Enhancing the Effectiveness of Information and Communication Technology

A Research ICT Project being executed by the Caribbean Disaster Emergency Response Agency in collaboration with the Seismic Research Unit of the University of the West Indies with the Financial Assistance of the International Research Development Centre, Ottawa, Canada

FINAL TECHNICAL PROGRESS REPORT

Project #: 103827-001

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IMPLEMENTING AGENCY:	Caribbean Disaster Emergency Response Agency (CDERA)
COLLABORATING INSTITUTIONS:	University of the West Indies (Seismic Research Unit and Disaster Risk Reduction Centre); National Disaster Organisations of CDERA Participating States
FUNDING AGENCIES:	IDRC; CDERA; UWI; National Disaster Organisations
BUDGET:	BD$930,716 (IDRC BD$704,211; CDERA and Collaborators BD$226,505)

*Reflects a 7.5 month no cost extension

LIST OF ACRONYMS

CDERA	Caribbean Disaster Emergency Response Agency
CDM	Comprehensive Disaster Management
CIMS	Crisis Information Management Systems
CU	Coordinating Unit [CDERA]
DRR	Disaster Risk Reduction
ERCB	Earthquake Readiness & Capacity Building Project
EWS	Early Warning System
GIS	Geographic Information System
HAM	Amateur Radio [Operator]
HF	High Frequency
ICT	Information & Communication Technology
IDRC	International Development Research Centre
JPCC	Joint Planning Coordination Committee
MGC	Memorandum of Grant Conditions
NDC	National Disaster Coordinator
NDO	National Disaster Organisation
ODPEM	Office of Disaster Preparedness & Emergency Management
PACTOR	Packet Over Radio
PMF	Project Monitoring Framework
PS	Participating State
PSC	Project Steering Committee
RBM	Results Based Management
SSA	Special Service Agreement
SRU	Seismic Research Unit
TCHWS	Tsunami & other Coastal Hazards Warning System Project
USAID/OFDA	United States Agency for International Development / Office of Foreign Disaster Assistance
UWI	University of the West Indies
WIP	Work Implementation Plan

INTRODUCTION

This is the Final Technical Report for the IDRC funded project "*Enhancing the Effectiveness of Information and Communication Technology Applications and Tools for Disaster Management in the Caribbean Region Project"* This report has been preceded by three (3) Technical Progress Reports for the periods: - (i) Sept 2007 – April 2008, (ii) May – October 2008 and (iii) October 2008 - May 2009.

This report summarises the activities of the project from inception but with particular emphasis on activities since May 2009. Activities for this period were focused on (i) completion of the pilot studies identified in the initial research findings, (ii) the facilitation of the Regional Workshop to present these findings and (iii) the drafting of ICT Policy Recommendations.

The Executive Director of CDERA, in his remarks at the Regional Workshop in August 2009 stated "It should be recognised that the *Enhancing the Effectiveness of Information and Communication Technology Applications and Tools for Disaster Management in the Caribbean Region Project* is an important undertaking for CDEMA[1] given the potential outcomes which are viewed as crucial underpinning activities towards establishing technological platforms for emergency communications within the region. The research studies coupled with the actual field data gained from the pilot projects will provide valuable information for ongoing efforts and pioneering activities within the region which may have potential for broad-based application for early warning systems (EWS) across CDERA Participating States."

The CDERA/IDRC ICT Project is being implemented as a component of the broader CU Programme which includes ICT applications for Disaster Management. Other projects with ICT applications being coordinated by the CU include (i) Earthquake Readiness Capacity Building *(ERCB*), (ii) Tsunami and Coastal Hazards Warning Systems Project (*TCHWS)* and (iii) Institutional Support and the Capacity Building for Disaster Management in the Caribbean (EDF).

To maximise opportunities for synergies and to rationalise and harmonise efforts amongst the three (3) initiatives, the IDRC project participated in joint project steering committee meetings designed to provide oversight and guidance on the management and implementation of the respective projects. This was formalised through the establishment of the Joint Project Coordinating Committee (JPCC), which met as a body twice.

The project has had to deal with a number of operational challenges which combined and impacted the start of the pilot activities. These delays necessitated a request for a 7.5 month extension from the original end date of February 2009, which was granted. The revised project end date was 16 October, 2009.

The ideal ICT tool for disaster management for CDERA participating states would (i) allow free communication between the disaster agencies and the communities, (ii) be fully functional after serious events even when electricity is down, (iii) relatively easy to use and (iv) widely accessible to the public.

Some of the findings of the research and Pilot activity are: (i) Amateur Ham Radio is a viable ICT tool for disaster managers and efforts should be made to establish at least two (2) PACTOR stations per country as part of a Regional PACTOR Network (ii) portable GPS can be effectively used at various stages in disaster management by officials and (iii) community participation and empowerment is integral for earthquakes.

2.0 THE RESEARCH PROBLEM

Early access to information is generally promoted as important to informing monitoring, alerting and changing behavior. The CDERA/IDRC ICT Project looked at several modes of information and communications and their impact on Early Warning Systems. Specifically it is designed to conduct a series of research studies on ICT related tools and technology being used in CDERA

[1] CDERA underwent a name change Sept01, 2009 and became Caribbean Disaster Emergency Management Agency (CDEMA) therefore throughout the document the names may be used interchangeably.

Participating States. If found viable, the project would then support (i) basic training, (ii) equipment acquisition and installation and (iii) the documentation of processes for replicating these systems across the region.

The research studies focused in four (4) primary areas:

i. Jamaica's E-Messaging System and its suitability as an information system for early warning;
ii. Use of the Amateur Radio digital communications mode "Packet over Radio (PACTOR)" and its application for the transmission of digital data for early warning;
iii. The extent to which GIS tools & technology developed as a result of predecessor projects are being utilized in CDERA Participating States;
iv. The collection and dissemination of post impact earthquake damage data and how this process may be enhanced using ICTs.

The E-Messaging and PACTOR components of the project examined the suitability of these technologies for early warning, and the GIS for EWS sought to determine the extent to which existing GIS is being used to inform scenario planning and decision making. Seismic Research Unit of the University of the West Indies reviewed their existing process for collecting and transmitting post impact earthquake data and how this may be enhanced by applying ICTs.

3.0 OBJECTIVES

The objectives of the Project are:

(i) General Objective

To enhance the effectiveness of Disaster Management practices in the Caribbean region through the identification and testing of innovative Information and Communication Technologies (ICTs) applications.

(ii) Specific Objectives

Objective 1:
To identify and assess the effectiveness of innovative ICT tools in national notification protocols for fast onset hazards in the Caribbean, with a focus on e-messaging, amateur Ham radio (PACTOR) and GIS (Geographic Information Systems) applications.

Objective 2:
To test and analyse the role of ICTs to strengthen community knowledge and support in the collection of post event information for earthquake in the Eastern Caribbean.

Objective 3:
To develop a set of policy recommendations in the form of a strategic paper, aimed at enhancing regional strategies to respond to natural hazards with the use of ICT tools and applications.

4.0 PROJECT IMPLEMENTATION & RESEARCH FINDINGS

Following the publication of RFPs and an extensive selection process three (3) regional consultants and a regional research institution were selected to conduct the various elements of the project.

Mr. Lionel Ellis, a regional communications consultant, was contracted to undertake the *PACTOR Study*; Mr. Stephen Louis a regional consultant in Information Technology was contracted to undertake *E-messaging Study*; Dr Jacob Opadeyi was contracted to undertake the study on the use of *GIS Technology* and Seismic Research Centre based in Trinidad worked on objective two of the project.

The project design was for an initial period of research to be followed up by specific pilot project activity to explore the research findings with recommendations on the specific component.

The research studies component of the project focused on four (4) primary areas:

- Use of the Amateur Radio digital communications mode “Packet over Radio (PACTOR)” and its application for the transmission of digital data for early warning;

- Jamaica’s E-Messaging System and its suitability as an information system for early warning;

- The extent to which GIS tools & technology developed as a result of predecessor projects are being utilized in CDERA Participating States; and

- Collection and dissemination of post impact damage data and how this process may be enhanced using ICTs.

The findings of the various elements are presented below:-

4.1 Packet Over Radio (PACTOR) Component Research Findings:

Under this component, Mr. *Lionel Ellis,* a regional communications consultant was contracted to undertake the Amateur Ham Radio/ PACTOR Study. PACTOR is a communications protocol for digital radio communications on HF radio.

The research study focused on an analysis of Trinidad and Tobago’s experience in using PACTOR and determined how best PACTOR technology can be used to support Data Communications for Early Warning and emergency response purposes in Trinidad and Tobago, as well as other CDERA Participating States (PS). The research was conducted through a combination of field visits, desk top study, questionnaires and direct contact. ***(PACTOR Final Report: Appendix 1)***

Fig 1: PACTOR Station

The initial consultancy determined from its original research and assessment that the potential use of PACTOR for disaster management in the CDERA PS are as follows:

i. PACTOR use is only expected to be beneficial where other means of data communications are not available;

ii. There is known to be some resistance in the region to the continued use of HF radio as a communications tool as other newer technologies such as mobile telephones and satellite are considered to be far superior. Additionally, the resilience of the region's public telecommunications networks has improved over the years, making them less likely to fail during a disaster;

iii. Modern disaster management emphasizes decision-making that relies on precise information which can be more accurately communicated through text and data than through voice;

iv. PACTOR technology offers communications capability where public telecommunications infrastructure has been disabled, such as in a disaster;

v. The technical expertise for installation and maintenance of PACTOR stations is widely available within the Amateur Radio community in the region;

vi. The availability of interconnection to the internet increases the potential value of PACTOR;

vii. The existence of HF radios in most of the NDOs of CDERA PS means that equipment needed for implementing PACTOR stations is already viable.

The consensus was that although there was limited usage of PACTOR in Trinidad and Tobago, PACTOR offered tremendous potential as a tool to support disaster related communications in the Caribbean. The conducting of a pilot project would further examine the suitability of PACTOR to support disaster management within the specific context of the Caribbean.

4.1.1 Pilot Project

Following the initial research a pilot was designed that would (i) increase awareness of PACTOR among National Disaster Offices (ii) assess the requirements for installing, maintaining and using PACTOR stations and (iii) test PACTOR communications under different propagation conditions. The criteria for selecting countries for the pilot were:

- The availability of supporting equipment and facilities required for successful implementation;

- The level of interest demonstrated;
- Ability to organize and maintain the local participation required;
- The potential benefit of PACTOR technology in general, and the pilot project in particular, to the State; and
- The relative ease of executing, monitoring and assessing the pilot with regard to cost, logistics and communication.

Based upon the above criterion Antigua and Barbuda and Saint Lucia, were selected as the pilot countries. Components for two (2) PACTOR stations were purchased and delivered to the pilot countries. Overall some 11 persons selected by the National Disaster Organistions of Saint Lucia and Antigua and Barbuda were trained to use PACTOR. The training included:

Installing and using the High Frequency (HF) radio system
- Installation of HF system
- Operating HF station
- Types of frequencies
- Adjustment and alignment to other PACTOR stations

Assembling the PACTOR station
- Installing and configuring the TNC
- Installing and configuring the software

Sending and Receiving Messages
- Overview of messaging procedures
- Using the messaging software
- Sending messages to other PACTOR stations
- Sending Internet E-mail
- Receiving messages

Additional activities included:

	Type of activity	**Purpose / Remarks**
1	PACTOR-PACTOR communication between the pilot sites	For practice and evaluation of sending messages directly between PACTOR stations operated by the NDOs.
2	PACTOR-PACTOR communication involving NDOs and third-party	Further practice and evaluation of sending messages directly between PACTOR stations. It is proposed that the Amateur PACTOR operators identified in Trinidad be asked to assist in this regard. This will allow a greater number of stations to be involved and will possibly allow a broader range of technical and operational issues to be identified
3	Pilot sites to contact all non-PACTOR NDOs via E-mail	This will allow practice and evaluation of sending Internet E-mail messages from PACTOR stations
4	non-PACTOR NDOs to send E-mail messages to the PACTOR stations via e-mail	For practice and evaluation of the ability to receive Internet e-mail on PACTOR stations

Fig 2: Installing the Antennae in Pilot State

4.1.2 Outcomes

The main outcome of this research has been creation of the capability to exploit an additional means of communication to support disaster communications in the Caribbean. As a result of the research, there is now a better understanding within the regional Disaster Management community of the technical and operational characteristics of PACTOR, and how these are relevant to the region's needs for effective communication tools in times of disasters. The installation of the pilot stations and the training of national level personnel in PACTOR use have also created the operational capability to use PACTOR. Further, the involvement of consultants and Amateur Radio operators who have long histories of contributing to the development of ICT and Telecommunications within the region's Disaster Management community has created the capacity for ongoing support and development of this capability.

The research has also led to renewed interest in the role of Amateur Radio in supporting disaster communications, and a desire to re-engage with the Amateur Radio community in that regard. Evidence of this emerged during the discussions of the potential role of PACTOR at the *Regional Workshop on ICT Applications and Tools for Disaster Management in the Caribbean*. This creates an opportunity to expand the resource base available to support Disaster Management.

4.1.3 Recommendations

The results of the Pilot Project provided evidence to support the initial conclusion of the study of that PACTOR offered an additional means of communications to support Disaster Management in the Caribbean. This conclusion was endorsed by participants at *Regional Workshop on ICT Applications and Tools for Disaster Management in the Caribbean*. The Pilot Project also helped to identified specific issues that would require attention in order to ensure maximum benefit could be derived from investment in this form of technology. In this regard the recommendations are for *(i) creation of a regional PACTOR network and (ii) training and capacity building.*

Creation of a Regional PACTOR Network

As reported in the Pilot Project report, the results of tests conducted showed that communication between the two pilot stations was much more reliable than communication involving the third-party stations on the *Winlink* network. Also, participants in the PACTOR Working Group at the *Regional Workshop on ICT Applications and Tools for Disaster Management in the Caribbean* recommended that PACTOR stations be installed in each of CDERA's Participating States to create a PACTOR Network. The proposed Regional PACTOR Network will have the following characteristics:

- Availability of functioning PACTOR stations in each of CDERA's Participating States and at the CDERA Coordinating Unit;
- Ability to route messages between the PACTOR network and the Internet, and through other networks such as *Winlink*;
- Capacity to effectively use and support the network;
- Ability to rapidly redeploy or activate PACTOR stations in the event of a disaster.

The Working Group from the Workshop proposed that two (2) PACTOR stations be installed in each Participating State – one under the control of the NDO and the second under the control of the local Amateur Radio Club.

The Working Group also proposed that the network include two (2) "mailbox" stations to provide interconnectivity with the Internet, and that the geographic location of these mailboxes be such that connectivity is available throughout the network.

In addition whereas the Working Group recognised that the overall cost of creating such a network for the entire Caribbean would be significant, and would require additional funding, the possibility of a country funding at least two (2) additional stations could be pursued to augment the existing resources that have been provided under the IDRC project. This strategy would be relatively low-cost and easy to implement, and can be pursued immediately while the proposal for implementing a regional network is being explored.

Now that the capability to use PACTOR has been created through the installation of the pilot stations and training of personnel, it is important that this capability be sustained and further developed. In order to ensure this it is recommended that weekly tests of PACTOR communication be conducted, and a log of these tests be maintained. The tests will involve the following:

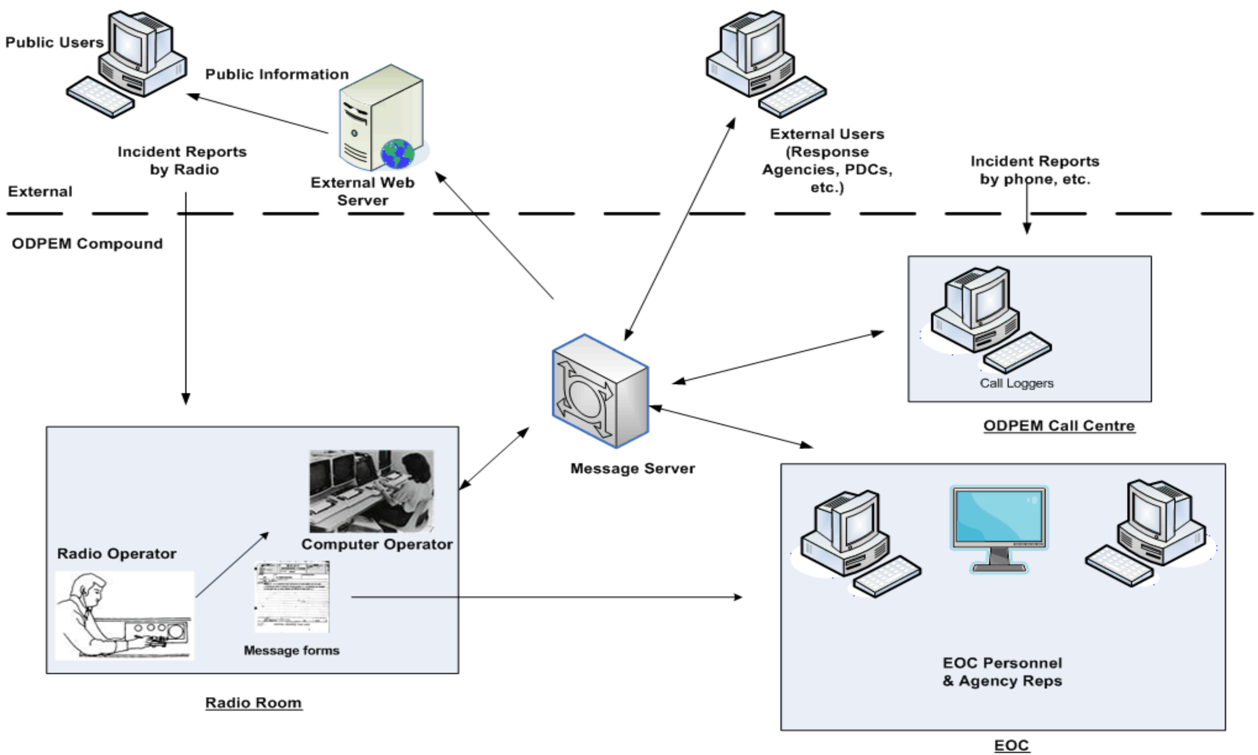
- Sending and receiving messages between the existing stations;
- Sending Internet e-mail to the CDERA CU or other NDOs;
- Receiving Internet e-mail from non-PACTOR sources on the PACTOR stations.

These tests will also ensure that the personnel involved continue to develop experience and skill in using PACTOR, and that nuances in the use of the technology that are specific to their context can be identified.

4.2 E-Messaging

Mr. Stephen Louis, a regional consultant in Information Technology, was contracted to undertake the E-Messaging component of the research. This involved the examination of the emergency messaging system being used in Jamaica and make recommendations if to carry out a regional pilot project. ***(E-messaging Final Report: Appendix 2).***

The analysis concluded that implementation of similar Emergency Message Handling systems in other CDERA Participating States will contribute to strengthening of Disaster Management at both the national and regional levels. The primary contribution will be in improved management of the emergency response, (including the pre- and post-event phases) as well as the subsequent analysis of impact and the evaluation of response.



ODPEM E-Messaging System: Concept of Operations

Based on the analysis, the execution of the proposed pilot project, as a pre-cursor to wider implementation of E-messaging systems in CDERA PS, was recommended. However, it was recognised that proceeding with the "Jamaica model" was not the most appropriate due to various factors including (i) a regional initiative on e-messaging using a different platform is underway (ii) only Jamaica and the CDERA CU had the infrastructure to support the Jamaica model and (iii) uncertainty with regards to country commitment and participation in light of the above.

Furthermore, the consultant recognised that designing a pilot project using the WebEOC platform would be challenging for two (2) specific reasons:

a) Defining a discrete activity that is consistent with the policies and objectives of both IDRC and US SOUTHCOM and;

b) Defining an implementation timeframe that allows for appropriate sequencing of related activities between the two projects.

In light of above, having reviewed the options going forward as presented by the consultant a recommendation was made to IDRC that there be no pilot project on e-messaging, and the *consultants SSA be modified accordingly*. Mr. Stephen Louis, the consultant contracted to undertake the E-messaging component agreed to a modification in his SSA to reflect that there would no longer be an E-messaging Pilot component.

4.2.1 Recommendations

While it was concluded that it was not beneficial to conduct a Pilot Project to implement Jamaica's NEMHS in other CDERA Participating States, there are lessons from the Jamaica experience that can be used to ensure the maximum benefit is derived from future implementation of other Crisis Information Management Systems(CIMS) , such as WebEOC, in the Caribbean.

Need for CIMS Capability

The decision to implement the NEMHS in Jamaica was internally driven, based on the need to address specific emergency message and information handling problems. ODPEM had identified specific shortcomings in its manual system that needed to be addressed by such a system. ODPEM has also been able to identify specific benefits derived from the implementation.

While the scale of Jamaica's Disaster Management operations is larger than most of the other CDERA Participating States because of the larger geographic area, larger population and greater frequency of incidents, the information handling problems identified also exist among other CDERA states. Thus the experience of implementing and using NEMHS provides some indications of how such systems can be used to address the problems faced by NDOs in the region.

Challenges in using CIMS

Jamaica's experience shows that despite the strong internally-driven justification for the system and apparent strong support from users, there were some important challenges that were encountered. Examples include:

- *Technical challenges.* The absence of a suitable WAN infrastructure contributed to the non-use of the potential capability for PDCs and agency users to access the system remotely. Also, the lack of an interface to the GIS reduced the potential value for post-event analysis.

- "*Resource" challenges*. Insufficient numbers of workstations were available in the EOC to allow "real-time" access to the system, making it necessary to printing messages and using paper-based methods.

- *Operational challenges*. The reliance on a parallel paper based system for passing messages to agency representatives (partly due to the "resource challenges" identified above) meant that much of the data generated during response operations never entered the system. This again limited the value of the system for post-event analysis.

Recommendations for future CIMS implementation

Using the results of this study and drawing on traditional Information System Management literature as well as more recent literature specific to the use of ICT in Disaster Management, the following recommendations can be derived:

(a) **Ownership**

Participating States must see the system being there for their benefit, and must be willing to accept responsibility for its effective use. This is particularly where the implementation is externally funded or directed. Thus in promoting the use of CIMS among Participating States, the arguments should focus on how the States will benefit individually and collectively, and why they should be willing to commit the effort and resources to achieve the expected benefits. It is import that the States are not left with the perception that their use of the system is primarily to comply with an external obligation.

(b) **Relevance to operations**

The system must directly address the needs of the individual NDOs who are using it and of the Region Response Mechanism (RRM) in general. It should be capable of support the typical disaster response scenarios likely to occur, and produce the required outputs. This implies therefore, that as far as practical, the operational procedures used by NDOs should be synchronized with the operations of the system. This may require customization of the system as well as adjustment of existing procedures and retraining of staff.

(c) “**Embeddedness”**

This is related to (b) above and means that the system should become an integral part of the operational framework of the NDOs and the RRM, and be perceived by users as such. If a CIMS is in use, it should not operate as a parallel system to others being used by the target organizations, as this is likely to lead to duplication of effort and discrepancies in the information used for different purposes. As in (b), this will also require synchronization of system operation with existing operational procedures.

4.3 Geographical Information Systems (GIS)

Dr. Jacob Opadeyi, a regional consultant from the University of the West Indies, was contracted to undertake the Study on the use of GIS Technology for disaster Early Warning Systems (EWS). **(GIS *Final Report: Appendix 3)*** In terms of EWS, his research indicated that there was great fluctuation in the use of GIS throughout the region but not for EWS. The research also indicated that GIS technology can be used to enhance the following components:

1. Hazard mapping
2. Data management
3. Monitoring systems
4. Forecasting and warning systems
5. Effective communication systems and equipment
6. Warning messages
7. Disaster preparedness and response plans
8. Public awareness and education
9. Vulnerability assessment
10. Risk assessment

Whereas EWS development is at its infancy in the Caribbean, hurricane EWS is fully developed, efforts are being undertaken to install Tsunami EWS and flood EWS ranges from gauge watching to automated systems. However the research found no evidence of EWS in the Caribbean that is integrated with GIS.

In the Caribbean it was determined that a successful integration of GIS technology into EWS would require the addressing of the following:

- Poor institutional linkages that do not support collaboration between the National Disaster Office and National GIS Agencies;
- Inadequate availability and access to current and accurate database(s) of critical facilities, biophysical and anthropogenic features;
- Unavailability of current and densified digital meteorological and hydrological data;
- Inadequate access to trained and qualified personnel (Hydrologist and GIS specialist);
- Lack of access to GIS hardware and software;
- High cost of data transmission and dissemination (Internet connection);
- Inadequate allocation of funds for systems maintenance and upgrade;
- Long history of system neglect;
- Inadequate institutional support;
- Weak knowledge-base on hazard prediction;
- Inadequate record of hazard information: hazard maps, vulnerability assessment, risk assessment.

The consultants determined that going forward with a EWS/GIS integrated system for the Caribbean that is consistent with the basic standard requirements the following matters will need to be addressed:-

1. A sound scientific basis of understanding the meteorological and hydrological dynamics and their predictability;
2. Rapid access to global, regional and local meteorological and hydrological data in support of forecasting requirements;
3. Modern hazard monitoring and detection systems;
4. Computer hardware and software in support of data acquisition, data management, data analysis, and data dissemination; and
5. Efficient and effective communication system.

4.3.1 Pilot Project

For the pilot it was decided that a GIS based flood Early Warning System would be the focus for monitoring. Floods were chosen for the following reasons (i) degree of impact on human, social and economic activities, (ii) frequency of occurrence of the disastrous hazard, (iii) predictability of occurrence and (iv) a real extent of the impact of the hazard. Following discussions between Project staff and the consultant Grenada was chosen as the pilot country.

In order to demonstrate the use of GIS, three GIS-based disaster management scenarios were developed and tested in Grenada through this project. The applications are based on the integration of the following technologies: Juno mobile handheld computer and ArcPad mobile GIS software. These scenarios included (i) pre hurricane vulnerability assessment of buildings, (ii) incident mapping and (iii) responding to emergency calls.

Fig 4: GIS Workshop in Grenada

The training workshop focused the following issues raised by the participants:

- **Integration of data from the different sectors** It was suggested that there was the need for the development of an integrated data policy for Grenada that would define a standard system, enhance data sharing, and add value-added to existing datasets;

- **Appreciation of how ArcPad & Juno can be used to enhance efficiency.** Participants examined how the system can be used in their individual departments. e.g. Land Use updating, land ownership data collection, shelter management etc;

- **Need for a more persons at all levels to become familiar with GPS and GIS technology.** This would be facilitated by more in-depth training for field operators and NaDMA staff in ArcPad and ArcGIS ;

- **Need for a more integrated approach towards data collection.** It was suggested that government, private and public sectors communicate with each other about what information is being collected so that cost, time and resources can be saved along with creating better partnerships;

- **Software and licenses for ArcPad and ArcGIS is required** for NaDMA and other departments that would be using the system (Juno & ArcPad);

- **Need for a GIS specialist to be working in close contact with NaDMA** staff and persons using system as a resource person to assist with map generation and use of GIS techniques and analysis. Currently there are GIS specialists in Land Use (Agriculture) and Physical Planning.

4.4 Role of ICT in Strengthening Community Knowledge and Support in the Collecting of Post Impact Earthquake Damage Data

The *Seismic Research Centre* through its research increased their knowledge on the status of ICT applications and tools for disaster management as it advanced work on the role of ICTs to strengthen community knowledge and support in the collection of post event information for earthquake in the Eastern Caribbean. SRC utilised a three phased approach of research, design and development /pilot study and GIS development. ***(Final Report: Appendix 4)***

Initial research findings suggested that the ideal ICT tool for post earthquake event that would be best for CDERA participating states would (i) allow free communication between the disaster agencies and the communities, (ii) be fully functional after serious events even when electricity is down, (iii) relatively easy to use and (iv) widely accessible to the public.

From this assessment it was found that the CDERA participating states are currently utilising various ICT applications, none of which, on its own, fits the criteria for being the 'ideal' ICT tool that should be selected.

4.4.1 Pilot Activity

The pilot activity was designed to (i) look at how communities can be empowered through training in ICT to help them determine the most appropriate method(s) of sending post event (earthquake) data and (ii) develop and test a prototype for the automatic collection of data using GIS technology.

Based upon the information gathered from the initial research survey and questionnaire the pilot was designed around two (2) ICT applications, the internet and Ham Radio/PACTOR. The two ICT tools selected for use in the proposed macro seismic data collection system were tested in three different CDERA Participating islands: Trinidad, Tobago and Grenada. The criteria used for pilot study location selection were:

- ❖ Annual/occasional occurrence of earthquakes – community should be somewhat accustomed to earthquake activity;
- ❖ Easy access to the community to test the ICT application (contact organisations to advise on a suitable test community);
- ❖ Availability of volunteers to participate in the study and support from community leaders/disaster management officials;
- ❖ Existence of secure location to perform the training for the pilot study;
- ❖ Community must be located in close proximity to strong motion instruments – to allow for the comparison between macro seismic and instrumental data.

The internet was tested in communities in Tobago and Grenada and the amateur HAM radio tested in Trinidad. Volunteers were identified to participate in the internet testing using the following criteria:

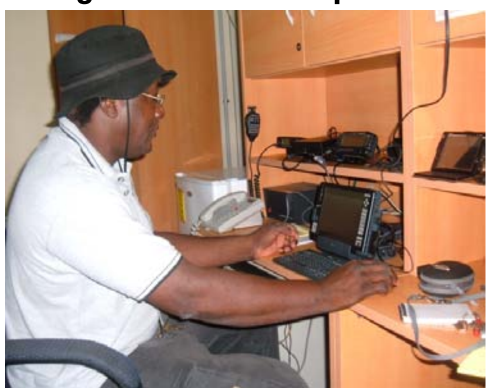
- ❖ Computer Literate – knowledgeable on the use of the computer and the internet
- ❖ Must attend training session
- ❖ Easy access to internet - preferably at home with an active account
- ❖ Must participate in simulation exercises
- ❖ Must possess the ability to accurately describe observations after a real earthquake

SRC adapted the earthquake intensity form they usually use for the purposes of the pilot to one with a twelve (12) question multiple choice answer format, corresponding to an intensity value ranging from *I to X* on the *Modified Mercalli Intensity Scale (MMI)*.

For the internet component of the pilot there were eighteen (18) volunteers from Tobago and fifteen (15) from Grenada, (in some instances internet service was provided at the residences for two months) that took part in the exercises. Two (2) simulation exercises in Tobago were conducted on 25th September and 3rd October, 2008, and one (1) exercise in Grenada on 20th November, 2008. The volunteers were asked to recall their most recent earthquake experience and, on a designated day and time, fill out the revised Felt Report Form on the SRC website. The most important lesson learned during the simulations is the need to motivate persons to report felt events. Constant reminders and updates were provided.

The Ham radio component held two (2) simulation exercises were conducted on 20th September and 22nd November, which tested voice data and digital data transfer (APRS) respectively. The Office of Disaster Preparedness and Management (OPDM) acted as the receiving centre for the simulated reports from the different HAM radio stations, while the TTARL's main office located in Arima served as a base control, directing traffic through to ODPM and also verifying and relaying reports when appropriate. During the simulations reports were collected from twelve (12) different communities in Trinidad.

Fig 5: Ham Radio Operator



Some Key Lessons learnt in this component included:

1. General apathy to internet use unless part of regular activity of the community (SRC subsidised the cost of internet access during the pilot activity);

2. ICT tools were not being directed at hazard impact studies; and

3. Further that the combination of HAM radio and internet would be ideal tools for collecting post earthquake event data from communities whom would be closest to the event.

In summary this component has enabled SRC to (i) investigate and streamline the methodology used to collect post event data following felt earthquakes in the Caribbean and to the determination of an automated system which the Centre will implement in the next few months once it has been fully tested and all elements of the system fully developed. This will provide data that will be used in the future to update hazard maps. The GIS database that is being developed will contribute to ongoing work on quantifying the risk associated with seismic hazard in the region and is major unanticipated outcome of the project.

5.0 REGIONAL WORKSHOP

The Regional Workshop was held at the Crowne Plaza Hotel in Trinidad and Tobago on the 13th and 14th August, 2009. The workshop was convened to present and discuss the findings of the research and pilot studies of the four (4) components under the project: (i) Use of Geographic

Information Systems for Early Warning systems, (ii) ICT applications in damage assessment process for earthquakes, (iii) Use of PACTOR/HAM Radio for enhancing communication systems for Early Warning and (iv) use of E-Messaging Systems in Jamaica for transmitting real time data for Early Warning. ***(Regional Workshop Report: Appendix 5)***

Sixteen (16) Participating States were in attendance except for Anguilla, Guyana and Turks and Caicos. There were thirty-two (32) participants in total including representatives from regional organisations. The meeting heard the findings of the different components of the project, and through panel discussions and working groups came up with specific recommendations for the application of ICT in the Caribbean. These recommendations have been incorporated into the draft CDEMA ICT Framework Policy.

The recommendations focused on matters related to (i) the absorptive capacity of the countries for the technology and (ii) sustainability issues related to the integration and operational functionality of these tools in advancing disaster management in the Caribbean:-

- More involvement of the private sector in particular the utility companies with respect to access and use of GIS for vulnerability profiling;
- Increased GIS Training among NDOs;
- PACTOR stations need to be established in the various countries and requisite training needs to be undertaken;
- Regional PACTOR Network needs to be established;
- Increased dialogue on CIMS to ensure operational standardisation (deployment, templates/forms, training);
- Deepening /strengthen relationships with various regional/national institutions) through *Memoranda of Understanding;*
- Greater engagement of the Youth in Disaster Management issues by linking to modern technology and looking at introduction into schools curricula;
- Ensuring that I ICT applications being used should have a degree of redundancy to them, especially from the response side;
- Revaluation of the competencies of the NDOs in light of ICT applications.

6.0 CHALLENGES IN PROJECT IMPLEMENTATION AND MITIGATION MEASURES

During the life time of the project there have been some implementation challenges including (i) turnover of Project Staff, (ii) equipment procurement challenges and (iii) administrative delays.

i. Project Management

Mr. Donovan Gentles commenced working in mid *September 2007*, and was primarily responsible for developing the Project's Work Implementation Plans (WIP) and TORs for recruiting other project staff in consultation with the CDERA Management Team. TORs for engaging the research consultants were also developed during the first quarter of the project. He subsequently relinquished his position in *October 2008.*

In the interim the Acting Deputy Coordinator, **Ms. Elizabeth Riley**, took up oversight of the ongoing Project activities and **Ms. Nicole Alleyne** the day to day activities. Subsequently a new Project Manager **Mr. John Wilson** assumed duties in January 2009.

Secretary/Accounts Clerk

Mrs. Kim Stanley joined the project staff in *December 2007* and left in May 2008. She was replaced in *June 2008* by **Ms. Sandra Lewis** whose service to the project ended on *February 01, 2009.* Ms. Lewis was then replaced by **Mrs. Laura Stanton** whose service to the project ended on *June 19, 2009*. The current Secretary/Accounts Clerk is **Ms. Nicola Drakes.**

Despite these changes in personnel the management of the project did not suffer as CDERA was able to tap into its staff resource pool to provide adequate coverage.

ii. Pilot Project: Equipment Procurement

The procurement and subsequent deployment of the equipment for the pilot projects took a longer than anticipated time due to (i) identification of providers, (ii) changes in the specs by the manufacturer by the time the order was to be made and (iii) unexpected delivery delays.

The delay in getting the equipment sourced via the traditional RFQ was addressed through sole source procurement. Lessons learnt from the administrative delays (Customs) have been incorporated into future equipment procurement by the agency.

iii. Administrative Challenges

The time taken for decisions to be made at key points was also a factor that impacted the implementation process of the project (*e.g. E-messaging modification and granting of project extension)*.

