To identify areas vulnerable to SWS hazard	1:25,000	1996	Hazard and Risk Assessment Project (HRAP)	No information provided
Haiti	To assess the capacity of the country to respond to natural and human induced disaster	1:300,000	2002	Le Bureau D´Oxfam-GB, Haiti	No information provided
Jamaica	To identify areas most likely to be affected by SWS hazards - Kingston	***unknown***	June 1999	Natural Resources Conservation Authority [NRCA]	No information provided
	Preliminary hazard assessment (flood and storm)	1:25,000	1987	Mines and Geology Division	No information provided

Country/ Territory	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Martinique	To map areas affected by storm surges and coastal erosion	1:25,000	1999	Bureau de Recherche Géologique et Minières (BRGM)	Map scale not detailed enough for local level planning
	To show areas prone to storm surges, erosion	1:10,000	2002	Préfecture de la Région Martinique; Direction Départemental de l'équipement (DDE)	No information provided
Bahamas	To map storm surge and inundation resulting from hypothetical hurricanes using the SLOSH model	A grid of a telescoping system with 90 arc lengths and 104 radials	2000	National Weather Service of the Bahamas	See note 1
Montserrat	To identify areas at risk to storm surge	1:2,500	2003	Emergency Operations Centre (EOC)	Exists in hard copy format
Puerto Rico	To map areas prone to high-wind hazard	1:450,000	2002	*Universidad Metropolitana (UMET)*	No information provided
St. Kitts/ Nevis	Hazard mitigation plan development (SWS hazards)	1:25,000	2001	Department of Physical Planning, Natural Resources & Environment (DPPNRE)	Scale of mapping did not support local area planning; lack of current digital data

Note 1: Outdated maps, low resolution of final maps, anomalous water heights, exclusion of local wave, tides, rainfall, and flooding data from the model; problems in determining maximum wind speed. Technical jargon used in the atlas plus its limited distribution prevented its wide use and circulation. The atlas does not apply to the entire country.

Sample copies of storm hazard maps for the following countries/territories: Anguilla and Martinique are shown in Appendix III-2.

3.1.3 Volcanic Eruption Hazard Maps

Five countries/territories have undertaken the production of volcanic eruption hazard maps in the region. These are Dominica, Grenada, Martinique, Saint Lucia and St. Kitts and Nevis. The scales of these maps are mainly at 1:25,000 except for Dominica,

which was done at 1:50,000 and Martinique, done at 1:10,000. Mapping scale is also an issue for users of these maps. A scale of 1:10,000 or larger is being advocated particularly for local area planning. Table 3.3 shows the countries which have produced volcanic eruption hazard maps in the region.

Table 3.3: Volcanic Hazard Maps produced for Caribbean countries

Country/ Territory	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Dominica	To map & assess volcanic hazards	1:50,000	June 2000	Physical Planning Section & Seismic Research Unit, (SRU) UWI	No limitations were noted
Grenada	To identify areas prone to natural hazards and recommend mitigation measures	1:25,000	June 1988	OAS; Physical Planning Division, Ministry of Finance and Planning	No limitations were noted
Martinique	To map areas likely to be affected by volcanic hazards	Unknown	Unknown	Bureau de Recherche Géologique et Minières (BRGM) http://www.brgm.fr /risques/antilles/	No limitations were noted
Montserrat	To determine volcanic hazard zones	1:25,000	2003	EOC	Scale of the hazard maps does not allow for the identification of individual elements at risk
St. Kitts and Nevis	Development of hazard mitigation plan	1:25,000	2001	Seismic Research Unit, UWI	Scale of mapping did not support local area planning. Constraint to the use of the maps at the community level of disaster management because of a lack of training in map reading.
Saint Lucia	To map areas likely to be affected by volcanic hazards	1:25,000	2002	Physical Planning Section, Min. of Phys. Planning, Environment & Housing; SRU	No limitations were noted.

Sample copies of volcanic hazards maps for the following countries/territories: Dominica, the island St. Kitts, and Martinique are shown in Appendix III-3.

3.2 Local hazard maps

Natural hazards whose impacts are small in extent and are contained within the political or geographic extent of a country or territory are classified in this report as local hazards. Coastal/inland flooding, landslides, coastal/inland erosion and fire belong to this class of hazards.

3.2.1 Flood Hazard Maps

Flooding is the most common hazard affecting Caribbean territories. It is influenced mostly by heavy rainfall, land use pattern, and the geomorphological properties of the territories. Jamaica is the most flood-affected country and hence has undertaken the largest number (11) of flood hazard mapping initiatives in the region. This is followed by Puerto Rico with two (2) flood hazard maps as shown in Table 3.4.

Table 3.4: Flood Hazard Maps produced for Caribbean countries

Country/ Territory	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Anguilla	Disaster preparedness	1:2,500	2000	ODP	Methodology used to identify the hazard zones is limited
	Disaster preparedness	1:2,500	2003	ODP	Methodology used to identify the hazard zones is limited
Antigua & Barbuda	Hazard mitigation plan development	1:50,000	2001	National Office of Disaster Services	See Note 1
Barbados	Development control and planning	1:2,500	unknown	Ministry of Public Works	No information was provided.
	Development control and planning	1:1,000	1994	Coastal Zone Management Unit	1. Unavailability of adequate profile data and topographic data. 2. Limited areal extent (south and west coasts of the island).

Country/ Territory	***Purpose***	***Scale***	***Date produced***	***Primary sources***	***Limitations***
Belize	To determine flood risk category	1:50,000	1999	Land Information Centre	The scale of flood risk maps are generally too coarse for local application.
BVI	Identify areas at risk to flooding	1:25,000	1996	Department of Disaster Management	Accurate delineation of flood prone zones was affected by the small quantities of floodwater and a lack of detailed topographic data.
Dominica	To undertake flood hazard mapping of the Roseau River Basin.	Unknown	Dec 2002	CDERA	No information was given
Grenada	(Multi-hazard map) To identify areas prone to natural hazards and recommend mitigation measures	1:25,000	June 1988	OAS; Physical Planning Division, Ministry of Finance and Planning	No information was provided
Haiti	To assess the capacity of the country to respond to natural and human induced disaster	1:300,000	2002	Le Bureau D´Oxfam-GB, Haiti	The project report is not yet made official and its distribution is limited.
Jamaica	Planning, insurance, disaster mitigation	1:4,000	1994	Water Resources Authority	No information was provided
		1:5,000	1994	Water Resources Authority	
	Unknown	1:10,000	1988	ODPEM	

Country/ Territory	***Purpose***	***Scale***	***Date produced***	***Primary sources***	***Limitations***
Jamaica	To identify evacuation routes & traffic control points for flood prone areas	1:22,500	***unknown***	Office of Disaster Preparedness and Emergency Management [ODPEM]	No information was provided
	Disaster mitigation, and planning	1:5,000	***unknown***	Water Resources Authority	
		1:5,000	2004		
	To show flood prone areas	1:5,000	May 1994	Underground Water Authority	
	To show flood plains associated with rivers	1:4,000	May 1994	Underground Water Authority	
	To define water levels in the Morass Area	1:4,800	April, 2002	National Irrigation Commission	
	To model flood frequency and rainfall/runoff	1:50,000	***unknown***	Underground Water Authority	
	To identify critical hazard areas	1:25,000	2001	Forestry Department	
	unknown (*Flood & Landslide)*	1:5,000	1987	Geological Survey Division	
	To map areas prone to landslides & floods	1:250,000	***unknown***	ODPEM	
	To guide land use planning and development	1:500,000	1998	***unknown***	
Jamaica	Preliminary hazard assessment	From 1:250,000	1987	Mines and Geology Division	
St. Kitts and Nevis	Development of hazard mitigation plan	1:25,000	2001	Physical Planning Unit, St. Kitts	See Note 1
Turks & Caicos Islands	To inform all development planning.	1:5,000 1:10,000	1999	Planning Department & Department of Disaster Management and Emergencies	No information was provided

Country/ Territory	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Martinique	To map areas prone to flooding	Unknown	Unknown	Bureau de Recherche Géologique et Minières (BRGM) http://www.brgm.fr/risques/antilles/	No information was provided
	To show areas prone to flooding	1:10 000	Sept 2002	Préfecture de la Région Martinique; Direction Départemental de l'équipement (DDE)	
Puerto Rico	To prepare maps based on the 100-year flood	1:450,000	2002	*Universidad Metropolitana*	No limitations were given
	Disaster mitigation for coastal flooding	Unknown	2002	URS Corporation; *Universidad Metropolitana*	No limitations were given

Note 1:
1. Scale of mapping did not support local area planning.
2. Coarse contour intervals and limited data on flood heights.
3. The models used to predict flooding were forced to make assumptions and use mean values.
4. Use of mean values reduced the impact of extreme events in the results of the studies.
5. Short period of data collection limited amount of data available for analysis and the quality of the map produced.
6. More local knowledge should have been incorporated into the data used for modeling.
7. Constraint to the use of the maps at the community level of disaster management because of a lack of training in map reading.

