CDERA
The Caribbean Disaster Emergency Response Agency
Managing Disasters with Preparedness

JICA
Japan International Cooperation Agency

Agence canadienne de développement international
Canadian International Development Agency

Organization of American States

STATUS OF HAZARD MAPS VULNERABILITY ASSESSMENTS AND DIGITAL MAPS

COMMONWEALTH OF PUERTO RICO REPORT

THE CARIBBEAN DISASTER EMERGENCY RESPONSE AGENCY (CDERA)

October 2003

Table of Contents

Preface

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.

This survey reviewed the status of these thematic activities in sixteen (16) CDERA Participating States, Haiti, Martinique, Suriname and Puerto Rico over the period August – October 2003. 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.

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

1.0 Introduction

1.1 Physical and socio-economic background

The Commonwealth of Puerto Rico is made up of the main island of Puerto Rico and the nearby islands of Vieques, Culebra, Palomino, Mona, Monita and other small islands. The main island of Puerto Rico, with an area of 3,500 square miles (9,104 km^2), and measuring 35 miles (90.6 km) wide by 100 miles (259 km) long, is the eastern-most island of the Greater Antilles found at the northern part of the Caribbean basin. It is located at 18º 15' N and 66º 30' W, between the Dominican Republic to the west and the Virgin Islands to the east, and 1000 miles (2,590 km) to the southeast of Florida, US. To the north of Puerto Rico lies the Puerto Rican Trench, the deepest part of the North Atlantic Ocean, going to a depth of 28,000 feet (8,500 m) and to the south is the Venezuelan Basin, 16,400 feet (5,000 m) deep.

Puerto Rico is divided into three physiographic zones: the Cordillera Central, an east-west trending range of mountain making up roughly 60% of the island found in the southern part of the island; the coastal lowlands; and the karst or limestone area. The highest peak is Cerro La Punta standing at 4,285 feet (1,338 m) high in the central part of the island. The main rivers drain the northern and southern coastal plains, and areas to the west and have often flooded in times of heavy rains. The coastal lowlands to the north vary in width from 8 to 12 miles (13 to 19 km) and those to the south vary from 2 to 8 miles (3-13 km). The karst region in the north of the island extends from Aguadilla on the west coast to Loíza, just east of San Juan, the capital city. Typical karst features seen here are caves, sinkholes, mogotes and dolines. Some 2000 caves are found in the Cueva del Infierno. Part of the Río Camuy runs underground, forming the third largest subterranean river in the world. (http://welcome.topuertorico.org/descrip.shtml).

Puerto Rico experiences a Tropical Marine type of climate, with mean annual temperatures of 24ºC, and a prevailing wind from the east. The dry season is from December to March, and the wet season is from April to November, in which tropical storms and hurricanes occur between August to October. The north coast receives twice as much rainfall as the south coast. Relative humidity is high throughout the year.

Several thousand species of flora and fauna of the rainforest are found in the island. The unique dry forest vegetation of Guaníca, in the southwestern part of the island, is now part of UNESCO's International Biosphere Reserve.

The island of Puerto Rico was ceded to the United States of America (US) at the end of the Spanish-American war and is today a Commonwealth of the US. Puerto Ricans have been granted US citizenship in 1917 but opted for internal self-government in 1948 with the Governor as the elected head of government. Puerto Rico has 78 "*municipios*" or municipalities. Each is governed by a popularly elected mayor and municipal assembly.

Puerto Rico has very few natural resources of economic value, namely, stone, fish, copper and nickel, but it has the potential for on-shore and off-shore crude oil production. Its economy relies heavily on Federal Aid from the United States Government, which initiated industrialization programs by offering tax incentives to US investors, particularly in the manufacturing industry.

