TSUNAMI SCENARIO SIMULATOR: A TOOL FOR ENSURING EFFECTIVE DISASTER MANAGEMENT AND COASTAL EVACUATION IN A MULTILANGUAGE SOCIETY

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ABSTRACT

An emergent paradigm in disaster-risk reduction is the issue of Multilanguage societies within the context of risk information and communication. The primary mitigation measure for tsunamis is the development of effective warning systems and evacuation strategies. The scale of the earthquake, the level of maintenance of prevention structures, such as seawalls, efficiency of the information dissemination system and the residents' willingness to evacuate, influence the impact of a tsunami disaster. Therefore, the goal of tsunami disaster reduction is concerned not only with the use of prevention infrastructures but also with encouraging residents to evacuate quickly through the provision of disaster education and the relay of disaster information in a manner comprehendible by all groups in society. The simulator combines hydrodynamic simulation of tsunamis with warning and human-response simulations for evacuation. Additionally, because of its visual 3D/GIS presentation the simulator is an effective tool for educating the public.

Keywords: Tsunami Scenario Simulator, Risk Communication, Multilanguage Groups**,** Risk Information, Disaster Management, and Disaster Education

1. INTRODUCTION

The generation of risk information and its timely and effective communication to stakeholders in a disaster management jurisdiction is the essence of strategies for hazard/disaster loss reduction. However, the latter is a major challenge for disaster managers, especially in an increasingly globalized world characterized by higher levels of Multilanguage as more and more people migrate to locations outside their culture zones where not only language differs, but also perceptions of and attitudes towards hazard/disaster risk (Martin 2003). Disaster managers therefore have to design effective risk communication strategies that span language differences and are sensitive to the various language groups present in the society, so that warnings can be encompassing and inclusive. There is therefore a need for disaster management decisions to reflect an understanding of risk.

Over the years, several theories and models have been developed to explain the risk communication-disaster management interface and, in response to the failure of traditional practice theories, to address multicultural issues (Cross, T, et al 1989; Green, J.W. 1995; LaFromboise, T.D, & Foster, S.L 1992 ; Sue, D.W. & Sue, D. 1990 & Sue, D.W, 1992) such as language differences. Language is a defining criterion of culture and as such, differences in language can prove a formidable barrier to effective risk communication. Since learning a new language requires time and patience, recent immigrants as well as visitors to a country may experience information communication gaps. In fact, some elderly people may never develop the language skills required to effectively communicate in a new society. Therefore, emergency preparedness and response information will require effective translation to be fully understood by different cultural/language groups. Translations should convey the message clearly and be delivered in a manner respectful of cultural differences. In addition, during an emergency, language skills which are normally adequate may be impaired due to stress and pressure (Solis G. et al 1997).

Given the complexities of effectively communicating to mixed groups there is increasing suggestion that multiple media and tools be used to communicate with residents in emergency situations. To develop a single model or tool that would embrace all aspects of ethnical and cultural risk perceptions (beliefs, values, gender, and age) and all aspects of risk communication strategy is, to say the least, a formidable challenge. While there are many cultural issues that can affect risk perception and subsequently disaster management response, this paper will focus primarily on how to overcome challenges in communicating in a society where multiple languages are spoken and how the application of this model will allow disaster managers to effectively communicate risk information in a Multilanguage society.

In the Turks and Caicos Islands (TCI), approximately 65% of the population is foreigners

(Clerveaux 2005) and the majority is not competent in English, the national language. This situation poses a serious problem for disaster managers in the TCI especially as this relates to effectively communicating risk information and warnings. Like the rest of the Caribbean region, the TCI is unprepared to deal with a tsunami hazard. Warning systems are non-existent and the bulk of the resort facilities and non-English-speaking nationals are located in a zone vulnerable to tsunamis. It is in that regard that the tsunami scenario simulator model was designed to ensure that during the occurrence of a tsunami risk/warning information being communicated is understood by both English and non-native English speakers. This simulator can be used as an educational tool by disaster management decision-makers in the TCI and the general population, allowing them to become more accountable for their actions. This is because the model has the capacity to simulate different 3D scenarios that are determined by the actions taken by residents. Through the use of this simulator, disaster managers will be better able to effectively communicate risk information in a Multilanguage setting by using several media simultaneously. These will include sound, speech and text, thus ensuring that the dissemination of risk information is not biased towards any particular language group. In other words, the use of this simulator by disaster administrators can be an effective mitigation tool as it displays the complexities that are involved in communicating disaster risk information in a Multilanguage society.

2.0 METHODS

2.1 Multilanguage Perspective in the Design of the Model

One of the most important requirements for social life is communication. Every human culture includes a language; language is the primary means of linking members of a society together. During a disaster, communication between people may fail due to language differences. This could reduce the efficiency of the overall response system. For this reason, minority language groups in our society may be at a greater risk in a disaster. It is therefore the responsibility of emergency planners and responders to identify and work to overcome these barriers. Emergency planners must find alternative methods to reach out to ensure that all community members are aware of emergency procedures. The communication network developed to spread preparedness information may also be useful during emergency response. An effective means of communication could be a lifeline to victims of a disaster (Solis, G et al 1997).In designing the model the following were taken into consideration to enhance the communication of risk/warning information in a Multilanguage society:

1.
2. Identification of members of ethnic/language groups to determine the number of different languages and dialects spoken among them.
3. Translation of warning information into the main languages spoken in the country since during emergency, language skills which are normally adequate may be impaired due to stress and pressure.
4. Repetition of warning messages
5. Use of several media to communicate warning information since people who do not speak English fluently may not receive information through mainstream radio, television and newspapers.
6. Use of oral communication: the model recognizes that even the most meticulous disaster preparation cannot guarantee that communication efforts in times of emergency will be effective. Serious disasters may disable infrastructure such as telephone lines or television and radio transmission. There may remain a small number of people who do not receive critical information, and as such, the model takes into consideration the need to convey information by alternate means.
7. Use of simple terminology in the body of the warning message to ensure that the message will be understood by all groups in society regardless of educational attainment.
8. 3D simulation of residents' behavioral output. The realistic visual output of the simulator makes it a great tool for encouraging residents to take appropriate measures to cope with disasters.

