UNCTAD National Workshop Saint Lucia

24 – 26 May 2017, Rodney Bay, Saint Lucia

"Climate Change Impacts and Adaptation for Coastal Transport Infrastructure in Caribbean SIDS"

Impacts of Natural Hazards on the Transport Infrastructure Sector

By

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St Lucia Workshop
May 2017

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Objectives

The main objectives of this presentation are:

A. To give an overview of the natural hazards that affect transport infrastructure in the Caribbean.
B. To summarize the most common impacts that occur as a result of these, notably hurricanes, earthquakes, extreme rainfall events, tsunami and climate change effects;
C. To provide guidelines relating to adaptation and recovery.

Overview of natural hazards affecting the Caribbean

What are the hazards that affect Caribbean infrastructure?

Hazards that can affect the region include:

- Volcanoes
- Earthquakes
- Landslides/Mudslides
- Tsunami
- Hurricanes (High Winds; Storm Surge; Extreme Rainfall)
- Floods (Land based)
- Anthropogenic/Technological (fire, hazardous spill, etc.)
- Climate Change Induced

Toll of Hazards and their Regional Distribution

Over 6,000 lives lost in the Caribbean over past 30 years due to natural disasters, plus 222,000 in the 2010 earthquake in Haiti.

Greater Antilles

(Cuba, Jamaica, Hispañola, Puerto Rico)

- Hurricanes
- Floods
- Earthquakes

Lesser Antilles

(St. Maarten to Trinidad)

- Hurricanes
- Volcanic Eruptions (Ash fallout)
- Earthquakes
- Tsunamis

Hurricanes in the Caribbean: Historical Account

Records of hurricane damage exist in the archives of the Caribbean for over five centuries;

Since approximately 1900, detailed hurricane records and characteristics have been maintained by the National Hurricane Center (NHC) and NOAA in Florida, USA.

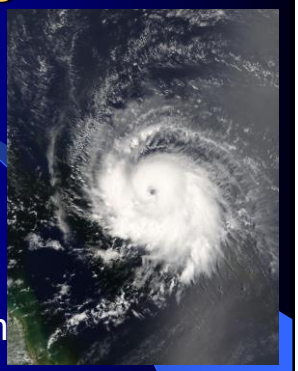
These records have improved in accuracy and detail since the 1950's, first with the ability of special reconnaissance aircraft to fly into the eye of these storms, and later, with the aid of satellite imagery.

Hurricanes in the Caribbean: Patterns

- The records over the past century show a wide band of hurricane activity across the Caribbean, with the least activity occurring in the area of Trinidad;
- In general, damage occurs from storm surge, waves, wind and rainfall, as all of the islands have vulnerable aspects to them;

Hurricanes in the Caribbean: Paths

Damage from Hurricanes



Occurs primarily from
- Hurricane waves;
- Shoreline erosion;
- Storm surge;
- Land based Flooding;
- High Winds

Hurricane Waves

- Deep water waves resulting from hurricanes can be very damaging. Estimates of extreme (i.e. design) wave heights made throughout the region show a gradient of risk:

Island	1 in 50 year Return period (m)	1 in 100 year (m)
Jamaica	7.6	8.6
Antigua	13.3	14.9
Grenada	8.1	9.6