The population of Puerto Rio, as estimated at July 2003, stood at 3,885,877. Population growth is 0.58% per annum with an out-migration rate of –1.54 migrants per 1000 of the population (2003). 22.9% of its people are under 15 years old and the economically active population makes up 65.2% of the population. Its per capita GDP is an estimated US$11,500 (2002), with the sectors of agriculture, industry and services contributing 1%, 45% and 54% (1999) respectively to the Gross Domestic Product. (Source of statistics: Central Intelligence Agency (CIA) Fact Book, 2003) found at: http://www.cia.gov/cia/publications/factbook/geos/gj.html.

1.2 Major disaster issues confronting the country

Puerto Rico is affected by numerous natural hazards, namely, coastal and riverine flooding, rain-induced and earthquake-induced landslides, tropical storms and hurricanes, storm surges, tsunamis, liquefaction and ground shaking. With the passing of Hurricane Georges in September 1998, Puerto Rico experienced the worst natural disaster in 70 years. The hurricane incurred some US$2 billion in damage, that included damage to 217,000 homes, no potable water to 900,000 people, total disruption of electricity, 29,000 people left homeless, 40 bridges damaged or rendered impassable, substantial loss of agricultural goods and loss of lives.

Coastal flooding is a common occurrence in Puerto Rico and is associated with storm surges generated by the passage of low-pressure systems, tropical storms and hurricanes. Offshore bathymetry, coastal topography, soil saturation, tidal levels and wave type are some factors that affect the level of the storm surge. The direct impact of storm surges often cause damage to structures in their paths.

Riverine flooding is caused by heavy rains that become floods when the banks of the rivers cannot contain the runoff. Such floods often occur in narrow channels of mountainous areas and on flat, low-lying coastal areas. Coastal lowlands are usually densely populated areas and flooding can easily result in a natural disaster.

In Puerto Rico, the movement of loose, unconsolidated rock and soil material due to the effects of gravity can take the form of debris slides and debris flows, block slides and slumps, and earth flows. Though steep topography and shallow, fine-grained soils produced by weathering of the underlying bedrock are some factors that permit the development of landslides, heavy rainfall is cited as the single most contributing factor. Intense or prolonged rainfall causes an increase in soil water content and provides lubrication along planes of weaknesses that can promote slumping or sliding of material that can be termed rain-induced landslides. Debris flow is the most common type of mass movement, in which unconsolidated soil and rock particles mix with rainwater to form a slurry that can flow down steep slopes of gullies. When it moves rapidly it becomes a debris avalanche. In Puerto Rico, deforestation, excavation and leveling of slopes for road and building construction, particularly on steep and unstable slopes are major factors that contribute to the occurrence of landslides. The storm of October 1985 produced block slides and slumps that resulted in the loss of 129 lives in the Mameyes district ;and debris slides and flows along the south coast of Puerto Rico in the areas of Penuelo and Coamo destroying many homes and buildings.

Earthquakes can induce landslides on slopes due to ground shaking caused by the release of energy from movements of tectonic plates. These landslides are a factor of the geology, the slope steepness, water content of the rock material, the magnitude of the earthquake and the intensity of ground shaking.

Located at the northern edge of the Caribbean plate, Puerto Rico has had a long history of earthquakes. These occurred in 1520, 1615, 1751, 1776, 1787, 1867, 1918, 1943 and 1946. In 1867 and 1918, Puerto Rico experienced earthquakes of magnitudes 7.3 and 7.5 respectively. Damage to buildings and infrastructure that result from earthquakes are caused by ground shaking, liquefaction and landslides.

Tsunamis are another hazard facing Puerto Rico. They are ocean waves created by an abrupt disturbance within the ocean due to an earthquake or volcano. Earthquakes of 1867 and 1918 produced tsunamis, with the 1918 earthquake generating 19-feet high tsunamis that caused damage to the northwestern coast, killing 116 persons. The northwestern coast of Puerto Rico faces the greatest threat from tsunamis.