The most challenging time for project implementation occurred between the original end of project date and notification that the extension would be granted. The timeframe for processing the administrative requirements related to the extension was somewhat protracted, and this resulted in a “hold” on the procurement of the pilot equipment by the project team initially.

However, once it was realised that the project was going to get its extension, and pending the receipt of the *Amendment to the Memorandum of Grant Conditions,* the project staff (i) informed all the Participating States that the project was being extended and the next steps (ii) sent official correspondence to the pilot countries requesting their consent, and (iii) sought and received permission to go ahead with the procurement of the equipment.

The time taken to process the project extension coupled with delays in procuring the equipment created extra challenges for the consultants’ schedules. To mitigate these impacts, the project staff sought to advance work on the pilot projects through (i) engaging the proposed pilot countries (ii) facilitating the procurement of the equipment for the GIS and HAM/PACTOR pilots and (iii) giving the consultants more flexibility with the deliverables.

It should be noted that he management of a research driven project created operational challenges as events in the field did not always fall within the projected timelines of the project design which necessitated some flexibility and innovation by both the funding agency and the project management team.

7.0 PROJECT OUTPUTS

The following specific outputs were realised during the lifetime of the project:

Research

- Study on use of PACTOR for Disaster Related Communications in the Caribbean;
- Study on Use of E-messaging System in Jamaica;
- Findings and Design of Prototype GIS-based Flood Early Warning System for the Caribbean;
- Study on Testing and analyzing the role of Information and Communication Technologies to strengthen community knowledge and support the collection of post event information for earthquake in CDERA participating States.

Capacity Building

- Two (2) functional Pactor Stations established (Antigua and Barbuda and St. Lucia);
- Eleven (11) persons trained in two countries in the use of PACTOR;
- Seventy (70) community persons trained in ICT applications for post disaster information gathering;
- Ten (10) persons trained in the application of Handheld GPS systems for disaster management;
- Five (5) Juno hand held GPS systems distributed to Grenadian offices.

Policy and Practice

- A more ham radio user friendly post earthquake disaster form has been developed by Seismic Research Centre;
- Draft ICT Strategy being developed;
- More effective harmonisation of ICT related projects within the Coordinating Unit;
- Commitment to develop a forum to facilitate inputs from the technical working groups into the operations of the Coordinating Unit;
- Renewed interest in reactivating Amateur Ham Radio throughout the Caribbean (Regional PACTOR Network);
- Focus on getting Youth more involved with Disaster Management.

8.0 PROJECT OUTCOMES

Organisational Change:

This project served as a catalyst in building and strengthening CDERA's ICT portfolio and facilitated the rationalisation of the ICT components of various projects being implemented by

CDERA and also allowed for administrative harmonisation through participation in Joint Project Steering Committee meetings.

This was accomplished through the establishment of an *ICT Internal Focus Group* consisting of the ICT Leads from across the projects and programmes. The Group's mandate is to generally bring technical leadership and guidance to the various ICT activities being implemented by the CDERA CU. The Internal ICT Focus Group will liaise with the ICT Advisory Committee of the CDERA Board on broader programming and implementation issues across the Organisation.

9.0 PROJECT VISIBILITY

During the lifetime of the Project there were a number of opportunities to publicise the project and its activities, these included (i) press releases, (ii) radio/television interviews and (iii) presentations at various meetings and workshops. There will also be a series of presentations from the IDRC Project at the December 2009 CDM Conference in Montego Bay Jamaica.

10.0 OVERALL PROJECT ASSESSMENT AND RECOMMENDATIONS:

Overall CDEMA is satisfied that the project has not only met the various specific project objectives but has been extremely useful and beneficial to CDEMA in that it has:-

1. Facilitated the administrative harmonisation of ICT projects being executed by the agency;

2. Provided useful recommendations regarding the use and introduction of ICT in disaster management in the Caribbean; and

3. Heightened awareness of the applicability of ICT for disaster management.

Specifically the research and pilot findings with respect to *Specific Objective 1* have indicated that of the various tools examined (e-messaging, Ham Radio/PACTOR and GIS), the **Ham Radio/PACTOR** tool is viewed as a tool which can be effective for fast onset disasters. The opportunity for utilising this tool has been emerging in a more significant way through existing programs being implemented at the CDEMA CU. This is specifically as we seek to enhance preparedness for earthquake and tsunami hazards which are both fast onset hazards.

1) The Ham PACTOR can be used in the collection of post tsunami and earthquake impact data.
2) Monitoring and communication among emergency response and relief personnel, especially in the event of normal communication modes e.g. normal internet, fax, telephone, and cell phone being inoperable due to a preceding earthquake or the tsunami occurrence itself. Communication to be a critical area in post event response in need of attention for enhancements. The PACTOR offers a low cost, reliable service to fill some of the post event communication gaps.
3) PACTOR is critically more effective given its potential usefulness as a community-based tool. Communities are the first responders and the potential for being applicable and useful to enhance this is important.
4) Ham PACTOR can also be similarly effective where other coastal hazards impact on specific sites.

Additional support for HAM RADIO/PACTOR as a useful tool for disaster management came from the findings of the research conducted by Seismic Research Centre with respect to Specific *Objective 2.*

A draft ICT Strategic Paper including policy recommendations is currently being reviewed by the various processes within the Agency in accordance with *Specific Objective 3*.

During the lifetime of the Project there were a number of useful lessons learned both for donor and executing partner. These include:-

- The initial design of the project and the various subcomponents should have(i) factored in a comparative mechanism that would have allowed for an objective evaluation of the various ICT tools examined and (ii) allowed for greater synergy between the various components as opposed to being treated as separate parts;

- A mid term multi stakeholder review and consultation based upon the results of the research findings should still have been held according to the original schedule despite the late start to the research. This mid term review would have allowed for an in depth discussion and may have facilitated discussion on pilot design and other activities;

- There should have been an intensive review of the project prior to the six(6) month extension being granted to re-evaluate and re-prioritise the outcomes;

- Procurement and supply of equipment protocols and procedures need to be re-examined in light of the (i) administrative (Customs) delays, (ii) shipping delays and (iii) sourcing of specialised equipment experienced;

- Contracts for consultants may need to adjusted to include (i) time bound deliverables with associated payments and (ii) contingency clause(s) to address delays in implementation which translate into project extensions;

- The changes in personnel within the project office including the gap between August 2008 and January 2009 with no dedicated project manager had an impact on project implementation despite interim measures taken within the agency;

- The time taken in getting the administrative approval for the six month extension (2 $^{1/2}$ months) could have been added to the pilot phase allowing for more time for the collection of data in the various pilots activities.

11.0 POST IDRC ACTIVITIES:

Following the end of project (October 16, 2009) it is expected that there will be follow-up with Participating States and donors on various aspects of applying information gathered from this project.

It should be noted that discussions have already taken place with various projects being managed by CDEMA and developing partners to examine how the knowledge gained from the IDRC Project can be utilised. Certain GIS components of the Project can be integrated into activities of the earthquake and tsunami projects, and Canada/ Caribbean Disaster Risk Management Fund is looking at lessons learned from the PACTOR component to maximise efficiencies for grants under this particular activity.

CDEMA will also be working on the finalization of the ICT Framework Policy Document, as well as pursue options that will facilitate the renewed interest in Amateur HAM radio and the establishment of a Regional PACTOR Network.

GIS can be an effective tool in the hazard and vulnerability assessments re: tsunamis and other coastal hazards. This tool can be used during mitigation and preparation as well as response to inform of safe places etc. Its use is even more critical in the hand held form given the possibilities of critical infrastructure being destroyed and can assist in creating a preliminary database.

APPENDICES

Appendix 1

Study on Use of (PACTOR) for Disaster-related Communication in the Caribbean

<u>Final Technical Report</u>

Prepared for Caribbean Disaster Emergency Response Agency (CDERA)

Lionel Ellis
Stephen Louis

August 2009

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LIST OF ACRONYMS

AMTOR	Amateur Teleprinting Over Radio
CANTO	Caribbean Association of National Telecommunications Organizations
CDERA	Caribbean Disaster Emergency Response Agency
CDM	Comprehensive Disaster Management
CTO	Commonwealth Telecommunications Organization
D-Star	Digital Smart Technology for Amateur Radio
EOC	Emergency Operations Centre
HF	High Frequency
ICT	Information and Communications Technology
IDRC	International Development Research Centre
ITU	International Telecommunications Union
NDO	National Disaster Organization
ODPM	Office of Disaster Preparedness and Emergency Management (Trinidad and Tobago)
RTTY	Radio Teletype
SITOR	Simplex Telex Over Radio
TNC	Terminal Node Controller
UHF	Ultra High Frequency
UNDP	United Nations Development Programme
VHF	Very High Frequency

ABSTRACT

The document reports on the use of PACTOR technology to support Disaster-related communications in the Caribbean. The study was commissioned by the Caribbean Disaster Emergency Response Agency (CDERA) in collaboration with the International Development Research Centre (IDRC) and is one of a set of studies on the application of Information and Communication Technology (ICTs) in Disaster Management in the Caribbean region.

The overall objective of the study was "to enhance the effectiveness of Disaster Management practices in the Caribbean region through the identification and testing of innovative Information and Communication Technologies (ICTs) applications." The "PACTOR" component of the project, which is the subject of this report, assessed the current and potential use of PACTOR to support disaster communications in the Caribbean, through a combination of research methods, and the execution of a Pilot Project.

The research concluded that PACTOR offered good potential as a tool to support disaster-related communications in the Caribbean. This conclusion was reinforced by the results of a Pilot Project involving the installation of PACTOR stations in St Lucia and Antigua, and was endorsed by participants at a *Regional Workshop on ICT Applications and Tools for Disaster Management in the Caribbean*.

Given the above conclusion, it was recommended that a regional PACTOR network be implemented to support disaster communications in the region. It was also recommended that a system of weekly tests of PACTOR communication along with a programme of practice for users be implemented in order to sustain an adequate level of capability for PACTOR use.

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1. Introduction

The document reports on the use of PACTOR technology to support Disaster-related communications in the Caribbean. The study was commissioned by the Caribbean Disaster Emergency Response Agency (CDERA) in collaboration with the International Development Research Centre (IDRC) and is one of a set of studies on the application of Information and Communication Technology (ICTs) in Disaster Management in the Caribbean region.

The purpose of the study was to analyze Trinidad & Tobago's experience in using *PACTOR* and to determine how best PACTOR technology could be used to support Data Communications for Early Warning and emergency response purposes in Trinidad and Tobago, and other CDERA Participating States. The PACTOR project had two main components:

- An initial research study, involving a field visit to Trinidad, to assess the extent of use of PACTOR by the local Amateur Radio community, as well as review of available literature and documentation, to make an initial determination on whether there was a case for increased use of PACTOR to support Disaster Management in the Caribbean
- A Pilot Project involving the installation of PACTOR stations in two CDERA Participating States to allow more thorough assessment of the technology's potential.

2. The Research Problem

The research problem, as outlined in the Project Proposal and the First Technical Report, was articulated in terms of the need to improve "early warning" for Disaster Management in the Caribbean. In particular, it was pointed out in the Project Proposal that:

> "… increasing urbanization and greater concentration of key infrastructure and population centres along coastal areas have contributed to an increase in the level of vulnerability and risk from natural hazards in the region. It is estimated that the population of the insular Caribbean has grown from about 7 million in 1900 through 23 million in 1960 to almost 40 million at the end of the last century. High levels of poverty and unplanned or ill-conceived development have also contributed to growing vulnerability."

In order to reduce the vulnerability of the population of CDERA's Participating States, it is necessary to improve the ability to provide early warning of disasters. Information and Communications Technologies (ICTs) have been identified as a potential tool for improvement of early warning. One of the specific ICT tools identified as having potential for greater use was PACTOR. However, while there were prior indications that PACTOR was being used by the Amateur ("HAM") Radio community within the region, there had been no prior exploration as to how it might be applied to support Disaster Management in the Caribbean.

While the background project documents and the Terms of Reference (TOR) provided to the consultants referred specifically to the use of PACTOR for "Early Warning", this appeared to be a very narrow focus. There was prior evidence that CDERA and its Participating States were attempting to take greater advantage ICTs to support all aspects of Disaster management. Thus the consultants decided to broaden the interpretation of the research problem to explore more generally, the potential role of PACTOR in supporting Disaster Management in the Caribbean, including the potential role in Early Warning.

3. Objectives

According to the *First Technical Report*, the general objective of the project is "to enhance the effectiveness of Disaster Management practices in the Caribbean region through the identification and testing of innovative Information and Communication Technologies (ICTs) applications." It further identifies the following Specific Objectives:

- Objective 1: To identify and assess the effectiveness of innovative ICT tools in national notification protocols for fast onset hazards in the Caribbean, with a focus on e-messaging, amateur Ham radio and GIS (Geographic Information Systems) applications.

- Objective 2: To test and analyze the role of ICTs to strengthen community knowledge and support in the collection of post event information for earthquake in the Eastern Caribbean

- Objective 3: To develop a set of policy recommendations in the form of a strategic paper, aimed at enhancing regional strategies to respond to natural hazards with the use of ICT tools and applications

These objectives apply collectively to all the studies that were undertaken under the overall CDERA/IDRC project. Objectives 1 and 3 above are applicable to the PACTOR project. In order to design a suitable approach and methodology for undertaking the PACTOR study, the consultants' derived a more specific interpretation of objectives for the Study, based on the following:

- The brief outline of the project provided in the *Consultancy Notice* for the project
- Explanations provided in response to requests for clarification about the requirements of the project
- Prior experience of the consultants in several relevant areas including Amateur Radio, Emergency Communications and ICT.

From the above information, it was concluded that the purpose of the study covered by this report is to analyze Trinidad & Tobago's experience in using *PACTOR* and to determine how best PACTOR technology can be used to support Data Communications for Early Warning and Disaster Management purposes in Trinidad and Tobago, and other CDERA Participating States.

Specifically, the project was expected to:

- Assess and document the experience of Trinidad and Tobago in implementing and using PACTOR for emergency data communications.
- Determine whether PACTOR is suitable for use as a tool for emergency data communications in other CDERA Participating States
- Make recommendations that specify the requirements for implementing PACTOR-based emergency data communication systems in other CDERA Participating States
- Provide training to relevant personnel to improve the use of PACTOR for emergency data communications in Trinidad and Tobago and other CDERA Participating States.
- Test the applicability of PACTOR for use in other CDERA Participating States through the design and execution of a suitable pilot project.

As explained in Section 2 above, while the wording of the project document referred specifically to use of PACTOR for "Early Warning", the objectives of the project were interpreted more broadly, to cover the use of PACTOR to support disaster-related communications. Also, while the consultants initially interpreted the TOR as indicating that the focus of the study and subsequent Pilot Project should be on Trinidad and Tobago, this interpretation was revised as the project progressed, as it became clearer that the intention was instead to use the experience of Trinidad and Tobago to assess the potential for PACTOR elsewhere in the region.

4. Methodology

The research was conducted through a combination of methods. These were:

- **Field Visit**. The Lead Consultant undertook a field visit to Trinidad in June 2008 to identify members of the Trinidad and Tobago Amateur Radio Society who were currently using PACTOR, and to assess their use of PACTOR. Activities during the visit included discussions with Amateur Radio operators and inspection of existing PACTOR stations. A data collection questionnaire was designed for collection of the data required for this assessment.

- **"Desk Research".** This was used for gathering technical and background information key topics relevant to the research and reviewing available literature – particularly:
    - Technical information on PACTOR and related technologies
    - Documented experiences on use of PACTOR
    - Background information on application of ICT to Disaster Management

  A wide variety of documents, including textbooks, published (but not necessarily refereed) papers, as well as websites, were reviewed as part of this process.

- **Questionnaires**. This was primarily used for soliciting information on the use of PACTOR by Amateur Radio operators in other CDERA Participating States. A questionnaire was circulated via e-mail to over 100 Amateur Radio operators in all CDERA Participating States, (with the exception of Belize, Bahamas and Turks and Caicos islands, due to the lack of necessary contact information). The aim of this exercise was to identify additional PACTOR users in the region. However, despite follow-up contact, this did not produce any responses.

- **Direct contact**. This was used to contact members of the Amateur Radio community and other persons whom the consultants believed may be knowledgeable about PACTOR and related technologies, and who may be in a position to provide additional information on use of PACTOR in the Caribbean.

- ❖ **Pilot Project**. Following completion of the initial study, a Pilot Project was conducted in 2 CDERA Participating States to provide a more thorough evaluation of the potential of PACTOR to support disaster-related communications in CDERA's Participating States. A separate report on the design and execution of the Pilot Study is available.

The above combination allowed for assessment of PACTOR from different perspectives including technical characteristics, ease of use, experience of prior use in the Caribbean and elsewhere. The Assessment Framework used to determine the potential suitability of PACTOR during the initial study is shown at Appendix A.

5. Project Outputs

The key outputs of the project were as follows:

5.1 Comprehensive report on PACTOR

The report entitled *Study on Use of (PACTOR) for Disaster-related Communication in the Caribbean: Final Report*, submitted in September 2008, provided an assessment of PACTOR technology, and its potential to support Disaster Communications in the Caribbean. The assessment was based on available literature on PACTOR use, and on the results of the field study of PACTOR use by Amateur Radio operators in Trinidad and Tobago.

The report concluded that despite the study only finding evidence of limited usage in Trinidad and Tobago, PACTOR offered good potential as a tool to support disaster-related communications in the Caribbean. It was recommended that the proposed pilot project be conducted in two CDERA Participating States to further evaluate the suitability of PACTOR to support Disaster Management within the specific context of the Caribbean. A plan for such a pilot project was also outlined.

5.2 Pilot Stations

Two pilot PACTOR stations were installed and commissioned under the project – one at the office of the National Emergency Management Organization (NEMO) in St Lucia and the second at the office of the National Office of Disaster Services (NODS) in Antigua. These stations were shown to be able to communicate with each other, and with other PACTOR stations that are part of the Winlink 2000 network, to send and receive data messages including Internet e-mail.

The stations are currently functional and available for use.

5.3 Report on Pilot Project

A *Pilot Project Report* was prepared to document the execution of the pilot project. The report outlines the objectives of the design and execution of the pilot, and summarizes the key outputs, results and lessons learnt.

5.4 Training Outline and Presentations for PACTOR Training

An outline for training of pilot project participants was prepared, and is included in the *Pilot Project Report*. The outline identifies the main objectives of the training, the target audience, and the topics to be covered during training.
A formal presentation was also prepared for the training conducted during the pilot project. The presentation is intended to provide an overview of the project and an introduction to PACTOR technology, in order to prepare participants for the "hands-on" sessions.

Additionally two presentations covering the project and its findings were presented. The first was at CDERA's annual *CDM Conference* in December 2008, while the second was at the *Regional Workshop on ICT Applications and Tools for Disaster Management in the Caribbean* held at the end of the CDERA/IDRC Project. These presentations were intended to disseminate information about the project and generate interest in the use of PACTOR technology as an additional tool for supporting disaster communications in the region.

5.5 Development of Capacity to use PACTOR

During the pilot project, a total of 11 persons selected by the National Disaster Organizations of Saint Lucia and Antigua & Barbuda were trained to use PACTOR. The pilot project also allowed a cadre of persons to develop skill and experience in using PACTOR and further enhanced the consultants' theoretical understanding of PACTOR as well as their understanding of how if functions under different conditions in the context of operations of the NDOs.

6. Outcomes

The main outcome of this research has been creation of the capability to exploit an additional means of communication to support disaster communications in the Caribbean. As a result of the research, there is now a better understanding within the regional Disaster Management community of the technical and operational characteristics of PACTOR, and how these are relevant to the region's needs. The installation of the pilot stations and the training of national level personnel in PACTOR use have also created the operational capability to use PACTOR. Further, the involvement of consultants and Amateur Radio operators who have long histories of contributing to the development of ICT and Telecommunications within the region's Disaster Management community, has created the capacity for ongoing support and development of this capability.

The research has also led to renewed interest in the role of Amateur Radio in supporting disaster communications, and a desire to re-engage with the Amateur Radio community in that regard. Evidence of this emerged during the discussions of the potential role of PACTOR at the *Regional Workshop on ICT Applications and Tools for Disaster Management in the Caribbean*. This creates an opportunity to expand the resource base available to support Disaster Management.

7. Recommendations

The results of the Pilot Project provided evidence to support the initial conclusion of the study of that PACTOR offered an additional means of communications to support Disaster Management in the Caribbean. This conclusion was endorsed by participants at *Regional Workshop on ICT Applications and Tools for Disaster Management in the Caribbean*. The Pilot Project also helped to identified specific issues that would require attention in order to ensure maximum benefit could be derived from investment in this form of technology.
The following recommendations have been derived:

7.1 Creation of a regional PACTOR network

As reported in the Pilot Project report, the results of tests conducted showed that communication between the two pilot stations was much more reliable than communication involving the third-party stations on the *Winlink* network. Also, participants in the PACTOR Working Group at the *Regional Workshop on ICT Applications and Tools for Disaster Management in the Caribbean* recommended that PACTOR stations be installed in each of CDERA's Participating States.

The above have led to a recommendation to create a Regional PACTOR Network for Disaster Communications within the Caribbean. The proposed network will have the following characteristics:

- Availability of functioning PACTOR stations in each of CDERA's Participating States and at the CDERA Coordinating Unit.
- Ability to route messages between the PACTOR network and the Internet, and through other networks such as *Winlink*.
- Capacity to effectively use and support the network
- Ability to rapidly redeploy or activate PACTOR stations in the event of a disaster

The Working Group proposed that 2 PACTOR stations be installed in each Participating State – one under the control of the NDO and the second under the control of the local Amateur Radio Club. The Working Group also proposed that the network include 2 "mailbox" stations to provide interconnectivity with the Internet, and that the geographic location of these mailboxes be such that connectivity is available throughout the network.

It was recognized that the overall cost of creating such a network would be significant, and may require external funding. However, we recommend that in the interim at least two (2) additional stations are implemented, as proposed below, to augment the existing resources that have been provided under the IDRC project:

i. A portable PACTOR station. This should be configured so that it can rapidly be deployed to any of CDERA's Participating States that may require such a resource.
ii. A "mailbox" station to provide a gateway to the Internet.

The above would be relatively low-cost and easy to implement, and can be pursued immediately while the proposal for implementing a regional network is being explored.

7.2 Conducting Weekly Tests and Ongoing Training

Now that the capability to use PACTOR has been created through the installation of the pilot stations and training of personnel, it is important that this capability be sustained and further developed. In order to ensure this it is recommended that weekly tests of PACTOR communication be conducted, and a log of these tests be maintained.
The tests will involve the following:

- Sending and receiving messages between the existing stations
- Sending Internet e-mail to the CDERA CU or other NDOs
- Receiving Internet e-mail from non-PACTOR sources on the PACTOR stations

These tests will also ensure that the personnel involved continue to develop experience and skill in using PACTOR, and that nuances in the use of the technology that are specific to their context can be identified.

APPENDIX A: FRAMEWORK FOR ASESSING SUITABILITY OF PACTOR

	Assessment Parameters	**Description/ Remarks**
1	User Expectations and Requirements	This will consider the expectations and requirements of the target user group (the region's Disaster Management community) with respect to the features and benefits to be provided by suitable communications technology. This is likely to include characteristics such as resilience, reliability, security, portability/mobility, ease-of-use, ease of access, affordability, ability to transmit various types of data, ability to transmit in real-time, suitability for use in emergency situations, etc. These considerations will provide a basis for determining the suitability of PACTOR technology.
2	Capabilities of PACTOR technology	This will address the specific capabilities of the PACTOR technology, and also the comparison to other available technologies.
3	Technical/ operational requirements and cost	This will address the specific technical requirements for implementing, operating and maintaining PACTOR stations/service, and the associated costs. This includes specification of required equipment and software, as well as supporting infrastructure and facilities. It will also address operational requirements such as licensing and allocation of frequencies.
4	Skill requirements	This will address the technical skills required to implement and use PACTOR, and to support such use on an ongoing basis, under the conditions likely to exist in the target countries. Issues to be considered include the technical skills required, availability of persons with suitable skills, types of training needed, likelihood of being able to successfully train a suitable number of persons, likelihood of suitably skilled persons being available at most critical times.
5	Limitations and Risks	This will address limitations of the PACTOR technology, particularly with regard to the expectations and requirements in (a) above. It will address potential technical and operational weaknesses of the technology, and aim to identify under what conditions the technology is likely to fail to meet expectations. It will also address other issues which may undermine the potential value of PACTOR technology for the regional Disaster Management community.

Appendix 2

Study on Use of E-Messaging System in Jamaica

Final Report

Prepared for Caribbean Disaster Emergency Response Agency (CDERA)

Stephen Louis
BusinessTech Research, Inc
August 2009

BusinessTech Research Inc.
Putting IT together

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ACRONYMS

ARRL	Amateur Radio Relay League
CANTO	Caribbean Association of National Telecommunications Organizations
CDM	Comprehensive Disaster Management
CDERA	Caribbean Disaster Emergency Response Agency
CIMS	Crisis Information Management System
CTO	Commonwealth Telecommunications Organization
EOC	Emergency Operations Centre
FEMA	Federal Emergency Management Agency (US)
GIS	Geographic Information System
ICT	Information and Communications Technology
MPRD	Mitigation, Planning and Research Department (ODPEM, Jamaica)
NEMHS	National Emergency Message Handling System (ODPEM, Jamaica)
NDO	National Disaster Organization
ODPEM	Office of Disaster Preparedness and Emergency Management (Jamaica)
PDC	Parish Disaster Committee
TCP/IP	Transmission Control Protocol/ Internet Protocol

ABSTRACT

The document reports on a study of the "E-messaging" system implemented by the Office of Disaster Preparedness and Emergency Management (ODPEM) in Jamaica. The system, which is called the National Emergency Message Handling System (NEMHS), is an example of what is referred to as a Crisis Information Management System (CIMS).

The NEMHS system was developed and improved by ODPEM over a number of years. The initiative was driven by a need to address the many limitations of the manual system for message handling that was previously used and also to help build an ICT platform to support strengthening of ODPEM's operations.

The NEMHS was developed on the Lotus Domino platform. The current version is web-based and supports both on-site and remote access. Currently however, the remote access capabilities are not being used.

Key functions of the system include:
.
- Message receipt and logging.
- Message prioritization.
- Message Assignment.
- Message Routing.
- Monitoring and Follow-up.
- Customizable views

The availability of the system has allowed ODPEM to improve its information handling during disaster situations. In particular, it has reduced the incidence of problems such as lost messages, messages not being actioned, and messages being inadvertently actioned more than once. It has also simplified the preparation of public information, particular Situation Reports and News Releases, during and after disasters. ODPEM acknowledges however, that the system's capabilities are currently underutilized, due to a combination of technical and administrative reasons.

It has been decided that Jamaica's NEMHS will not be implemented in other CDERA Participating States as an alternative CIMS – WebEOC, is being implemented. Nonetheless, Jamaica's experience in implementing and using the NEMHS provides valuable lessons about both the benefits of such systems and the challenges of using them. Recommendations derived from Jamaica's experience are also presented.

1. Introduction

The document reports on a study of the "E-messaging" system used by the Office of Disaster Preparedness and Emergency Management (ODPEM) in Jamaica. The purpose of the study was to analyze Jamaica's experience in implementing and using the E-Messaging system and to determine how best such a system can be used to support disaster-related communications in Jamaica and other CDERA Participating States. Specifically, the study was intended to:

- Assess and document the experience of Jamaica in implementing and using the E-Messaging system for disaster-related communications.
- Determine whether such a system is suitable for use as a tool for communications for National Disaster Organizations (NDOs) in other CDERA Participating States
- Make recommendations that specify the requirements for implementing such a system in other CDERA Participating States

The original Terms of Reference (TOR) for the study also included the following:

- Test the replicability of the E-Messaging system by implementing such a system in another CDERA Participating State through execution of a suitable Pilot Project.
- Provide training to relevant personnel at the national level in the pilot country to allow them to make suitable use of the system during the pilot project.
- Evaluate the Pilot Project and document the findings in a Case Study report.

On completion of activities (a) – (c) however, it was concluded that there was not sufficient justification for proceeding with items (d) – (f) in light of the introduction of the *WebEOC* system, which would provide similar functionality, in all CDERA's Participating States. Thus this report covers items (a) – (c) above. It also uses the results of the assessment of the Jamaica system, as well as current research into such systems, to derive recommendations that are relevant to the implementation and use of similar systems in the Caribbean and elsewhere.

2. Background

2.1 ICT and Disaster Management

The potential for Information and Communications Technology (ICT) to contribute to strengthening Disaster Management has long been recognized. Advocacy in support of increased use of ICT in Disaster Management has come from many quarters, including Disaster Management practitioners, researchers, government policymakers and the general public. For example, Stephenson and Anderson(1997) argue that until the late 1970s, civilian application of ICT in Disaster Management was confined to a few specialized departments of universities, large companies and government, but that from the early 1990s onwards, "powerful and inter-connectable computer equipment had evolved to become an indispensible component of disaster operations worldwide" (p. 305.) Fischer (1998) points out the potential use of technologies such as DVD ROM, Internet, multimedia, website and e-mail for both training of Disaster Management professional as well as for improved public education.

Within the Caribbean, several entities, including CDERA, National Disaster Organizations, regional and international development agencies as well as private sector and civil society groups have promoted increased use of ICT to support disaster management. For example, in May 2002, CDERA collaborated with the United Nations Development Programme (UNDP) to host a *Regional Seminar on the Use of Information Technology in Comprehensive Disaster Management* (CDERA, 2002). This seminar, which brought together representatives of NDOs, donor partners, the private sector and technical resource agencies explored the ways in which ICT could be used to support development of Disaster Management in the Caribbean, with a specific focus around the Comprehensive Disaster Management (CDM) Strategy.

In September 2006, CDERA also collaborated in the execution of a "multi-stakeholder Forum" entitled, “Using ICT for Effective Disaster Management: Caribbean Forum” (Commonwealth Telecommunications Organization, 2006), which was held in Jamaica. The forum was organised by the Commonwealth Telecommunications Organisation (CTO) with assistance from the International Telecommunications Union (ITU) and the Caribbean Association of National Telecoms Operators (CANTO) and was hosted by Jamaica’s Office of Utilities Regulation. The Caribbean Forum was the second in a series of four such fora on Using ICT for Effective Disaster Management, being delivered between June 2006 and June 2007 as part of the CTO’s ICT for Disaster Management Programme (ICT4DM), the overarching objective of which was to increase and improve stakeholders’ use of Information and Communication Technologies (ICTs) in all four stages of the Disaster Management Cycle: Preparedness, Mitigation, Relief and Reconstruction.

ICT can be used to support all phases of the Disaster Management Cycle. For example, Geographic Information Systems (GIS) can be used to support hazard mapping and mitigation activities, while supply management system can be used to improve the effectiveness of relief operations. Support for disaster-related communications has traditionally been one of the most important applications of ICT in Disaster Management. Increasingly however, ICT is being applied to support the effectiveness of emergency response operations through improved management of information and decision-making.

2.2 ICT and Emergency Information Management

The response to disaster and emergency situations can generate large volumes of information, and in many cases, Emergency Management is largely an exercise in information management and decision-making. The difficulties associated with this in the Caribbean has been recognized by the CDERA Coordinating Unit which states that “Collecting, collating, and disseminating timely Situation Reports to all stakeholders for decision making continues to be a challenge in the majority of events in CDERA member states”. (CDERA, 2005). The CDERA CU therefore proposed the acquisition and installation of software to assist in that regard.

The use of ICT for information management in disaster and emergency situations (“Crisis Management”) is now attracting considerable attention internationally, both from practitioners and researchers. For example, the International Community on Information Systems for Crisis Response and Management (ISCRAM) holds an annual *International Conference on Information Systems for Crisis Response and Management*, featuring the latest research in this field. Also, the US Department of Justice implemented a “Crisis Information Management Software (CIMS) Test Bed Project” to assist Emergency Management Agencies (EMAs) in the US in evaluating and selecting such software (US Department of Justice, 2002).

3. What is and “E-Messaging” System?

The Terms of Reference (TOR) for the study did not state explicitly what was meant by an “E-messaging” system. However, the system that is the focus of the study is referred to by ODPEM as the National Emergency Message Handling System (NEMHS). Given the role and function of that system, the term “e-messaging system” can be interpreted in this context to be *a computer-based Emergency Message Handling System*. Further, we will consider an Emergency Message Handling System to be one that substantially supports the management of emergency messages, including sending and receiving, tracking, "actioning", monitoring and follow-up, and post-event evaluation.

While we will continue to use the term “E-messaging” in this document for consistency, it should be noted that the term is not widely used in this context as it is a fairly generic term. A search for “e-messaging” on the Google search engine (www.google.com) returns information on a wide variety of systems associated with some form of computer-based messaging. An alternative term, which is used by the “Public Safety” community in the US, is *Crisis Information Management System (CIMS)*. The US Department of Justice defines crisis information management software as “software found in emergency management operation centers, [that] supports the management of crisis information and the corresponding response by public safety agencies”. (US Department of Justice, 2002).

One of the considerations implied by the above definitions is that the role of such a system goes far beyond the receipt and transmission of messages. The critical function of such systems is to assist in Disaster or Emergency response operations through the efficient management of emergency information.

4. Jamaica’s E-Messaging System

4.1 Background

ODPEM’s decision to develop the NEMHS was initially driven by the need to overcome the many limitations of the manual message handling system that previously used. According to ODPEM, these included:

- Ineligible writing by loggers, making messages difficult to read
- Inadequate system in place to categorize and prioritize messages
- Inadequate system in place to track messages
- Challenges in routing messages
- Risk of messages being misplaced
- Time consuming process to compile information from messages to produce news releases and situation reports

ODPEM also wished to build and ICT platform to support its operations, as part of the overall strategy for strengthening the organization. Thus introducing the message handling system provided an opportunity to move in that direction.

Initially, the system was developed by ODPEM personnel “in-house”. Subsequently however, ODPEM secured the service of IBM, which was one of ODPEM’s IT service providers, to further enhance the system. IBM also engaged a local company – Syncon Technologies, as a subcontractor to develop the software.

The software was developed using the Lotus Domino/ Lotus Notes groupware platform. Initially, the messages were communicated using the Lotus Notes client, but a custom interface was subsequently created for this purpose. The system has undergone several upgrades since it was first developed and is currently "web-based", with users accessing it through a web browser.

4.2 Hardware and Software Platform

The NEMHS based on the Lotus Domino server technology, and uses Lotus Domino's proprietary *NSF* database format. It runs on the Microsoft Windows Server platform. Currently, at least one Lotus Notes client is required for database administration. However, Lotus Notes is no longer required by users accessing the system.

In addition to the views and reports provided in the system, it is possible to create custom reports to extract and analyze data. This can be accomplished using the *Crystal Reports* software package. This is a widely available commercial reporting package.

