Final Report

Vulnerability Assessment of Critical Facilities, Grenada, West Indies

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EXECUTIVE SUMMARY

The Caribbean Development Bank (CDB) and the Caribbean Disaster Emergency Response Management Agency (CDERA) have collaborated on a multi-phased project to support the development and/or enhancement of national hazard mitigation plans in Saint Lucia, Grenada, and Belize. The hazard mitigation planning process is expected to extend over a two and half year timeframe from 2003 to 2006 and comprises of five distinct but inter-related phases.

The Hazard Mapping and Vulnerability Assessment (HMVA) phase of the national hazard mitigation plan development process is especially important in that it provides a firm foundation for the development of goals, objectives, strategic interventions and mitigation actions for each of the three pilot states. As part of this project, CDB has selected the consulting firm of CIPA, Inc. to conduct a vulnerability assessment of critical facilities and other resources at risk for Grenada. The vulnerability assessment was conducted at two different scales; an island-wide assessment at 1:25,000 and a more detailed assessment for the St. John's River Basin Pilot Study Area at 1:10,000. The preparation of a vulnerability assessment of critical facilities will inform the preparation of a hazard mitigation strategy and specific plan actions.

The Vulnerability Assessment project was initiated by combined project inception meetings, training needs assessment, data collection and field mapping in Grenada. The vulnerability assessment was conducted with the assistance of the Government of Grenada National Disaster Management Agency (NaDMA). The findings of the vulnerability assessment were presented at the Plan Actions Workshop, held June 18-19, 2006 at NaDMA's conference facility in St. Georges, Grenada. A separate vulnerability assessment training workshop was conducted June 6-8, 2006, at the ISIS World Corporation Training facility in Castries, Saint Lucia, to train government staff in conducting similar vulnerability assessments in the future.

The vulnerability assessment builds upon hazard prioritization and hazard mapping consultancies conducted under previous CDERA/CDB consultancies. These included: hazard prioritization; development of a common digital database; and hazard mapping for inland flood hazard (island wide and St. John's river basin - pilot area), coastal erosion hazard, and landslide hazard.

Inception Meeting

Project team members met with the NaDMA staff and other key stakeholders to discuss the vulnerability assessment inception mission and methodology. NaDMA representatives facilitated introductions to the standing HMVA Subcommittee and the consultant team delivered a PowerPoint presentation that outlined the project expectations and objectives, technical approach, data needs and collection, and project execution and timeframe. Following the presentation, a discussion focused on data collection needs and training needs assessment issues.

Data Collection

The consultant project team discussed technical issues with Subcommittee members related to developing a vulnerability assessment for critical facilities. The data collection and field mapping effort spanned over a two week period in April – May 2006 and was conducted by a geographer and a GIS specialist/surveyor, in addition to local government representatives with intimate knowledge of the island. The local government representatives helped locate critical facilities and gather important information about structures/facilities. The project team focused on gathering information pertaining to facility name, contact information, facility operations and structural features.

Vulnerability Training Needs Assessment

The development of a Vulnerability Assessment Training Needs Assessment was a critical step in developing an understanding of the country's technological capabilities, especially in relation to using GIS, and determining training needs for the implementation of a national vulnerability assessment. The consultant team utilized a user questionnaire that focused on general organizational information, technology, mapping and analytical needs, computer capabilities, and organizational needs. The results of the needs assessment indicated a substantial need and/or requirements for technical vulnerability assessment training for selected key staff in several line ministries to develop a nation-wide assessment capability.

Vulnerability Assessment

The vulnerability assessment methodology utilized in this study follows methodologies developed by the United States National Oceanographic and Atmospheric Administration (NOAA) Coastal Services Center (CSC). Methodologies employed in this study have been modified to focus on critical facilities. The approach comprises of three measures:

1. Hazard Scores. This involves identifying the location critical facilities within hazard areas. The "Hazard Score" depicts a facility's location within a designated hazard "intensity" area (i.e. areas that are most likely to be affected by a given hazard). Intensity parameters have been defined in qualitative terms and have been given numerical ratings (Low=1, Medium = 2; High =3).

2. Exposure Scores. This involves developing a critical facility rating on several factors. The critical facilities were classified according to "Exposure Type Score" (dollar value of the facility) and an "Importance Factor" (criticality of use or importance following a disaster event). This allows the facility to be assessed on two important elements (i.e. economic versus importance/functional factors).

3. Cumulative Vulnerability Score. This step combines the data and analysis developed under previous steps to understand the hazard/exposure combination for each critical facility. Once the hazard and exposure scores have been assigned to each facility they will be calculated to determine the Cumulative Vulnerability for each facility.

Tabular Reports and Mapping Presentation

The methodology utilizes simple GIS procedures, databases, spreadsheets and maps to identify: (a) vulnerability of each group of risk elements to each mapped hazard; (b) cumulative vulnerability of all risk elements to each mapped hazard; and (c) cumulative vulnerability of all risk elements to all mapped hazards.

Hazard scores were used to identify the vulnerability of facilities (i.e. location of facility in hazard area). Individual hazard scores provided a means to compare susceptibility of facilities to different hazards; while the cumulative vulnerability of risk elements was identified by summing individual hazard scores (i.e. Total Hazard Scores). The methodology also combined the total hazard score with exposure parameters (exposure type score and importance factor) to identify the cumulative vulnerability of all risk elements to the identified hazards. To achieve these objectives three sets of maps and tables will be presented (hazard, exposure, and cumulative scores) for all designated at risk facilities.

1 Hazard Score Table: provides a summary of individual hazard scores, average hazard scores and total hazard scores.

2 Exposure Score Table: Provides exposure scores based on attribution of "Exposure Type Score" and "Importance Factors".

3 Cumulative Vulnerability Score Table: Total Hazard Score (each facility) * Exposure Score (each facility).

The results of this analysis informs hazard mitigation planning by identifying critical facilities that are vulnerable to natural hazards and their degree of vulnerability – i.e. those located in high-risk areas, of high economic value, and of importance to emergency response and disaster management. The scoring methodology provides a tool for prioritizing actions to reduce the vulnerability of critical facilities.

Vulnerability Assessment Training

The Vulnerability Assessment training took place June 6-8, 2006 at the ISIS World Corporation Training Facility in Castries, Saint Lucia. The training course was designed and developed to help HMVA subcommittee members and/or designates understand tools (GIS, GPS, etc.) and/or reinforce concepts required for the implementation of a comprehensive vulnerability assessment to natural hazards. The training course was provided in a lecture format that outlined a step-by-step process for conducting a vulnerability assessment. It consisted of lectures interspersed with classroom demonstrations and/or exercises.

1.0 INTRODUCTION

1.1 PROJECT UNDERSTANDING

The Caribbean Development Bank (CDB) through the Disaster Mitigation Facility for the Caribbean (DMFC), and the Caribbean Disaster Emergency Response Management Agency (CDERA) through the Caribbean Hazard Mitigation Capacity Building Programme (CHAMP), have collaborated on a multi-phased project to support the development and/or enhancement of national hazard mitigation plans in Saint Lucia, Grenada and Belize. The hazard mitigation planning process is expected to extend over a two and half year timeframe from 2003 to 2006 and comprises of five distinct but inter-related phases.

The Hazard Mapping and Vulnerability Assessment (HMVA) phase of the national hazard mitigation plan development process provides a firm foundation for the development of goals, objectives, intervention strategies and mitigation actions in each of these Participating States. As part of this phase of the CHAMP Project, CDB has selected the consulting firm of CIPA, Inc. to conduct and implement specific tasked defined in the Terms of Reference (TOR) of this consultancy. The consultant team members are listed in Appendix A.

Specific TOR tasks performed under this consultancy included: 1) an Inception Mission[1], 2) Vulnerability Assessment, 3) Technical Training, and 4) Documentation. The itinerary for the Inception Mission is provided as Appendix B. The Inception Mission included a) a brief to the HMVA subcommittee on the objectives and expected outcomes of the consultancy, b) population and development of a critical facility database[2], and (c) an assessment of training needs regarding vulnerability assessments in a GIS environment.

A vulnerability assessment was employed to identify: (a) vulnerability of each group of risk elements to each mapped hazard; (b) cumulative vulnerability of all risk elements to each mapped hazard; and (c) cumulative vulnerability of all risk elements to all mapped hazards.

An introductory training class was also provided for selected Government employees in Grenada on the vulnerability assessment methodology, including the following elements: (a) database design, maintenance and reporting; (b) incorporating information from databases into ArcView/ArcGIS; (c) updating and documenting GIS data structures and procedures; and (d) applying the vulnerability assessment tool and understanding automated procedures in the GIS environment.

The Vulnerability Assessment for Grenada must be viewed as a critical step in a national risk reduction program. The assessment of critical facilities can be expanded and applied to assess the vulnerability of other assets and/or population groupings. The vulnerability assessment, and more importantly the results thereof, may be used to build awareness, mobilize community stakeholders and help prioritize mitigation investment. In areas with repetitive disaster losses, consideration should be given to refocus traditional economic development projects to conduct detailed structural assessments and make improvements which reduce the vulnerability of critical facilities.