Hurricanes, though predictable, cannot be avoided. The high winds over 74 miles per hour, associated with tropical storms and hurricanes, are particularly destructive of buildings and infrastructure that stand in their path. Wind-borne debris has the potential to add further damage. Storm surges and heavy rainfall accompanying these intense weather systems also add to their destructive potential.

2.0 Hazard Mapping Initiatives

The most recent initiative to prepare and update a seismic hazard map for Puerto Rico was done in 2003 by the US Geological Survey (USGS), Carlton University, and the University of Puerto Rico, with the intention of using it for hazard assessment and mitigation.

In 2002, a hazard mapping initiative undertaken by the Commonwealth of Puerto Rico was the Integrated Hazard Assessment (IHA) for the island of Puerto Rico. It was collaborative effort among:

- *Universidad Metropolitana* (UMET), San Juan, Puerto Rico
- Representatives of the Federal Emergency Management Agency (FEMA)
- The Governor's Authorized Representative (GAR)
- Puerto Rico Planning Board (PRPB)
- Department of Natural and Environmental Resources (DNRA)
- Administration of Regulations and Permits (ARPE)
- Department of Housing (DEV)
- Department of Transportation (DTOP)

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The main objective of the IHA was to provide local and state officials with a consistent framework for comparing and integrating disparate natural hazards in an attempt to reduce their adverse effects in Puerto Rico. The information provided by the IHA would be used to:

- Demarcate areas at risk
- Develop areas not at risk to the occurrence of natural hazards
- Inform better decision-making for the public's safety
- Prepare vulnerability assessments

Hazard maps for each of the main natural hazards that affect Puerto Rico were first prepared, out of which a composite hazard map was done that integrated each hazard studied. Maps were done and presented to each of the 78 municipalities in Puerto Rico: Adjuntas, Aguada, Aguadilla, Aguas Buenas, Aibonito, Anasco, Arecibo, Arroyo, Barceloneta, Barranquitas, Bayamon, Cabo Rojo, Caguas, Camuy, Canovanas, Carolina, Catano, Cayey, Ceiba, Ciales, Cidra, Coamo, Comerio, Corozal, Culebra, Dorado, Fajardo, Florida, Guanica, Guayama, Guayanilla, Guaynabo, Gurabo, Hatillo, Hormigueros, Humacao, Isabela, Jayuya, Juana Diaz, Juncos, Lajas, Lares, Las Marias, Las Piedras, Loiza, Luquillo, Manati, Maricao, Maunabo, Mayaguez, Moca, Morovis, Naguabo, Naranjito, Orocovis, Patillas, Penuelas, Ponce, Quebradillas, Rincon, Rio Grande, Sabana Grande, Salinas, San German, San Juan, San Lorenzo, San Sebastian, Santa Isabel, Toa Alta, Toa Baja, Trujillo Alto, Utuado, Vega Alta, Vega Baja, Vieques, Villalba, Yabucoa, and Yauco.

The study proceeded along six steps in which the natural hazards are identified; intensity/frequency relationships for each hazard identified; susceptibility maps developed; damage functions relating hazard intensity to damage potential were developed and calculated; and the development of a composite hazard ranking for use at the municipal, regional and Central Government levels was created.

The entire documentation (including hazard maps) on the Integrated Hazard Assessment (IHA) for the island of Puerto Rico is available at the website: http://gis-srv.suagm.edu

Another hazard mapping initiative recently completed is the Puerto Rico Tsunami Warning and Mitigation Programme undertaken by the University of Puerto Rico at Mayaguez in February 2002 in which the main objective was to produce maps of coastal flooding due to the occurrence of tsunamis. It was a programme funded by the Federal Emergency Management Agency (FEMA) of the US and the University of Puerto Rico. Two tasks were involved in achieving this objective:

- The development of 269 potential earthquake scenarios for use in the tsunami simulations
- Preparation of the flood maps using the tsunami simulations for each earthquake scenario.