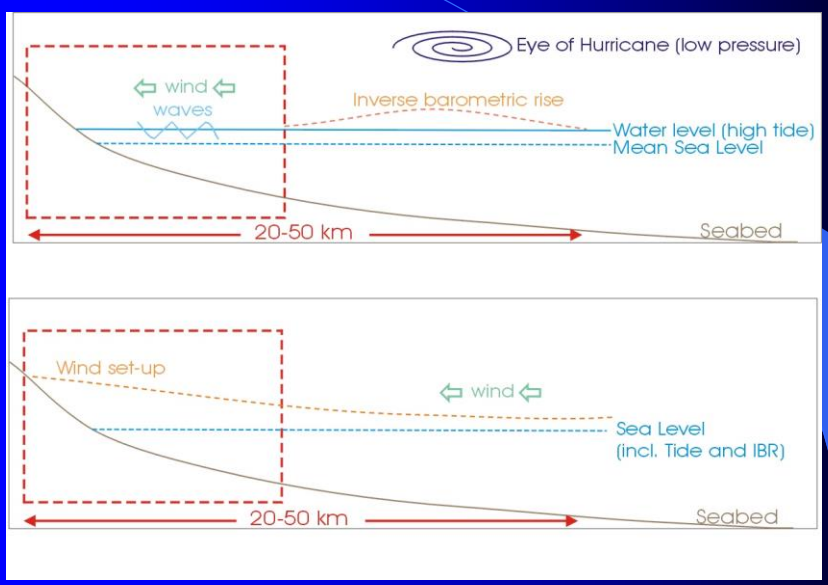
Port Zante, St. Kitts

Shoreline Erosion

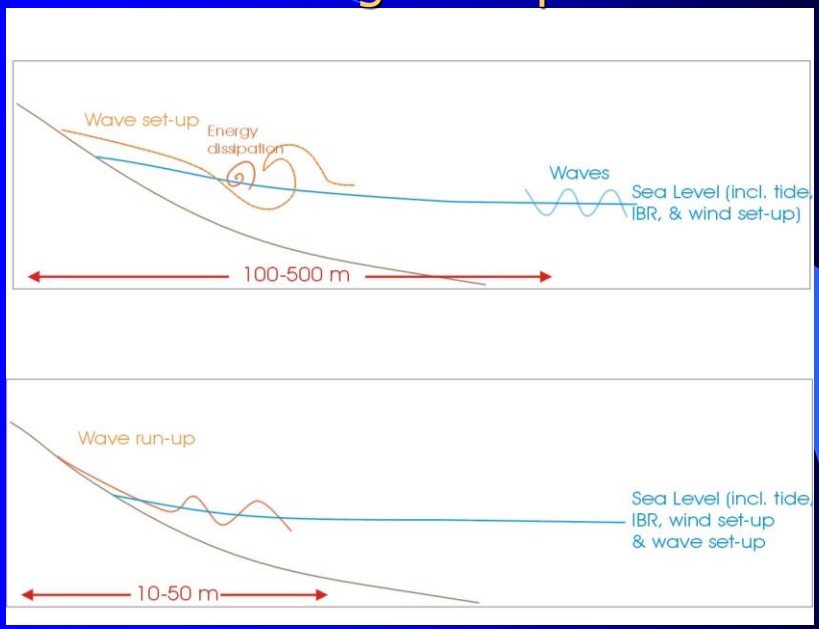
- Storm and swell events, can result in severe erosion of the beach and/or shoreline.

Negril, Jamaica – 1m/year erosion rate

Storm Surge Components



Storm Surge Components



Example of Storm Surge

High storm waves

Inundation of waterfront promenade, Dominica – Approx. 3m of Storm Surge, wav run up

Flooding in the Caribbean: Historical Account

- In the Lesser Antilles, flooding has been associated primarily with tropical waves and hurricanes;
- Flooding may take the form of excessive ponding, as occurred in Antigua during Hurricane Lenny, or flash flooding as can occur in the more hilly or mountainous islands such as Nevis and Dominica;
- In general, all of the islands and their communities are vulnerable to flooding and drainage systems and river training must be designed to take this into account.

Flooding in the Caribbean: Historical Account

- In St Lucia, river flooding has been exacerbated by debris in rivers, which block waterways and force rivers to forge new (often undesirable) pathways;
- Culverts and bridge openings should now be designed for more extreme events, in accordance with CC predictions.

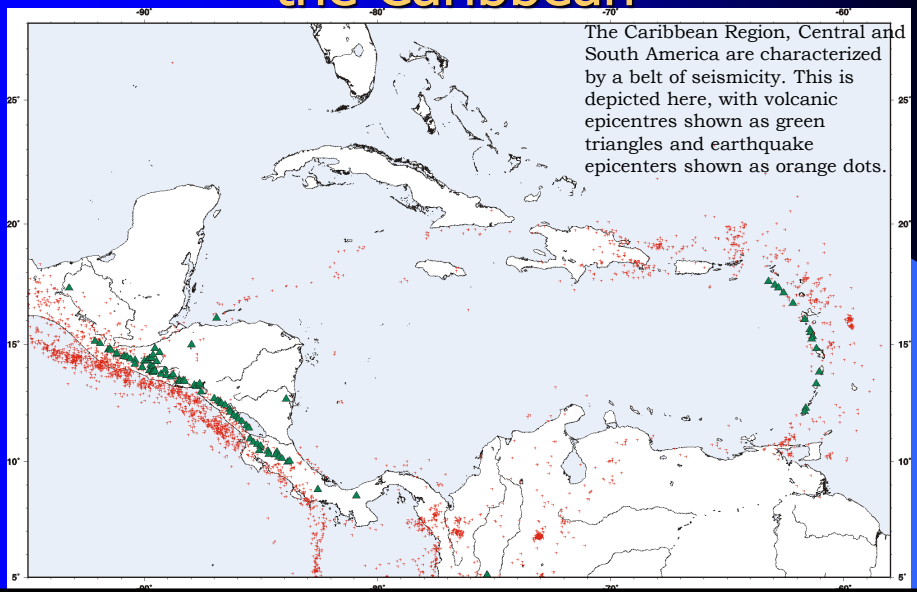
December 2013 Floods in St Lucia

Hewanerra Airport flooded during Christmas Eve 2013 trough

Hurricane Wind Speeds - The Saffir-Simpson Scale

STATUS	WINDS (km/hr)	WINDS (mph)	PRESSURE
Depression	<56	<35 mph	------
Tropical Storm	56-117	35-73 mph	------
Category 1	**118-152**	**74-95 mph**	**966 mb>**
Category 2	**153-176**	**96-110 mph**	**980-965 mb**
Category 3	**177-208**	**111-130 mph**	**964-945 mb**
Category 4	**209-248**	**131-155 mph**	**944-920 mb**
Category 5	**248 +**	**155 mph+**	**<920 mb**

Earthquakes and Volcanoes in the Caribbean



The Caribbean Region, Central and South America are characterized by a belt of seismicity. This is depicted here, with volcanic epicentres shown as green triangles and earthquake epicenters shown as orange dots.