This project seeks to minimize post-disaster expenditures and put in place mechanisms to efficiently utilize financial resources, limit environmental degradation and promote disaster resistant development. Not only

[1] Inception mission occurred from April 23 – May 5, 2006. The inception mission consisted of HMVA meetings, Vulnerability Assessment Training Need Assessment, and field mapping throughout the island.

[2] As outlined in the inception report, the facility database provided as part of the CDD proved to be inappropriate for vulnerability assessment purposes. A field data sheet was presented in the consultant's inception report that provided attributes for gathering structural and operational features as defined by NOAA CSC.

does this project seek to reduce post-disaster expenditures, it promotes long-term sustainable benefits that are many times larger than the cost of the project itself. These benefits would accrue at the national level and the methodology could be applied to other areas that have been identified as having special economic development or social needs.

The vulnerability assessment builds upon hazard prioritization and hazard mapping consultancies conducted under previous CDERA/CDB consultancies. These include: 1) the one day Hazard Mapping and Vulnerability Assessment Prioritization Workshop (May 2004); 2) Generation of a Common Digital Database for use in Hazard Mapping and Vulnerability Assessment (September 2004); 3) Development of Coastal Erosion Hazard Maps (April 2006), 4) Development of Landslide Hazard Maps (February 2006); and 5) Development of In-land Flood Maps (February 2006).

1.2 PROJECT STUDY AREA AND EXPECTED OUTPUTS

In this project, the vulnerability assessment was confined to critical facilities and performed at a national level. Special attention was given to a pilot area for the flood hazard in the St. Johns River Basin. It is important to note, however, the scale of output was tied to the input scale of hazard maps, expected to be at a 1: 10,000 or greater. Expected outputs of the project include:

1. An Inception Report, to be submitted to CDB and the HMVA Sub-Committee, after completion of the inception mission, key meetings with the HMVA, population of a digital database of critical facilities and an assessment of training needs. A brief on the inception meeting is provided in Appendix C. The inception report will include:

   - an outline of the training needs in the context of vulnerability assessment and make recommendations for the feasibility/utility of the training, and
   - a detailed work plan for implementation of the recommended training needs proposed in the consultancy.

2. Draft Final Reports, to be submitted to CDB and the HMVA Sub-Committee, after the completion of the vulnerability assessment. The draft report will include:

   - copies of the vulnerability assessment digital database generated as part of the consultancy, including all GIS data layers utilized and developed.
   - a technical report to include descriptions of structure and content of the vulnerability maps, methodology employed in map preparation (including data collected, analysis method, list of data layers used in final map preparation).
   - draft non-technical summary of the vulnerability assessment suitable for inclusion in the national hazard mitigation plan.
   - draft report of the training activity conducted for selected Government employees of Grenada.

3. Final Reports incorporating the comments of CDB and Grenada. The final report will include:

   - copies of all training guidance documents and manuals produced under this consultancy,

- a list of existing data layers in the vulnerability assessment database, and
- copies of the vulnerability assessment digital database

The final reports and maps will be submitted in hard copy and digital copy format. The final vulnerability assessment digital database will be submitted in GIS format.

2.0 METHODOLOGY

The vulnerability assessment methodology utilized in this study follows methodologies developed by the United States National Oceanographic and Atmospheric Administration (NOAA) Coastal Services Center (CSC). Methodologies employed in this study have been modified to focus on critical facilities and meet the objectives of assisting emergency managers, planners, and the public to understand hazard vulnerability..

The NOAA CSC methodology employed in New Hanover County was assessed for its application in Grenada. It was deemed that this methodology precipitated the need for the collection of detailed information and the need for trained professional specialists or engineers (NOAA CSC). The NOAA CSC approach mandates the collection of facility databases, collection of facility attributes such as information on damage history, and information on structural and operational vulnerabilities. Such a detailed investigation posed real limitations for the project team due to the lack of national hazard mapping data, limited critical facility data, and limited local technical resources. When these factors were considered, the consultant project team sought out a more appropriate methodology.

The NOAA CSC sponsored study implemented for the US State of Rhode Island provided a more appropriate approach for Grenada. Originally this methodology was developed to perform regional vulnerability assessments using publicly available data and simple procedures. The Rhode Island methodology was designed to understand aggregate vulnerabilities distributed across a region (i.e. social vulnerabilities, economic vulnerabilities, and critical facility vulnerabilities). This methodology has been modified to rate facilities individually without aggregating results to specific regions. It is consistent with the Rhode Island method, in that it utilizes the classification categories for facilities (i.e. exposure type and importance factors) for the calculation of cumulative vulnerability scores. This methodology was specifically chosen because it was within the current capabilities[3] of government agencies charged with preparing disaster mitigation plans and replicating a vulnerability assessment throughout the nation.

The expected results of the employed methodology were similar to those of the NOAA CSC New Hanover County method. When applied to critical facilities, it provides an assessment of each facility addressing its location relative to hazard areas. It also considers other factors - economic and importance factors - when rating the vulnerability of each critical facility. It also facilitates the combination of these factors to assess cumulative vulnerability of each facility. The results provide emergency managers, planners, the public and other stakeholders with information required to prioritize actions, and thus allocate limited hazard mitigation planning resources and mitigation dollars to the most vulnerable facilities.

The following discussion introduces the NOAA CSC Vulnerability Technique and provides a detailed overview of the methodology employed during this study.

2.1 NOAA CSC COMMUNITY VULNERABILITY ASSESSMENT TECHNIQUE

The NOAA Coastal Services Center “Community Vulnerability Assessment Technique” is designed to provide a general assessment of the community’s physical, social, environmental and economic vulnerabilities. The Community Vulnerability Assessment Technique has several distinct steps to define the abovementioned vulnerabilities. They include:

1 Hazard Identification. This step involves a determination of which hazards to evaluate in a vulnerability assessment.

[3] General technical and administrative capabilities of Government departments were assessed as part of the inception mission.

2 Hazard Analysis. This step involves mapping the hazard for the study area and rating the hazard in order to facilitate a ranking of hazard zones within the study area. Again for this consultancy, hazard mapping and hazard susceptibility ratings were developed under other consultancies and provided to the consultant project team.

3 Critical Facilities Analysis. This step involves a systematic assessment of the vulnerability of critical facilities or key resources to hazard impacts. It involves: 1) identifying the categories of structures that are considered critical facilities; 2) establishing a critical facilities database by collecting some general information; 3) identifying hazard scores for each of the critical facilities; and 4) conducting an individual assessment addressing the location of the facility relative to the hazard areas along with damage history and structural and operational vulnerability[4]

4 Societal Analysis. This step involves identifying geographic areas with a concentration of at risk populations (i.e. elderly, low income, etc.) – areas where resources are minimal and personal resources for dealing with hazards are limited-- and identifying where special consideration communities intersect with hazard information. This is done in order to identify areas of potential mitigation opportunities.

5 Economic Analysis. This step involves identifying economic sectors in the community, identifying where areas of economic importance intersect with hazard prone areas. This may include conducting a general inventory of structures in the economic center/high-risk intersections in order to identify potential mitigation opportunities.

6 Environmental Analysis. This step involves identifying locations that have a potential for secondary environmental impacts from natural hazards (i.e. hazardous or toxic materials, etc.). Once secondary sites are identified, hazard information is overlain to identify potential mitigation opportunities. Consideration should also be given to preservation and restoration as these sites may be environmentally sensitive areas.

7 Mitigation Opportunity Analysis. This step involves identifying vacant or undeveloped land and understanding its intersection with hazard areas in order to target future development away from high hazard locations. [5]

2.2 GRENADA VULNERABILITY ASSESSMENT METHOD

The methodology utilized follows a NOAA sponsored vulnerability assessment conducted for the State of Rhode Island. The Rhode Island methodology has been modified to focus on determining the vulnerability of key individual facilities, lifelines, or resources within the study area. The methodology utilizes six (6) steps for assessing the vulnerability to critical facilities:

1. Hazard Identification. Similar to the NOAA CSC, this step involves a determination of which hazards to evaluate in a vulnerability assessment. In this consultancy, the hazards investigated were wind, storm surge, and coastal erosion. These were identified by the national community as priority hazards during a hazard prioritization workshop held in 2004.

[4] http://www.csc.noaa.gov/products/nchaz/htm/case3.htm

[5] The NOAA methodology enables communities to evaluate social, economic and environmental vulnerabilities, in addition to identifying areas with high opportunity for future sustainable development (steps four through seven); however, resources did not allow for conducting these analyzes in Grenada.

2. Critical Facility Categorization. The consultant team developed three critical facility categories for purpose of analysis. They are: essential facilities, transportation infrastructure/utilities and infrastructure.

3. Critical Facility Database. A database was developed to identify facility by its unique name or identifying code for purposes of incorporating data into critical facility database.