Table 1 provides the particulars of hazard maps that have been produced for Puerto Rico.

Table 1 – Hazard Mapping

Type	**Purpose**	**Coverage**	**Date Produced**	**Primary Sources**	**Author**
Ground shaking	unknown	Entire island	2002	URS Corporation; *Universidad Metropolitana (UMET)*	URS Corporation
Seismic ground motion	To map expected seismic ground motions for 500 & 2500 year periods	Entire island	2003	US Geological Survey, CGHT	Charles Mueller, Geophysicist USGS

Liquefaction		Entire island	2002	URS Corporation; *Universidad Metropolitana (UMET)*	URS Corporation
Earthquake-induced landslides		Entire island	2002	URS Corporation	URS Corporation
Coastal flooding		Monitored beaches	2002	URS Corporation; *Universidad Metropolitana*	URS Corporation
Rain-induced landslides		Entire island	2002		*Universidad Metropolitana (UMET)*
Riverine flooding		Entire island	2002	*Universidad Metropolitana*	URS Corporation
High-wind hazard		Entire island	2002	*Universidad Metropolitana (UMET)*	*Universidad Metropolitana (UMET)*
Tsunami	To produce tsunami generated flood maps of: 1.Contour plot of sea surface elevation 2. Inland flood limit	Entire island	2003	University of Puerto Rico, Mayaguez (UPRM)	University of Puerto Rico, Mayaguez (UPRM)

2.1 Methods of preparation and distribution

2.1.1 Earthquake ground shaking

The earthquake ground shaking hazard map done in 2002 at a scale of 1:450,000 showed ground motion intensities with a probability of not being exceeded for a 100-year return period. It was based on the Seismic Hazard Map of 1994 (Earth Science Consultants, 1994), in which ground-shaking intensity was calculated for various return periods for the geology and soils of Puerto Rico. The earthquake ground shaking hazard map will be updated by work done in 2003 for Puerto Rico by the USGS.

The earthquake ground shaking motions were classed as ‘Very high’, ‘High’, ‘Moderate’, ‘Low’, ‘and ‘Very low’. Please see pages A-2 to A-7 of *Appendix A: Integrated Hazard Assessment Methodology.pdf* of section entitled “Project documentation, metadata and tools” at the website for the Integrated Hazard Assessment Project: http://gis-srv.suagm.edu/iha_project/AppendixA.pdf for further details on the calculation of ground motion.

2.1.2 Liquefaction

Liquefaction occurs when loose, unconsolidated soils lose their strength and behave like a thick liquid due to earthquake ground shaking. It is affected by ground shaking intensity (Peak Ground Acceleration, PGA), the liquefaction susceptibility category, of sedimentary deposits in particular, the magnitude of the earthquake, geology and depth to ground water. The Liquefaction Hazard Map produced at a scale of 1:450,000 for the island of Puerto Rico showed liquefaction susceptibility classes as ‘Very high’, ‘High’, ‘Moderate’, ‘Low’, and ‘Very low’.

Please see pages A-11 to A-16 of *Appendix A: Integrated Hazard Assessment Methodology.pdf* of section entitled “Project documentation, metadata and tools” at the website for the Integrated Hazard Assessment Project: http://gis-srv.suagm.edu/iha_project/AppendixA.pdf for further details on the calculation of liquefaction susceptibility.

2.1.3 Earthquake-induced landslides

Earthquake tremors can render slopes unstable and cause failure in the form of landslides. Such landslides can occur in natural slopes, or where steep slopes have been cut for a particular use. The degree of ground shaking, the magnitude of the earthquake, geology, slope, water content of the slide material and previous slope history affect landslide occurrence. For the creation of the Earthquake-induced Landslide Hazard Map, at a scale of 1:450,000, the landslides mapped were a function of PGA and the landslide susceptibility category. Earthquake-induced landslide susceptibility was classed as ‘Very high’, ‘High’, ‘Moderate’, ‘Low’ and ‘Very low’.

