INFORMATION SOURCES

Information for the development of the Risk Assessment came from a variety of sources, including:

Hurricane

- NOAA National Climatic Data Center.
- American Society of Civil Engineers (ASCE) 7-05 Design Wind Speeds.
- *"Estimation of Potential Hurricane and Earthquake Losses to Water and Power Facilities"* (EQE international, 1994.)

Riverine Flooding

- Digital Flood Insurance Rate Maps (2007), which delineate the 100- year floodplain and VE SFHA boundaries
- USVI Flood Insurance Study (2007)
- USACE Digital Terrain Model

Coastal Flooding

- USACE SLOSH Model for Categories 1, 3, and 5 storms.
- USACE Digital Terrain Model

Earthquake

- 1000-year probabilistic ground shaking intensity maps (Earth Scientific Consultants 1999).
- Earthquake vulnerability maps, which classified acceleration factors for local site geology, using NEHRP[1] provisions to define localized site amplification classification (Earth Scientific Consultants, 1999)
- Puerto Rico Seismic Network, University of Puerto Rico (UPR)

Tsunami

- Oral communication with Tsunami hazard expert, Professor Roy Watlington, UVI
- USGS U.S. Geological Survey, "Earthquakes and Tsunamis in Puerto Rico and the U.S. Virgin Islands", Fact Sheet FS–141–00, 2001
- University of California Tsunami Research Group (http://www.usc.edu/dept/tsunamis/)
- Puerto Rico Seismic Network, University of Puerto Rico (UPR)

[1] NEHRP is the National Earthquake Hazards Reduction Program. This program's congressional mandate is "to reduce the risks to life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program".

Drought

- 2010): Average Annual Rainfall 1971 -2000, Oregon State University (OSU) Spatial Climate Analysis Service.
- USACE Digital Terrain Model (2008)
- Hydrologic Units for USVI (2002) U.S. Geological Survey in cooperation with the U.S. Department of Agriculture, Natural Resources Conservation Service
- The United States, Caribbean and Pacific Basin Major Land Resource Areas (MLRA) Geographic Database serves as the geospatial expression of the map products presented and described in Agricultural Handbook 296 (2006).

Rain-Induce Landslide

- (2010): Average Annual Rainfall 1971 -2000, Oregon State University (OSU) Spatial Climate Analysis Service.
- USACE Digital Terrain Model (2008)
- Hydrologic Units for USVI (2002) U.S. Geological Survey in cooperation with the U.S. Department of Agriculture, Natural Resources Conservation Service

Wildfire

- (2010): Average Annual Rainfall 1971 -2000, Oregon State University (OSU) Spatial Climate Analysis Service.
- USACE Digital Terrain Model (2008)
- Hydrologic Units for USVI (2002) U.S. Geological Survey in cooperation with the U.S. Department of Agriculture, Natural Resources Conservation Service
- The United States, Caribbean and Pacific Basin Major Land Resource Areas (MLRA) Geographic Database serves as the geospatial expression of the map products presented and described in Agricultural Handbook 296 (2006).

Inventory of Assets

- General Building Stock: Office of the Lt. Governor, Office of the Tax Assessor, Computer Mass Appraisal System Database and GIS Parcel Maps
- Critical Facilities and Infrastructure: VI Department of Property and Procurement and VITEMA

HAZARD PARAMETERS

To determine vulnerability, the following hazard parameters were used:

- Hurricane Design Wind Speed: The primary data input for the wind hazard model were the American Society of Civil Engineers (ASCE) 7-05 Design Wind Speed maps. The ASCE Design Wind Speeds take into account historical events such as hurricanes and tropical storms. Because probabilistic data was not readily available, ASCE design wind speeds were used. The design wind speed in ASCE 7-05 for the US Virgin Islands is 145 Mph.

- Flood Hazard Determination: FEMA Digital Flood Insurance Rate Maps (DFIRMS) were identified as the most comprehensive flood data for the US Virgin Islands. GIS overlay techniques were utilized to identify structures in the flood zone flood polygons. Flood depths were estimated for each estate on each island by overlaying the DFIRMS flood zone data on a digital elevation model.

