STORM SURGE TOOLKIT

FOR

TOWNSHIP PLANNING STRATEGIES:

ADAPTATION FOR CLIMATE CHANGE AND DISASTER MITIGATION

IN THE CARIBBEAN

2007

CDERA
The Caribbean Disaster Emergency Response Agency
Managing Disasters with Preparedness

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Prepared for the

Inter-American Development Bank and

The Caribbean Disaster Emergency Response Agency

Running Title: ADAPTATION FOR CLIMATE CHANGE AND DISASTER MITIGATION: TECHNICAL INFORMATION PACKAGE: **STORM SURGE TOOLKIT**

Preface

The Caribbean is one of the most hazard prone regions in the world and the impact of these hazards has been felt to varying degrees on livelihoods, infrastructure, social assets and economies in each of the CDERA member states. The vulnerability of coastal communities to global climate change is of particular concern to the small islands as well as the low lying states of the Caribbean. Climate change predictions indicate rising sea levels, increasingly extreme (erratic) weather patterns and increasing intensity of storms and hurricanes. Identification of the hazard impacts associated with this phenomenon, has led to initiatives aimed at assisting Caribbean countries with the development of adaptation strategies to deal with climate change.

CDERA as the CARICOM focal point for disaster management, is charged with the mandate to assist member states to manage all aspects of the disaster cycle, with the objective of reducing loss and dislocation. Risk management is the approach that is being applied. Risk identification forms the basis on which to implement planning for prevention and mitigation, preparedness and response, and recovery and rehabilitation. Other aspects of risk management, such as risk reduction and transfer, as well as legal, institutional and operational issues, together with awareness, have all been employed in the designing of this toolkit.
CDERA, in collaboration with regional institutions and development partners, is supporting efforts to mitigate the risks and strengthen regional and national capacity for adaptation to the climate change phenomenon.
The Adaptation for Climate Change and Disaster Mitigation: Township Planning Strategies for Storm Surge in the Caribbean Project, funded by The Inter-American Development Bank (IDB), and executed by CDERA, in collaboration with the Mainstreaming Adaptation to Climate Change (MACC) Project of the Caribbean Community Climate Change Center (CCCCC), and the Caribbean Institute of Meteorology and Hydrology (CIMH), has supported the development of capacity and methodologies for incorporating risk analysis into the long-term township development strategies.

The **"toolkit"** is a technical information package based on the findings of a pilot study of the storm surge risk in two townships of the Caribbean - Portmore Municipality, Jamaica, and St Peter in Barbados, which was commissioned by the Inter American Development Bank in February 2006. It addresses four thematic areas:

- Risk assessments through: (i) hazard maps; (ii) vulnerability assessments, and; (iii) risk assessments as a function of hazard and vulnerability, and their validation through review panels.
- Institutional issues, such as criteria for the analysis of the adequacy of: (i) the legal and organization framework; (ii) land use regulations, and; (iii) monitoring and forecasting.
- Awareness raising and improved preparedness through: (i) communication systems; (ii) early warning contingency planning, and; (iii) shelters.
- Potential prevention and mitigation measures, such as (i) structural mitigation works; (ii) land use planning and building codes, and; (iii) cost effective use of economic incentives.

The **toolkit** is intended to assist town planners, emergency managers, community leaders, and risk transfer providers in enhancing their disaster risk management capabilities as related to their respective areas of responsibility.

It is expected that this **Toolkit** will make a significant contribution to the understanding and practice of disaster risk management in the Region.

Acknowledgements

The Caribbean Disaster Emergency Response Agency is deeply grateful to the consulting team of Smith Warner International in partnership with Environmental Solutions Limited who led the process in developing the Storm Surge Toolkit for Township Planning Strategies: Adaptation to Climate Change and Disaster Mitigation in the Caribbean.

This Toolkit has benefited from the insights and professional guidance of the CDERA Project Steering Committee whose members represented the Barbados Coastal Zone Management Unit, The Portmore Municipal Council, The Caribbean Institute of Meteorology and Hydrology, Office of Disaster Preparedness and Emergency Management (ODPEM), Jamaica, The Barbados Department of Emergency Management, the Caribbean Community Climate Change Centre and the Centre for Resource Management and Environmental Studies (CERMES) of the University of the West Indies, Cave Hill Campus.

CDERA also acknowledges especially the inputs of the two National Steering Committees of the pilot states of Barbados and Jamaica – The Coastal Standing Committee in Barbados and the National Damage Assessment, Relocation and Rehabilitation sub-committee of The National Disaster Committee in Jamaica. Further, technical support provided by the CDERA project staff of the Adaptation for Climate Change and Disaster Mitigation: Township Planning Strategies for Storm Surge in the Caribbean project is also acknowledged. In addition, support provided by Mona Geoinformatics at the University of the West Indies (UWI) and the Barbados Statistical Department is acknowledged.

The contributions of the residents of the study areas, representatives of professional groups, business organizations, community groups, and civil society who participated in the regional Toolkit Validation workshop and the two national workshops are greatly appreciated, for their detailed review of the toolkit and useful and informative comments.

CDERA also expresses its appreciation to the Inter-American Development Bank for technical and financial support provided for the production of the Toolkit.

Glossary

Awareness Raising - Processes of informing the general population, increasing levels of consciousness about risks and how people can act to reduce their *exposure to hazards (ISDR, 2004).*

Critical Facilities - Facilities vital to the health, safety and welfare of the population and that are especially important following a hazardous event. Critical facilities include, but are not limited to, shelters, police and fire stations, hospitals, schools and critical roads and bridges". (NOAA, 1999).

Governance - "The act of affecting government and monitoring (through policy), the long-term strategy and direction of an organization. In general, governance comprises the traditions, institutions and processes that determine how power is exercised, how citizens are given a voice, and how decisions are made on issues of public concern"(www.phac-aspc.gc.ca/vs-sb/voluntarysector/glossary.html). Governance in the context of disaster risk management considers especially the strength of institutional framework.

Hurricane - This is a large rotating cyclonic system centered around an area of very low pressure, with strong winds increasing from a minimum in the "eye" of the system to a maximum typically 10-20 miles from the centre, blowing at an average speed in excess of 72 miles per hour. The whole storm system may be five to six miles high and 300 to 400 miles wide. These systems have a counter-clockwise wind rotation in the northern hemisphere. Further, they move forward at speeds of up to 30 miles per hour.

Mitigation - "Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards" (ISDR, 2004).

Preparedness - Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations (ISDR, 2004).

Return Period - Estimate of the likelihood of events such as earthquakes, floods or hurricanes of a certain intensity or size. It is a statistical measurement denoting the average recurrence interval over an extended period of time. It is usually required for risk analysis and also to dimension structures so that they are capable of withstanding an event of a certain return period (with its associated intensity).

Risk - 'The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions" (ISDR, 2004).

Risk Assessment and Analysis - A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend." (ISDR, 2004).

Storm Surge - The elevated water levels that accompany **hurricane storms,** creating flooding, and causing damage to coastal infrastructure is known as **storm surge**. Storm surge has several components, including water that is pushed toward the shore by the force of the storm winds; increase in water levels under the "eye" of the storm caused by the low pressure at the location; and other storm wave related occurrences.

Vulnerability - is "The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" (ISDR, 2004).

Vulnerability - is "the susceptibility of resources to negative impacts from hazard events" (NOAA, 1999).

Guide to Colour Coding

Throughout the document, the information provided has been highlighted in different colours. Following is the legend with the colours corresponding to each type of information.

- Information related to User Group A
- Information related to User Group B
- Information related to User Group C
- Information related to User Group D
- Key Words
- Definition
- Information Related
- Summary Points
- Case Studies
- Helpful Hints
- Methodology

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1. Introduction

This document presents a toolkit with criteria and guidelines for sound storm surge risk management in the Caribbean. It is intended to assist with the development of adaptation strategies and the building of capacity needed to manage the impact of severe weather events that are anticipated to occur in association with climate change. The themes addressed are as follows:

***Risk Assessment* – This** is germane to risk management, as it incorporates risk identification, reduction and transfer. Identification involves determination of hazard characteristics, vulnerability assessment and risk analysis. Measures to reduce exposure and vulnerability are assessed for 'reduction'. Risk transfer incorporates insurance, contingency funds and other instruments to reduce cost to the affected parties.

Institutional Issues* – *Effective risk management requires appropriate institutional and governance structures to facilitate mainstreaming and holistic approaches.

Awareness Raising and Improved Preparedness- Management of the storm surge hazard is particularly important for coastal areas, which are within the storm surge zone and tend to be highly populated within the Caribbean. Risk communication, crisis communication, early warning systems, contingency planning, evacuation planning and emergency shelter strategies are some of the critical components in the management of this hazard.

***Prevention and Mitigation Measures* – These** include structural and non- structural activities to reduce the impact of the hazard. These measures are informed by the findings of the hazard analysis and vulnerability assessment.

Figure 1. Hellshire Fishing Village, Portmore, Jamaica. One day after the passage of Hurricane Dean (August 2007)

This document constitutes the second major component of the Consultants' mandate, as part of the IDB funded Project *'Adaptation to Climate Change and Disaster Mitigation: Township Planning Strategies for Storm Surge in the Caribbean'.* The first component included the preparation of storm surge risk assessments of two pilot areas within the Caribbean region, and the development of proposals for actions in prevention, preparedness and mitigation measures to the storm surge risk. The second component focuses on the development of a technical information kit for the Caribbean, building on the findings of Component I as well as other relevant studies and experiences.

2. The Process

Jamaica and Barbados were selected as pilot cases in the first phase of the project, and storm surge was selected as the specific hazard to be investigated and mapped. Four types of user groups were identified as potential beneficiaries of the toolkit: (i) town planners, (ii) emergency managers, (iii) community groups, and (iv) private sector providers of risk transfer services. Four thematic areas were highlighted for the development of guidelines: risk assessments; institutional issues, awareness raising and improved preparedness; and potential prevention and mitigation measures.

The focus of the technical information package has therefore been on the development of capacity and methodology for:

1. Incorporating risk analysis into the long-term development strategies employed by town planners and emergency managers, considering Adaptation for Climate Change and Disaster Mitigation for Township Planning (allied professionals such as engineers, architects and environmental professionals will need to be included in this group);
2. Enhancing preparedness and response for emergency managers and community groups;
3. Carrying out hazard and vulnerability assessments for community groups, emergency managers, and risk transfer providers;
4. Incorporating risk analysis into risk transfer mechanisms.

The toolkit utilizes the approaches and findings from the Risk Assessment Studies undertaken for the pilot areas of Portmore Municipality, Kingston, Jamaica, and St Peter, Barbados. In addition, empirical data from other risk assessment and risk reduction work carried out in the region and elsewhere, has been drawn on, as well as disaster risk management initiatives taken within CDERA and its member territories.

Consultations with practitioners, community groups and other relevant stakeholders have helped to inform the content and presentation of the document.

2.1. Why the Toolkit?

The Toolkit constitutes a technical information package that is designed to assist development professionals in the Caribbean, identify and reduce risk from the storm surge hazard to which so many Caribbean territories are exposed. It suggests adaptation strategies based on the findings from pilot studies in Jamaica and Barbados, and from experiences gained elsewhere.

The Caribbean region lies squarely within the area of tropical meteorological systems, and is therefore exposed to extreme weather events such as hurricanes and floods. Many settlements, key infrastructure, and economic enterprise are located within the coastal zone, as most of the islands have limited geographical space and therefore limited options for settlement and land use in a remote interior.

Inappropriate land use practices and increasing urbanization, together with inadequate planning and poor enforcement of regulations, have served to exacerbate the impact of natural hazards on the region. These circumstances have influenced and magnified the effects of such events.

The fourth report of the Intergovernmental Panel on Climate Change (IPCC), indicates that climate change is occurring more rapidly than previously forecast. Erratic and variable patterns of weather and climate phenomena, have been contributing to major hurricanes, storms, drought and other severe hydro-meteorological events over the past ten to twenty years. Global warming has influenced sea surface temperatures and sea level rise, and will continue to exacerbate the effects of these already seemingly discordant patterns.

It is therefore imperative that the capacity for disaster risk management be enhanced among professionals, institutions and community groups that are engaged in development and disaster management.

2.2. What is the Toolkit – Concept and Content

The Toolkit is being presented as a practical instructional tool to specifically assist town planners, emergency managers, community groups and private sector providers of risk transfer services to manage storm surge risk.

The four main themes addressed in this Toolkit are as follows:

1. **Risk Assessment** incorporates risk identification and vulnerability assessment - The ***Risk Identification*** methodology for this assignment, included identification and analysis of the storm surge hazard through computer modeling. Surge inundation zones have been defined from the modeling exercises for the two pilot areas and these have been presented in GIS format.

The toolkit outlines the steps involved in the identification and analysis of the storm surge hazard, paying attention to hurricane conditions which generate surge, as well as to those characteristics of the coastal zone which enhance surge producing conditions.

The model used has been described and its use justified in terms of other models being used in the region for the prediction of storm surge. It is anticipated that user groups will either commission or use existing storm surge maps in their respective areas. Although most persons are not expected to generate the maps themselves, it is important to understand the relevant principles and methodology applied in the identification and analysis of the storm surge hazard.

Vulnerability Assessment - This constitutes the second step of the risk assessment methodology. Socio-economic parameters including demographics, settlement characteristics, livelihoods, transportation routes, places of employment, general land use, identification of critical facilities, and economic enterprise should all be mapped and overlain with the predicted surge hazard zones. This approach will help to identify the population, critical facilities, economic centres, and communities that are vulnerable to storm surge inundation, thereby contributing to **risk reduction.**

The Vulnerability Assessment Tool (VAT) developed by NOAA has been used with some adaptations, in this study. The VAT methodology is therefore presented for application by the relevant user groups in each territory within the region.

The relationship between vulnerable areas and the storm surge hazard will facilitate **estimation of the storm surge hazard risk**. Procedures for estimating the cost of possible damage and loss are also presented.

The Toolkit outlines the approach employed in the pilot studies paying particular attention to the need to be ***"place- specific"*** in the application. Data sources, field investigations, mapping methodologies, and source document reviews, are all included in the recommended approach, and the need for participatory data collection is emphasized.

The approach taken in the preparation of this Toolkit has been to customize the modeling of storm surge for Caribbean shorelines. It is considered important that the methodology and model used be rested in an appropriate regional institution. The Caribbean Institute for Meteorology and Hydrology (CIMH) has been identified as a key player in this regard.

2. **Institutional Issues** - Risk management requires that appropriate institutional and governance structures be in place. The Toolkit therefore demonstrates, through findings from the pilot study, the types of organizational arrangements, and effective approaches that are necessary for achieving sound management for disaster reduction. Also illustrated are the gaps that typically exist in such arrangements. Legal and institutional framework, early warning systems, land use regulations (zoning and enforcement), and monitoring, have been included.

   The issue of governance has been given particular emphasis, and the CARICOM Regional Framework 2005-2015 has been referenced in this regard.

3. **Awareness Raising and Improved Preparedness** - Proposals for improved prevention, mitigation, preparedness, response, and recovery

programming have been used to inform this aspect of the Toolkit. An emphasis on building community resilience, as stipulated in the ***Hyogo Framework for Action,*** has guided this component. Risk and Crisis communication procedures, early warning systems, contingency planning, including evacuation planning and "Home as shelter" programs, are highlighted.

4. **Prevention and Mitigation Measures** - These include (i) structural mitigation works, (ii) land use planning and building codes, and (iii) cost effective use of economic incentives, are all considered. The Toolkit therefore seeks to balance idealized expectations with the realities pertaining in Small Island Developing states, particularly as this relates to available land and cultural norms and customs in the small land areas of the Caribbean.

A highly participatory approach has therefore been employed in the development and finalization of the Toolkit. The main partner in this exercise has been CDERA, but also included are all the relevant stakeholders in the private sector, national and local authorities and civil society, who also contributed to the study.

The toolkit includes recommended approaches for data gathering on hazard risk and vulnerability assessment, behaviour modification at the level of professionals, policy-makers and practitioners and includes case studies on each aspect of risk management.

The risk management framework as developed by the IDB, the Caribbean Comprehensive Disaster Management Framework, and national strategies have all been applied as guidance documents for this exercise.

Finally, the Toolkit as developed under Component II, has been subjected to a validation process, facilitated through the delivery of a regional workshop (see Final Consultation Report – Regional Validation Workshop).

3. The Toolkit – Organization and Use

3.1. Toolkit Organization

The Toolkit presents methodologies for the evolution of the four main themes introduced in Sections 1 and 2. These themes are considered essential to disaster risk management and reduction and are summarized following.

- ***Risk Assessment***

The first section of the Toolkit addresses the steps and methodology to be followed in the preparation of a Risk Assessment:

- Identification and analysis of the hazard;
- Assessment of the levels of exposure of natural and socio-economic resources (vulnerability assessment); and
- Evaluation of potential cost of damage and loss (risk assessment).

- ***Institutional Issues***

This section deals with the institutional and governance structures required for risk management. Considerations include:

- Resource capacity;
- Policy, legislation, regulations and enforcement mechanisms regarding land use, zoning and building codes;
- Evacuation;
- Institutional and organizational arrangements within and among public, private and civil sectors, for national disaster risk management; and
- Mainstreaming policy and procedures for prevention, preparedness, mitigation, and recovery.

- ***Awareness Raising and Improved Preparedness***

Proposals for improved prevention, mitigation, preparedness, response, and recovery programming are used to inform this aspect of the Toolkit. An emphasis on building community resilience requires citizens to have a heightened awareness of the hazard and their respective vulnerabilities, as well as a good sense of the steps to take before, during and after an event in order to minimize loss and dislocation. This section presents and discusses risk and crisis communication procedures, early warning systems, contingency planning, evacuation planning and emergency shelter strategies, including the "Home as shelter" program from the CDERA shelter policy.

- ***Prevention and Mitigation Measures***

The final section of the Toolkit recommends guidelines and criteria for loss reduction through prevention and mitigation. Structural and non-structural approaches are suggested and the importance of knowledge of site specific conditions is emphasized. Community–based approaches are recommended to enhance community "buy-in" and to build community capacity and resilience.

Any considerations of prevention and mitigation in the Caribbean must include climate change adaptation planning. This is particularly relevant given the vulnerability of the region's states to sea level rise combined with variable and volatile climatic conditions.

3.2. How to Use the Toolkit

The Toolkit, as a "technical information package", provides background material which is applicable to all persons involved with disaster risk management.

The Toolkit tailors information towards four types of users, which is a requirement in keeping with the Project Terms of Reference.

- **USER GROUP A:** Town planners, as well as allied professionals such as Environmental Professionals, Engineers and Architects.
- **USER GROUP B:** Emergency managers.
- **USER GROUP C:** Community Emergency Leaders/Committees.
- **USER GROUP D:** Private Sector Providers of Risk Transfer Services.

Since each user group has its own specific requirements (see Section 3.3), the Toolkit is therefore designed to enable each group to access the guidelines and information most relevant to their needs.

This section is intended to assist each user to access general information relevant to their respective responsibility. The Flow Charts presented following, summarizes this information into the four main sections of the Toolkit: Risk Assessment, Governance; Awareness Raising and Improved Preparedness; and Prevention and Mitigation.

Information relevant to each of the user groups may be accessed using the following key:

- A: User Group A
- B: User Group B
- C: User Group C
- D: User Group D

In the following section, the functions, roles, detailed recommended tasks, as well as information needed for each of the four users within the Disaster Management Process, are presented.