Please see pages A-19 to A-23 of *Appendix A: Integrated Hazard Assessment Methodology.pdf* of section entitled “Project documentation, metadata and tools” at the website for the Integrated Hazard Assessment Project: http://gis-srv.suagm.edu/iha_project/AppendixA.pdf for further details on the calculation of earthquake-induced landslide hazard susceptibility.

2.1.4 High wind

High winds accompanying hurricanes and tropical storms with wind speeds greater than 75 miles per hour do great damage to buildings and infrastructure. The High Wind Hazard map created, at a scale of 1:450,000, was based on two sets of calculations, one from a wind hazard model and the other from a hurricane simulation model using the HURDAT hurricane database to generate synthetic storms for various return periods ranging from 10 to 1,000 years at 100 locations over the island. High wind hazard was classed as 'Very high', 'High', 'Moderate', 'Low' and 'Very low'.

Please see pages A-27 to A-31 of *Appendix A: Integrated Hazard Assessment Methodology.pdf* of section entitled "Project documentation, metadata and tools" at the website for the Integrated Hazard Assessment Project: http://gis-srv.suagm.edu/iha_project/AppendixA.pdf for further details on the calculation of high wind hazard.

2.1.5 Riverine floods

The Riverine Flood Susceptibility Map, created at a scale of 1:450,000, was based on the 100-year flood that represented the overall flood hazard in Puerto Rico. Not all areas in Puerto Rico had been mapped with respect to this return period. It was necessary to derive the 100-year floodplain, which required interpretation of a number of maps. GIS was used to create a Triangular Irregular Network (TIN) of water surface elevation. This was then subtracted from Base Flood Elevation surfaces to arrive at the flood depth for the 100-year flood occurrence. Flooding depths were generated for 1m, 2m, or 3m and greater.

Please see pages A-35 to A-36 of *Appendix A: Integrated Hazard Assessment Methodology.pdf* of section entitled "Project documentation, metadata and tools" at the website for the Integrated Hazard Assessment Project: http://gis-srv.suagm.edu/iha_project/AppendixA.pdf for further details on the calculation of the riverine flood hazard.

2.1.6. Coastal floods

Areas subject to flooding were defined by the VE zones (*coastal flood with velocity hazard (wave action); base flood elevation determined*) of FEMA. They were defined using the 100-year flood probability and relied on interpretation of a number of maps. The flood depth of the Coastal High Hazard Area was determined using GIS, wherein water surface elevation was subtracted from the base flood elevation of the VE zones. The low resolution of the topographic data required interpolation of the VE zones in order to arrive at the flooding depths of 1m, 2m, and 3m or greater. No preview of the coastal flooding hazard maps was included in Appendix A.

Please see page A-37 of *Appendix A: Integrated Hazard Assessment Methodology.pdf* of section entitled "Project documentation, metadata and tools" at the website for the Integrated Hazard Assessment Project: http://gis-srv.suagm.edu/iha_project/AppendixA.pdf for further details on the calculation of the coastal flood hazard.

2.1.7. Rainfall-induced landslides

The methodology used to create the rainfall-induced landslides hazard map is based on research done by Larsen and Torres-Sanchez (1998). Their study of the physiographic and climatic conditions of three representative watersheds in Puerto Rico revealed that four factors influenced the occurrences of landslides:

- Slopes (>12 º or 21%; East Northeast facing slopes; slopes >350m high).
- Geology (Limestone underlain by clay or marl layers had a high susceptibility; Volcanic bedrock moderate susceptibility; sedimentary rock formations of coastal plains, a low susceptibility)
- Presence of saprolite (weathered rock)
- Land use (areas affected by human settlement)

The results of this study were extrapolated to the rest of the island based on a matrix prepared for slope, elevation and aspect for each watershed. Ratios were calculated for each landslide in terms of the number of landslides/km^2 /10 years. Five landslide susceptibility categories were defined: Very Low, Low, Moderate, High, and Very High.