- Coastal Flood Hazard Determination: USACE inundation maps derived from a SLOSH (Sea, Lake, and Overland Surges from Hurricanes) model computes storm were identified as the most comprehensive coastal flood polygon data for the US Virgin Islands. Surge inundation polygons were developed for three categories of hurricanes as defined by the Saffir-Simpson scale (Categories 1, 3, and 5). GIS overlay techniques were utilized to identify structures in the coastal flood polygons. Flood depths were estimated for each estate affected by coastal flooding by overlaying the Q3 flood zone data on a digital elevation model.

- Earthquake Hazard Determination: The hazard assessment was developed using the Seismic Hazard Map of 1994 (Earth Science Consultants, 1999), which provides ground shaking intensity (expressed in terms of Peak Ground Acceleration (PGA) for 50-, 100-, 250-, and, 1,000-year return periods). The 1000-year ground shaking map was generated using an acceleration variability (σ) of 0.6 at a set of sites across each island. Acceleration factors were identified based on local soil conditions and the surficial geology. Local site geology was classified using NEHRP[2] provisions to define localized site amplification classification. GIS overlay techniques were used to assign each estate with an earthquake susceptibility factor (PGA).

- Tsunami Inundation Area Determination: The tsunami hazard maps used in this study were developed based on estimates of a historical event, the tsunami of 1867. The estimated maximum wave height of the tsunami of 1867 was 7 meters. This elevation was intersected with a digital elevation model to develop tsunami inundation maps. These maps are based on a historical tsunami scenario and expert interviews. Inundation maps

[2] NEHRP is the National Earthquake Hazards Reduction Program. This program's congressional mandate is "to reduce the risks to life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program".

may have no significant bearing on any actual tsunami event and should not be used during a real tsunami event. GIS overlay techniques were utilized to identify structures in the inundation areas. Flood depths were not estimated.

- Drought Hazard Susceptibility: The hazard assessment was developed using the by performing a GIS driven factor analysis that combined Average Annual Rainfall 1971 - 2000, USACE Digital Terrain Model (2008) and Hydrologic Units for USVI (2002) and Major Land Resource Areas (MLRA) classifications. GIS overlay techniques were used to assign each estate with a Drought susceptibility (very high, high, moderate, low, and very low) factor.

- Rain-Induced Landslide Susceptibility: The hazard assessment was developed using the by performing a GIS driven factor analysis that combined Average Annual Rainfall 1971 - 2000, USACE Digital Terrain Model (2008) and Hydrologic Units for USVI (2002) classifications.

- Wildfire Hazard Susceptibility: The hazard assessment was developed using the by performing a GIS driven factor analysis that combined Average Annual Rainfall 1971 - 2000, USACE Digital Terrain Model (2008) and Hydrologic Units for USVI (2002) classifications. Factors were inverted GIS overlay techniques were used to assign each estate with a wildfire landslide susceptibility (very high, high, moderate, low, and very low) factor.

STRUCTURE CLASSIFICATION

This subsection provides a technical description of the housing stock, in addition to building replacement and content values.

General Building Stock

Since the 2008 Plan Update, the Virgin Islands Tax Assessors Office (Division of the office of the Lt. Governor), have made revisions to the property valuations throughout the entire Territory of the Virgin Islands. This revised database was not made available to VITEMA, and as a result, the same database that was utilized during the 2008 Update was utilized to categorize the built environment.

The OLG database; however, had certain limitations related to structure classification. Field surveys were eliminated from the budget and not conducted during this Plan Update. The field investigations that were conducted during the 2005 and 2008 Plan Update were deemed to be satisfactory to determine the distribution of different building types and to gather structural information for each occupancy class.