3.0 Delineation of the Tsunami Scenario Simulation Model

The Tsunami Scenario Simulator model consists of three components:

i. Information Transmission Simulation Model
ii. Evacuation Transmission Simulation Model
iii. Tsunami Transmission Simulation Model
iv.

i. Information Transmission Simulation Model

The information transmission simulation model provides warning and other relevant information from the authorities to the public, through various communication media (Figure 1). The model also depicts informal means of communication between residents by expressing the communication that occurs by means of telecommunication (i.e. cellular phones and telephones) and face-to-face contact.

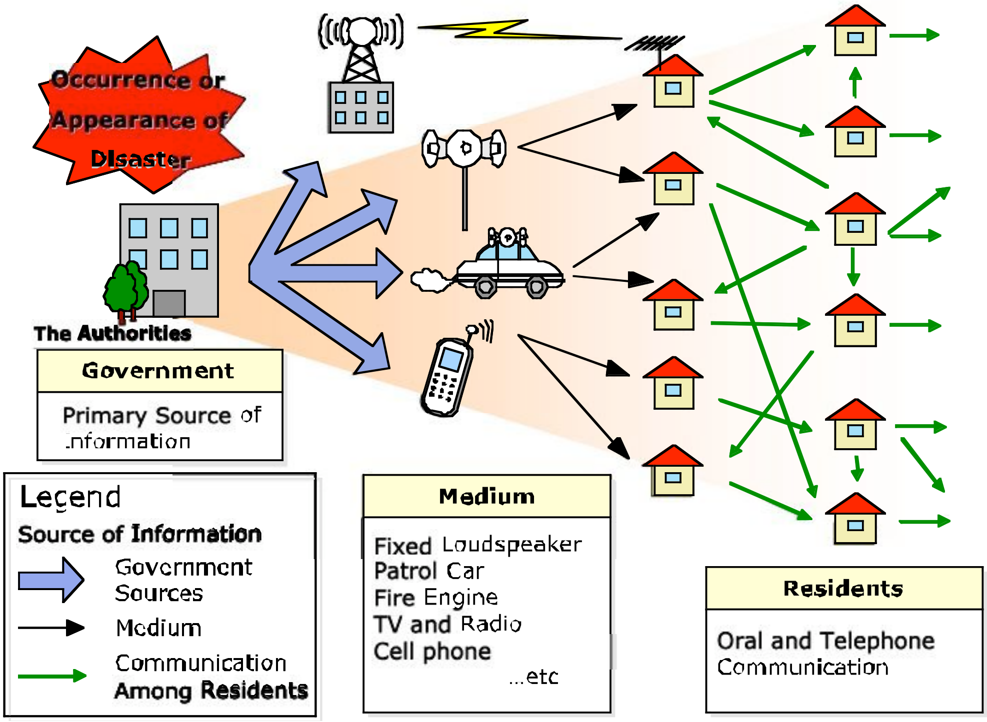

Figure 1: Information Dissemination Framework

The model also takes into consideration spatial distribution of information and the elapse of time of information communicated. The basic structure of this simulation model is constituted according to the Biased Net Model (Rapoport 1979). The information transmission model developed for Providenciales in the TCI takes into consideration:

1. Use of cell phones by government authorities to transmit risk/warning information to residents via SMS (Short Message Services) and an Emergency Ring Tone.
2. Simultaneous transmission of warning messages in the 3 main languages (English, French-Creole and Spanish) spoken in the country
3. Face to Face oral and Tel-communication (fixed line and cellular phones) by residents
4. Use of fixed loudspeakers to transmit a warning sound
5. Use of Patrol Car Speakers to disseminate warning information

ii. Evacuation Transmission Simulation Model

This aspect of the model expresses residents' evacuation behavior from their houses to the nearest shelter after the transmission of evacuation information. The model can also express the preparation time for evacuation, that is, the time that it takes residents to begin evacuation from the time the evacuation order was issued. The Evacuation model takes into consideration residents' decision-making processes with regard to evacuation i.e. whether or not to undertake evacuation. The model also takes into consideration other factors that might impinge on residents' evacuation behavior and the status of the threat situation at the time residents begin their evacuation to the shelters.

The model expresses residents' evacuation behavior in terms of a family unit, allowing users to establish the family's structure, evacuation speed, evacuation start time and destination. The model assumes that each family evacuates from their house to the nearest shelter at a constant speed. The shortest path from residence to shelter along an existing road network is used as the evacuation route by the simulator. The evacuation simulation has the capability to calculate the time required to undertake evacuation by identifying the shortest evacuation route, impassable routes due to fallen trees or utility poles and traffic congestion that might impede evacuation speed or movement. Therefore, integrating these various elements together, the time frame required for each resident to evacuate safely based on the calculated time that the tsunami will make landfall can be established, as well as variations in the distribution of evacuees due to changes in time flow.

iii. Tsunami Transmission Simulation Model

This component of the model uses a GIS-based framework to calculate the number of casualties that are likely to result from the occurrence of the tsunami, the location of potential evacuees at the onset and during the impact of a tsunami and the areas that would have been inundated by the tsunami. This tsunami simulation works independently from the two simulations previously discussed. This model simulates possible wave height and flood velocity by taking into consideration the geophysical characteristics (such as bathymetry) of the impact zone, during the occurrence of the tsunami. The model is mindful that the tsunami impact will be influenced by the magnitude and location of the hypocenter of the earthquake that caused the tsunami and the existence of prevention infrastructures (e.g. seawalls) in the area. In that regard, the model allows simulation of different scenarios involving earthquake characteristics, human interventions and behavior to mitigate impact.

4.0 DISCUSSION

4.1 Suitability of the TCI for Application of the Model

The Turks and Caicos Islands (TCI) is a small British Dependency covering 430 square kilometers and is situated at approximately 21 degrees latitude and 71 degrees longitude (Figure 2).