Sample copies of flood hazard maps are shown in Appendix III-4.

3.2.2 Landslide hazard maps

Jamaica has considerable experience compared to other Caribbean territories in the production of landslide hazard maps, as shown in Table 3.5. Most of the maps are prepared using locally available resources of the University of the West Indies, Mona campus; staff of the Mines and Geology Division; and the Forestry Department.

Table 3.5: Landslide Hazard Maps produced for Caribbean countries

Country/ Territory	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Anguilla	Disaster preparedness	1:2500	2003	Office of Disaster Preparedness (ODP)	Methodology used to identify the hazard zones is limited
Barbados	A guide for agricultural, residential & recreational land management	1:5,000	February to April 2000	Department of Agriculture	No information provided
Dominica	To map landslides occurrence.	1:50,000	Nov. 1987	Physical Planning Section	The landslide risk map, is not detailed enough to be site-specific. It also needs to be updated.
Haiti	To assess the capacity of the country to respond to natural and human induced disaster	1:300,000	2002	Le Bureau D´Oxfam-GB, Haiti	The project report is not yet made official and its distribution is limited.
Jamaica	Part of a landslide hazard assessment component (KMA) (*Deep and shallow landslides*)	1:50,000	1996-1998	www.oas.org/en/cdmp	Data deficiencies with respect to closer contours. A contour interval was desired for slope angles and curvatures; use of surrogate variables; deficiencies in the DeGraff method
	To highlight degrees of landslide susceptibility	1:50,000	1990	Main Library, The University of the West Indies [UWI], Mona	Not provided
	Landslide susceptibility investigation, Upper St. Andrew Area	1:10,000	1992	UWI, Mona	Small scale of aerial photos which obscured small slides in the analysis.

Country/ Territory	***Purpose***	***Scale***	***Date produced***	***Primary sources***	***Limitations***
Jamaica	To provide information for planners, developers, local authorities, Rio Grande area	1:50,000	2001	Mines and Geology Division	See Note 1
	Landslide susceptibility for areas in Portland	1:50,000	February, 2000	Ministry of Energy, Geology Division	Not provided
	Unknown	1:75,000	2002	Office of Disaster Preparedness and Emergency Management (ODPEM)	
	To identify critical hazard areas (*Landslide hazard & flood*)	1:25,000	2001	Forestry Department	
	Unknown *(Flood and landslide)*	1:5,000	1987	Geological Survey Division	
	To map areas prone to landslides & floods (*Multiple: [Flood, Landslide, & Soil erosion*)	1:250,000	***unknown***	ODPEM	
	To guide land use planning and development *(Flood, Earthquake, Landslide)*	1:500,000	1998	***unknown***	
Martinique	To map areas of landslide occurrence	Unknown	Unknown	Bureau de Recherche Géologique et Minières (BRGM) http://www.brgm.fr/ risques/antilles/	No information was provided
Puerto Rico	To map areas prone to earthquake-induced landslides	1:450,000	2002	URS Corporation	No limitations were given
	To map areas prone to rain-induced landslides	1:450,000	2002	URS Corporation; *Universidad Metropolitana*	

Country/ Territory	***Purpose***	***Scale***	***Date produced***	***Primary sources***	***Limitations***
Saint Lucia	To map landslides	1:50,000	Nov. 1985	Physical Planning Section, Min. of Phys. Planning, Environment & Housing	Small scale (1:50,000 - 1:75,000) allowed only planning at the regional level.
	To update the 1985 landslide hazard map	1:75,000	1992	Physical Planning Section, Min. of Phys. Planning.	Small scale allowed only planning at the regional level.
	To map debris flows and slides	1:75,000	1992	Physical Planning Section, Min. of Phys. Planning, Environment & Housing	See Note 2
St. Vincent	Not stated	1:25,000	1988	Dir. of Overseas Surveys, Surrey, England	See Note 3

Note 1:

1. Arbitrary distance between the hazard zones.
2. Hazard zones indicated an area's susceptibility to landslides. The prediction was based on the analyses of previous landslide occurrences and other related factors, for example, geology and slope.
3. Hazard zones studied were not an ideal indication of the size, type of landslide or the distance that it may travel.

Note 2:
Legend of the Debris Risk Severity map needed an accompanying explanation on the purpose of the map, a better interpretation of the areas at risk and the parameters used in their derivation, as the map is being used without its accompanying report.

Note 3:
1. Map was not in digital format
2. It could only be used for comparison among areas
3. Not detailed enough for specific areas.

Sample copies of landslide hazard maps are shown in Appendix III-5.

3.2.3 Other hazard maps

Maps of other hazards have been prepared in the Caribbean. These include: drought, fire, inland and coastal erosion, oil spills, and tsunami. The detail of these are provided in Table 3.6.

Table 3.6: Other Hazard Maps produced in the Caribbean countries

Country/ Territory	*Type of hazard*	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Antigua & Barbuda	Drought	Hazard mitigation planning development	1:50,000	2001	National office of Disaster Services	Lack of current digital data
	Inland erosion	Hazard mitigation plan development	1:50,000	2001	National office of Disaster Services	Lack of current digital data
BVI	Oil spill	Oil spill prevention	1:25,000	2000	NOAA	Map needs revision
Haiti	Geological Faults	To assess the capacity of the country to respond to natural and human induced disaster	1:300,000	2002	Le Bureau D´Oxfam-GB, Haiti	No information was provided
	Human-induced erosion	To assess the capacity of the country to respond to natural and human induced disaster	1:300,000	2002	Le Bureau D´Oxfam-GB, Haiti	No information provided
Nevis	Drought	Hazard mitigation planning development	1:25,000	2001	Department of Physical Planning Natural Resources & Environment (DPPNRE)	Scale of mapping did not support local area planning; maps are not current

Country/ Territory	*Type of hazard*	*Purpose*	*Scale*	*Date produced*	*Primary sources*	*Limitations*
Puerto Rico	Tsunami	To produce tsunami generated flood maps of: 1.Contour plot of sea surface elevation 2. Inland flood limit	1:450,000	2003	University of Puerto Rico, Mayaguez (UPRM)	No information provided

3.3 Users and Uses of Hazard Maps

The study identified the following wide-range of users of hazard maps in the Caribbean:

- Physical Planning Offices
- Non-Governmental Organizations
- Environmental Agencies
- Agricultural Departments
- Works Departments
- Utility Companies
- Insurance Agencies
- National Disaster Offices
- Security and Protective Services
- Lending Agencies
- Meteorology and Hydrology Departments
- Educational Institutions
- Land Developers
- General Public
- Foreign Investors
- Public Health Departments

The range of uses of hazard maps is as follows:

- Development control and planning
- Disaster mitigation planning
- Disaster management
- Policy formulation
- Law reforms
- Site analysis
- Review of insurance premium

- Review of loan applications
- Assessment of public facilities
- Vulnerability assessments
- Research
- Public awareness and education
- Evacuation and response planning
- Development of early warning systems
- Law enforcement
- Hazard prevention
- Development of building codes
- Siting of infrastructure

The range of users and uses begs for improvement in frequency, extent, and methodology and dissemination of hazard maps in the region. The study found that information on users and uses are provided based on the personal knowledge of the respondents and are not based on official records kept by the repository of the hazard map. This reflects the low level of attention paid to monitoring the effectiveness of hazard mapping in the region. In order to justify the resources expended in the production of hazard maps, it is important that an official record of users and uses be kept and maintained by a designated agency responsible for the dissemination of hazard maps in each country/territory. Apart from the record of users and uses, the designated agency should keep a record of limitations experienced by users. This information would help improve future updates of the hazard maps. Records of users and uses also provide supporting information needed to justify the cost of future updates.