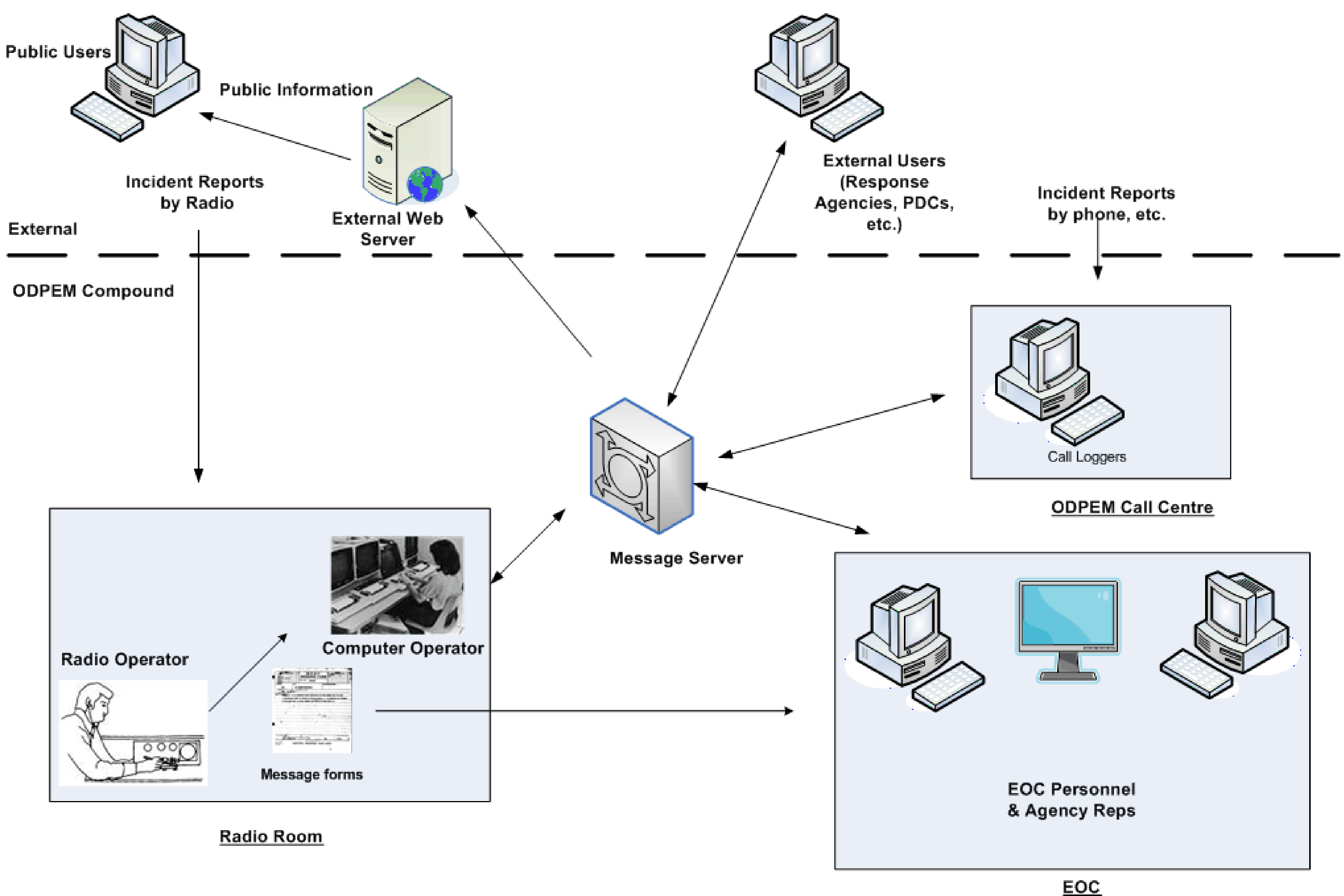
Since the current version of the system is "web-based", it can be run from a web browser on the client workstation that is accessing the system, and as such does not require any special software be installed on the workstations. (This is sometimes referred to as a "zero client" model). The fact that the system is web-based also means that it can be accessed via the TCP/IP networking protocol, whether on a Local Area Network (LAN) within ODPEM's premises, a Wide Area Network (WAN) involving other local response agencies, or via the Internet.

The underlying design of the system makes it possible to make a selected subset of the database available to the public via a website, if this was desired. For example, it would be possible to make status or situation reports available to the public using this feature. The data could be made accessible via an externally hosted website, so that the public does not have access to ODPEM's live database. This updating of the public website with the relevant data from the main database would be achieved through the Lotus Notes Replication capability.

ODPEM currently runs the e-messaging system on a server located at its premises. That machine is used as a dedicated messaging server. However, the design of the system allows for the server to be located at a different site and accessed remotely.

During the visit, the ODPEM personnel present were not able to confirm specific details regarding the current size of the database and the number of events and messages it contains. It was explained however, that from time to time old data was archived and then purged from the live database. This keeps the database size from growing indefinitely.

The Director General reported that thus far the ODPEM has not experienced performance problems (with regard to speed of operation) when using this system. It is expected that during EOC activation, the system can support up to 20 simultaneous users with data entry, as well as another 5 users doing only information retrieval.



ODPEM E-Messaging System: Concept of Operations

4.3 Functions

The diagram on the previous page provides an illustration of the concept of operation for the NEMHS. During a response operation, ODPEM receives messages from response agencies, members of the public and other sources through a variety of means. During a major operation, ODPEM may set up a call centre to receive and log messages. These messages are entered into the NEHMS, where they become available to EOC personnel. Messages received via radio are transcribed onto radio message forms before being entered into the NEMHS, as discussed below.

The system provides the capability for authorized response agencies to enter messages remotely, although this capability is not currently being used. Another capability not currently being used is the ability to publish selected information directly from the message database to a publicly accessible website for public information.

The key functions provided by the NEMHS include the following:

- **Message receipt and logging**. The "Create Message" function within the system allows the logger to record the details of a message and assign the priority. Information captured during the message creation process includes:
    - Caller identification/ contact information (name, address, telephone number, radio call sign, etc.)
    - Date and time of incident being reported
    - Precedence of the message (see "Message Prioritization" below)
    - The "Event" that the report is related to (e.g. Hurricane Dean)
    - The location of the incident being reported (Parish and other location details)
    - The type of incident or situation (from a pre-defined list)
    - Description of the incident

  Since the system requires user logins, the User ID of logger is automatically recorded with the message. The Date and Time the message is entered (which may different from date/time of incident) is also automatically captured. Also, a message number is automatically assigned to each message.

- **Message prioritization**. As part of the message entry, the logger is required to assign a *Precedence* to the message (using the ARRL recommend precedence list of Emergency/ Priority/ Welfare/ Routine). The training provided to loggers by ODPEM includes guidance on how to determine and assign the Precedence of messages. The Precedence of the messages can subsequently be used as part of the criteria in selecting, displaying and "actioning" messages.

- **Message Assignment**. The "Action Request" function within the system allows authorized EOC personnel to assign messages to specific agencies for action. Assigning a message involves specifying the following:
    - The Agency to which the message is being assigned (from a pre-established list)
    - (Optionally) the specific representative within the agency to whom the message is being assigned
    - The specific details of the action being requested
    - The due date for completion of the action

When an Action Request is entered, the system will generate an e-mail notification to the agency. This e-mail includes a web “link” to the Action Request. The recipient of the message can use the link to access the Action Request on the ODPEM server and update the record to reflect action taken in response to the request.

- **Message Routing**. Messages entered onto the system are automatically visible to authorized EOC personnel. Therefore, no separate action is required to route the incoming message to the EOC personnel. As explained above, when a message is assigned, an e-mail notification is sent to the designated agency or individual.

- **Monitoring and Follow-up**. When an Action Request is created for a message, the date due can be assigned. Monitoring and follow-up can be done through the various *views* available in the system. In some of these views, the *completion status* of the message is displayed. This is an icon that indicates whether the requested action is completed, overdue, or not yet due. When the requested action has taken place for an Action Request, the EOC or the agency to which the action has been assigned can mark the Action Request as “completed”.

- **Customizable views**. The system has a number of options for message retrieval and display that provide flexibility to users in monitoring the status of messages. The information displayed about each message (fields), the messages selected for display, and the order of display can all be customized into different “views”. The views listed in the NEMHS User Manual are:

View Name	What is displayed
All Messages	All logged messages
Calls by Precedence	All logged messages sorted by Precedence
By Parish	All logged messages sorted by Parish
Agency Assignments	Details of Action Requests
Actions Taken	All completed Action Requests with responses entered by agencies
By Incident	Messages sorted by Incident Name
By Event	Messages sorted by Event Name
MPRD/IT	This is a special view that provides access to additional information and is restricted to users from the Mitigation, Planning and Research Division (MPRD) and the IT Department

Within each view, users can also re-sort messages on specific columns and also filter messages on selected criteria so that only the desired subset of messages will be displayed.

- **Agency Interface**. The system provides an Agency interface that allows each response agency to access, update and monitor Action Requests assigned to it.

The system also has the capability to do alerting through SMS messages. (“Text” messages on cellular phones).

4.4 Experience and Use

The system had been used for all major events that ODPEM has responded to during the past few years. At the time of the visit to ODPEM, the last major event for which the system had been used was Hurricane Dean in 2007. It was also deployed by ODPEM during the Cricket World Cup tournament in 2007 (CWC 2007). This provided ODPEM with the first major opportunity to operate the system from a location external to the EOC.

The availability of the system has allowed ODPEM to improve its information handling during disaster situations. In particular, it has reduced the incidence of problems such as lost messages, messages not being actioned, and messages being inadvertently actioned more than once. It has also simplified the preparation of public information, particular Situation Reports and News Releases, during and after disasters.

ODPEM reported that the system has been well received by the local response agencies and the Parish Disaster Committees (PDCs). In the case of the PDCs, they welcomed the ability to easily retrieve messages and actions pertaining directly to their respective parishes.

However, ODPEM acknowledges that the capabilities of the system are not fully utilized. Some of the main reasons identified are summarized below.

(a) While the design of the software supports remote access via Parish Disaster Committees and other response agencies, this capability is not being utilized for a combination of technical and administrative reasons. Among them
   - The required WAN infrastructure was not currently in place
   - Problems of continuity when the designated contact persons in the local response agencies were changed or left the agencies

(b) Updating of Action Requests to reflect the actions taken or the completion status was not usually done in "real-time". Two main reasons were identified for this:

   - Pressures of time vs. shortage of personnel for data entry during EOC operations
   - In many cases agency representatives did not have access to a computer at the EOC. Action Requests were printed and distributed. The response to the Action Requests therefore had to be manually written and entered sometime afterwards.

   For reasons such as the above, many Action Requests are never updated, even after the event, a fact that undermines the ability to use the data for post-event analysis, as discussed below.

(c) The system is not being used for post-event analysis to the extent that it could. Reasons include:
   - As indicated in (b) above, in many cases the Action Requests are not updated to reflect the actions taken, so it is not possible to do a reliable assessment of what transpired.
   - ODPEM has not been able to make much use of the Crystal Reports software to develop custom reports for analysis of the data.
   - The NEMHS is not currently linked to ODPEM's GIS system, which is the primary tool used by the Mitigation, Planning and Research Department (MPRD) for post-event analysis. The MPRD collects the data that it requires (type and location of incidents, types and extent of damage, etc.) from the messages received and manually enters that data into the GIS for analysis. Consequently there is little need or incentive to revisit the NEMHS data for analysis.

(d) ODPEM has chosen to retain a manual procedure for recording radio messages. These messages subsequently have to be entered into NEHMS, causing some duplication of effort. The process is explained below.

Handling of Radio Messages

Although it is possible to enter messages received by radio directly into NEMHS, ODPEM has decided to retain the practice of recording radio messages using the traditional message form. Radio messages are written in duplicate by the radio operator. The written message is then keyed in to the NEMHS by a computer operator, while a hard copy of the message is simultaneously sent to the EOC from the radio room. It was reported that in many cases the written version (as opposed to the NEHMIS version) of message was the one used by EOC staff as this was the one that became available first.

5. Other E-Messaging Systems

During the time the study was being conducted, there was active discussion about the possible implementation of another product – *WebEOC*, in CDERA Participating States. Indications were that implementation of this system was being considered under an externally funded project.

WebEOC, from US-based ESI, is promoted in the vendor's product brochure as a "web-enabled collaborative information communications system that provides real time information sharing to facilitate decision making during a crisis or day-to-day operations".

The following description of WebEOC is provided in the Department of Justice Report referred to earlier (US Department of Justice, 2002, p. 32):

> "WebEOC is an application designed to deliver a wide range of features for the planning and management of real-time incident / event information. It is designed specific to emergency operations center functions constructed with a control panel (the "remote control) that, depending on configuration, can launch status boards, maps, and links to other applications or sites, etc. Easy to use, WebEOC Users are often trained in under 15 minutes. MapTac, a companion software product, can interface with other standard mapping applications and provides a tactical mapping capability that offers common or agency specific mapping views (fire, police, HazMat, etc). WebEOC is configurable at the administrator level without need of a programmer. The software can accommodate the Incident Command System (ICS) and FEMA's ESF structure. WebEOC offers chronological and categorical status boards of one or multiple incident/events with user configurable screens. Status reports can be directly input by individual responders. It also features a Drill Simulator offering the capability to construct exercises that are scenario based. Real-time links to 911 CAD systems are also possible through WebEOC. It is offered as both a self-hosted application and in the ASP model."

Note however that the above was prepared in 2002 and was based on version 5.3. Web EOC is currently at version 7.

WebEOC appears to be one of the most established and heavily promoted products in the CIMS market, as evidenced by several references to it in the results of web searches, and even in conference papers. While the author has not had the opportunity to review WebEOC directly, the information obtained from web searches and from discussions with ODPEM and CDERA personnel who have seen the product indicate that the product can provide the functionality currently offered by Jamaica's NEMHS.

There are concerns that need to be addressed however, including the following:

- The operational model embodied by the product appears to be based on the Federal Emergency Management Agency (FEMA) model (US) and some customization or configuration may be necessary to make the product more suited to the needs of the Caribbean.
- The proposed approach to be implementation will need to be revisited to ensure it is well-suited to the region.

There are other CIMS products on the market. Some of the alternative products identified in the Department of Justice (2002) report include:

- ESS Crisis Management Solution (www.ess-horm.com)
- E-Team (www.eteam.com)
- OpsCenter (www.opscenter.com)
- SoftRisk (www.softrisk.com)

6. Potential Implementation of "E-Messaging" Systems in the Caribbean

One of the requirements for this study is to make a recommendation on whether to proceed with a pilot project of Jamaica's E-messaging system, and if so, to make a recommendation for executing the pilot project. Given the arguments earlier, there is every reason to believe that implementation of such systems within CDERA Participating States will help to strengthen Disaster Response and Emergency Management capability. Further, the introduction of CMIS to NDOs will represent a continuation of the evolution of these entities into professional disaster management organizations.

The findings of this study therefore support a recommendation to implement E-messaging systems in CDERA Participating States. In addition to providing the capabilities previously targeted by ODPEM with the introduction of the NEMHS, introduction of these systems should also have the following objectives:

- To develop the capability for more structured coordination among response agencies, at the national and regional levels
- To support development of organizational capability through the accumulation of emergency response experience
- To improve the efficiency of operations.

While the above arguments provided clear support in principle for the wider implementation of CIMS in the Caribbean, they did not necessarily provide support for the proposed execution of a pilot project based on the use of Jamaica's NEMHS. The main reasons for this are as follows:

(a) Given the fact that CDERA Participating States had committed themselves to implementing the WebEOC system, it appeared highly unlikely that the NEMHS system would continue to be used in CDERA states other than Jamaica, beyond the end of the pilot.

(b) Significant commitment and investment would be required in order to successfully implement the pilot. Further, with the exception of Jamaica and the CDERA CU none of the disaster offices currently have the required software platform for the NEMHS. Given the view that is unlikely that use of the system will continue beyond the pilot, as stated in (a) above, the value of such an investment was questionable.

(c) Successful implementation of the pilot would require commitment and active participation from the pilot states. Again, given the arguments above, it seemed unrealistic to expect a high level of effort and participation from these states, knowing that the pilot system would only be in place for a few months.

A separate document outlining the options, issues in implementing a Pilot Project was prepared and discussed with the parties involved. Given the issues raised however, the decision was taken not to proceed with the Pilot Project.

7. Lessons for implementation CIMS in the Caribbean

While it was concluded that it was not beneficial to conduct a Pilot Project to implement Jamaica's NEMHS in other CDERA Participating States, there are lessons from the Jamaica experience that can be used to ensure the maximum benefit is derived from future implementation of other CIMS, such as WebEOC, in the Caribbean.

7.1 Need for CIMS capability

As indicated in Section 4.1 above, the decision to implement the NEMHS in Jamaica was internally driven, based on the need to address specific emergency message and information handling problems. ODPEM had identified specific shortcomings in its manual system that needed to be addressed by such a system. ODPEM has also been able to identify specific benefits derived from the implementation.

While the scale of Jamaica's Disaster Management operations is larger than most of the other CDERA Participating States because of the larger geographic area, larger population and greater frequency of incidents, the information handling problems identified also exist among other CDERA states. Thus the experience of implementing and using NEMHS provides some indications of how such systems can be used to address the problems faced by NDOs in the region.

7.2 Challenges in using CIMS

Jamaica's experience shows that despite the strong internally-driven justification for the system and apparent strong support from users, there were some important challenges that were encountered. Examples include:

- *Technical challenges*. The absence of a suitable WAN infrastructure contributed to the non-use of the potential capability for PDCs and agency users to access the system remotely. Also, the lack of an interface to the GIS reduced the potential value for post-event analysis.

- "*Resource" challenges*. Insufficient numbers of workstations were available in the EOC to allow "real-time" access to the system, making it necessary to printing messages and using paper-based methods.

- *Operational challenges*. The reliance on a parallel paper based system for passing messages to agency representatives (partly due to the "resource challenges" identified above) meant that much of the data generated during response operations never entered the system. This again limited the value of the system for post-event analysis.

The above illustrates that successful CIMS implementation has to go well beyond installation of the system and training of users.

7.3 Recommendations for future CIMS implementation

Using the results of this study and drawing on traditional Information System Management literature as well as more recent literature specific to the use of ICT in Disaster Management, the following recommendations can be derived:

(d) **Ownership**. Participating States must see the system being there for their benefit, and must be willing to accept responsibility for its effective use. This is particularly where the implementation is externally funded or directed. Thus in promoting the use of CIMS among Participating States, the arguments should focus on how the States will benefit individually and collectively, and why they should be willing to commit the effort and resources to achieve the expected benefits. It is import that the States are not left with the perception that their use of the system is primarily to comply with an external obligation.

(e) **Relevance to operations**. The system must directly address the needs of the individual NDOs who are using it, and of the Region Response Mechanism (RRM) in general. It should be capable of support the typical disaster response scenarios likely to occur, and produce the required outputs. This implies therefore, that as far as practical, the operational procedures used by NDOs should be synchronized with the operations of the system. This may require customization of the system as well as adjustment of existing procedures and retraining of staff.

(f) " **Embeddedness:"** This is related to (b) above and means that the system should become an integral part of the operational framework of the NDOs and the RRM, and be perceived by users as such. If a CIMS is in use, it should not operate as a parallel system to others being used by the target organizations, as this is likely to lead to duplication of effort and discrepancies in the information used for different purposes. As in (b), this will also require synchronization of system operation with existing operational procedures.

8. Limitations and opportunities for further study

One of the limitations of this study was the unavailability of quantitative measure that would allow the assessment of the performance and impact of the NEMHS. These include measures such as:

- Number of Event and Incidents occurring during a specified time period
- Number of messages captured in relation to the events and incidents
- Number or proportion of messages forwarded to other agencies for action
- Average time between capture and "Actioning"

This information was sought, ODPEM was unable to provide it during this study. It would be possible however, to derive this information through a combination of custom reports and database queries.

Another limitation was that the assessment only took into consideration the views of the staff at the ODPEM headquarters. Since the Parish Disaster Committee and the other agencies involved in national Disaster Management activities were also direct and indirect users of the system, it would have been useful to understand their perspectives on the effectiveness, strengths and weaknesses of the system.

While use of Jamaica's NEMHS is not going to be expanded to other CDERA States, the results of this study point to other opportunities for studying the implementation and impact of CIMS in the Caribbean. In particular, since the region is in the process of introducing a new CIMS – WebEOC, there is an opportunity for documenting "before and after" scenarios with regard to key indicators of success such as message handling effectiveness, attitude of users towards the system and impact of the system compared to stated expectations.

REFERENCES

CDERA (2005) ICT AND DISASTER MANAGEMENT: Retooling CDERA. Barbados: CDERA.

CDERA (2002) Report on the UNDP Caribbean Regional Seminar on the Use of Information Technology in Comprehensive Disaster Management. May 29 – 31, 2002 Kingston, JAMAICA. Barbados:

Commonwealth Telecommunications Organization (2006) Workshop on Using ICT for Effective Disaster Management Caribbean 2006. Ocho Rios, Jamaica, 26-28 September, 2006. Commonwealth Telecommunications Organization.

Fischer, H.W. (1998) The role of the new information technologies in emergency mitigation, planning, response and recovery. *Disaster Prevention and Management*, 7(1), 28-37.

Stephenson, R. and Anderson, P.S. (1997) Disasters and the Information Technology Revolution. *Disasters,* 21(4), 305-334.

US Department of Justice (2002) Crisis Information Management Software (CIMS) Feature Comparison Report. Washington, DC.: US Department of Justice

APPENDIX A: FRAMEWORK FOR EVALUATING E-MESSAGING SYSTEM

<table>
<tr><th></th><th>Assessment Parameters</th><th>Description/ Remarks</th></tr>
<tr><td>1</td><td>User Expectations and Requirements</td><td>This will consider the expectations and requirements of the target user group (the region’s Disaster Management community) with respect to the features and benefits to be provided by suitable communications technology. This is likely to include characteristics such as resilience, reliability, security, portability/mobility, ease-of-use, ease of access, affordability, ability to transmit various types of data, ability to transmit in real-time, suitability for use in emergency situations, etc.</td></tr>
<tr><td>2</td><td>System Characteristics</td><td>This will consider the technical characteristics of Jamaica’s E-Messaging system including:
Features and Functions
E-messaging functionality including transmission/receipt, recording, processing of messages
Reporting and analysis functionality
Security & auditing
Current hardware and software platform (what hardware is required/ what is currently available to ODPEM; what software platform is required/available platform with respect to Operating System, Database, etc)
Performance, Reliability and Robustness. This will consider how well the system performs with regard to response time, its ability to perform consistently and correctly, and its ability to recover satisfactorily with error situations or failures.
Networking and connectivity. How this system connects and interfaces with other systems, users, sources of data, etc, both internally and externally.</td></tr>
<tr><td>3</td><td>Use and Experience</td><td>This will assess the use of the system to date and lessons learnt from ODPEM’s use. Topics include:
How often has the system been used
What are the scenarios in which is has been used
What skills are required to use the system effectively and how are these skills developed and maintained?
Discussion of the experiences of use (What worked well, what did not work as expected, lessons learnt)
Main strengths and limitations of the system</td></tr>
</table>

	Assessment Parameters	**Description/ Remarks**
4	Implementation and Support	Requirements for implementing and supporting such a system, including: • Implementation options (e.g. “off-the-shelf” system, customized system, etc.) • Implementation costs (software costs, hardware and infrastructure costs, professional services for installation and configuration, training costs) • Support options and costs • Licensing requirements
5	Options Available	This will aim to identify other options available for implementing a suitable E-Messaging system and how these options compare to the system already implemented in Jamaica.

Appendix 3

THE UNIVERSITY OF THE WEST INDIES
ST. AUGUSTINE, TRINIDAD AND TOBAGO, WEST INDIES

SEISMIC RESEARCH CENTRE
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Testing and analyzing the role of Information and Communication Technologies (ICTs) to strengthen community knowledge and support the collection of post event information for earthquake in CDERA Participating States

Final Technical Report

CDERA/IDRC Project #: 103827-001

(January 2008 – June 2009)

27 August 2009
Seismic Research Centre, The University of the West Indies, St. Augustine, Trinidad

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The Problem

Rationale for the Project

In recent times, it has been reported by the United Nations International Strategy for Disaster Reduction (UN/ISDR) that 5,210 disasters were recorded in the world between 1991 and 2005 (Wattegama, 2007). The events that captured the world media included the Indian Ocean tsunami (2004) and earthquakes in Pakistan (2005), Indonesia (2006) and China (2008). The Caribbean region was also affected by significant natural hazards including the 2007 magnitude 7.4 earthquake that occurred near the island of Martinique in the Eastern Caribbean. This earthquake event was damaging in the islands of Martinique, St. Lucia and Barbados with minor damage as far south as Trinidad and as far north as Sint Maarten. Many persons can still recall their experience of this event, reminding the region of the reality of this hazard. Fortunately, the extent of damage was minimal there being no comparison with the thousands of lives lost in the Sichuan earthquake in China. The question naturally arises as to whether or not the region is prepared to manage such hazards that have the potential to cause disasters.

Increasing understanding and improvements in preparedness in the past few decades have unequivocally demonstrated that the damage caused by any natural hazard can be minimized through careful planning, mitigation and prompt action. In this respect, different facets of information communication technology (ICT) have been utilized throughout the disaster management process, playing a pivotal role in disaster prevention, mitigation and management. While in other parts of the world the use of ICT's to improve disaster response is quite extensive, in the Caribbean it is only recently that it is gradually becoming more popular.

During the 1980's, the Pan Caribbean Disaster Preparedness and Prevention Project (PCDPPP) initiated the use of ICT in disaster management in the Caribbean region by equipping 16 Caribbean states with HF radios in the event of hazard impact. Since then, however, a variety of ICT options have emerged including the radio and television, mobile telephones, short message service, cell broadcasting, satellite radio, amateur radio and the internet. Internationally, remote sensing has been used for early warning systems utilizing ICT tools such as telecommunication satellites and radar. After the 1999 earthquake in Turkey, the Internet proved to be the only communication network that was not damaged. Therefore, the Internet played a key role in planning aid disbursement and finding missing persons (Wattegama, 2007).

With a wide range of ICT options available, more research is needed to identify the appropriate tools for a given disaster management scenario, including early warning systems and rapid damage or impact assessments. In the Caribbean region, ICT has improved rapid acquisition of information on the impact of hazards at the community level. However, the collection of post event data still remains a challenge, with some Disaster Management Institutions not having access to or effectively utilizing the ICT tools available. Applications such as Geographical Information Systems (GIS) for hazard mapping and web-based data sources to facilitate research on the disaster management are currently not being fully utilized by these institutions. The challenge for these institutions has been cost, reliability, latency and lack of research in ICT applications and their benefits.

As a result, a project was proposed and funding secured from the International Development Research Centre (IDRC), to enhance the effectiveness of ICT Applications and Tools for Disaster Management in the Caribbean Region. The Seismic Research Centre (SRC) signed a

Letter of Agreement with the Caribbean Disaster Emergency Response Agency (CDERA) in January 2008 to execute Objective 2 of this IDRC project. This component is focused on using ICTs to collect post event information for earthquakes affecting CDERA Participating states (Table 1). The one-year project began in January 2008 but it became necessary to have its completion date rescheduled to June 2009. This report summarizes the activities throughout the investigation.

CDERA PS	DISASTER AGENCY	CDERA STATE	DISASTER AGENCY
Anguilla	Dept. of Disaster Management	Guyana	Civil Defense Commission
Antigua and Barbuda	National Office of Disaster services (NODS)	St. Vincent and the Grenadines	Office of the Prime Minister
Bahamas	Disaster management Unit	Montserrat	Disaster Management Coordination Agency.
British Virgin Islands	Dept. of Disaster Management	St. Kitts and Nevis	National Emergency Management Agency (NEMA)
Belize	National Emergency Management Org. (NEMO)	St. Lucia	National Emergency Management Org.
Barbados	Dept. of Emergency Management	Jamaica	Office of Disaster Preparedness & Emergency Management
Dominica	Office of Disaster Management	Trinidad and Tobago	Office of Disaster Preparedness and Management
Grenada	National Disaster Management Agency (NaDMA)	Turks and Caicos	Disaster Management & Emergencies

Table 1: List of CDERA Participating States and their Disaster Agencies

The Research Approach

The Seismic Research Centre (SRC) of The University of the West Indies is the agency responsible for monitoring earthquakes and volcanoes in the English-speaking islands of the Eastern Caribbean. One of the SCRs' functions is to conduct research into the distribution and frequency of earthquakes in the Eastern Caribbean and provide advice on earthquake risk. An important component of earthquake risk is quantifying the potential impact of strong earthquakes on vulnerable communities. The level of damage (i.e. impact) from an earthquake is dependent on several factors including: magnitude of the event, geology of the area, distance from the epicentre, population density and quality of building design and construction. Amongst these factors the one that is most easily controlled is design and construction of buildings, which is addressed through the implementation of building codes.

Seismic hazard is usually quoted in terms of peak ground acceleration (PGA), which is used by engineers to derive design parameters for construction purposes (Augusto, 2006). PGA quantifies the maximum horizontal force a building should be able to withstand, i.e. without collapse, during an earthquake, which then informs the applicable section of the Building Code. Buildings constructed according to the Building Code are expected, and have been shown to have less structural damage than those that did not follow the code. Due to the limited strong motion instrumental coverage that exists in the Caribbean determining the PGA index for an area is very difficult or even impossible. The rapid collection of macroseismic data following felt earthquakes are very important since they are often the only available data from which earthquake effects can be obtained and used to assess earthquake hazards.

Macroseismic intensity is defined by Grunthal (1998) as a classification of the severity of the ground shaking on the basis of observed effects in a limited area. Therefore, macroseismic intensity is a parameter that could be used to evaluate expected ground shaking (Augusto, 2006). The Caribbean has a low density of strong motion recording stations and therefore relies heavily on macroseismic data to determine earthquake effects. At present, felt impact or macroseismic data are collected by the SRC from the community through earthquake intensity report forms which capture data on time, date, location of observers and the effects of the event. It is important that the SRC have the capability to quickly gather this data from affected communities. Impact data can be analysed to yield important information to guide future building construction as well as for real-time response and preparedness programmes. The increase in construction of multi-storey complex structures in the Caribbean within recent years makes it imperative that hazard assessments are kept up to date so as to ensure that buildings are constructed consistent with the true hazard picture. This will minimise the structural damage that could potentially be caused by earthquake events. For areas without strong motion monitoring, macroseismic data are an important option in assessing the hazard. An efficient and thorough macroseismic data collection system would provide seismologists with data needed to update hazard assessments and provide engineers with the knowledge needed to apply the provisions of Building Codes.

Collecting earthquake impact data remains a challenge in the region and not all Caribbean institutions have been able to maximise the use of available resources. After an earthquake, macroseismic data are collected either via emails or field visits. Relatively few emails are received and, in general, predominantly originate from urban/suburban communities. Such sparse data creates information gaps that hinder seismologists from fine-tuning the impact of significant earthquakes. Field visits to these areas are not only time consuming but also require resources, which are limited at the SRC. As a result, creating intensity maps that illustrate the impact of an earthquake takes a longer time to produce and do not accurately reflect the reality for under reported areas. ICT applications offer many advantages in data collection, but research was needed to identity the ICT tool that best serves the needs of macroseismic data collection.
Since the data consist of people's experiences, it is vital to educate communities about earthquakes, teach them how to use the selected ICT and make useful observations and demonstrate how their cooperation could assist in building better structures. People from the communities need to be made aware of the importance of their reports and the need for proper reporting methods after an earthquake. Moreover, investigations are necessary to understand the reasons for the reporting pattern and identify ways to motivate the public to actively communicate with SRC after a felt earthquake event. It is an opportunity to assess whether the questionnaire, used by the SRC to collect information about the effects of the earthquake, is clear and easy to understand by the community.

Another aspect of improving the quality of the macroseismic data is ensuring the accuracy of the intensities that would be generated from the felt reports. Can personal reports give reliable information that can be used to assess earthquake impact? It would be ideal to compare the intensities derived from the macroseismic data with intensities derived from instrumental data (i.e. strong motion devices), to determine if the two data sets are consistent.

Improving the ability of communities to easily relay the effects of a significant event is also of importance to national disaster management organisations. Knowing when and where an earthquake is felt assists seismologists in assessing vulnerable areas on an island. The objective in using ICTs is to develop an automatic system for rapidly generating seismic intensity maps based on individual felt reports collected from those in the communities. Hazard assessments can then be quickly developed for communities reporting their experience, building up a historical report that can then be analysed to give the needed earthquake parameters that may be used for constructing new buildings.

Objectives

The specific objectives of this project were defined as follows:

1. To conduct an assessment of the current utilization of ICT applications in CDERA Participating States after a damaging earthquake;
2. To review the methods used by other regional and international seismological agencies to collect post event data with a view towards the identification of institutional best practices;
3. To identify the ICT options available for rapid transmission of information on earthquake effects from affected communities to scientists at the Seismic Research Centre (SRC);
4. To develop and implement a system for the automatic collection, analysis and dissemination of post event earthquake intensity data;
5. To establish a mechanism for the routine upgrade of the system designed for the collection of macroseismic data.
6.

It was agreed that the ICT tool(s) selected were to be tested in three different communities from three CDERA Participating states. These pilot projects sought to evaluate the relative value of the ICT tool(s) in supporting data harvesting after an earthquake.
The specific deliverables for the project were identified as follows:

1. A report on the Utilization of ICT applications in damage assessment for earthquakes affecting the CDERA Participating States;
2. Three Pilot Projects completed and documented;
3. At least 40 people from each of the pilot communities trained in the use of ICTs; (Is that what you mean or is it 40 people from a community in each CDERA participating state?);
4. System for receiving and sending post impact data developed, implemented and documented.

Methodology

The project was divided into three (3) phases:

- PHASE 1: Research and ICT Assessment
- PHASE 2: Design and Development /Pilot Study
- PHASE 3: GIS Development –Earthquake Database

Project Activities and Outputs

Research and ICT Assessment

The first phase of the project (January to March 2008) investigated existing ICT applications being used in CDERA Participating States and internationally for earthquake damage assessment. Various methods used by seismological agencies to collect post event information for earthquakes were examined and compared. From these results, the ICT tools that can best serve the region were selected.

The regional ICT status assessment targeted the disaster agencies and/or seismic monitoring agencies from CDERA Participating States using an online survey/questionnaire. The survey assessed the usage level of ICT applications in disaster management. The ICT tools were identified and classified into three (3) levels, as shown in Figure 1 below.

The answers obtained from the ICT status questionnaire were analysed and the extent to which ICT tools were being used by each agency was evaluated and categorised. Based on the type and use of the ICT tool, three categories were defined:

1. *Higher Tech* applications - established GIS applications, specialized software, heavy reliance on Internet, functioning E-messaging system, online intensity forms
2. *Mid Tech* applications - GIS construction, average use of internet, formation of e-messaging system, satellite phones
3. *Lower Tech* applications - heavy reliance on telephone (mobile, land lines), amateur Ham radio

For example, if the highest level of ICT tools utilized was mainly the telephone and HAM radio, then the category 'Lower Tech' was selected. However, if Geographical Information System (GIS) was incorporated in any stage of disaster management, the 'Higher Tech' category was chosen. Sixteen disaster agencies from the CDERA States were identified and assessed, using the questionnaire and follow-up telephone interviews. The questionnaire consisted of six (6) questions and was designed using a free online service. This method proved useful in allowing the disaster managers to participate in the assessment at their convenience and simultaneously documenting the responses for further analysis. The telephone verification process was important to clarify misunderstandings, answer immediate concerns and to explain unfamiliar terms where necessary.