Occupancy Class
To classify the built environment, the Virgin Islands Tax Assessors Office (Division of the office of the Lt. Governor) GIS and Tax database was collected and evaluated. The database has been updated and was reevaluated. The OLG data was found to be consistent with tax lot information and could be used to identify use of parcel and/or building.

During the development of 2008 Plan, a review of this information revealed that there were data limitations for detailed occupancy classification. These problems were not resolved during this Plan Update.

Structural Classification
Structural information is an important factor in determining the vulnerability or how likely structures are to fail when they are subjected to hazards, such as wind pressure that exceeds their design. In order to conduct basic analyses and gather information useful to determine general loss estimates, structural engineers and planners categorized buildings into ten different building types during the development of the 2005 and 2008 Plan Update. This was done so to capture general structural characteristics of buildings according to local building practices.

Model building types were determined based on experience with typical building construction in the US Virgin Islands. The basic structural systems were collapsed into 10 model building types with the following general construction characteristics: Wood, Steel, Reinforced Concrete, Steel-Frame, Un-reinforced Masonry, and Un-reinforced Masonry. These classifications were reviewed during this Plan Update and building height subclasses remained the same as was identified in the 2005 and 2008 Plan.

***Table 1* Model Building Types**

Building Type ID	Building Type	Description
1	Low Rise Wood Frame Dwelling	Not built to code (no shearwalls, holdowns, presence of cripple walls, etc); Hip roof connected to foundation, per retrofit effort taken island wide recently; Presence of slight decay of wood due to pests or water damage, or rusting of steel connectors. Foundations are not engineered; Buildings are an average of 30 - 100 years old;
2	Mid-rise Wood Frame Dwelling	Not built to code (no shearwalls, holdowns, presence of cripple walls, etc); Hip roof connected to foundation, per retrofit effort taken island wide recently; Presence of slight decay of wood due to pests or water damage, or rusting of steel connectors. Foundations are not engineered; Buildings are an average of 30 - 100 years old;
3	Low Rise Reinforced Concrete Dwelling	Not built to code (not designed for lateral movement, construction not supervised, etc); Most structures are regular in plan and elevation (box shaped, not L shaped); Most structures do not have a weak/soft story Presence of slight bar corrosion and rock pockets in concrete; Foundations are not engineered;

Building Type ID	Building Type	Description
		Buildings are an average of 30 - 100 years old;
4	Mid Rise Reinforced Concrete Dwelling	Built to code (designed for lateral movement, construction supervised, etc); Most structures are regular in plan and elevation (box shaped, not L shaped); Most structures do not have a weak/soft story Structural elements are in good condition; Foundations are engineered; Buildings are an average of 10 - 20 years old;
5	Low Rise Steel Building	Designed for lateral movement (wind loads); Most structures are regular in plan and elevation (box shaped, not L shaped); Most structures do not have a weak/soft story Structural elements are in good condition; Buildings are an average of 10 - 20 years old;
6	Mid Rise Steel Building	Designed for lateral movement (wind loads); Most structures are regular in plan and elevation (box shaped, not L shaped); Most structures do not have a weak/soft story Structural elements are in good condition; Buildings are an average of 10 - 20 years old;
7	Low Rise Un-reinforced Masonry Building	Not built to code (significant damage in strong earthquake); Foundations are not engineered; Buildings are an average of 40 - 200 years old;
8	Mid Rise Un-reinforced Masonry Building	Not built to code (collapse potential in strong earthquake); Foundations are not engineered; Buildings are an average of 40 - 200 years old;
9	Low Rise Reinforced Masonry Building	Built to code (designed for lateral movement, construction supervised, etc); Most structures are regular in plan and elevation (box shaped, not L shaped); Most structures do not have a weak/soft story; Structural elements are in good condition; Foundations are engineered; Buildings are an average of 10 - 20 years old;
10	Mid Rise Reinforced Masonry Building	Built to code (designed for lateral movement, construction supervised, etc); Most structures are regular in plan and elevation (box shaped, not L shaped); Most structures do not have a weak/soft story; Structural elements are in good condition; Foundations are engineered; Buildings are an average of 10 - 20 years old;

Each building type has a unique and distinct behavior to different hazards, due to a number of reasons which include material behavior, pre or post incorporation of building code requirements, inherent quality of traditional construction practices, and height of the structure.