RISK ASSESSMENT

ACTION	SUMMARIZED METHODOLOGY	USER GROUP	TOOLKIT SECTION
1. Undertake/ commission Storm Surge Hazard Mapping	1. Undertake Hazard Analysis. 2. Consult with community residents. 3. Use results to prepare storm surge maps.	A/D A/B A	SECTION 4
2. Conduct Vulnerability/ Risk Assessment	1. Use Maps to identify Inundation zones. 2. Obtain and utilize guidelines for Vulnerability Assessment. 3. Produce Vulnerability Maps. 4. Utilise guidelines for usage of Vulnerability Maps. 5. Utilise guidelines and conduct a Risk Assessment.	A/ B/ C/ D A/ B/ C/ D A A/ B/ C/ D A/ B/ C/ D	SECTION 4
3. Use Risk Assessment	1. Integrate results into long-term development. plans, engineering and architectural designs, and environmental assessments. 2. Use results to enhance national and community disaster plans. 3. Use risk assessment for enhancing insurance risk profile.	A/ B/ D	SECTION 5, 6, 7

INSTITUTIONAL ISSUES

ACTION	SUMMARIZED METHODOLOGY	USER GROUP	TOOLKIT SECTION
1. Assess the Legal, Regulatory and Policy Framework	1. Assessment of legislation in relation to: • Built environment, • Natural environment, • Regional Considerations, • International Legislation and Treaty Obligations and • Global Disaster Risk Reduction Initiatives. 2. Examination of the use and adequacy of the legislation and effectiveness of their implementation.	A/ D A/ B/ D	SECTION 5
2. Assess the Institutional and Management Arrangements	1. Assess management and operational structures. 2. Assess Early Warning Systems. 3. Assess Awareness Raising and Communication Systems.	A/ B/ C/ D B B	SECTION 5
3. Assess appropriateness of operational and Management Plans and Procedures	1. Assess Early Warning Systems. 2. Assess Awareness Raising and Communication Systems.	B/C B/C	SECTION 5

AWARENESS RAISING AND IMPROVED PREPAREDNESS

ACTION	SUMMARIZED METHODOLOGY	USER GROUP	TOOLKIT SECTION
1. Determine Approaches to improving awareness of storm surge vulnerability	1. Identify target Audience. 2. Develop appropriate message. 3. Determine media for communication.	B/C	SECTION 6
2. Develop an appropriate communication strategy and program for Crisis communication, EWS, Evacuation Planning, etc.	1. Establish linkages with all relevant agencies. 2. Enhance emergency communication systems – equipment, Standard Operating Procedures, etc .	B/C B B	SECTION 6
3. Establish Emergency Operating Centre and Procedures	1. Obtain appropriate space and rationalize procurement of equipment. 2. Follow provisions of National Disaster Plan and relevant sub-plans.	B/C	SECTION 6

PREVENTION AND MITIGATION MEASURES

ACTION	SUMMARIZED METHODOLOGY	USER GROUP	TOOLKIT SECTION
1. Identify non-structural opportunities to reduce impacts from the hazard	1. Enforcement of: • Land use regulations; and • Building Codes. 2. Identification of • Economic Incentives.	A	SECTION 7
2. Identify structural opportunities to reduce impacts from the hazard	1. Assessment of existing protective structures. 2. Assessment of drainage system. 3. Undertake 5 yearly structural condition surveys. 4. Identify appropriate soft mitigation measures. 5. Identify appropriate hard mitigation measures.	A	SECTION 7

3.3. Toolkit Users – Target Audience

As presented in the previous section, the Toolkit tailors information towards four types of users:

- USER GROUP A: Town planners, as well as allied professionals such as Environmental Professionals, Engineers and Architects.
- USER GROUP B: Emergency managers.
- USER GROUP C: Community Emergency Leaders/Committees .
- USER GROUP D: Private Sector Providers of Risk Transfer Services.

This section provides an overview of the main functions and roles, as well as the critical information that will be required by each group of users in the Disaster Management Process. Additionally, a set of tables lists tasks that would typically be carried out in the undertaking of a risk and vulnerability assessment, by persons from each group of users, the section in the Toolkit where specific and relevant information may be found, and general comments where applicable. The tables are colour coded for easy understanding of each group's task, as follows: User Group A – blue; User Group B – green; User Group C – Orange; User Group D – purple. These colours are also used throughout the Toolkit, when referring to these users.

3.3.1. Town Planners

Function

- Town and regional planning involves making both long and short-term decisions about the management and development of settlements and urban centres.
- Town Planners and allied professionals are responsible for determining and enforcing the most appropriate use of land for development and for enforcing the relevant zoning and development regulations. Town planners therefore need to work in collaboration with allied professionals such as environmental professionals, engineers and architects, land surveyors and master builders.
- Town planners need to take into account the views of a wide range of people, hence consulting and interacting with interest groups and key stakeholders, should be regarded as an integral part of their mandate.
- Consult with interested parties and negotiating development proposals with local authorities and others, including liaising with other professionals.
- Assess planning applications, enforcing and monitoring regulations as necessary.
- Draft policies.
- Interact with the public, which may often comprise of varied groups of people, with widely varying interests, through the presentation of proposals at public meetings or planning committees.

Role in Disaster Management

Planning professionals need to incorporate disaster risk management into long-term development plans. Such integration involves properly understanding the hazards to which the development area is exposed, the characteristics of the site and the situations that will influence vulnerability to loss from the identified hazards. It also requires the making of recommendations for mitigation and prevention measures in order to prevent loss of life, and damage to livelihoods, social structures, environmental resources, and economic assets.

Information Needed

- Hazard maps – National scale; storm surge inundation zones, coastal flood plain, and drainage channels in the coastal zone;
- Vulnerability Assessment – demographics, economic activity, critical facilities, transportation routes, settlement characteristics, ecological assets;
- Cultural heritage assets and sites;
- Risk assessment;
- Legal Framework;
- Institutional and Organizational Framework.

GROUP A - TOWN PLANNERS: Some recommended Tasks		**Toolkit Reference**
IDENTIFYING THE HAZARD	▪ Identify areas which may be prone to flooding. ▪ Consult coastal topographic maps. ▪ Compile reports on historical records. ▪ Use GIS to superimpose storm surge information on topographic maps. ▪ If GIS capability is not available seek collaboration to map storm surge hazard. ▪ Review floodplains and estuaries with respect to storm surge interface. ▪ Ascertain estimates of sea level rise. ▪ Seek collaboration to model storm surge risk for respective island.	Sections 4.1, 4.1.1, 4.1.2, 4.2, 4.4 and Annex I
ASSESSING VULNERABILITY	▪ Review settlement patterns and population characteristics. ▪ Examine land use patterns. ▪ Identify and locate critical facilities – shelters, health facilities, etc. ▪ Assess accessibility, vulnerability of structure, flood risk, and suitability re amenities, facilities. ▪ Review economic activity and livelihoods. ▪ Identify and assess ecological assets.	Section 4.5
DETERMINING RISK	▪ Superimpose vulnerability factors and inundation zones. ▪ Calculate value of potential loss. ▪ Review economic implication of storm surge risk. ▪ Examine catastrophic risk insurance and implication for planning.	Section 4.3 Section 4.3 Section 4.4 Section 4.4

	GROUP A - TOWN PLANNERS: Some recommended Tasks	**Toolkit Reference**
INSTITUTIONAL ASSESSMENT	▪ Review relevant legislation.	Section 5
	▪ Review status of hazard mitigation and the development planning process.	Section 7
MITIGATION OPPORTUNITIES	▪ Review building codes - adapt as necessary and appropriate to take account of sea level rise, increased intensity of hurricane and associated storm surge and waves.	Section 7
	▪ Determine mitigation measures - set back, elevation of buildings.	Section 7
	▪ Integrate hazard information into development plans.	Section 7
	▪ Recommend siting for coastal protection works - structural and non-structural.	Section 7
	▪ Determine optimal location for housing developments. Recommend mitigation for existing vulnerable locations.	Section 7
	▪ Determine vulnerability of fishing villages- recommend mitigation measures for loss reduction.	Section 4.3, Section 7
	▪ Identify standards for resort developments (set backs, step-up's, etc.).	Section 7
	▪ Forge institutional linkages with UWI, UTech, CIMH, etc. community colleges.	Section 5
	▪ Forge professional linkages with engineers and architects so as to better integrate hazard vulnerability into the design and construction process.	Section 5, Section 7

3.3.2. Emergency Managers

Function

- Provide leadership in preparedness and response to extraordinary conditions which create emergencies.

Role in Disaster Management

- Generate and garner information necessary to inform national and community disaster management plans.
- Recruit technical and support persons to facilitate preparedness and response functions.
- Document events and create an archive of historical extreme occurrences.
- Coordinate teams to deliver required services.
- Liaise with multi-stakeholder groups – private, public, civil sectors.
- Integrate storm surge risk into national disaster plans.

Information Needed

- Hazard Maps – National Scale
- Vulnerability Assessment
- Legal and Institutional Framework
- National and Community profiles
- Disaster Management Plan

GROUP B - EMERGENCY MANAGERS: Some Recommended Tasks		**Toolkit Reference**
IDENTIFYING THE HAZARD	▪ Obtain and review storm surge hazard and vulnerability maps – inundation zones and vulnerable populations and livelihoods. ▪ Seek support for preparation of maps if none exist for island or specific community. ▪ Review historical records. ▪ Document incidents based on review of documents and community consultation (anecdotal).	Section 4.1.1, 4.3 Section 4.1, 4.1.1
INSTITUTIONAL ISSUES	▪ Determine adequacy of staff complement and organizational structure in National Disaster Office, and community linkages to handle storm surge emergencies before, during and after an event. ▪ Assess adequacy of the Early Warning System (EWS). ▪ Evaluate adequacy of Emergency Operations Centre – location, communications equipment and systems, supplies.	Section 5 Section 6 Section 6

	GROUP B - EMERGENCY MANAGERS: Some Recommended Tasks	**Toolkit Reference**
AWARENESS RAISING AND IMPROVED PREPAREDNESS	▪ Enhance understanding of hurricane characteristics, tracks, and implication for storm surge impact on coast.	Section 6
	▪ Build awareness through local planning and professional associations.	Section 6
	▪ Develop an Early Warning System.	Section 6
	▪ Establish and equip Emergency Operations Centre.	Section 6
	▪ Develop evacuation plans in collaboration with community organizations, planners.	
	▪ Develop transport and strengthen links with forecasting.	Section 6
	▪ Develop/Strengthen network of emergency response agencies and develop response network.	Section 6
	▪ Develop /review shelter policy in context of storm surge hazard predictions.	Section 6
	▪ Conduct/Review vulnerability assessments of shelters.	Section 4.5
	▪ Collaborate with allied Ministries (e.g. Works) and professional organizations to implement prevention and mitigation works to reduce exposure - structural and non-structural measures.	Section 4.5
	▪ Develop/enhance collaboration with environmental agencies for protection of natural coastal resources.	Section 7
	▪ Design and deliver awareness programs regarding hurricanes, sea level rise, storm surge risk.	Section 6
	▪ Work with water resources and supply agencies to secure supply from storm surge inundation and saline intrusion.	Section 6
	▪ Develop contingency plans as appropriate for critical facilities.	Section 6
	▪ Strengthen response mechanisms.	Section 6
	▪ Develop training programs for risk awareness in key agencies of public, private and civil sectors.	Section 6

3.3.3. Community Emergency Leaders and Committees

Function

- To serve the interests of citizens through stakeholder organizations.

Role in Disaster Management

- Heighten awareness and understanding of hazard vulnerability within communities.
- Facilitate the building of capacity of citizens and community organizations to prepare for and respond to emergencies.
- Utilise experience and social systems to build coping mechanisms – resilience building.

Information Needed

- Hazard maps – detailed community scale
- Early Warning Procedures
- Disaster Management Plan – community level
- Evacuation Plan - Community Level
- Shelter Program - In community

GROUP C - COMMUNITY EMERGENCY LEADERS/COMMITTEES: Some Recommended Tasks		**Toolkit reference**
IDENTIFYING THE HAZARD	▪ Work with National Disaster Management Office to identify hazard exposure, vulnerability and risk at community level. ▪ Record storm surge (wave) height and flood limits inland.	Section 6 Section 6
UNDERSTANDING VULNERABILITY	▪ Train community leaders to identify vulnerability. ▪ Evaluate location of water supply sources and works for households. ▪ Evaluate vulnerability of critical facilities, (e.g. shelter, health, transport) in terms of location.	Section 4.5
RAISING AWARENESS AND DEVELOPING PREPAREDNESS MEASURES	▪ Obtain hazard maps and sensitize community to storm surge exposure. ▪ Actively participate in development and implementation of Early Warning System and Evacuation Planning. ▪ Disseminate information on shelter location and procedures for access. ▪ Train community leaders to assist with shelter management.	Section 6

	GROUP C - COMMUNITY EMERGENCY LEADERS/COMMITTEES: Some Recommended Tasks	**Toolkit reference**
PREVENTION AND MITIGATION MEASURES	▪ Collaboration with emergency managers and professionals to implement vulnerability reduction measures for critical facilities.	Section 6
	▪ Evaluate location of sanitation systems - implement measures to reduce problem of wash out from storm waves.	Section 4.3
	▪ Collaborate and cooperate with national disaster management agencies to reduce exposure to loss.	Section 6
	▪ Train community leaders to implement measures to reduce vulnerability.	Section 6

3.3.3.1.

Function

- Strategic consulting for underwriting environmental insurance programs;
- Environmental risk analysis and cost estimating;
- Regulatory analysis and negotiation;
- Risk financing optimization and decision analysis;
- Program management; and
- Contractor selection and project management.

Role in Disaster Management

- Promote prevention and mitigation through incentives and awareness programs;
- Use hazard vulnerability and risk information to cost underwriting risk more accurately; and
- Promote loss reduction.

Information Needed

- Hazard Maps – National and Regional scales
- Risk Analysis – National Scale
- Community profile – National scale
- Legal Framework

GROUP D - PRIVATE SECTOR PROVIDERS OF RISK TRANSFER SERVICES: Some Recommended Tasks	**Toolkit reference**
▪ Support development of hazard risk maps. ▪ Develop zonation of insurance risk based on hazard risk. ▪ Collaborate with Emergency Managers on awareness programs. ▪ Promote continuity planning at level of household, community and livelihood.	Section 4.3, 4.4.3, and 4.5 Section 6 Section 6
▪ Promote Continuity planning within public sector. ▪ Collaborate with planners and allied professionals to enforce regulations, which are designed to reduce loss. ▪ Promote business continuity planning within the private sector. ▪ Support clients to develop inventory and assess risk on on-going basis.	Section 6 Section 6 Section 6

4. Risk Assessment

Risk Assessment Defined:

"A risk assessment or analysis is a methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend (ISDR, 2004).

"The process of conducting a risk assessment is based on:

a) A review of the technical features of the hazard such as:

- Location
- Intensity
- Frequency
- Probability

b) Analysis of the impact of the hazard:

- Physical
- Social
- Economic and
- Environmental dimensions of vulnerability and exposure, while taking particular account of the coping capabilities pertinent to the risk scenarios" (ISDR, 2004)

Vulnerability Assessment Tool (VAT)

The Vulnerability Assessment Tool (VAT) developed and applied by NOAA in Hanover County, North Carolina, USA has been adapted and used as the basic methodology for risk assessment in the pilot case studies. It is proposed that this methodology be accepted as being "user friendly" for the region, notwithstanding the constraints of data availability. The steps and activity chart are presented below in Table 1.

Key Words

Risk assessment, vulnerability assessment, Vulnerability Assessment Tool (VAT), threat, hazard analysis, hazard identification, hurricanes, storm surge, storm surge modeling, inundation zones, lifelines, resource capacity, governance, legal and institutional framework, societal analysis, land use, demography, economic analysis, critical facilities analysis, environmental analysis, risk analysis, vulnerability scoring, damage history scoring, structural vulnerability scoring, operational vulnerability scoring.

Definition

"A risk assessment or analysis is a methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend" (ISDR, 2004).

References

- Risk Assessment Report, Portmore, Jamaica; by CDERA & IDB, September, 2007
- Risk Assessment Report, St. Peter, Barbados; by CDERA & IDB, September, 2007

Table 1: Community VAT Methodology, NOAA (1999)

Component / Step	Activity	Output / Value
I. **Hazard Identification**	Storm surge modeling and mapping.	Hazard Maps – Zone of impact.
II. **Hazard Analysis**	Definition of high-risk areas with respect to inundation and impact.	Facilitate targeted analysis of preliminary vulnerable elements including critical facilities as identified below. Guide for development of mitigation measures. Input for risk assessment.
III. **Societal Analysis**	Identify and map land use, population characteristics, vulnerable population groups, social services and networks.	Inventory of societal attributes – housing, services, vulnerable groups etc. Guide to mitigation measures. Land use maps.
IV. **Critical facilities Analysis**	Systematic assessment of lifelines, key resources and systems.	Critical facilities inventory. Identification of critical facilities in storm surge high-risk areas.
V. **Environmental Analysis**	Identification and mapping of environmental assets that serve as protection, for example wetlands, "flashes", beaches, dunes, coastal vegetation, landforms (peninsulas /spits) and coral reefs.	Identification of environmental attributes in high risk areas; and guide to mitigation measures.
VI. **Economic Analysis**	Identification of critical economic components and evaluation of economic impact of storm surge and flooding.	Inventory of economic assets and activities. Identification of high risk areas based on economic components. Guide to mitigation measures.
VII. **Mitigation Opportunities Analysis**	Identify and assess potential for risk reduction as it relates to structural and non-structural interventions. Include systematic assessment of interface between vulnerable areas and the storm surge hazard.	Mitigation strategies for vulnerable and high risk areas, groups and elements of the pilot areas.

4.1. Identifying the Threat - Hazard Identification and Analysis

Hazard Analysis defined by the ISDR (2004) involves the "Identification, studies and monitoring of any hazard to determine its potential, origin, characteristics and behaviour". The subject hazard of this analysis is **storm surge.** Storm surge is generated by hurricanes and the relationship is described below.

4.1.1 Site Assessment and Consultation with Community Residents

A first step in the hazard analysis is an assessment of the coastal area in terms of shoreline orientation, topography, terrestrial drainage lines, vegetation, etc.

Local knowledge and experience plays an important role in hazard determination, therefore consultation with community residents regarding past events is encouraged.

Definition

Hazard Analysis involves the "Identification studies and monitoring of any hazard to determine its potential, origin, characteristics and behaviour".

4.1.2 Hurricanes- Generation of Storm Surge

4.1.2.1 Hurricanes Defined

A **hurricane** is a tropical weather system of strong thunderstorms with a well-defined surface circulation and sustained winds of at least 33 m/s (64 kt, 74 mph, or 118 km/h). A cyclone of this intensity tends to develop an eye at the centre of circulation (Figure 2.). The eye is an area of relative calm with the lowest atmospheric pressure and is often visible in satellite images as a small, circular, cloud-free spot. Surrounding the eye is the eyewall, a zone about 16–80 km (10–50 mi) wide in which the strongest thunderstorms and winds circulate around the storm's center. Maximum sustained winds in the strongest tropical cyclones have been estimated at about 85 m/s (165 kt, 190 mph, 305 km/h).

Hurricanes have deepening low-pressure centres that take in moist air and thermal energy from the water's surface. Convection lifts the air, and as the air continues to rise, it eventually hits high pressure and is pushed outward. The resultant action can be viewed in the Figure .

Figure 2. Hurricane Dean approaching the Yucatan Peninsula

Definition

A hurricane is a tropical weather system of strong thunderstorms with a well-defined surface circulation and sustained winds of at least 33 m/s (64 kt, 74 mph, or 118 km/h).

A detailed description of tropical cyclones, their classification, formation, physical characteristics, movement and track is provided in Annex I, Section 8.