Earthquakes in the Caribbean

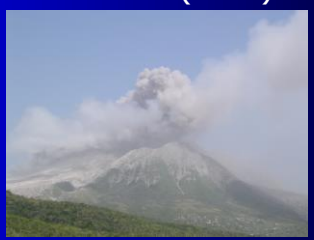
- Major Earthquakes
  - Jamaica (1692)
  - Trinidad (1766)
  - Antigua (1843)
  - Haiti (2010)
- Minor Events
  - St. Lucia (1953)
  - Trinidad (1954)
  - Antigua (1974)

Volcanoes:
A source of risk to property and life

Soufriere Hills, Montserrat

A significant Hazard in the Lesser Antilles

- Soufriere (1718, 812, 1902-3, 1979)
- Mt. Pelee (1902, 1929-32)
- Soufriere Hills (1997)

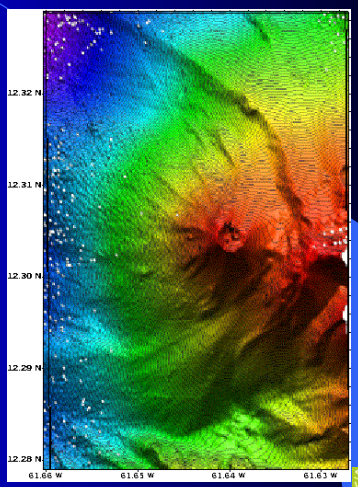


Volcanoes in the Caribbean: Historical Account

- 17 Volcanoes erupted in the Eastern Caribbean.
- 25 Volcanic Centres with the potential to erupt.
- Approx. 40,000 lives lost in 1902 eruptions (St. Vincent and Martinique).
- Warning time has ranged from 14 days to 14 years.
- The famous Port Royal disaster of 1692 was initially caused by an earthquake which liquefied an alluvial plane causing it to slide into the sea, the resulting tsunami was several metres in height and caused over 2000 deaths.

Tsunamis: another source of risk

- Caused by ocean centered earthquakes, volcanic eruptions, or plate movement.
- Some risk presently posed by "Kick 'em Jenny"



SeaBeam image of Kick 'em Jenny constructed from measurements taken from the NOAA Research Vessel Ronald H. Brown on March 12 2002.

Tsunamis in the Caribbean: Historical Account

Date	Location	Comment
1897-Nov-29	West Indies	Large tsunami at Montserrat
1907-Jan-14	Jamaica	Tsunami generated, main damage at Kingston
1918-Oct-11	Puerto Rico	Tsunami caused fatalities and damage at Point Borinquen and Aguadilla; also damage at Mayaguez
1946-Aug	Dominican Republic	Town of Matanzas badly damaged and abandoned; more than 100 persons killed; minor damage on coast of Haiti
1953-May-31	Dominican Republic	Very slight tsunami; amplitude 0.2 ft at Puerto Plata
1955-Jan-18	Venezuela	Tsunami caused damage at La Vela, Venezuela

Transport and related Infrastructure

Infrastructure sub-sectors include:

- Roads and Transport
- Sea Ports and Air Ports

Roads and Transport

- For the small island states of the Caribbean region, the network of coastal roads is a critical one.
- Roads connect main urban centres to rural fishing, agricultural or smaller communities.
- They serve as vital links between these communities.
- They facilitate routes for evacuation when needed.
- Roads also facilitate the distribution of services

North to Middle Caicos Causeway following TS Hanna and Hurricane Ike, 2008

Roads/Transport - Rehabilitation

- Reconstruct to revised minimum standards to include CC projections;
- Allow for retaining walls; coastal revetments; drainage structures, etc.
- Allow for debris clearance (e.g. as happened in Cayman after Hurricane Ivan in 2004)

Sea Ports and Airports

Port Zante, St. Kitts following Hurricane Lenny, 1999

Airplane hanger, Grand Turk, following Hurricane Ike, 2008

Sea Ports and Airports - Damage

Physical damage can include;

- Damage to specific equipment – e.g. perimeter fencing; terminal buildings;
- Damage to aircraft and boats;
- Damage to physical plant – air conditioners; desalination plants; landing and/or navigation equipment; runway damage; warehouse or dock damage;

Summary of **loss** of income:

- Landing charges; berthing and demurrage rates; departure tax; duty free sales.

Sea Ports and Airports Examples

Reconstruction Suggestions

- Proper appreciation of **mechanisms** of damage
- Adoption of an acceptable level of **risk** for national infrastructure
- Adoption of techniques or design methods to reduce vulnerability (e.g. assessing WL)
- Use of "Best Value" engineering or rehabilitation techniques to reduce long-term vulnerability

Reconstruction Suggestions

For Design Water Surface Elevations (WSE) for example, we should consider:

- MSL
- Tide amplitude
- Thermal expansion (July – Nov)
- Climate change (GSLR)
- Storm surge (including wave set-up)
- Wave run-up (dynamic component)