In the case where hazard maps are disseminated via the Internet, e.g. OAS/PGDM and OAS/CDMP, it is important that a record and basic information on the users of this web-based information should be captured as well.

The record of users and uses also provides the information needed for conducting a cost-benefit analysis of hazard maps preparation in the region.

3.4 Issues and Limitations

The critical success factors of hazard mapping initiatives in the region are the following:

g. Leadership of regional organizations with commitment to serve countries in the region
h. Determination of national organizations to pursue hazard mapping recognizing this as an important initial step for disaster management
i. Effective collaboration among local agencies
j. Vested interest of the affected local communities
k. Continuous monitoring of the hazardous event
l. Use of digital methods in the preparation of the maps

The regional hazard maps in particular do enjoy the following critical success factors:

- Funding that individual countries would not have been able to provide
- Use of international experts
- Consistency of methodology
- Web-based dissemination of outputs
- Ease of updates

These factors should be considered by future hazard mapping projects.

The production of hazard maps in the region is faced with the following issues that need urgent attention. These are: *reliance on external funding, dissemination of output maps, quantity and quality of input data, appropriateness of map scale, and map reading capability of the local communities*.

The mapping of regional hazards is generally *funded by international and/or regional agencies*. In most of the countries (with the exception of Antigua and Barbuda, Belize, Jamaica, Montserrat, St. Kitts and Nevis, and the British Virgin Isles), regional hazard maps are the most current maps of hazard attributable to seismic events and the first storm hazard map. The consequences of this arrangement are:

- Limited involvement of local personnel
- Input data and outputs are mostly kept outside the countries/territories.
- Countries have little influence on the updating cycles of the mapping activities
- Outputs are poorly disseminated within the countries/territories and thus inadequately used.

The value of hazard maps can only be realized if they are effectively distributed to the end users. *Poor dissemination of hazard maps* is sometimes responsible for the low level of hazard awareness in the region. For a lot of the projects reviewed, hazard maps are part of a bound copy of the final report with no plan or resources for disseminating the maps to all potential users. In recent times, the use of the Internet as a medium for map distribution is becoming popular in the region. The following projects effectively used the Internet to disseminate the hazard maps produced to the wider community: OAS/CDMP; OAS/PGDM, SRU regional seismic hazard maps. Puerto Rico and Martinique provide the best example in this regard. The assessment of the effectiveness of Internet-based map distribution for the local communities in the region is, however, questionable at this time given the relatively low level of Internet access in the local community.

The *poor quality and inadequacy of input data* used for the production of hazard maps in the region remain a critical issue. Due to the poor state of the region's spatial data infrastructure, the base data required for undertaking hazard maps are grossly lacking, dated, and unreliable, thus degrading the quality of the outputs. Several projects reviewed attributed these as the weaknesses of their outputs. It is important that the

issues of input data be addressed before hazard map projects are commissioned.

The *appropriateness of scale used for the output maps* is a contentious issue. Several respondents expressed their disappointment in not being able to use the maps for disaster mitigation and local area planning. This is because most of the hazard maps are produced for regional analysis. Outputs are more of an atlas rather than maps i.e. they do not have metric qualities thus providing only a global view. Efforts should be made to ensure the output maps of future hazard maps meet the needs of the local community of users.

A fundamental issue that governs the effectiveness of hazard map is the *map reading literacy of the local community*. A concerted effort should be made to include the training of local communities in the appropriate use of the output maps through the development of their map reading skills.

Flood Hazard Maps: Most of the flood hazard maps produced in the region are maps showing areas that have experienced floods rather than areas prone to flooding, the reason being the lack of resources and experience required to undertake flood modeling exercises. Jamaica, in recent times, has used flood-modeling software such as HEC-RAS and WMS to produce digital flood hazard maps. Puerto Rico and Martinique have benefited from technical and financial capabilities from USA and France, respectively, in using flood models to produce flood hazard maps.

CADM project is producing flood hazard maps using FLO-2D™ newly introduced by a Japanese expert to hydrologists of Caribbean Institute of Meteorology and Hydrology (CIMH) and UWI for inundation simulation of low-lying areas, in addition to HEC-RAS™ and Watershed Management Software [WMS™] being used traditionally in the region.

The study found the following limitations to the flood hazard maps in the Caribbean:

m. Low level of use of digital approach to the production of flood hazard maps.
n. Lack of a standardized methodology to the production of flood hazard maps even within a country.
o. Use of methodologies that are considered to be limiting in scope.
p. Coarse contour intervals of topographic maps.
q. Limited data on historic flood heights.
r. Inadequate input data such as cross-sections, rainfall, stream flow and land use.
s. Little use of flood hazard maps in community disaster management.
t. Existing flood hazard maps are considered to be dated and need to be updated.
u. Assumptions made in using predictive models are not valid.
v. Use of mean values instead of actual values reduced the impact of extreme events.
w. Short period of data collection due to lack of historic data.
x. Lack of current land use map to assess level of risk.

The choice of the scale of flood hazard maps presented another challenge in the Caribbean. Four categories of scales are generally used depending on the area of interest. Fifteen (15) of the mapping initiatives used large-scales that are below 1:10,000 and 1:25,000, while eight (8) used scales of 1:25,000 and smaller. The relatively large countries such as Jamaica, Puerto Rico, and Haiti used scales between 1:250,000 to 1:450,000. These extremely small-scale maps are at best useful for regional analysis.

Landslide hazard maps: Landslide hazard maps have been prepared in the region for a number of reasons, some of which are:

- Guide to land management - Barbados
- Occurrence mapping - Dominica, Saint Lucia, Martinique
- Susceptibility mapping - Jamaica, Saint Lucia
- Guide to development planning - Jamaica
- Debris flow - St. Lucia

Landslide susceptibility modelling and mapping is still not very popular in the region. Most of the efforts are on occurrence mapping. Occurrence mapping, though very important, is not undertaken on a regular basis; as such, existing data are not complete, comprehensive and current. The reason attributable to these shortcomings is due to the 'complain and map' approach being used. A lot of current information on occurrence may be obtained if satellite imagery is used to identify landslide incidence. This approach calls for a regular programme of imagery acquisition and analysis by respective state agencies. Occurrence maps are valuable and essential inputs to susceptibility mapping. The accuracy of susceptibility mapping can be negatively affected by the lack of currency and completeness of occurrence maps.

Scale of landslide hazard maps is also of importance if the map is to be of use to land managers and land developers. Map scale smaller that 1:10,000 is of little use for local area planning and hazard mitigation. Of the over 20 landslide hazard map initiatives in the region, only four are of the scale 1:10,000 and larger. Of these five, two were produced in Jamaica, and one each in Anguilla and Barbados and one in Martinique.

The use of a computerized modelling approach is limited. Most of the region used an analogue approach to landslide hazard mapping, except for Barbados, Jamaica (OAS/CDMP), Martinique and Puerto Rico. The analogue approach is difficult to update and the methodology used is mainly based on the knowledge of those who prepared the maps. The computerized approach lends itself to continuous update and refinement.

The following are the major limitations expressed by users of the landslide hazard maps in the Caribbean:

- Scale too small for site-specific analysis
- Input data deficiencies (lack of currency)

- Use of surrogate variables
- Deficiencies of the DeGraff method
- Inadequate topographic data
- Legend of map not understood by end-users.

4.0 Vulnerability Assessment Studies

Hazard management involves the following step-wise approach:

a. Hazard identification, quantification and monitoring
b. Mapping of areal extent
c. Vulnerability assessment
d. Establishment of policy, law and tools such as an early warning system towards its mitigation or reduction of impacts.