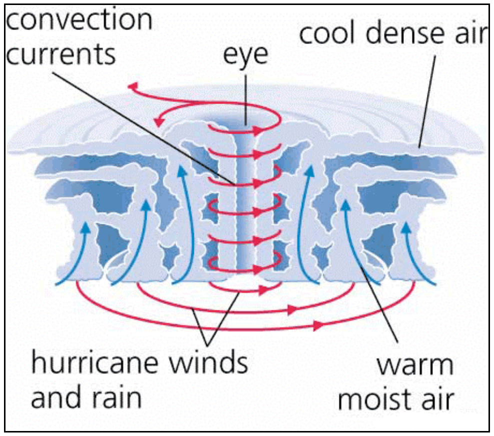


Figure 3. Hurricane diagram (www.katrinahelp.com/hurricane-diagram.gif)

4.1.2.2 Hurricanes – Categories

Hurricanes are categorized according to the strength of their winds using the Saffir-Simpson Hurricane Scale (see **Table 2**). A Category 1 storm has the lowest wind speeds, while a Category 5 hurricane has the strongest. **These are relative terms, because lower category storms can sometimes inflict greater damage than higher category storms, depending on where they strike and the particular hazards they bring.**

In fact, tropical storms can also produce significant damage and loss of life, mainly due to flooding. Table 3 gives approximate relationships between the hurricane categories, the central pressure of the hurricane, expected levels of storm surge and a description of expected damage.

Generally, the most common damages that can be associated with each of these categories of hurricanes are described in greater detail in Table 4.

Table 2 The Saffir Simpson Hurricane Intensity Scale

Category	1	2	3	4	5
V_{max} (knots)	64-83	84-95	96-113	114-135	>135
V_{max} (miles/hr)	74-95	96-110	111-130	131-155	>155
V_{max} (km/hr)	119-154	155-178	179-210	211-250	>250
V_{max} (m/s)	33-43	44-49	50-58	59-70	>70

Table 3 Saffir Simpson Hurricane Scale with Central Barometric Pressure Ranges

CATEGORY	CENTRAL PRESSURE		WINDS	SURGE	DAMAGE
	MILLIBARS	INCHES	(MPH)	(FT)	
1	>980	>28.94	74-95	4-5	Minimal
2	965-979	28.50-28.91	96-110	6-8	Moderate
3	945-964	27.91-28.47	111-130	9-12	Extensive
4	920-944	27.17-27.88	131-155	13-18	Extreme
5	<920	<27.17	>155	>18	Catastrophic

Table 4 Damage associated to different category of hurricanes

CATEGORY	ASSOCIATED DAMAGE
1	• No real damage to buildings. • Damage to unanchored mobile homes. • Some damage to poorly constructed signs. • Also, some coastal flooding and minor pier damage.
2	• Some damage to building roofs, doors and windows. • Considerable damage to mobile homes. • Flooding damages piers, and small craft in unprotected moorings may break their moorings. • Some trees blown down.
3	• Some structural damage to small residences and utility buildings. • Large trees blown down. • Mobile homes and poorly built signs destroyed. • Flooding near the coast destroys smaller structures with larger structures damaged by floating debris. • Terrain may be flooded well inland.
4	• More extensive curtain wall failures with some complete roof structure failure on small residences. • Major erosion of beach areas. • Terrain may be flooded well inland.
5	• Complete roof failure on many residences and industrial buildings. • Some complete building failures with small utility buildings blown over or away. • Flooding causes major damage to lower floors of all structures near the shoreline. • Massive evacuation of residential areas may be required.

4.1.3 History of Hurricanes in the Caribbean

Every year between the months of June and November, the North Atlantic Basin becomes very vulnerable to hurricanes.

Hurricanes occur in the North Atlantic and are more prevalent there than within the Caribbean basin. The mountains of the chain of islands from Puerto Rico to Cuba push most of these storms on a northwesterly track. Upon approach to the US eastern seaboard, the hurricanes tend to veer off on a north-easterly track due to the imposing landmass, frontal systems from the mainland and coercion from the warm Gulf Stream.

Figure 4 shows typical hurricane tracks across the Atlantic Ocean and Caribbean Sea.

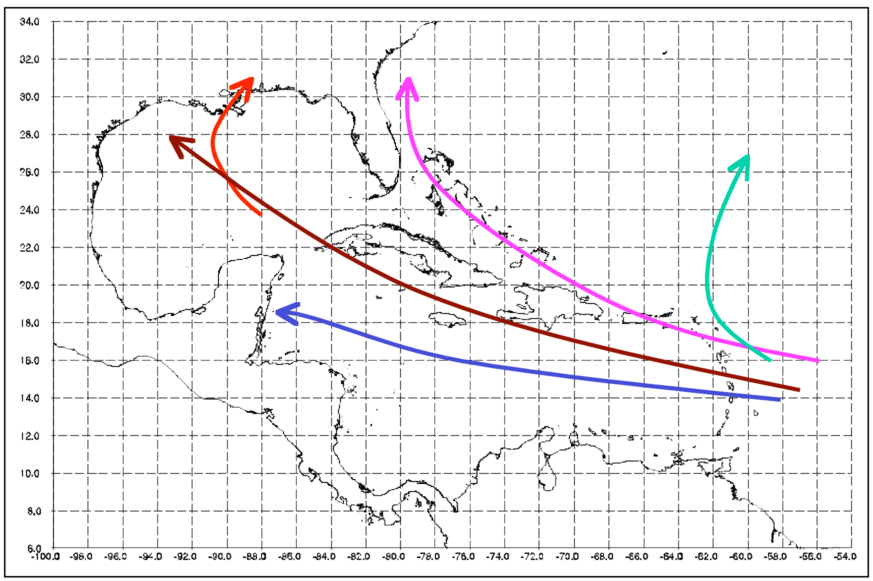


Figure 4. Typical hurricane tracks across the Atlantic Ocean

4.1.4 Long term trends in hurricane activity – Global Warming

While the number of storms in the Atlantic has increased since 1995, there is no obvious global trend; the annual global number of hurricanes remains about 87±10. However, there is some evidence that the intensity of hurricanes is increasing. "Records of hurricane activity worldwide show an upswing of both the maximum wind speed and the duration of hurricanes. The energy released by the average hurricane (again considering all hurricanes worldwide) seems to have increased by around 70% in the past 30 years or so, corresponding to about a 15% increase in the maximum wind speed and a 60% increase in storm lifetime" (Kerry, 2006).

Atlantic storms are becoming more destructive financially. Five of the ten most expensive storms in the Caribbean historic record have occurred since 1988. This can be attributed to:

- the increased intensity and duration of hurricanes striking the Caribbean region;
- increased coastal development and population growth since the last surge in Atlantic hurricane activity in the 1960s.

In recent years, and particularly since 1995, the North Atlantic Basin has seen an increase in the frequency and intensity of tropical cyclones. It has been proposed that this increase may be as a result of the global warming phenomena.

Global warming

Most climatologists agree that a single storm, or even a single season, cannot clearly be attributed to a single cause such as global warming or natural variation. Nevertheless, they also agree that potential hurricane destructiveness, a measure combining hurricane strength, duration, and frequency, is highly correlated with tropical sea surface temperature, reflecting well-documented climate signals, including multidecadal oscillations in the North Atlantic and North Pacific, and global warming.

Sea surface temperatures are considered vital to the development of cyclones. The increase in temperatures is believed to be due to global warming and the hypothesized Atlantic Multidecadal Oscillation (AMO), a possible 50–70 year pattern of temperature variability. However, the recent temperature increase is outside the range of previous sea surface temperature peaks. Thus, both global warming and a natural variation such as the AMO could have contributed to the warming of the tropical Atlantic over the past decades, though an exact attribution has not been defined.

4.1.5 Considerations Related to Adaptation to Climate Change

Climate change is anticipated to result in increasing average atmospheric temperatures in the Caribbean, increasing sea surface temperatures, rising sea levels, changes in precipitation patterns and, for some areas, an increase in the frequency and severity of extreme weather events. The projected impacts of change are likely to occur over medium to relatively short time spans.

The rapid rise in water level that accompanies an intense hurricane is mainly due to the effects of strong winds and low pressure as the storm passes a given point in shallow water.

In addition to the hurricane driven effects, it is therefore important to consider other factors in the estimation of the water levels generated by hurricanes, such as the long-term trends on local and global water levels.

Rising Sea Level

The determination of long term sea level rise for an island location should take into account both the rate at which the mean sea level is rising, as well as the tectonic movements that are occurring for the various land masses being considered. The latter would make the water level increases different for different areas within the region. The limited available data on tectonic movements in the region suggests that sea level rates associated with these movements are less than one-tenth of those associated with global sea level rise. Experts have predicted that it is expected that there could be as much as 0.25 m rise in *global sea levels* (GSL) over the next 100 years. In addition, the possibility of an acceleration of the global sea level rise rate due to the melting of ice caps could be a factor worth while considering.

Increase in the frequency and intensity of extreme weather events in the Caribbean

As described previously, in recent years and particularly since 1995, the North Atlantic Basin (and therefore, the Caribbean) has seen an increase in the frequency and intensity of tropical cyclones.

Summary Points

- The Global Sea Level Rise factor should be added to the predicted static storm surge level in order to determine the potential inundation level in the study area.
- The anticipated increases in frequency of occurrence and storm intensity should be considered in the prediction of wave and water level conditions in the Caribbean region, and in the development of design criteria for coastal and marine infrastructure.

4.1.6 Hurricanes – Their Effects

The main destructive impacts from hurricanes are a result of heavy rainfall, strong winds, destructive storm surges and landslides. After the hurricane has passed, the impact on human settlements often continues. For example, standing water can cause the spread of disease (dengue, malaria etc through the activity od mosquitoes.), and transportation, utilities and communications infrastructure is often destroyed. How devastating a hurricane is depends mainly on its intensity, size, and where it impacts, as well as on the degree of preparedness of the affected community.

Main Impacts

Hurricanes on the open sea result in large waves, heavy rain, and high winds, disrupting international shipping and, at times, causing shipwrecks. However, the most devastating effects of a hurricane occur when they approach land or make landfall. The associated strong winds can damage or destroy infrastructure and property, turning loose debris into deadly flying projectiles.

The two worst impacts of hurricanes result from:

- The **storm surge**, or the increase in mean sea level due to the hurricane, which is typically the worst effect from landfalling hurricanes for coastal regions.
- The thunderstorm activity in a hurricane, which produces **intense rainfall**, potentially resulting in flooding and, or landslides.

Secondary Impacts

Often, the secondary effects of a hurricane produced by a combination of storm surge and intense rainfall, can be equally damaging. These include:

- Spread of **disease,** which claims lives long after the storm passes, resulting from compromised sanitation. For example, infections of cuts and bruises can be greatly amplified by wading in sewage-**polluted water**. Large areas of standing water caused by flooding also contribute to mosquito-borne illnesses. Furthermore, crowded evacuees in shelters increase the risk of disease propagation.
- Hurricanes often **knock out power** to tens or hundreds of thousands of people, preventing vital communication and hampering rescue efforts.
- Hurricanes often **destroy key bridges, and roads**, complicating efforts to transport food, clean water and medicine to the areas that need it.
- Furthermore, the damage caused by hurricanes to general infrastructure can result in **economic damage** to a region.

Summary Points

- The effects of hurricanes are the impacts these systems have on the affected . The main destructive impacts happen at the moment of landfall.
- The main impacts of hurricanes are: storm surge, heavy rains, inland flooding, strong winds, etc.
- The secondary effects of a hurricane associated with the combination of storm surge impact and intense rainfall include diseases, water contamination, loss of power, destruction of general infrastructure and property, etc.

4.1.7 Hurricanes and Storm Surge Generation: Concept, Components and Inundation Levels

Concept

The elevated water levels that accompany hurricanes, creating flooding, and causing damage to coastal infrastructure, is known as **storm surge**. Storm surge is simply the increase in water levels at the shoreline resulting from the passage of a storm. Often storm surge in the Caribbean can be up to 2 – 3 metres above MSL. In addition, wind waves are superimposed onto the storm surge, resulting in wave run-up.

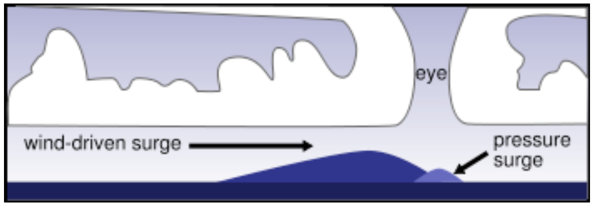
The term "storm surge" in casual (non-scientific) use is **storm tide** (Figure 5.); that is, it refers to the rise of water associated with the storm, plus tide, wave run-up, and freshwater flooding. When referencing storm surge height, it is important to clarify the usage, as well as the reference point.

This rise in water level can cause severe flooding in coastal areas. Because many of the island states have densely populated coastlines which lie less than 10 feet above mean sea level, the danger from storm tides is large.

Further, the storm surge combined with wave action can cause extensive damage, severely eroding beaches and coastal highways. Many buildings are able to withstand hurricane force winds until their foundations, undermined by erosion, weaken and fail.

Definition

Storm Surge is an offshore rise of water associated with a low pressure weather system, typically a tropical cyclone (hurricane).



Components

Storm surge can be considered to have static and dynamic components. Figure 5 and 6 show the definition of the various components of static and dynamic storm surge, while Table 5 indicates the effects of these components and their anticipated duration.

a) The **static storm surge** is comprised of (see Table 5 for definitions):

- Inverse Barometric Pressure Rise (IBR)
- Wind Setup
- Wave Setup

b) The **dynamic storm surge** is a result of ***wave run-up***. Elevated water levels due to the static surge could remain constant for hours during a storm, whereas water levels in the wave run-up zone will fluctuate as waves run up and down the beach, and therefore, this zone will not always be wet.

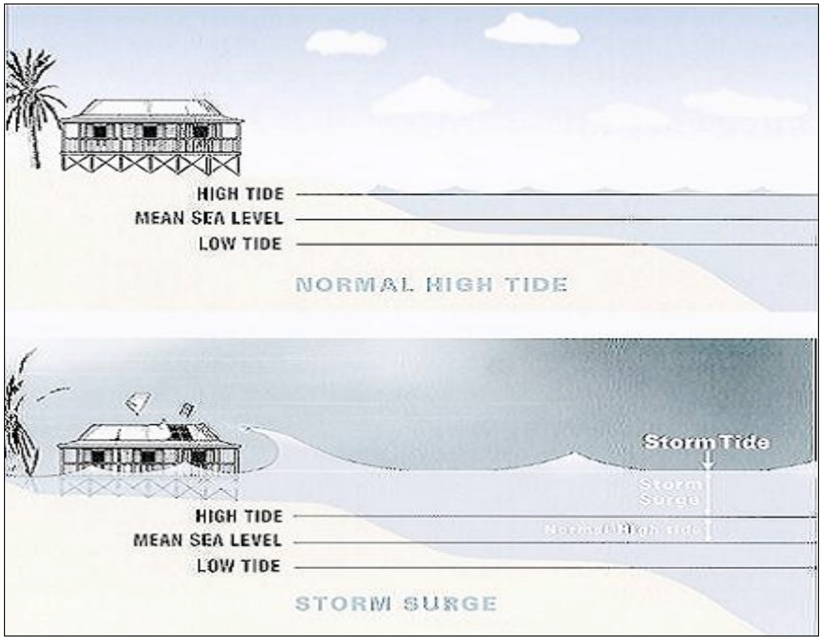


Figure 5. Storm Surge and Storm Tide Diagram

(www.bom.gov.au/.../stormsurge_tide_smaller.jpg)

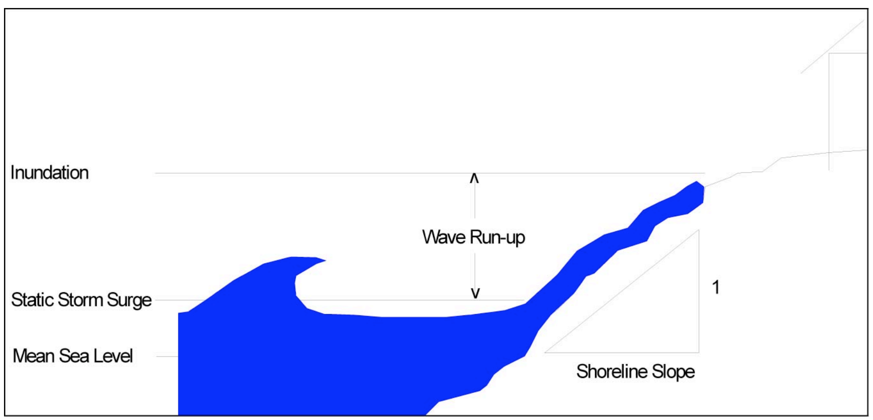


Figure 6. Definition sketch of storm surge

Table 5 Definition of storm surge components

COMPONENT	DEFINITION / EFFECT	TIME SCALE
Static Storm Surge		
Inverse barometric rise	The low pressure in the "eye" of the hurricane compared with surrounding atmospheric pressure elevates the water level under the eye.	• 4 – 8 hours
Wind set-up	In very deep water, wind set-up has little effect on the mean water level. As the hurricane moves toward shore and encounters the continental or island shelf, the wind piles the water on to the shore.	• 4 – 8 hours
Wave set-up	As waves break in the nearshore, the forward motion of wave energy halts and is balanced by an increase in the mean sea level.	Duration of high seas • (4– 8 hours)
Dynamic Storm Surge		
Wave Run-up	As waves reach the shoreline, they break and run up the shore.	• 10 - 15 seconds

Computation of Inundation Levels

The rapid rise in water level that accompanies an intense hurricane is therefore mainly due to the effects of strong winds and low pressure as the storm passes a given point in shallow water. In order to determine the inundation levels resulting from the occurrence of such an intense event, the following factors should be considered in addition to the storm surge:

- First, the expect ed long-term trends on local and global water levels should be known. Experts have predicted that there could be up to 0.25 m rise in *global sea levels* (GSLR) over the next 100 years.
- Tidal variations must also be taken into account.

The various components are then added to obtain the final inundation level.

Summary Points

Storm surge can be considered to have a static and a dynamic components.

- The **static component** is comprised of:

  - Inverse Barometric Pressure Rise

  - Wind Setup

  - Wave Setup

- The **dynamic component** is a result of wave runup.
- **Inundation Level** = IBR + Wind Setup + Wave Setup + Wave Runup + GSLR + Tides

4.2 Storm Surge Prediction and Mapping

The prediction of storm surge resulting from the combined meteorological, oceanic and astronomic effects coincident with the arrival of a hurricane at the coast, is a crucial problem, that is at the same time difficult to solve accurately.

The capability for the prediction of hurricane surge is based primarily on the use of analytic and mathematical models, which estimate the interactions between the winds, the ocean, and the land.

4.2.1 Developing Design Criteria for Storm Surge Prediction

The primary challenge in the prediction of storm surge and inundation levels at the coastline, lies in the development of design conditions corresponding to a particular extreme event, such as the 1 in 100 year return period event.

The recommended approach to the derivation of the storm conditions associated with a hurricane consists of the following steps (Goda, 1988):

Step 1: Estimation of the deep water wave and water level conditions

Existing Approaches

In order to determine these wave heights, there must be some form of statistical manipulation of the modeled individual wave heights and/or of the database of storms that generated these waves.

Statistical methods for cyclonic waves differ in the manner in which the historical data are statistically manipulated. The traditional methods (hereafter referred to as the ***Historical Approach***) require only the fitting of the historical data to various known statistical distributions and thereafter deriving the exceedance levels for desired return periods. Others, such as the ***Monte Carlo Approach***, require the generation of a synthetic database of storms using the properties of the existing historical population, to augment the historical database.

The *Historical Approach* has the advantage in that it represents the real storm data set, while the *Monte Carlo* method has the advantage of giving a more reliable statistical interpretation of the probable storm occurrences and intensity because of the use of a larger database. Assumptions for the validity of this method include the statistical independence of the main parameters. In general, the randomness associated with hurricane tracks and their peak velocities makes this method quite applicable to the development of design criteria.