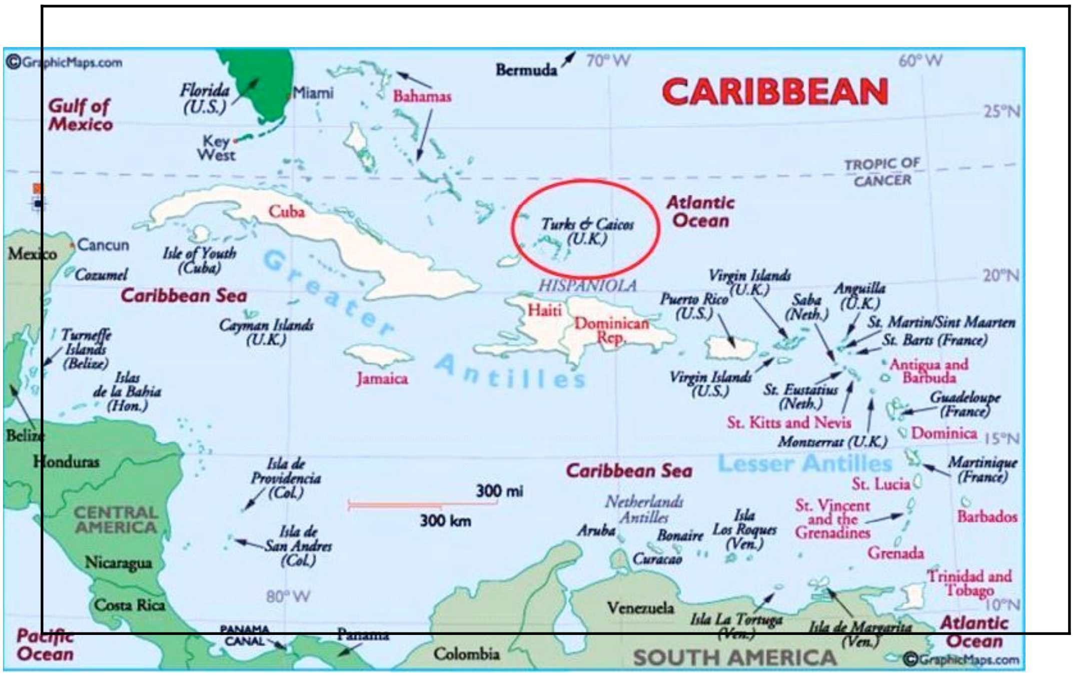

Figure 2: Location of the Turks and Caicos Islands

With a national population of only 11,750 people, the TCI is unable to fill much of its human resource demand for educators, medical practitioners etc, from local sources and as a result, relies heavily on the active recruitment of skilled and unskilled migrant workers to fulfill these needs. The TCI is also deficient in physical resources such as agricultural land and fresh water supply. In spite of these deficiencies, the country has maintained a standard of living that surpasses many of the neighboring Caribbean islands, owing to vibrant tourism and offshore banking industries. In essence, the relative prosperity of the TCI has served as a pull factor for migrants throughout the Caribbean region and other countries outside the region (Clerveaux 2005). Currently, the migrant population of the TCI accounts for approximately 65 percent of the 33,202 people living in these islands (DEPS 2006). Although English is the official language of the TCI both Spanish and French-Creole are commonly spoken owing to the influx of migrants from neighboring Dominican Republic and Haiti.

4.2. Multilanguage Concerns in the Turks and Caicos Islands

The issue of Multilanguage is one of the emergent paradigms in disaster management, especially within the context of risk information and risk communication for hazard/disaster risk reduction. The Caribbean region is no stranger to multiculturalism and Multilanguage and even before the formation of the Caribbean Common Market (CARICOM), significant intra-regional movement of people occurred. The recent strengthening of CARICOM through the establishment of the Caribbean Single Market and Economy (CSME) is resulting in even greater movement and resettling of people and languages in host destinations. In a region that is among the most disaster prone in the world and where the multicultural mix involves not only people with different languages, but also differences within the same language, the issue of communicating disaster-related information in an efficient and effective way becomes particularly relevant.

Over the years, the migrant population of the TCI has been increasing steadily. This trend is likely to continue in the foreseeable future especially in light of the increasing economic development based on one of the most vibrant tourism industries in the Caribbean region and the continued shortage of local sources of labor. Since it is the responsibility of the national government of the TCI to facilitate the safety of visitors and migrants alike, and in light of the ever-increasing numbers of visitors and migrants, there is extreme urgency for the formulation and implementation of measures that will ensure the safety of all during an emergency. As such, the need for strategies that will allow timely and effective communication of disaster-related information within the context of the Multilanguage environment cannot be overstated. Warning and evacuation information are most critical in that regard as ineffectiveness in their communication can make the difference between life and death during hazard emergencies such as a tsunami occurrence. The proposed application of the Tsunami Simulation Model on the island of Providenciales in the TCI attempts to address the need for a mechanism that can ensure effective information dissemination and communication, predict the impact of a tsunami on Providenciales and reinforce the need to plan and implement appropriate evacuation measures. The tsunami disaster simulator that is proposed for application in Providenciales has three interrelated components:

1. Transmission of evacuation information
2. The Residents' evacuation behavior
3. Number of casualties in relation to residents' response time

The integration of the above 3 simulators make this tool effective for:
i. Communicating disaster risk information
ii. Analyzing the processes involved in disseminating risk information in Multilanguage society
iii. Analyzing different levels of responses to warnings
iv. Identifying the limitations of present disaster mitigation strategies and,
v. Educating residents on the consequences of their various responses to warning information.

4.3. Aptness of the Island of Providenciales for the Application of the Model

Providenciales is the urban centre of the Turks and Caicos Islands and is situated on the west side of the Caicos archipelago. Providenciales has an area of 38 square miles and is the most developed island in the Turks and Caicos Islands owing to a vibrant tourism industry. Prior to 1960, the island had a population of 500, but today, with a population of approximately 24, 358 (DEPS 2006), it has the largest population concentration in the TCI, accounting for 73% of the resident population of the country. This island also accounts for the largest concentration of non-native population, consisting primarily of Haitians and Dominicans with a recent increase in the number of migrants from within the Caribbean region and outside the region such as from China, Philippines and India. In that regard, Providenciales consist of the largest number of Multilanguage groups in the Turks and Caicos Islands.

In addition, the bulk of the tourism infrastructure of the TCI is concentrated on Providenciales, specifically in Grace Bay which features the famous 12 mile Grace Bay Beach (Clerveaux 2005). Approximately 60 percent of the employment in Providenciales is derived directly or indirectly from tourist-related services and the island has a tourist-to-resident ratio of 10.02 to 1. Grand Turk, which is the capital and the second most developed island in the TCI, and South Caicos, the third most economically vibrant island, and the other islands have a tourist-to-resident ratio of approximately 0.97, 0.62 and 2.88 to 1 respectively. In 2003, Providenciales accounted for 94 % of total tourist arrivals to the TCI. In essence, in the absence of appropriate and effective communication of related risk information to the population of Providenciales and the design of related evacuation measures, the impact of a tsunami or high magnitude hazard on this island would spell unparalleled economic disaster for the rest of the country. In light of the recent focus of Caribbean disaster managers on coastal evacuation planning in the aftermath of the Asian Tsunami and the limited horizontal evacuation options offered by the low topography of Providenciales, the time is opportune for the application of a model that not only ensures effective risk communication but also provides measures for smooth and efficient evacuation during and after the occurrence of a tsunami.