4. Hazard Score. The proposed methodology utilizes a "Hazard Score" which is similar to the NOAA Vulnerability Assessment for New Hanover County[6]. The "Hazard Score" depicts a facility's location within a designated hazard "intensity" area (i.e. areas that are most likely to be affected by a given hazard). Intensity parameters (i.e. wind speeds, 10yr to 50yr flooding, etc.) that describe the type of forces that characterize each hazard are inclusive and have been defined in qualitative terms. In order to rate or score the hazards, qualitative measures have been given numerical values (Low=1, Medium=2, High=3) and facilities have been rated accordingly.

   The resultant "Hazard Scores" provide a basis to understand potential vulnerability to a particular hazard, while a "Total Hazard Score" provides an understanding of the cumulative hazard rating of a particular facility to all of the identified hazards.

5. Exposure Score. Although the NOAA New Hanover County study utilizes several indicators[7] to understand vulnerability for a facility, this study uses exposure parameters as an interim step in the development of vulnerability scores. The "Exposure Score" is not a replacement for vulnerability but rather used to enhance an understanding thereof. The "Exposure Score" classifies critical facilities according to their "Exposure Type" (economic value of the facility) and the "Importance Factor" (criticality of use or importance before, during or following a disaster event). An "Exposure Type Score" is determined by utilizing a common index that assigns a "score" based on a range of economic values. The "Importance Factor" uses a common index to classify the criticality of the facility in pre- and post disaster events.

   The utilization of exposure parameter provides a pragmatic approach to this project. While not addressing the damage history and operational history of each facility, it provided an appropriate method to address both the economic exposure of the facilities as well as the criticality of the structures. In this regard, the "Importance Factor" provides a crude understanding of "operational vulnerability" by classifying the facility's use or function in pre- or post-disaster events. The "Exposure Type Score" classifies facilities according to their economic value and can be used to provide a coarse indication of potential economic losses[8] to each hazard. Therefore, an "Exposure Score" is calculated by combining an "Exposure Type Score" and an "Importance Factor".

[6] The NOAA CSC methodology references two indicators: 1) a "Hazard Category Priority Score" which is used to provide an understanding of the relative priority of each hazard being addressed, and 2) a "Risk Consideration Area Score" which provides a numerical score for each hazard area (i.e. hazard boundary) where the facility is located. All hazards were identified and prioritized during a previous consultancy in 2004.

[7] NOAA New Hanover Study utilizes three parameters in its calculation: 1) damage history score based on historical records or personal accounts of previously caused damages, 2) structural vulnerability score based on a subjective investigation and requires knowledge of the construction of the facility, and 3) operational vulnerability score based on potential operational impacts of the hazard in which highest scores are to be given to the most catastrophic or life-threatening impacts.

[8] Economic parameters were collected by the project team; however, risk or potential losses to each facility were not calculated in this study. Economic parameters, specifically replacement costs (structure and contents) are key factors for a detailed quantitative risk assessment.

6. Cumulative Vulnerability Score. The Cumulative Vulnerability Score is utilized to determine an overall vulnerability score for the critical facilities. This is consistent with both the NOAA New Hanover and NOAA Rhode Island studies in that facility ratings or scores are combined to identify trends for the broad prioritization of hazard mitigation options.

   The "Cumulative Vulnerability Score" differs from the vulnerability calculations used in the New Hanover County study in that it does not combine the hazard score with damage history, operational or structural parameters. Instead it is calculated by taking the "Total Hazard Score" and multiplying it by the "Exposure Score". In this regard, the "Exposure Score" functions as a surrogate for the abovementioned parameters (i.e. operational and structural) and provides a basis from understanding of vulnerability from an economic and criticality of use perspective.

   The hazard/exposure combinations, therefore, provide the basis for determine the relative vulnerability for all of the critical facilities in the study area. This allows the user to consider hazard scores, exposure scores, and cumulative scores for individual facilities. The combination of these factors also provides a basis for deciding on a numerical threshold for determining low, moderate, and high vulnerability[9].

   By combining these factors, this methodology provides useful results for policy making and hazard mitigation. It provides thresholds will help to establish a focused list of vulnerable critical facilities for undertaking appropriate mitigation actions.

[9] Cumulative Vulnerability Scores do not provide a dollar loss or any other direct measures of risk.

3.0 IMPLEMENTATION OF VULNERABILITY ASSESSMENT METHODOLOGY IN GRENADA

The employed methodology follows the six (6) steps outlined in the section above. This section describes how this methodology was implemented in Grenada. The analysis was performed at the national level. The level of analysis is confined to critical facilities and the scale of output is tied to the input scale of hazard maps.

3.1 HAZARD IDENTIFICATION

Hazard information used in this study was extracted from a national common digital database for Grenada that was developed under an earlier phase of the national hazard mitigation plan process. During a previous workshop, held in the spring of 2004, the national hazard mitigation plan development committee identified and prioritized natural hazards in Grenada. The following hazards were then selected for hazard mapping and vulnerability assessment:

- Inland Flood
- Coastal Erosion
- Landslide
- Inland flood (St. John's River Basin Pilot Area)

These hazards were chosen and prioritized by key stakeholders through a consultative process and have a reasonable probability of occurring within the study region. Technical and non-technical reports on the hazard mapping process provided an overview of the hazard assessment methodology and process whereby the maps were produced. While some hazard maps were in national projection systems, other maps required re-projection to national grid reference systems. Re-projection of the output data layers of these hazard maps presented no special difficulties.

3.2 CRITICAL FACILITY CATEGORIZATION

The primary focus of this task is to develop a list of critical facilities for this study. Three hundred and sixteen (316) facilities were identified to provide a comprehensive assessment of infrastructure, public buildings and facilities. It is necessary to note, that several key facilities and/or infrastructures originally identified by the HMVA Subcommittee were not included due to logistics in either mapping these facilities or because information was not readily available. For the expanded list of facilities, the following three-part definition of critical facilities and infrastructure was considered:

<u>Essential Facilities</u>

Essential facilities are facilities that provide services to the community and should be functional after a disaster event. They include:

1. Hospitals
2. Police stations
3. Fire stations
4. Schools (shelters)

Transportation Infrastructure

Transportation Infrastructure includes facilities that enable the movement of goods, particularly emergency relief supplies. Of particular importance to offshore islands, transportation infrastructure includes:

1. Marine Transportation (marina and port facilities)
2. Airports
3. Roads[10]

Utilities and Infrastructure

Utilities and Infrastructure are facilities that, if damaged, could have far-reaching consequences for residents, visitors and the natural environment. They include:

1. Electrical Power Generating Plants
2. Water Treatment Plants
3. Wastewater Treatment Plants
4. Potable Water Pump Stations
5. Water Storage Tanks

From past experience and knowledge of national datasets, the consultant project team identified national level contacts to obtain the Critical Facility data. In Grenada, these sources included the technical personnel in Ministry of Agriculture, Land Use Unit and Cable and Wireless. Numerous copies of the same datasets were found to be maintained separately by the individual government agencies, some with little or no coordination. Therefore, all datasets were requested in ArcGIS shapefile format for evaluation by project staff.

3.3 CRITICAL FACILITY DATABASE

This step involves integrating hazard information and critical facilities into a common database for analytical purposes. Where data was not present, data was captured by either digitizing features from scanned 1:25,000 scale base maps[11] or collected in the field via GPS.

3.3.1 Data Capture

Digitizing features from scanned records or images was conducted by utilizing geo-referenced scanned maps or satellite imagery. Because the base maps had already been referenced to a local coordinate system data capture of features was relatively easy.

Simple data capture protocols were used by the consultant project team to extract the required data (i.e. general facilities and government buildings). Features were captured using an on-screen digitizing process which involves manually tracing the lines or marking points on a computer screen over the top of the scanned raster image.

3.3.2 Collection of Attribute Information

Field data capture forms provided in the CDD were redesigned and simplified for the capture of required information (i.e. facility, structural, operational features) for a comprehensive vulnerability assessment. A

[10] Spatial queries were performed to identify linear km/miles of roads in each hazard area. The consultant project team was not able to gather information on cost per linear km/mile of road. Therefore, the resultant estimation provides a qualitative estimate of vulnerability/susceptibility not a dollar estimate of exposure.

[11] Scanned based maps were provided as part of the Grenada Common Digital Database

sample of consultant's field data capture form is provided in Appendix D. During field data capture mission it was necessary for the consultant team to focus its attention on gathering three levels of information:

1 Level I data: facility name, address, contact name, phone/fax number and e-mail address.

2 Level II data: information about the damage history, operational features (occupancy/use, capacity of the building or facility) and economic features (economic value) of the building or facility.

3 Level III data: information collected in the field that describes the structure or construction type (wood frame, concrete, masonry and/or type of structural frame system) .

For the collection of Level I and Level II data, it was necessary for the consultant team to work directly with user agencies or stakeholders (i.e. utilities, etc.) to identify persons in charge of certain facilities in different regions of the country. Much of this data was not readily available and required persistent follow-up and internal ministry/agency research.