Please see page A-41 to A-47 of *Appendix A: Integrated Hazard Assessment Methodology.pdf* of section entitled "Project documentation, metadata and tools" at the website for the Integrated Hazard Assessment Project: http://gis-srv.suagm.edu/iha_project/AppendixA.pdf for further details on the calculation of rainfall-induced landslide hazard.

2.1.8 Tsunamis

The methodology for arriving at the tsunami flood hazard maps involved the preparation of computational grids using bathymetric and topographic data; selecting a tsunami model (the Japanese TIME tsunami model) and high-resolution computational grids; and preparation of final maps. The results of the simulations were presented in two ways:

- A contour plot of sea surface elevations at 0.5m intervals at a scale of 1:20,000 in NAD27 coordinate system
- Inland flood limits digitized manually onto IKONOS satellite imagery in NAD83 Puerto Rico State Plane Coordinates. The legend for this map read: 'Inland flood limits' and 'Non-floodable isolated areas'.

For details on the methodology used to create the tsunami inundation maps, please see document *PRTWMP-Final Report-Task_1-Flood_Mapping.pdf* on the website: http://poseidon.uprm.edu.

2.1.9 Seismic ground motion

The seismic hazard maps produced by the USGS in 2003 show probabilistic ground motion in terms of PGA, 1.0-second spectral response, and 0.2-second spectral response, with 2% and 10% probability of exceedance in 50 years, corresponding to return times of approximately 2500 and 500 years, respectively. The USGS methodology utilized gridded and smoothed historical seismicity of earthquake magnitudes equal to or greater than 4.5, and fault sources with known slip-rate or recurrence information.

The maps are to be used for earthquake mitigation and response planning and will inform future updates of building codes. Further details of the methodology, given in the report, “Documentation for 2003 USGS Seismic Hazard Maps for Puerto Rico and the U.S. Virgin Isles” by Mueller et al., along with maps, are available at http://geohazards.cr.usgs.gov/eq/html/prvi2003.html.

2.2 Users and uses

The Integrated Hazard Assessment methodology is used by all municipalities, the Planning Board and the AEMEAD for identifying each barrio, its structures at risk and ascertaining the cost of reducing the threat posed by the hazard.

2.3 Current condition and limitations

No limitations were given on the use of the maps from the Integrated Hazard Assessment.

2.4 Critical success factors

The IHA is a document that, by law, must be used at all levels of planning from the local level to the state level. Also in its preparation, public involvement was mandatory in order to gain acceptance and support of the citizens. If a citizen refuses to comply with the recommendations of the IHA, and builds in a hazard-prone area, the individual will not be entitled to any financial assistance from the state.

The executing agency for the procedure set out in the IHA is the AEMEAD, which was set up by law in 1999, to coordinate with state and local emergency management agencies in every aspect of emergency management. The AEMEAD has a director for each aspect of emergency management: Preparation; Mitigation and Recovery; Operations.

2.5 Respondents

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3.0 Vulnerability Assessment Studies

The IHA utilized a quantitative risk assessment approach in estimating the probability of various levels of loss in order to arrive at a more complete understanding of the risks posed by the hazards. The assessment proceeded by:

- Identifying the hazard
- Determining the hazard frequency and intensity
- Preparing susceptibility maps
- Calculating the 'Damage function'
- Integrating the damage potential of individual hazards into a Composite Hazard Map.

The Composite Hazard Map showed the intensity or levels of overall hazard for the island in terms of damage potential in categories of Very Low, Low, Moderate, High, and Very High. Some details of this map are provided in Table 2. The damage potential is calculated for each hazard in terms of the economic loss to buildings and contents for a specified return period of 100 years. This allowed comparison of hazards in a more rational and systematic manner.