Building Replacement and Content Values

To relate the number of building and occupancy classes to specific building types, a two-dimensional matrix was developed. It allowed project team members to understand the distribution of model building types for a specific occupancy class at the estate level for each island. To estimate replacement and content values for buildings in each estate, the following data were considered for this Plan Update.

- *Replacement Value by Occupancy*. The Virgin Islands Tax Assessors Office (Division of the Office of the Lt. Governor), in response to an order of the U.S. District Court, has completely revised the property valuations of the entire Territory of the Virgin Islands. The resulting database is current as to the 'fair market value" of all privately held properties throughout the Territory and the valuation methodology is more uniform. This database provides a comprehensive listing of residential and commercial properties and their respective values.

- *Content Value by Occupancy* Using the "fair market value" information derived above for replacement costs, content values for both residential and commercial properties were determined as a percent of the replacement costs (i.e. multiply building replacement costs or fair market value by content cost percentage to calculate content value). Content values or cost percentages followed FEMA standardized percentages for residential properties (30%), while a 100% content value was utilized for commercial properties.

The analysis generated a distribution of model building types for each estate boundary on each island. These occupancy-building type mapping schemes were developed to determine the distribution of model type distributions to determine specific damage and loss characteristic parameters (i.e. vulnerability characteristics) for each island jurisdiction.

<u>Inventory Aggregation and Valuation</u>
The composition of the general building stock (i.e. residential and commercial building stock) was therefore aggregated to given estate boundaries and is assumed to be evenly distributed throughout the estate boundary. This analysis, which is consistent with HAZUS-MH Level 2 Analysis[3], was conducted using a Geographic Information System. The simplified steps for manual estimation of exposure are described below:

Critical Facilities and Infrastructure

For purposes of this plan, the following three part definition of critical facilities and infrastructure shall apply:

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[3] At this point, some basic background information about HAZUS analyses is needed. HAZUS analyses can be undertaken on three levels dependent on the amount of data that is available:

- *Level 1* analyses use default data that has been assembled for HAZUS from national databases. This data provides a basic estimate of exposure that is useful for broad scale planning efforts. This data is not available for US Virgin Islands.
- *Level 2* analyses involve the input of more detailed data about local conditions, building stocks etc. and yields correspondingly more detailed and useful results.
- Likewise, *Level 3* analyses provide the most accurate estimates of losses but require detailed engineering and physical conditions data to customize results at a level that is not clearly warranted by this type of study.

Critical Facilities: Critical facilities are those facilities that provide services to the community and should be functional after a hazard event and include:

- Government buildings necessary for continuity of operations,
- Hospitals,
- Police stations,
- Fire stations,
- Schools, and
- Homes for the aging.

Transportation Infrastructure: Transportation Infrastructure are those facilities that important for the movement of goods, especially emergency relief supplies between islands and include:

- Highways and Roads
- Marine Facilities
- Airports

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

- Electrical Power Generating Plants
- Water Treatment Plants
- Wastewater Treatment Plants
- Potable Water Pumps
- Water Tanks

Building Replacement and Content Values

A detailed list of critical facilities and infrastructure was developed by VITEMA with the input of each respective island hazard mitigation committee. This list was then provided to the consultant project team.

- A detailed list of critical facilities and infrastructure was developed by VITEMA with the input of each respective Island Hazard Mitigation Committee. This list was then provided to the Consultant Project Team. It was identified that detailed attribute information needed to conduct a vulnerability and risk assessment was missing. Therefore, site visits were undertaken to obtain information on their structural characteristics and general conditions.

- Facilities and infrastructure were categorized by their structural characteristics relevant to vulnerability to the prominent hazards identified in the study. The field investigation also allowed the Consultant Project Team to determine the approximate square footage for each facility/structure or group of buildings.