The collection of Level II data proved to be more challenging. Many of the user agencies, especially NaDMA, lacked a data management system for life-cycle costs and records of past disaster damages. Furthermore, much of the information that was available was not computerized and was held either in hand written or tabular format. The poor management of data/information within agencies therefore presented a challenge for the consultant project team for data collection.

Detailed historical records or personal accounts for critical facilities were not readily available. The consultant team did not have required information to assess historical or repetitive damages of facilities. Economic values for facilities were also requested but were difficult to obtain from user agencies. Where data was unavailable, the consultant team depended on field observation/verification to estimate square footage of the facility. The structure value was determined using a simple cost estimation approach. The cost approach valuation takes into account the size of the structure (i.e. square footage) and is multiplied by standard construction cost estimates per square foot[12]. For utilities or non-structural facilities where value information was not provided by user agencies (i.e. waste water lift stations), the values were determined using international valuation guidelines[13].

The structural components that were gathered in the field provide a basis for future analysis (i.e. retrofits, damage curve development, and loss estimation). Information gathered in the field; however, proved inadequate to rate the facility's operational vulnerability. Operational vulnerability as defined by NOAA CSC requires knowledge of the daily activities that are conducted within the structure. The consultant project team did not have access to all structures and respective agencies were unable to provide this information.

While the structural data gathered by the consultant team provides an excellent starting point, professionally trained inspectors or engineers are required to rate the structural vulnerability of these facilities. Specialists are required to have knowledge about the construction of the facility and the existing building codes governing local construction. Structural information gathered was either subjective and/or based on the evaluations gathered from facility managers or owners.

[12] For economic valuation of structures/facilities, the consultant project team relied on estimated square footage data provided by Ministry of Works

[13] Vermeiren, and Pollner (1994): A probable maximum loss study of critical infrastructure in three Caribbean island states, Washington, DC: World Bank/OAS Report. http://www.oas.org/CDMP/document/pml/pml.htm; FEMA HAZUS-MH

3.4 HAZARD SCORING

The hazard score for each hazard type is computed as a measure of the level of intensity and/or effect of a hazard. For each hazard, a qualitative measure has already been computed by other consultants, based on different characteristics of the hazard itself (i.e. level of flooding). This resulted in maps designating "high", "medium", and "low" hazard zones for inland flood, coastal erosion hazard, and landslide hazards.

The hazard mapping consultant defined the hazard zones as follows:

- "High" hazardous zone is defined as a zone where hazardous conditions are likely to occur during an average lifetime;
- A "Medium" hazardous zone is defined as one where such conditions are less likely to occur in an average lifetime; and,
- "Low" hazardous zone where such conditions are unlikely to occur in a lifetime.

The procedure for determining each component of the hazard score is described in the following subsections.

3.4.1 In-Land Flooding Hazard

The flood hazard map utilized in this study was a medium-scale flood hazard map for the entire island of Grenada. The model is based on the ranking and interaction of the major contributing factors that determine the extent and frequency of flooding, namely, land cover and soil hydrologic characteristics of the upper catchments, extreme daily rainfall, and the gradient of the catchment basin.

The flood map has been broken into three categories of "high," "medium" and "low" is based on recommendations from a study (Bureau of Reclamation, 1988; see Figure 1) that related the dangers posed by flooding. For the island-wide analysis in which it is difficult to assess velocity, only the depth category has been used. Thus the classifications were based on the values shown in Table below.

Hazard Score Lookup Table

Flood Risk	Description	Hazard Score
Low	<3 ft (0.91 m)	1
Medium	3 to 4.5 ft (0.91 to 1.37 m)	2
High	> 4.5 ft (1.37 m)	3

Inland flood maps in the St. John River Basin, Grenada are rated similarly to the island wide hazard maps. Low risk values are rated 1, medium risk values are rated 2, and high risk values are rated 3.

3.4.2 Coastal Erosion Hazard

The coastal erosion hazard map for Grenada was produced by creating a GIS layer to depict the extent of erosion at each profile (point). The maximum erosion distances for each profile were classified into four (4) erosion categories:

- 10-30m metres
- 30-50m metres
- 50-70m metres
- 70m metres

Each hazard category or zone were thematically displayed on the maps with a color coded linear feature that depicted long term erosion due to sea level rise over 20 years. In order to perform the vulnerability analysis, the linear features were transformed into polygon features in ArcGIS software program. Each polygon feature was developed to match the erosion width.

Intensity Score Lookup Table based on Erosion Buffer

<table>
<tr><th>Erosion Value</th><th>Erosion Width</th><th>Intensity Score</th></tr>
<tr><td>1</td><td>10-30m</td><td rowspan="2">1</td></tr>
<tr><td>2</td><td>30-50m</td></tr>
<tr><td>3</td><td>50-70M</td><td>2</td></tr>
<tr><td>4</td><td>> 70m</td><td>3</td></tr>
</table>

3.4.3 Landslide Hazard

The landslide hazard map was developed for the entire island utilizing a series of different factors. A series of GIS spatial queries determined the number of landslides, identified during field reconnaissance missions that fell within different geologic or physiographic categories. GIS queries and overlay techniques were utilized to calculate the percentage of landslides and total area of each geologic and physiographic category and finally, the percentage of area of abovementioned categories were compared to the total area of the study area. These spatial queries allowed an estimation of relative landslide susceptibility based on a comparison ratio (percentage of land in a geologic/physiographic category related to percentage of landslides mapped in the same category).

This ratio provided a quantitative measure to rate the primary factors according to their relative susceptibility. Comparison ratios were then used to develop susceptibility factors for each data set. Distinct categories within each data set (i.e. elevation interval, soil type, geology unit, etc.) were classified according to susceptibility levels based on the outcomes of the spatial analysis, review of descriptive documents and field observation. This resulted in the development of reclassified factor maps for elevation, slope angle, slope aspect, soils and geology.

The resulting factor maps were reclassified, converted to raster format and modeled spatially. A susceptibility mapping equation model for was developed for each island that used a simple mathematical overlay process that adds the susceptibility ranking for the corresponding cells of each factor map together. The output of the model was classified into five susceptibility categories: *Very Low, Low, Moderate, High, and Severe*. These five categories were aggregated into three hazard scores and provide an indicator of landslide susceptibility in the study area.

Hazard Score Lookup Table

<table>
<tr><th>Landslide Value</th><th>Landslide Susceptibility</th><th>Hazard Score</th></tr>
<tr><td>1</td><td>Very Low</td><td rowspan="2">1</td></tr>
<tr><td>2</td><td>Low</td></tr>
<tr><td>3</td><td>Medium</td><td>2</td></tr>
<tr><td>4</td><td>High</td><td rowspan="2">3</td></tr>
<tr><td>5</td><td>Severe</td></tr>
</table>

3.5 EXPOSURE SCORE

Based on attributes collected during field reconnaissance, critical facilities were classified according to "Exposure Type" (dollar value of the structure/facility) and the "Importance Factor" or function (criticality of use or importance during a disaster event).

This allows the facility to be assessed on two critical factors that are useful for determining vulnerability: Exposure Type (i.e. economic) and Importance (i.e. criticality of use). For each factor, a lookup table was developed to relate a measure of the economic value and criticality to a common exposure index for critical facilities.

The exposure score for each facility was calculated using the following formula:

EXPOSURE SCORE = (EXPOSURE TYPE SCORE) * (IMPORTANCE FACTOR SCORE)

3.5.1 Exposure Type Factor

The project team was able to obtain approximate economic data for the replacement costs for most facilities. In some instances, this information was not readily available and required persistent follow-up and internal ministry/agency research. Where economic values for facilities were not provided, the consultant project team depended on field observation/verification to estimate square footage of the facility. The facility values were determined using a cost estimation approach for facility valuation. For structures, the cost approach valuation takes into account the size of the structure (i.e. square footage) and is multiplied by the construction costs per square foot. For utilities or non-structural facilities where value information was not provided (i.e. waste water lift stations), the replacement value was determined using international valuation guidelines.

Therefore, the figures included should not be taken as absolute and should be used as estimates. The final value, obtained by either of the methods mentioned above, was used as the actual economic value. The value was used to determine an exposure type score by using the Property Value Lookup Table below.

Exposure Type Factor Score

Property Value (US $)	Exposure Type
0	0
100,000-249,999	1
250,000-499,000	2
500,000 -1,499,999	3
1,500,000 - 5,000,000	4
5,000,000 +	5

Once the economic value of a facility was determined, it was given an economic factor to evaluate the overall score for the exposure type. For example, a critical facility having a value of $500,000 was given an economic factor of 3.

3.5.2 Importance Factor

The proposed factors for facility importance follow the guidance provided by the NOAA sponsored vulnerability assessment conducted for the State of Rhode Island. Importance factors, ranging from 0.85 to 1.3, were used to account for the critical nature of some types of facilities.