Monte Carlo Approach

Based on the information provided in the preceding sections regarding the long-term trends in hurricane activity, it may be more prudent to apply the *Monte Carlo Approach* as an intermediate step in the estimation of the deep water waves and water level conditions. The underlying trends suggest that reliance soley on analysis of the past storms, is insufficient and that some level of forecasting must also be done. This allows for the expansion of the database of tracks to examine other possibilities of occurrence that have either not been recorded or have been incorrectly estimated, while modeling the effects of long term trends in peak wind speed and frequency of cyclonic occurrence.

Steps of the Recommended Approach

1. Using the Monte Carlo simulation method, generate a synthetic database of storms using the properties of the existing historical population, to augment the historical database.
2. In order to estimate the deep water conditions, it will be necessary to use a **hindcast model** to define the waves in the storm, based on measurements of the maximum wind speeds and central pressure of the hurricane. Such models range from complex spectral to simpler parametric models. The spectral models give excellent predictions, but are computationally inefficient, and therefore the number of storms that can be simulated is relatively small. Parametric models, such as

Cooper (1988) and Young (1988 and 1996) (which have been used in this analysis) allow for the simulation of large numbers of storms.

- The National Oceanic and Atmospheric Administration (NOAA) of the USA, through the National Hurricane Center (NHC), maintains much of the historical records of hurricanes. They maintain what is called the "best-track data". This represents a post-season analysis of all tropical cyclone intensities and tracks at 6-hour intervals. The data set includes the 6-hour track positions and the equivalent measurements or approximations of the maximum wind speed, V_{max}, and the central pressure, P_c. From these measurements, and by means of the hindcast model selected, the deep water waves and water level conditions can be estimated.

3. An appropriate data set must first be selected. Typically, this could be:

   - A peak value series, where only the peak wave height from each storm is used. The underlying assumption is that each point can be considered to be a random independent variable.
   - An annual maximum series, whereby only the maximum wave height from all storm occurrences in a given year is used. One drawback to this method is that in an active year, near-maximum wave heights would be ignored.
   - Both methods assume that future storms resemble past storms and that there are no meteorological trends in storm generation. This latter assumption may be invalid, given the inferences from global warming.

4. Then, an **Extremal Analysis** should be performed in order to extract the design waves for different **return periods**.

   - This analysis includes fitting the computed wave and/or water level data to various statistical distributions. Typically used distributions include 1) Fisher Tippett type I or Gumbel Distribution, 2) Fisher Tippett type II or Frechet Distribution and 3) 3-Parameter Weibull Distribution.
   - The best-fit distribution should be determined from the correlation, as well as from the goodness of the fit to the most extreme values in the distribution.
   - Using a number of data fitting methods (e.g. graphical, least squares, moments, etc.), the design waves can be extracted for given return periods.

As a very approximate guide, and for many Caribbean locations, the 1 in 50 year return period event can be considered roughly equivalent to a Category 3 event. The 1 in 100 year hurricane has been found to be equivalent to a Category 4 event, while the 1 in 150 year hurricane would be equivalent to a Category 5. It should be remembered, however, that this is somewhat of an oversimplification, as even a Category 3 storm could result in damage equivalent to a 1 in 100 year hazard, depending on its approach direction and forward speed.

Summary Points

- The increase in intensity and frequency of hurricanes in the Caribbean Region suggests that rather than just carrying out an analysis of the past storms, some level of forecasting must also be done. A **Monte Carlo** approach is recommended for the estimation of the deep water hurricane waves and water levels.
- The historical records of hurricanes in the region can be obtained from the National Oceanic and Atmospheric Administration (**NOAA**) of the USA, through the National Hurricane Center (**NHC**).
- The **Return Period** is an estimate of the likelihood of events such as hurricanes of a certain intensity or size. It is a statistical measurement denoting the average recurrence interval over an extended period of time.
- As a very approximate guide in the Caribbean, the 1 in 50, 1 in 100 and 1 in 150 year return period events can be considered roughly equivalent to a Category 3, Category 4 and Category 5 event, respectively.

Step 2: Generation of computational grids representing the bathymetry and topography of the study area

The second step in the general methodology of the storm surge prediction process is the setup of a rectangular computational grid representing the **bathymetry** and **topography** of the study area. This step requires a good knowledge of the bathymetry adjacent to the shoreline being considered, and its topography.

The computational grid is used in the numerical transformation of the deep water hurricane conditions up to the nearshore areas. This grid should extend beyond the island shelf in order to allow the input of deep water conditions to the numerical model. It is recommended that the grid should have a reasonably good resolution (less than 100 m by 100 m) in order to represent any bathymetric or topographic features that may affect the transformation of wave and water level conditions, or their impact on the shore areas (see Case Study 1).

Summary Points

This step requires a good knowledge of the **bathymetry** adjacent to the shoreline being considered, and its **topography**.

CASE STUDY #1
Storm Surge Prediction Computational Grid Setup - PORTMORE

A computational grid was set-up, encompassing the areas of Portmore and Kingston, the nearshore areas in front of them and the drop off of the island shelf to deep water regions. A 50-m grid spacing was used. The grid covered an area of approximately 40x40 km. The south-east and south-west limits of the grid extend beyond the shelf to allow the model to be run from deep water. Water depths on the shelf go well beyond 500 m and rise rapidly to the island platform.

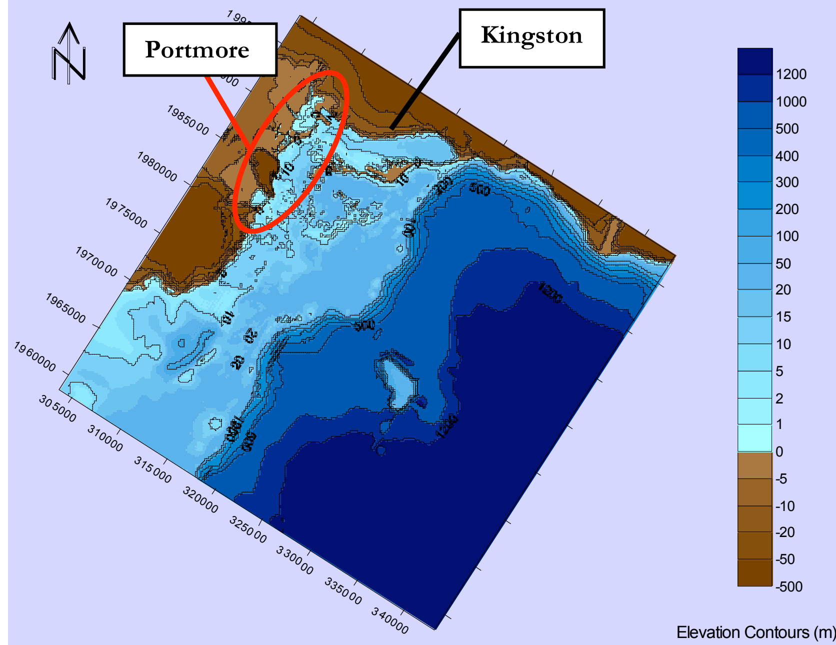


Figure 7. Example of a computational grid: Bathymetric and topographic characteristics of the nearshore and offshore areas in the vicinity of Portmore (Jamaica)

Step 3: Transformation of the hurricane waves from deep to shallow water

The deep water wave conditions (from Step 1) must then be input to the model boundaries (from Step 2) and transformed to the nearshore regions in order to obtain the values of storm surge and wave heights at the shoreline.

One of the more suitable models for carrying out this transformation is the 2D numerical model **SWAN** (Simulating Waves Nearshore), a third-generation wave model that computes random, short-crested wind-generated waves in coastal regions and inland waters. This model is also able to simulate the complex nearshore processes that lead to storm surge (see Case Study #2), and takes into account the impact of wind on local wave generation.

The SWAN model is available as freeware from the following home page site: http://www.citg.tudelft.nl/live/pagina.jsp?id=f928097d-81bb-4042-971b-e028c00e3326&lang=en

In addition, a tutorial for SWAN may be accessed from the following website: http://vlm089.citg.tudelft.nl/swan/index.htm

Helpful Hints

SWAN links:

- http://www.citg.tudelft.nl/live/pagina.jsp?id=f928097d-81bb-4042-971b-e028c00e3326&lang=en
- http://vlm089.citg.tudelft.nl/swan/index.htm

CASE STUDY #2

Storm Surge Prediction: Transformation of hurricane waves – PORTMORE

The following figure presents an example of the results of the hurricane wave transformation modelling, performed using SWAN for the area of Portmore.

The figure shows the static storm surge levels in a spatial manner along the shoreline. The static storm surge is seen to vary for the different shoreline sections.

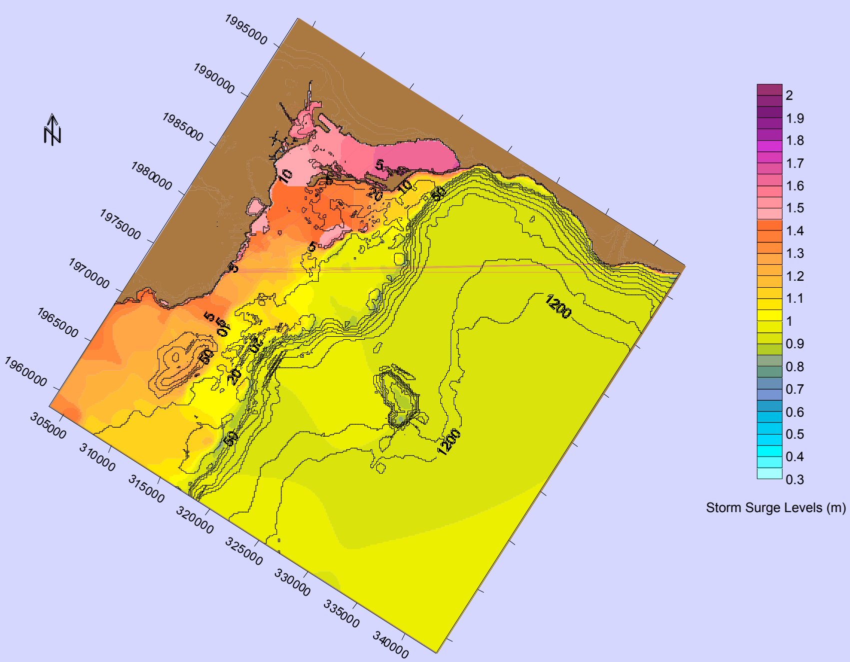


Figure 8. Example of a nearshore transformation: Static storm surge results for a 150-yr hurricane event from the ESE direction

Step 4: Estimation of the nearshore values of both waves and storm surge

The impact of the storm surge in a certain area will depend on the characteristics of the shoreline directly adjacent to that area, the topography of the area, the distance to the sea or to any water body connected to the sea, and the amount and type of obstacles (buildings, protective structures, vegetation, etc.) that lie between the shoreline and the specific area.

As a result, the values of predicted wave heights and storm surge will be different for different sections of the shoreline. These values can be interpolated from the computer model plots, as shown in Step 3.

Maximum values of the static storm surge level (*SSSL*) and wave heights predicted at the different sections of the shoreline can be used for planning and preparedness activities.

In general, areas closer to the coastline, will be subjected to the highest storm surge impact, and will suffer the most extreme floods. In addition, they will be severely impacted by the action of the waves and the forces that these waves exert on any adjacent structures.

For areas farther away from the shoreline, the effects of both the static and the dynamic components of storm surge will normally be significantly diminished. In addition, it is very likely that these areas will be at higher elevation with respect to the sea level, thereby having reduced vulnerability.

Step 5: Mapping of storm surge levels and inundation zones

Storm Surge Hazard Maps can now be prepared by integrating the predicted inundation zones and topography of the study area in a GIS (Geographic Information System) compatible environment, overlaid on top of satellite imagery.

Summary Points

The impact of **storm surge** depends on:

- Coastal morphology
- Topography of the area
- Distance to sea or to any water body connected to sea
- Amount and type of obstacles that lie between the shoreline and a specific area

Storm Surge Hazard Maps can now be prepared by integrating the predicted inundation zones and topography of the study area in a **GIS** (Geographic Information System) compatible environment, overlaid on top of satellite imagery.

Helpful Hints

Maximum values of the static storm surge level (*SSSL*) and wave heights predicted at the different sections of the shoreline can be used for planning and preparedness activities.

METHODOLOGY - STORM SURGE PREDICTION

The general methodology for the prediction of the storm surge values at the shoreline consists of the following steps:

1. Estimation of the deep water wave and water level conditions;
2. Generation of computational grids representing the bathymetry and topography of the study area;
3. Transformation of the hurricane waves from deep to shallow water;
4. Estimation of the nearshore values for both waves and storm surge; and
5. Mapping of storm surge levels and inundation zones.

Information Needed

- Historical records of hurricanes from the National Oceanic and Atmospheric Administration (NOAA) of the USA, through the National Hurricane Center (NHC)
- Bathymetry adjacent to the shoreline being considered
- Topography of the study area
- 2D numerical model SWAN (Simulating WAves Nearshore)
- GIS (Geographic Information System)

4.2.2 Models Presently Available for Storm Surge Prediction

Probably the most commonly known models for hurricane forecasting are those currently used to do real time forecasting. These models use a combination of statistical and meteorological factors to predict the paths of cyclones. The lesser known models are those that, given the track of the cyclone and its characteristic components, estimate the generated wave heights within the cyclones.

Cyclonic wave prediction models have taken different forms. They range from complex spectral models to simpler parametric models. In this context, the term "parametric" refers to models requiring the input of only a few parameters. The *parametric models*, in most cases, use a simplification (or parameterization) of numerical formulations related to wind-wave generation theories in combination with the results of complex spectral models.

Although the *spectral models*, understandably, will outperform their parametric counterparts, the complexity involved in their application requires far more computational time, effort and budget. *Parametric models* have the advantage that they may be easily applied to a much larger database of storms (hundreds of storms). With the *parametric models*, one can therefore achieve a much more comprehensive data set on which to perform statistical analyses. In this way, more robust statistics can be achieved than is easily possible from the use of a *spectral model*.

A brief description of some of the models presently in use is given following.

Models used by the Climate Studies Group Mona of the University of the West Indies (CSGM)

The CSGM is currently using three regional models: *MM5*, *PRECIS* and *ETA*.

- The *MM5* is a mesoscale model developed at the National Center of Atmospheric Research in Boulder Colorado and at the Penn State University. MM5 has a spatial resolution of 9 km and possesses flexible and multiple nesting capability. This model is currently running simulations in *real time mode,* but can also be used in a *climate prediction mode*.
- The *PRECIS* is a regional model produced by the Hadley Centre (UK). The model has a resolution of 50 km. This model is being run in a *climate change mode*.
- The *ETA* model was developed by the National Center for Environmental Protection and has a resolution of 80 km. The model is being used in a *climate prediction mode* to investigate the dynamics of the Caribbean low level atmospheric jet.

All of these models presently operate at scales of resolution that are too coarse for the application envisaged under this project.

Model used by the Caribbean Institute of Meteorology and Hydrology (CIMH)

The CIMH currently uses *TAOS/L*, a Caribbean version of the TAOS model, for computation of storm surge levels. The Arbiter of Storms (TAOS) is a computer-based hazard model, developed with the support of USAID/OAS Caribbean Disaster Mitigation Project (CDMP), for assessing the impact of storm surge and wave action on coastal areas throughout the region. Model runs can be made for any historical storm, for probable maximum events associated with different return periods, or using real-time tropical storm forecasts from the US National Hurricane Center (NHC).

TAOS can simulate tropical systems on a variety of scales, from 1 arc-second (30.8 m) per cell through 5 arc minutes (9850 m/cell). Version TAOS/L is being currently used only at a regional scale, making it inappropriate for the current study.

Conclusion

In spite of the promising applications that these models present for future projects, these models are not considered to be applicable to the present project, primarily because of their coarse grid characteristics (too large resolutions) in comparison with the coastal extent of both project areas (10 km). With regards to the TAOS model, it is likely that the 1 arc-second version would be appropriate for use at the project scales considered here. Its use would therefore require an update, by the CIMH, to the model presently used by them. Regional models do not facilitate the level of detail necessary for projects which focus on towns within small islands states.

Although not completely directed to give the type of output required in projects of this type, these models could still provide some feedback to the storm surge study. However, some of them are still in the early stages of application, and are not as yet ready to provide any additional information for the risk assessment studies performed in Portmore, Jamaica and St. Peter, Barbados. Finally, the computational time for these models is quite long (order of magnitude of days) making it a major inconvenience for projects of this type.

Summary Points

- The regional models presently used by different institutions in the Caribbean for the prediction of storm surge are not considered to be applicable to projects of this type, because their grid is likely to be too coarse in comparison with the coastal extent of corresponding project.
- Although not completely directed to give the type of output required in projects of this type, these models could still provide some feedback to the storm surge study.

4.2.3 Identification of Data Requirements

The data requirements necessary for the study of storm surge hazards, include a knowledge of the hurricane history (history of extreme events) of the study area, as well as reliable bathymetric and topographic data. These data characteristics are summarized following, in a generalized manner.

Data Collection and Collation

- Bathymetry from the shoreline out to the 100 m water depth contour
- Beach profile data for the area(s) in question.
- Topographic data from the MSL landward to the +5 m land contour
- Historical database of hurricanes from at least 1900 to date, with data on wind distributions, track details, central pressure, forward speed, radius to maximum winds and maximum wind speeds.
- Mapped information relating to infrastructure adjacent to the coastline. This could be shown in an aerial or satellite image, or included in a GIS database.

Dealing with Data Constraints

Very often the data that is required to carry out a proper computation of the storm surge parameter is not readily available to the investigator. One of the most fundamental of the data requirements for the computation of storm surge is adequate bathymetry. Presently, bathymetry is available for most of the islands in the Caribbean in both map and electronic formats. In most cases, these charts are based on old mapping carried out by British Admiralty and/or US Navy charters. Very often also, there is little or no bathymetric detail in the zone from 3 m water depth up to the shoreline. Some islands have carried out mapping of their coastal waters, either through the use of boat-based surveys, or by use of LIDAR technology (e.g. Barbados, Bermuda). The recommendation that can be made here in the case of an island community that does not have this information, is as follows:

- Use existing chart (mapped or electronic) data to give bathymetric detail from deep water in to approximately the 2 m or 3 m contour.
- Commission a beach profile and wading survey in the zones of interest to include profile data starting from the +3 m - 5 m land elevation, out to the -2 m water depth contour. The spacing between profiles will need to be determined based on the extent of area for which the storm surge is to be determined, the project budget and the degree of accuracy intended for the work.

A large amount of topographic data is usually available, as most islands have been surveyed extensively. The main problem to be expected is that since previous surveys have not been carried out to facilitate storm surge computations, the contour interval that is usually found is of the order of 10 m, rather than the required 0.5 m or 1 m for proper mapping of storm surge on a coastline. This level of detail may be picked up to some extent by the shoreline profiles recommended in the previous paragraph, with some interpolation being done between profiles.

Historical hurricane data may be easily accessed from the National Hurricane Center, NOAA, in Florida. These data span from 1900 to date and a significant amount of data has been archived for each hurricane season, and for each storm. In general, therefore, there is more than adequate information to supply this data requirement.

Finally, it is now possible to obtain up-to-date satellite imagery (e.g. Ikonos) for each island. This data can be used as the backdrop to the storm surge mapping, with land and sea contours being superimposed onto the images, followed by the predicted storm surge. This approach is expected to facilitate the estimation of vulnerability resulting from such events.