Vulnerability Assessment Studies are a necessary next step after hazard mapping. Upon the quantification of the areal extent of the hazards, it becomes necessary that an assessment of all the vulnerable elements with zones of impacts of that hazard be undertaken.

Table 4.1 presents an inventory of Vulnerability Assessment Studies (VAS) that have been undertaken in the region. The study found a total of 56 studies. The general purposes of Vulnerability Assessment Studies in the region are for:

- Disaster mitigation
- Identification of vulnerable elements
- Quantification of economic losses
- Improvement of structural design
- Assessment of management plans
- Location of facilities
- Response planning
- Assessment of adaptation measures
- Evacuation planning
- Establishment of community development plans
- Control of impacts
- Risk assessment
- Calculation of damage potentials

Table 4.1: Inventory of Vulnerability Assessment Studies in the Caribbean

Country/ Territory	Year	Title of Project	Type of Assessment	Type of Hazard	Purpose of Assessment
Anguilla	2000	Anguilla Drainage Study	Multiple	Flood	Mitigating incident of flood
	2000	Anguilla Slope Stability Study	Multiple	Landslide	Identifying unstable slope areas
	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources
	1999	Vulnerability of Schools & Shelters to Natural Hazard	Structural	Multiple	Towards improvement in structural design
Antigua & Barbuda	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources
	1999	Vulnerability of Schools & Shelters to Natural Hazard	Structural	Multiple	Towards improvement in structural design
Country/ Territory	**Year**	**Title of Project**	**Type of Assessment**	**Type of Hazard**	**Purpose of Assessment**
Antigua & Barbuda	2001	Hazard Vulnerability Assessment	Multiple	Multiple	Disaster mitigation planning
Barbados	2002	Potential Impacts of Sea level Rise	Multiple	Multiple	To assess the effects of sea level rise
	1996	Storm water Drainage Study	Multiple	Flood	To delineate floodprone areas
	1999	Evaluation of Tsunami Impacts: North West Barbados	Multiple	Tsunami	To investigate likely inundation at the Marina
Belize	2001	Hurricane Rehabilitation & Disaster Preparedness	Structural	Hurricane	Location analysis of shelters
	2001	Hurricane Rehabilitation & Disaster Preparedness	Structural	Flood	Location analysis of shelters
	2001	Hurricane Rehabilitation & Disaster Preparedness	Structural	Seismic activities	Location analysis of shelters
	2001	Investigation of the Belize River	Economic	Flood	To understand the flooding problem
	2000	Hazard Risk Assessment	Structural	Storm surge	Reduction of vulnerability & improving response
	2000	Hazard Risk Assessment	Structural	Flood	Reduction of vulnerability & improving response
	2000	Hazard Risk Assessment	Structural	Fire	Reduction of vulnerability & improving response
Dominica	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources
		Probable Maximum Loss of Critical Infrastructure	Economic	Hurricane	To calculate losses due to wind hazard
	1996	Risk Assessment of Electrical Utilities	Economic	Hurricane	Disaster mitigation

Country/ Territory	Year	Title of Project	Type of Assessment	Type of Hazard	Purpose of Assessment
	2001	Initial National Comm. Under the UN Framework & Co	Multiple	Greenhouse Gas Emission	Minimizing negative impact of climate change
	1999	Landslide Dam in the Layou River	Structural and Human	Landslide	To assist with monitoring of landslide activity
	1996	Wave Hazard Assessment West Coast of Dominica	Structural	Storm surge	To assess the impact of wave hazard
Grenada	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources
	2001	Coastal Vulnerability Assessment Study	Multiple	Sea Level Rise	To identify resources vulnerable to sea level rise
Guyana	2002	Vulnerability Assessment to Sea Level Rise	Bio-geophysical & Socio-econ	Sea Level Rise	To assess the effects of sea level rise
Haiti	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources
		Assessment of floodplain: Artibonite	Human and Economic	Flood	Evacuation planning
	1999	Hazard Mitigation & Vulne. Reduction: Jeremie	Multiple	Multiple	To establish community disaster programs
Jamaica	2001	Hazard & Fluvial Assessment	Multiple	Floods & Landslides	Examine feasibility of national park location
		Assessment of beach erosion at Negril	Economic	Coastal erosion	To address the concern of coastal erosion
	1996	Montego Bay 100-year Hurricane Coastal Flooding	Multiple	Flood	River & harbour engineering flood control
	1996	Milk River Floodplain mapping	Multiple	Flood	Flood control and hydrological appraisal
		Hydrological Appraisal of flood damage: Western Jamaica	Multiple	Flood	Flood control and hydrological appraisal
	1993	Montego Bay 100-year Hurricane Coastal Flooding	Multiple	Flood	To determine causes of run-off
	1997	Nightingale Grove Vulnerability Assessment	Structural	Flood	To recommend mitigation plans
Martinique		GEMITIS	Multiple	Earthquake	To evaluate the consequences of an earthquake
	2003	Plan for the Prevention of Natural Risk (PPR)	Structural and Human	Multiple	To map different degrees of vulnerability
Montserrat	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources
	2003	Integrated Vulnerability Assessment of Montserrat	Human	Multiple	Delineation of hazard zones & assessment of risk

Country/ Territory	Year	Title of Project	Type of Assessment	Type of Hazard	Purpose of Assessment
Puerto Rico	2002	Composite Hazard Map	Structural	Multiple	To calculate damage potential for each hazard
St. Lucia	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources
		Probable Maximum Loss of Critical Infrastructure	Economic	Hurricane	To calculate losses due to wind hazard
	1996	Risk Assessment of Electrical Utilities	Economic	Hurricane	Disaster mitigation
	2001	Climate Change Vulnerability & Adaptation Assess.	Economic	Sea level Rise	Assessment of adaptation measures
St. Kitts & Nevis	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources
	1999	Vulnerability of Schools & Shelters to Natural Hazard	Structural	Multiple	Towards improvement in structural design
	1999	Probable Maximum Loss of Critical Infrastructure	Economic	Hurricane	To calculate losses due to wind hazard
	2001	Hazard Vulnerability Assessment: St. Kitts & Nevis	Multiple	Hurricane	Preparation of disaster mitigation plans
St. Vincent	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources
	1996	Risk Assessment of Electrical Utilities	Economic	Hurricane	Disaster mitigation
Suriname	1999	Country Study: Vulnerability to Climate Change	Human & Economic	Sea Level Rise	To asses the impact of sea level rise
The BVI	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources
	1997	Hazard and Risk Assessment Project [HRAP]	Multiple	Multiple	Identify impacts of hazards
		Quantitative Risk Assessment Projects	Structural	Multiple	Identification of areas at risk
Turks & Caicos	1996	Coast and Beach Stability in Lesser Antilles	Economic	Coastal erosion	Assessment and management of beach resources

The type of vulnerability assessment ranges from economic, human, structural to multiple. Table 4.2 provides the type of assessment, hazard type and the vulnerable elements that were assessed. Economic assessment is the most popular and these were done mostly on coastal resources. This is followed by multiple assessments. Structural assessment is mainly done for storm, wind and surge hazard. Multiple hazards usually comprise wind and surge hazard. While multiple assessments usually comprise a mix of human and structural, and human and economic. In Guyana, the multiple assessments included the assessment of impacts on bio-geophysical elements.

The use of multiple assessments is becoming popular because of cost-efficiency. Its value may be diminished if the impacts of individual elements are lumped. The common vulnerable elements assessed are coastal resources; critical infrastructure; schools and shelters; and field assets of electricity agencies.