5.0 RESULTS

5.1. Application of the Tsunami Simulation Model to Providenciales

A. Basic Settings Outlined

1. Information Transmission Model

The transmission of information in this model can be described as a 'web of communication' since there is communication taking place between official and informal sources. However, it is worth nothing that the government is the primary source of dissemination of warning information to the public (Figure 1). In this model, the government will utilize a number of media as a means of communicating risk information to the public. These media are loudspeakers, patrol cars, cell phones, and the mass media. On the other hand, residents will engage in face-to-face communication and communication via cell phones and fixed line telephone as a means of verifying the authenticity of the risk information received and in deciding if they should evacuate.

i. Use of loudspeakers:

In the scenario analysis for Providenciales, a proportionate sampling technique was used to determine the optimum number of fixed loudspeakers that should be located in each of its 15 districts. The methodological approach was to first determine the total population of each district as well as the proportion of the population accounted for by the major non-English speaking ethnic groups. Based on population density and sound-range information it is considered appropriate to install 3 loudspeakers for districts with populations exceeding 1000, 2 for districts with populations between 600-999 and 1 loudspeaker where the district population is less than 600. Therefore, a total of 31 loudspeakers would need to be strategically installed throughout the island of Providenciales, assuming a range of 250 meters for each loudspeaker (Figure 3).

Figure 3: Strategic Positioning of Fixed Loudspeakers and Patrol Routes to be used during an emergency situation

The proposed warning sound is a unique one and involves the transmission of three distinct sounds or pitches recorded from the blowing of a conch shell, which in itself is a very distinct sound. Each pitch will be used to communicate 3 main phases of warning information to residents. For example:

Pitch 1: A large earthquake has just occurred.

Pitch 2: There is a possibility that the TCI might be affected by a tsunami, make preparation to evacuate.

Pitch 3: Evacuate Immediately!

It is a known fact that issues such as language differences can hinder the communication process. This may even be the case where two people speak the same language but are of different nationalities: this may lead to the possibility of misinterpretation of information. It is for this reason that the model proposes the use of sound via its fixed loudspeakers. The use of sound, instead of language, via the fixed loudspeakers ensures that, regardless of primary language, there is no ambiguity or misinterpretation of the risk information being communicated. The information conveyed by the pitch of the conch shell is a universal one as long as people learn the meanings of the different pitches and are sensitized as to what actions are expected following each pitch alert. To accomplish this, a major educational campaign and mock-drills, at regular intervals, will be conducted to enhance preparedness levels. Pitch alerts during a mock drill will differ in length from alerts during an actual hazard occurrence. The former alerts will be short and a one-off sound. However, during an actual hazard pitch alerts would be long and repeated at regular intervals.

The efficiency of the fixed loudspeakers was measured on both resident and tourist population segments in terms of the number of people that can be expected to be reached through this medium. It was found that using this medium, approximately 45 percent of the resident and 30 percent of the tourist population would be able to be reached via this medium. If loudspeakers are to be efficiently located without transmission overlap, some areas will be peripheral to the transmission range and will therefore not be covered. Therefore, patrol cars are proposed to be used to provide information to these areas (Figure 3).

ii. Use of patrol cars:

A total of 8 patrol cars will be dispatched from designated locations along paved roads to disseminate disaster information to the public, especially in those areas not covered by the loudspeakers. Patrol cars will be required to cover a maximum distance of 11 kilometers at a speed of about 20 km per hour. As in the case of the loudspeakers, the patrol cars will also be able to broadcast information at a distance of approximately 250m. For each district, the population size, nationality and primary language of each household was ascertained and plotted on the map. This information is important in order to determine the location of ethnic/language groups, since there is a tendency for persons from similar language/cultural backgrounds to cluster together, and would allow emergency managers to better customize the risk information. Also for each district, the primary language of each household was tabulated and the various languages were then grouped as: English, French-Creole, Spanish and Other (Figure 4†). These languages were then assigned ranking based on prevalence and the rank was used to determine the order in which the patrol cars would relay the warning information to residents in various communities. For instance, if the dominant language in a district is French-Creole, this language would be given priority in transmission followed by the next dominant language

Figure 4: Agglomeration of Population by Primary Language in Providenciales

. *Further investigation proves that the above map closely represents the actual situation which exists in Providenciales in terms of where ethnic groups are presently clustered.

Given the fact that approximately 60 percent of the migrants in the TCI originated from Haiti and owing to the fact that the majority of Haitians are more eloquent in speaking French-Creole rather than standard French, it was deemed prudent that the information being relayed by the patrol car speakers should be disseminated in French-Creole. Additionally, given the absence of data on migrants' educational attainment, it was decided that the information relayed to the residents be simple and brief. This would ensure accuracy and efficiency in the timing of information dissemination from the disaster officials' standpoint and easy comprehension and hopefully prompt responses from residents.

iii. Use of cellular phones*:*

Use of cellular phones to transmit short messages with warning information to the public is another method employed in this simulation. It is estimated that the TCI has a techno-density of two cell phones per person (Oral Communication with Telecommunication Providers, 2007).

