

HURRICANE SIMULATION EFFICACY FOR INCREASED EVENT PREPAREDNESS: U.S. VIRGIN ISLANDS

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ABSTRACT: *Increasing tolls in disasters have prompted hazard researchers and managers alike to investigate creative methods for reducing vulnerability to extreme environmental events. Locations that experience resource scarcity are faced with the additional challenges of logistic and resource limitations imposed on preparedness efforts. Such is the case with small tropical islands, including the U.S. Virgin Islands (USVI). Hazard simulations may serve as an appropriate preparedness tool contributing to vulnerability reduction in locations with resource scarcity issues. Event simulations are used extensively for high-risk emergency preparedness, such as fire response, hazardous materials and search and rescue, but these exercises are not widely applied to hurricane emergencies. In March 1997, the Federal Emergency Management Agency, in concert with the Virgin Islands government and local hazard responders, conducted a hurricane simulation - "HURREX '97". This marked the first opportunity to observe a hurricane simulation in the U.S. Virgin Islands. This paper addresses the major components of "HURREX '97", assessing the efficacy and applicability of future simulations to vulnerability reduction in the USVI. Strengths and weaknesses of the simulation are addressed and suggestions are presented to improve the relevance of hurricane simulations in the USVI. With contextual adjustments, regular play, and post-event assessment, simulations may prove to be valuable tools for hazard preparedness in the USVI and other insular locations.*

INTRODUCTION

The U.S. Virgin Islands (USVI) are situated at the northeastern edge of the Caribbean Sea (Figure 1. U.S. Virgin Islands Location Map). This location is subject to a wide variety of potentially severe hazards, to include earthquakes and hurricanes. Given the smallness and insularity of the USVI, hazardous events may easily become disastrous events. This can result in devastating impacts for households, businesses and the government, paralyzing the economy and disrupting the daily routine of life. These events invariably result in the need for external financial assistance and the consumption of scarce resources to return the islands to a functional state.

In recent years, this vulnerability has been evidenced through Hurricanes Hugo (1989), Marilyn (1995) and to a lesser degree, Bertha (1996). The

extreme experiences of these events, however, have not resulted in the application of preparedness efforts sufficient to reduce widespread vulnerability in the Virgin Islands. Compounding this vulnerability, mitigation and recovery tools such as insurance or protective construction techniques may not be viable for future events due to increased costs precipitated from past events. It is presently difficult to purchase property insurance in the USVI as it is quite costly for residents and businesses as a result of extensive losses suffered from Hugo, Marilyn and Bertha.

Significant preparedness efforts must be employed in the USVI in order to prevent the repetition of errors made in previous hurricanes and to reduce individual and collective vulnerability. Limited human and financial resources to facilitate comprehensive planning necessitate creative methods of disaster preparedness. The 1996 Virgin Islands Territorial Emergency Operations Plan (VI-TEOP) is still undergoing development, thus, the islands have