Table 4.2: Type of Assessment and the Vulnerable Elements Assessed

Type of Assessment	Country/ Territory	Hazard Type	Vulnerable Elements	Purpose of Assessment
Economic	Regional (in 11 countries/territories)	Coastal erosion	Tourist industry	Assessment and management of beach resources
	Belize	Flood	Landuse	To understand the flooding problem
	Dominica, St. Lucia, and St. Kitts	Hurricane	Infrastructure	To calculate losses due to wind hazard
	Dominica, St. Lucia, and St. Vincent	Hurricane	Assets of Electricity Companies	Disaster mitigation
	Jamaica	Coastal erosion	Coastal developments	To address the concern of coastal erosion
	St. Lucia	Sea level Rise	Coastal ecosystems: agriculture, water, tourism	Assessment of adaptation measures
Human	Montserrat	Multiple	Human development	Delineation of hazard zones & assessment of risk
Human & Economic	Suriname	Sea Level Rise	Socio-economic activities and the environment	To asses the impact of sea level rise
	Haiti	Flood	Life & property	Evacuation planning
Multiple	Anguilla	Flood	Communities, Agriculture, and Infrastructure	Mitigating incident of flood
	Anguilla	Landslide	Infrastructure	Identifying unstable slope areas
	Antigua	Multiple	Critical Facilities	Disaster mitigation planning
	Barbados	Multiple	Agriculture, Tourism, Water Supply, and Fisheries	To assess the effects of sea level rise
	Barbados	Flood		To delineate floodprone areas
	Barbados	Tsunami	Buildings, infrastructure, and facilities	To investigate likely inundation at the Marina
	Dominica	Sea Level Rise	Ecosystem, infrastructure	Minimizing negative impact of climate change

Type of Assessment	Country/ Territory	Hazard Type	Vulnerable Elements	Purpose of Assessment
Multiple	Grenada	Sea Level Rise	Beaches, Infrastructure, Buildings, Hotels	To identify resources vulnerable to sea level rise
	Haiti	Multiple	Human and economic	To establish community disaster programs
	Jamaica	Floods & Landslides	Property	Examine feasibility of national park location
	Jamaica	Flood	Life and Property	River & harbour engineering flood control
	Jamaica	Flood	Life and Property	Flood control and hydrological appraisal
	Jamaica	Flood	Life and Property	Flood control and hydrological appraisal
	Jamaica	Flood	Life and Property	To determine causes of run-off
	Martinique	Earthquake	Public Buildings	To evaluate the consequences of an earthquake
	St. Kitts & Nevis	Hurricane	Critical facilities	Preparation of disaster mitigation plans
	The British Virgin Islands	Multiple	Buildings, Utilities, Critical Facilities	Identify impacts of hazards
Structural	Anguilla, Antigua, & St. Kitts	Multiple	Schools and shelters	Towards improvement in structural design
	Belize	Multiple: Hurricane, flood, Seismic	Shelters	Location analysis of shelters
	Belize	Multiple: Storm surge, flood, fire	Buildings, Transportation	Reduction of vulnerability & improving response
	Dominica	Storm surge	Seawalls, Roads, Jetties	To assess the impact of wave hazard
	Jamaica	Flood	Buildings and population	To recommend mitigation plans
	Puerto Rico	Multiple	Buildings	To calculate damage potential for each hazard
	The British Virgin Islands	Multiple	Buildings and Natural Resources	Identification of areas at risk

Type of Assessment	Country/ Territory	Hazard Type	Vulnerable Elements	Purpose of Assessment
Structural and Human	Dominica	Landslide	Settlements and Infrastructure	To assist with monitoring of landslide activity
	Martinique	Multiple	Buildings and roads	To map different degrees of vulnerability
Bio-geophysical & Socio-econ	Guyana	Sea Level Rise	Agriculture, Human, Tourism, Water supply, Fish	To assess the effects of sea level rise

4.1 Methodologies Used

A variety of methods have been used to conduct Vulnerability Assessment Studies in the region. These include:

a. Use of historical data, analysis of topographic data, and flood modeling
b. Use of historical data on slope instability and site inspection of the geology
c. Beach monitoring, identification of causes and assessment of mitigating options
d. Generation of damageability models
e. Probabilistic hazard-vulnerability with financial analysis
f. Use of Bruun rule concept
g. Hydrological and hydraulic analysis
h. Computation of storm surge followed by hydraulic/hydrologic analysis and site evaluation
i. Flow simulation modeling
j. Evaluation of hazard and risk
k. Calculation of potential damage based on degree of vulnerability
l. Literature research and consultation with local communities
m. Generation of a one-metre rise in sea level over the coastal regions
n. Overlay of hazard maps on land use map as the basis for the expert assessment
o. Modeling of wave run-up based on three scenarios
p. Variety of methods used to determine offshore wave parameters
q. Maps of each hazard and their stakes prepared for each commune
r. Field mapping and analysis

With the exception of the OAS/PGDM project most of the other studies did not provide details of the methodology used nor were copies lodged with the relevant agencies in

the countries/territories. This limits capacity building and the ability of the users to use the result with confidence. It also prevents future work from benefiting from the shortfalls of past works.

The following are the critical success factors cited by respondents for most of the Vulnerability Assessment Studies:

a. Collaboration among local agencies
b. Involvement of local personnel
c. Access to external funding (OAS/CDMP; OAS PGDM)
d. Public consultation as input into the assessment (Martinique)
e. Island-wide or country-wide coverage (Martinique and Puerto Rico)
f. Standardization of methodology (OAS/CDMP; Martinique; and Puerto Rico).

4.2 Users and Uses

The list is similar to that of the Hazard Maps although less extensive. The uses are quite limited to the following:

- Planning of civil works
- Development planning and control
- Damage assessment
- Institutional strengthening
- Public education and awareness
- Hazard mitigation

The limited categories of users and uses can be attributed to poor circulation of output of Vulnerability Assessment Studies (VAS). The output of VAS is usually hardcopy, written reports that have to be read through in order to discover points or issues of interest. The language and format used may not be user-friendly to attract non-professional users. The hardcopy format places a resource challenge to the effective dissemination of the report to potential users. Usually, only 2 or 3 copies of the reports are submitted to local clients who may not have the resources to summarize the conclusions and recommendations and further disseminate the same to the community of local and regional users.

4.3 Limitations

The study came across the following limitations expressed by users of vulnerability assessment studies in the region:

m. Assessment is mostly qualitative
n. Inadequacy of input data: profile and elevation data, for example
o. Lack of water level data during severe storm events.
p. Changes to original methodology due to inadequate input data

q. Limited field data
r. Prolonged delays in start up
s. Non-availability of high resolution and current data
t. Multiple assessment did not assess vulnerability of specific elements
u. High level of generality in the methodology used
v. Non- incorporation of local knowledge
w. Short time frame of the study
x. Lacking continuity

These limitations where present, reduce the effectiveness of the studies and efforts should be made to avoid these limitations in future works.

4.4 Other Issues

The study identified the following other issues critical to effective preparation and use of vulnerability assessment studies in the region:

i. Very little use of hazard maps in the conduct of vulnerability assessment.
j. No measure of effectiveness of the studies when disasters do occur.
k. Vulnerability assessment studies are mostly event driven and not legally enforced as in Martinique and Puerto Rico.
l. The National Disaster Coordinators do not have access to the outputs of the studies and may not be informed or involved in the early stages of the studies.
m. Outputs of the studies are generally poorly disseminated to end-user. In fact dissemination of outputs is mostly not considered as an essential part of the studies and not properly included in the budget.
n. Little involvement of indigenous knowledge.
o. No budgetary allocation for follow-up studies or updating of dated studies.
p. The lack of documented and published methodology.

5.0 Digital Mapping Initiatives

In the past decade, there has been an increase in the production of digital maps in the Caribbean. Increased awareness of the utility of Geographic Information Systems (GIS) is largely responsible for the creation of these digital maps. The Database Report provides a listing of digital maps available in each of the countries studied, with the exception of Haiti and The Bahamas. Although the study was not able to compile the list of digital maps in Haiti and The Bahamas, the two countries have a well-established national digital map database that contains base maps relevant to hazard mapping and vulnerability assessment.

The study notes that there are several agencies within a country producing digital maps. There is little effort in coordinating the initiatives of these agencies. Table 5.1 contains the number of agencies which are repositories of digital maps in each country/territory. These pose management challenges. The absence of a national data clearinghouse means the community of users would have to go from one agency to another in order to get the datasets required for their works. Aside from this, the users have the responsibility of ascertaining the completeness and quality of the datasets obtainable from each agency.