Information Needed

- Bathymetry from the shoreline out to the 100 m water depth contour
- Beach profile data for the area(s) in question
- Topographic data from the MSL landward to the +5 m land contour
- Historical database of hurricanes from at least 1900 to date
- Mapped information relating to infrastructure adjacent to the coastline

Possible Sources of Information

- Historical record – newspapers, library, Nat'l Disaster Offices, Met Services, Consultation with Community members and organizations (anecdotal information)
- Regional organizations - CDERA, CIMH, CDB, OECS
- Tertiary Institutions - UWI, Utech, USVI, Community colleges,U. Puerto Rico
- Environmental reports, Engineering professionals, Planning departments,
- SIDSNET – www.sidsnet.org
- Caribbean Disaster Information Network (CARDIN) http://www..mona.uwi.edu/cardin/home.asp

4.2.4 Mapping

Storm Surge Hazard Maps can be prepared by integrating the predicted inundation zones and topography of the study area in a GIS (Geographic Information System) compatible environment, overlaid on top of satellite imagery.

Hazard Maps can be prepared for the different scenarios investigated. In the case of the Risk Assessment Studies performed for Portmore, Jamaica and St. Peter, Barbados, storm surge hazard maps were prepared for the 50-yr, 100-yr and 150-yr storm events.

In addition, hazard maps showing the depth of water throughout the extent of the storm surge impact zone, can also be prepared for the different periods. These maps would reflect the decrease of the flooding depth from the areas close to the shoreline to the areas located further inland.

The different hazard maps form the basis for the elaboration of the vulnerability and risk maps (see following sections). These maps superimpose the result of the vulnerability and risk assessments on the storm surge hazard maps.

CASE STUDY #3

Hazard Mapping – St. Peter

The following figure presents an example of the storm surge hazard map produced for the impact of a 150-year hurricane in the area of St. Peter, Barbados.

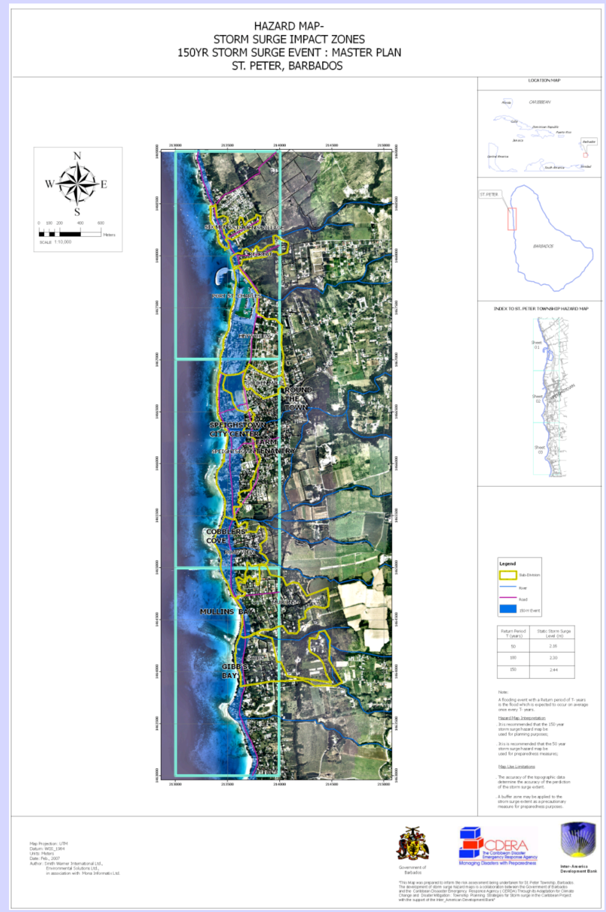


Figure 9. Hazard Map: Storm Surge Impact Zones, 150-yr Storm Surge Event from the WNW, St. Peter (Barbados)

4.3 Vulnerability Assessment

4.3.1 Vulnerability Defined

Vulnerability has been defined by the International Strategy for Disaster Reduction (ISDR 2004) as *"the conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards".* In their Community Vulnerability Assessment Tool (VAT), NOAA defines vulnerability as "the susceptibility of resources to negative impacts from hazard events" (NOAA, 1999).

4.3.2 Assessment of Vulnerability

Vulnerability assessment evaluates the susceptibility of a community to negative impacts from a hazard event. The hazard under consideration in this evaluation is storm surge. This vulnerability or susceptibility may be influenced by physical, social, economic or environmental conditions. Such assessment therefore requires the skills of the several disciplines related to each of the conditions.

4.3.3 Steps in the Assessment

The vulnerability assessment includes several steps:

1. Hazard Analysis and Site Assessment
2. Vulnerability Analysis
   i. Societal Analysis
   ii. Critical Facilities Analysis
   iii. Environmental Analysis
   iv. Economic Analysis

Each of these steps is addressed following.

Definition

Vulnerability is "the susceptibility of resources to negative impacts from hazard events" (NOAA, 1999).

Summary Points

Vulnerability Analysis includes:

- Societal Analysis
- Critical facilities Analysis
- Environmental Analysis
- Economic Analysis

1. Hazard Analysis and Site Assessment

Hazard Analysis was defined in Section 4.1 according to the ISDR as "Identification, studies and monitoring of any hazard to determine its potential, origin, characteristics and behaviour", (ISDR, 2004). Included in this analysis should be a review of the physical characteristics of the site (topography, geology, drainage, etc), historical hurricane tracks, history of storm surge, storm surge maps as prepared or commissioned for the analysis, anecdotal reports and any documentation from community residents and community organizations.

2. Vulnerability Analysis

There is no single "correct" method for conducting a vulnerability assessment (NOAA, 1999). The assessment should seek to answer:

- What and where are aspects of the coast that are exposed to damage and loss from the impact of storm surge?
- How and why are they vulnerable?

The methodology used in the pilot studies for Portmore and St. Peter was adapted from the NOAA methodology as applied in the Vulnerability Assessment Tool (VAT). The VAT involves an assessment of physical, social, environmental, and economic vulnerabilities of a selected area, and makes recommendations for mitigation measures.

The methodology allows some flexibility for utilizing a wide range of data sources. It can be expanded to include more in-depth analyses or condensed to focus on fewer vulnerability factors. This is particularly useful in the case of the Caribbean where there are differences in data availability among states.

Summary Points

- What and where are aspects of the coast that are exposed to damage and loss from the impact of storm surge?
- How and why are they vulnerable?

i. Hazard Identification

The hazard is storm surge. This has been addressed in Section 4.1.2.

ii. Hazard Analysis

This has been addressed in Section 4.1.2.

iii. Societal Analysis

The societal analysis has two main components:

1. Land use assessment
2. Analysis of demographics and identification of vulnerable groups.

The NOAA approach to societal analysis encourages the identification of special consideration and high-risk locations at the level of the neighbourhood, and a scoring system to determine how vulnerable they are to the hazard impacts.

In Portmore and St. Peter, collecting data at the neighbourhood level was not feasible and the approach was modified to collect it at the community level. The reasons for this related both to size and availability of databases. It is recommended that similar considerations be given to other areas under future study.

METHODOLOGY - SOCIETAL ANALYSIS

1. Land Use Assessment

- Identify and map the main land use sectors and their distribution. (e.g. agriculture, resort, residential, industry, economic centres, major/ minor roads, drainage network, recreational areas, etc).
- Use satellite imagery and/ aerial photography to review overall spatial patterns of land use.
- Conduct field investigations using GPS to verify uses identified.

2. Analysis of demographics and identification of vulnerable groups

- Identify areas of special consideration where individual resources are minimal and personal resources for dealing with hazards can be extremely limited.
- Identify intersections of special consideration areas with high-risk areas.
- Conduct a general inventory of special consideration and high-risk locations so as to summarize the special condition households that may require assistance in these areas.
- Calculate a **social vulnerability score** from the demographics and health data for each community.
- Calculate **total vulnerability scores** for all communities. Use range to define the areas from highest to lowest vulnerability ***(CASE STUDY #3).***
- Map communities/areas by range of vulnerabilities.

Information Needed and Possible Sources

- Land use map - Department of Physical Planning
- Poverty Data - Statistical Office
- Age - Statistical Office
- Public assistance - Social Services Agencies
- Rental households - Statistical Office
- Single parent households - Statistical Office
- Number of vehicles - Motor vehicle dept

Helpful Hints

Town Planners

- Remember people are at the center of development and loss reduction! Population characteristics of the development area are therefore important. Data is sometimes incomplete or not available as exactly needed. Ascertain from the Statistical Office how demographic data is collected. Select study approach accordingly.
- Try to obtain Ikonos imagery if possible to assist land use assessment. Field checking is important for verification.
- Use Google Earth also as source for satellite photography. Check site www.earth.google.com.
- GIS is the most useful tool for showing interface between inundation zones and population and settlement characteristics.
- Dialogue with stakeholders also an important source of information; do not be afraid to use "anecdotal information" to supplement hard data where appropriate.
- For large communities, where identifying vulnerable individuals may not be practical, some measure of the problem can be obtained by estimating the incidence of occurrence among the population from national data bases.

Emergency Managers

- Community profiles will greatly assist development of community preparedness and response plans. Liaise with Planning department and community organizations.

Community Groups

- Keep information current on population with special needs. Develop preparedness and response procedures for this group.

Risk Transfer Providers

- Social vulnerability scores can provide a useful guide to calculation of insurance risk and opportunity.

Analysis of Demographics and Vulnerable Groups

A flexible approach is often required in assessing demographics and vulnerable groups, as such analysis is dependent on available data. What is important is the identification and protection of those citizens whose social conditions, make them vulnerable to the hazard and also dependent on the state for their post event welfare. Vulnerability indices are used to indicate the presence of physical challenges so as to better plan for the affected citizens.

Table 6 presents the indices recommended by NOAA to be used in a Vulnerability Assessment. However, some of these indices are not available. This was the case for the pilot areas of Portmore and St. Peter, for which only the indices presented in Table 7 were available.

Particularly Vulnerable Groups or Communities

Each regional territory has its own known, particularly vulnerable groups. They exist, for example, in marginalized and/or squatter communities, fishing communities, other isolated coastal communities, nursing homes, hospitals, homes for the indigent, and children's homes.

Identification of these 'at risk' groups, mapping their locations and surveying their circumstances, is the main objective of any social vulnerability assessment.

Identified vulnerable communities should be placed on the selected base map so as to facilitate overlay with the storm surge hazard.

The fishing beaches in both pilot areas, Portmore and St. Peter, were designated as particularly vulnerable groups.

Table 6: Social Vulnerability Indices Recommended for Use by NOAA

Vulnerability Indices by %	Reason for Choice of Indicator
Minority Populations	Potential language or cultural considerations
Households below Poverty	Limited resources.
Population over Age 65	Possible mobility or cultural considerations.
Single Parent with Child Families	Special child care considerations.
No High School Diploma	Possible need for personal interactivity in lieu of written communication.
Households with Public Assistance Income	Households likely to require public disaster aid.
Housing Rental	Households where contents are least likely to be insured.
Housing Units with No Vehicle Available	Possible mobility considerations.

Table 7: Selected Vulnerability Indices for Portmore and St. Peter

Portmore	St. Peter
Sight	Sight
Hearing	Hearing
Asthma	Mental disability
Hypertension	Loss of use of lower limbs
Diabetes	

CASE STUDY #4
Social Vulnerability Scoring Methodology - PORTMORE

The NOAA scoring system was adapted to Portmore and used to score the social vulnerability indices: population over 65, number of single parent households and number of rental housing. The percentage for each of these variables is first calculated and then the scores are calculated based on these percentages using the following formula:

(X*14)/100= Vulnerability Score

X= percentage

14= (14 is equivalent to 100%)

An average was then calculated for each community and the scores placed in five distinct ranges as shown below:

Low	**(0-2)**
Moderately Low	**(3-5)**
Moderate	**(6-8)**
Moderately High	**(9-11)**
High	**(12-14)**

The same approach was taken for the health variables. The scores for the social vulnerability indices and the health variables were added and averaged to give the total social vulnerability score (see Table 8).

Social Vulnerability Scoring Interpretation

Waterford is described as moderately vulnerable, followed by Portsmouth which has a moderately low vulnerability. These are the two largest communities in the impact zone and therefore the number of projected cases would be greater.

The fishing beaches were also scored because they were regarded as particularly vulnerable communities in relation to the hazard. However, not enough data was available to give a comprehensive score. However, all of the fishing beaches received a low disability score.

Table 8: Social Vulnerability Scores, Portmore

Community	Disability Score	Demographic Score	Average Social Vulnerability Score
Waterford	6	6	**6**
Portsmouth	3	3	**3**
Passage Fort	1	1	**1**
Bridge View	1	1	**1**
Garveymeade	0	0	**0**
West Bay	0	0	**0**
Westmeade	0	0	**0**
Bridgeport	0	0	**0**
Independence. City	0	0	**0**
Edgewater	1	1	**1**
Westchester	1	1	**1**
Port Henderson Main Rd.	0	-	**-**
Portmore Town. Centre	-	-	**-**
Port Henderson Beach	0	-	**-**
Forum Beach	0	-	**-**
Pigeon Shoot Beach	0	-	**-**
Hunts Bay Beach	0	-	**-**
Hellshire Beach	0	-	**-**

iv. Critical Facilities Analysis

According to NOAA (1999), critical facilities are defined as "facilities vital to the health, safety and welfare of the population and that are especially important following a hazardous event. Critical facilities include, but are not limited to, shelters, police and fire stations, hospitals, schools and critical roads and bridges". The functional integrity of the facility must be sufficient to allow the affected community and resources to return to normalcy (functionality) within the shortest possible time with or without outside assistance. There may be some overlap between vulnerable groups as described above, and critical facilities (e.g. hospitals).

A critical facilities analysis assesses the vulnerability of critical elements or key resources in a community to storm surge in a systematic way. It can be used to identify and prioritize mitigation projects.

Damage History Score

- Based on historical records or personal accounts, identify any known previous damages caused specifically by storm surge. This should help estimate vulnerability based on past damage experience.
- The scoring range in this category is higher than that in the structural and operational categories because the determination is less subjective and serves as direct proof of vulnerability.
- If no damages have historically occurred, it implies that the level of vulnerability is reduced. A damage-free past however, does not guarantee a damage-free future.
- This score ranges from "0" for no damage history to "6" for major or repetitive damage.

Recent scientific reports further confirm that global warming and climate change will result *inter alia* in elevated sea surface temperatures, increasingly erratic and variable weather patterns, increasing intensity of hurricanes, and sea level rise. Storm surge associated with hurricanes must therefore become a heightened consideration for coastal areas in the Caribbean and therefore **vulnerability scores with *no damage history* should be considered skewed and not indicative of the major steps to be taken to reduce risk.**

Structural Vulnerability Score

- Scoring of this variable requires some knowledge about the construction of the facility and the existing building codes governing local construction. The scoring in this exercise must therefore be considered preliminary. It is a first-level subjective and qualitative effort at identifying facilities that require more thorough structural investigation with a view to designing any required mitigation measures.

Operational Vulnerability Score

- Operational vulnerability requires knowledge of where daily activities are conducted within the structure. This is necessary to determine which areas of the structure are important to conducting critical daily activities.
- For example, if the first floor of a fire station includes the command centre with radio room and other logistical equipment and supplies, as well as fire trucks, storm surge damage would greatly hamper fire response capabilities. Therefore, the operational vulnerability score would be defined as having "life-threatening impacts", as firefighters would not be readily available to respond to a call.

A “non-operational” score means that the structure is completely unusable and all the equipment is unusable because of damage received.

METHODOLOGY - CRITICAL FACILITIES ANALYSIS

- Identify categories of critical facilities within the inundation zone (Annex I).
- Collect data using a data capture form, (see Annex I).
- Locate and map the critical facilities.
- Identify which critical facilities fall within high-risk areas.
- Assess their vulnerability to physical and operational impacts from the hazard.
- Use scoring methodology to indicate the vulnerability of a facility.

- The scoring system (see Table 9). Critical Facilities Scores should be based on:
  - Damage history;
  - Structural vulnerability; and
  - Operational vulnerability.
- Calculate total vulnerability scores for each facility by adding the scores for damage history, structural vulnerability and operational vulnerability. An example of this can be seen in **Table 10: Vulnerability Scores for two (2) Critical Facilities in the Portmore Community, Jamaica.**
- Map each facility using a colour code to indicate range from highest to lowest vulnerability.

Information Needed and Possible Sources

- Fire & Rescue services - Fire dept
- Police stations - Police Dept
- Transportation network and public vehicles - Public Works Dept, Bus services
- Communication facilities – telecommunications agencies, emergency services
- Hospitals – Health Ministry
- Shelters - Disaster Management Office, Red Cross , other emergency services
- Evacuation routes - Disaster Management Office, Public Works
- Schools

Helpful Hints

Town Planners

Inundation zones should be used as a base to guide siting of critical facilities such as health, transportation, schools, community centres, and in some instances housing developments.

Emergency Managers

Evaluation of the vulnerability of critical facilities to inundation is essential to preparedness and response planning. If storm surge inundation data not available, discussion with community residents is a useful place to start.

Evacuation planning should be guided by critical facilities assessment – roads, transportation centres, shelters, health facilities, etc. Operational vulnerability should be reviewed and factored into planning.

Community Organizations

Community members should be made aware of the location of critical facilities that would need to be accessed during a crisis. Lead time for access is also important, especially if inundation of access routes is a possibility. This information should form part of awareness building.

Operational vulnerability should be reviewed and factored into planning.

Risk transfer

Scoring of the vulnerability of critical facilities can be helpful in assessing insurance risk. However, no damage history is no indication of possible damage in the future. The potential inundation zone should be the dominant consideration.

Structural Vulnerability should be used to encourage implementation of mitigation measures among insured.

Table 9: Critical Facilities Scores

DAMAGE HISTORY		STRUCTURAL VULNERABILITY		OPERATIONAL VULNERABILITY		TOTAL FACILTIES SCORE	
No History	0	Hazard Specific Protection	0	No effect	0	Low	0-2
Minor Damage	2	Meets Building Code	1	Minimal Effect	1	Moderately low	3-5
Moderate Damage	4	Does not meet Building Code	2	Significant Effect	2	Moderate	6-8
Major or Repetitive Damage	6	Hazard Deficiencies	3	Life Threatening Impact	3	Moderately High	9-11
				Non-operational	4	High	12-14

Table 10: [1]Vulnerability Scores for two (2) Critical Facilities in the Portmore Community, Jamaica

TYPE OF FACILITY	FACILITY NAME	LOCATION	DAMAGE HISTORY SCORE	STRUCTURAL VULNERABILITY SCORE	OPERATIONAL VULNERABILITY SCORE	FACILTIES VULNERABILITY SCORE
Police Stations	Waterford Police	Waterford	0	1	4	5
	Bridgeport Police	Bridgeport	0	3	4	7

The results in the table above, show that the Bridgeport Police Station is more vulnerable than the Waterford Police Station. The difference in score is due to its structural vulnerability score. Bridgeport Police Station is moderately vulnerable whereas the Waterford Police Station has a moderately low vulnerability.

[1] Extracted from the Adaptation for Climate Change and Disaster Mitigation: Township Planning Strategies for Storm Surge in the Caribbean- Intermediate Risk Assessment Report, Portmore, Jamaica

v. Environmental Analysis

Natural environmental features can play a major role in non-structural mitigation of storm surge impacts. Assets need to be identified and their status assessed. The identification of the ecological assets included two categories:

1. Assets that are vulnerable to storm surge
2. Assets that would serve a function in minimizing the effects of storm surge.