Importance Factors Score	
Occupancy Category	**Importance Factor**
I	0.85
II	1
III	1.2
IV	1.3

Occupancy Categories	
Occupancy	**Category**
Fire, Police, Medical Facilities	IV
Emergency Shelters (Including some school buildings)	IV
Government Buildings	III
Utilities	II
Other Public Structures	II

Please note that this approach is consistent with US and international building code standards, which assign a higher importance factor to critical facility structures than utility installations. Once the occupancy of the structure was determined, it was given an importance factor score. Exposure type scores and the importance factor score were combined to evaluate the overall exposure score.

3.6 CUMULATIVE VULNERABILITY SCORE

In this section the Total Hazard Score/Total Exposure Score are calculated to understand the cumulative vulnerability for each facility. The "Cumulative Vulnerability Score" is then calculated by taking the Total Hazard Score and multiplying by the Exposure Score. Cumulative Vulnerability Scores were determined using the following formula:

CUMULATIVE VULNERABILITY SCORE = (TOTAL HAZARD SCORE) * (TOTAL EXPOSURE SCORE)

The combination of these factors allows the user to consider both the hazard susceptibility and the potential for economic damages to the critical facility from future disaster events. The hazard/exposure combinations then provide the basis to determine the relative vulnerability ranking for all of the critical facilities in the study area.

A Data Dictionary for base data, hazard data and hazard, exposure and vulnerability scores is included as Appendix E.

4.0 VULNERABILITY ASSESSMENT RESULTS

The Vulnerability Assessment results identify the (1) vulnerability of risk elements to each mapped hazard (hazard scores), and (2) cumulative vulnerability of risk elements to each mapped hazard (total hazard score); and (3) cumulative vulnerability of all risk elements all mapped hazards (hazard/exposure combinations). To achieve these objectives three sets of maps present the hazard, exposure, and cumulative scores for the all at risk facilities.

Hazard Scores

Hazard Scores were determined for each facility based on the methodology described above. The maps depict the location of each facility relative to designated hazard zones. The following table shows the hazard score for each of the hazards considered, as well as the average and cumulative hazard scores tabulated for each hazard. The following maps and tables are presented in this section:

- Hazard Score Table
- Wind Hazard Map
- Wave and Storm Surge Hazard Map
- Inland Flood Hazard Map
- Total Hazard Score Map

Exposure Score

Exposure Scores were determined for each facility based on the methodology described above. The maps presented below show the distribution of summary exposure scores throughout the study region. The table and maps presented below shows the exposure scores tabulated for Exposure Type and Importance Factors) considered, as well as the overall Exposure Score. The following maps and tables are presented in this section:

- Exposure Score Table
- Exposure Type Map
- Importance Factor Map
- Total Exposure Map

Cumulative Vulnerability Score

In this section the Total Hazard Score and Exposure Score are calculated to understand the cumulative vulnerability for each hazard. Specifically, the Cumulative Vulnerability Score is calculated by taking the Total Hazard Score and multiplying by the Total Exposure Score. The following maps and tables are presented in this section:

- Cumulative Vulnerability Table
- Cumulative Vulnerability Map

The results of this analysis informs hazard mitigation planners by identifying critical facilities that are vulnerable to priority natural hazards and their degree of vulnerability – i.e. those located in high-risk areas, of high economic value, and of importance to emergency response and disaster management. The cumulative scoring then provides a tool for prioritizing mitigation actions based on a combination of these factors.

Vulnerability Assessment Findings

Vulnerability assessment results for the entire island and St. John's River Basin are located in separate Annexes to this report. Annex A presents results for Grenada Island-wide, Annex B for St. John's River Basin Pilot Area.

5.0 HAZARD MITIGATION ANALYSIS FOR GRENADA

The hazard, exposure and vulnerability scores are all valuable inputs to hazard mitigation planning for Grenada. The hazard mapping effort conducted by others provides valuable information for physical planning and development review for future development throughout the island. When the hazard and exposure scores are combined it provides a powerful tool for hazard mitigation planning, by providing a ranking of the vulnerability of critical facilities in Grenada. Scarce financial resources can then be effectively targeted to retrofitting only the most vulnerable critical facilities.

5.1 HAZARD SCORES

5.1.1 Inland Flood Hazard Score

The inland flood hazard scores ranged from 0 to 3.00. The facilities with the highest flood hazard scores are presented in the table below.

Facility ID	Facility Type	Facility Name	Flood Score
137	Community Center	La Taste Community Centre	3
184	Health Centre	Woburn Medical Station	3
1	School	Beaulieu Pre-school	2
322	Water Store/Dist	Union Spring Plant	2

The table below lists the total length of roads within the inland flood hazard area.

Hazard Score	Total length of road in the area (km)
1	885.8
2	31.3
3	28.3

There are a range of wet and dry flood proofing measures that should be considered for critical facilities and other non-critical structures located within the two designated inland flood hazard zones. Wet flood proofing measures allow floodwaters to flow into and around structures and involve waterproofing key components of the critical facilities. Elevating key components, particularly electrical, above the estimated height of the storm surge is an effective wet flood proofing technique. Dry flood proofing measures involve hardening doors, windows and other openings in the structures to keep floodwaters out. Dry flood proofing techniques are most effective in areas of shallow flooding areas; when considered in areas subject to flash flooding – structural design must address the additional forces associated with high velocity floodwaters.

Elevation of the structures is most likely not a viable flood proofing measure for the critical facilities noted above. Construction of berms and other dry flood proofing techniques to prevent floodwaters from entering structures should be considered but may not be feasible, particularly where flash flooding is possible. Wet flood proofing measures such as elevating electrical components and valuable medical or communication equipment is a low cost option that should receive serious consideration. Any assessment of potential cost-effective hazard mitigation measures for these facilities should be conducted by a licensed structural engineer.

There are a range of mitigation measures and best management practices that should be considered by the Government of Grenada to minimize flood damages to the existing road network. Consideration should be given to increasing the ability of storm drainage systems in the designated flood hazard zones to convey floodwaters. In addition, a more effective maintenance program is necessary to periodically clear debris, vegetation and sediment that reduce the conveyance of the existing drainage system. The areas designated as flood prone should receive the highest priority for drainage maintenance efforts. The flood hazard maps should be provided to the Ministry of Works and, in turn, to road contractors so that this destructive hazard can be proactively addressed in the design of future road improvements or new road construction in or adjacent to the mapped flood zones island-wide and within the St. John's Basin Pilot Area.

The flood hazard maps should also be used by appropriate government agencies and the private sector in order to restrict intensive development from being built within the two designated flood hazard zones. This is especially true for public sector investments. Public facilities that must be located within the designated flood hazard zones should be designed to withstand, at least a 50-year event, and preferably the 100-year storm. Should the question arise in the future to substantially upgrade one of the above listed critical facilities, a detailed cost/benefit analysis should be first conducted to determine whether it makes more sense in the long term to relocate the facility outside of the designated flood hazard zone. If the risk-based decision to upgrade the facility in place, then a flood retrofit evaluation should be conducted to protect the Government's investment.

5.1.2 Coastal Erosion Hazard Score

The wave and storm surge hazard scores ranged from 0 to 3.00. The facilities with the highest coastal erosion hazard scores are presented in the table below.

Facility ID	Facility Type	Facility Name	Coastal Erosion Score
7	School	Boca Secondary	2
44	School	L'Esterre Pre School	2
64	School	St.Giles Anglicah School	2
92	School	St. Andrew's Anglican Pri	2
123	School	Union Pre School	2
328	Water Store/Dist	Grand Roy Plant	2

The table below lists the total length of roads within the coastal erosion hazard area.

Hazard Score	Total length of road in the area (km)
1	3.7
2	12.4
3	9.7

Six critical facilities were identified as being within a coastal area that may be affected by coastal erosion over the next twenty years. Although no immediate action is warranted, monitoring of coastal erosion in the vicinity of these facilities is essential. If any of these facilities is threatened, a cost/benefit analysis should be conducted to evaluate structural alternatives against the option of relocating the facility inland. For private sector facilities, the public benefits provided by these facilities must also be considered. For public facilities, any future improvements should be weighed against the coastal erosion hazard risk and estimated costs to provide appropriate sea defenses to protect the facilities from the hazard.

The coastal erosion hazard maps are a valuable tool for prevention of future losses to the coastal erosion hazard. No major capital investments, such as roadways or other infrastructure should be permitted within the coastal area anticipated to be effected by coastal erosion. Sea defenses should only be considered as a last resort because they are very expensive to build and maintain, in addition, they often have adverse secondary impacts on the coastal ecosystem. They should be considered only for essential water-dependant facilities. The coastal erosion maps should be referred to whenever major public or private development projects are proposed along the study area coastline.

5.1.3 Landslide Hazard Score

The Landslide hazard scores ranged from 1 to 3.00. The facilities with the highest Landslide hazard scores are presented in the table below.

Facility ID	Facility Type	Facility Name	Landslide Score
137	Community Center	La Taste Community Centre	3
16	Communication	Cable & Wireless	3
27	Communication	C & W Mt Royal Antenna An	3
36	Community Center	Community Center	3
58	Community Center	Community Center	3
59	Community Center	Clozier Community Centre	3
106	Fulid Utility	Texaco Service Station	3
326	Water Store/Dist	Dougaliston Plant	3

The table below lists the total length of roads within the landslide hazard area.