Therefore, it was felt that the use of such a communication medium would aid the relevant government officials in transmitting information quickly and in multiple languages. The message that will be relayed via the cellular phone will be tailored to ensure that it is straightforward but informative as to what action is required by residents. An advantage of using short message services (SMS) during a disaster is that it takes less time for the information to be transmitted than using dialogue. Therefore, this medium can prove to be effective during the warning stages of the disaster. Prior to an emergency the government and telecommunication providers on the island would need to cooperate to implement such a system that would allow the transmission of a designated warning tone and the dissemination of risk information in the form of SMS in multiple languages simultaneously via this medium. Such an arrangement would allow the government to transmit the warning sound and text message to all cellular phone holders during an emergency. It would also be required that this sound be heard even if the cellular phone instrument is turned off or is on silent mode by allowing the telecommunication providers to automatically override the codes in the cell phones in order to transmit that warning message or tone. This would therefore further increase the chance of warnings being received by all members of the society.

iv. Use of the mass media

Use of the mass media (radio and television) to communicate disaster information, especially during the onset of a disaster, is one of the oldest media used worldwide. In order to effectively utilize this medium during an imminent threat from a hazard, prior collaboration with local broadcasters would be required. This collaboration can take the form of the disaster office providing personnel who will go on the air to directly relay the warning message from the disaster office to the public or allowing the disaster office to tailor the content as well as the language order in which the information will be broadcasted. The information that will be disseminated through this medium can be very informative, informing residents about the imminent threat, what measures they should be presently undertaking and perhaps, if possible, how much time they have to safely evacuate. This message can also be site specific that is, informing the public of which areas are likely to be impacted first or the expected hardest hit areas and any new development that occurred re the hazard. The use of the mass media is very important because if individuals are located outside the audible range of both the loudspeakers and the patrol car speakers' routes, then the mass media can be relied upon for transmission of risk information to those residents.

v. Use of oral communication

Another medium utilized for information/warning transmission in the model is the use of oral communication. In the context of this model, communication takes place between residents via telecommunication and face-to-face contact. This parameter was incorporated because in many societies, and especially those that contain large mixed groups, where not only culture is different but also language, there is a tendency for the agglomeration of people either by nationality or language and additionally for mistrust of government. In this model, oral communication is said to take place between residents as a means of verifying the warning message issued and in deciding what action to take. According to Katada et al. (2006), “during a disaster there is increased oral communication between residents. In fact, communication parameters, such as distance of each contact, number of contacts (receivers) and timing of each contact, which usually exist during normal days (i.e. days when there is no imminent threat from a hazard occurrence) tend to increase during a disaster, a factor that explains jammed telecommunication circuits during emergencies. Therefore, it is assumed that oral communication will take place not only between closest neighbors but also with distant friends.” This type of communication is especially significant among persons from similar cultural and language backgrounds. During a disaster there is an increased demand by residents for relevant information. However, there is the possibility that communication systems could be damaged and, because of this, oral communication networks will prove to be an effective medium (Katada et al. 1996). Having established a communication web for the dissemination of risk information, disaster managers can therefore determine the information-receipt time for each district in Providenciales (figure 5).

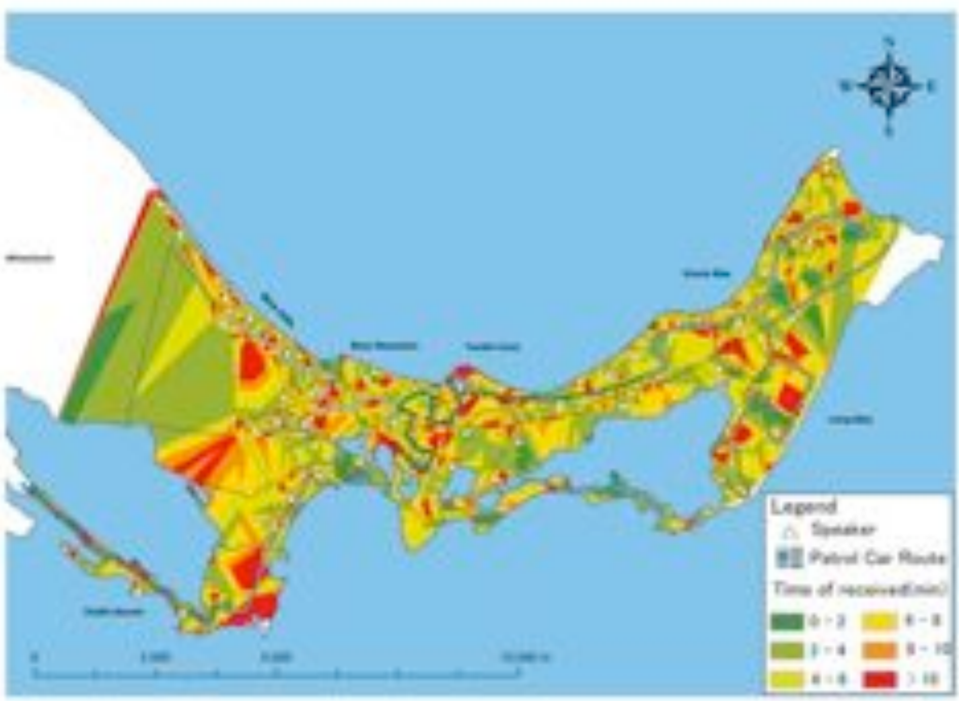

Figure 5: Estimated Information Receive Time by District in Providenciales

They are then in a better position to determine the likely impact a delay in information will have on households.

2. Evacuation Transmission Model

Based on the topography of the island it was decided that all areas below 10 meters could be vulnerable to a tsunami or high magnitude flooding. The inundation level was decided by the authors after taking several factors into consideration such as:

1. Maximum wave height of past tsunamis in the Caribbean.
2. Geographical relief of the seabed near and in the TCI
3. Maximum distance traveled by past Caribbean tsunamis
4. Geographical relief of Providenciales

It is important to note that the inundation depth chosen for Providenciales is not fixed and can be easily modified with the availability of new data or to reflect current situations. Nonetheless, the model in its existing state acts as a type of benchmarking tool that allows disaster managers to simulate different disaster scenarios based on the earthquake characteristic and the origin of the earthquake, and local characteristics of the country etc allowing better preparation for various hazard scenarios. Analysis of the current available data for hazard vulnerability of the TCI suggests that a tsunami hazard is not a significant threat as other hazards such as flooding, hurricane, and storm surge. While tsunamis are not publicly recognized as a major hazard for the TCI, the country is not immune from such threats and sea level changes. It is a well known fact that the earthquake that occurred in Lisbon Portugal in 1755 did travel great distances generating tsunami waves that crossed the Atlantic Ocean, reaching as far as the Lesser Antilles. According to James Lander (1997), the Lisbon Earthquake, in Portugal, "… sent waves into the Caribbean with amplitudes of 7m at Saba, 3.6m at Antigua and Dominica, 4.5m at St. Martin, and 1.5-1.8m at Barbados." Therefore, the Caribbean region is not only vulnerable to tsunamis generated within the region but is also vulnerable to teletsunamis, which may have their origin outside of the region. Given this reality, the implementation of mitigation measures against a possible tsunami occurrence in the TCI can be considered foresightedness and the tsunami model proposed in this study will allow disaster managers to achieve this goal.