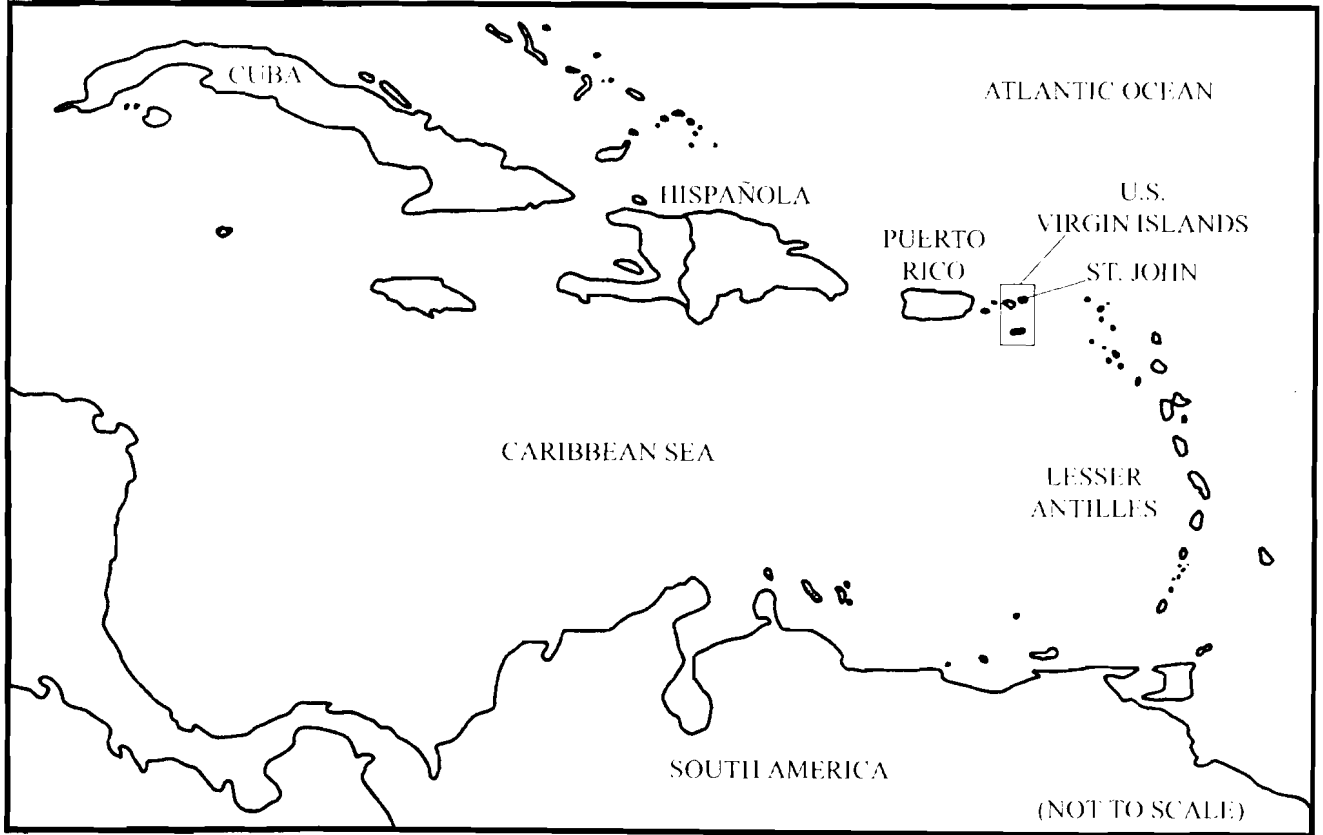


Figure 1. U.S. Virgin Islands location map

an incomplete disaster mitigation, preparedness and recovery plan. Its incompleteness may be beneficial at this point, as the plan's development could be positively influenced by successful simulation exercises.

Emergency management in the USVI is coordinated by the Executive Branch of the government, guided by the Emergency Management Council under the auspices of the Governor and Adjutant General. The Virgin Islands Territorial Emergency Management Agency (VITEMA), created in 1987, works in coordination with the Federal Emergency Management Agency (FEMA) and other state and federal agencies for ongoing preparedness, response, recovery and mitigation efforts. Each of the three largest islands - St. Thomas, St. Croix and St. John - is represented by a VITEMA Emergency Services Coordinator and support staff. All governmental agencies and some non-

governmental organizations (NGOs) also play significant roles in disaster response in the USVI.

SIMULATION APPLICATIONS

Simulation is a technique used by many organizations and industries, public and private, to prepare for real-life threats, usually those that are severely damaging in nature. Simulations are commonly used for fire, search and rescue, medical emergencies, hazardous materials, airport emergencies and other high-risk events. General objectives of simulations are: 1) to prepare responders, 2) to highlight strengths and weaknesses in response capabilities, 3) to test new procedures, and 4) to result in corrective actions for poorly functioning procedures (FEMA, 1997, p.1). Various

simulation techniques can provide several levels of preparedness activities suitable to all financial situations and human resource limitations. Because of the ability to telescope the scale of simulation exercises from organizational discussions to full-scale exercises, the burden of financial, temporal or human resource costs can be distributed over time for an optimal cost-benefit ratio.