- Replacement and content values for facilities were provided by the VI Department of Property and Procurement. An evaluation of these data based on Consultant Project Team field inspections indicated that approximate building area and construction cost (i.e.

exposure) were overstated. Instead, for each critical facility, the replacement and content value was determined using the FEMA HAZUS-MH guidelines of content value as a percentage of building replacement value.

- Quality Assurance and Control procedures, which included field assessments and review of insurance valuation data, assisted in verification of variations in building characteristics and construction patterns on each island to determine the estimated value of critical facilities in the USVI.

LOSS ESTIMATE PARAMETERS

A vulnerability assessment was used to estimate losses to each hazard. The estimation of hazard related damage to buildings is based on the characteristics of the model building types and an estimate of the hazard intensity (wind speed, flood level, etc.). The extent and severity of damage to structural and nonstructural components of a building is described by one of five damage states:

- Very Low, (no, or negligible damage)
- Low, (easily repairable damage mainly to part of nonstructural components and/or contents)
- Moderate, (considerable, yet repairable damage to mainly non-structural components)
- High (considerable damage to both structural and non-structural
- components), and
- Very High (that the extent of damage is too high to be repaired; the facility has to be demolished and replaced).

The qualitative vulnerability ratings relate to a percentage of damage for each model building types. The damage estimation methods for critical facilities and infrastructure are identical to those utilized to estimate damage with general building stock, except that classification or grouping of facilities was not needed.

In order to conduct this phase of the analysis, special consideration was given to specific building characteristics. Each building type has a unique and distinct behavior to different hazards, due to a number of reasons which may include material behavior, incorporation of building code requirements, inherent quality of traditional construction practices, and height of the structure. In general, building damages can range from cosmetic to complete structure failure, depending on wind speed, level of ground shaking, movement and location of the building.

- Vulnerability: General Building Stock. Based on both the hazard intensity level and an analysis of structural characteristics, a hazard vulnerability rating ranging from very low to very high was assigned to each building type for each hazard.

- Vulnerability: Critical Facilities. Structural engineers and planners performed field visits to critical facilities. Field visits focused on understanding structural characteristics and general conditions of each critical facility.

LOSS ESTIMATE CALCULATIONS

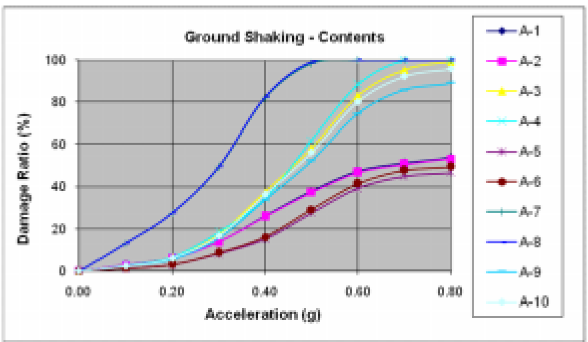
The last step of the risk assessment is loss estimation. To estimate losses, the results of the hazard identification and profiling are used together with the findings of the vulnerability assessment to understand potential losses for general building stock and critical facilities.

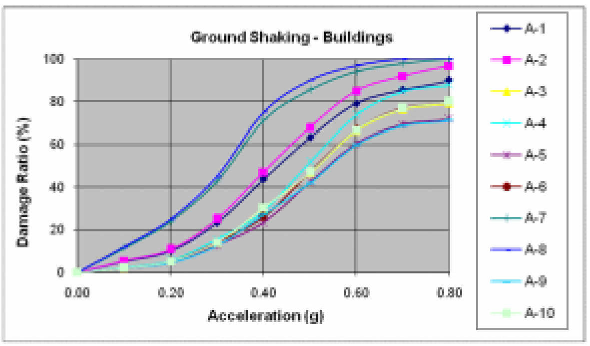
1. Hazard maps (location) and hazard profile information (intensity) were used to identify the natural hazard areas affecting a particular area. Based on the intersection of hazard areas, each estate was assigned a particular hazard intensity level (i.e. flood depth).