Table 5.1 Numbers of Agencies with GIS Data

Country/Territory	***Number of Agencies***
Anguilla	2
Antigua and Barbuda	4
Barbados[1]	8
Belize[1]	3
Dominica[1]	1
Grenada	1
Guyana[1]	5
Haiti[1]	1
Jamaica	20
Martinique	1
Montserrat	4
Puerto Rico	10
St. Kitts and Nevis	3
Saint Lucia	4
St. Vincent & the Grenadines	1
Suriname	5
The Bahamas[1]	1
The British Virgin Islands[1]	3
Trinidad & Tobago[1]	6
Turks & Caicos Islands	5

Note 1: These countries have a central agency with active responsibility of generating national digital maps

Critical to Hazard Maps and Vulnerability Assessment Studies is the availability of the following digital maps in each country: elevation/contour, landuse, hydrology, soils, geology, vegetation, and infrastructure/ roads/buildings. Table 5.2 gives an overview of the existing digital maps in the Caribbean. The currency and accuracy of these maps need to be evaluated before they are used in any project. Efforts to obtain information on existing digital data in Haiti and The Bahamas were futile.

Table 5.2: Existence of Critical Digital Maps

Country/Territory	*Elevation*	*Landuse*	*Watercourses*	*Soils*	*Geology*	*Vegetation*	*Buildings*	*Utilities*	*Roads*
Anguilla	√			√			√		√
Antigua and Barbuda	√	√	√					√	√
Barbados	√	√	√	√	√	√	√	√	√
Belize		√	√	√		√		√	√
Dominica	√		√	√		√		√	√
Grenada	√	√	√	√	√	√	√		√
Guyana	√	√	√	√	√	√			√
Haiti	No information was provided								
Jamaica	√	√	√	√	√	√		√	
Martinique	√	√	√				√		√
Montserrat	√		√				√	√	√
Puerto Rico	√	√	√	√	√				√
St. Kitts and Nevis	√	√	√	√	√	√	√	√	√
Saint Lucia	√	√	√	√	√	√	√	√	√
St. Vincent & the Grenadines	√		√		√	√			√
Suriname	√	√	√	√	√	√			√
The Bahamas	No information was provided								
The British Virgin Islands	√	√	√		√			√	√
Trinidad & Tobago	√	√	√	√	√	√	√	√	√
Turks & Caicos Islands	√	√				√	√	√	√

The existence of digital hazard maps was also considered. Table 5.3 provides a list of hazard maps that are available in digital GIS formats in the countries. The existence of digital hazard maps in GIS formats will support continuity and improvement on previous works. The availability of digital GIS-based hazard maps within the countries/territories also posed a challenge. In cases where the hazard mapping projects were undertaken by foreign consultants, the outputs in digital formats (not screen dumps and JPEGs) are

not normally logged with the relevant national agency. With the exception of the OAS/PGDM that created a website www.oas.org/pgdm/data/gis_data.htm for the dissemination of project inputs and outputs datasets, the availability of these critical resources is a challenge. The unconstrained dissemination of digital GIS-based maps will reduce duplication of efforts and increase usability of the maps. Of the twenty countries studied, only the following embraced the notion of a national GIS database: Haiti, The Bahamas, Trinidad and Tobago, Puerto Rico, and Martinique.

Table 5.3 Existing Digital Hazard Maps (HM) in the Caribbean

Country/Territory	Seismic HM	Storm/Wind/ Wave HM	Volcanic Eruption HM	Flood HM	Landslide HM	Erosion HM	Multiple HM	*Total*
Anguilla	2	1	-	2	1	1	-	7
Antigua and Barbuda	2	4	-	1	1	1	-	9
Barbados	2	1	-	2	1	-	-	6
Belize	1	3	-	1				5
Dominica	2	-	1	-	1	-	1	5
Grenada	2	1	-	-	-	-	1	4
Guyana	3	-	-	-	-	-	-	3
Haiti	1	1	-	-	-	-	1	3
Jamaica	1	4	-	11	7	1	-	24
Martinique	2	2	2	2	2	-	-	10
Montserrat	2	4	1	-	-	-	-	7
Puerto Rico	3	1	-	4	2	-	-	10
St. Kitts and Nevis	4	5	1	1	-	2	-	13
Saint Lucia	2	1	1	-	3	-	-	7
St. Vincent & the Grenadines	2	1	-	-	1	-	-	4
Suriname	1	-	-	-	-	-	-	1
The Bahamas	2	1	-	-	-	-	-	3
The British Virgin Islands	3	5	-	1	-	-	-	9
Trinidad & Tobago	2	1	-	-	-	-	-	3
Turks & Caicos Islands	2	-	-	1	-	-	-	3
Total	**41**	**36**	**6**	**26**	**19**	**5**	**3**	**132**

The map scale, datum and projection of existing digital maps are of concern to all hazard maps and vulnerability assessment studies (HMVAS) projects. It is very important that HMVAS projects are undertaken using datasets that are of the same map scale, map datum, and map projections. A change in any of these characteristics in one or more of the datasets will significantly affect the ability to combine all the datasets in a

unified manner for HMVAS activity. For example, when digital landuse map data compiled from a 1:10,000 scale map is overlayed with digital contour map compiled from 1:50,000 scale map, the result would be a dilution of map resolution and creation of inaccuracy in the spatial analysis. Similar inaccuracy will occur when dataset based on different map datum and map projections are combined. Table 5.4 provides a list of map datum, ellipsoid, and map projections used by the countries studies with the exception of Haiti and Martinique.

Table 5.4: Map Parameters of Caribbean Countries/territories

Country/Territory	*Datum*	*Ellipsoid*	*Projection/Grid*
1. Anguilla	Anguilla 1957 NAD 1927	Clarke 1880 Clarke 1866	TM/BWI TM
2. Antigua	Antigua 1943	Clarke 1880 modified	TM/BWI TM/National Grid 1943
3. Barbuda	NAD27 NAD83	Clarke 1866 GRS80	UTM
4. Bahamas	Cape Canaveral NAD27 NAD83	Clarke 1866 GRS80	
5. Barbados	HMS Challenger Astro 1938	Clarke 1880 GRS80	TM/BWI TM/National Grid
6. Belize	NAD27 NAD83	Clarke 1866 GRS80	TM
7. British Virgin Islands	NAD83 Puerto Rico	Clarke 1866	UTM
8. Dominica	Dominica 1945 NAD27	Clarke 1880 modified Clarke 1866	TM/BWI UTM
9. Grenada	Grenada 1953 NAD27	Clarke 1880 modified Clarke 1866	TM/BWI
10. Guyana	Prov. SA 1956	International 1924	UTM
11. Haiti	NAD27 NAD27	Clarke 1866 Clarke 1866	TM with UTM Grid Haiti Lambert
12. Jamaica	Jamaica 1875 JAD69 JAD2001 Ft. Charles NAD27 NAD83	WGS84 Clarke 1880 Clarke 1866 GRS80	Jamaica Old Grid Jamaica National Grid Lambert Conformal Conic Lambert Conic Orthomorphic
13. Martinique		International 1924	UTM
14. Montserrat	Montserrat 1958	Clarke 1880 modified	TM/BWI
15. Puerto Rico	NAD27 NAD83 Puerto Rico	Clarke 1880 Clarke 1888 Clarke 1866	State Plane Coordinates 1927 UTM zone 20N
16. St. Kitts and Nevis	St. Kitts 1955	WGS84 Clarke 1880 modified	TM/BWI

Country/Territory	***Datum***	***Ellipsoid***	***Projection/Grid***
17. Saint Lucia	St. Lucia 1955	Clarke 1880 modified International 1924	TM/BWI
18. St. Vincent & the Grenadines	St. Vincent 1945 NAD27	Clarke 1880 modified Clarke 1889	TM/BWI UTM
19. Suriname	Zanderij	International 1924 WGS84	Suriname TM UTM zone 21N
20. Tobago	Mt. Dillon 1949	Clarke 1858	Cassini Soldner
21. Trinidad	Naparima 1955 Naparima 1972	International 1924 South American 1969 Clarke 1855	TM/UTM zone 20N
22.Turks & Caicos Islands	NAD27 NAD83	Clarke 1866 GRS80	TM

TM Transverse Mercator; UTM Universal Transverse Mercator, BWI British West Indies Grid; NAD North American Datum; WGS World Geodetic System, JAD Jamaica Datum

Another utilization challenge of digital maps is the variety of available digital file formats. The ESRI™ data formats: ArcINFO™ and ArcView Shapefile™ are the most common data formats used in the region. Table 5.5 provides the type of data formats of existing digital maps in the region. Although most popular GIS software provide for the conversion from one format to another, the ability of these conversion routines to undertake a two-way conversion without loss of integrity cannot be guaranteed.