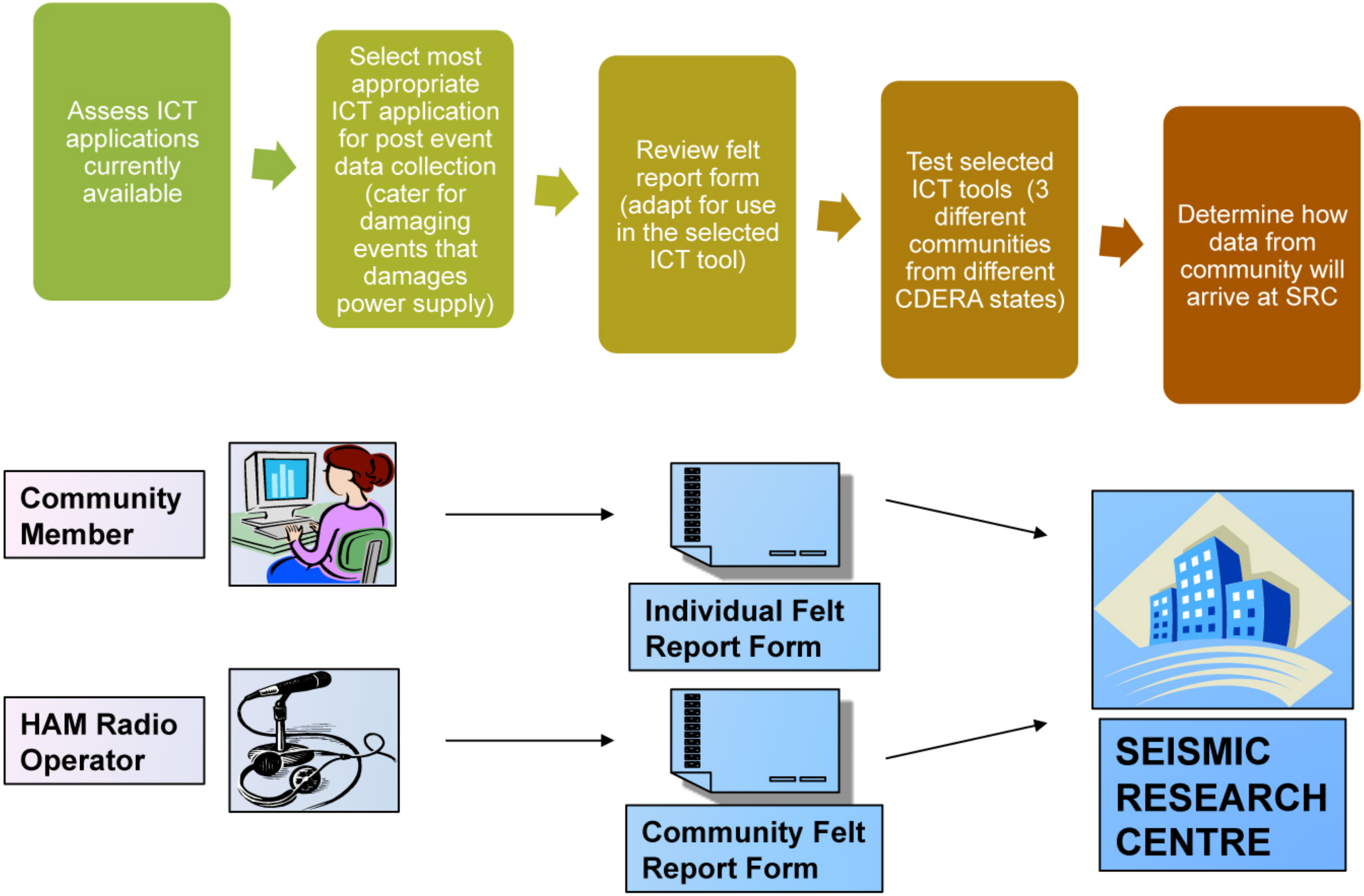

Figure 1: Schematic of Methodology used in the assessment and testing of ICT application for use in post event data collection.

The questionnaire was also placed on Seismic Research Unit's website to capture international responses. However, despite the fact that the survey report indicated that 27 attempts were made to complete the questionnaire, for unknown reasons, none was completed. Multiple attempts by a respondent or total failure to complete all questions may have contributed to this result. Unfortunately, it was not possible to track the identities of those respondents as the online questionnaire service used did not offer that option. As a result, the international input used for the assessment was gathered from individual agencies' websites and email communication. ICT applications used by disaster management agencies in the United States of America, the Netherlands, Japan, Nepal, United Kingdom, Italy and New Zealand were considered. The results from the regional and international assessment were used to select the best ICT tools suitable for collecting post earthquake data in the Caribbean region.

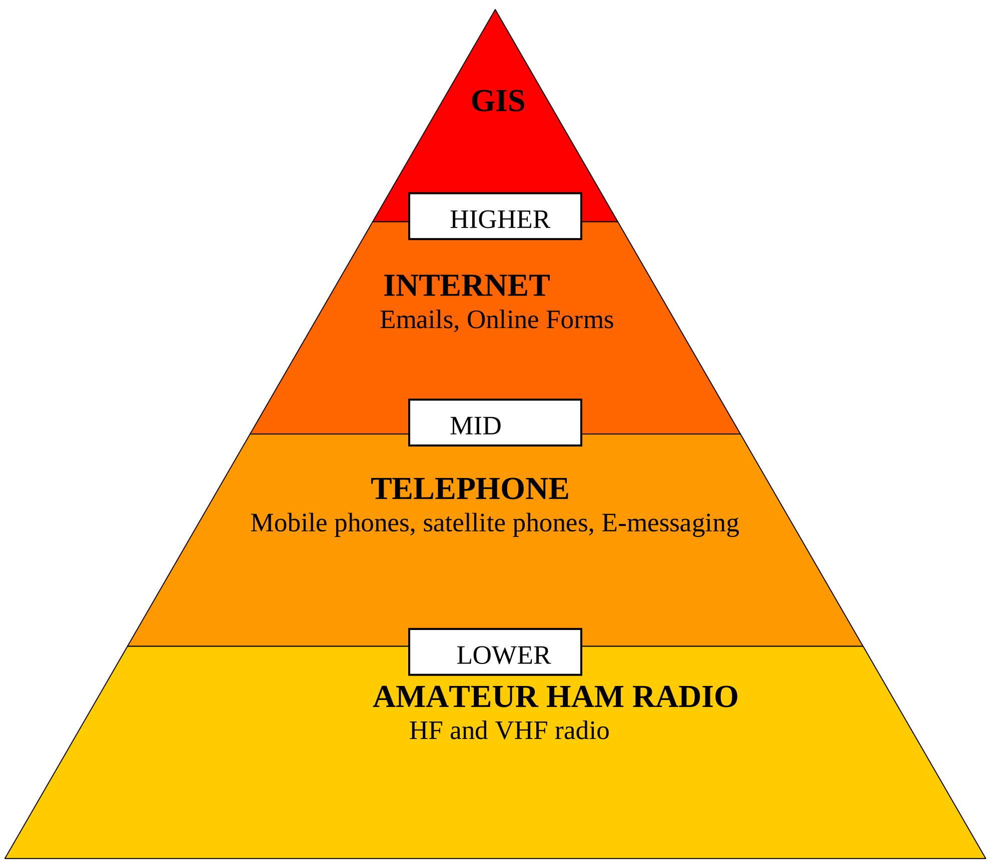

Figure 2: Criteria used to categorise the utilization of ICT tools in CDERA Participating States

Regional ICT Assessment Results

Responses from the online questionnaire and telephone interviews revealed that, in the field of disaster management, ICT applications were, generally being under utilized in the Caribbean. While plans to use ICT tools for hurricanes, flooding and storm surges were developing, post earthquake response plans were lacking. Some islands, such as St. Kitts and Nevis, Belize, the

Bahamas, Turks and Caicos and Guyana, explained that because they very rarely experience earthquakes there was no focus on ICT applications to deal specifically with earthquakes.

The results of the analysis of the current utilization of ICT applications within the disaster management sector throughout CDERA states are summarized in Figure 2. The 'lower tech' category had the largest number of CDERA states (Antigua and Barbuda, Barbados, Dominica, Guyana, St. Kitts and Nevis, St. Vincent and Turks and Caicos Islands). They relied solely on HAM radios and telephones to provide communications between the communities and the disaster agencies. Most 'Lower Tech' states mentioned that a contributing factor slowing technological development is the absence of a government policy and lack of government support.

The governments of St. Kitts & Nevis and Antigua & Barbuda have formulated an ICT policy

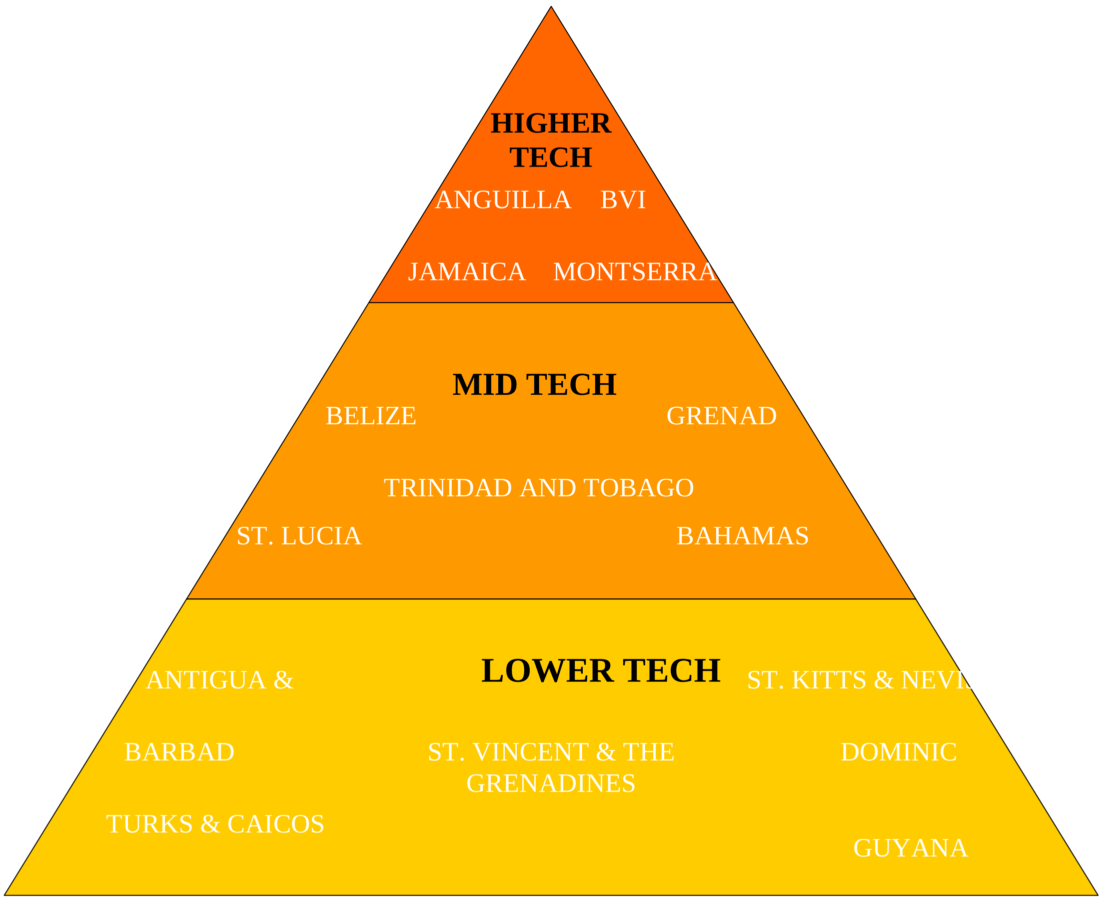

Figure 2: Results from the ICT Assessment in CDERA Participating States

for the Public Sector. However, the focus has been on E-commerce, Internet marketing, software development and E-education, not on disaster management activities.

HAM radios were actively used by these ‘Lower Tech’ states. The advantages of using HAM radios for communication during and after disasters, as identified by the disaster agencies, included:

- Reliability and robustness – available for use even when electricity is not available or when telephone networks are down or congested
- Ability to penetrate rural areas where telephone reception is poor
- HAM radio operators can be found in nearly all communities throughout the islands, ensuring that the population as a whole remains well connected.
- Can be used to call for international assistance.

However, some of these ‘Lower Tech’ states, such as St. Kitts & Nevis, Turks and Caicos and Barbados, were currently working on plans to integrate the use of GIS and the Internet in the near future to better improve their communications network. St. Vincent and the Grenadines were launching their website and, along with Turks and Caicos, planned to develop an E-messaging system for disseminating information on preparedness, response and recovery information.

The ‘Mid Tech’ states, with the exception of Bahamas and Trinidad and Tobago, have recently made ICT upgrades with an E-messaging system already developed or tested. Belize, Grenada and Saint Lucia tested the E-messaging system in the 2007 hurricane season. However, Grenada encountered problems with the E-messaging system. The National Emergency Relief Organization (NERO) in Grenada collaborated with one of the mobile communication providers to relay warnings issued by NERO to the public via text messages. However, many did not receive the warning because a significant portion of the population had cell phones from a different cellular provider. Therefore, agreements with all telephone networks are needed in order to achieve full coverage throughout the islands, to make the E- messaging effective.

GIS has been recognised as an important tool for ‘Mid Tech’ states and they have recently integrated GIS applications in their work programmes. Whilst the Internet is used to communicate with the media and the public (via the Disaster agency’s website), there is an acknowledged need for more applications using the Internet because a growing percentage of their populations has access to the Internet. Additionally, introducing new technology requires specialist personnel, office space and training. Several disaster managers indicated that it is more cost effective for the Disaster Agency to outsource their upgrade plans rather than host developments in house; the GIS mapping applications recently acquired in Grenada is a case in point.

The states in the ‘Higher Tech’ category were most advanced in using ICT tools for disaster management. These include Anguilla, British Virgin Islands, Jamaica and Montserrat. In addition to using tools designated ‘Low Tech’ in this study – HAM radio and telephone – they have been actively using E-messaging systems alongside GIS technology. The British Virgin Island’s Department of Disaster Management (DDM) works in collaboration with the Puerto Rico Seismic Network (PRSN). They have established access to the PRSN via the department’s website, providing information on earthquake events and the macroseismic data that are collected. The Pacific Tsunami Warning Centre provides a 24 hr service for the BVI by faxing advisories to their office once an earthquake occurs in the region. The advisory would indicate whether or not the earthquake has the potential to generate a tsunami. Amateur radio is currently being used in times of emergencies to assist the DDM in communications. GIS data are used to identify vulnerable areas prone to flooding and storm surges. During emergencies, the Internet is relied upon heavily to update the public via the DDM website. DDM has noted that since they began to utilize the Internet, the number of telephone inquiries has been significantly reduced by at least 50%. This frees staff members to address other important matters and contributes to reduced stress levels.

An important constraint for DDM is that its website is not hosted locally. Therefore, if their provider's server goes down for any reason, DDM would have no access to their system and alerting the public via the web would be impossible. Nevertheless, the Internet is still considered to be the simplest and easiest way of communicating with the public.

Jamaica's Earthquake Unit was the only agency in the 'Higher Tech' category that collected post earthquake event data. GIS technology was used to create intensity maps for felt earthquakes. Approximately 95% of these maps were generated using intensity reports gathered via telephone. The Earthquake Unit also had intensity forms on their website and encouraged the public to complete these forms online. However, less than 1% of the reports received are Internet generated. For events greater than magnitude 4, the affected areas were visited or calls made to reliable offices, e.g. post offices, were used to collect additional data.

The Jamaica Office of Disaster Preparedness and Emergency Management (ODPEM) had been using E-messaging systems for four years. However, the Emergency Operation Centre (EOC) uses Low Tech ICT tools, HAM radio and telephone, for public advisories. In the event of an emergency, ODPEM receives information, which is relayed to the appropriate agency (e.g. police, fire department, health authorities) via E-messaging. Agencies also used messaging to communicate with the EOC. This allowed near real time status assessments and reports.

Anguilla, also a 'Higher Tech' category state, is reported to use GIS application for hazard modelling and predictive modelling, integrated with ArcIMS Web Portal training,. GIS development in Anguilla has increased significantly in recent years, and has been identified as an important tool for Hazard Mitigation and Disaster management. GIS is also a new tool used in disaster management in Montserrat. It is used primarily to present Risk Maps superimposed on aerial photographs, enabling decision makers have a clearer understanding of the risk to the island's population.

International ICT Assessment Results

Questionnaires proved to be the most common medium for collecting post earthquake data around the world. However, the methods that the seismologists use for the collecting and evaluating the macroseismic data are not based on any written procedure. Methods have developed heuristically and tend to be region specific (Musson, 2002). As such, the methods for collecting macroseismic data are based on:

1. The strength of the earthquake – in some countries, such as the United Kingdom and Italy, data are collected only for earthquakes above a certain threshold;

2. The existence of a network of earthquake observers and the density of this network – volunteers, who are committed to reporting their observations after an earthquake;
3. The duration of the earthquake sequence - for some areas seismologists are forced to collect data only for significant events because the large number of aftershocks might lead to disassociation of observations;
4. The financial situation of the institution collecting the data;
5. The target population.

Despite the large variety of methods used to collect macroseismic data, the questionnaire is most favoured. The questionnaire usually consists of several questions that follow a specific macroseismic scale. Some were designed in the "multiple choice" format while others provided for observer accounts. Additionally, some questions may not be derived from the macroseismic scale, but sought to capture any 'weird' observations that occurred in association with the earthquake event. An underlying consideration in the design of questionnaires is the need for brevity, since participation is voluntary. If the form is too lengthy or difficult to understand then fewer people would complete the form. In some countries, the questionnaire survey was combined with an incentive, e.g. a raffle, to encourage people to respond.

The method by which the questionnaire is distributed has over the years progressed from being printed in the local newspaper to using electronic media. Most institutions have their macroseismic questionnaire available on their websites. This has been notably successful in the United States, where there is arguably a larger percent of people online than in other countries. The "Did You feel It?" project developed by the United States Geological Survey's (USGS) is probably the best-known web-based system for the rapid generation of seismic intensity maps. It is based on shaking and damage reports collected from Internet users immediately following an earthquake (Wald,1999). This system utilizes Community Internet Intensity Maps (CIIM), which summarizes the questionnaire responses provided by the public. An algorithm that was developed by Dengler and Dewey (1998) converts the numerical values, which were assigned to each answer on the questionnaire, to Community Intensities. Single intensities are then calculated for each ZIP code from multiple intensity estimations derived from community reports (Haubrock, 2007). The map is updated automatically within a few minutes after an event and after additional data upload.

Almost all Internet-based macroseismic data collection in the US is done via USGS CIIM portal, allowing thousands of reports to be collected and analysed. Since mid 2004 the CIIM portal has been in operation and it has received thousands of responses from Europe, Africa, Asia, Middle East, Central and South America and the Caribbean. Recently, the USGS expanded the DYFI system to the global scale so that users from all over the world can now contribute their own observations. Online intensity reporting provides the opportunity for many more people to submit felt reports. The USGS reported that for the 2007 Martinique earthquake, more than 1800 intensity reports were collected from Colombia, Barbados, Brazil and the Dominican

ICT Tools	Limitations
Radio Communication	Limited Information Sounds easily cancel each other Used only with sufficient electric power supply Unsuitable for the Deaf and elderly who have poor hearing
Mobile Phone Internet	Limited battery No use if the base stations are damaged Unavailable in case of jams or disconnection of aerial lines
PC	Need time to start up
Telephone (“171" Dial # for Disaster)	Unavailable in case of jams or disconnection of aerial lines Time difference in communication between affected areas and unaffected areas Need of service cognition to users in advance Recently started multilingual service
Personal Handyphone System (PHS) [2]	Strong in disasters, but few users
Television	The worse the devastation is, the poorer the performance
FAX	Risk of spreading devastation due to failure in receipt Confirmation needed for end of transmission
Beeper	Effective in disasters, but few users
Siren	Difficult to recognise in heavy rains Different types of siren in each region
Loudspeaker van	Unreachable to citizens who are outside of its driving area Highly depends on the road conditions
By word of mouth	No proof for validity of the information Overflow of information

Table 2: List of ICT tools used for Disaster Management and their limitations (Source: www.obi.giti.waseda.ac.jp/UNDR_itu-waseda_ictcenter.pdf)

Republic. After five years of operation, the USGS has received over 350,000 individual questionnaire responses covering all 50 states, the District of Colombia and territories of Guam, the Virgin Islands and Puerto Rico. Furthermore, the CIIM portal provides an opportunity for public education and has built public enthusiasm in the data collection process. The USGS also plans to continue their traditional collection of macroseismic data, using direct interviews and field surveys where necessary, to verify the CIIM data.

Countries such as the Netherlands, Italy, Nepal , Australia , New Zealand and Britain have used similar methods to that utilized by USGS to collect macroseismic data. However, the methods were modified to suit the various populations. In Nepal, for example, the online intensity form is used for data collection along with interviews so that spontaneous responses and behaviours can be captured. Nepal’s experiences showed that for areas where illiteracy is high and modern technology is unavailable, intensity forms should be carefully designed. Large gaps in

[2] PHS is a TDMA-based cellular phone system introduced in Japan in mid-1995.

macroseismic data often result due to not receiving reports from rural areas. Therefore, satellite imagery is used to compare pre and post event conditions to determine impact of earthquakes.
The Japanese have experimented with numerous ICT tools in disaster management. The 'ICT in Disaster Reduction & the Japanese Challenge for Global Standard' report produced by the Waseda ICT Centre in 2005, lists various ICT tools and the problems encountered in their implementation in disaster management (Table 2).

After experimenting with these simple 'Low Tech' solutions, the Japanese then incorporated more modern technology, especially the Internet, for two-way communication. As a result, a system using Internet technology to provide a wide range of information including climate, earthquake, regional and hazard maps, called the Hyogo Phoenix Disaster Management System, was developed. Furthermore, a survey done in Yokosuka City highlighted the fact that there is also great demand for cell phones to be used to collect post disaster information due to the large number of persons possessing mobile telephones.

Selecting Appropriate ICT tools for CDERA Participating States

The assessment of ICT status of CDERA Participating States revealed that more emphasis has been placed on sending messages to the communities than receiving reports from them. Five of the sixteen CDERA states used an E-messaging system to send out disaster warnings to the public. However, this same system is difficult to use to collect post earthquake event data from cell phone users. The data required by seismologists are too detailed to be transmitted using mobile phones.

Only three of the CDERA participating states - Jamaica, Trinidad and Tobago and the British Virgin Islands (BVI)- were concerned about macroseismic data collection. Jamaica was in the development stage for an online questionnaire application, but noted that getting the public to use online forms, instead of the telephone to make their reports, was proving a challenge. Therefore, to be successful proper advertising along with promotional inducements may be necessary to inform and motivate the public to report their earthquake experiences.

From the assessment, all disaster agencies from the CDERA participating states used the Internet to communicate with the media, issue warnings and gather feedback from the public. The agencies that did not have their own websites (e.g. St. Vincent and the Grenadines), indicated that the websites were under construction. Most disaster agencies agreed that the internet should be used as the main ICT tool to communicate with the public and are moving towards developing their communication methods to incorporate Internet technology. Furthermore, the percentage of the population that uses the Internet in the Caribbean is growing annually, making the Internet a feasible ICT tool to capture post event data from the public.

Internationally, the leading ICT tool used to collect macroseismic data is the internet, usually supported by GIS software. The criteria for the 'ideal' ICT tool include:

- Accessibility & Availability – the most appropriate ICT application should not only be readily available, but also easily accessible to most of the public across the Caribbean
- Ability to quickly transmit a reasonably large amount of data
- Easy to use

- Automatic location determination – the ICT application should allow detection of the location of respondents
- Has the lowest probability of failure after a destructive earthquake event

However, the internet cannot satisfy all the criteria listed above on its own. The 'ideal' ICT tool that would be best for data collection would not only allow uninterrupted, easy communication between the disaster agencies and the communities, but also be fully functional after a serious event when electricity may be down. Earthquake monitoring institutions should still be able to collect macroseismic data even if electricity, servers and telephone networks are down. Therefore, it would be unwise to depend solely on the internet as the ICT tool for collecting and communicating post event data. All of the CDERA participating states were familiar with HAM radio operations, many islands having trained HAM radio operators in every community across the state. As a result, *both the internet and the HAM radio* were selected as the most effective ICT tools for use in post event data collection for the region.

Design and Development

The results from PHASE 1 of the project revealed that, in the Caribbean, the internet and the HAM radio are the ideal tools for post earthquake event data collection. All of the CDERA participating states have access to both technologies; therefore, implementation of a system that incorporates these ICT tools should be inexpensive and relatively easy.

ICT Application: The INTERNET

Utilizing the internet in the design of the automated macroseismic data collection system would put the regional seismic community on the same level as other countries throughout the world with respect to macroseismic data collection. While some institutions may experiment with other ICT tools, such as laptop seismic sensors, most disaster response agencies and earthquake monitoring institutions utilize online questionnaires and GIS technologies to collect and publish the post earthquake event data.

As described earlier, the answers to online macroseismic questionnaires are usually converted to intensities using an algorithm. The USGS and KNMI use the algorithm defined by Dengler and Dewey (1998), which may be tailored, if necessary, to suit the needs of any region in which it is being implemented. Designs for Earthquake Intensity Maps based on community reports have recently included the use of Google's Application Programming Interface (API) (Haubrock, 2007). Google created this API to allow developers to integrate Google maps into their websites with their own data points. Currently Google Maps API does not contain advertisements and is a free service. The integration of Google Maps with the felt report forms allows the selection of the geographic coordinates of the observer. This is essential for accurately mapping the estimated intensities. This facility allows the rapid creation of accurate intensity maps that can be quickly published. Additionally, remotely sensed imagery can be freely obtained from Google maps. Though road networks and street addresses are not very detailed for the Caribbean region, at this time, the possibility exists that in the near future more data will be added. The use of Google Maps API was incorporated into the design of the automated post event data collection system for CDERA Participating states.

The proposed Community Internet Intensity System (CIIS) for CDERA PS has the following basic components:

1. The Earthquake Report Form /Macroseismic Questionnaire
2. Community Intensity Calculations
3. GIS mapping software – Google API
4. Earthquake reports database

The activities that the CIIS facilitates include:

1. Observer access to felt report form on SCRs' website to answer the questions describing the effects felt after an earthquake event.
2. User selects location using Google Maps
3. Latitude and Longitude extracted, symbol assigned to the location
4. Algorithm (Dengler and Dewey,1998) applied to descriptions after being converted to numerical values for estimated intensity calculation
5. The estimated intensity and coordinates are saved on the SCRs' database
6. Average Community Intensity is calculated per community (point list with attributes)
7. Average Community Intensity sent to the Google Maps API together with Symbol Information
8. Google Maps API returns a map showing Average Community Intensities with the chosen symbol information
9. Intensity Map integrated into SCRs' webpage

Figure 4 illustrates the design for the communication architecture of the system (after Haubrock, 2007).

ICT Application: HAM Radio

In the Caribbean region, HAM radio has been effectively used for decades to report disasters and maintain communication between communities, islands and countries. It is, therefore, important to maintain this proven system in the modernised post event data collection system. The HAM radio can be used as a back-up tool that would ensure the collection of post earthquake event data, even when the internet may be down following power failure.

HAM radio operators can relay the required information using Automatic Pacquet Reporting System (APRS) technology, which transfers data files using radio waves. To facilitate this, the

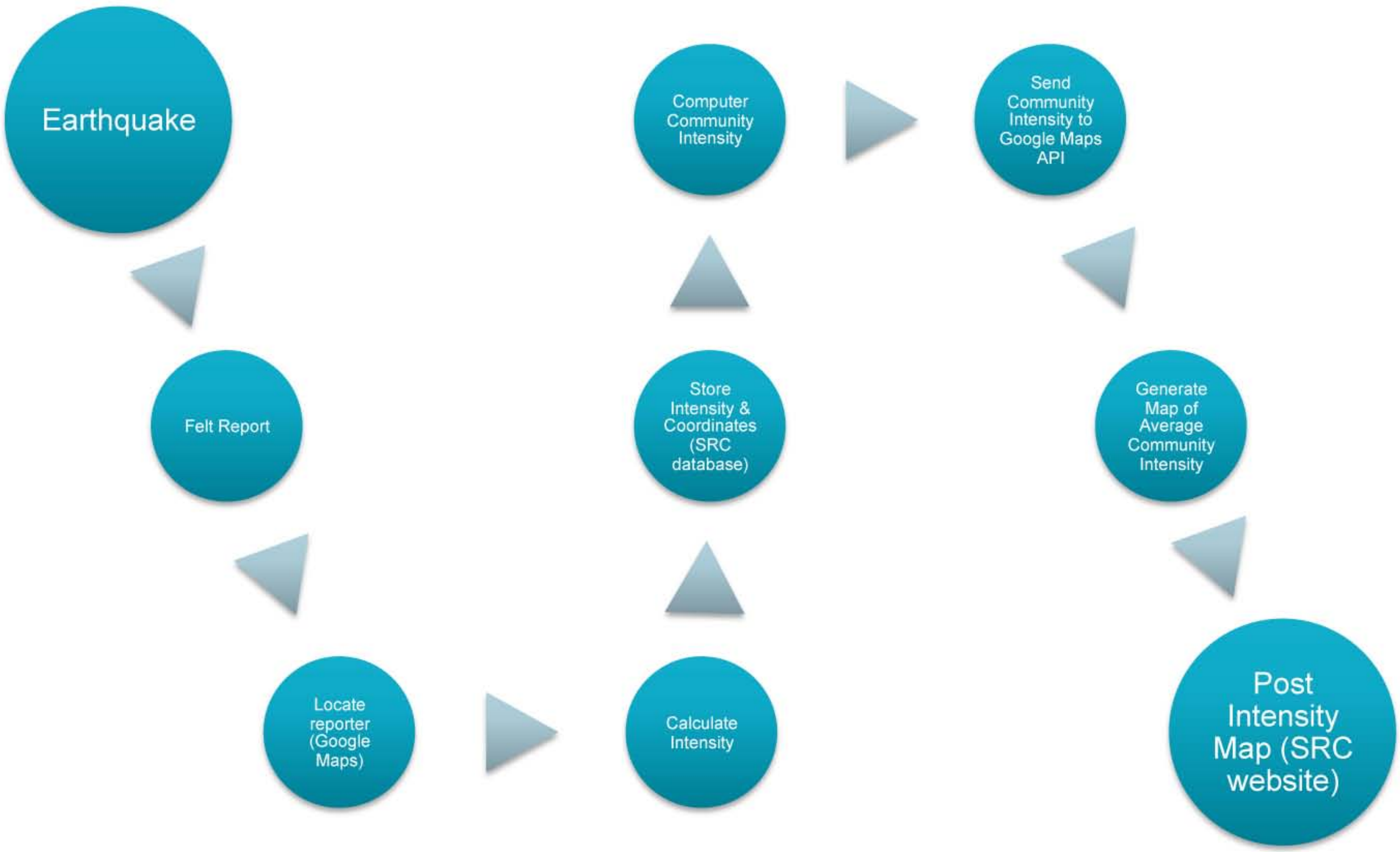

Figure 3: Conceptual design of the Community Internet Intensity System (CIIS)

questionnaire should associate each question and each answer with a unique number. This will serve to expedite the information transfer. Each operator would be responsible for describing the effects he/she witnessed in his/her community. While it is expected that the Internet would generate larger numbers of reports from a wider range of people across the islands, the HAM radio network would ensure that at least one report per community is in the database. This applies whether the internet is functional or not. In the circumstance where other types of reporting are not available, the HAM radio network might be the only communication technology operational. The HAM radio solution working along with the Internet solution would allow the data collection process to be uninterrupted, even after very significant earthquake events. This means that the SRC must ensure that a functioning HAM radio system is one of its resources.

Design of Macroseismic Questionnaire

The earthquake intensity form that was used at the SRC to capture the public's response was revised and redesigned for the purpose of this project. The estimation of earthquake intensities is based on the standardized Modified Mercalli Intensity Scale. Therefore, the effects described in the scale, from intensities I to XII, were used as a guide in composing questions for the questionnaire. The answer to each question gave key information that would be needed to assign the value of the intensity.

The format of the form was determined based on how the answers, given by the user, would be further analysed and processed. It is important that the macroseismic data be collected in a standard format to allow digital analysis of the information. Therefore, the format chosen offered a selection of possible answers for each question instead of the free-form format. However, the opportunity to relate observations that are not captured by the MMI scale was included for research purposes. At times, some people may not feel the earthquake but others around them may have felt it. This information was also considered important to seismologists and the option to report 'not felt' events was included in the questionnaire.

The comparison of different earthquake report forms from Italy, U.S.A., Britain, the Netherlands and Nepal revealed that the number of questions asked should be kept to a minimum. To facilitate in-depth macroseismic research, the questionnaire is divided into sections describing effects on buildings, people and animals. For example the Instituto Nazionale di Geofisia (ING) has a questionnaire consisting of 79 questions, 59 of which relate to a specific intensity value. However, asking persons to voluntarily fill out a form with that many questions in the Caribbean region was not practical. The people who would be targeted to contribute their experiences are not of a scientific background and may be overwhelmed by too many questions. Additionally, people are generally busy and may be unable to spend a long time completing forms. Therefore, the revised felt report form contained twelve questions, each with multiple answers that correspond to an intensity value. In Figure 5, the number of answers that can be selected on the questionnaire to suggest intensity is illustrated. Although the questionnaire considered intensities I to X on the MMI scale, it gives more options to evaluate intensities IV to VIII because most of the seismic activity for the region falls within in this range. Moreover, standard non-technical language was used to meet the general educational level. Intensity scale I to X on the MMI scale were considered on the questionnaire.

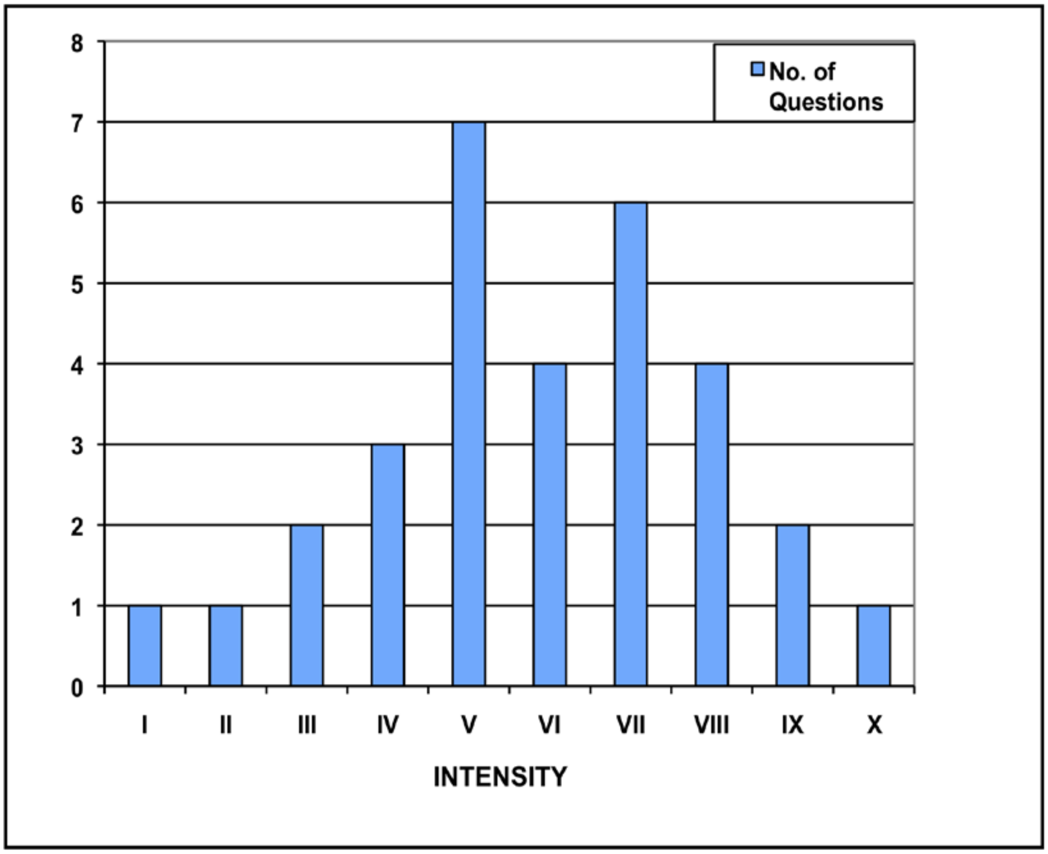

Figure 4: Graph relating the number of answers for each MMI degree in the revised SRC macroseismic questionnaire

Pilot Study

Pilot Study Selection and Implementation

The two ICT tools selected for use in the proposed macroseismic data collection system were tested in three different CDERA Participating islands: Trinidad, Tobago and Grenada. The criteria used for pilot study location selection were:

- ❖ Annual/occasional occurrence of earthquakes – community should be somewhat accustomed to earthquake activity
- ❖ Easy access to the community to test the ICT application (contact organizations to advise on a suitable test community)
- ❖ Availability of volunteers to participate in the study and support from community leaders/disaster management officials
- ❖ Existence of secure location to perform the training for the pilot study
- ❖ Community must be located in close proximity to strong motion instruments – to allow for the comparison between macroseismic and instrumental data

The internet was tested in communities in Tobago and Grenada and the amateur HAM radio tested in Trinidad. Volunteers were identified to participate in the internet testing using the following criteria:

- ❖ Computer Literate – knowledgeable on the use of the computer and the internet
- ❖ Must attend training session
- ❖ Easy access to internet - preferably at home with an active account
- ❖ Must participate in simulation exercises
- ❖ Must possess the ability to accurately describe observations after a real earthquake

Testing the Internet

The National Emergency Management Agency (NEMA) in Tobago and the National Disaster Management Agency (NADMA) in Grenada volunteered their support to assist in identifying participants for the study. Since it was difficult to find qualified persons at home during the daytime, government offices were visited and employees were invited to volunteer. In Grenada, volunteers were sourced from already existing community emergency support groups and secondary schools. From Tobago and Grenada, eighteen (18) and fifteen (15) persons respectively volunteered. Training sessions were held with the volunteers to describe the project, how to complete the felt report forms and appoint a date and time for simulation exercises.
Motivating persons to participate proved to be challenging. Since internet access was an essential requirement for participation, it was proposed that two months of internet service at the participant's residence might be sponsored as a benefit. This idea was received with encouraging enthusiasm.