METHODOLOGY - ENVIRONMENTAL ANALYSIS

1. Identify and map environmental assets in the study area, e.g. mangroves, coral reefs.
2. Assess their ability to act as non-structural measures to buffer the impact of storm surge.
3. Identify intersections of environmentally sensitive areas, secondary risk sites, and natural hazard risk consideration areas.
4. Identify the location of hazardous material and determine the vulnerability to natural hazards.
5. Determine the vulnerability of the critical natural resources to secondary hazard impacts.
6. Assess corrective action required and design program for mitigation.
7. The environmental assets can also be scored to determine the vulnerability of each. (see Case Study #4). The environmental assets scored are those that are most vulnerable to a storm surge event but offer some protection to land based activities. They have been scored both qualitatively (geographical location) and quantitatively (area). The closer the asset is to the coast and the greater the area, the greater is its vulnerability.

Information Needed and Possible Sources

- Ecologic assets e.g. mangroves, coral reefs
- Hazardous material - Health Ministry, Industry
- Sewage facilities - Water and Sewage agency
- Oil facilities - Petrol marketing companies
- Marinas - Tourism agency, Coast guard
- Ports - Transport Ministry, Port Authority
- Effluent Discharge sites - Health and environmental agencies, sewage authority, resorts

Helpful Hints

Town Planners

Use information on natural resources for coastal protection to guide zoning and recommended setbacks.

Link with environmental agencies to obtain required information on coral reefs, beach dunes/berms, seagrass beds, mangroves and other wetlands etc.

Important to review drainage channels that empty into inundation zones – flood history, settlement alongside, etc. Talk with residents of these areas to glean information on experience that may not be recorded elsewhere.

Recommend potential areas of study required to assist town planners with setback requirements – e.g condition of coastal protection - and other land use zoning recommendations for the coast.

Emergency Managers, Community Groups, and Insurance Providers

Lobby for statutes to optimize coastal protection.

CASE STUDY # 5
Environmental Scoring – ST. PETER

Coral reefs are the only environmental asset that was scored in this study. There are two types of coral reefs found along the coast of the study area. **Fringe reefs** are located almost directly off the coastline and are found in patches, whereas **bank reefs** are found further away from the coastline. Bank reefs are directly exposed to storm surge waves and are therefore more vulnerable than fringe reefs. The fringe reefs are protected by the bank reefs and cover a slightly greater area than the bank reefs (See the table below).

The environmental asset was scored both qualitatively, based on the geographical location, and quantitatively, based on the area that they covered. The closer the asset was to the coast and the greater the area, the greater was its vulnerability.

The scores for the qualitative assessment were assigned as follows:

- Exposed 3
- Partially protected 2
- Protected 1

The scores for the quantitative assessment were assigned as follows:

- 0 – 17.8 Ha 1
- 17.9 – 35.7 Ha 2

ENVIRONMENTAL ASSET	GEOGRAPHICAL LOCATION	SCORE	AREA(Ha)	SCORE
Coral Reefs	Bank Reefs	**3**	33.65	**2**
	Fringe Reefs	**2**	35.60	**2**

vi. Economic Analysis

The objective of the economic analysis is to identify the primary economic sectors and how vulnerable they are to the hazard. The NOAA recommended approach for community economic vulnerability assessment is to identify economic vulnerability using five main steps, as summarized next.

In practice this requires identifying primary economic sectors, locating their main economic centers and undertaking an inventory of main economic structures within these centers. This can be facilitated by identifying the largest employers and mapping their locations relative to the high risk areas. This process helps to identify and locate the communities' economically vulnerable assets. Evaluating structures of the larger employers, along the lines of a critical facility, adds a further level of vulnerability assessment. The desired outputs are 1) to use a consultative approach with large employers and other stakeholders to identify, describe and map the sectors that are most vulnerable to the hazard, and 2) to suggest appropriate mitigation measures that can be taken to reduce the hazard's impact.

The hazard impact zone sometimes presents challenges in complexity or size that require adaptations to the above NOAA methodology. The Portmore Pilot Project provides a good example of this. Here the hazard impact area contained a population of some 65,000 persons living in 12 large residential communities, which collectively accounted for only one of five important economic centres. An inventory and mapping of important individual assets would have been very time consuming. The approach taken was to group and locate generally vulnerable assets within five broad economic centers, which were then compared by a scoring system, based on loss of person days of employment projected as arising from the duration of the hazard's impact. For example, the five fishing beaches located within the hazard impact zone, were grouped and analyzed collectively as Fisheries.

Similarly, the Portmore Town Centre was evaluated from the standpoint of it being the main commercial and business centre.

METHODOLOGY: ECONOMIC ANALYSIS (NOAA)

1. Identify primary economic sectors and locate economic centres.
2. Identify intersections of economic centres and high risk areas.
3. Conduct general inventory of high-risk economic sectors.
4. Identify large employers and their intersection with the hazard area.
5. Where possible conduct vulnerability analysis on structures of large employers as critical facilities.

CASE STUDY # 6
Economic Scoring – ST. PETER

A similar approach was adopted for the St. Peter Pilot Project although the hazard area more readily lent itself to the application of the NOAA model than did Portmore. Here, economic sub sectors were used. The table below shows the main sub-sectors defined and their respective loss of person days based on the main employers identified (where applicable).

Estimates of employment were based on interviews conducted at high management levels in firms identified as market leaders. Using estimated market share and their own knowledge of competitors operations, a collective employment figure was calculated for the main firms or groups in each sub sector. To this figure, a 6 or 7 day event period was applied depending on the sector, to arrive at loss of person days.

	ITEM	Employment Numbers	Loss of Person / RRR Days	%	Score
1	**Tourism**	**1,208**	**7,245**	**74.6**	**10**
	▪ Accommodation etc Establishments Little Good Harbour Port St. Charles Heywoods-Almond Beach Sunset Sands Beach Cassandra Beach Capsian Beach The Villas Schooners Bay Cobblers Cove Sandridge Beach Kings Beach	1,108	6,645		
	▪ Restaurants (incl. fast foods) Establishments Pizza Man Doc Fishermans Pub Mango's By The Sea Kentucky Fried Chicken Chefette Restaurant Smaller	100	600		
2	**Retail & Wholesale**	**352**	**2,108**	21.7	**3**
	▪ Food Jordans Eddie's Supermart Hawkers	172	1,028		
	▪ Furniture Courts Manny's Archer Hall	30	180		

	ITEM	Employment Numbers	Loss of Person / RRR Days	%	Score
	▪ Hardware Lincoln Rouck Do It Best Dacosta Mannings	150	900		
3	**Fisheries**	**60**	**360**	**3.7**	**1**
	Speightstown Area Six Mens Bay				
4	**Transportation**	-	-	-	-
5	**Heritage impact**	-	-	-	-
6	**Housing**	-	-	-	-
7	**Sub Total Estimated Loss**	**1,620**	**9,713**		
8	Margin of Error Estimate (+25%)		2,428	20.0	
9	**Total Estimated Loss**		**12,141**		

Information Needed and Possible Sources

- Entertainment Facilities - Statistics Dept, Planning Dept, Local authorities
- Wholesale & Retail Operations - Planning Dept , Local authorities
- Transportation Network and Facilities – Public Works, Ministry of Transport
- Services - Professional agencies, planning department
- Agricultural land use, operations, and earnings - Ministry of Agriculture
- Tourism enterprises and earnings – Tourism Ministry
- Manufacturing - Min Industry, Industrial promotions
- Finance, Insurance – Insurance agencies, Finance Ministry

4.4 Risk Analysis

The risk analysis examines the consequences of the hazard event in terms of the estimated damage and loss, as it relates to those assets identified and mapped. A significant proportion of this damage estimation, focuses on the economic analysis, since in estimating loss,, these assets are amenable to traditional damage assessment cost methods, and are therefore good indicators of the impact of the hazard.. However, other groups discussed within the vulnerability assessment, such as critical areas and environmental assets are also impacted and therefore need to be factored into the analysis.

Definition

Risk = Hazard x Vulnerability

METHODOLOGY - RISK ANALYSIS

In estimating damage the following approach is used:

Physical Structures:

- Identify which **economic** sectors and **centers** fall within the storm surge zone.
- **Buildings including bridges and other infrastructure -** determine replacement cost per unit of measure (for example, cost per square meter), and apply this to the proportion of total building area assumed to be impacted **(see Case Study #7).**

Economic Enterprises:

- **Income loss**- by interviewing business persons in the economic centres, determine potential loss of revenue resulting from the storm surge event.
- **Inventory** - by interviewing business persons in the economic centres, determine potential loss of inventory.
- **Employment**- interviewing business persons in the economic centres, determine potential loss of employment (and monetarize by using wages) **(see Case Study #8).**

Human Resources:

- Loss of Labour Productivity
- Loss of Personal Assets
- Special Vulnerabilities

Natural Resources:

- Estimate area of natural resources impacted.
- Identify protected species within impacted area.
- Where value of individual species is ignored allocate high, medium and low risk areas in relation to area of specific resources impacted.

Adaptations to the NOAA Methodology

In the study of Portmore and St Peter, a modified approach was used with somewhat more satisfactory results. Particular circumstances in both areas facilitated this (see Case Study #6).

- **Buildings -** An average cost of repairs per square meter, based on likely water damage was applied to both residential and commercial structures. This eliminated building area as the base measurement, requiring instead an estimation of internal and external wall measurements.

However such a method is very time consuming and was only used in the Pilot Projects because particular circumstances relating to common building designs, made this feasible.

CASE STUDY # 7
Building Valuation – PORTMORE

Using survey methodology the average square metre of building area was determined for each impacted structure. Since the potential average inundation level was estimated across the inundation zone, this enabled estimates of the total square area to be done for buildings at risk in each community.

Applied to this was a basket of repair costs tailored to the likely severity of the event. This included electrical inspections and plumbing repairs, furniture loss and non-securable appliance repairs. This basket of repairs was modified for commercial buildings and a further differentiation was made for shoreline buildings where structural damage to foundations could be expected.

CASE STUDY # 8
Estimation of Business Loss – PORTMORE

The *Portmore Town Center* comprises over two hundred businesses. The businesses conducted in the town centre were categorized by type and size. In arriving at an indication of the potential damages and loss of income and employment arising from inundation of this critical business centre, structural loss was estimated by applying a 'basket of repair costs' based on assumptions about the severity of water damage related to the event. Data was generated through observation, inspection, interviewing, and best assumptions.

Food Sector

The approach taken with the food sector was found to yield acceptable results and was applied to other categories of businesses where possible.

The restaurant trade is dominated by 3 major fast food chains. The cooperation of one chain allowed its daily loss of revenue arising from the event to be estimated. Its own relative market share and that of its competitors in the Town Centre was used to extrapolate revenue, inventory and employment loss for all food establishments within the Town Centre.

The hardware, electronic, jewelry and clothing sectors, the supermarket, cosmetics and beauty trades were also estimated using this stratagem, see table below.

Number of Buildings estimated for	**27**
Total Impacted Building Area (Sq.m)	40,430
Estimated Damage to Buildings US$(000)	8,832
Loss of Business Income US$(000)	2,131
Estimated Loss of Inventory US$(000)	199,851
Total Damage Assessment US$(000)	202,870
No of Workers Effected (Direct)	1,435
Lost Person Days	8,600

Helpful Hints

- The larger the impact zone the more practical it becomes to use sampling methodologies to drive the assessment.
- The shorter the time frame for conducting the assessment the more selective the data bases should be, but correspondingly the more inferential the resulting conclusions might be.
- The less available or reliable existing data bases are, the greater the reliance that should be placed on informal data sources and rapid appraisal approaches for developing such data.
- Collecting sensitive income data can be facilitated by undertaking to keep individual enterprise data confidential. Further resistance can also be overcome if leading industry players are asked to estimate income loss among competitors by reference to their own market share. This can be done without disclosing their own market share and therefore income.

- **Who will benefit from the Risk Analysis?**

Risk Transfer Providers

- Insurance companies, Business continuity planning, Government contingency funds

Town Planners and Allied Professionals

- Engineers and architects – maintenance, retrofitting, new designs
- Trades persons – maintenance and retrofitting
- Environmental professionals – non-structural mitigation

Community Groups

- Business persons, residents, service providers, Governmenet Departments

5. Institutional Issues

Governance Defined:

"The act of affecting government and monitoring (through policy) the long-term strategy and direction of an organization. In general, governance comprises the traditions, institutions and processes that determine how power is exercised, how citizens are given a voice, and how decisions are made on issues of public concern". www.phac-aspc.gc.ca/vs-sb/voluntarysector/glossary.html.

"Governance in many ways is about the processes of making decisions and the distribution of public responsibility across multiple stakeholders. … there is no single governance model that pertains to disaster risk reduction. What is important is that we must have a clear understanding of the institutional structures, systems and resources within which a disaster risk reduction programme will unfold" (after Collymore, 2006).

Attention to Institutional issues should be more appropriately described as Governance - Legal and Institutional Framework.

Whereas assessment of the institutional framework by which disaster management is facilitated is not part of the NOAA methodology for risk and vulnerability assessment, in the context of the Caribbean and indeed SIDS in general, institutional issues assume sufficient importance to be included in risk analysis.

Building resilience or the ability to cope has been identified as a key focus for disaster risk management in the Caribbean. Central to this task is the issue of governance which involves consideration of the legal and institutional framework which underpins disaster management, as well as partnerships and institutional linkages which can facilitate collaboration and accountability toward effective disaster risk reduction.

The methodology to be followed requires the consideration of the following issues:

- Assessing the legal, regulatory and policy framework; and
- Assessing institutional and management arrangements.

Key Words

Governance, Mainstreaming, Disaster Risk Management, Disaster Risk Reduction, Legal and regulatory framework, partnerships, linkages, Hyogo Framework, ISDR Global Platform for Disaster Risk Reduction, ISDR Caribbean Platform for Disaster Risk Reduction, IDB Disaster Management Policy, IDB Disaster Prevention Fund, Built Environment, Early Warning systems, Capacity Enhancement, Hurricane Forecasting, preparedness, response.

METHODOLOGY - ASSESSING THE LEGAL, REGULATORY AND POLICY FRAMEWORK

Assess the Legal and Institutional Framework as relevant to the hazard under the following subheadings:

- **Built environment** e.g. Housing Acts, Building Codes, Planning and Zoning Regulations, Disaster Management Acts, etc.
- **Natural environment** e.g. Beach Control , Flood Water Control
- **Regional Considerations** e.g. Caribbean Comprehensive Disaster Management (CDM) Framework, Caribbean Platform for Action (ISDR)
- **International Legislation and Treaty Obligations** e.g. IDB Disaster Risk Management Policy
- **Global Disaster Risk Reduction Initiatives** e.g. Global Platform for Disaster Risk Reduction.

- The legislation which addresses the built environment, natural environment and disaster management can then be scored using a matrix, in Table .
- The scores for this assessment were assigned as follows:

- Legislation Exists, YES	1
- Legislation Exists, NO	2
- Legislation Fully Enforced	1
- Legislation Partially Enforced	2
- Legislation Not Enforced	3

Table 11: Legislation Scoring

	LEGISLATION	EXISTS	ENFORCED
BUILT ENVIRONMENT			
NATURAL ENVIRONMENT			
DISASTER MANAGEMENT			

Information Needed and Possible Sources

Legislation for:

- Built environment - Environmental agencies, Town Planning Depts, Legislative agencies;
- Natural environment - Environmental agencies, Legislative agencies;
- Regional consideration – Min. Foreign Affairs, CARICOM, OECS;
- International legislation - Min Foreign Affairs, www.sidsnet.com; and
- Global disaster risk reduction initiatives - CARDIN, CDERA, UNDP.

METHODOLOGY -- ASSESSING INSTITUTIONAL AND MANAGEMENT ARRANGEMENTS

Indicate whether these arrangements exist. If they do, determine whether they need to be improved. If not in place, indicate reason and seek advice as to how to recommend steps to implement.

Management and operational structures

▪ National Disaster Management Office	Y/N
▪ Staff Complement	Meets benchmark
▪ District level organization	Y/N
▪ Linkages for preparedness and response	Y/N
▪ Linkages for Prevention and Mitigation	Y/N
▪ Linkages for recovery	Y/N

Early Warning Systems

- Linkages with forecasting service
- Linkages with community receptors – key stakeholders/organisations
- Relevant Communication network

Development planning process

- Are there building codes?
- Are the resources adequate for enforcement?
- Do zoning ordinances exist?
- Are they enforced?
- Does development planning include hazard vulnerability assessment?
- Are historic storm surges documented?

Emergency management process

- Is there a National Emergency Operations Centre?
- Is the centre well-equipped? – communications, supplies?
- Are there disaster management committees?
- Is there a communication system with appropriate and synchronized radio connections?
- Are roles and responsibilities of all emergency managers clearly defined?
- Have linkages been agreed and documented for emergency assistance, damage assessment and for early recovery?

Community prevention, preparedness and mitigation capabilities

- Are communities aware of the storm surge risk – areas to be inundated?
- Have opportunities been identified to reduce the impact of storm surge on settlements, economic livelihoods, other land use?
- Have evacuation plans been developed with community participation?
- Have shelters been identified and checked for structural soundness and flood resistance?
- Is there a clearly enunciated policy for relief? Are there community organizations linked to provide early response ?
- Have these procedures been effectively understood and accepted by the population and key stakeholders?

Readiness

- Are there risk transfer opportunities and arrangements?
- Are there contingency funds to support response and early recovery?
- Are disaster management plans and policies current – evacuation plans, shelter plans and disaster relief policies?

Each Category of assessment is considered important to Disaster Risk Management. Where the answer to the question is "No", this item should be placed on an action list. The appropriate and relevant approaches for development and implementation should be explored.

See Case Study #9 below.

Information Needed and Possible sources

- Management and operational structures - Disaster Mgt agencies, Emergency services;
- Early warning systems - Disaster Mgt agencies, Emergency services;
- Development plans - Planning Departments;
- Emergency management plans - Disaster mgt agency, emergency services;

CASE STUDY #9
Hazard Risk Management - BRITISH VIRGIN ISLANDS

Background. Hurricane Hugo had a major effect on the physical and socio-economic fabric of the BVI in September 1989. Losses amounted to US$40 million and 30 per cent of the country's housing stock was destroyed. This event was a catalyst for the introduction of an administrative, operational and policy framework to reduce the impacts of future hazard events. In response, the Government recruited regional disaster management professionals for advice on how best to strengthen the country's technical capacity for disaster management.

A new approach to disasters. The post-Hurricane Hugo assessment study undertaken in 1993, represented an important departure from the traditional approaches to disaster management that focused on response and recovery, and shifted the emphasis to mitigation. This study influenced all subsequent work on hazard assessment and disaster mitigation in the BVI, including the 1997 Hazard Risk Assessment, the 1999 Building Regulations, revised development standards, environmental protection measures and the current Mitigation Strategy, which was recently submitted to Executive Council.

Lessons.

1. Disaster and hazard risk management in the BVI has benefited tremendously from strong political support of the territory's Governor and Deputy Governor. Successive Chief Ministers have also provided financial and political support.

2. Much emphasis has been placed on public awareness and education for disaster and hazard risk management. The aggressive approach of the national disaster agencies, is reflected in the high level of consciousness among residents of the need to adopt appropriate hazard resistant construction practices. Almost all new buildings are equipped with hurricane shutters, which are manufactured locally and exempted from government taxes—a practical example of government's commitment to disaster mitigation.

3. The BVI has pursued an integrated approach to disaster management at the institutional level. Collaboration between the Physical Planning Department, Development Planning Unit and the Department of Disaster Management resulted in a framework for incorporating disaster and hazard risk management into physical and economic planning. The disaster office, for instance, provides direct budget assistance to other sectors in the development of hazard contingency plans.