FEMA Simulation Categories

Simulations vary in the degree to which emergency functions are tested and the degree of realism involved in the exercise. Simulation events include tabletop exercises, functional exercises and full-scale exercises. Tabletop exercises involve informal discussions regarding a simulated emergency. Agencies convene in a conference-like arrangement with the goal of discussing, developing and evaluating hazard and disaster management, plans and protocol, emphasizing agency responsibility and coordination. A functional exercise, such as the one discussed in this paper, is an actual game-play event. The Emergency Operations Center (EOC) is activated with participants from the actual agency in attendance. The exercise is conducted with actual communications and event simulation, but without activity in the field, and it usually tests only selected emergency functions. A full-scale exercise is a simulation that involves the mobilization of all resources, to include field activity. This type of simulation tests all emergency functions, policies and procedures. Organizational meetings and drills are related exercises that are often needed prior to actual simulations, regardless of which level of game play is employed (FEMA, 1995, p. 2).

Each of these exercises requires different financial, temporal and human resource commitments, thus a jurisdiction could employ a tabletop exercise in the early stages of policy development in order to test ideas without significant costs. At the culmination of policy formation, a jurisdiction can elect to commit significant resources for testing a full-scale event. This multi-level structure of activities provides for low-cost preparedness activity for resource-restricted jurisdictions.

FEMA Simulation Programs

Simulations have had extensive application in emergency response, particularly those high-risk events previously mentioned, but it is relatively recent that multi-hazard, multi-jurisdiction exercises have been employed. As such, FEMA has developed the Comprehensive Exercise Program (CEP) in an effort to apply simulations to natural hazard events, including hurricanes and earthquakes. The purpose of FEMA's CEP is "to develop, implement, and conduct comprehensive, all hazard, and risk-based exercises" as well as assist state governments with emergency simulations, to include environmental hazards and social hazards such as terrorism (FEMA, 1995, p.1).

The CEP facilitates the regular implementation of all-hazard disaster exercises to help prepare U.S. jurisdictions for potentially disastrous events. The ultimate goal of the CEP is to have jurisdictions test their Emergency Operation Plans (EOPs) for weaknesses in policy, procedure and training (FEMA, 1995). FEMA has been conducting large-scale disaster exercises throughout the US and its territories since 1984 to test hazard management responses. The most recent event, "Response '98", was a multi-jurisdictional hurricane simulation involving the northeastern US and Canada. A previous multi-jurisdictional event, "HURREX '97" was conducted in the USVI from March 18-20, 1997 to test the preparedness and operations of the Virgin Islands hazard management system, Federal activity, and simulation planning.

As a territory of the United States, the USVI is eligible to participate in programs administered by FEMA, including the CEP, and the USVI should continue to avail itself of the programs facilitated and supported by the CEP. The more opportunities that are made available to train hazard managers and governmental representatives, the greater the opportunity for devising effective policies and procedures prior to an actual event.

HURREX '97 SUMMARY

Simulation Objectives

Operations of the Emergency Management Council, offices of the Adjutant General, VITEMA, FEMA, VITEMA Emergency Services Coordinator and support staff, other state and federal agencies, and selected non-governmental organizations were the subject of HURREX '97 assessment. Objectives of HURREX '97 as stated in FEMA's *After Action Report* include testing of: 1) alert and notification capabilities, 2) direction and control, 3) resource management 4) communications, 5) facilities, equipment and displays, and 6) media information (FEMA, 1997, p. 79). Specific objectives according to guidelines provided to event participants included: 1) testing and evaluating the VI-TEOP, 2) evaluating response and recovery plans with an emphasis on communications, 3) exercising the St. Thomas, St. John and St. Croix EOCs, 4) testing Emergency Support Functions (ESF) 1, 3 and 6 (ESF 1 is transportation, ESF 3 is public works and utilities, ESF 6 is mass care), 5) integrating response agencies, and 6) exercising management structures of FEMA (FEMA, 1997, pp. 84-85). The Regional Operations Center (ROC), Territorial Coordinating Center (TCC) and the EOCs were tested primarily for ability to mobilize, run emergency response from their location, mobilize and manage resources, and maintain communications as necessary for the response.