In the scenario analysis site for Providenciales there are 15 Government-designated emergency shelters (schools, churches, and community centers) (Figure 6). However, all of these shelters are currently sited below the 10m line. Providenciales has a total of 4926 households but only 886 households are located in areas of 10m height or above. In other words, approximately 79% of households in Providenciales are below the 10m line and will need to be evacuated in the event of a tsunami or high magnitude meteorological hazard.

Figure 6: Current Location of Shelters and the Emergency Operation Center

Using the model it was determined that, given the current location and number of shelters, if residents were to evacuate by foot, it would take the majority of the population more then 30 minutes to complete evacuation (figure 7) and that the population density in the shelters would be high.

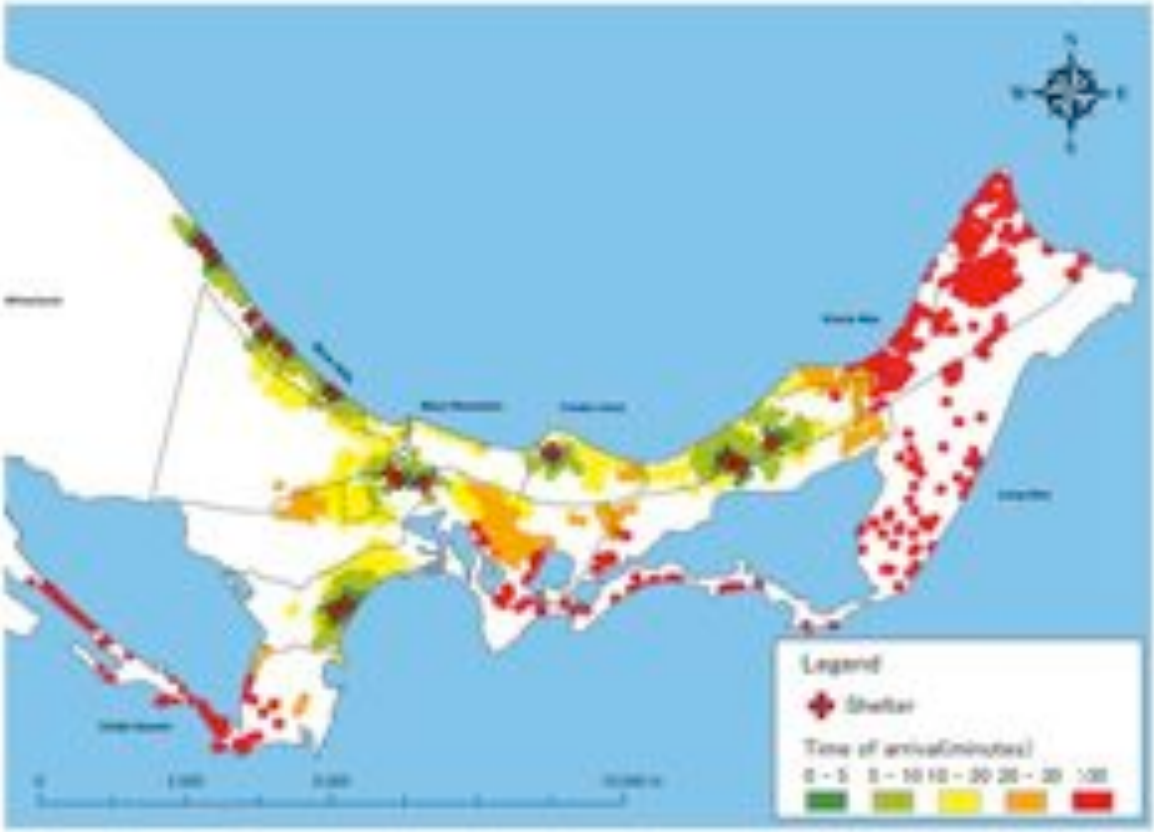

Figure 7: Estimated Evacuation Time by District in Providenciales for Current Shelters

Currently, all the government-designated shelters and the Emergency Management Center, from which disaster mangers are expected to relay warning information, are below the 10m-height level. The model was therefore, able to suggest suitable areas for the strategic relocation of the current shelters, the Emergency Center and the proposed additional 19 shelters, to higher ground throughout the island of Providenciales (Figure 8).

Figure 8: Proposed Relocation of Shelters and the Emergency Operation Center to Higher Ground

Care was taken to ensure that, as far as possible, a shelter would be located in each district. However, this parameter was difficult to achieve given the fact that not all districts had areas of 10m or higher. In order to resolve this problem, shelters were located as near as possible to each district in areas that are 10m or higher. In addition, the time factor required to evacuate quickly from a tsunami was taken into consideration when siting the shelters. However, given the relief of the land, a few shelters had to be located approximately 5 kilometers away from residents in particular districts and therefore evacuation by foot, though the desired mode in order to prevent traffic congestion, would be impossible in light of the time factor involved in evacuating from an imminent tsunami.

Re-simulation of the time required to safely evacuate to shelters based on the relocation of the shelters and the availability of additional shelters indicated that there is a significant decrease of 10 minutes in the time that would be required to complete evacuation on foot by residents. This variance in time can be the difference between life and death in an emergency situation (figure 9).