Source: http://www.oas.org/cdmp/riskmatrix/RM_CGCED.DOC

UNDP/CRMI 2005. Best Practice Case Study of the BVI. Integration of Disaster Risk Management into the Development Agenda

6. Awareness Raising and Improved Preparedness

Awareness Raising Defined *- processes of informing the general population, increasing levels of consciousness about risks and how people can act to reduce their exposure to hazards (ISDR, 2004).*

Preparedness Defined *- Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations (ISDR, 2004).*

The methodology to be followed requires the consideration of the following issues:

- Raising awareness – risk communication
- Crisis communication
- Early warning systems
- Contingency planning
- Evacuation planning

Key Words

Awareness, risk communication, crisis communication, acceptable risk, early warning systems, contingency planning, shelters, evacuation planning,, gender sensitivity

Summary Points

"Culturally adaptive communication programmes should be developed in case of disaster".

(Workshop on Awareness- Raising in Disaster Management in Sri Lanka)

METHODOLOGY - RAISING AWARENESS – RISK COMMUNICATION

Raising awareness is an important step toward improved preparedness. Both awareness raising and improved preparedness for the storm surge hazard are particularly important for coastal areas, which are within the storm surge zone and tend to be highly populated within the Caribbean. The following activities should be included:

- Risk communication
- Crisis communication
- Early warning systems
- Contingency planning
- Evacuation planning
- Emergency shelter strategies

The VAT serves as a diagnostic instrument, and its application to a selected community generates data on risk which can in turn be used to inform awareness.

Risk communication involves the dissemination of information on the hazard in a manner that is easily understood by each of the selected target audiences. The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions are also included. For the Caribbean, heightened understanding of the storm surge hazard and coastal vulnerability is an essential target, particularly in the light of climate change. Climate change will engender sea level rise and increase the incidence and intensity of extreme hydro meteorological events. Storm surge should be explained in terms of how it is related to the hurricane approaching, the track, pressure, and wind speed. The data presented in section 2.1 should be used.

What should we do and what should we learn?

- Understand the nature and characteristics of hurricanes.
- Understand the nature of hurricanes and associated surge levels. When a hurricane is approaching pay attention to the track. Determine how the system will pass your territory – southerly, northerly, over land etc. The direction will influence the type and level of surge impact on the respective coastline.
- Understand the nature and characteristics of storm surge. How is it generated?
- What is the likely impact on your community?
- What preparedness measures are needed to minimize loss of lives and property?
- What are the needs of female-headed households?

Information Needed:

- Damage history for your area. – Disaster Management Agency, Public Works, Community organizations, CDERA;
- Storm surge inundation maps - Planning, CDERA;
- Communities at risk – CDERA, Met services, Works Ministry, Agriculture and Social service Ministries;
- Hurricane tracks - Met services, Disaster Agency, CDERA; and
- Gender characteristics of community population – Statistics Dept.

Recommendations:

- Segment the audience and develop targeted messages for each of the user groups – planners including engineers, architects, and environmental professionals.
- Emphasize hurricane tracking and barometric pressure at the centre (eye), see Table .
- Identify key informants – local disaster committees, relief/response agencies.
- Develop a plan - Identify network for information dissemination as appropriate to country/community – national organization, disaster committees, community groups, relief agencies etc.
- Conduct awareness sessions at the level of community – expose participants to surge inundation maps.
- Discuss issues of vulnerability – natural and created.
- Solicit participatory input for development of preparedness plans.
- Solicit community feedback on any particular needs of women.

Table 12: Saffir Simpson Hurricane Scale with Central Barimetric Pressure Ranges

CATEGORY	CENTRAL PRESSURE		WINDS	SURGE	DAMAGE
	mbars	In	(mph)	(ft)	
1	>980	>28.94	74-95	4-5	Minimal
2	965-979	28.50-28.91	96-110	6-8	Moderate
3	945-964	27.91-28.47	111-130	9-12	Extensive
4	920-944	27.17-27.88	131-155	13-18	Extreme
5	<920	<27.17	>155	>18	Catastrophic

Information Needed and Possible Sources

- Risk communication systems – CDERA
- Crisis communication systems - CDERA
- Early warning systems – Disaster Mgt Agency, CDERA, UNDP
- Contingency plans - Disaster Mgt Agency, CDERA, UNDP
- Evacuation plans - Disaster Mgt Agency, CDERA, UNDP
- Emergency shelter strategies – CDERA

METHODOLOGY - CRISIS COMMUNICATION

- Crisis Communication is part of preparedness planning to handle the event itself. A plan should be developed before an event to identify procedures for communicating with the various publics that relate to each of the target audiences for this toolkit. (see Case Study # 10): These are:
  - Development Professionals - Town Planners, engineers, architects;
  - Environmental professionals;
  - Emergency Managers;
  - Community Managers; and
  - Risk Transfer Specialists.
- Agencies of Government, private sector entities, and community organizations should each:
  - Develop a communication plan.
  - Identify a leader and spokesperson.
  - Establish the protocol for receiving and disseminating messages related to crisis associated with the storm surge and related flooding.
- A media communication plan is important to this process as the media has a key role to play in getting the correct message out in the appropriate time through radio, television, and print. The plan should include:
  - Information on the characteristics of the storm surge hazard as relates to the impending hurricane.
  - Maps of potential inundation areas should be posted and disseminated to key stakeholders.
  - Vulnerable facilities and communities, economic enterprise should be highlighted.
  - Vulnerable facilities, communities, special groups and economic enterprise should be highlighted.

METHODOLOGY - EARLY WARNING SYSTEMS

"The provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response" (ISDR).

Early warning systems involve a series of components:

- understanding and mapping the hazard;
- defining the inundation zone;
- monitoring and forecasting impending hurricane events;
- establishing links with meteorological services;
- processing and disseminating understandable warnings to political authorities and the population;
- establishing an effective communication system with the required equipment and transmission capabilities; and
- inclusion of EWS as part of the contingency planning.

METHODOLOGY - CONTINGENCY PLANNING

"The means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster".

Contingency planning enables the undertaking of appropriate and timely actions in response to s disaster. It involves:

- the development of community focal point groups;
- the development of a disaster plan that is linked with the national disaster plan and its hurricane sub-plan;
- the incorporation of storm surge hazard information;
- a communication system;
- response agencies such as (Red Cross, ADRA, Salvation Army, etc) which are essential to this process; and
- the cooperation of businesses, which should be encouraged and assisted to identify aspects of their vulnerability to storm surge and develop disaster contingency plans.

METHODOLOGY - EVACUATION PLANNING

- Hazard maps should be used to determine evacuation routes for public transportation (for mass evacuation) and evacuation routes for individual evacuation.
- Community groups should be involved in the evacuation planning process.
- Community focal points should be identified.
- Vulnerable groups within each community should be identified, and included within the plan.
- Shelters and/ or receiving points should be defined.
- Early Warning Systems should inform the activation of the Plan.
- The plan should include guidelines which speak to the return to residences after the passage of a hazard event.
- Evacuation plans should be improved as population grows and as major changes in the communities take place, such as the construction of new roads, or the creation of one-ways, etc.

METHODOLOGY: EMERGENCY SHELTER STRATEGIES

- Shelters should be located outside of storm surge zones (located far from the coast, rivers and other waterways).
- Each shelter's structural soundness should be properly assessed (see critical facilities above).
- Each shelter should have adequate facilities, such as toilets, kitchens and standby generators. Considerations of gender needs should be included.
- There should be a list of facilities available for each community and this should also be included in the evacuation plan.
- The "Home as Shelter" aspect of the CDERA Shelter strategy will not be appropriate for homes that lie within the inundation zone.

CASE STUDY #10
Community Involvement in reducing risks – DOMINICAN REPUBLIC

In the Dominican Republic, the Asociación Dominicana de Mitigación de Desastres (ADMD) and a coalition of NGOs have championed disaster preparedness and prevention among the most vulnerable communities, conducting workshops in over 700 communities since 1995. In these workshops, local participants prepare a community emergency plan, which is built on an assessment of local hazard vulnerabilities and of locally available resources to address those vulnerabilities.

During hurricane Georges (1998), communities that had established emergency committees through this program successfully evacuated people from flood prone areas, established shelters, organized clean-up brigades, and requested and distributed assistance without incident. In addition, these communities have identified and implemented small risk reduction projects and actions. Projects, such as the construction of containment walls and drainage ditch embankments, are designed to address local health and environmental contamination problems as well as reduce and mitigate the constant floods and landslides, which are a daily concern for these communities. The positive effect of these initiatives was demonstrated by the reduced impact of hurricane Georges on the participating communities.

http://www.oas.org/cdmp/riskmatrix/RM_CGCED.DOC

7. Prevention and Mitigation Measures

Prevention Defined:

"Activities to provide outright avoidance of the adverse impact of hazards and means to minimize related environmental, technological and biological disasters" (ISDR, 2004).

Mitigation Defined:

"Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards" (ISDR, 2004).

The mitigation measures should be designed to minimize or eliminate damage from a storm surge event. Mitigation measures can address the physical, social and environmental vulnerability, and should be a combination of structural and non-structural measures. The period after a disaster provides an important window of opportunity for implementing risk management measures. These measures should be implemented as a component of prevention planning, but should also inform recovery so as to avoid rebuilding vulnerability.

The methodology draws heavily on the hazard and vulnerability maps that have been generated for the risk assessment. The principal objective of the methodology is to identify opportunities to reduce adverse impacts from the storm surge.

Key Words

Vulnerability, mitigation, structural measures, non-structural measures, land use planning, building codes, post disaster measures, environmental measures, socio-economic measures, post disaster measures.

Summary Points

Mitigation measures should be designed to minimize or eliminate damage from a storm surge event.

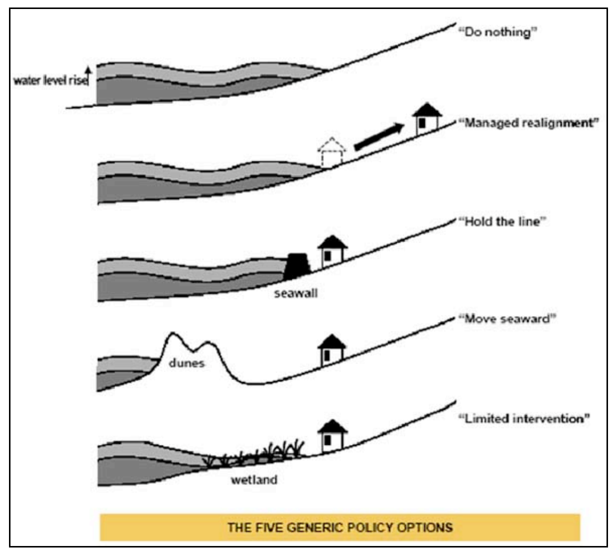


Figure 10. Five general coastal management strategies (http://en.wikipedia.org/wiki/Coastal_defence)

METHODOLOGY:
IDENTIFY PREVENTION AND MITIGATION MEASURES

- Locate and gather data on historical incidence of storm surge.
- Identify people, property and resources that are vulnerable to the hazard.
- Identify undeveloped land and existing zoning ordinances.
- Assess the status of the existing perils (hazard) insurance program participation.
- Identify potential mitigation measures (structural and non-structural)for storm surge loss reduction.

Structural Measures:

- These include any actions that require the construction or strengthening of facilities or altering of the environment to reduce the effects of a storm surge.

Environmental Measures

- These may be used to protect existing, or to rehabilitate degraded, environmental systems that have the capacity to reduce the impacts of natural hazards. Beach protection works such as groynes and artificial reefs are examples.

Non- Structural Measures:

- These include policies and programs that guide future development and investment towards reduced hazard vulnerability. For example, physical development plans, development regulations, acquisition of hazardous properties, tax and fiscal incentives and public education.
- Land Use Planning - "involves studies and mapping, analysis of environmental and hazard data, formulation of alternative land-use decisions and design of a long-range plan for different geographical and administrative scales. It can help to mitigate disasters and reduce risks by discouraging high-density settlements and construction of key installations in hazard-prone areas, control of population density and expansion, and in the siting of service routes for transport, power, water, sewage and other critical facilities" (ISDR,2004).
- Building Codes- "These are ordinances and regulations controlling the design, construction, materials, alteration and occupancy of any structure to insure human safety and welfare. Building codes include both technical and functional standards" (ISDR, 2004).

Socio-economic Measures

- National Disaster Offices, through their district- or community-level organizations, build awareness of hazards and vulnerabilities and help construct community and mutual assistance networks and programs. Public- and private-sector employment protection programs help ensure the availability of jobs and income after hazard events. Effective community- and national-level social networks and health systems also contribute to assuring continuity and recovery after a disaster event.

Environmental Measures

- These can be policies, programs, and regulations such as zoning, development control, and environmental assessments. These measures can provide data and mechanisms to reduce or eliminate the effect of storm surge on human settlements, livelihoods and economic enterprise. Natural hazard vulnerability considerations should be integrated into project development so as to minimize potential loss.
- Secondary environmental impacts should also be minimized e.g. oil spills caused by storm wave impact on storage facilities.

Post-disaster Measures:

- It is important that vulnerability is not increased after a disaster. Reconstruction and rehabilitation should be good enough to stand up to future events.
- Reconstruction policy and practices should form an important component of a comprehensive risk reduction program.

See Case Studies # 11-14

Information Needed

- Structural measures - Engineering Organisations, Works Ministry
- Non-structural measures – Environmental agencies, Engineering Profession
- Policy status - Lands and surveys Dept
- Undeveloped land - Lands and surveys Dept
- Population projections - Statistics Dept
- Land cover change - Lands and surveys Dept
- Zoning – Planning Dept

CASE STUDY # 11
Suggested Mitigation Measures – ST. PETER

For Speightstown, the built environment is fully developed in a strip along the coastline. **For this town, structural mitigation measures include the possible reinforcement of an existing seawall, to withstand the predicted level of storm surge for this area. In addition, a structural condition survey should be carried out at a frequency of approximately once every 5 years, and any structural deficiencies noted and repairs carried out.**

For adjacent areas in St. Peter, structural mitigation measures may include beach nourishment, achieved either with sand alone or through the use of retaining structures such as groynes or breakwaters. In addition, buried revetments may be used to act as a last line of defense in the protection of building property.

Intermediate Risk Assessment Report: St. Peter, Barbados. Adaptation for Climate Change and Disaster Mitigation: Township Planning Strategies for Storm Surge in the Caribbean (CDERA and IDB (2007).

CASE STUDY # 12
Safer Housing in Vulnerable Communities

A large portion of the housing in the region is constructed outside of the formal development process. Inadequate building materials and standards render much of this housing vulnerable to natural hazards. To address this vulnerability, national development foundations in Antigua and Barbuda, Dominica and St. Lucia have implemented hurricane-resistant home improvement programs at the community level. These programs are designed to strengthen safer building practices in the informal housing sector by conducting safer building training workshops for builders and artisans, and by providing access to loans for home retrofit and upgrade.

http://www.oas.org/cdmp/riskmatrix/RM_CGCED.DOC

CASE STUDY # 13
Costs and Benefits of Building Resilient Infrastructure:
Lessons from Port Zante - ST. KITTS & NEVIS

Background. In September 1998, Hurricane Georges inflicted particularly severe damage on St. Kitts and Nevis. Besides damage to a large number of houses in low-income communities as well as to an important hospital, a critical cruise ship facility at Port Zante for was damaged and put out of action for four years.

Issue: invest more up-front in a stronger port facility or take a chance on a rare disaster?

How big were the losses? The original cost of construction of Port Zante is estimated at US$22.5M, and the damage from hurricane Georges at US$10.1M. Payment on insurance claims for material damage and business interruption amounted to US$8.1M. Reconstruction was started shortly afterwards, but was further interrupted by Hurricane Lenny. Damage from that event amounted to US$14.1M, with the insurance paying out US$11.7M. The cost of reconstruction following Lenny is estimated at US$26.2M. Assuming a cost of reconstruction of US$4.0M between Georges and Lenny, the government of St. Kitts & Nevis will have spent a total of US$32.9M on construction and reconstruction, net of insurance receipts—US$10.4M more than the original construction cost. In addition, there has been a critical loss of revenue to the national economy over a 4 year period and additional finance charges incurred by government for reconstruction.

What could have been done to avoid the losses? Good practice in building port facilities in the Caribbean is to design the structures to withstand the 1 in 50 year storm. The additional cost, based on experience elsewhere, to withstand higher wave heights is estimated in the 10-15% range. The pier in Plymouth, Montserrat, which has a tropical storm exposure similar to Port Zante, was designed for a 50 year wave, built in 1993, and has not suffered any damage to date.[2]

Lessons

1. If the facility had been designed and built from the outset to withstand a 50 year wave, it is highly unlikely that it would have suffered significant damage from either hurricane. Based on experience in similar projects throughout the region, the additional investment cost is estimated in the 10 to 15% range, or around $3.0M. This is less than one third of the net additional cost for rebuilding the port, and only slightly more than the estimated additional yearly income [$2 million] a fully operational Port Zante would have generated. Thorough hazard assessments and independent reviews of designs should be required when investing in critical infrastructure.

http://www.oas.org/cdmp/riskmatrix/RM_CGCED.DOC

[2] See http://cdcm.eng.uwi.tt/

CASE STUDY # 14

Natural Hazard Risk Management - BRITISH VIRGIN ISLANDS

Disaster Management in the BVI received a shot in the arm following the traumatic effects of Hurricane Hugo on the physical and socio-economic fabric of the country and on the psyche of the people in September 1989. Losses from Hurricane Hugo amounted to US$40 million and 30 per cent of the country's housing stock was destroyed. The Government recruited regional disaster management professionals for advice and to strengthen the country's technical capacity for disaster management. A 1993 post-Hurricane Hugo Assessment Study commissioned by PAHO focused on sustainable development issues and recommended specific mitigation measures and an approach to integrating disaster mitigation into the country's development process.

Hurricane Hugo prompted a new approach. To a large extent, the experience of Hugo was the catalyst for introduction of an administrative, operational and policy framework to reduce the impacts of future hazard events. The post-Hurricane Hugo Assessment Study also represented a departure from the traditional approaches to disaster management that focused on response and recovery and shifted the emphasis to mitigation. The Study informed all subsequent work on hazard assessment and disaster mitigation in the BVI, including the 1997 Hazard Risk Assessment, the 1999 Building Regulations, revised development standards, environmental protection measures and the current Mitigation Strategy that was recently submitted to Executive Council for its approval.

Under a UNDP/UNCHS project initiative a draft National Physical Development Plan for the BVI was started in 1992. As part of the plan preparation process the need for detailed information on hazard risks facing the country was recognized. This culminated in the completion of a comprehensive Hazard and Risk Assessment Study for the territory in 1997. The Study identified and mapped all major hazards affecting the territory.

Strong Political Support for Hazard Risk Management. Disaster management and mitigation in the BVI has also benefited from the strong political support of the territory's Governor and Deputy Governor who have demonstrated a keen understanding of relevant disaster issues and what is required to address them and are willing to champion the cause of disaster management and mitigation. Successive Chief Ministers have also provided financial and political support for disaster management. Furthermore, the BVI can afford to and does invest heavily in implementation of disaster mitigation measures, strengthening institutional capacity and manpower development and training.

Public Awareness. Much emphasis has been placed on public awareness and education with respect to disaster management and mitigation. The aggressive approach of the national disaster agencies paid dividends and this is reflected in the high level of consciousness among residents of the need to adopt appropriate hazard resistant construction techniques. It is estimated that almost 100% of new buildings are equipped with hurricane shutters, which are exempted from government taxes—a practical example of government's commitment to disaster mitigation. Local industries also manufacture shutters, making them easily available locally and for export to other Caribbean islands.