Simulation Framework

Planning

The simulation premise and procedures were developed and administered by FEMA according to FEMA guidelines. USVI officials were involved in facilitating the event, but not in the development of its premise and agenda. Controllers and evaluators were FEMA personnel trained in advance of the exercise. Preparation of participants prior to the simulation was limited. No specific training exercises for USVI participants were

conducted prior to HURREX '97, and, in fact, a number of participants had never previously experienced official responsibilities during a hazard event in the USVI. Recent governmental elections resulted in the attendance of new agency representatives unfamiliar with the VI-TEOP and their own agency's responsibilities during an emergency event. Notification of and invitation to the event for some agencies was delayed due to the recent elections and changeover of government personnel. The majority of participant preparation for HURREX '97 consisted of distribution of written description of the exercise and a briefing.

Procedures

The simulation occurred over the course of three days, March 18-20, and simulation time was condensed into actual time to facilitate completing the exercise within regular government working hours. HURREX '97 exercises encompassed the four islands in the USVI, St. Thomas, St. John, St. Croix, and Water Island, although activities for Water Island were conducted through the St. Thomas EOC. Participants gathered in the EOCs with player representation from actual agency staff. Controllers and evaluators monitored the event and doubled as players. The course of game play was executed by real and simulated communications from controllers, the ROC, TCC, EOCs and participating agencies. Exercise assumptions included the absence of field play, the simulated "arrival" of persons already on-site who normally would arrive during the event, and the simulated presence of persons or agencies not in attendance (FEMA, 1997, p. 70).

Event Summary

The HURREX '97 simulation began on Tuesday, March 18, 1997 with the notification that Hurricane Ross, a Category 3 storm on the Saffir-Simpson Scale, was approaching the Virgin Islands. The appropriate Federal and Territorial agencies were mobilized and the EOCs were opened. The brunt of the storm, damage and response occurred on March 19, with the end of the storm and the close of the exercise on March 20. The track of Hurricane Ross brought the eye within ten miles of St. Thomas and

St. John and thirty-four miles of St. Croix, for a total duration of twelve hours in the area, beginning at 1:30 a.m. March 17 (FEMA, 1997, p. 84).

To include sociological variables of hazard and the multi-hazard character of the exercise, the simulation provided for the general strike of hotel workers preceding landfall and terrorist threats during the event. The simulated hurricane struck with considerable force, knocking out power, downing trees, damaging coastal structures and exacting widespread damage and deaths. Shelter was needed for large numbers of people on all three islands, and shortages of food, water and other supplies were severe.

Salient impacts for the islands included extensive damage and casualties, insufficient shelter space for evacuees, and reduced shelter capacity during the storm (FEMA, 1997, p. 93). Many buildings were damaged or destroyed, roadways were undermined or blocked by flooding and debris, and utilities were severely damaged. Airports and seaports closed due to high winds, severe waves and damaged infrastructure. Telephone communications were negatively impacted resulting in limited communication in and out of the islands. Flooding, cistern damage, and fuel, food and water shortages were prevalent on all three islands. A terrorist bombing was experienced in a shelter on St. Thomas.

SIMULATION ASSESSMENT

An assessment of the simulation and its outcomes reveals strengths and weaknesses in the exercise, and highlights areas that show promise for future simulation successes. Of analytic concern is whether the exercise met the general objectives of a simulation - preparing responders, highlighting strengths and weaknesses, testing new procedures, and resulting in corrective actions. Also considered are the results of FEMA's particular objectives for the exercise. As written, FEMA's objectives were to test mobilization of disaster response, which was accomplished implicitly by virtue of exercise completion. Notable are the areas that experienced problems, as determined by the general simulation

objectives. Overall, HURREX '97 produced variable results, but demonstrates the significant potential of simulations to provide a manageable tool for preparedness in the USVI. An overview is presented in this paper, and an in-depth analysis is presented in related research.