Hazard Score	Total length of road in the area (km)
1	844.7
2	411.3
3	100.4

The eight (8) critical facilities located in the severe landslide hazard rating score include community facilities, commercial enterprises and utility/communications infrastructure. Although the landslide hazard mapping consultancy for Grenada has the most value as a proactive tool for future development, its application in the vulnerability assessment highlights critical facilities that may be at risk to landslide hazards. One potential mitigation action that should be considered for the ongoing development of a national hazard mitigation plan is to conduct an evaluation of the specific landslide risk for these eight critical facilities. The evaluation would need to be conducted by an experienced engineering geologist who would determine the site-specific geological conditions and consider whether cost-effective mitigation measures to reduce the potential of landslides above the critical facilities noted above. One potential mitigation measure is to construct drainage swales to divert surface run-off above and around the critical facilities.

Section 3.4 of the Final Project Report entitled, *Development of Landslide Hazard Maps for Saint Lucia and Grenada,* includes a series of specific recommendations for development planning, general site planning and best management practices for construction of structures and infrastructure on steep slopes. These recommendations pertain to development review procedures for major and minor development projects, road construction best management practices and avoiding development on extremely steep slopes (greater than 50 percent slope). These preventative measures should be incorporated into the day-to-day development review protocols and also should be considered when conducting long-term national or sectoral development plans by the Government of Grenada. Although the landslide mapping consultancy is a powerful predictive tool, it is important to note that the limitations of the methodology utilized dictate that site-specific geologic investigations be conducted for major development projects proposed in the severe landslide hazard rating classes. Landslide susceptibility should be an important consideration for any major development projects being evaluated through the Environmental Impact Assessment (EIA) process.

5.1.4 Total Hazard Score

The Total Hazard Scores ranged from 0 to 7.00. The facilities with the highest total hazard scores are presented in the table below.

Facility ID	Facility Type	Facility Name	Total Hazard Score
137	Community Center	La Taste Community Centre	7
184	Health Centre	Woburn Medical Station	5
16	Communication	Cable & Wireless	5
27	Communication	C & W Mt Royal Antenna An	5
36	Community Center	Committee Center	5
58	Community Center	Community Center	5
59	Community Center	Clozier Community Centre	5
106	Fulid Utility	Texaco Service Station	5
326	Water Store/Dist	D0ugaliston Plant	5

The table above lists the top nine (9) critical facilities ranked in descending order of hazard severity. This ranking combines the inland flooding, coastal erosion and landslide hazard scores. On its own it has little utility; however, when combined with the exposure scores, it allows for a comprehensive assessment of vulnerability.

5.2 EXPOSURE SCORE

The Total Exposure Score ranged from 0 to 6.50. The facilities with the highest Total Exposure Score included in the table.

Facility ID	Facility Type	Facility Name	Approx Economic Value	Total Exposure Score
164	Police Station	SSU	$ 5,385,000.00	6.5
190	HOSPITAL	Princess Alice Hosptial	$ 6,000,000.00	6.5
194	HOSPITAL	General Hospital	$ 5,250,000.00	6.5
31	Airport	Lauriston Airport	$ 28,000,000.00	6
34	Power Plant	Grenlec Power Station	$ 500,000,000.00	6
127	Govt. Office	Ministry of Health Sauteu	$ 6,000,000.00	6
132	Govt. Office	Volcanico Monitor Station	$ 6,000,000.00	6
160	Police Station	Head Quater	$ 2,531,850.00	5.2
163	Police Station	South St. George	$ 2,394,750.00	5.2
166	Police Station	Pearl/SSU	$ 3,461,700.00	5.2
243	Hospital	Mental Hospital	$ 3,750,000.00	5.2
254	Hospital	St. Augustine Hospital	$ 4,344,750.00	5.2
271	Water Store/Dist	Sewer System	$ 200,000,000.00	5
281	Electricity	Grenlec	$ 20,000,000.00	5
282	Electricity	Grenlec	$ 20,000,000.00	5

From the combined perspective of economic value and criticality, the above list of fifteen (15) critical facilities is provided in descending order of priority. These critical facilities represent substantial investments by the government or private sector and should be considered for retrofitting because of their economic importance or value to civil society following a disaster event.

5.3 CUMULATIVE VULNERABILITY SCORE

The Cumulative Vulnerability Score ranged from 3 – 24.00. The facilities with the Highest Cumulative Vulnerability Score included in the table below.

Facility ID	Facility Type	Facility Name	Total Hazard Score	Total Exposure Score	Cumulative Vulnerability Score
31	Airport	Lauriston Airport	4.0	6	24.0
106	Fulid Utility	Texaco Service Station	5.0	4.8	24.0
127	Govt. Office	Ministry of Health Sauteu	4.0	6	24.0
160	Police Station	Head Quater	4.0	5.2	20.8
16	Communication	Cable & Wireless	5.0	4	20.0
27	Communication	C & W Mt Royal Antenna An	5.0	4	20.0
281	Electricity	Grenlec	4.0	5	20.0
164	Police Station	SSU	3.0	6.5	19.5
190	HOSPITAL	Princess Alice Hosptial	3.0	6.5	19.5
194	HOSPITAL	General Hospital	3.0	6.5	19.5
7	School	Boca Secondary	4.0	4.8	19.2
107	Fulid Utility	Shell LPG Gas Plant	4.0	4.8	19.2
108	Fuilid Utility	Shell Gas Plant	4.0	4.8	19.2
109	Fulid Utility	Shell Gas Plant	4.0	4.8	19.2
111	FulidUtility	Shell Gas Plant	4.0	4.8	19.2
128	School	St Patricks Roman Catholi	4.0	4.8	19.2
210	School	St Mark's Secondary Schoo	4.0	4.8	19.2
236	School	Anglican High School	4.0	4.8	19.2
274	Fulid Utility	GBN Station Site	4.0	4.8	19.2
34	Power Plant	Grenlec Power Station	3.0	6	18.0
132	Govt. Office	Volcanico Monitor Station	3.0	6	18.0

The preceding table is the most important summary table from this vulnerability assessment in that it combines the hazard scores for each of three natural hazards evaluated with the exposure scores to provide a comprehensive assessment of vulnerability. The list of the top twenty-one (21) vulnerable critical facilities is providing in descending order of priority. As such, it provides a valuable tool to optimize limited funds that may become available to make critical facilities in Grenada less vulnerable to natural disasters. The next logical step for the Government of Grenada is to conduct a structural assessment of the identified facilities to determine whether there are cost effective mitigation measures that can be implemented to reduce the vulnerability of these critical facilities. The study would need to be conducted by a competent structural engineer with experience in assessing the vulnerability of flooding, coastal erosion and landslide hazards. The engineer would need to develop alternative retrofitting solutions for each of the appropriate hazards and be knowledgeable in preparing cost/benefit analyses. As funds become available for retrofitting the most cost-effective measures, they should be implemented in order of priority as determined by this cumulative vulnerability ranking.

5.4 HAZARD MITIGATION SUMMARY

The findings of the vulnerability assessment and previous hazard prioritization and hazard mapping consultancies need to be viewed in the following contexts:

- Existing versus Future Vulnerabilities
- Pre- versus Post-Disaster Scenarios
- National Hazard Mitigation Plan Development Process

The explanatory text in the previous subsections assumes that one of major outcomes of the vulnerability assessment is to reduce the existing vulnerability in Grenada. This will require a structural assessment of the highly vulnerable critical facilities to determine the most cost-effective solutions to retrofit or "harden" the facilities. The text also hinted at the value of the HMVA consultancies to reduce future vulnerability by their use in evaluating major development projects, including both private and public sector initiatives. This will require the distribution of hard and electronic versions of the hazard mapping and vulnerability assessment outputs to appropriate Government agencies so that the findings of these consultancies can be used in the project design and approval process. The hazard mapping and vulnerability assessment information also needs to be readily available to developers, NGOs and community organizations.

The implementation of hazard mitigation or risk reduction actions is normally done in the pre-disaster scenario. Preventative measures to reduce vulnerability are best implemented before the disaster strikes. However, the post-disaster environment provides a tremendous opportunity to ensure that risk reduction measures are incorporated in the design and construction of damaged or destroyed buildings and infrastructure. Mainstreaming disaster risk reduction in the recovery and reconstruction process poses many challenges, such as political and societal pressures to return to prevailing pre-disaster conditions, work against taking maximum advantage of this window of opportunity.

The hazard mapping and vulnerability assessment findings funded by CDB/CDERA can assist in this effort by assisting in the decision-making process of determining whether to rebuild in place or relocate critical infrastructure outside of mapped hazard zones. The CDERA/CDB Collaboration, through previous consultancies has recommended that the Government of Grenada consider elements in the enhancement of their draft national hazard mitigation plan to mainstream disaster risk reduction in post-disaster conditions.