The other issue of concern is the lack of metadata prepared for existing digital datasets. This impinges of the ability of the data user to have a perspective of the origin of the data and other characteristics needed to be known before a decision is made whether or not to use a particular dataset.

Table 5.5 Formats of Digital Maps in the Caribbean

Country/ Territory	*ArcINFO*	*Shapefile*	*MapInfo*	*Canvas file*	*Grass raster*	*GeoTIFF*	*MGE .dng*	*AutoCAD*
Anguilla	√							
Antigua and Barbuda		√						
Barbados	√	√						√
Belize		√						
Dominica		√						
Grenada		√						
Guyana		√	√					
Haiti								
Jamaica	√	√		√	√	√		√
Martinique		√	√					
Montserrat		√						
Puerto Rico		√						
St. Kitts and Nevis		√						
Saint Lucia		√						√
St. Vincent & the Grenadines		√						
Suriname		√				√		√
The Bahamas								
The British Virgin Islands		√						√
Trinidad & Tobago	√	√				√	√	
Turks & Caicos Islands		√				√		√

6.0 Martinique: the Best Practice in the Caribbean

As a result of a law of 1982, the Préfecture de la Région Martinique, in an effort to regulate the use of land subjected to natural hazards, undertook the development of a study entitled *Plans d'Exposition aux Risques naturels prévisibles* (PER), whose aim was to prevent and curtail damage due to natural hazards by delimiting vulnerable areas and by prescribing measures of prevention. The law of 1995 replaced PER by the study, the *Plan de Prevention des Risques naturels* (PPR), in an attempt to clarify and simplify the method of risk prevention while making it more effective.

The French territory of Martinique recently concluded in September 2002, a very comprehensive, large-scale, multi-hazard, and vulnerability and mitigative study entitled the *Plan de Prevention des Risques naturels* (PPR). The PPR built upon a pre-existing study, introduced in 1982 that aimed at preventing and curtailing damage due to natural hazards by delimiting vulnerable areas and by prescribing measures of prevention. The PPR is an attempt to clarify, simplify and make more effective the method of risk prevention against natural hazards in the prefecture of Martinique.

The success of this undertaking lies in the following:

6.1 Approach used

Martinique used both a collaborative and consultative approach in implementing a comprehensive approach to Hazard Mapping and Vulnerability Assessments.

A collaborative approach

The PPR brought the local powers that be at the start of the project. A committee, formed in June 2001, comprised:

- The Préfecture of Martinique
- The Regional Council
- The General Council
- The Mayors' Association of Martinique
- Those with responsibility for the urban areas, which have their specific problems that make them more at risk from the hazards than the rest of the island
- Members of working groups that included professionals from the construction industry, corporate bodies, specialist associations such as the *Association Pour La Prévention des Risques Majeurs à la Martinique* (APRM),
- Officials from various state agencies such the *Direction Départemental de l'équipement* (DDE).

A consultative approach

In the development of the PPR, consultation was held at regular intervals in each of the 34 communes, with members of the community, representatives of the municipal

council, the DDE and research units to reach agreement on the Plan. The consultation proceeded in a series of stages:

- Definition of the 'stakes' – those elements of the physical and human environment that are likely to be affected by the hazard
- Presentation of the hazard study results
- Presentation of the regulatory map showing the hazard areas and the stake zones to the municipal council at an official consultation.

6.2 Clearly stated objectives

The committee agreed that the main concerns of the study should:

- Take into account the constraints specific to Martinique (its insularity, department status, population density, multiple hazards)
- Make recommendations rather than rules, which may cause hardships on those who may not be able to abide by them.
- Identify clearly the zones at stake in order to refine the recommendations to be formulated.

6.3 Spatial extent

The PPR was done for the entire territory of Martinique at the level of commune or administrative units. There are 34 communes that make up the territory of Martinique.

6.4 Nature of the hazard mapping and vulnerability exercise.

- *Use of one common map scale*, as far as possible. Choice of scale selected: 1:10,000. This allowed communities to see their streets and house location with respect to the hazard.

- *Selection of recurrent and potentially damaging hazards*: earthquakes, liquefaction, volcanic eruption, landslides, coastal and riverine flooding, hurricanes, coastal erosion.

- *Use of pilot sites to test methodology.*

- *Updating of all relevant maps*, using field surveys, and aerial photographs.

- *Use of GIS for preparation, analysis, modelling and update of maps.*

- *Use of a standardized legend for hazard, regulatory and 'stake' maps.*

- *Use of expertise* with competence in data collection, analysis and modelling, both from Martinique and France.

- *Timely completion of study* (June 2001 to September 2002)

Introduction of a new concept of "stakes" –The PPR was aimed at assuring people's safety and reducing the vulnerability of inhabitants, their property and activities in hazard–prone areas. In this regard, the PPR indicated the nature of the analysis of hazards in a given area to arrive at a demarcation of hazard zones. "Stakes" are those elements of the human environment, namely buildings and the population housed in these buildings that would be impacted upon by the occurrence of particular levels of hazards. In other words, stakes are the vulnerable elements.

Three zones of different degrees of stakes were defined through public consultation:

- Very high stakes –zones making up the historic centre, commercial areas
- High stakes – zones of actual and potential urban activity
- Moderate stakes – agricultural areas, rural areas and natural areas.

The rationale for the introduction of this concept is that a designated level of hazard does not have the same impact on the human and natural environment but when it is combined with the elements of the human environment that would be affected (based on the number of people and buildings), the interpretation of the hazard becomes more meaningful to end-users of the maps.

*Derivation of regulatory z*ones from a matrix of levels of hazards and levels of stakes.

Standardization of the colours in the legend for regulatory zones so that all white, yellow and orange coloured zones indicate that construction is possible to varying degrees; red coloured zone in which no construction is authorized except for activities like farming and fishing; violet coloured zone in which a major hazard is highly likely and no construction is permitted. See example below for flood hazard.

ZONAGE POUR L'ALEA INONDATION

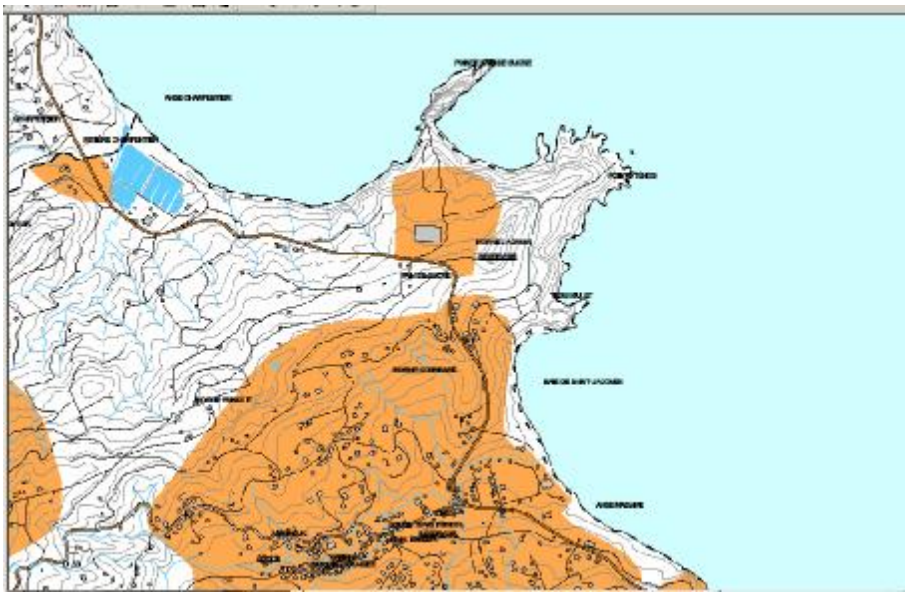
	ALEA MAJEUR	ALEA FORT	ALEA MOYEN
Enjeux très forts (Centre historique)	Pas de construction autorisée Possibilité d'expropriation ZONE VIOLETTE	Application de prescriptions particulières (Ex : Construction à Q_{100} * + 0.50 m, libre écoulement des eaux) ZONE JAUNE	Application de prescriptions particulières (Ex : Construction à Q_{100} * + 0.50 m, libre écoulement des eaux) ZONE JAUNE
Enjeux forts (Développement urbain)	Pas de construction autorisée Possibilité d'expropriation ZONE VIOLETTE	Application de prescriptions particulières et réalisation d'un aménagement global ZONE ORANGE	Application de prescriptions particulières et réalisation d'un aménagement global ZONE ORANGE
Enjeux modérés	Pas de construction autorisée Possibilité d'expropriation ZONE VIOLETTE	Pas de constructions autorisées sauf exceptions précisées au règlement joint ZONE ROUGE (Risque fort)	Pas de constructions autorisées sauf exceptions précisées au règlement joint ZONE ROUGE (Préservation champ d'expansion des crues)