Background and Objectives

The premise of HURREX '97 was sound and timely. The USVI experiences significant vulnerability from tropical storms and hurricanes, and readiness is of great concern to all residents. The simulated hurricane was comparable to Hurricane Marilyn in scope and effect, thus reflecting a potentially real event. The introduction of man-made threat - terrorism - represented the unknowns that occur in a real event, although local reaction viewed terrorism as an unrealistic threat. Looting or smuggling may have been a better contextual choice, based on historical experience. The set-up and game-play went according to simulation design and procedures, despite some shortcomings in the event premise. Objectives of testing alert and notification capabilities, management, communications, facilities and equipment, media information, the VI-TEOP, the EOCs, ESFs 1, 3 and 6, response agencies, and FEMA structures of were achieved, as testing these factors is implicit in conducting the exercise. The objectives set forth by FEMA of "testing" are best left for organizational meetings, drills and tabletop exercises. More specific objectives should be employed to clarify agency roles, responsibilities and expectations during a simulation.

Simulation Framework

Planning

Complications with simulation planning that arose are the purview of FEMA and the simulation designers to correct. These failures had a trickle-down effect on the rest of the exercise, causing compounded problems. Problems identified by FEMA included: 1) planners also had to function as players due to personnel shortages, 2) lists of major events for the exercise were submitted late and could not be reviewed for quality and accuracy, 3) some of

the major event lists were not realistic enough, thus did not sufficiently test response capabilities, and 4) the weather scenario was exclusive of the timing of the exercise, resulting in responders operating during the brunt of the storm, which they normally would not (FEMA, 1995, p. 99).

Future planning and exercise design should include contextual variables specific to the USVI, the addition of which could make a significant difference in event performance. For example, events based on past experiences may include a shortage of Department of Education personnel in shelters, the failure of communications prior to the storm resulting in the use of boaters' HAM radios for communications, or the absence of a high-level emergency response decision-maker, all of which occurred in Hurricane Marilyn.

Public response as scripted in the simulation did not reflect actual responses evidenced in history. As shown through past events, emergent norms of society experienced during an emergency event in the USVI deviate significantly from the bureaucratic norms planned for by VITEMA and FEMA, resulting in misguided official response and potential chaos (Schneider, 1995, p. 80). Norms in a USVI disaster involve significant individual self-reliance in the absence of official response, ranging from looting of essential supplies to community self-mobilization for clearing impassable roads. Bureaucratic norms as put forth in HURREX '97 assumed the lack of self-motivation and spontaneous action of victims and simulated the timely response of emergency management agencies, neither of which is demonstrated historically. These examples are some of the many contextual variables potentially addressable in USVI simulations.

Communications should also be scripted so as to present assumptions that reflect actual probabilities. Communications often fail ahead of storm landfall as experienced during Hurricane Marilyn. Official scripting for HURREX '97 participants had telephone capabilities for the EOCs simultaneously down for one hour, while telephone, cellular phone and pager service was reported by official reports during the exercise to be, in most cases, not possible (Mossler, 1997). Intra-island, inter-island and overseas communications are severely hampered during hurricanes in the USVI,

and this should be directly addressed in planning any simulation for the islands.

Additional planning concerns involve the lack of pre-event exercises, training, briefing and debriefing. The absence of these exercises contributed to the confusion and mistakes encountered during game play. Future events should be preceded by drills and tabletop exercise to avoid this counterproductive oversight. Particularly relevant are orientations explaining the goals and purposes of simulations, drills exercising mass care personnel, or tabletop exercises focusing on pre-event preparedness of medical personnel and public works. All simulations should be followed by debriefing and analysis to distill and highlight areas in greatest need of attention.