Table 2 – Vulnerability Assessment

Type	***Purpose***	***Coverage***	***Date produced***	***Primary source***	***Author***
Composite Hazard Map	To allow comparison of hazards	Entire island	2002	URS Corporation; *Universidad Metropolitana (UMET*	URS Corporation

3.1 Methods of preparation and distribution

The following procedure was used to create the Composite Hazard Map for vulnerability to the hazards:

Step 1: Identifying the hazard

This is given in section 2.1 of this report.

Step 2: Determining the hazard frequency and intensity

In arriving at this, two parameters were defined:

- The annual probability of occurrence of the natural hazard.
- The intensity or damage-generating aspect of the hazard associated with the 100-year return period.

Step 3: Preparing susceptibility maps

Factors relating to the hazards were overlaid in GIS to produce maps for each hazard.

Step 4: Calculating the 'Damage function'

The damage or vulnerability function is a mathematical function that relates hazard intensity to the economic loss potential. Damage loss was measured with respect to a building damage ratio defined as the repair or replacement cost divided by the total replacement cost for the building (structural damage) and for building content (personal loss) for a typical single-family residence. This method allowed vulnerability assessment to be done without need to collect costly and time-consuming economic data. Calculating damage potential facilitated the comparison, ranking and integrating of disparate hazards.

Step 5: Integrating the damage potential of individual hazards into a Composite Hazard Map.

The damage potential of all the hazards were combined using GIS to produce the Composite Hazard Map. The map showed the levels of composite damage estimates for the entire island in five categories of Very Low, Low, Moderate, High, and Very High.

Other vulnerability assessments were done for technological hazards:
- Oil spills
- Transport of hazardous material
- Disposal of hazardous waste into rivers

No details were made available for the methodology used in these vulnerability assessments.

3.2 Users and uses

The hazard information database developed and maps produced within the IHA can be used for public education on the natural hazards and their risks posed; and for ranking areas prone to multiple-hazards, particularly in the rural municipalities. Local and state officials, and the general public use the Composite Hazard Map for mitigation and land use planning purposes.

3.3 Current condition and limitations

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No limitations were given on the use of the maps from the Integrated Hazard Assessment.

3.4 Critical success factors

The IHA is a document that, by law, must be used at all levels of planning from the local level to the state level.

3.5 Respondent

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4.0 Digital Maps

Table 3 indicates digital data available at The Puerto Rico Planning Board:

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Table 3: Digital data available at the Puerto Rico Planning Board

***Theme**	***Input scale***	***Year produced***	***Coverage***	***Primary source***
**Hazards	1:20,000	Unknown	Entire island	Planning Board
Contours				USGS
Soils				NRCS
Geology				USGS
Roads				ACT
Rivers				USGS
Electricity lines				AEE
Population				US Census

***Data themes are in ArcView shapefile format.
Datum: NAD 83
Projection: State Plane Coordinates

**Hazards were not disaggregated by the respondent. No response has since been received to an email request for this information.

5.0 Conclusions and Remarks

The Commonwealth of Puerto Rico has taken very seriously the negative impacts that both natural and technological hazards have on their state. As a result the authorities have sought to update hazard maps and incorporate them into the planning process in a legal framework. The Integrated Hazard Assessment produced in 2002 is one such approach. It must be noted that Puerto Rico is part of the US and is guided by the policies of the Federal Emergency Management Agency (FEMA) that operates throughout the US. FEMA funded the IHA through its Hazard Mitigation Grant Programme and was directly involved in the IHA. This is the main factor in the successful completion and adoption of the results of the IHA.

Part of the public acceptance of the IHA was a series of three workshops on the hazard information provided by the IHA to be used as a natural hazard planning guide for members of the local community, key personnel in the municipalities and local government officials. The workshops exposed citizens to natural hazards and sustainability planning, and the development of a local hazard mitigation plan. The focus was to offer advice on how a community can work together to reduce vulnerability to natural hazards.