Plate 1: Photos of the Internet training sessions held in Tobago (left) and Grenada (right).

Two simulation exercises in Tobago were conducted on 2008 September 25 and October 3, and one exercise in Grenada on 2008 November 20. The volunteers were asked to recall their most recent earthquake experience and, on a designated day and time, fill out the revised felt report form on the SRC website. From the 18 volunteers in Tobago, 11 persons participated in the simulation and 8 persons from the 15 volunteers in Grenada. The most important lesson learned during the simulations is the need to motivate persons to report felt events. Constant reminders and updates were provided; however, a hundred percent volunteer participation was never obtained for any of the internet pilot studies.

Testing Amateur HAM Radio

The Trinidad and Tobago Amateur Radio League (TTARL) is an active group of HAM radio operators in various communities throughout the islands of Trinidad and Tobago. TTARL was successful in providing important emergency data to law enforcement agencies and relevant governmental offices, such as the Office of Disaster Preparedness and Management (ODPM). Volunteers to participate in the study came from the TTARL group since members already had access to the tool, were familiar with the capabilities of the tool and were already involved in emergency response activities.

A training session held at one of TTARL's monthly meetings explained the objectives of the project and why their participation was important. Twenty-three (23) members from TTARL volunteered to participate in the study. Two simulation exercises were conducted on September 20 and November 22, which tested voice data and digital data transfer (APRS) respectively. The Office of Disaster Preparedness and Management acted as the receiving centre for the simulated reports from the different HAM radio stations, while the TTARL's main office located in Arima served as a base control, directing traffic through to ODPM and also verifying and relaying reports when appropriate. During the simulations reports were collected from twelve (12) different communities in Trinidad.

The lessons learnt from the first simulation exercise improved the second exercise. The use of APRS to send the data in a text format was preferred to that of voice data transfer. This reduced the time taken in data collection and ensured that the report answered the questions on the macroseismic questionnaire. Multiple digital reports came in at the same time, reducing traffic on the radio, and allowed the reports to be more detailed. The second simulation exercise was very successful, with more participants than in the first simulation. The volunteers were very motivated and were excited about contributing to the collection of the macroseismic data.

GIS Development

The final phase of the project developed the design for a GIS for Earthquake Hazard Assessment. Geographical Information Systems allow visualisation and analyses of graphical, numerical and text data. The intensities determined from the CIIS will be easily verified within the GIS, comparing it to computed intensities from instrumental data or other macroseismic data. Although the CIIS intensities are not strictly comparable to those on the Mercalli scale, continued collection and use of macroseismic intensities will improve the understanding of the CIIS intensities.

Plate 2: Photos of the HAM Radio training sessions held with TTARL volunteers in Trinidad.

Earthquake Hazard Assessment is an important exercise, in which the SRC is involved. In hazard assessment, "recurrence interval" is a key parameter in assessing the probability of significant future events. The analysis of historical events, within the available earthquake catalogues, and quantifying their "return periods", allows scientists to project when a significant magnitude event should be expected to occur in a given area. In general, there appears to be a relationship between magnitude and return period. While these studies are already being pursued by the SRC, a GIS would improve data collection and accessibility of earthquake data.

The datasets in Figure 5 below provides details of the datasets required for a typical earthquake hazard assessment. These datasets are comprehensive and, therefore, the time investment for a thorough job is significant. The requirements outlined in Figure 5 cover all aspects of earthquake hazard assessment using a GIS. In general, costs are involved in acquiring datasets, however, free data may be accessed from the internet. The rule of thumb is that cost increases with spatial resolution and detail of image data.

Therefore, resolution and detail weighed against cost must of necessity guide the decision on an acceptable product. Image data from State-owned sensors is often free of charge. Some sources of free data include:

1. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data – for excellent spectral/spatial detail (using stereo images) and used to create digital elevation models (vertical accuracy of approximately 11-25 meters) Shuttle Radar Topography Mission (SRTM) data – near global 30 m resolution digital elevation model
2. Landsat Images – provided by the Global Landcover Facility (in early 2009, all data were provided free of charge)
3. Digital Chart of the World (DCW) – thematic data such as coastlines, cities, airports, roads, etc (limited data available for certain Caribbean islands)

Baseline & Other Thematic Data Needed:

- Topographic maps
- Elevation, relief, drainage patterns
- Remotely sensed data
  - Passive and active remote sensing data;
  - Interferometer data;
  - High-resolution seismic reflecting surveys;
  - Gravity maps;
  - Magnetic maps, and
  - Seismic refraction surveys
  - Spectroscopic data
- GPS network

Geomorphologic input:

- Terrain units
- Slope and aspect map
- Digital Elevation Model
- Erosion map
- Slope Instability map
- Slopes susceptible to landslides (30° or more)

Soil inputs:

- Soil types
- Engineering soil maps showing bearing
- Capacity of soils soil thickness unconsolidated
- Sediments down to real bedrock
- The age and mineral composition of the soil.
- The depth of the ground-water table.
- Borehole data related to rock types, soil and

Geological input:

- Inventory of reports and maps on the geology, structure and soil involved
- Surface and sub-surface geology (age and rock types)
- Stratigraphy
- Structural Geological & tectonic mapping of the area/region with a detailed account of

Structural Input:

- Fault styles (Dip slip/fault slip/oblique)
- Fault type (Normal/reverse/transform faulting)
- Fault classification(active/reactivated)
- Fault geometry
- Average displacement across the fault
- Depth of fault

Parameters derived from seismic data:

- Magnitude of the earthquake
- Seismic energy released by the earthquake
- The spatial dimensions of ruptured fault
- The elastic constants of the medium in which the fault is located
- Depth and Orientation of the fault
- Average displacement across the fault
- Velocity with which rupture propagates on the fault
- Known faults and epicentres
  - The stress drop across the fault

Seismological input:

- Historical seismicity catalogue of the region
- Recurrence curve plots
- Review of historical shaking, damage and other intensity information(CIIS) near the site
- Correlation of epicentre locations and tectonic structures
- Seismic attenuation and response data

Groundwater input:

- Groundwater level
- Drainage network
- Borehole data related to subsurface

Vulnerability Data :

- Data on damage from historical events;
- Vulnerability curves for different structural types

Data for elements at risk:

- buildings (classification according to age, use, social class, building material, number of floors, contents)
- network of roads and railways
- network of major water conduits
- distribution of sanitation facilities
- network of gas and electric lines
- distribution of hospitals, fire station and other public structure
- population (age distribution, average number of people per household, gender distribution, socioeconomic classification)
- economic activities;
- lowland areas subject to liquefaction;
- area subject to freshwater inundation;

Figure 5: Illustration of datasets required for a typical earthquake hazard assessment.

4. Google Earth – high resolution images available; can be saved with a Google Earth Pro license and then integrated with other spatial data in the GIS

Unfortunately, detailed population information for the Caribbean is not generally found on the internet. However, the census data may be obtained from the various Census and Statistics Offices. The Environmental Systems Research Institute's (ESRI) ArcGIS software is most popular throughout the CDERA participating states. However, there are free open GIS software packages, such as the Integrated Land and Water System (ILWIS), which may offer more economical solutions.

The CIIS will be integrated with the GIS to assist seismologists at the SRC to not only assess, but also map the seismic risk for the region. Figure 7 illustrates the process, calculating risk based on the United Nations International Strategy for Disaster Reduction (UN-ISDR) standard. The UN-ISDR defined risk assessment as 'a methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, livelihoods and the environment on which they depend.' Therefore, risk assessment is based on a review of both technical features of the hazard and also the analysis of the physical, social, economic and environmental dimensions. The equation used in Figure 7 is actually calculated with spatial data in the GIS to quantify risk, determining physical, population and even economic losses.

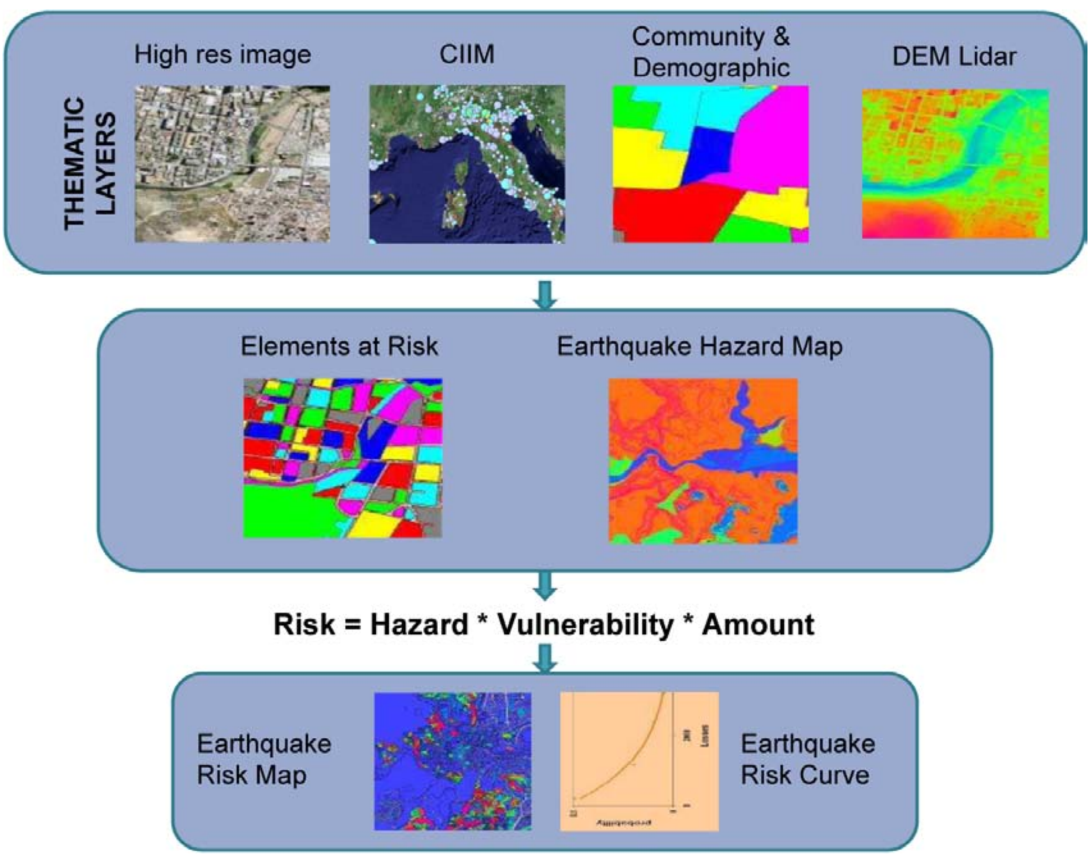

Figure 6: Determining Seismic Risk using Geographical Data.

Overall Assessment and Recommendations

The main objective of this project was to identify the best ICT tool for the region and to integrate it into the macroseismic data collection process within CDERA participating states. There were five (5) deliverables, as shown in Table 3 below.

Firstly, an assessment of the current utilization of ICT tools for post event earthquake data amongst these states revealed that ICTs were not being used to their full potential and were rarely used to collect macroseismic data. The disaster agencies in the CDERA participating states routinely used the internet and HAM radio; therefore, these tools were included in the newly designed post earthquake data collection system. Furthermore, the assessment also revealed that GIS is a useful tool for disaster management and most of the disaster agencies were using or planning to use this tool in their work.

Table 3: Summary of Deliverables and Delivered Tasks for the Project.

The use of the internet and HAM radio to report earthquake experiences were tested in two (2)

Deliverables	**Delivered**
1. An assessment report on the Utilization of ICT applications in the earthquake damage assessment process in the CDERA Participating States.	Submitted
2. Three Pilot Projects completed and documented.	Executed in Tobago and Grenada (Online Questionnaire) and Trinidad (HAM Radio) Report Submitted
3. At least 40 Community People Trained in the use of ICTs	Total No. of persons trained with ICT tool: 70 Total No. of persons participated in simulation exercises: 42
4. System for receiving and sending post impact data determined, implemented and documented	Conceptual Design of Community Intensity System for the Region Implementation (pending)
5. To establish a mechanism for the ongoing monitoring and review of the system designed for the collection of macroseismic data;	GIS for Earthquake Hazard Assessment : Datasets Identified Free data collected

different CDERA Participating States: Trinidad and Tobago and Grenada. This was a crucial step in the project since the macroseismic data collection process is people-driven. Unless people are aware of the facility for reporting their earthquake experiences and motivated to do so, the process will fail. In total seventy (70) persons were trained to use the ICT tools. It was more difficult to get persons to volunteer to test the internet than to test the HAM radio. This may be due to the fact that the HAM radio volunteers were already involved in responding to hazardous events and they understood how important it was to assist SRC and contribute to scientific research aimed at improving the system. However, the average citizen had to be convinced of their need to participate. As a result, in the simulation exercises, most of the HAM radio volunteers participated while only a few internet volunteers did so.

The system that was developed for the macroseismic data collection incorporated the internet as the main tool with HAM Radio as a back-up tool in cases where the internet is not available. If the system is to be successfully implemented, then proper advertising and education directing persons to the SRC’s website to report their observations are necessary. However, more education is considered necessary because the average Caribbean citizen is not as inclined to report, especially if it is a new type of behaviour being promoted in the communities. For most internet volunteers, the idea of free internet access over a couple months was sufficient motivation. For sustained participation, the process should be simple and not be costly for the volunteer. Funds provided through the project allowed computers to be purchased that would be located at and left in the care of the disaster agency’s office in the pilot countries. Internet access, with appropriate restrictions, was made available for anyone in the community to report their experiences. Therefore, if an event occurs in the near future, volunteers for the study or others from the community can report their earthquake experience.

Although an automated macroseismic data collection system was designed for the project, it has not yet been implemented, because a prototype of a working system is still being developed. This prototype will be reviewed by SRC prior to full implementation. This approach was decided upon to simplify the implementation and to quickly address unforeseen problems.
The mechanism suggested for reviewing and monitoring the CIIS is within the formation of a GIS for Earthquake Hazard assessment. Although development of the GIS database suggested requires significant time, the datasets can be prioritised according to the needs of SRC. Remotely sensed data for the region that are free of charge can be downloaded and used to start populating the database. The GIS database would give SRC the resources to readily quantify spatial vulnerability and perform hazard assessment for the region. Additionally, areas with the potential to be affected by the secondary effects from significant earthquakes, such as landslides and liquefaction, can be identified.

ICT development has changed the face of disaster management in recent decades, however, in CDERA participating states the technology is under-utilised. The suggestions in this report are geared to correcting this situation, making the macroseismic collection process on par with best practices in the United States and some European countries.

This project has enabled the SRC to investigate and streamline the methodology used to collect post event data following felt earthquakes in the Caribbean. It has led to the determination of an automated system which the Centre will implement in the next few months once it has been fully tested and all elements of the system fully developed. This will provide data that will be used in the future to update hazard maps. The GIS database that is being developed will contribute to ongoing work on quantifying the risk associated with seismic hazard in the region and is major unanticipated outcome of the project.

Appendix 4

Enhancing the Effectiveness of Information and Communication Technology Applications and Tools for Disaster Management in the Caribbean:

Research on the Application of Geographic Information Systems for Disaster Early Warning Systems

Final Technical Report

Prepared by
Spatial Systems Caribbean Ltd

August, 2009

Published by CDEMA

Enhancing the Effectiveness of Information and Communication Technology Applications and Tools for Disaster Management in the Caribbean: Research on the Application of Geographic Information Systems for Disaster Early Warning Systems

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Abstract

Information and Communication Technologies (ICTs) have improved prospects for solving technical problems through the use of Geographical Information Systems (GIS) for hazard mapping and modeling, the use of web-based data sources to facilitate research on disaster management and the use of searchable databases for hazard information. Not all Caribbean countries however have been able to fully utilize these opportunities. This CDERA/International Development Research Centre initiative on "Enhancing the Effectiveness of Information and Communication Technology Applications and Tools for Disaster Management in the Caribbean Region" is an ICT related "Research Project" with 3 objectives that support the cross-cutting theme of ICTs of the Caribbean Strategy for Comprehensive Disaster Management.

The specific objectives are to:

a) Gain an understanding of international good practice on the use of GIS for early warnings and identify their relevance and adaptability to the Caribbean
b) Gain knowledge on the status of GIS utilization for early warnings in the Caribbean
c) Propose an implementation plan for effective use of GIS for early warnings in the Caribbean
d) Obtain feedback from stakeholders on the appropriateness of the proposed plan
e) Develop an implementation plan for the installation and use of the prototype in a CDERA PS

These objectives were met using the following methodical approach:

a. A review of theoretical concepts and guiding principles on the design, implementation and evaluation of EWS.
b. A review of EWS at the global and regional levels based on best practice principles.
c. Conceptual and logical design of a GIS-based EWS for the Caribbean using the knowledge gleaned.
d. Development of an implementation plan for a GIS-based EWS for the Caribbean.

The following are some of the challenges to GIS-EWS integration in the Caribbean:

- Weak institutional linkages that does not support joint initiatives between the National Disaster Office and National GIS Agencies
- Inadequate availability and access to current and accurate database of critical facilities, biophysical, and anthropogenic features
- Unavailability of current and densified digital meteorological and hydrological data
  Inadequate access to trained and qualified personnel (Hydrologist and GIS specialist)
- Lack of access to GIS hardware and software
- High cost of data transmission and dissemination (Internet connection)
- Inadequate allocation of funds for systems maintenance and upgrade
- Long history of system neglect
- Inadequate institutional support
- Weak knowledge-base on hazard prediction
- Inadequate record of hazard information: hazard maps, vulnerability assessment, risk assessment

In reviewing the adequacy of existing EWS in the Caribbean using the ISDR (2006) best practice principles, below are the findings:

a. Apart from the regional Hurricane EWS and flood EWS in Jamaica, none of the systems reviewed was established with a coherent set of linked operational responsibilities among the relevant agencies
b. None of the system reviewed are explicitly linked to a broader program of national hazard mitigation and vulnerability reduction. A project approach rather than a program approach was used most of the time.
c. Responsibility for the issuance of early warnings is explicitly designated in all the countries.

d. Authoritative decision makers with political responsibility for decisions taken were easily identified at the national level
e. Actions taken are all based on well-established procedures
f. There is no evidence to support the notion that existing EWS are based on documented risk analysis
g. No study has been done to monitor and forecast changes in vulnerability patterns at both the community and national levels
h. Only in Jamaica can evidence of this be found
i. The range of communication methods are mostly limited and no evidence to support BPP that the warning should provide multiple strategies for risk reduction.
j. Only the regional hurricane EWS and the Jamaican Flood EWS have evidence of the involvement of stakeholders. Funding remains a drawback to system sustainability.

With regards to how well the Caribbean EWS meets Zillman's technical requirements, below are the findings:

a. The level of metrological and hydrological model of catchment is at its infancy in the Caribbean none of the system reviewed were based on a sound knowledge of the metrological and hydrological factors due mainly to lack of data and short supply of qualified personnel.
b. Apart from the regional Hurricane EWS, none of the systems reviewed incorporated global or regional data streams for short to medium range forecast process. On occasion satellite rainfall forecast are used without a rigid coupling to the EWS.
c. The lack of a reliable regional data that can be assessed quickly weakened all the systems reviewed.
d. All the systems reviewed experienced inadequate computer hardware and software with the exception of the new systems in Anguilla.
e. The effectiveness of existing sensors is inadequate due to a poor maintenance regime and vandalism.
f. The current state of information communication tools used is inadequate due mainly to budgetary constraints to acquire and adapt to modern and cheaper ICT.

Following the pilot project conducted, below are key recommendations:

a. Integration of data from the different sectors is important. It was suggested that there was the need for the development of an integrated data policy for Grenada that would define a standard system, enhance data sharing, and add value-added to existing datasets.
b. Appreciation of how ArcPad & Juno can be used to enhance efficiency: participants made attempts to show how the system can be used in their individual environments, for e.g. Land Use updating, land ownership data collection, shelter management etc
c. Appreciation for more complete recording of metadata
d. Need for a more persons at all levels to become familiar with GPS and GIS technology.
e. Need for a more integrated approach towards data collection. It was suggested that government, private and public sectors communicate with each other about what information is being collected so that cost, time and resources can be saved along with creating better partnerships.
f. Software and license for ArcPad and ArcGIS is required for NaDMA and other departments that would be using the system (Juno & ArcPad)
g. More in-depth training is required for field operators and NaDMA staff in ArcPad and ArcGIS
h. More equipment is required- handhelds and accessories (memory cards, screen filters, stylus)
i. Need for a GIS specialist to be working in close contact with NaDMA staff and persons using system as a resource person to assist with map generation and use of GIS techniques and analysis. Currently there are GIS specialists in Land Use (Agriculture) and Physical Planning

These recommended national efforts should be built into a regional development programme so that the Caribbean can advance its capacity to effectively use ICT for disaster risk reduction.

Keywords: Comprehensive Disaster Management, Early Warning Systems, Geographic Information Systems, Satellite Remote Sensing

1.0 Background

Information and Communication Technologies (ICTs) have improved prospects for solving technical problems through the use of Geographical Information Systems (GIS) for hazard mapping and modeling, the use of web-based data sources to facilitate research on disaster management and the use of searchable databases for hazard information. Not all Caribbean countries however have been able to fully utilize these opportunities. This CDERA/International Development Research Centre (IDRC) initiative on "Enhancing the Effectiveness of Information and Communication Technology Applications and Tools for Disaster Management in the Caribbean Region" is an ICT related "Research Project" with 3 objectives that support the cross-cutting theme of ICTs of the Caribbean Strategy for Comprehensive Disaster Management (CDM).

2.0 Goals and Objectives

The goal of the research is to gain knowledge and understanding of the use of GIS in the design and implementation of disaster early warning systems and to apply these towards the design of a GIS-based Early Warning System (EWS) that will improve the effectiveness of early warnings in the Caribbean.

The specific objectives are to:

a) Gain an understanding of international good practice on the use of GIS for early warnings and identify their relevance and adaptability to the Caribbean
b) Gain knowledge on the status of GIS utilization for early warnings in the Caribbean
c) Propose an implementation plan for effective use of GIS for early warnings in the Caribbean
d) Obtain feedback from stakeholders on the appropriateness of the proposed plan
e) Develop an implementation plan for the installation and use of the prototype in a CDERA PS

3.0 Method

The specific objectives of the research study are met using the following methodical approach:

e. A review of theoretical concepts and guiding principles on the design, implementation and evaluation of EWS.
f. A review of EWS at the global and regional levels based on best practice principles.
g. Conceptual and logical design of a GIS-based EWS for the Caribbean using the knowledge gleaned.
h. Development of an implementation plan for a GIS-based EWS for the Caribbean.

4.0 Theoretical Concepts: GIS for Early Warning Systems

4.0.1 Principles and concepts of Early Warning Systems (EWS)

Reducing the impact of natural disasters continue to engage the attention of national, regional, and international agencies. There is increasing awareness that total reliance on structural measures is unrealistic since these measures are subject to fail with the increasing intensity and frequency of natural hazards. The move towards the use of non-structural measures is an attempt to ensure a holistic approach to measures that could reduce the impact of natural disaster. Structural measures are actions that focus on the building of infrastructure like dykes, dams, retention ponds and sea defence walls to mitigate the impact of natural hazards. Non-structural measures on the other hand are activities that focus on improving human capacity to cope with the impact of natural hazards e.g. land use planning, hazard mapping, vulnerability assessment, public awareness programme, early warning systems etc. The idea is that improving human capacity to cope with the incidence of natural hazards coupled with the development of physical infrastructure that could mitigate the impact of natural hazards will provide communities with adequate protection from perennial loss from the incidence of natural hazards.

Early Warning Systems (EWS) is defined as the communication of information about a hazard or threat to a population at risk, in order for them to take appropriate action to mitigate any potentially negative impacts on themselves, those in their care and their property (Samarajiva et al, 2005). According to IDNDR, (1997), the objective of early warning is to empower individuals and communities, threatened by natural or similar hazards, to act in sufficient time and in an appropriate manner so as to reduce the possibility of personal injury, loss of life and damage to property, or nearby and fragile environments.

The absence of an Early Warning System led to the destruction of many lives in the aftermath of the 2004 tsunami that hit several countries in the Asian region and the 2005 Kashmir earthquake that affected the Northern region of Pakistan. The ability to forecast the path of Hurricane Katrina in 2005 provided ample time for the warning and evacuation of the large population of New Orleans. Timely warning provides the opportunity for both the community and the official responders to take appropriate action that will minimize loss of life and property.

Some of the benefits of EWS include:

- Reduction in loss of life and property
- Early notification of emergency services
- Orderly disruption of social and economic facilities
- Improved opportunity for traffic control
- Reduced stress

4.0.2 Best Practice Principles for the Application of Early Warning

ISDR (2006) advanced the following governing best practice principles for the development and use of EWS:

- A coherent set of linked operational responsibilities should be established
- It should be components of a broader programme of national hazard mitigation and vulnerability reduction.
- Sole responsibility for the issuance of early warnings should be designated by the Government
- Authoritative decision makers with political responsibility for their decisions should be identified
- Action taken should be based on well-established disaster management procedures
- Early Warning Systems must be based upon risk analysis that includes the assessment of the occurrence of hazards, the nature of their effects and prevailing types of vulnerability, at national and local levels of responsibility
- Need to monitor and forecast changes in vulnerability patterns, particularly at local levels, including those arising from social developments such as rapid urbanization, abrupt migration, economic changes, nearby civil conflict, or similar elements
- To facilitate appropriate community actions, there is a need for detailed knowledge and experience of local factors and risks, decision-making procedures, roles and mandates of authorities, means of public communication and established coping strategies
- Locally appropriate warning systems need to provide a range of communication methods and to provoke multiple strategies for protection and risk reduction
- To be sustainable, all aspects of the design and implementation of Early Warning Systems require the substantive involvement of stakeholders at local and national levels

4.0.3 Measuring the Effectiveness of an EWS

The following parameters are used to measure the effectiveness of EWS:

- Forecast timing and accuracy
- Assessment of each stage of the warning process against specific targets such as proportion of audience reached and time taken to reach them
- Quality of warning system design and operation
- Level of public understanding of warnings
- Amount of human and economic loss avoided
- Knowledge and implementation of timely and appropriate actions
- Level of public satisfaction with the warning service

4.0.4 Technical Requires for EWS

In designing EWS, the following technical requirements are required (Zillman, 2003)

- A sound knowledge of the meteorological and hydrological model of the catchment
- Rapid access to global data streams in order to initialize forecast models for short–to-medium range forecast process
- Rapid access to regional data in order to initiate short-range regional models in order to provide prior and during-the-event guidance and monitoring
- Computer hardware and software to store, retrieve, process, display information
- Sensors to detect and alert forecasters to severe weather events
- Information communication tools to transmit data and information to end-users

4.0.5 Information Communication Tools for EWS

Improvements in information and communication technology have led to the use of the following tools for EW communication. A challenge exists in the selection and use of the most effective mix of tools.

- Radio and Television
- Telephone (Fixed, mobile, satellite)
- Short Message Service (SMS)
- Cell Broadcasting
- Satellite Radio
- Internet and Email
- Amateur Radio and Community Radio
- Megaphones/Callers
- Car siren

4.0.6 Elements of Integrated EWS

There are five keys elements of a community-based integrated EWS. These are risk knowledge, hazard monitoring and warning services, disaster risk information, dissemination and communication, emergency response management, and institutional environment (ISDR (2006), Schmidt, 2003)

a. Risk Knowledge

The Yokohama Strategy for a safe World (The World Conference on Natural Disaster Reduction 1994) placed special emphasis on the importance of risk assessment in the development of successful disaster reduction policies and measures. Risks arise from the combination of the hazards and the vulnerabilities to hazards that are present at a particular location or region. Assessments of risk require systematic collection and analysis of data and should take into account the dynamic nature and variability of hazards and vulnerabilities that arise from processes such as urbanization, rural land-use change, environmental degradation and climate change. Risk assessments and risk maps help in motivating people, prioritizing EWS needs and guiding the preparation response and disaster mitigation activities. The goal of risk knowledge is the establishment of a systematic, standardized process to collect and assess data, maps and trends on hazards and vulnerability. It has the following sub-elements:

- Hazard Mapping
- Vulnerability Assessment
- Risk Assessment
- Data Management
- Organizational Development

b. Hazard Monitoring and Warning Service

Warning services lie at the core of the system. They must have a sound scientific basis for predicting and forecasting and must reliably operate 24 hours a day. Continuous monitoring of hazard parameters and precursors is necessary to generate accurate warnings in a timely fashion. Warning services for the different hazards should be coordinated where possible to gain the benefit of shared institutional, procedural and communication networks. The goal of hazard monitoring and warning service is the establishment of an effective hazard monitoring and warning service with a sound scientific and technological basis. It has the following sub-elements:

Monitoring Systems Developed
Forecasting and Warning Systems Established
Institutional Mechanisms Established

c. Information Dissemination and Communication

The warnings must get to those at risk. For people to understand the warnings, they must contain clear, useful information that enables proper responses. Regional, national and community level communication channels and tools must be pre-identified and one authoritative voice established. The use of multiple communication channels is necessary to ensure everyone is reached and to avoid failure of any one channel, as well as to reinforce the warning message. The goal of the information dissemination and communication element is the development of communication and dissemination systems to ensure local, national and regional coordination & information exchange. It has the following sub-elements:

Effective Communication Systems and Equipment Installed
Warning Messages Recognised and Understood
Organizational and Decision-making Processes
Institutionalized

d. Emergency Response

It is essential that communities understand their risks; they must also respect the warning service and should know how to react. This requires systematic education and preparedness programmes led by disaster management authorities. It is essential that disaster management plans are in place, are well practiced and tested and that the community is well informed on options for safe behavior and escape and on means to avoid damage and loss to property. Response capacity focuses on strengthening of the ability of communities to respond to natural disasters through enhanced education on natural hazard risks, community participation and disaster preparedness. Its sub-elements are:

Warnings Respected
Disaster Preparedness and Response Plans
Community Response Capacity
Public Awareness and Education

e. Institutional Environment

The overall effectiveness and sustainability of EWS is dependent on the establishment and maintenance of an institutional environment that supports its existence. Elements of the institutional support include: good governance, well articulated disaster risk reduction policy and legislation, involvement of local knowledge, recognition of the marginal population, and adequate human and financial resources. The goal of institutional arrangement is the development of national, institutional, legislative and policy frameworks that support the implementation and maintenance of effective EWS. Its sub-elements are:

- Early Warning Secured as a Long Term National and Local Priority
- Legal and Policy Frameworks to Support Early Warning
- Institutional Capacities
- Financial Resources

Elements	Sub-elements
Risk Knowledge	Hazard Mapping
	Vulnerability Assessment
	Risk Assessment
	Data Management
	Organizational Development
Hazard Monitoring and Warning Service	Monitoring Systems
	Forecasting and Warning Systems
	Institutional Mechanisms
Information Dissemination and Communication	Effective Communication Systems and Equipment
	Warning Messages
	Organizational and Decision-making Processes
Emergency Response	Warnings Respected
	Disaster Preparedness and Response Plans
	Community Response Capacity
	Public Awareness and Education
Institutional Environment	Early Warning Secured as a Long Term National and Local Priority
	Legal and Policy Frameworks to Support Early Warning
	Institutional Capacities and Financial Resources

4.0.7 Principles and Concepts of Geographic Information Systems (GIS)

Improvements in information technology have provided unimaginable opportunities to support data analyses and communications in the last two decades. GIS has provided new and exciting ways of acquiring natural resource data and also providing efficient means of processing, managing, integrating, and visualizing this data. GIS is an organized collection of computer hardware, software, geographic data and personnel, designed to efficiently *capture, store, update, manipulate, analyze and display* all forms of geographically referenced information (Opadeyi, 1992). Geographic information plays an important role in activities such as environmental monitoring, management of land and water resources and real estate transactions. The increasing use of GIS in the varying professional fields has produced both tangible and intangible benefits that are enough to sustain its use into the future. Below are some of the of the use of GIS and Remote Satellite Systems (RSS) in disaster preparedness and management operations (DPMO):

- Provides integrated data storage and data retrieval capabilities.

- Encourages a more systematic approach to data collection.
- Leads to reduction in the overall costs of data collection and management by facilitating data sharing.
- Increases comparability and compatibility of diverse data sets.
- Makes data accessible to a wider range of decision-makers.
- Encourages the spatial analysis of the impacts of natural disaster.

Over the past decade, computer hardware and software constraints to GIS development have been reduced. Data acquisition however, remains a challenge even with advances in remote sensing technology and decreasing cost of data acquisition. The removal of the intentional error in Global Navigation Satellite Systems (GNSS) readings and the availability of satellite imagery with one-metre spatial resolution have provided some relief to these constraints. The recent commercialization of the IKONOS satellite imagery with the one metre panchromatic and four-metre multi-band resolutions is revolutionizing the use of GIS for DPMO. Vulnerability or capacity assessments are an indispensable complement to hazard assessment exercises. The Organization of American States (OAS) has been one of the pioneers in Latin America and the Caribbean in using GIS tools for physical vulnerability assessment, focused on infrastructure and critical facilities. A pilot project launched early in the 1980s has implemented more than 200 activities in 20 countries by integrating hazards, natural resources, population and infrastructure data (UNISDR, 2004).

The use of GIS techniques has broadened the possibilities of undertaking multi-hazard assessments (UNISDR, 2004). GIS has been used extensively to drive the multi-hazard analysis and assessment in various parts of the world such as Costa Rica, Australia and Sweden. Risk-GIS, as it has been named in the Cities Project in Australia, is a fusion of the decision support capabilities of GIS and the philosophy of risk management. This would prove useful in the islands of the Caribbean due to their proneness to various natural disasters over the centuries.