2. This analysis resulted in a determination of the number and value of buildings affected by a specific hazard. GIS Queries were performed to estimate the percentages of area affected by flood for each estate to understand how many buildings, by building type were affected by the flood hazard.

3. Vulnerability ratings for each building type were related to loss estimation tables for a specific hazard level. Qualitative vulnerability levels were related to specific loss estimation tables to determine a specific percentage of damage to a structure (i.e. replacement and content value).

4. Qualitative vulnerability levels such as very low, low, moderate, high and very high pertain to a certain level of expected damage. To calculate losses, the expected percentage of damage (i.e. expressed as vulnerability function in the figure below) was applied to each building type and multiplied by the structure replacement cost and content value. An example of a damage curve is provided in the figure below.





The building values are multiplied by loss estimates highlighted in the vulnerability function. The same process is conducted for content values. The damages for replacement costs and content values are then added to estimate aggregate losses for a particular building type for each estate. This methodology is applied for buildings that fall within a specific hazard area (i.e. a flood plain or earthquake hazard prone area) as well as can be applied across an entire region (i.e. hurricane winds) based on a buildings particular vulnerability to a particular hazard level.

Structural Assessment Checklist (example)

STRUCTURAL HAZARD CHECKLIST - EARTHQUAKE
EVALUATION OF CRITICAL FACILITIES
USVI HAZARD LOSS ESTIMATION

Building: Police Station
Location: St. Croix
Superstructure: 3.00

Building Frame: 0.30

Masonry	3.00	
Steel	1.00	x
Concrete	2.00	
Wood	1.00	

Lateral System: 0.25

Moment Frame	0.70	
Braced Frame	0.80	x
Shear Wall - Ductile	1.00	
Shear Wall - Non ductile	4.00	
Dual System	1.00	

Story H/L Ratio: 0.10

<0.5	1.00	
1.0	1.50	
1.5	2.00	x
>2.0	3.00	

Number of Floors: 0.12

1	1.00	
2-3	1.25	x
4-7	1.75	
>8	2.20	

Building Configuration in Plan and Elevation: 0.15

Regular in Plan	0.50	x
Re-entrant Corner	1.50	
Horizontal offset in Walls	1.30	
Non-parallel Walls	1.30	

Regular in Elevation	0.50	
Vertical offset/projection in upper story	1.50	
Weak/Soft Story	2.00	x
Geometric Irregularity	1.50	

Frame Infill: 0.03

Masonry Infill	3.00	
Concrete Infill	2.00	
None	1.00	x

Cladding: 0.05

Brick/Stone	3	x
Stucco	2	
Steel Stud/Window Wall	1.00	
GFRC/EIFS	0.50	
Wood	1.30	

Foundation: 2.50

Basement: 0.10

Yes	2.00	
No	1.00	x

Material: 0.25

Masonry	3.00	
Concrete	1.00	x
Wood	3.00	

Type: 0.45

Mat	0.20	
Spread w/o grade beams	3.00	
Spread with grade beams	1.00	x
Concrete Piles	0.40	
Steel Piles	0.65	
Wood Piles	2.00	
No Foundation	15	

Slope: 0.20

Level	0.00	
Slope<20 degrees	1.50	
Slope>20 degrees	2.50	x

Condition of Structure: 1.50

Date: 0.50

Pre 1906	5.00	
Up to 1945	4.00	
Up to 1976	3.00	x
Up to 1990	1.00	
Recent	0.20	

Modifications: -0.40

Underpinned	0.20	
Major Rehabilitation	0.50	
Seismic Upgrade	1.00	x
None	0.00	

Extent of Damage: 0.50

Walls	4.00	
Columns	4.00	
Beams	4.00	
Cladding	2.00	
None	0.00	x

Total Structural Seismic Hazard Score

EQ Hazard Score = 8.22