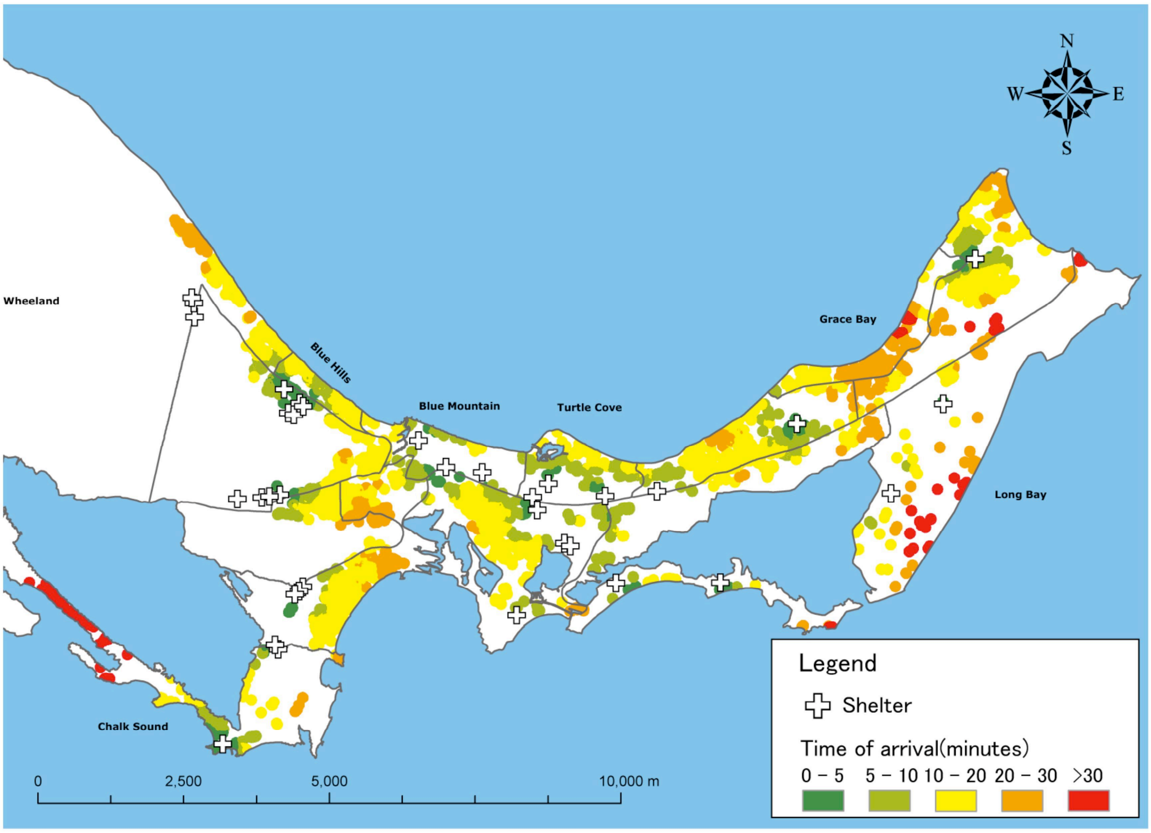

Figure 9: Estimated Evacuation Time by District in Providenciales for Amended Location of Shelters.

In addition, tsunami towers, able to accommodate a higher number of persons, were placed in areas that had a high population density and where the siting of the nearest shelter would still be difficult based both on the parameters of relief and shortest distance to a shelter. Currently, the areas where the tsunami towers have been sited have approximately a combined total population of 4,547 residents and 1,891 hotel room occupancy. It therefore means that shelters would possibly have to be provided for all persons. Of equal importance is the fact that the tsunami towers will be sited near the coast as, according to NOAA (2006), beaches are most vulnerable to loss of life and a 2 meter tsunami would result in high mortality near sea level. Research indicated that in Providenciales approximately 97% (Figure 10) of the hotels are located on relatively low-lying areas (lower than 10m) and of these hotels, only a few are multi-storey.

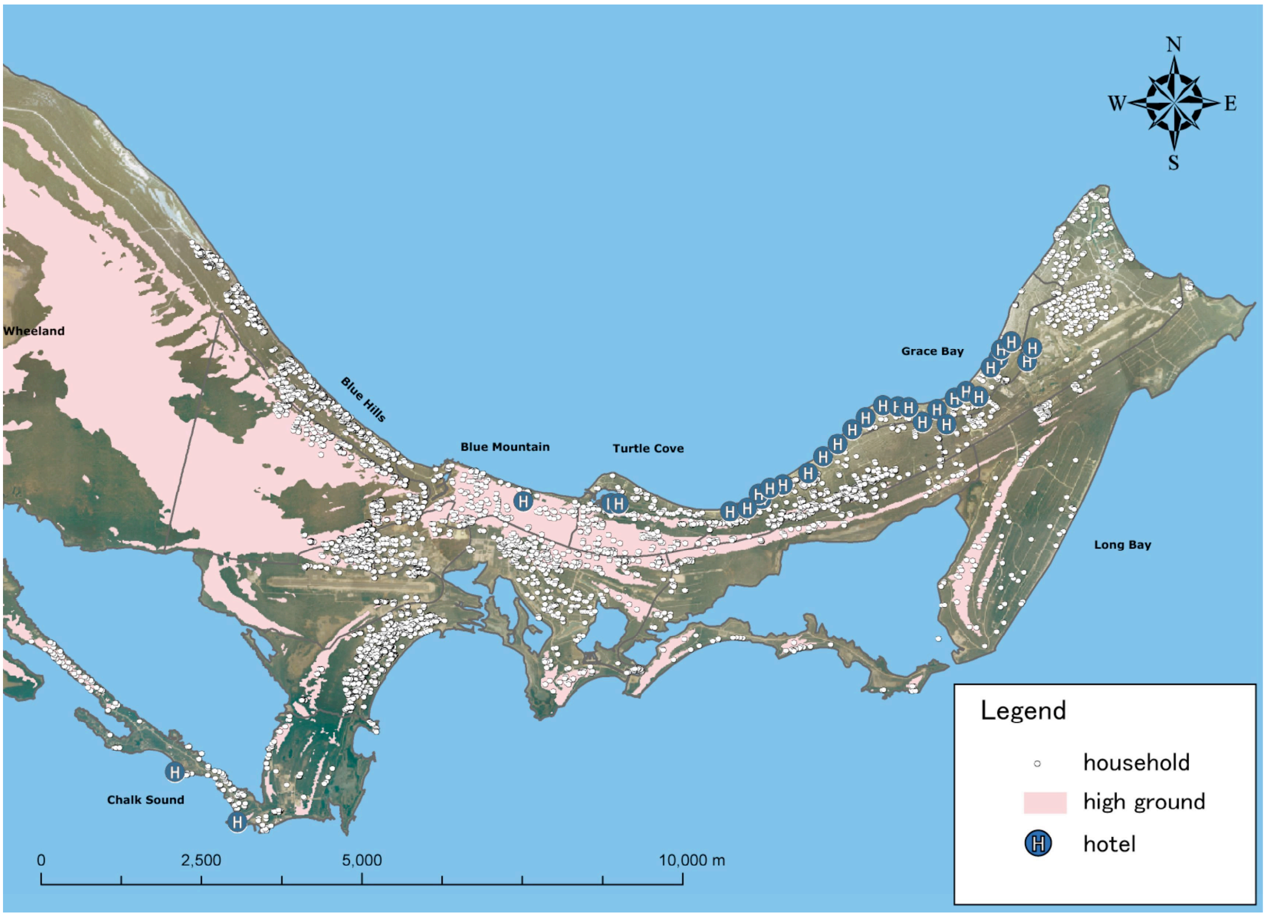

Figure 10: Location of Hotels in Providenciales

Another criteria set up in the simulator was that most households would evacuate to the nearest emergency shelter on foot at a speed of approximately 80 meters per minute. However, persons in areas that are substantially distant from the nearest shelter would have to evacuate via car. For example, the distance from Chalk Sound to the nearest shelter is 5 km, and if residents were to evacuate on foot at 80 meters per minute it would take them approximately 60 minutes to complete evacuation, a potentially dangerous scenario.