The BVI experience also highlights the importance of an integrated approach to disaster management at the institutional level. Collaboration between the Physical Planning Department, Development Planning Unit and the Department of Disaster Management resulted in development of a framework for incorporating disaster management and mitigation into physical and economic planning.

http://www.oas.org/cdmp/riskmatrix/RM_CGCED.DOC

8. Annex I: Tropical Cyclones

8.1 Tropical Cyclones – Concept and Classification

8.1.1 Concept

A **tropical cyclone** is a type of storm system characterized by a low pressure center and thunderstorms, producing strong wind and flooding rain. A tropical cyclone feeds on the heat released when moist air rises and the water vapor condenses. Because tropical cyclones are "warm core" storm systems, they are fueled by a different heat mechanism than other cyclonic windstorms such as nor'easters, European windstorms, and polar lows.

Tropical cyclones can produce extremely strong and powerful winds, tornadoes, torrential rain, high waves, and storm surge. They are born and sustained over large bodies of warm water, and lose their strength over land. This is the reason coastal regions can receive significant damage from a tropical cyclone, while inland regions are relatively safe from receiving strong winds. Heavy rains, however, can produce significant flooding inland, and storm surges can produce extensive coastal flooding up to 25 mi (40 km) inland. Although their effects on human populations can be devastating, tropical cyclones can also relieve drought conditions. They carry heat and energy away from the tropics towards the temperate latitudes, an important mechanism of the global atmospheric circulation that helps maintain equilibrium in the Earth's troposphere, and to maintain a relatively stable and warm temperature worldwide.

Many tropical cyclones develop when the atmospheric conditions around a weak disturbance in the atmosphere are favorable. Others form when other types of cyclones acquire tropical characteristics. Tropical systems are then moved by steering winds in the troposphere; if the conditions remain favorable, the tropical disturbance intensifies, and can develop an eye. On the other end of the spectrum, if the conditions around the system deteriorate, or the tropical cyclone makes landfall, the system weakens and dissipates.

8.1.2 Classification

Tropical cyclones can be classified based on their location and their intensity.

a) According to the location of the world in which they originate, tropical cyclones are known as **hurricanes, typhoons, severe tropical cyclones, cyclonic storms, and tropical cyclones.**

- A **hurricane** is a severe tropical storm that forms in the North Atlantic Ocean, the Northeast Pacific Ocean east of the dateline, or the South Pacific Ocean east of 160E.
- A **typhoon** is a severe tropical storm that forms in the Northwest Pacific Ocean west of the dateline.
- A **severe tropical cyclone** is a tropical storm that originates in the Southwest Pacific Ocean west of 160E or Southeast Indian Ocean east of 90E.
- A **cyclonic storm** is a severe tropical storm that originates in the North Indian Ocean.
- A **tropical cyclone** is a severe tropical storm that originates in the Southwest Indian Ocean.

b) Tropical cyclones are classified into three main groups, based on intensity: **tropical depressions, tropical storms,** and a third group of more intense storms, whose name, as indicated above, depends on the region of the world in which they originate.

- A **tropical depression** is an organized system of clouds and thunderstorms with a defined surface circulation and maximum sustained winds[3] of less than 17 m/s (33 kt[4], 38 mph, or 62 km/h). It has no eye and does not typically have the organization or the spiral shape of more powerful storms. However, it is already a low-pressure system, hence the name "depression."

- A **tropical storm** is an organized system of strong thunderstorms with a defined surface circulation and maximum sustained winds between 17 and 32 m/s (34–63 kt, 39–73 mph, or 62–117 km/h). At this point, the distinctive cyclonic shape starts to develop, although an eye is not usually present.
- A **hurricane** or **typhoon** (sometimes simply referred to as a tropical cyclone, as opposed to a depression or storm) is a tropical weather system of strong thunderstorms with a well-defined surface circulation and sustained winds of at least 33 m/s (64 kt, 74 mph, or 118 km/h). A cyclone of this intensity tends to develop an eye, an area of relative calm (and lowest atmospheric pressure) at the center of circulation. The eye is often visible in satellite images as a small, circular, cloud-free spot. Surrounding the eye is the eyewall, an area about 16–80 km (10–50 mi) wide in which the strongest thunderstorms and winds circulate around the storm's center. Maximum sustained winds in the strongest tropical cyclones have been estimated at about 85 m/s (165 kt, 190 mph, 305 km/h).

As shown above, each basin uses a separate system of terminology, making comparisons between different basins difficult.

[3] Sustained Winds: a 1-minute average wind measured at about 33 ft (10 m) above the surface.

[4] 1 knot = 1 nautical mile per hour or 1.15 statue miles per hour. Abbreviated as “kt”.

8.2 Tropical Cyclones – Formation

8.2.1 Factors

The formation of tropical cyclones is the topic of extensive ongoing research and is still not fully understood. Six factors appear to be generally necessary, although tropical cyclones may occasionally form without meeting all of these conditions.

1. Water temperatures of at least 26.5 °C (80°F) are needed down to a depth of at least 50 m (150 feet). Waters of this temperature cause the overlying atmosphere to be unstable enough to sustain convection and thunderstorms.
2. Another factor is rapid cooling with height. This allows the release of latent heat, which is the source of energy in a tropical cyclone.
3. High humidity is needed, especially in the lower-to-mid troposphere; when there is a great deal of moisture in the atmosphere, conditions are more favorable for disturbances to develop.
4. Low amounts of wind shear are needed, as when shear is high, the convection in a cyclone or disturbance will be disrupted, preventing formation of the feedback loop.
5. Tropical cyclones generally need to form over 500 km (310 miles) or 5 degrees from the equator. This allows the Coriolis force to deflect winds blowing towards the low pressure center, causing a circulation.
6. Lastly, a formative tropical cyclone needs pre-existing system of disturbed weather. The system must have some sort of circulation as well as a low pressure center.

8.2.2 Locations of formation

Most tropical cyclones form in a worldwide band of thunderstorm activity called by several names: the Intertropical Discontinuity (ITD), the Intertropical Convergence Zone (ITCZ), or the monsoon trough. Another important source of atmospheric instability is found in tropical waves, which cause about 85% of intense tropical cyclones in the Atlantic ocean, and which most of the tropical cyclones in the Eastern Pacific basin.

Tropical cyclones form where sea temperatures are high, usually at about 27 degrees celsius. They originate on the eastern side of oceans, but move west, intensifying as they move. Most of these systems form between 10 and 30 degrees of the equator and 87% form within 20 degrees of it. Because the Coriolis effect initiates and maintains tropical cyclone rotation, tropical cyclones rarely form or move within about 5 degrees of the equator, where the Coriolis effect is weakest. However, it is possible for tropical cyclones to form within this boundary.

8.2.3 Times of Formation

Worldwide, tropical cyclone activity peaks in late summer when the difference between temperatures aloft and sea surface temperatures are the greatest. However, each particular basin has its own seasonal patterns. On a worldwide scale, May is the least active month, while September is the most active.

In the North Atlantic, a distinct hurricane season occurs from June 1 to November 30, sharply peaking from late August through September. The statistical peak of the North Atlantic hurricane season is September 10. The Northeast Pacific has a broader period of activity, but in a similar time frame to the Atlantic. The Northwest Pacific sees tropical cyclones year-round, with a minimum in February and a peak in early September. In the North Indian basin, storms are most common from April to December, with peaks in May and November.

In the Southern Hemisphere, tropical cyclone activity begins in late October and ends in May. Southern Hemisphere activity peaks in mid-February to early March.

8.3 Tropical Cyclones – Physical Structure: Parameters and Mechanics

All tropical cyclones rotate around an area of low atmospheric pressure near the Earth's surface. The pressures recorded at the centers of tropical cyclones are among the lowest that occur on Earth's surface at sea level. Tropical cyclones are characterized and driven by the release of large amounts of latent heat of condensation as moist air is carried upwards and its water vapor condenses. This heat is distributed vertically, around the center of the storm. Thus, at any given altitude (except close to the surface where water temperature dictates air temperature) the environment inside the cyclone is warmer than its outer surroundings. Rainbands are bands of showers and thunderstorms that spiral cyclonically toward the storm center. High wind gusts and heavy downpours often occur in individual rainbands, with relatively calm weather between bands. Tornadoes often form in the rainbands of landfalling tropical cyclones. Intense annular tropical cyclones are distinctive for their lack of rainbands. While all surface low pressure areas require divergence aloft to continue deepening, the divergence over tropical cyclones is in all directions away from the center. The upper levels of a tropical cyclone feature winds headed away from the center of the storm with an anticyclonic rotation, due to the Coriolis force. Winds at the surface are strongly cyclonic, weaken with height, and eventually reverse themselves. Tropical cyclones owe this unique characteristic to requiring a relative lack of vertical wind shear to maintain the warm core at the center of the storm.

A strong tropical cyclone will harbor an area of sinking air at the center of circulation, developing into an eye. Weather in the eye is normally calm and free of clouds, however, the sea may be extremely violent. The eye is normally circular in shape, and may range in size from 3 to 370 km (2–230 miles) in diameter.

There are other features that either surround the eye, or cover it. The central dense overcast (CDO) is the shield of cirrus clouds produced by the eyewall thunderstorms; in weaker tropical cyclones, the CDO may cover the eye completely. The eyewall is a band around the eye, in which the greatest wind speeds are found, and where clouds reach the highest and precipitation is the heaviest. The heaviest wind damage occurs where a hurricane's eyewall passes over land. Associated with eyewalls are eyewall replacement cycles, which occur naturally in intense tropical cyclones. When cyclones reach peak intensity they usually - but not always - have an eyewall and radius of maximum winds that contract to a very small size, around 10–25 km (5 to 15 miles). At this point, some of the outer rainbands may organize into an outer ring of thunderstorms that slowly moves inward and robs the inner eyewall of its needed moisture and angular momentum. During this phase, the tropical cyclone weakens (i.e. the maximum winds die off a bit and the central pressure goes up), but eventually the outer eyewall replaces the inner one completely. The storm can be of the same intensity as it was previously or, in some cases, it can be even stronger after the eyewall replacement cycle. Even if the cyclone is weaker at the end of the cycle, the fact that it has just undergone one and will not undergo another one soon will allow it to strengthen further, if other conditions allow it to do so.

8.3.1 Parameters

Figure shows a schematic of the characteristic components of a tropical cyclone or hurricane. These severe weather systems range in diameter from 200-1300 km and have life spans lasting between one and 30 days. Winds in a hurricane increase from their lowest speeds at the eye (low-pressure center) to a maximum, immediately beyond the eye. The wind speed then decreases gradually outwards from the eye. The radius at which *maximum wind speeds* (V_{max}) occur is termed as the *radius to maximum winds* (R_{max}). The maximum wind speeds around the eye are the same order of magnitude even though the overall distribution of the wind speed over the entire body of the hurricane varies. In particular, winds in the right front quadrant are strongest because of the additional forward component due to the movement of the hurricane.

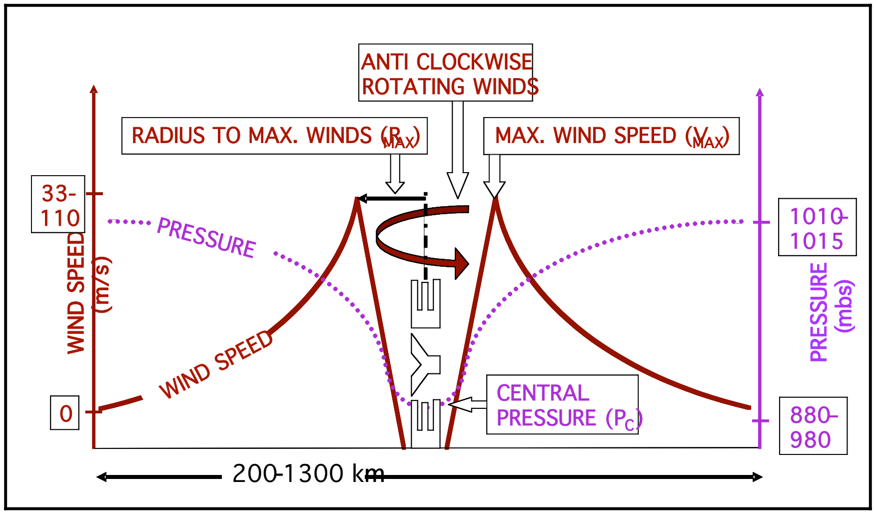


Figure 11. Characteristic Components of a Hurricane

The wind speed indicates the intensity of the hurricane but even more indicative of the intensity, is the *central pressure* (P_c). This is the pressure at the eye of the hurricane. Half of all hurricane observations have central pressures of 980 mb or lower (James B. Elsner and A. Birol Kara, 1999). The hurricane moves along its track with a *forward velocity* (V_{fd}) ranging from 2 m/s to 12 m/s.

8.3.2 Mechanics

Structurally, a tropical cyclone is a large, rotating system of clouds, wind, and thunderstorms. Its primary energy source is the release of the heat of condensation from water vapor condensing at high altitudes, the heat being ultimately derived from the sun. Therefore, a tropical cyclone can be visualized as a giant vertical heat engine supported by mechanics driven by physical forces such as the rotation and gravity of the Earth. In another way, tropical cyclones could be viewed as a special type of Mesoscale Convective Complex, which continues to develop over a vast source of relative warmth and moisture. Condensation leads to higher wind speeds, as a tiny fraction of the released energy is converted into mechanical energy; the faster winds and lower pressure associated with them in turn cause increased surface evaporation and thus even more condensation. Much of the released energy drives updrafts that increase the height of the storm clouds, speeding up condensation. This gives rise to factors that provide the system with enough energy to be self-sufficient and cause a positive feedback loop, where it can draw more energy as long as the source of heat, warm water, remains. Factors such as a continued lack of equilibrium in air mass distribution would also give supporting energy to the cyclone. The rotation of the Earth causes the system to spin, an effect known as the Coriolis effect, giving it a cyclonic characteristic and affecting the trajectory of the storm.

As presented before, the factors to form a tropical cyclone include a pre-existing weather disturbance, warm tropical oceans, moisture, and relatively light winds aloft. If the right conditions persist and allow it to create a feedback loop by maximizing the energy intake possible – for example, such as high winds to increase the rate of evaporation – they can combine to produce the violent winds, incredible waves, torrential rains, and floods associated with this phenomenon.

Deep convection as a driving force is what primarily distinguishes tropical cyclones from other meteorological phenomena. Because this is strongest in a tropical climate, this defines the initial domain of the tropical cyclone. By contrast, mid-latitude cyclones draw their energy mostly from pre-existing horizontal temperature gradients in the atmosphere. To continue to drive its heat engine, a tropical cyclone must remain over warm water, which provides the needed atmospheric moisture. The evaporation of this moisture is accelerated by the high winds and reduced atmospheric pressure in the storm, resulting in a positive feedback loop. As a result, when a tropical cyclone passes over land, its strength diminishes rapidly.

The passage of a tropical cyclone over the ocean can cause the upper ocean to cool substantially, which can influence subsequent cyclone development. Cooling is primarily caused by upwelling of cold water from below due to the wind stresses the tropical cyclone itself induces upon the upper layers of the ocean. Additional cooling may come from cold water from falling raindrops. Cloud cover may also play a role in cooling the ocean by shielding the ocean surface from direct sunlight before and slightly after the storm passage. All these effects can combine to produce a dramatic drop in sea surface temperature over a large area in just a few days.

Scientists at the National Center for Atmospheric Research estimate that a tropical cyclone releases heat energy at the rate of 50 to 200 trillion joules per day. For comparison, this rate of energy release is equivalent to exploding a 10-megaton nuclear bomb every 20 minutes or 200 times the world-wide electrical generating capacity per day.

While the most obvious motion of clouds is toward the center, tropical cyclones also develop an upper-level (high-altitude) outward flow of clouds. These originate from air that has released its moisture and is expelled at high altitude through the "chimney" of the storm engine. This outflow produces high, thin cirrus clouds that spiral away from the center. The high cirrus clouds may be the first signs of an approaching tropical cyclone.

8.4 Tropical Cyclones – Movement and Track

8.4.1 Steering winds

Although tropical cyclones are large systems generating enormous energy, their movements over the Earth's surface are controlled by large-scale winds - the streams in the Earth's atmosphere. The path of motion is referred to as a tropical cyclone's *track*.

Tropical systems, while generally located equatorward of the 20th parallel, are steered primarily westward by the east-to-west winds on the equatorward side of the subtropical ridge, a persistent high pressure area over the world's oceans. In the tropical North Atlantic and Northeast Pacific oceans, trade winds, another name for the westward-moving wind currents, steer tropical waves westward from the African coast and towards the Caribbean Sea, North America, and ultimately into the central Pacific ocean before the waves dampen out. These waves are the precursors to many tropical cyclones within this region. In the Indian Ocean and Western Pacific (north and south of the equator), tropical cyclogenesis is strongly influenced by the seasonal movement of the Intertropical Convergence Zone and the monsoon trough, rather than by easterly waves.

8.4.2 Coriolis effect

The Earth's rotation imparts an acceleration known as the *Coriolis Acceleration* or *Coriolis Effect.* This acceleration causes cyclonic systems to turn towards the poles in the absence of strong steering currents. The poleward portion of a tropical cyclone has winds blowing towards the west, and the Coriolis acceleration pulls them slightly more poleward. The winds blowing towards the east on the equatorward portion of the cyclone are pulled slightly towards the equator. But because the Coriolis acceleration is increasingly weak as you move toward the equator, the net drag on the cyclone is poleward. Thus, tropical cyclones in the Northern Hemisphere normally turn north (before being blown east), and tropical cyclones in the Southern Hemisphere normally turn south (before being blown east), if no strong pressure systems counteract the Coriolis acceleration.

The Coriolis acceleration also initiates cyclonic rotation, but it is not the driving force that brings this rotation to high speeds. These speeds instead result from the conservation of angular momentum. This means that air is drawn in from an area much larger than the cyclone such that the tiny rotational speed (originally imparted by the Coriolis acceleration) is magnified greatly as the air is drawn into the low pressure center.

8.4.3 Interaction with the mid-latitude westerlies

When a tropical cyclone crosses the subtropical ridge axis, its general track around the high-pressure area is deflected significantly by winds moving towards the general low-pressure area to its north. When the cyclone track becomes strongly poleward with an easterly component, the cyclone has begun *recurvature.* A typhoon moving through the Pacific Ocean towards Asia, for example, will recurve to the north and then northeast offshore of Japan if the typhoon encounters winds blowing northeastward toward a low-pressure system passing over China or Siberia. Many tropical cyclones are eventually forced toward the northeast by extratropical cyclones, which move from west to east to the north of the subtropical ridge.

Landfall

Officially, "landfall" is when a storm's center (the center of its circulation, not its edge) crosses the coastline. Storm conditions may be experienced on the coast and inland hours before landfall. For a storm moving inland, the landfall area experiences half the storm by the time of actual landfall. For emergency preparedness, actions should be timed from when a certain wind speed or intensity of rainfall will reach land, not from when landfall will occur.

Annex 1: Data Capture Form for Critical Facilities

Name of Collector:____

Date:____

Area/ Community:____

Type of Facility	Name of Facility	Location/ Zone (GPS readings)	Capacity/Type	Tenure/ Responsibility Ownership	Damage History Score	Structural Vulnerability Score	Operational Vulnerability Score	Facility Vulnerability Score
Utilities -Electrical -Water & Sewage -Fuel Installations								
Flood Control Structures- Overland drainage for floodwaters. -Dyke -Canals -Drains -Gullies								
Public, Safety & Security -Police -Fire -Defence Force								

Type of Facility	Name of Facility	Location/ Zone (GPS readings)	Capacity/Type	Tenure/ Responsibility Ownership	Damage History Score	Structural Vulnerability Score	Operational Vulnerability Score	Facility Vulnerability Score
Transportation -Air -Road -Water/Sea								
Evacuation Routes								
Communication Facilities								
Petrol Stations								
Nursery & Day-care Facilities								
Health Facilities -Hospitals -Clinics -Nursing Homes								
Schools								
Shelters -School -Place of worship -Community Centre								

Government Offices								
Waste Disposal Sites								
Cemetery								

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