In recent years, risk assessment methodologies have increasingly incorporated the use of GIS as a means of increasing their overall utility. The Hazard United States Multi-Hazard (HAZUS-MH) methodology and software programme is one such example. HAZUS-MH, an offspring of the Hazard U.S. (HAZUS) methodology developed by the nation's Federal Emergency Management Agency (FEMA), aims at standardizing the risk assessment and loss estimation process for flood, wind, hurricane and earthquake hazards across the U.S. (FEMA, 2004). One of the ground-breaking merits of this program is that it offers, free of charge, an extensive collection of hazard and vulnerability data (FEMA, 2004); another is its incorporation of GIS capabilities. The HAZUS-MH risk assessment process consists of five stages (FEMA, 2004):

- Identification of Hazards
- Profiling of Hazards
- Inventory of Assets
- Estimation of Losses
- Consideration of Mitigation Options

In all but the last stage, GIS is used as a means of mapping and displaying hazard data, modeling hazard scenarios and displaying the results of loss estimates for the built environment (FEMA, 1997; FEMA, 2004). The challenge of integrating input data with diverse scales, formats and levels of accuracy is virtually solved by incorporating them into a GIS. The incorporation of GIS into HAZUS also allows users to analyze scenarios and estimate losses from hazards that are not modeled by the HAZUS-MH software (FEMA, 2004). In other words, HAZUS-MH's GIS component allows users to go beyond the limitations of the program. Although the software's data content restricts full applicability to regions within the U.S. (FEMA, 1997; FEMA, 2004), HAZUS-MH methodology can still be highly useful to Caribbean territories, and therefore should be made available to risk managers in the region. If used in its present state, the main challenge of the use of HAZUS-MH for Caribbean scenarios would be data acquisition.

GIS comprise is of the followings components: computer hardware, computer software, data and databases, personnel, and applications. These components work together to generate products and services. The products and services of GIS are mainly software-based and are mostly specific to organizations which utilize its capabilities. Among the seemingly unlimited list of global GIS products and services are: standard maps, custom maps, digital data transfers, aerial photography, and subscription based web access. The cost of GIS products, services and implementation varies largely and is often based on its specific uses and level of detail required.

4.0.8 The Use of GIS and Remote Satellite Sensing in Support of Early Warning Systems

Disaster Preparedness and Management Operations [DPMO] are currently benefiting from improvements in technological innovations and techniques. The increasing use of these computer-assisted techniques may diminish the gap between the information produced through technical risk assessments and the understanding of risk by people. Three notable elements of DPMO that have benefited are: data acquisition, data management, and data analysis. The impacts of technological applications in these three elements are reviewed below.

Technological innovations have provided efficiency and effectiveness in the data acquisition challenges of DPMO. The following are the notable technologies that have a positive impact on DPMO: high resolution commercial observational satellites; airborne video; GNSS; and telemetric data acquisition systems. These technologies have brought dramatic benefits such as: lower cost of data collection, higher data resolution and accuracy, shorter time frame with possibility for real-time data collection and higher repeatability. Data acquisition is essential in three phases of DPMO. These are pre-disaster, response, and recovery phases.

A. Pre-disaster Phase

In the pre-disaster phase, an inventory of current natural and built resources is required. The knowledge of the location, magnitude, and extent of these resources should be accurate, current, detailed and complete for an effective DPMO. The traditional sources of this information are the topographic and thematic maps obtainable from the national mapping agency. These maps (especially in the Caribbean) are mostly out-of-date, of inappropriate resolution, and are available only in hardcopy formats. They are thus grossly inappropriate for a modern approach to DPMO. Most agencies still rely on the use of maps that are over 20 years old for DPMO, even in the face of the continuing social and economic developments of these countries.

The use of high-resolution satellite imagery such as IKONOS and Quick Bird with ground resolution of one metre or better has removed the dependency on published hardcopy maps. The fast turnaround time in the acquisition of satellite imagery, the relatively lower cost of acquisition and its immediate usability, has made it an indispensable tool for vulnerability assessment. The value of any vulnerability assessment is dependent on currency and resolution of the data input. It is therefore, imperative that for any effective DPMO, the acquisition of high resolution and current data on the status of the natural and built resources should be priority. The use of image maps (a by-product of satellite imagery) is far superior to the use of vector maps; image maps provide the “feel and look” of the real world as opposed to polygon hatching and colour patches used in the production of vector maps as shown in Figure 1.

Incorporating Modelling into GIS can add power to disaster planning in the pre-disaster phase. This will allow the relevant disaster managers to view the scope of a disaster, where the damage may be the greatest, the properties that are at highest risk, and the response required. Immediately following a large-scale event, one of the first tasks performed is locating shelters and facilitating welfare action plans. The Office of Disaster Preparedness and Emergency Management (ODPEM) in Jamaica has embarked on the development of an emergency management GIS, which is integrated across their functional business units. Spatial Innovision Ltd was contracted to implement a GIS database design to support the ODPEM. The methodology involved a mass data conversion and data acquisition from other related agencies. A master input list was created and agencies were approached in the data acquisition process. A data model, which outlined the various aspects of the ODPEM's business tasks, was created and Spatial Innovision created a customized application to address these business processes. GIS maps and tables were created using the offices' internal data that were resident in folders and hard copy maps (Lewis and Edwards, 2004).

B. Response Phase

Data acquisition at the response phase is more critical than during the pre-disaster phase. It requires real-time location of features and lives that are under threat. The improvements in the use of GNSS have provided the ability to determine the geographic position of any phenomenon with high precision at any time of the day and in any weather condition. The use of GNSS in kinematic mode also provides the ability to track the movement of any phenomena under threat. The integration of GNSS positioning with communication satellite systems has revolutionized Search and Rescue Programmes worldwide. A geostationary satellite with an altitude of about 35,000km can be used to detect and locate air-based, marine-based, or land-based distress anywhere in the world. The international Cospas-Sarsat Program and the NOAA-SARSAT are currently providing leadership in the use of this technology to save lives.

The management and operations of vehicles and giving real-time information to users that will lead to cost-effective and satisfied service to passengers is possible nowadays using a GPS based vehicle navigation system and communication via remote sensing. In many parts of the world GNSS and remote sensing technologies have been merged together to form an efficient disaster management system. The potential of such a merger in the Caribbean is not far-fetched. This would however demand strong collaboration between the regional emergency rapid response and disaster management agencies.

Internationally, GPS has given citizens and disasters managers alike a quantum leap forward in efficient operation of their emergency response teams. The ability to effectively identify and view the location of police, fire, rescue, and individual vehicles or boats, and how their location relates to an entire network of transportation systems in a geographic area, has become very crucial in the disaster response phase. Location information provided by GPS, coupled with automation, reduces delay in the dispatch of emergency services. Today's widespread placement of GPS location systems in passenger cars provides another leap in developing a comprehensive safety net. Today, many ground and maritime vehicles are equipped with autonomous crash sensors and GPS. This information, when coupled with automatic communication systems, enables a call for help even when occupants are unable to do so.

ESA/ESRIN and Eurimage started the *Earth Watching* project in 1993 to supply satellite data and pertinent information quickly in cases of natural disasters. The project uses satellite data to monitor various disastrous events worldwide. Radar satellite systems such as RADARSAT and ERS-1/2 satellites with their all-weather capability and ability to penetrate clouds are used for monitoring hazards like floods and oil spills. Optical satellite systems such as AVHRR, Landsat 7, SPOT and MODIS are used to monitor incidences of fires and volcanic activities. Their properties of wide-swath, high-pass repetition, and their ability to provide precise details of already active fires and burnt areas make them indispensable for DPMO (http://earth.esa.int/ew/). Synthetic Aperture Radar Interferometry (INSAR) is being used for the monitoring of earthquakes and volcanoes, land subsidence, glacier dynamics, classification of different land types and construction of Digital Elevation Models (DEM's) of the Earth's surface.

C. Recovery Phase

Data acquisition, during the recovery phase of a disaster, is important for damage assessment and monitoring of post-event behaviour of the disaster itself. High-resolution satellite imagery acquired before and after the disastrous event, provides the input required for the estimation of the damage caused and the identification of safe areas for relocation and relief programmes. Using image processing techniques, it is less tedious for computer software to identify and quantify damaged resources from the before and after satellite imageries. In the case of seismic activities, continuous data acquisition using both GNSS and satellite imagery provides effective monitoring of disastrous events.

An example of the use of satellite imageries for DPMO can be drawn from the management of the 1993 flooding of the Mississippi, Missouri and Illinois Rivers in the United States of America. Two geo-rectified Landsat satellite images: one 'pre-flood' image and one 'during-flood image were acquired. Scaled image maps were created to determine the extent and size of the flooded areas and to quickly identify those areas still at risk from flooding and prevent further damage by planning defence and recovery operations to contain the flood. Using ERDAS IMAGINE software, a comparison between the temporal images immediately illustrated the extent of the flood and production of a flood risk assessment plan, within the disaster context. This helped to determine remedial flood defence work to be undertaken and to prevent further damage in near real time.

4.1 Applications of GIS in Disaster Risk Management

GIS provides the platform for undertaking the following spatial analyses which are peculiar to DPMO. These are:

- Temporal analysis of natural hazard parameters.
- Trend analysis of the occurrence of disasters.
- Spatial analysis of the impact of disaster over a geographic region.
- Three dimensional analysis of the effect of natural hazards.
- Multivariable risk analysis.
- Natural hazard prediction and modeling.
- Simulation of response rate to vulnerable communities.
- Cause-Effect analysis.
- Analysis of impact zones or anticipated degree of severity.
- Storm runoff prediction from urban watersheds.
- Site suitability screening for hazardous waste facilities.

Hamilton [2000] provided justification and examples for the use of technology for hazard and risk assessment. A range of GIS applications for solving disaster management challenges has been investigated within the region. These include: hazard mapping and vulnerability assessment in Antigua and Barbuda [Hodgkinson-Chin and Rogers, 2001], hazardous chemical transport in Barbados [Riley, 2001] and the development of a hazard emergency management information system in Trinidad and Tobago [Ali, 2001].

4.2 GIS and Remote Satellite Sensing in Disaster Management

GIS can be loosely defined as a system of hardware and software used for storage, retrieval, mapping and analysis of geographic data. Spatial features are stored in a coordinate system (latitude, longitude, state plane etc.) that references a particular place on the earth. Descriptive attributes in tabular form are associated with spatial features. Spatial data and associated attributes in the same coordinate system can then be layered together for mapping and analysis. GIS can be used for scientific investigations, resource management and development planning.

Remote sensing is the measurement or acquisition of information about an object or phenomenon, by a recording device that is not in physical or intimate contact with the object. In practice, remote sensing is the remote utilization (as from aircraft, spacecraft, satellite or ship) of any device for gathering information about the environment. Thus, an aircraft taking photographs, earth observation and weather satellites, monitoring of a foetus in the womb via ultrasound, and space probes are all examples of remote sensing. In modern usage, the term generally refers to techniques involving the use of instruments aboard aircraft and spacecraft.

GIS and remote sensing are examples of ICT tools being widely used in almost all the phases of disaster management activities. In the planning phase GIS can be used to identify and pinpoint risk prone geographical areas, as a GIS-based 3D map provides much more information compared to an ordinary 2D map. Earth observation satellites can be used to view the same area over long periods of time and as a result, make it possible to monitor environmental change, human impact and natural processes. In the mitigation phase, GIS is helpful in monitoring. GIS also play several roles in the recovery phase. It can identify the damage, assess it and begin to establish priorities for action (triage). GIS can also ensure uniformity in the distribution of supplies (medicine, food, water, clothing, etc.) to emergency distribution centres. They can be assigned in proper amounts based on the amount and type of damage in each area.

Followings are examples of the advantages of GIS-based hydrologic modeling (1993):

- collecting of rainfall data from the available remote sensors;
- identifying the area of the potential occurrence of extreme meteorological events on the basis of the whole set of remotely sensed information;
- running distributed rainfall-runoff procedures using the rainfall scenarios predicted on small scales by stochastic space-time rainfall models as an input;
- providing predicted and/or simulated hydrographs at sections of interest along the drainage network for different probability levels; and
- providing maps of eventually flooded areas and the vulnerability of the landscape with reference to the predicted events.

4.3 GIS tools and Applications that can be integrated with EWS

Using the five key elements of EWS (ISDR, 2006 and Schmidt 2003), the extent to which GIS can be interpreted to EWS is provided in table below. The table contains the aims of each of the five elements, the sub-elements and specific GIS tools can be used to support each of the sub-elements. It is important to note that GIS cannot be used to support elements and sub-elements that are mainly institutional or sociological in nature.

Key Element 1: RISK KNOWLEDGE	
Aim: To e*stablish a systematic, standardized process to collect and assess data, maps and trends on hazards and vulnerability.*	
Sub-Elements	Supporting GIS Tools and Applications
1. Hazards Mapping	Digital hazard maps

	Database of bio-physical resources
2. Vulnerability Assessment	Database of vulnerable human and environmental resources
3. Risks Assessment	Production and maintenance of disaster risk maps
4. Data Management	Database management system
5. Organizational Development	Not applicable
Key Element 2: HAZARD MONITORING AND WARNING SERVICE	
Aim: *Establish an effective hazard monitoring and warning service with a sound scientific and technological basis.*	
Sub-Elements	Supporting GIS Tools
1. Monitoring Systems Developed	Satellite remote sensing of the environment Selection of monitoring stations
2. Forecasting and Warning Systems Established	Hazard modeling systems
3. Institutional Mechanisms Established	Not applicable
Key Element 3: INFORMATION DISSEMINATION AND COMMUNICATION	
Aim: *Develop communication and dissemination systems to ensure local, national and regional coordination & information exchange.*	
Sub-Elements	Supporting GIS Tools
1. Effective Communication Systems and Equipment Installed	Web-based and PDA-based GIS
2. Warning Messages Recognized and Understood	Not applicable
3. Organizational and Decision-making Processes Institutionalized	Not applicable
Key Element 4: RESPONSE CAPABILITY	
Aim: *Strengthen the ability of communities to respond to natural disasters through enhanced education of natural hazard risks, community participation and disaster preparedness.*	
Sub-Elements	Supporting GIS Tools
1. Warnings Respected	Not applicable
2. Disaster Preparedness and Response Plans Established	Risk mapping Disaster resources mapping
3. Community Response Capacity Assessed and Strengthened	Not applicable
4. Public Awareness and Education Enhanced	Web-based mapping Virtual reality-GIS mapping
Key Element 5: INSTITUTIONAL ARRANGEMENTS	
Aim: *Develop national institutional, legislative and policy frameworks that support the implementation and maintenance of effective early warning systems.*	
Sub-Elements	Supporting GIS Tools
1. Early Warning Secured as a Long Term National and Local Priority	Not applicable
2. Legal and Policy Frameworks to Support Early Warning Established	Not applicable
3. Institutional Capacities Assessed and Enhanced	Not applicable
4. Financial Resources Secured	Not applicable

4.4 Integrating GIS into EWS

The uses of GIS in different phases of the Early Warning System include:

- Planning - Using a GIS, it is possible to pinpoint hazard trends and initiate evaluation of the consequences of potential emergencies or disasters.
- Preparedness - GIS can accurately support better response planning in areas such as determining evacuation routes or locating vulnerable infrastructure and vital lifelines, etc. It also supports logistical planning to be able to provide relief supplies by displaying previously available information on roads, bridges, airports, railway and port conditions and limitations.

According to Sorensen (2000), for EWS to be effective, it must integrate the sub-element of detection, hazard information management, and public response. This integration is made possible through improvements in the sciences of hazard monitoring, hazard forecasting, and GIS technology, as well as social re-engineering. The integration of GIS into the design of EWS is inevitable since GIS promotes the effectiveness of EWS through the following:

- Development of spatial databases of bio-physical and anthropogenic features critical to disaster risk knowledge
- Integration of hazard monitoring and warning services to spatial locations of critical and response facilities
- Use of web-GIS to enhance the dissemination and communication of warning information to the general public
- Development of virtual reality GIS in support of public awareness and education
- Development of GIS databases of disaster response resources for quick mobilization
- Support for institutional integration through data sharing

Paul (1999) established the following principles for the design of a GIS-based flood EWS:

- Design improved meteorological observing network
- Design improved hydrological network (precipitation and stream gauges)
- Automate the meteorological and hydrological networks
- Establish real-time communication system to move data reliably from field to the forecast office
- Establish operational network maintenance plan
- Determine feasibility of existing and new ground-based radar for estimating quantitative precipitation products
- Determine feasibility of using geostationary and polar orbiting satellite products
- Integrate in-situ precipitation data with satellite and radar precipitation estimates
- Establish hydrometeorological database and management system
- Select hydrological and hydraulic models appropriate for river basin conditions and needs of the users
- Establish real-time linkages between databases and modeling system

4.5 Framework for integration

Revisiting the elements of EWS presented in Table 1.1, GIS can support sub-elements of EWS as indicated in Table 1.2 below. GIS can be used to enhance the following components of EWS:

- Hazard Mapping
- Vulnerability Assessment
- Risk Assessment
- Data Management
- Monitoring Systems
- Forecasting and Warning Systems

- Effective Communication Systems and Equipment
- Warning Messages
- Disaster Preparedness and Response Plans
- Public Awareness and Education

4.6 Challenges to GIS/EWS integration

The integration of GIS into EWS is however, faced with challenges in the following areas:

- Availability of geographic data in digital format,
- Currency of data
- Availability of high-speed computer hardware and data processing software
- High cost of data communication and data maintenance
- Availability of training personnel
- Institutional support

4.7 Evaluating EWS

In evaluating the effectiveness and efficiency of EWS, the integrated modules as illustrated in Figure 4.1 must be considered

Module I: Hazard Information Management (HIM)
This module is designed to monitor, map, and predict the behaviour of a particular natural hazard. It comprises the following sub-systems of integrated EWS: hazard monitoring, hazard mapping, and hazard forecasting. It relies on the scientific knowledge of natural hazards modelling, earth observation technology, and GIS integrated analytical power. The effectiveness of this phase is measured by its accuracy to forecast impeding hazardous events, reliability of its performance, and the lead time it provides for adequate disaster preparedness and response management.

Module II: Risk Knowledge Management (RKM)
The risk management module has the following sub-systems: vulnerability assessment, risk assessment, and response planning. It is designed to model elements at risk and emergency response activities that will mitigate losses to life and properties. It relies on the scientific knowledge of the linkages between hazard occurrences and demographic, social, and economic variables. GIS spatial analysis functionalities provide an efficient platform for these linkages.

Figure 4.1: Systems Environment for the full Integration of GIS and EWS

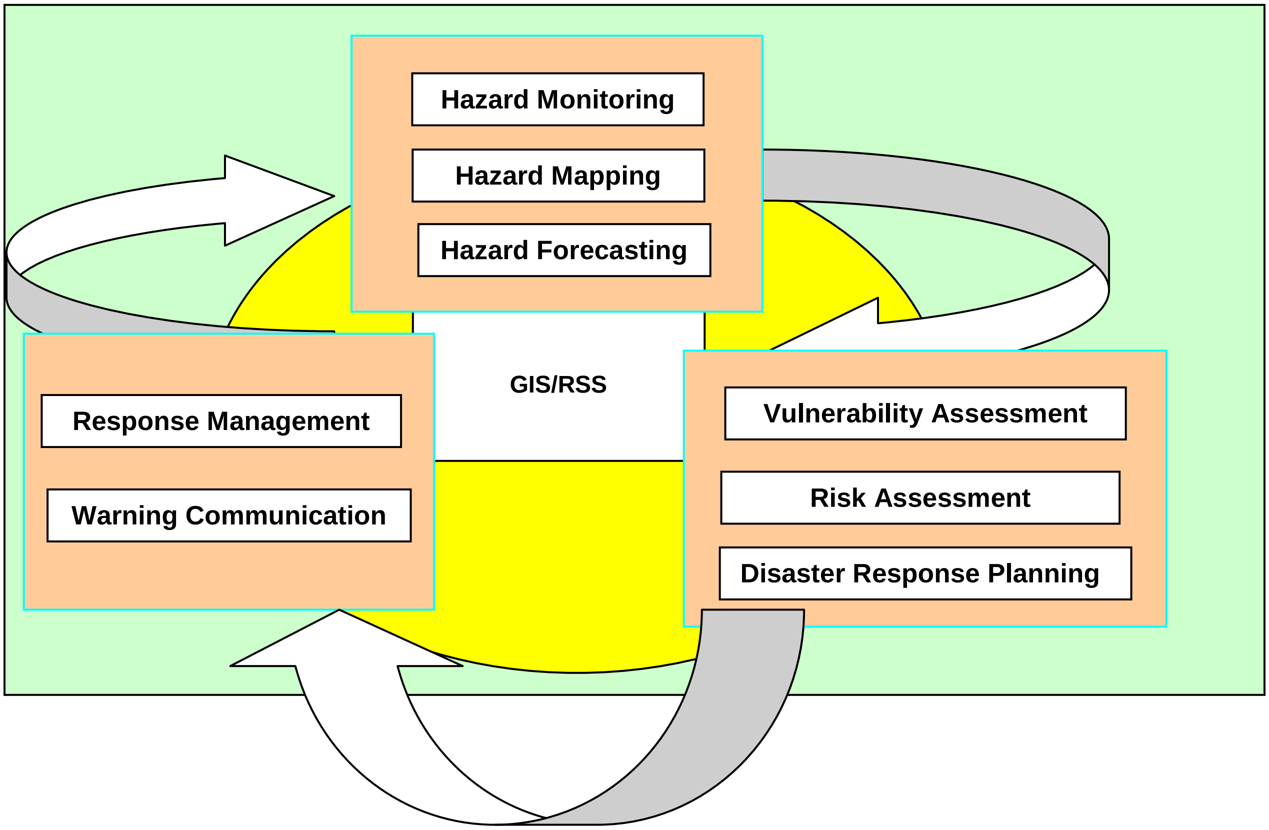


Figure 7: Systems Environment for the full Integration of GIS and EWS

Module III: Community Response Management (CRM)
The response management module provides the platform for the communication of warning information to affected communities and responders as well as the ability to monitor and manage response activities. The module comprises the following EWS sub-elements: risk communication and response management. GIS provides a mechanism for efficient management of warning messages and efficient management of response activities.

5.0 Review of EWS and GIS in Selected Caribbean States

Although the Caribbean is vulnerable to multiple hazards including tropical cyclones, storm surge, floods, drought, Tsunami, landslides, climate change, technological hazards, biological hazards and social hazards, however, the infrastructure for early warning is notably absent for most hazards. Plans are afoot to develop EWS for hazards such as tsunami, climate change and for technological, biological and social hazards. Table 3.1 provides an indication of countries with EWS while Table 3.2 provides the status of EWS in the region. The dominant systems are for tropical cyclone and flood hazards.

Table 3.1: Early Warning Systems in Selected Caribbean States (CDERA, Year)

Country	Tropical Cyclone	Strom surge	Flooding	Drought	Landslide	Volcano
Antigua and Barbuda	√	√				
Bahamas, the	√	√				
Barbados	√	√				
Belize	√	√	√			
Grenada	√	√				√
Guyana			√			

Martinique	√	√	√		√	√
Saint Lucia	√	√				
St. Vincent and the Grenadines	√	√				√
Trinidad and Tobago	√	√	√	√		

Table 3.2: Status of Early Warning Systems in Selected Caribbean States (CDERA, Year)

Hazard Type	Frequency of the Hazard	EWS	Operational Status (yes/no)	Plans to develop EWS
Tropical cyclone	Annually	Yes	Yes	n/a
Storm surge	Annually	Yes	Yes	n/a
Flood	Seasonal	Yes	Yes	n/a
Tsunami	Historical	No	n/a	Yes
Landslide	Annual	No	No	No
Climate change	Future	No	No	Yes
Technological	Occasionally	No	No	Yes
Biological	Occasionally	No	No	Yes
Social	Occasionally	No	No	Yes
Drought	Annually	Yes	Yes	n/a

The technical and operational features of EWS of selected countries in the Caribbean are provided below. The review considered the following hazards: tropical cyclone, flood, drought, landslide, and volcano.

5.1 Tropical Cyclone Early Warning System in the Caribbean

The Meteorological services of the Caribbean share information and capabilities through the Caribbean Meteorological Organization (CMO) and its governing body the World Meteorological Organization (WMO). In addition, the National Hurricane Centre and National Weather Service of the National Oceanic and Atmospheric Administration (NOAA) of the United States bolster and supplement the information and forecasting skills of Caribbean Meteorological Services.

Through the World Weather Watch (WWW) Program, WMO Members coordinate and implement standardization of measuring methods and techniques, common telecommunication procedures, and the presentation of observed data and processed information in a manner that is understood by all, regardless of language. These arrangements, as well as the operation of the WWW facilities, are coordinated and monitored by WMO with a view to ensuring that every country has access to all of the information it needs to provide weather services on a day-to-day basis as well as for long-term planning and research. The information in WWW website is based on advisories issued by Regional Specialized Meteorological Centres (RSMC), and official warnings issued by National Meteorological and Hydrological Services (NMHSs) for their respective countries or regions. The information is freely available.

The tropical cyclone warning system in the Caribbean is part of a wider Caribbean and Atlantic warning system linked to the Hurricane Center in Miami, Florida and the National Oceanic and Atmospheric Administration (NOAA). In addition, the regional Tropical cyclone EWS is part of the World Meteorological

Organization Regional Association 4 (RA4) grouping of national meteorological services that include North and Central America and the Caribbean. NOAA contains 9 centers managed by the Office of the Director at the National Centers for Environmental Prediction. The Centers include the:

- *Aviation Weather Center* that provides aviation warnings and forecasts of hazardous flight conditions at all levels within domestic and international air space.
- *Climate Prediction Center* that monitors and forecasts short-term climate fluctuations and provides information on the effects of climate patterns.
- *Environmental Modeling Center* develops and improves numerical weather, climate, hydrological and ocean prediction through a broad program in partnership with the research community.
- *Hydro-meteorological Prediction Center* provides nationwide analysis and forecast guidance products out through seven days.
- NCEP Central Operations sustains and executes the operational suite of numerical analyses and forecast models and prepares NCEP products for dissemination.
- *Ocean Prediction Center* issues weather warnings and forecasts out to five days for the Atlantic and Pacific Oceans north of 30 degrees North.
- *Space Environment Center* provides space weather alerts and warnings for disturbances that can affect people and equipment working in space and on earth.
- *Storm Prediction Center* provides tornado and severe weather watches for the contiguous United States along with a suite of hazardous weather forecasts.
- *Tropical Prediction Center* includes the National Hurricane Center and provides forecasts of the movement and strength of tropical weather systems and issues watches and warnings for the U.S. and surrounding areas.

The *Tropical Analysis and Forecast Branch* (TAFB) is an integral part of the *Tropical Prediction Center / National Hurricane Center* (NHC). The TAFB performs a number of functions within the Tropical Prediction Center and its products include: marine high seas forecasts over the tropics and subtropics, offshore waters forecasts over the tropics and subtropics, tropical weather discussions over the tropics and subtropics, and surface weather analyses and forecasts over the tropics, subtropics, and mid-latitudes. The TAFB provides support for NHC during the hurricane season. This includes satellite-derived tropical cyclone position and intensity estimates, WSR-88D radar fixes for tropical cyclones, tropical cyclone forecast support, media support, and general operational support. Unlike the NHC which is only fully staffed for operations during the hurricane season, the TAFB is staffed and operated 24 hours a day 365 days per year. TAFB has at least three meteorologists working at all times, and usually has five meteorologists working during weekdays and during tropical cyclone landfall events. The TAFB products include:

- High Seas Forecast
- Offshore Waters
- Wind/Wave Forecasts
- Surface Forecasts
- Atlantic Sea State Analysis
- Peak Wave Period / Primary Swell Direction
- Tropical Cyclone Danger Areas
- Tropical Weather Discussion
- Marine Weather Discussion
- Pan-American Temperature & Precipitation
- Satellite Rainfall Estimates
- 5-day Satellite Hovmöller diagrams
- Upper-Air Time-Section Analyses

- Unified Surface Analysis
- Specialized Tropical Surface Analyses
- Streamline
- Sea Surface Temperature Analyses

5.1.1 Technical Features

Technical features of tropical cyclone EWS includes the collection and analysis of hydro-meteorological data on Atlantic cyclones and the transmission of related data and information through a network of collaborating countries throughout the Caribbean Basin. Data analysis and information generation is largely undertaken by the National Hurricane Center in Florida, USA

5.1.2 Technical Components

Given the regional scope of tropical cyclone warnings, the technical components of the EWS include RADAR, Satellites, reconnaissance aircrafts, National Hurricane Center Models and Rawindsonde devices.

- *Radar* – When a hurricane approaches an island, it is monitored by land-based weather radar. This radar provides detailed information on hurricane wind fields and other changes to support accurate short-term warnings for especially flooding.
- *Satellites* – Geostationary satellites orbiting the earth at an altitude of about 37000 km provide the National Hurricane Centre with imagery that helps provide estimates of the location, size and intensity of a tropical storm and its surrounding environment.
- *Reconnaissance Aircraft* – The US Air Force provides operational reconnaissance by flying aircrafts into the core of hurricanes to measure wind, pressure, temperature and humidity as well as to provide accurate location of the centre of the hurricane. The National Oceanic and Atmospheric Administration also flies aircrafts into hurricanes to aid scientist in better understanding the dynamics of these systems and improve forecast capabilities.
- *National Hurricane Center Models* – The National Hurricane Center uses several computer models to help forecast the path, speed, and strength of hurricanes. Data from weather satellites, reconnaissance aircrafts and other sources are fed into the models.

Data generated through these networks of components is analyzed and resultant information communicated throughout collaborating countries of the Caribbean region.

5.1.3 Operational Description

Cyclone-related technical information is received by the National Meteorological Services. The Meteorological Services collaborates with the National Disaster Organization (NDO) on the issuance of bulletins, advisories, watches and warnings each marking increasing probability of impact from a cyclone. Mode of issuance includes mass media, facsimile and electronic mail. Issuance via mass media is reserved for warning of the general public while other modes are used for communication among relevant agencies that have a role to play in emergency response. EWS coverage for tropical cyclones is country-wide and sub-regional-wide. Some NMS provide hydro-meteorological information including on tropical cyclones to their neighboring jurisdictions through a collaborative agreement. Input data includes a range of hydro-meteorological data related to the generation, characteristics and movement of tropical cyclones. These data include:

- Rainfall quantity and intensity
- Cloud pattern/height
- Wind direction and speed
- Humidity/temperature

- Atmospheric pressure

5.1.4 Alert Modes

The tropical cyclone alert mode involves four basic levels of warning:

- *Tropical Storm Watch* – Tropical Storm (organized system of strong thunderstorms with defined circulation and maximum sustained winds of 64-118 km/h) conditions are possible within 36 hours.
- *Tropical Storm Warning* - Tropical Storm conditions expected to impact the island within 24 hours
- *Hurricane Watch* – Hurricane (intense tropical weather system with well defined circulation and maximum sustained winds of 119km/h or higher) conditions expected to impact the island within 36 hours.
- *Hurricane Warning* – Hurricane conditions are expected to impact the island within 24 hours.

The tropical cyclone EWS is usually triggered at the stage of Watch (for both tropical storm and hurricane) i.e. at 36 hours before anticipated impact. The issuance of warning for tropical cyclones falls within the joint portfolio of the National Meteorological Services (NMS) and NDO. Operation and management of the EWS is the responsibility of the National Meteorological services. Tropical cyclone warnings are disseminated via the mass media and electronically through the internet and facsimile.

5.1.5 EWS Installation

The EWS for tropical cyclones in the Caribbean has been in existence for several years, probably since the 1960s and is also used for aviation purposes. Given that the region is part of a wider tropical cyclone early warning network, cost of installation, maintenance cost and number of persons responsibility for the operation of the system must be evaluated from an international perspective. Most regional States through their NMS nevertheless own, maintain and operate local hydro-meteorological facilities that contribute to the early warning network for tropical cyclones. Three national agencies share responsibility for early warning as indicated in Table 3.3.

Table 3.3: EWS Institutional Responsibilities

Institution	Responsibilities
National Meteorological Services	Monitoring, Maintenance, issuance of warnings, data collection
National Disaster Organization	Issuance of warnings, response recovery
Drainage Unit	Flood monitoring

The Meteorological Services in conjunction with CERO is responsible for the issuance of warnings but the NMS has sole responsibility for data collection and maintenance and operation of the existing system. The operation and use of tropical cyclone early warning systems has been effective for many years in informing related emergency response. Given the comparatively high level of literacy in the region, most residents have received tropical cyclone warnings through the mass media with over 68 percent responding immediately to these warnings. In that regard the warnings are extremely effective in the Caribbean context.

5.1.6 Limitations of EWS

One of the biggest limitations of the tropical cyclone EWS in the region is that the most countries do not have their own radar that could be used for micro-location forecast and warnings. There are however ongoing efforts to acquire a Doppler radar under the Radar Project initiative. In the meantime some islands continue to access forecast and warning information through existing collaborative arrangements with other English and non-English countries/territories. In this regard, acquisition of new weather radar to complete the development of a dedicated EWS for tropical cyclones is given highest priority among disaster mitigation tasks in some countries.

5.1.7 Improvements Required to EWS

The followings lists the most urgently needed improvements to the EWS in the region:

- Need for automated weather stations in countries that did not have such a station to monitor local conditions.
- Need to extend or densify the network of weather stations throughout the region
- Need to increase the use of satellite telephones as landline and wireless telephones are unreliable during catastrophic events
- Need for dedicated a web-server for the dissemination of warning messages via the World Wide Web.
- Need to augment radio and media coverage in low population islands
- Need for satellite image processing facilities
- Need to improve the capacity of local personnel in the area of weather forecasting.

5.1.8 Regional and Global Collaboration for Hurricane EWS

The national early warning for hurricane is supported by the regional and global World Weather Watch (WWW). The Meteorological services of the Caribbean share information and capabilities through the Caribbean Meteorological Organization (CMO) and its governing body the World Meteorological Organization (WMO). In addition, the National Hurricane Centre and National Weather Service of the National Oceanic and Atmospheric Administration (NOAA) of the United States bolster and supplement the information and forecasting skills of Caribbean Meteorological Services. Countries in the region also collaborate in terms of the siting of weather stations in order to maximize coverage. Table 3.4 provides a list of the islands covered by weather radar stations in the region.

Table 3.4: Coverage of Radar Weather Stations

Station	Sub-regional Coverage
Antigua	Antigua, Barbuda, St. Kitts, Nevis, Anguilla, British Virgin Islands, and Montserrat
Bahamas	All of the Bahamas islands and the Turks and Caicos Islands
Barbados	Barbados St. Vincent and the Grenadines, Martinique, and Guadeloupe
Trinidad	Trinidad, Tobago, and Grenada
Belize	Belize

To predict the weather, modern meteorology depends on near instantaneous exchange of weather information across the entire globe. The World Weather Watch (WWW), the core of the WMO Programmes, combines observing systems, telecommunication facilities, and data-processing and forecasting centres - operated by members - to make available meteorological and related geophysical information needed to provide efficient services in all countries. The WMO indicates that the WWW “is a unique achievement in international cooperation” in that it is a world-wide operational system to which all Meteorological services contribute on a daily basis.

Through the WWW Program, WMO Members coordinate and implement standardization of measuring methods and techniques, common telecommunication procedures, and the presentation of observed data and processed information in a manner that is understood by all, regardless of language. These arrangements, as well as the operation of the WWW facilities, are coordinated and monitored by WMO with a view to ensuring that every country has available all of the information it needs to provide weather services on a day-to-day basis as well as for long-term planning and research. The information in WWW web site is based on advisories issued by Regional Specialized Meteorological Centres (RSMC), and official warnings issued by National Meteorological and Hydrological Services (NMHSs) for their respective countries or regions. The information is freely available.