Reference: CD entitled PPR-SAINTE MARIE, Folder "Note de Présentation". Page 150.

6.5 Content of final delivery

For **each** administrative unit, the deliverable contained:

- Objectives of the PPR
- Description of its physical, and demographic characteristics
- Explanation of hazards and their consequences
- Analysis of hazards
- Presentation of the legend for hazard maps
- Results of studies conducted on each hazard likely to affect the commune, with the use of maps and photographs
- Explanation of the classification of levels of hazards
- Explanation of the derivation of regulatory zones or zones likely to suffer losses
- Measures for prevention, protection and safeguard required in areas that suffer hazards.
- Maps in .pdf format for each hazard and a map of 'stakes'. The screen dump below shows part of the map of 'stakes'. In this commune, areas of concern fell in the orange coloured category of 'stakes'.



6.6 Method of dissemination

Hard copy of the map is to be located at the Mayor's office of each commune that included:

- Reports, explanation of the nature of the hazards, the levels of each hazard, interpretation of each category of 'stakes'; recommendations to accompany each level of hazard and the level of stakes

- Maps for each commune that showed the relevant hazard.
- Maps of the levels of 'stakes'.
- *Digital copy* of above for each commune to be located at each Mayor's office.

6.7 Method of implementation

Risk preparedness plans of the PPR are state-approved and enforced.

Depending in the hazard zones defined, the PPR would grant permission to develop in those areas not prone to hazards or give advice on urban issues such as construction and management in those vulnerable areas.

The public is expected to adhere to the approved PPR by going through the local urban plans that must respect the recommendations of the PPR.

Non-compliance with the caveats and prescriptions of the PPR makes one liable to penalties as stated in article L.480 of the *Code de l'Urbanisme*.

The PPR does not define the nature of construction in a given area. It merely indicates the vulnerable zones and the related hazards and the constraints affecting these zones if they were to be built upon.

6.8 Funding availability

The cost of preparing the PPR was € 1 million that came from the French central government, The Préfecture of Martinique, The Regional Council, The General Council and The Mayors' Association of Martinique.

7.0 Conclusion and Recommendations

This study revealed that a number of hazard maps were available which had already been produced with considerable resources and time in the past. Regional, national, and community organizations should make maximum use of these maps for disaster management and any other purposes.

The study identified areas that had been covered by hazard maps and those not covered by such maps. Regional and national organizations should be encouraged to produce hazard maps for the latter so that all areas vulnerable to disasters in the region may be covered as early as possible in the future by hazard maps against specific disasters the areas might face.

The study also revealed there were a number of deficiencies with the hazard maps so far produced. Whilst encouraging the production and the use of hazard maps as mentioned above, efforts should be made to overcome the deficiencies for the improvement in the production and the effective use of hazard maps. The recommendations of this chapter focus on this aspects.

The variety and quantum of digital maps existing in the Caribbean provides the spatial infrastructure needed for the increased use of digital approach to the production of hazard maps and the conduct of vulnerability assessment studies with supporting digital maps. Some attempts at this digital methodology have been attempted in Jamaica, Antigua and Barbuda, and St. Kitts and Nevis, and Haiti. In Puerto Rico and Martinique a full use of digital methodology has been achieved. In order to attain the full use of digital methods, all the base data required must be available in digital formats, at the same scale, same datum and map projection.

In order to achieve this desirable goal, it is paramount that a national data clearinghouse be established in each country/territory with the responsibility for: quality control and quality assurance; maintenance of metadata; dissemination of data; and updating of data.

It is also important that a capacity building programme be established for the training to digital data providers and data users so as to ensure the increased utilization of the datasets existing in each country.

The issue of data availability remains a major challenge in the region. Access to data is being constrained due to the absence of a data dissemination policy. The region as a whole would greatly benefit from a policy that ensures that digital map data is freely made available to users. The benefits include the development of an information conscious society and the empowerment of the community of users.

Production of hazard maps is still in its infancy in the Caribbean. Most of the mapping

suffers from the following deficiencies:

1. Output maps are poorly disseminated to end-users
2. Scale is too small for site specific analysis
3. Input data are grossly inadequate, unavailable, and not current
4. Methodology used is not properly documented and known to repository agencies
5. Map legend used do not effectively communicate to end-users
6. No budgetary allocation for updating the maps and extending the mapping to other parts of the countries/territories
7. Analogue approach to mapping makes the cost of updating and improving the methodology unattractive
8. Little involvement of local agencies and local communities, which affects the accuracy of mapping and interpretation
9. No official record of users and uses

In order to reduce the impacts of these deficiencies, the following recommendations are offered.

Production, Dissemination, Use, and Updating

j. There is a need to institutionalize hazard mapping in the region to develop a standardized methodology, to review/improve hazard maps produced, to disseminate to users, to monitor the impacts of hazard maps and to develop regional capacity for hazard mapping and their uses. The most practical way will be to establish a partnership of existing regional organizations as pursued by CADM project for flood hazard mapping. Establishment of new agencies such as the Seismic Research Unit will also be considered as an alternative way.

k. Copies of the database and other products generated by regional or externally funded projects should be provided to local agencies charged with the responsibility of producing and maintaining hazard maps, vulnerability assessments and digital maps.

l. The use of hazard mapping, vulnerability assessment studies in development-related activities should be actively encouraged.

m. The production and dissemination of hazard maps should be mandated by law if the reduction of vulnerability to hazard through the building of more resilient society is to be achieved.

n. A more user-centred approach to the production and dissemination of hazard maps should be pursued as a matter of urgency.

o. The designated national agencies should be provided with the resources needed

for effective dissemination of the outputs of the hazard mapping, vulnerability assessment studies and digital mapping data in the country/territory.

p. Adequate funding should be provided for the building of capacity in disaster mitigation. This would ensure a reduction of loss of life, property and the biophysical environment. The current disaster-trigger approach and reliance on external funding cannot adequately be used to support the long-term nature of the effects of natural hazards in the region.

q. There is a need to obtain feedback from the project stakeholders before the final reports of hazard mapping and vulnerability assessment studies are published.

r. A national record of users and uses of hazard maps and vulnerability assessment results should be maintained.

Role of National Agencies

f. There is urgent need to upgrade the infrastructure of National Disaster Offices so as to ensure that the use of hazard maps is fully integrated into their routine activities.

g. In each country, a national agency should be designated as the repository of hazard mapping, vulnerability assessment studies and digital mapping data.

h. A national coordinating body should be designated with the responsibility to specify, monitor and coordinate activities relating to hazard mapping, vulnerability assessment studies and digital mapping data production in the country/territory.

i. A national clearinghouse should be established with responsibility to specify, monitor, evaluate, and disseminate digital mapping in the country/territory.

j. National Disaster Offices should be adequately informed and involved in every hazard mapping and vulnerability assessment study to be undertaken in each country/territory.

This study has created the infrastructure needed to ensure that information on hazard mapping, vulnerability assessment studies and digital mapping can be easily collected and disseminated. It is necessary therefore that this infrastructure be maintained.