The vulnerability assessment is just one important step in the process leading to the development of a national hazard mitigation plan for Grenada. It builds upon the previous hazard prioritization and hazard mapping consultancies and informs the development of mitigation actions for consideration in the national plan. The Plan Development Committee (PDC), created to facilitate the development of the national plan, should consider both structural (hard) mitigation actions to address specific hazard vulnerabilities in addition to soft (programmatic) mitigation actions in plan development process.

The PDC should consider the following recommendations for inclusion in the national hazard mitigation plan:

- Propose a mechanism for identifying and prioritizing areas or regions for subsequent hazard mapping and vulnerability assessments (HMVA). This is particularly relevant for areas known to be prone to inland or coastal flooding, in order to undertake detailed flood studies as was conducted for the St. John's River Basin Pilot Area.

- NaDMA should consider developing a mechanism in concert with relevant line ministries to rapidly collect damage assessment data in post-disaster conditions, especially to critical facilities, and develop a simple, effective database for storing, updating and maintaining damage assessment information over time.

- One obvious mitigation action for consideration by the PDC is "Conduct a structural assessment and benefit/cost analysis for the top twenty-one (21) vulnerable critical facilities identified in the CDB document entitled, *Vulnerability assessment of Critical Facilities, Grenada, West Indies, in order to develop retrofit priorities, as funding becomes available".*

- NaDMA should consider expanding the *Saint Lucia Vulnerability Assessment of Critical Facilities* to address societal, economic and environmental sectors, in addition to conducting a more comprehensive mitigation opportunity analysis (see Section 2.1).

6.0 VULNERABILITY ASSESSMENT TRAINING

The Vulnerability Assessment training for Saint Lucia and Grenada took place June 6-8, 2006 at the ISIS World Corporation Training Centre in Castries, St. Lucia. Training was organized by the Caribbean Development Bank (CDB) and local logistics were organized by the Saint Lucia National Emergency Management Organization (NEMO). Attendees came from different government agencies on both island nations.

A Vulnerability Assessment Training Needs Assessment Interview Form was provided to select Government representatives during the inception mission to determine focus areas for the three-day training. The assessment form is provided as Appendix F.

6.1 TRAINING PROCESS

Training was conducted by the Consultant Project Team. The lecturer was Mrs. Valrie Grant-Harry. The training course was developed to help HMVA subcommittee members and/or designates to understand and/or reinforce concepts and tools required for the implementation of a comprehensive vulnerability assessment to natural hazards. The training course was provided in a lecture format that outlined a step-by-step process for conducting a vulnerability assessment. It placed emphasis on participants acquiring sound understanding of generic GIS and database techniques, with which they would be able to handle implementing a comprehensive vulnerability assessment. The course ran for three days and consisted of lectures interspersed with classroom demonstrations and/or exercises:

1. **Day One: Overview of Hazard, Vulnerability & Risk Terms and Tools**. Participants were introduced to key vulnerability terminology such as hazard, vulnerability and risk. Emphasis was placed on the vulnerability assessment methodology and subsequent processes, definition of study regions and prerequisites for implementation of a vulnerability assessment.

2. **Day Two: Data Collection: GPS Field Mapping and Database Development**. Participants were introduced to inventory classification issues such as classification of facility types and attribute requirements for facility by type. Fundamental GPS and GIS concepts were also covered and emphasized. Attention was given to the utilization of field data capture tools and techniques, field data capture and integration into an ArcGIS geodatabase. Basic database functions will be covered that illustrate how spatial data and attributes are created, accessed, used, edited, managed and stored in the geodatabase.

3. **Day Three: Spatial Analysis and Reporting**. Participants were instructed on how to perform basic spatial analysis for the implementation of a vulnerability assessment. Emphasis was placed on using ArcGIS, particularly the Spatial Analyst extension, to perform spatial overlays, query GIS databases, manipulate tabular data, create, run, and edit spatial models as well as present data in maps and tables.

6.2 TRAINING PROGRAM FOCUS AREAS

The Vulnerability Assessment training empowered candidates to receive an understanding of:

- Hazard Risk Reduction Components
- NOAA Vulnerability Methodology
- ESRI ArcGIS tools
- Trimble GPS basics and tools

- Vulnerability assessment attribute requirements (Economic, Operational Structural Requirements)
- Data collection Techniques, including a performance of a Data Gap Analysis
- Data capture Procedures (Mapping vs. Attribute Collection)
- Development of a database, including design and construction.
- Overview of data capture Techniques (digitizing, imagery, field Mapping using GPS)
- Database classification and data integration techniques in GIS
- ArcGIS Spatial Analyst tools
- ArcGIS presentation and thematic display

6.3 MAJOR ISSUES

The participants indicated several major issues that should be considered by HMVA and CDERA. These include:

- participants were under the impression that training was a computerized course and would have more hands on training.

- participants indicated there should have been NaDMA representatives participating in the training course. Also, participants expressed concerns that only technical personnel were present and that there should have been more Hazard Mapping and Vulnerability Assessment Subcommittee members participating in the training.

- limited technical resources within NaDMA (trained personnel, software, etc.). This precipitates the need to depend on outside agencies for technical inputs and expertise. It also leads to poor utilization of information, particularly hazard maps and vulnerability information.

- related to the above, NaDMA needs GIS Software as well as GPS equipment.

- the utilization of GIS and GPS technologies is very limited in the country.

- there are no data standards (projection and coordinate systems) developed for previous hazard mapping consultancies which creates a problem for receipt and utilization of data.

- participants indicated they have not received hazard map data under previous consultancies.

- participants indicated that there was no clear categorization of critical facilities, especially for emergency shelters.

6.4 THE WAY FORWARD

The participants focused on several key points to take the process to the next level. These include the:

- establishment of a GIS Department in NaDMA to streamline and harness the information gathering and collaboration between government agencies. It was suggested that an initial step would be to have a technical resource assigned to GIS and mapping matters from each agency.

- identification of areas of focus for the HMVA with regard to information gathering, particularly in regards to shelters and classification of critical facilities. Attention should be given to shelter capacity and population serviced by shelters.

- dissemination of hazard and vulnerability information to communities through public awareness campaigns and involve local communities in vulnerability assessments. This was stated as the best way to have persons understand hazards and potential impacts in their local communities

- implementation of mechanisms, particularly web-based GIS, to increase public awareness among younger populations.

- use of hazard information in development planning, especially in the review of large subdivision or public developments.

- emphasis of hazard and vulnerability information in emergency preparedness exercises, especially hazard map utilization in modeling and simulation of impact of hazard events.

These recommendations made by the participants of the vulnerability assessment training are very important and should receive consideration by the PDC in the ongoing revisions being made to the draft national hazard mitigation plan.

6.5 CONCLUSION

The evaluation of the workshop was very favorable. All participants expressed their appreciation for all aspects of the training. Sixty-three (63%) of participants indicated that the information they received from the training was new and useful. Eighty-eight (88%) percent of all participants indicated that the knowledge gained would be a great help in future HMVA endeavors. All participants felt that the workshop was well organized, had the right mix of demonstrations and exercises and that different modules were presented clearly and easy to understand. Presentation format had the right blend of technology and practical issues, as most participants indicated they were not familiar with the practices presented during the training.

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APPENDICES

APPENDIX A: CIPA PROJECT TEAM MEMBERS

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APPENDIX B: INCEPTION MISSION ITINERARY

The CDB Vulnerability Assessment Inception Mission meeting was held in Grenada on April 24, 2006. In each location, the inception meeting included a briefing session with Hazard Mapping and Vulnerability Assessment (HMVA) Sub-Committee and Government Officials and follow-up meetings with key ministries, departments and units. The inception mission also included data collection, compilation and field mapping.

Time	Activity	Representatives Involved
Day One		
10:00am	**Meeting with Hazard Mapping and Vulnerability Assessment Subcommittee**	
	1. Welcome & Introductions –	NaDMA (Grenada), CDB – (Dr. Cassandra Rogers)
	2. Project Expectations 3. Project Objectives 4. Technical Approach 5. Data Needs and Collection 6. Project Execution & Timeframe	Mr. Euwema, CIPA Project Director
1:00am – 5:00pm	**Field Mapping Breakout**	
GIS Field Mapping Breakout – CIPA will identify list of specific data needs and requirements.		Mr. Euwema and Mr. Samuels will establish an agenda and priorities for field mapping and database development.
Day Two/Three/Four		
9:00am -5:00pm	**GIS Field Mapping and Data Collection**	
9:00am – 5:00pm	Field Mapping and Data Collection	Mr. Samuels to conduct field mapping and attribution of database with key stakeholders.
9:00am -5:00pm	**Needs Assessment for Vulnerability Assessment Training**	
9:00am – 5:00pm		Mr. Euwema to meet with key representatives of ministries to identify requirements for Vulnerability Assessment training

APPENDIX C: BRIEF ON INCEPTION MEETING

The preparation of a vulnerability assessment of critical facilities is part of the effort to inform Hazard Mitigation plan strategies and actions.