The Tropical Analysis and Forecast Branch (TAFB) is an integral part of the Tropical Prediction Center / National Hurricane Center (NHC). The TAFB performs a number of functions within the Tropical Prediction Center and its products include: marine high seas forecasts over the tropics and subtropics, offshore waters forecasts over the tropics and subtropics, tropical weather discussions over the tropics and subtropics, and surface weather analyses and forecasts over the tropics, subtropics, and mid-latitudes. The TAFB provides support for NHC during the hurricane season. This includes satellite-derived tropical cyclone position and intensity estimates, WSR-88D radar fixes for tropical cyclones, tropical cyclone forecast support, media support, and general operational support. Unlike the NHC which is only fully staffed for operations during the hurricane season, the TAFB is staffed and operated 24 hours a day 365 days per year. TAFB has at least three meteorologists working at all times, and usually has five meteorologists working during weekdays and during tropical cyclone landfall events.

5.2 Manual Flood Early Warning System: Belize

Inland river flooding is a source of major annual hazards in Belize. The following communities are affected by inland flooding: San Victor, Douglas, San Roman, Crooked Tree, Freetown Sibun, Gracie Rock, Roaring Creek, and San Ignacio. The two technical tools used for monitoring the hazard are: level gauge of rivers and precipitation forecast. The operation of the system is quite simple. It comprises the measurement of the stage of the river and this is compared to the mean value. The rate of increase is monitored. Precipitation forecast is used to subjectively predict new river levels. If the new level is expected to exceed bankful, then various levels of alerts are issued.

In the event of a flood, the wave is tracked and alerts are issued for communities downstream. The different alert modes and their meanings are as follows

- Alert – Intense rainfall for 24 hours over next two days.
- Watch - Intense rainfall for 36 hours over next two days
- Warning – Intense rainfall to continue for next 36 hours

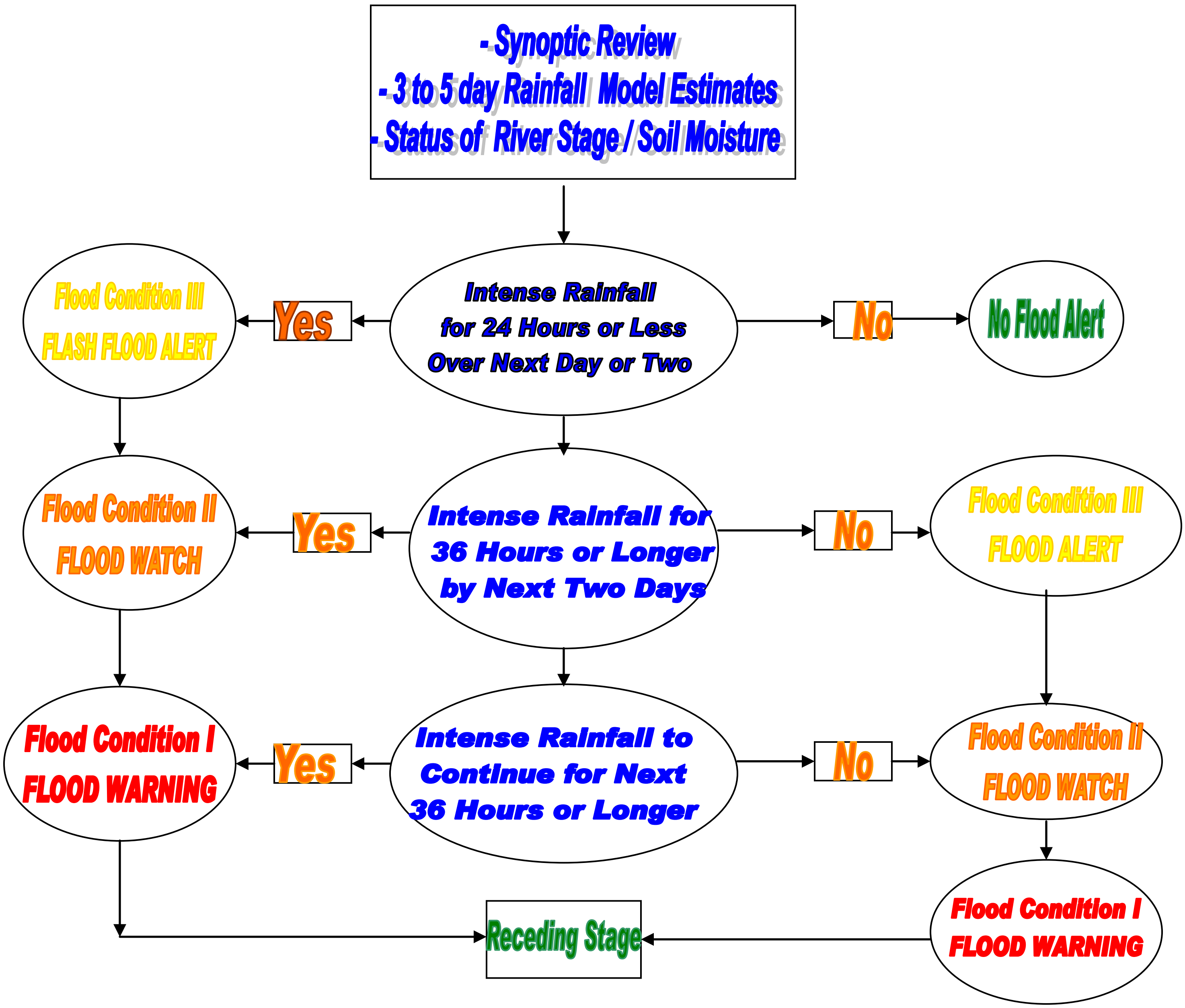
The National Meteorological Services has the authority for issuance of the warnings. The modes and means of warning information dissemination are radio and television. District disaster coordinators, community leaders and selected individuals participate in the reading of the water level gauges and dissemination of the information to NMS. The warnings are triggered NMS precipitation forecasts.

The EWS is managed by the NMS. It was installed in early 1990. The staff of the hydrology section of NMS designed the system. The Flood EWS is fully owned by the Government of Belize. The system uses all available weather data integrated with local knowledge. The system is operated and managed by 35 members of staff of the NMS. The cost of acquisition and operation of the system is about US$200,000 while annual maintenance cost is about US$50,000. On an annual basis, the system has been used to issue warnings to the following communities: Douglas, San Roman, Crooked Tree, Gracie Rock, Roaring Creek, San Ignacio, and Freetown Sibun. In all cases, warnings issued were followed by a forecasted event.

Warnings are transmitted through a multiple of media. These are: emails, radios, cell phones, satellite phones, sirens, bull horns, and a.m. transmitters, fixed frequency receivers, SMS ready cell systems, internet access, countrywide media (radio & TV) coverage.

Figure 5.1: Water Level Gauge in Belize

Figure 5.2: Schematic of the structure for the Flood Early Warning System for the Greater Belize River Basin.



The system relies on good cooperation from communities and some ham radio operators in reading and transmitting information. The strengths of the system are community involvement,; public awareness, and a variety of warning methods that allow for redundancy. The system is weakened by insufficient equipment deployed for accurate and timely warnings in all vulnerable areas. The current limitation of the EWS is that it is highly subjective.

The system can be improved by undertaking the following tasks:

- Installation of more stage

- Improved rainfall monitoring
- Availability of Topographical maps of higher resolution
- Improving the density of river cross-sections
- Telecommunication facilities to get data in real time

Even though the communities found the system to be unreliable, they mostly obey the warnings issued

5.3 Flood Early Warning Systems in Trinidad and Tobago

The flood early warning system comprises transmitters/receivers, rain gauges, tipping buckets, and water level sensors. The water level sensors and rainfall gauges are placed at strategic locations within the river basin. The changes in river levels and rainfall amounts are transmitted via telephone or airwaves to a receiver at base in St. Joseph. As the event unfolds, the water levels and rainfall are tracked. Each river has its warning and alert levels, the predicted time for flood wave to peak and spill its banks. The system currently serves the following communities: Caparo, South Oropouche, Sangre Grande, and San Juan. The essential data used by the EWS are rainfall and water levels. The EWS for floods uses two alert modes. The first mode is a warning, which indicates that an event may occur dependent on continuous rainfall and the second mode is an alert, which indicates that it is more than likely that because of levels reached, flooding will occur. The areas that will be inundated are also given. The trigger for the EWS for floods is continuous rainfall and high-intensity rainfall. The Water Resources Manager of the Water Resources Agency (WRA) is the source of authority for issuance of the warning. The warning information dissemination via telephone calls to the relevant agencies.

The EWS for floods was installed in 2005 and designed by the Senior Hydrological Technicians of the WRA. It is also owned by the WRA. It costs about US$ 2.0 – 2.8 million to acquire and operate and approximately US$34,000 in annual maintenance cost. The Water Resources Agency manages the EWS for floods but does not have the ultimate responsibility for it. Three persons are responsible for its operation.

- Limitations

Current limitations were identified as the failure of remote terminal units to capture data, lack of community involvement in the EWS, and poor coordination among technical organizations involved.

- Improvements required

The improvements need to improve the EWS were identified as equipment upgrade, undertaking a demonstration of the EWS for communities to respond to, performing a simulation exercise and the establishment of Memoranda of Understanding among organizations for procedural guidelines.

5.4 Volcanic Eruption Early warning systems in Grenada

Volcanic eruptions on Grenada can result from effusive or explosive activity from an eruption centre at Mt. St. Catherine. The hazards they can produce are pyroclastic flows, ash fall, lahars and ballistic projectiles. Integrated hazard maps for each of these scenarios for the island show that settlements such as Sauteurs, Victoria, Gouyave, Grenville and River Sallee in the northern part of the island are in the very high to high integrated volcanic hazard zones, and as such, evacuation of these communities is advised prior to the onset of eruptive activity (Robertson, Richard, 2005. Grenada. In Lindsay, et al., (eds) 2005).

Technical Features

- Technical components, operational components and coverage

The Seismic Research Unit (SRU) of the University of the West Indies, St. Augustine, Trinidad has had the responsibility for monitoring volcanic activity from 19 potentially active sites in the Commonwealth Eastern Caribbean since 1952. These islands are Grenada, along with the submarine volcano, Kick 'em Jenny, St. Vincent, Saint Lucia, Dominica, St. Kitts, Nevis, Saba and St. Eustatius.

The three main aspects of the volcano monitoring programme are seismic monitoring, ground deformation monitoring, and temperature measurement and gas analysis at active fumaroles. Seismic monitoring is done through an integrated seismograph network of 55 seismic stations in the Eastern Caribbean, comprising 10 three-component broadband and 45 short-period seismograph stations.

The three-component broadband seismograph stations equipped with Guralp CMG40-T seismometers are in operation. These seismometers have a bandwidth which ranges from 0.033Hz (30-second period) to 50 Hz and a nominal dynamic range of 146dB. Each CMG40-T is interfaced directly to an on-site PC based data acquisition/monitoring system which record digitally at 100 samples per second. The output from each of the three components of the seismometer is buffered, filtered and fed in two gain ranges (x2 and x0.2) to separate channels of a sixteen-bit digitizing adapter on the PC. The PC also hosts a satellite synchronizing system to accurately timestamp the data with various interfaces for remote communication. One broadband station (ALNG, Trinidad) is additionally equipped with a Kinemetrics K2 accelerograph which is designed with extended dynamic range to make accurate recording of ground motions up to two times as large as acceleration due to gravity. The K2 is interfaced to the RS232 (COM Port) of the Computer. Three of the fourteen remote data acquisition/monitoring stations are equipped with three-component short-period seismometers. These are the St. Eustatius, Saba and Barbados installations. Barbados is also equipped with a three-component long period sensor. The short period stations are equipped with single vertical component seismometers and are linked to a sub-network data acquisition system via analogue radio telemetry systems. The signals are retrieved at the hub and recorded alongside the broadband signals. Short period station data is substantially less accurate than broadband data but nevertheless these stations play key roles in constraining earthquake source parameters and are very useful in providing early information about volcanic unrest. They are far less expensive and much easier to procure, deploy and operate.

All remote acquisition and monitoring stations send their data, and those from associated single component stations, to an Internet FTP server from where they are downloaded to Trinidad when required. This is done routinely but data may also be retrieved on demand by direct telephone connection. Real-time processing of data is limited by the constraints of the access communications network. Should the activity at a particular subnet increase to critical level, staff may be deployed to man the system locally and carry out processing in real time.

There are four Kinemetrics K2 strong motion accelerographs In Trinidad. These autonomously recording instruments, which are equipped with GPS timing systems, are primarily intended to record strong earthquakes. Some are however fitted with gain boards to provide increased sensitivity to smaller earthquakes. Data are usually collected from these instruments when needed such as after a felt earthquake. (Seismic Research Unit, 2005)

The SRU also receives information on seismic activity from other agencies that have set up seismic stations in the rest of the Caribbean, namely, the Institut de Physique du Globe de Paris (IPGP), the Montserrat Volcano Observatory (MVO), and the Fundacion Venezolana de Investigaciones Sismologicas (FUNVISIS), as shown in Figure 1. The SRU also uses volcanic gas surveillance and ground deformation monitoring to help detect pre-cursory volcanic activity (Lindsay, et al. (eds) 2005).

Ground deformation monitoring is done by the dry-tilt leveling method through the use of GPS and Total Station technology to provide precise measurement of line lengths on an established network. Gas analysis is done with the assistance of local disaster management personnel who take periodic temperature measurements and by the geochemist as the SRU who analyses it. These three aspects are considered short-term surveillance of volcanic activity which provides early warning of potential volcanic eruptions for civil authorities and scientists, thus putting them on the alert.

Long-term surveillance involves the identification of potentially hazardous volcanic centres, preparation of volcanic hazard maps and drafting of evacuation plans. The recently published *Volcanic Hazard Atlas of the Lesser Antilles* in 2005 by the SRU is a major undertaking that has detailed descriptions of volcanic hazards associated with eruptive scenarios for each live volcanic centre, accompanied by maps of volcanic hazards and integrated volcanic hazards. Copies of the atlas have been distributed to civil authorities for incorporation into their national disaster plans.

In Grenada, SRU has a monitoring network consisting of two seismic and eight GPS stations for studying ground deformation, seismicity, and geochemistry of the hot springs and fumaroles around Mt. St. Catherine. Signals from the seismic network on the island are sent to a collection point at the observatory in Sauteurs in the north of the island. Data are downloaded at the SRU in Trinidad via the Internet. There have been few earthquakes associated with volcanic activity on the island. Felt earthquakes are related to activity of Kick 'em Jenny, a submarine volcano 9 km northwest of the island (Robertson, Richard, 2005. Grenada. In Lindsay, et al., (eds) 2005). The most recent eruption occurred on 04 December 2001 that was preceded by an intensive volcanic earthquake swarm.

- Alert modes and their meanings

There are four alert levels that are used to describe the state of activity of a volcanic centre, as shown in Table 3.5, which shows the alert levels for Kick 'em Jenny. Such an alert level table shows the behaviour of the volcano and the recommended actions to be taken by the scientists, civil authorities and the public.

- Threshold of triggers

Scientists at the SRU can determine whether there has been any increased volcanic activity above a pre-existing level by analyzing data received from volcano monitoring sites. When the frequency and magnitude of earthquakes are such that they constitute a swarm whose location is identified in relation to a volcanic centre, along with observed increased fumarolic activity, or ground deformation, the SRU determines the alert level.

- Source of Authority for issuance of the warning

The Seismic Research Unit is the source of authority for issuance of warning of a potentially threatening volcanic activity in the islands. Their first notification to the island is through the National Disaster Coordinator, who takes action related to the alert level posted, as shown in Table 1. If activity continues to increase, the SRU informs the Government directly. During the development of the crisis, use is made of the media to convey information on the volcano, and also the website maintained by the SRU, once approval to release such sensitive information is given by the local authorities. The table of alert levels, as in Table 1, gives the state of activity and the accompanying action to be taken.

- Installation

The monitoring equipment has been installed over the period that the Unit has been in existence, with constant update and maintenance being provided. As the SRU monitors seismic activity for both volcanoes and tectonic movements, it is difficult to separate the cost of monitoring volcanic activity alone. The annual budget of the SRU is about US $0.8 million that comes from annual contributions made by the contributing territories. The running costs for telemetry for the Eastern Caribbean is roughly $US 30,000 per year. Responsible institutions are the SRU and the national disaster coordinating agency on the islands.

Since 1952, a heightened state of alert has been reached at one of the volcanic centres at least once or twice a year. There have been over 20 volcano-seismic crises considered critical during this period, indicated by the nature of seismic swarms beneath the volcanic centre. Phreatic explosions may also accompany volcanic crises from the volcanic centres. On at least five occasions, phreatic explosions have developed into fully-fledged magmatic eruptions (Robertson, 1997).

- Limitations

The use of high band width circuits that have been introduced to provide high quality has resulted in a loss in real time data required for monitoring. Transmission of real time data across the Internet has not yet been realized.

- Improvements required

SRU sees the use of VSAT in improving real time data availability.

Alert Level	Symptoms	Action by Scientists	Recommended action by Civil Authorities and the Public
GREEN	Volcano is quiet. Seismicity and fumarolic (steam vent) activity are below the historical level at the volcano. No other unusual activity detected.	Maintain basic monitoring system.	- Undertake public awareness campaigns. -Prepare evacuation plan for vulnerable areas. - Check the Seismic Research Unit website regularly for change in status. - Visiting scientists should submit a complete plan of their proposed activities to NERO, Grenada, for approval
YELLOW	Volcano is restless: seismicity and/or fumarolic activity are above the historical level or other unusual activity has been observed or can be expected without warning.	- Bring monitoring system to full capability. - Civil authorities will be alerted and communication system tested.	- Intensify public awareness campaigns. - An exclusion zone of 1.5km from the summit of the volcano should be enforced for non-essential shipping. - Visiting scientists should ensure that the Sauteurs Observatory is manned throughout their visit (at their expense) and that the Observatory can contact their ship at any time. They must also be prepared to leave the exclusion zones immediately upon request.
ORANGE	Highly elevated level of seismic and/or fumarolic activity or other unusual activity. Eruption may begin with less than twenty-four hours notice.	- All regional governments alerted through Disaster Coordinators and Venezuelan diplomatic missions. - Sauteurs Observatory continuously manned. - Continuous communication with NERO. (Grenada and St. Vincent and the Grenadines). - Summit area under continuous visual surveillance. - Scientists and emergency personnel	- Vulnerable communities advised of evacuation routes and transport put on standby. - Local radio stations in Grenada, St. Vincent, Barbados and Trinidad placed on alert. - Public listens to local radio continuously for updates and visits the Seismic Research Unit website if possible. -All shipping stays outside the first exclusion zone (1.5km from the summit). - Non-essential shipping (pleasure craft etc) stays 5km clear of the summit (second exclusion zone). - Visiting scientists who are not taking part in essential monitoring are regarded as

		within exclusion zones maintain continuous contact with the Observatory.	**non-essential.**
RED	**Eruption is in progress or may begin without further warning.**	**- Measurements within the exclusion zones as permitted by activity. - Aerial reconnaissance whenever possible.**	**- Vulnerable areas prepared for immediate evacuation. - All shipping stays 5km clear of summit (i.e. out of the first and second exclusion zones). - Public in all vulnerable zones should listen to local radio stations for updates.**

Table 5.1: Alert level for Kick 'em Jenny (Source: http://www.uwiseismic.com)

5.5 Flood Early Warning System in Guyana

The disastrous flood event of January 2005 saw the preparation of an early warning plan for floods for the East Demerara Water Conservancy (EDWC) by the Strategic Emergency Engineering Committee (SEEC) in June 2005. The Conservancy impounds 50,000 million gallons of water for irrigation and potable water supply to the estates of the East Bank and East Coast Demerara. Breaching of the dam along a section of the EDWC contributed to flooding which severely affected 40% of the coastal population. One of the initiatives for a more effective monitoring, reporting and management of the EDWC was the production of the East Demerara Water Conservancy Management Manual that set out to improve the management of water levels in the EDWC.

Technical components

The technical components of water level management for the EDWC comprise an operational water level for flood relief structures; a classification of alert water levels; and irrigation needs. During the rainy season, outlets are to be opened when the water level reaches 56.5 ft GD (17.22m GD). Water levels should not exceed 58.50ft GD (17.83m GD) and water level in the EDWC should be 57.50 ft GD (17.53m GD) at the end of each rainy season. Details of these components are given in the Draft Water Level Management Manual for the East Demerara Water Conservancy.

The operational description

The operation of the EDWC management plan focuses on a radio and telephone communication network that would be upgraded to three base stations and eight mobile VHF/HF sets for patrolling the Conservancy. The radio operator at Lama House would report on rainfall data and water level gauge readings to the radio operator at Enmore Estate, East Coast Demerara. This information is then passed on to the Ministry of Agriculture, who forwards it to NDIA, the SEEC and the Hydro-meteorological Office. Should rising water levels pose a threat the CDC, Office of the President and the NDCs/Local Government Structure would also be alerted.

Input data required

The input data required to operate the proposed water level management for floods in the EDWC are water levels at the Lama, Kofi, Land of Canaan, Maduni and Cunia intakes, stage gauge readings, rainfall readings every 08:00 hours, and weather forecast from the Meteorological Centre

Alert modes and threshold of triggers

There are four alert levels for flood levels proposed. These are Green, Yellow, Orange and Red. The Green Alert is to be posted when the water in the dam crosses 57.00 ft GD (17.37m GD); the Yellow Alert is to be posted when the water level rises to 57.75 ft GD (17.60m GD); the Orange Alert is to be posted when the water level rises to 58.50 ft GD (17.83m GD); the Red Alert is to be effected when the water level rises to 58.75 ft GD (17.90m GD) and over.

Source of Authority for issuance of the warning

It was recommended that the SEEC should be the body responsible for advising the EDWC Board on actions to be carried out in times of emergencies such as breaches and overtopping of the Conservancy dam. The CDC would handle evacuation of people and the Ministry of Agriculture would organize relocation of livestock.

Modes and means of warning information dissemination

- In the **Green Alert phase**, there would be more frequent readings and reporting; checking outfalls, and meeting with the repair Force management team;
- In the **Yellow Alert phase**, the CDC and the Office of the President, and Ministry of Agriculture would be given a status report on conditions at the EDWC. Warnings would be given to prepare to round up livestock, notify those people likely to be affected, verify medical provisions, personnel and equipment, availability of vehicles and boats, meet with the CDC, order opening of the Lama #1 gate;
- In the **Orange Alert phase**, the Office of the President would be informed of need to decide on evacuation notices, call to round up livestock to higher ground; performing intensive inspections of dam and structures.
- In the **Red Alert phase**, the disaster plan would be implemented.

Responsible institutions

Flood mitigation and management proposes the coordination of the following agencies:

- Office of the President which would be responsible for making a decision for evacuation in the event of opening sluices or the risk of overtopping and for ensuring that all other organizations are ready.
- EDWC Board which would be responsible for the operation and maintenance of the dam, structures and waterways.
- National Drainage and Irrigation Authority (NDIA) which would be responsible for the ensuring that the EDWC Management is functional at all times.
- Task Force for Infrastructure Rehabilitation would be responsible for repair works.
- Civil Defence Commission and Community/Local Government Structure which would be responsible for management and response of any flood occurring. It would collaborate with the NDCs/Local Government Structure.

Limitations

There is no real-time water management system to support the EDWC. At the moment, there is a qualitative early warning system based on weather forecasts from the Hydro-meteorological Office. At present the network of rainfall recording gauges does not yet extend to the coastal areas to facilitate computing of stage data.

Improvements required
A landline to be installed at Land of Canaan to improve 24-hour reliability of communication is recommended. There is urgent need to enhance the rain gauge network to arrive at flood attenuation values.

5.6 Flood Early Warning Systems in Jamaica

Jamaica operates both a manual (community operated) and automated Flood EWS in different parts of the country. The following factors are considered for the establishment of FWS in Jamaica (Douglas, 2003):

- Geology
- Vulnerable population
- Frequency of Flooding
- Nature of Flooding
- Flood Impacts
- Availability of Hydrological data
- Existing Community groups
- Community's willingness to participate
- Proximity of Critical facilities (hospital, schools, water supply system)

5.6.1 Community Manual Flood Warning Systems in Jamaica: Pedro River

The System is installed in Pedro River/Concord and Environs, Jamaica in December 2004. The causes of flooding in the Pedro River comprised of a number of reasons: Heavy rainfall that produces runoff in excess of the infiltration capacity of its sinkhole systems. Flood Water is ponded within the normal flood plain of the river eventually filling to a point where it spills into the North Pedro River. Surface runoff from both perennial and seasonal springs as well as over land flow from surrounding slopes also contributes to flooding in Pedro River and Concord. The Floors of the depressions are largely filled with clay and water that is trapped and drains slowly towards Lluidas Vale where it recharges the headwaters of the Rio Cobre.

Following are the components of the Community Flood Warning System (Douglas, 2003):

- Observers: Observe rainfall and water level gauges
- Communication Network: Relays information to response teams and disaster agencies when alert and critical flood levels are reached.
- Decision Component: Community decides whether or not to evacuate based on rainfall or water level observations.
- Response: Community packs away valuables at alert level and evacuates to emergency shelter at critical level.

System Description
The Monitoring System which is used is governed by the MET office. It is human based; Readers observe the rainfall and water levels. The goal of the flood-threat recognition system is to enable early identification, location, and degree of potential flood situations.

Figure 5.3: Water Level Gauge in Pedro River (Douglas, 2003)

The Warning System is also manual whereby if the levels reach to an alert status Readers record water level and time at 15-minute intervals and inform Callers and Runners. Some of the community warning methods include: audio alarms, beeper systems to call key officials, the use of public radio and television, Door-to-door warning, sirens and public address systems. The main Communication Systems in place are the Callers and the Runners. When the critical levels are reached, Callers inform ODPEM/PDCs, WRA and Emergency services. the Runners inform the communities and raise the alarm.

The form of Response is through the ODPEM/PDCs which gives a directive to evacuate the community. This includes: providing evacuation assistance, curtailing/establishing traffic controls & rescue services.

Figure 5.4: Flood Warning Gauges in Pedro (Douglas, 2003)

GIS was not particularly highlighted as being used, but in the Flood-Threat Recognition stage there was mention of: data assembly and display & data processing and analysis.

Institutional Arrangements

Agency	Responsibilities
Office of Disaster Preparedness and Emergency Management (ODPEM)	• Sources funding for early warning systems • Coordinates the establishment and operation of early warning systems • Mobilizes regional and community groups • Raises community awareness • Trains community flood response teams • Establishes emergency shelters • Assists with evacuation and coordinates disaster relief
Water Resources Authority (WRA)	• Collects hydrological data • Designs early warning systems • Sources and installs equipment • Collaborates in raising community awareness • Trains community flood response teams • Reviews rainfall-runoff relationships
Meteorological Office (MET)	• Forecasts weather • Issues news broadcasts and bulletins
Community Flood Response Team	• Participate in training and simulation exercises • Observe rainfall and flood levels • Communicate with disaster agencies • Mobilize community evacuation

Highlights of the system

Below are the highlights of the system;

1. Complete ownership of project initiatives by PDC and community members
2. Community disaster plan developed, tested and used
3. Trained Flood Alert Team
4. Prediction and monitoring capability
5. Informal & Formal Communication
6. Preparation and response capacity to natural hazards strengthened and coordinated in St. Ann (and within target community in particular)
7. Negative impacts of natural hazards reduced
8. Improved engagement of community members in local level disaster management

5.6.2 Automatic Flood Warning Systems in Jamaica: Rio Cobre

The system was installed in Rio Cobre Basin, Jamaica between September 1985 and December 1989. The Rio Cobre Basin has a drainage area of approximately 500 km^2 and is located in the south-central end of Jamaica. The Rio Cobre Watershed is characterized by plateaus, sinkholes, steep-sided valleys and elevations ranging from sea level to approximately 800m at the highest point. The basin receives between 1524 and 2032 millimetres of rain annually. The system includes a set of rainfall and water level meters set up over key points in a watershed. Every station transmits its information in real time to repeater stations which are linked to a master station where the data from all basins are received and processed and the change in water level at different points of interest can be closely watched. When flooding is likely to occur, a flood warning will be issued by the ODPEM and appropriate action taken to reduce damage and save lives.

System Description

The Monitoring System consists of automatic self reporting rainfall gauges with omni directional antennae, water level (pressure) transducers (river gauges) with directional antennae, and radio repeaters. The transponders transmit data on water levels to the repeaters which re-transmit the signal to the base station. These incoming signals from remote sites are evaluated by both the computer and a trained operator. The monitoring system is managed by the Underground Water Authority.

The Warning System operates by an initial alert Message from the MET Office indicating that a Severe Weather System poses a threat. The River Flood Forecast Centre will then run a flood forecast model, based on the intensity, quality and duration of the severe weather event. Once Flooding is expected, a Warning must be formulated at the River Flood Forecast Centre (RFFC) to be sent to the Office of Disaster Preparedness and Emergency Management (ODPEM) and the National Meteorological Service.

Figure 5.5: Automatic Sensors

The Communication system is managed by the ODPEM. This agency receives information from the RFFC and issues warning messages to the general public under the direction of the Director of the Office of Disaster Preparedness. The RFFC has no direct linkage to the general public. The RFFC also sends early warning information to the National Irrigation Commission (provider of raw water used for Domestic Water Supply), which has the capability to actively regulate the flows along the channel of the Rio Cobre.

The Response which occurs in the case of expected flooding is through the ODP who will commence mitigation efforts. They will alert the Media, Police/Military and other local authorities. They will in turn inform the public as to what action is to be taken.

Institutional Arrangements

Agency	Responsibilities
Underground Water Authority	Operation and Maintenance of the Flood Warning System Operate the River Flood Forecast Centre
River Flood Forecast Centre	Produce Forecast and Warnings to the Office of Disaster Preparedness and Meteorological Services Collecting, Evaluating and Processing Flood related data Deciding on specific warning messages Formulating Hindsight Review
National Meteorological Service	To advise the other two collaborating Agencies of the onset and status of any severe weather system Provide estimate of expected rainfall over the catchment
Office of Disaster Preparedness and Emergency Management	Dissemination of messages from the River Forecast Centre

Summary of Technology used

- Water level (pressure) transducers (river gauges) with directional antennae
- Rainfall gauges with omni directional antennae
- Radio repeaters
- Base Station
- HYDROMET 1.0 software, developed by the US National Weather Service

System Recommendations

Some of these recommendations include:

- Simulation exercises should be conducted for checking the parameters and the system.
- The base station should be located at the Underground Water Authority with the back-up station at the MET office, since the UWA is responsible for operation and maintenance of the system.
- Once a month, maintenance should be carried out using the required test instruments and a log sheet system should be used with the necessary check boxes to show what was tested and if any changes were noticed.
- During routine maintenance inspections to repeater stations, each antenna should be checked with an ohm meter or continuity tester, so as to confirm continuity without resistance.

5.6.3 Lessons Learnt

The following are some of the successes recorded for the use of flood warning systems in Jamaica:

- Timely warning for evacuation of communities;
- Saving of lives, livestock and personal belongings in Cave River, Rio Cobre and Rio Grande Valleys;
- Low capital and operational costs;
- Closer ties between communities, public and private sectors;
- Positive changes in land use and solid waste disposal;
- Political barriers overcome;
- Communities take greater responsibilities;
- Launch of other projects supporting flood disaster mitigation.

The system is however faced with technical challenges in the following areas:

- Availability of hydrological data;
- Diverse topography and geology;
- Sediment loading;
- Changes to channel geometry;
- Urban flooding;
- Telecommunications systems.

Institutional challenges faced by the system include:

- Lack of resources to conduct hazard assessments;
- Lack of resources to conduct monitoring and evaluation of the systems;
- No effort to conduct cost benefit analyses;
- Inadequate cooperation between Government agencies;
- Lack of private sector involvement;
- Low-level of community ownership and interest;
- Lack of financial sustainability;
- Lack of economic incentives.

5.7 Anguilla National Warning System

The Anguilla National Warning System is the most modern early warning system among CDERA Participating States. It is a general warning system with no link to hazard forecasting system. It was designed to provide notification, warnings, and alerts to the public. In order to ensure compatibility and portability, its design incorporated the following:

- An ITU standard that allows a warning message to be consistently disseminated simultaneously over different systems
- The Common Alerting Protocol (CAP) can be deployed worldwide giving technical compatibility for users across all countries.
- Lightweight XML-based schema that provides a general-purpose format for the exchange of emergency alerts

The system benefits from the following features of CAP

- Flexible geographic targeting using lat/long "boxes" and other geospatial representations in three dimensions;
- Multilingual and multi-audience messaging;
- Phased and delayed effective times and expirations;
- Enhanced message update and cancellation features;
- Template support for framing complete and effective warning messages;
- Digital encryption and signature capability; and,
- Facility for digital images, audio and video.

Its implementation in Anguilla is subset into three phases. Phase III has just been initiated (Klute, 2008):

- Phase I: Piloting and installing via Radio: RDS (Radio Data System) FM Radio receivers and defining the larger system plan.
- Phase II: Installing and integrating the Common Alerting Protocol (CAP) network backbone, a web based activation interface, Radio Broadcast interruption, text to voice broadcast, and computer popups, email etc. for Government Internal.
- Phase III: Installation of a public alert registration server that will address non English speaking populations and allow the public to register for all island alert and zoned (targeted) alerts.

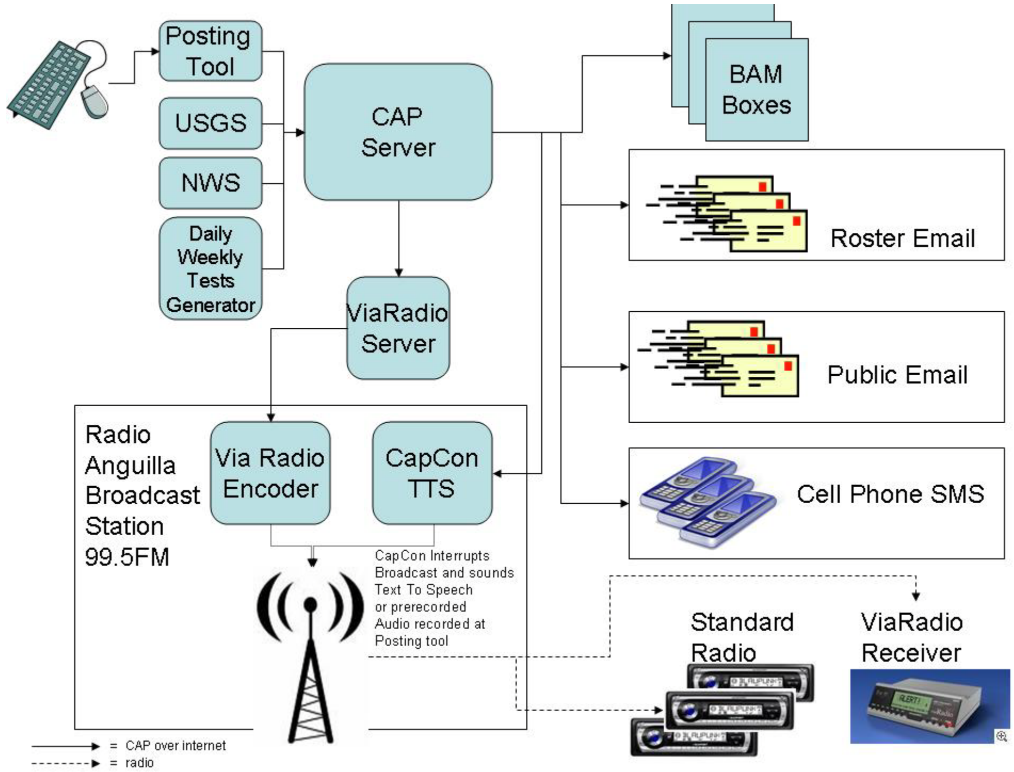


Figure 5.6: Configuration of the Anguilla National Warning System (Klute, 2008)

Benefits of GIS Integration (Klute, 2008)

- Allow for the immediate and automated import of hurricane track models
- You do not need to be a GIS person to use it
- Provide a mapping interface for rapid display of expected impacts prior to a storm or event (Tsunami etc.)
- Provide situation status in the NEOC after the incident such as impacts to critical infrastructure, shelters open/closed; roads open//blocked etc.
- Provide for ongoing tracking of relief and other field operations during recovery
- Provide a mechanism to do prediction modelling off storm surge inundation for early warning, evacuation and response planning and for defining mitigation projects and many more benefits
- Complete the comprehensive disaster management cycle.