3. Tsunami Simulation Model

The tsunami simulator component of the model was used to simulate the different impact scenarios that are possible based on the characteristics of the earthquake and the geological features of the sea floor around Providenciales. The model was used to simulate both a worst and a best-case scenario of a tsunami occurrence in the Caribbean with different possible wave heights estimated reaching the shores of the TCI. Based on these various scenarios/estimates gaps in current disaster management policies were highlighted. Additionally, the range of probable damage was simulated and the location of vulnerable populations and infrastructures in the island identified. The model will therefore allow the relevant authorities to establish and put in place relevant and essential mitigation strategies for use against the impact of a tsunami. Use of this model will also enable smooth and orderly evacuation of persons located along the coast or other vulnerable sites. In addition, the model can be used to inform land use planning by encouraging the construction of hard measures against tsunamis such as the construction of sea walls or other types of embankment. However, it is important to note that employment of hard measures alone will not stop the tsunami though it may help to reduce its impact. Therefore, a balance between the use of hard measures and soft measures, such as investing in information transmission and educating residents on tsunamis, will be effective in saving lives.

6.0 CONCLUSIONS

The model can be considered a type of dynamic digital "hazard map" as it informs, educates and identifies vulnerable populations. Utility of the model is enhanced by its capacity to depict various scenarios in three-dimensional or graphical formats. This makes presentation of the results more realistic and thus more appealing to residents, irrespective of language differences. The realistic nature scenarios in the model should better persuade residents of the need to take appropriate measures to protect themselves, their family and property from various disasters. The wide range of devices/media used to communicate risk information should ensure maximum and comprehensive coverage of all residents in the Providenciales Multilanguage landscape thus allowing for effective communication of risk information that should result in prompt evacuation from vulnerable areas in the face of an imminent threat. From the disaster managers perspective the tsunami model can be considered as a type of digital disaster manual as it can be used to assess the effectiveness of current disaster management strategies that are in place.

6. REFERENCES

Clerveaux, I. Virginia (2005) Migrants and Resource Utilization in the Turks and Caicos Islands. MPhil Thesis. The University of the West Indies, Mona Jamaica. Unpublished

Cross, T., Bazron, B.J., Dennis, K.K., & Isaacs, M.R. (1989). Towards a culturally competent system of care. Washington, DC: Howard University Press

Department of Economics Planning and Statistics (DEPS).(2006, Turks and Caicos Islands. depstc.org/pressreleases/2006/jun06/0629a.html

Fararo, T.J. (1981. Biased networks and social structure theorems. Social Networks, 2, 1-18.

Green, J.W. (1995). Cultural awareness in the human services. Second Ed. Toronto: Allyn & Bacon.

Imamura, F. (1996. Review of tsunami simulation with a finite difference method. In Long Wave Run-up Models (H. Yeh, P. Liu, and C. Synolakis Ed.) 25-42.

Katada, Toshitaka, Noriyuki Kuwasawa, Harry Yeh, Cherri Pancake (2006) Integrated Simulation of Tsunami Hazards. EERI's Eighth U.S. National Conference on Earthquake Engineering (8NCEE), Paper No.1727.

Katada, Toshitaka, Kuwasawa, Noriyuki, Kanai, Masanobu and Hosoi, Kyohei (2004). Execution and the Evaluation of Disaster Prevention Teaching to the Owase City people using Tsunami Disaster Scenario Simulator Social technological Research Paper Collection, Vol.2, pp.199-208, and October.

Katada, Toshitaka Junsaku Asada, Noriyuki Kuwasawa and Yasushi Oikawa (2000) Development of Practical Scenario Simulator for Dissemination of Disaster Information Journal of Civil Engineering Information Processing System, Vol.9, pp.129-136,

Katada, T., Aoshima, S., and Oikawa. Y. (1996) Oral Communication Network Model for Refuge Warning against Disaster. Proceedings of Japan Urban Planning Society, 31, 757-762. (Japanese)

LaFromboise, T.D., & Foster, S.L. (1992) Cross-cultural training: scientist-practitioner model and methods. Counseling Psychologist, 20(3), 472-489.

James F. Lander and Lowell S. Whiteside (19972) Caribbean Tsunamis: An Initial History. http://www.eird.org/deslizamientos/pdf/eng/doc10729/doc10729.htm. Retrieved December 10, 2007.

Lin, P., Chang, K. -A., & Liu, P. L.-F. (1999) Runup and rundown of solitary waves on sloping beaches, Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE, 125, 247-255.

Martin, F. LaTanya (2003) Cultural Differences in Risk Perception: An Examination of USA and Ghanaian Perception of Risk Communication. MSc. Thesis. Virginia Polytechnic Institute and State University.

Rapoport, A. (1979) A probabilistic approach to networks. Social Networks, 2, 1-18.

Smith Warner International (2006) Turks and Caicos Islands Hazard & Vulnerability Assessment.

Solis, Y. Gabriela, Henry C. Hightower, June Kawaguchi et.al (1995).Guideline on Cultural Diversity and Disaster Management. Final Report Produced within the Canadian Framework for the International Decade for Natural Disaster Reduction. www.epc-pcc.gc.ac/pub/manuals/en_cult.htm. Retrieved October 12, 2005.

Sue, D.W., Arredondo, P., & McDavis, R.J (1992) Multicultural counseling competencies and standards: a call to the profession. Journal of Multicultural Counseling and Development, (20), 64-88.

Sue, D.W. & Sue, D. (1990) Counseling the culturally different. Toronto: Wiley.

Titov, V. V. & Synolakis, C. E. (1998) Numerical modeling of tidal wave run up. Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE, 124(4), 157-171.