Grenada

CIPA project team met with the National Disaster Management Agency (NaDMA) staff and members of the Hazard Mapping and Vulnerability Assessment (HMVA) Sub-Committee to discuss the vulnerability assessment inception mission.

Mrs. Denise Guy of NaDMA facilitated introductions to participants. Shortly thereafter, Dr. Cassandra Rogers of the Caribbean Development Bank provided an overview of the project, its objectives and timeframe. Mr. Euwema then facilitated a PowerPoint presentation which outlined:

1. Project Expectations
2. Project Objectives
3. Technical Approach
4. Data Needs and Collection
5. Project Execution & Timeframe

Again, discussions focused on the definition of critical facilities. Mr. Euwema provided a definition and tried to focus the discussion to facilities in which data was readily available (i.e. national data in GIS format). Issues were also raised about the scope of the consultancy. Questions were asked why the consultancy was focused on critical facilities and not on socially vulnerable groups or communities – i.e. poverty, persons over sixty-five years of age, etc.

Mr. Euwema facilitated the strategic planning exercise that focused on the preliminary data needs based on requirements as well as the Vulnerability Assessment Training Needs Assessment and pursuant interview process. The result of this exercise was to identify national ministries or departments that had experience in technologies or technical skills that would be useful for the implementation of a vulnerability assessment.

Attendence

Name	Ministry
Dr. Cassandra Rogers	CDB
Mrs. Denise Guy	NaDMA
Kenrick Noel	Cable and Wireless
Kelvin Dottin	Ministry Health & Environment
Fabian Purcell	Physical Planning
Elizabeth Charles-Soomer	Agency for Reconstruction and Development
Christopher Greenridge	NaWasa
Jeffrey Euwema	CIPA
Mark Samuels	CIPA

APPENDIX D: FIELD DATA CAPTURE FORM

General Use

Facility ID/Location

Facility ID

Facility Classification

Latitude

Longitude

Economic Features

Est. Sq. ft.

Approx. Economic Value

Calculated Economic Value

Repetitive Loss Information

Damage History

Damages Experienced

Estimated Percentage Of Loss during Last Event

General Facility Information

Name

Address

Locality

Telephone

Fax

Email

Name of person-in-charge

Operational Features

Level of Service

Back-up Power Facilities

Date of Construction

Pre 1906

Up to 1945

Up to 1976

Up to 1990

Up to 2000

Recent

Modifications:

Underpinned

Major Rehabilitation

Hazard Upgrade/retrofit

None

Structure Information

Building Frame:

Masonry

Steel

Concrete

Wood

Other:

Number of Floors:

1

2-3

4-7

>8

Elevation of First Floor of Building

1ft

2-3ft

3-5ft

>5ft

Slope:

Level

Slope<20 degrees

Slope>20 degrees

Roof & Fenstration

Roof connection (to foundation) ?.	
Yes	
No	

Roof span greater than 40 feet from support to support?	
Yes	
No	

Height of roof less than 30 feet above ground level?	
Yes	
No	

Pitch of roof greater than 30 degrees?	
Yes	
No	

Glass Door and Window Opening (%)	

Operational Features

Occupancy	
Capacity of Persons	
Toilets #	
Showers/Bathing Facilities	

Lifelines

Potable Water/Waste Water

Facility ID	
Capacity of Facility	
Construction Material	
Elevated (yes/no)	
Approximate Elevation	

Communication

Facility ID	
Capacity of Facility	
Construction Material	
Elevated (yes/no)	
Approximate Elevation	

Electric Power

Facility ID	
Capacity of Power Generation Facility	
Capacity of Power Substation	

Highway/Roads

Facility ID	
Number of Lanes (or tracks)	
Material	
Elevated or At-Grade	

Piers

Facility ID	
Material	

Bridges

Facility ID	
Number of Lanes (or tracks)	
Material	
Elevated or At-Grade	

Other Comments

APPENDIX E: DATA DICTIONARY

Hazard Data	Format (GIS or Tabular	Description
Coastal Erosion	shapefile	Coastal Erosion Hazard Map
Flood	shapefile	Flood Hazard Map
Landslide	shapefile	Landslide Hazard Map
Pilot_25yrvel&depth	shapefile	Pilot area flood map
Base Data		
roads	shapefile	Linear Feature
tingrid	grid	Raster feature - DEM
Analysis		
facility_w_cumulative_vul	shapefile	Point Feature - contains cumulative vulnerability score
facility_w_exposure	shapefile	Point Feature - contains exposure score
facility_w_hazard	shapefile	Point Feature - contains hazard score
facility_pilotarea	shapefile	Point Feature - contains all score in pilot area
GRE_Hazard_and_value_4.xls	Microsoft Excel	Tabular Reports - of all results and rating

APPENDIX F: VULNERABILITY ASSESSMENT TRAINING NEEDS ASSESSMENT INTERVIEW FORM

General Information

National Ministries and Agencies:

Agency/Ministry: Date:

Department: Title:

Name: Phone Number:

Email:

Department Organizational Structure (Number of Personnel, Job Positions, Work Flow):

Major Department Functions:

Information Technology Infrastructure:

Current Hardware:

Number of Servers:
Number of Workstations:
Scanners
Printers
Plotters

Current Software:

Basic Computer Processing
Management Systems
GIS
Databases (storage)

Mapping and Analytical Capabilities:

Uses of GIS:

1.
2.
3.
4.
5.
6.
7.

Type of GIS Data Sets or Products (i.e. paper maps, databases, etc):

General Description of Existing GIS Data (map layers, databases, etc)

Number of GIS Users:

Names:

Current Experience/Understanding of GIS, CAD, and Database Systems:

	Understanding/Knowledge		
Software	**Limited**	**Moderate**	**Extensive/ Proficient**
ESRI GIS Software			
ArcGIS Desktop 8.x, 9.x (ArcInfo, ArcEditor, ArcView)			
ArcObjects			
ArcIMS 8.x, 9.x			
ArcSDE 8.x, 9.x			
ArcGIS Server 8.x, 9.x			
Other Software			
Databases:			
Oracle 10g, 9i, 8i			
Microsoft SQL Server 2000			
Microsoft Access			
MySQL			
Postgres/PostGIS			
Other			
Languages:			
Microsoft Technologies: NET with C# (CSharp), Visual Basic, ASP.NET			
Javascript			
PHP			
Java			
Macromedia: ColdFusion, Flash			
Other			
Other Technologies:			
Python			
HTML			
XML			
Oracle PL/SQL			
JSP			
Other			
General Software Applications:			
MS SQL Enterprise Manager			
Oracle Enterprise Manager			
Microsoft Project, Visio, Office			

Institutional Context

Relationships With NADMA ??? departments (Data Transfer, Technical Support, etc.):

Perceived role of your agency in development of national vulnerability assessment:

Availability of existing department personnel for participants in vulnerability assessment:

APPENDIX G: KEY TERMS

Hazard – A potentially damaging physical event, phenomenon and or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

Hazard Mitigation – Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards. In climate change terminology, hazard mitigation is synonymous with adaptation to some degree. Climate change adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

Hazard Risk Management - The systematic management of administrative decisions, organization, operational skills and responsibilities to apply policies, strategies and practices for hazard risk reduction.

Hazard Risk Reduction – The development and application of policies, procedures and capacities by the society and communities to lessen the negative impacts of possible natural hazards and related environmental and technological disasters. This includes structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse impact of hazards, as well as the development of coping capabilities.

Mitigation – In the context of natural hazards risk reduction, mitigation refers to sustained actions taken to reduce or eliminate long-term risk to people and property from hazards and their effects.

Vulnerability - The level of exposure of human life, property and resources to damage from natural hazards.

Operational Analysis — This analysis requires knowledge of where daily activities are conducted within the structure. This helps determine how daily activities what will be affected if the building is damaged or if utility services are interrupted.

Structural Analysis — used to examine the structural integrity of the building and its ability to withstand potential hazard impacts. This may require knowledge about the construction of the facility and the existing building codes governing local construction.

Hazard Score – is a numerical value that is utilized in order to score facilities based on their location within a designated hazard "intensity" area. Intensity parameters (i.e. wind speeds, 10yr to 50yr flooding, etc.) that describe the type of forces that characterize each hazard are inclusive. Intensity parameters have already been taken into account by utilizing numerical scores for qualitative measures (i.e. low, moderate, high) for each hazard. Qualitative measures for each hazard were developed under previous consultancies have been given numerical scores (Low=1, Medium=2, High=3) in order to score the hazards.

Exposure Score -- classifies critical facilities according to their "Exposure Type" (economic value or replacement cost of the facility) and the "Importance Factor" (criticality of use or importance before, during or following a disaster event).

Exposure Type Score -- is determined by utilizing a common index that assigns a "score" based on a range of economic values.

Importance Factor -- provides an understanding of the criticality of the use of the facility in both pre- and post-disaster settings.

Cumulative Vulnerability -- is calculated by taking the Total Hazard Score and multiplying it by the Total Exposure Score. Whereas individual item scores should be compared to establish trends and identify specific deficiencies, the cumulative vulnerability score can help establish a broad prioritization options.