The system has many of the features similar to the ALERT system commonly used in the USA.

5.8 Evaluating EWS Development in the Caribbean

EWS development is at its infancy in the Caribbean. The concepts and principles are slowly but steadily being understood and politically supported more so because of recent disasters in New Orleans and Tsunamic disaster in the Caribbean. Hurricane EWS is fully developed in the region with assistance from international agencies such as WMO, NHS, NOAA. Flood EWS has improved form a manual system (gauge watching in Belize, Trinidad Dominica and Jamaica) to automated systems in Trinidad and Jamaica. Efforts are underway to install modern Tsunami EWS throughout the Caribbean Basin.

Through support from JICA, GIS-based flood hazard maps are to be developed for several Caribbean states. CIMH with support from WMO is embarking on enhancing instrumentation and density of hydrometrological gauges throughout the Caribbean as well as the development of a hydrometrological database for the Caribbean. These efforts are laudable but they are challenged by the following:

a. A lack of a regional coordinating mechanism to ensure system interpretation system sustainability and capacity development
b. A lack of systematic development framework
c. Use of ad hoc project driven (funding driven approach as opposed to a program driven approach)
d. A lack of continuity through local support for funding and system maintenance
e. Inadequate community involvement (except in Jamaica)

The research found no evidence of EWS in the Caribbean that is integrated with GIS. The automated flood early warning system in Jamaica has the potential for such integration. The Anguilla National Warning System has the interface for GIS integration but very little has been done at this moment for such integration.

The following are some of the challenges to GIS-EWS integration in the Caribbean:

- Weak institutional linkages that does not support joint initiatives between the National Disaster Office and National GIS Agencies
- Inadequate availability and access to current and accurate database of critical facilities, biophysical, and anthropogenic features
- Unavailability of current and densified digital meteorological and hydrological data
  Inadequate access to trained and qualified personnel (Hydrologist and GIS specialist)
- Lack of access to GIS hardware and software
- High cost of data transmission and dissemination (Internet connection)
- Inadequate allocation of funds for systems maintenance and upgrade
- Long history of system neglect
- Inadequate institutional support
- Weak knowledge-base on hazard prediction
- Inadequate record of hazard information: hazard maps, vulnerability assessment, risk assessment

In reviewing the adequacy of existing EWS in the Caribbean using the ISDR (2006) best practice principles (Section 1.2.1), below are the findings:

k. Apart from the regional Hurricane EWS and flood EWS in Jamaica, none of the systems reviewed was established with a coherent set of linked operational responsibilities among the relevant agencies
l. None of the system reviewed are explicitly linked to a broader program of national hazard mitigation and vulnerability reduction. A project approach rather than a program approach was used most of the time.
m. Responsibility for the issuance of early warnings is explicitly designated in all the countries.
n. Authoritative decision makers with political responsibility for decisions taken were easily identified at the national level
o. Actions taken are all based on well-established procedures
p. There is no evidence to support the notion that existing EWS are based on documented risk analysis
q. No study has been done to monitor and forecast changes in vulnerability patterns at both the community and national levels
r. Only in Jamaica can evidence of this be found
s. The range of communication methods are mostly limited and no evidence to support BPP that the warning should provide multiple strategies for risk reduction.
t. Only the regional hurricane EWS and the Jamaican Flood EWS have evidence of the involvement of stakeholders. Funding remains a drawback to system sustainability.

With regards to how well the Caribbean EWS meets Zillman's technical requirements, below are the findings:

g. The level of metrological and hydrological model of catchment is at its infancy in the Caribbean none of the system reviewed were based on a sound knowledge of the metrological and hydrological factors due mainly to lack of data and short supply of qualified personnel.
h. Apart from the regional Hurricane EWS, none of the systems reviewed incorporated global or regional data streams for short to medium range forecast process. On occasion satellite rainfall forecast are used without a rigid coupling to the EWS.
i. The lack of a reliable regional data that can be assessed quickly weakened all the systems reviewed.
j. All the systems reviewed experienced inadequate computer hardware and software with the exception of the new systems in Anguilla.
k. The effectiveness of existing sensors is inadequate due to a poor maintenance regime and vandalism.
l. The current state of information communication tools used is inadequate due mainly to budgetary constraints to acquire and adapt to modern and cheaper ICT.

6.0 Towards a GIS-based Flood EWS in the Caribbean

In this section, a conceptual and logical design of a GIS-based flood EWS for the Caribbean is proposed. Flood hazard was chosen due mainly to the frequency of occurrence in the region particularly during the rainy and tropical storm seasons.

6.1 The Context

In the Caribbean, flooding is usually due to flash flooding caused by excessive, intensive, and sometimes prolonged rainfall as well as hurricane storms that dump very large volumes of rainwater. The impact is usually felt by communities living in low-lying coastal areas and along river channels. The timing of the impending hazard is usually too short to provide the affected communities with adequate warnings. The other contextual issues are availability/density of meteorological and hydrological data, adequacy of the use of information and communication technologies in the public sector and local communities, and capacity of local technical officials with regards to training in hydrological modelling. Building EWS for small catchment is a challenge due to the following factors (Gutknecht, 2003):

- Extreme rainfall events that cause flash floods have random occurrence, high intensity, and short duration.
- It is difficult to predict exactly where and when they occur on a particular catchment
- Historic data on their occurrence are difficult to find due to low spatial density of operational gauges
- Their occurrence makes it difficult to justify the cost of instrumentation and data collection

6.2 Design considerations

The proposed system is conceptualized based on the following requirements identified by Zillman (2003):

- A sound scientific basis of understanding the meteorological and hydrological dynamics and their predictability
- Rapid access to global, regional and local meteorological and hydrological data in support of forecasting requirements
- Modern hazard monitoring and detection systems

- Computer hardware and software in support of data acquisition, data management, data analysis, and data dissemination.
- Efficient and effective communication system

6.3 System Components and Features

The system has eight (8) components: risk assessment, hazard monitoring, hazard forecasting, issuance of warnings, dissemination of warnings, disaster response, institutional support, and monitoring and evaluation. Figure 3.12 provides the framework of the system.

Before developing EWS for any community, a risk assessment study of the community should first be undertaken. The objective is to identify hazards that threaten the community, the vulnerability of the community to these hazards, and the development of a community disaster management plan.

Based on the output of the risk assessment study, techniques for monitoring the hazard should be developed using a combination of scientific and cultural knowledge. Hazard monitoring will provide valuable information for modelling the dynamics of the hazard and thus provide a knowledge base for designing an EWS.
Using the knowledge derived from hazard monitoring, a hazard forecasting system can be built for predicting the likelihood of occurrences. The accuracy of predicting future occurrence enhances the effectiveness of the EWS. A combination of scientific and cultural knowledge is also required for this component. Critical to hazard forecasting is the availability of appropriate model of the hazard and quality data.

Once the mechanism for hazard monitoring and forecasting have been developed, the next challenge is the development of mechanism for the issuance of warnings. This entails the identification of threshold and triggers that will prompt the need to take actions. In the case of flood hazards, rainfall depth, river stages, soils saturations are parameters that may be used to develop indicators for the issuance of warning messages. The institutional dimension of this component is the assignment of authority for the issuance of warning and the design of appropriate warning messages for the different sectors of the community.

Critical to EWS is the dissemination of warning messages in and efficient and effective manner. This component deals with the use and integration of appropriate technological and cultural solutions for disseminating emergency information to all members of a community.

As soon as warning messages are disseminated to the public, disaster response systems should be activated. This component is derived from the community disaster management plan; a product of the risk assessment component. It requires the involvement of community first responders and collaborating public agencies. The mitigation of disaster risk is dependent on a well coordinated and rehearsed disaster response plan.

The effectiveness and efficiency of EWS should be monitored and evaluated in order to ensure that resources expended on developing EWS are not wasted. This component entails the development of systems for monitoring and evaluating every component of the EWS function to their designed maximum capacity.

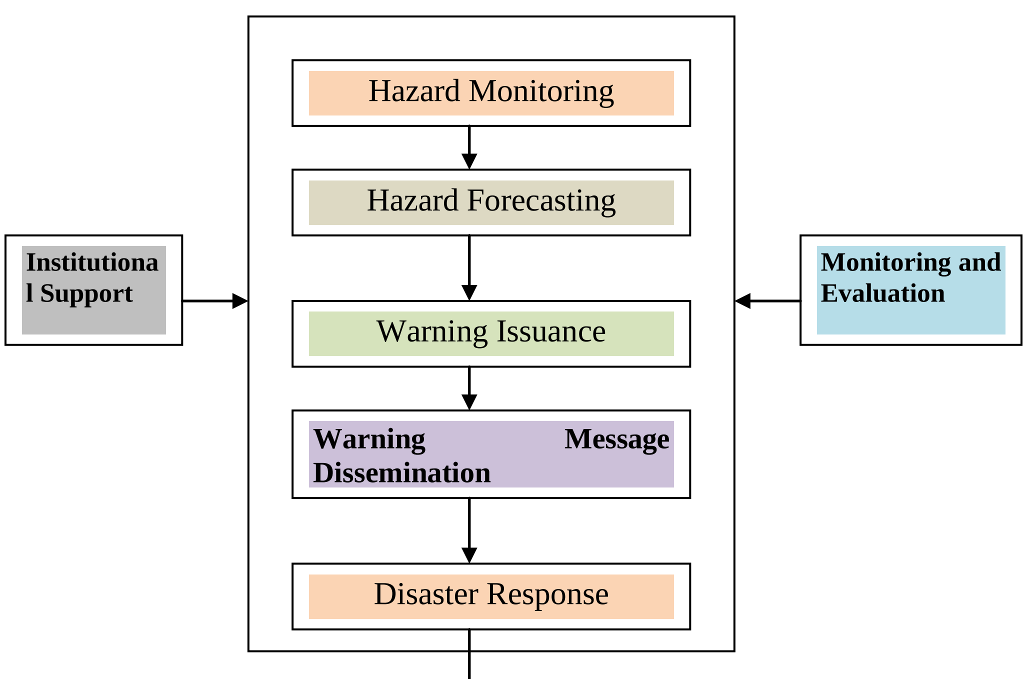
Technological solution by themselves cannot yield the desired results without the development of an efficient institutional support for the EWS. Whereas technological solutions may be purchased or institutional solutions are indigenous local knowledge and resources designed to ensure that the system developed is sustained. Policy, legislation, and funding are examples of institutional support required by EWS.

The activities within each of these components are presented in the table below:

Components	Activities (Tasks)
Risk Assessment	Hazard mapping
	Vulnerability assessment

	Risk assessment
	Community disaster management plan
Hazard Monitoring	Rainfall observation and recording of depth
	Stream flow observation and recording of rate of flow
	River stages observation and recording of raising rate
	Transmission of data to control station
	Data assembly and visualization
	Quality control and assurance
Hazard Forecasting	Data processing
	Data analysis (rainfall-runoff modelling)
	Model validation and calibration
Warning Issuance	Identification of threshold and triggers
	Formulation of warning messages
	Assignment of responsibilities
	Coordination of messages
Warning Messages Dissemination	Identification of appropriate channels
	Development of protocols for warning dissemination
	GIS support for warning dissemination
Disaster Response (Shelter and evacuation route activation)	Formulation of conditions for the activation of response plan
	Implementation of response plan
	Evaluation of response plan
	GIS in support of response planning and implementation)
Monitoring and Evaluation (timeliness and impact: Sorensen, 2000)	Design of evaluation criteria
	Design of monitoring and evaluation plans
	Assignment of responsibilities and resources for M&E
	Preparation of M&E reports
	System modification and enhancement
Institutional Support	EWS policy and legislation
	Assignment of responsibilities
	Allocation of financial resources
	Capacity building
	Empowerment of community organizations
	Public and private section alliance

Figure 6.1 System Framework



6.4 Technological requirements

Figure 6.1 provides the logical model of the flood EWS within a watershed. It comprises of a system of hydro-meteorological data collection tools, a telemetric system for data transmission, and a base station for data analysis and data dissemination to stakeholders.

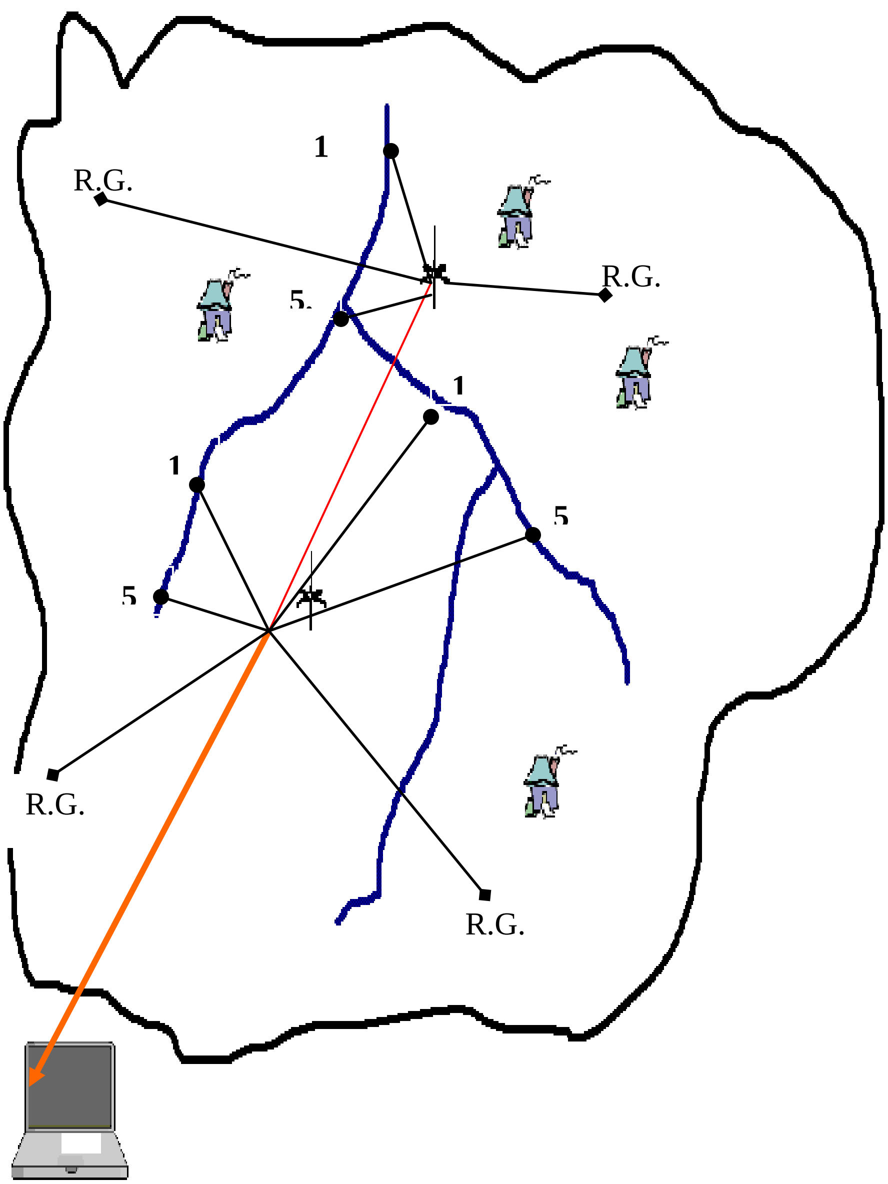


Figure 6.2: Logical Model of a Flood Early Warning System

Below are the technological resources required to build the prototype GIS-based flood EWS.

System Elements	Equipment Required
Flood hazard monitoring	Rain gauges
	Stream gauges
	River stages
	Data loggers
Flood hazard modelling software	Rainfall-run-off models
	WMS
	HEC-RAS
	FLO-2D
	MIKE II
Satellite Remotes Sensing Data	High resolution multispectral imageries (e.g. IKONOS)
	Low resolution multispectral imageries (e.g. MODIS)
	Medium resolution radar imageries (e.g RADARSAT)
	Aerial photographs
Risk Assessment Applications	HAZUS or Vulnerability Assessment Tool (VAT)
GIS databases	Bio-physical databases
	Anthropogenic databases
	Critical facility databases
	Transportation databases
	Demographic databases
	Climate and weather databases
	Multi-hazard incidence databases
Data transmission and communication	Telemetric systems
	ALERT
Information technology	Personal computer
	Laptop computers
	Palm computers
	GIS software (ArcGIS, ArcPAD
	Database software (MS Access)
	Global positioning systems (GPS)

7.0 Proposed Implementation Plan

In implementing the GIS-based Flood EWS for the Caribbean, a four-phase approach is recommended. The phases and the tasks to be performed in each phase are provided below:

Phase I: Development of Institutional support

1.	Consultation with affected communities
2.	Selection of pilot watershed
3.	Identification and evaluation of existing human and technical resources
4.	Development of project implementation team
5.	Development of project implementation plan and resources required

Phase II: Risk Assessment

1.	Collection and assembly of existing meteorological, hydrological, bio-physical, and anthropogenic data
2.	Acquisition of addition data to supplement gaps in existing data
3.	Design and development of GIS databases
4.	Training: GIS database Development, Data Acquisition, Data Automation
5.	Acquisition and installation of field and office equipment
6.	Hazard mapping
7.	Vulnerability assessment
8.	Development of community disaster plan
9.	Training: Hazard mapping and vulnerability assessment

Phase III: Hazard Monitoring and Forecasting

1.	Acquisition and installation of hazard monitoring systems
2.	Acquisition and installation of data transmission systems
3.	Development of hazard modelling and forecasting system
4.	Development of quality assurance system

Phase IV: Warning issuance and Dissemination

1.	Identification of threshold and triggers for the issuance of warnings
2.	Design of warning messages
3.	Design of warning communication protocols and systems
4.	Design of public awareness programs
5.	Testing of warning messages

Phase V: Disaster Response, Monitoring and Evaluation

1.	Review of disaster response plans
2.	Development of monitoring and evaluation (M&E) plans
3.	Testing of disaster response plans
4.	Preparation and review of M&E reports

8.0 Project Outputs

In order to demonstrate the use of GIS, three GIS-based disaster management scenarios were developed and tested in Grenada through this project. The applications are based on the integration of the following technologies: Juno mobile handheld computer and ArcPad mobile GIS software. The details of these are provided in the section below.

Features of the Juno SC mobile computer

The Juno Sc Mobile Computer hardware

- Operating system: Windows Mobile OS
- 3 megapixel camera
- High-sensitivity GPS receiver
- Integrated Bluetooth radio
- Wireless LAN
- Cellular modem
- Portability
- User friendly
- Compatible with mapping & GIS software
- Allows for the capture of high quality images for data collection.
- Integrated cellular modem provides internet connectivity for access to data, emails and the internet
- Integrated Bluetooth and wireless LAN enables connections to networks and other devices
- Allows connection to an office computer to transfer data, files etc

I. Pre-hurricane Vulnerability Assessment of Buildings

Scenario: The National Hurricane Center has issued a hurricane watch to NaDMA. Apart from the Standard Operating Procedure (SOP), you are expected to undertake a rapid vulnerability assessment (VA) of buildings likely to be affected if there is a direct hit of hurricane category 2 (God forbids).

Actions:

1. Contact all community disaster management officers who have been issued Juno/ArcPad system.
2. Request that each officer undertake a rapid VA of all buildings in their communities.
3. Before leaving home, each officer should ensure that the Juno is fully charged and in proper working conditions.
4. The following data layers should be loaded in respect of each community: roads, buildings, shelters, community centres, and dangerous sites.
5. Visit each building and evaluate the conditions of the building: rate each as good, fair or weak
   - Roofs (good, fair, or weak)
   - Windows (good, fair, or weak)
   - Doors (good, fair, or weak)
   - Walls (good, fair, or weak)
6. Note the number of occupants in each building.
7. Make the appropriate entries with respect to #5 and #6 in the attributes of the Building Layer.
8. Using the GPS and the Camera, identify the location of dangerous locations along your way.
9. Send by email the updated map layers (buildings and dangerous locations) to the base station at NaDMA.

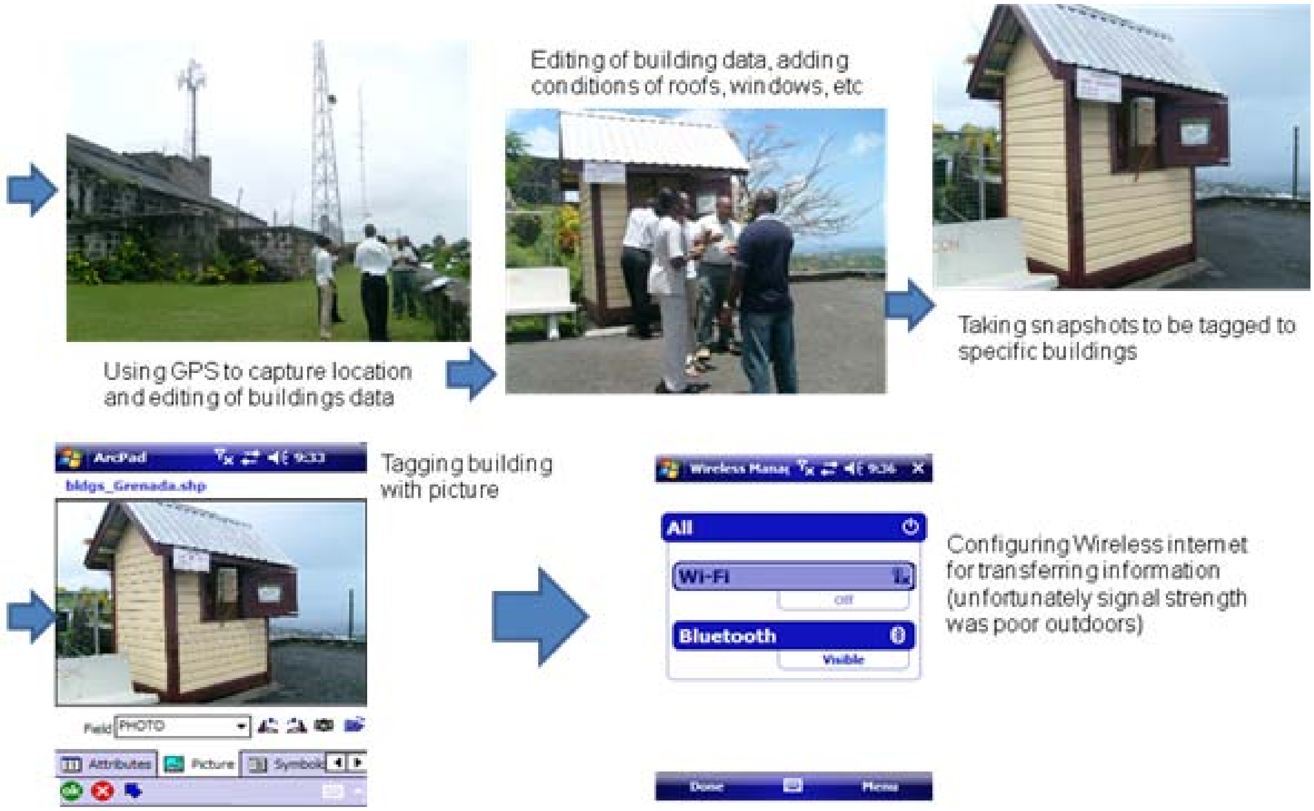
Getting familiar with the equipment

Checking that device is fully charged and operational

Understanding current scenario and Brainstorming data layers needed.

Setting up GPS

Capturing GPS locations along route to building



The details of the steps in implementing these actions are provided in Annex 1 of this report.

II. Incident Mapping

Scenario: NaDMA has just received a phone call with respect to roof damage following a torrential rainfall or freak storm.

Actions:

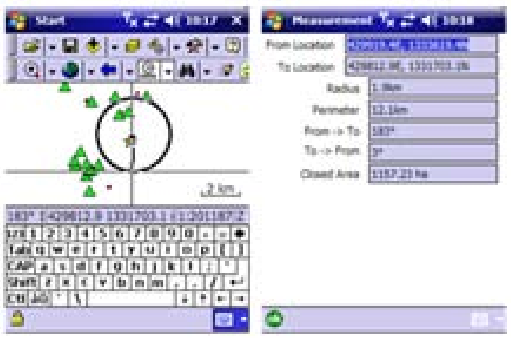
1. Identify the caller by: Name, Phone number, Address of affected building (street name, community, nearest landmark).
2. Log the report in the incident register.
3. Identify the affected building on Juno/ArcPad
4. Dispatch the nearest relief team to the affected building.
5. Identify the closets shelter and activate the shelter
6. On reaching the location of the affected building,
    a. Locate the occupants and assess the impact on the occupant,
    b. Inspect the building; take pictures of the damage along with the GPS coordinates,
    c. Make entries with respect to the roof level damage (100%, 75%, 50%, 25%),
    d. If considered necessary, evacuate the occupants to the shelter, and
    e. Prepare a short report on the causes of the damage.
7. On return to the office,
    a. Download data collected to the base station at NaDMA, and
    b. Prepare an incident report along with maps and photos.

Braining storming to determine what datasets are needed and equipment to be used in such a situation

Creating a layer in house with different descriptors to be used for capturing landslide information

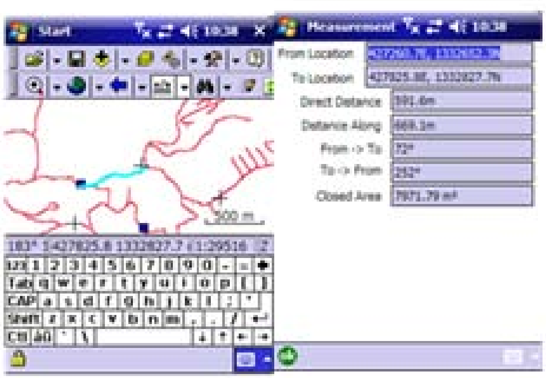
There was some rain outside but we were determined to get some GPS locations and pictures of simulated landslides

Some of us came up with new attachments for the Juno



Determining distance and bearing to nearest resource

Back in house we thought that distance along roadways would be a better measure to a resource



Distance along roadways and using layer symbology

Reflecting on the day's activities

The details of the steps in implementing these actions are provided in Annex 1 of this report.

III. Responding to Emergency Calls

Based on what was learnt so far try to do the following (Using local data):

Scenario: You are a staff of NaDMA. Your unit has been called out to investigate and contain a reported gas leak that has resulted from a vehicular accident on one of your major roads.

Actions and general steps to be followed:

a. Identify on a map where the accident has occurred. (Use satellite imagery for a particular part of the country and use the find tool to search the name of road in the road layer. This will require persons to first assign labels to roads. This will allow persons to locate where the accident is before visiting): Steps
    i. Add the road layer and satellite imagery to an empty map document.
    ii. Add labels to the road layer.
    iii. Use the road layer to locate the general whereabouts of the accident and the satellite imagery to give a more realistic view of this area.
b. Determine the closest emergency response crew in that area: Steps
    i. Add the response crew layer.
    ii. Zoom to the general area of the accident.
    iii. Use the measure tool to measure the distance along routes between response crews and the site of the accident to determine the closest response crew.
c. Identify affected/likely to be affected community
   Steps
    i. Create a shapefile showing the location of the accident.
    ii. Add the Community layer
    iii. Overlay the Accident layer and the Communities layer
    iv. Use the Identify Tool to identify the name of the vulnerable community.
d. Inform community through a cell phone broadcast: Steps
    i. Alert relevant authorities in the vulnerable community about the present problem.
e. Identify all connected pipelines and location of valves: Steps
    i. Add Pipelines layer and Valves layer
    ii. Overlay layers onto affected Community
    iii. Determine using visual analysis which valves must be shut off
f. Issue order to shut off the valve(s): Steps
    i. Issue order to relevant authorizes alerting them of which valves must be shut off
g. Identify shelters and health facilities: Steps
    i. Add the Shelters and Health Facilities layers
    ii. Identify those facilities away from the area of potential hazard and therefore suitable for housing persons.
h. Identify evacuation routes (Using the street layer): Steps
    i. Use the Measure Tool to identify shortest evacuation routes from the affected community to the nearest shelters.
i. Issue evacuation order: Steps
    i. Issue order

j. Determine number of resources required: Steps
    i. View the attributes of the Communities layer to determine the number of persons in the affected community.
    ii. Determine the number of resources required to meet this request.

k. Evacuate persons/animals likely to be affected: Steps
    i. Carry out evacuation plan

l. Carry out an assessment of the situation: Steps
    i. Take snapshots and GPS locations of damaged buildings and make assessment of present situation.

m. Removal of evacuation order through a cell broadcast: Steps
    i. Issue order

n. Carry out an assessment of the response: Steps
    i. Carry out planned response

Exploring satellite imagery

Showing how to use the Various distance measure Tools to determine closest facilities and optimum routes

Explaining map datums and projections and why roads and satellite imagery did not align themselves

Discussion and Comment from Workshop participants

The workshop addressed the following issues raised by the participants:

- Integration of data from the different sectors is important. It was suggested that there was the need for the development of an integrated data policy for Grenada that would define a standard system, enhance data sharing, and add value-added to existing datasets.
- Appreciation of how ArcPad & Juno can be used to enhance efficiency: participants made attempts to show how the system can be used in their individual environments, for e.g. Land Use updating, land ownership data collection, shelter management etc
- Appreciation for more complete recording of metadata
- Need for a more persons at all levels to become familiar with GPS and GIS technology.
- Need for a more integrated approach towards data collection. It was suggested that government, private and public sectors communicate with each other about what information is being collected so that cost, time and resources can be saved along with creating better partnerships.
- Software and license for ArcPad and ArcGIS is required for NaDMA and other departments that would be using the system (Juno & ArcPad)
- More in-depth training is required for field operators and NaDMA staff in ArcPad and ArcGIS
- More equipment is required- handhelds and accessories (memory cards, screen filters, stylus)
- Need for a GIS specialist to be working in close contact with NaDMA staff and persons using system as a resource person to assist with map generation and use of GIS techniques and analysis. Currently there are GIS specialists in Land Use (Agriculture) and Physical Planning

Workshop Participants:

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References

Alexander, W.J.R. (2003) "Early Warning Systems for the Detection and Response to Severe Floods" in Early Warning Systems for Natural Disaster Reduction" eds. Zschau, J and A. N. Kuppers. Springer, New York; pp311-318

Ali. S. 2001. *'The Design & Development of an Automated Hazard Emergency Management Systems',* in Proceedings of the URISA Caribbean GIS Conference September, 2001

Billa, L., S. Mansor, and A. R. Mahmud (2004) "Spatial Information Technology in the Flood Early Warning Systems: an overview of theory, application and latest developments in Malaysia". Disaster Prevention and Management: 13(5) pp356-363.

Douglas, E. (2003). "Flood Hazard Management, Mapping and Early Warning Systems in Jamaica". Water Resources Authority, Jamaica

Federal Emergency Agency (1997), "HAZUS: Standard Risk Assessment (Loss Estimation) Methodology" *Multi Hazard Identification and Risk Assessment: A Cornerstone of the National Mitigation Strategy.*

Federal Emergency Agency (2004), HAZUS-MH *Risk Assessment and other Group Series: Using HAZUS-MH for Risk Assessment.*

Gruntfest, E. and C. Huber, (1989). "Status Report on Flood Warning Systems in the United States". Environmental Management 13(3) pp 279-286

Guarin, G.P. et al (2004). "Community-Based Flood Risk Assessment Using GIS for the Town of San Sebastián, Guatemala" http://www.itc.nl/library/Papers_2005/p_jrnl/vanwesten_com.pdf

Gutknecht, D. (2003). "Extreme Runoff Events in Small Catchments: the need for a proper modelling strategy for early warning systems". In Early Warning Systems for Natural Disaster Reduction" eds. Zschau, J and A. N. Kuppers.

Hamilton, R. M. (2000). Science and Technology for Natural Disaster Reduction. Natural Hazards Review 1(1): 56-60.

Hodgkinson-Chin, E. & Rogers, C. 2001. *'GIS as a tool in the assessment of natural hazard vulnerability, Antigua and Barbuda',* in Proceedings of the URISA Caribbean GIS Conference September, 2001

ISDR (2006): "Developing Early Warning Systems: A Key Checklist". The Third International Conference on Early Warning (EWC III)) hosted by the Government of Germany under the auspices of the United Nations, from 27 to 29 March 2006 in Bonn, Germany.

Klute, E (2008). "The Anguilla National Warning System" Presentation made at the UNSPIDER workshop in Barbados

Lawal Billa, Shattri Mansor, and Ahmad Rodzi Mahmud, (2004) "Spatial information technology in flood early warning systems: an overview of theory, application and latest developments in Malaysia" Journal: **Disaster Prevention and Management**. Volume: 13; Number: 5; Year: 2004; pp: 356-363

Mildner, S. (2003). "The Role of the WMO World Weather Watch System in Mitigating Hydro-Meteorological Disasters". In Early Warning Systems for Natural Disaster Reduction" eds. Zschau, J and A. N. Kuppers. Springer, New York; pp127-134

Mohanty, S.H. Karelia, and R. Issar (n/d). "ICT for Disaster Risk Reduction: the India Experience" National Disaster Management Division, Ministry of Home Affairs, Government of India.

NOAA/NWS (date). "Local Flood Warning Systems (LFWS)". Handbook No. 2 (WSHH#2)

Opadeyi J. (1992) *Concepts, design and applications of geographic information systems for water resource management*. In Proceedings of the Caribbean Workshop on Water Resources Management and the Environment. Trinidad. 1992.

Opadeyi, et al (2006) "Inventory of disaster early warning systems in the Caribbean": a Technical report prepared for CDERA.

Paul J. Pilon. (1999) "Guidelines for Reducing Flood Losses" UN Department of Economic and Social Affairs (DESA) available on-line at www.unisdr.org

Riley, E. 2001. '*Using GIS to determine best routes for transporting hazardous chemicals in Barbados',* in Proceedings of the URISA Caribbean GIS Conference September, 2001

Robertson, Richard, 2005. Grenada. In Lindsay, et al., (eds) 2005).

Schmidt, H.S. (2003). "Technical Requirements for Early Warning Systems" In Early Warning Systems for Natural Disaster Reduction" eds. Zschau, J and A. N. Kuppers. Springer, New York; pp817-822

Sorensen, J.H. (2000). "Hazard Warning Systems: Review of 20 years of Progress". Natural Hazards Review, May 2000, pp 119-125

Star J and Estes J. 1990. Geographic information systems: an introduction. New Jersey: Prentice Hall.

Sujit Mohanty, Hemang Karelia and Rajeev Issar (dddd) ICT for Disaster Risk Reduction: *The Indian Experience.* Government of India, Ministry of Home Affairs, National Disaster Management Division

United Nations International Strategy for Disaster Reduction (2004), Risk Assessment; *Chapter 2 section 3, pp 62-7.*
[22] GPS World (2005). "U.S. issues GNSS statements with Japan, Russia". FindArticles.com. Website: http://findarticles.com/p/articles/mi_m0BPW/is_1_16/ai_n9486389. Accessed: 2008-05-19

Wattegama C. (2007) "ICT for Disaster Management" Asia-Pacific Development Information Programme (UNDP-APDIP). Springer, New York; pp265-270

Zillman, J. W. (2003). "Meteorological and Hydrological early Warning Systems" in Early Warning Systems for Natural Disaster Reduction" eds. Zschau, J and A. N. Kuppers. Springer, New York; pp135-166