Procedures

Participants were not made aware of many simulation assumptions and procedures, which tended to cause confusion during the exercise. Basic procedure was problematic at times, particularly for those participants who had never experienced agency responsibility during either a real or simulated hurricane. For example, many participants were not aware that the Virgin Islands exercises a 72-hour delay before Federal disaster assistance is received, even though such assistance legally may be brought in earlier (FEMA, 1997, p. 106). This procedure is promulgated by the VI-TEOP in order to encourage self-sufficiency and organization of management prior to the arrival of external assistance (VITEMA, 1996, p. 13).

The absence of certain personnel also caused debate and confusion. For example, Red Cross representatives and shelter managers were absent from St. John on the first day of the exercise, creating dissention as to whether to simulate their presence or simulate their absence. The actions at the EOC level to accommodate this absence then placed demands on higher management levels for resolution. While an absence may be a highly likely event (thus worthwhile to simulate), assumptions for this exercise called for simulating the presence of absent personnel, a fact of which participants were not necessarily aware. (VITEMA/FEMA, 1997; FEMA, 1997). In the Virgin Islands, this assumption is

probably best *not* made, as travel between the islands can be problematic and absences are a distinct possibility. Procedural confusion also existed in determining the correct flow of paperwork and chain of responsibility for addressing requests to and from the TCC, although these problems were eventually clarified during the exercise.

Simulation Efficacy

Responder preparedness

The first general objective, to prepare responders, was met for many participants. Since the exercise tested only certain ESFs extensively, most of the ESFs were not directly stressed. A lack of awareness that not every ESF would be exercised resulted in some confusion among participants as to their roles. Those with lesser roles remained on the periphery of the exercise and somewhat dissociated from the preparedness efforts of the overall picture. In an extreme example, one participant questioned why his agency (fire) needed to be at the simulation at all, not grasping the purpose of the functional exercise. Other participants, particularly those who were new to EOC operations, gained much relative to their preparedness roles. Overall, the need for substantial preparedness efforts was successfully conveyed to the group as a whole, despite individual lack of awareness.

Strengths and weaknesses

The second general objective of simulations, to highlight strengths and weaknesses, met with success. Strengths were revealed in the way the simulation brought out agency interaction and sharing of ideas, demonstrated strengths and weaknesses in preparedness and management, increasing awareness of officials and participants in need for planning, developed and stimulating organizational links, demonstrated need for organizational meetings and drills and table top exercises, showed need for improved equipment and training, and increased understanding of hazard management by participants. Particularly salient were the post-simulation initiatives shown by the business

communities and other NGOs in addressing issues of communication and cooperation.

The simulation involved the business community to a limited degree, but post-event activity indicates that this will likely change, inspired by simulation events. The simulation also occurred shortly after the appointment of a new VITEMA director and a new St. Thomas/St. John Red Cross director. The simulation provided these incoming officials and the newly elected and appointed government representatives with an opportunity to observe the USVI hazard management system in operation. Through HURREX '97, they could assess policies and procedures without having to wait for a potentially disastrous actual event.

Weaknesses were demonstrated throughout the game play. Major communications problems occurred throughout the exercise, including procedural and information failures, technological gaps, and the lack of response to the EOCs by the TCC. Communications issues are desperately in need of further work as poor communications resulted in many unresolved issues. Organizational meetings and drills between agencies are low-cost simulation activities that could serve to establish priorities, procedures and solutions for future simulations and actual events. Additionally, explanation of procedures, assumptions and goals could be better communicated by FEMA to participants prior to the event through pre-simulation briefings.

Information communicated was problematic if it was not scripted. For example, the National Hurricane Center contributed an unplanned change to the storm, which would be appropriate given the changing nature of forecasts, as shown by Hurricane Marilyn in the USVI. However, FEMA found the change inappropriate and confusing to the exercise and participants. In fact, unknown operations and deliberate inject of false information are useful in simulations to realistically reflect information inconsistencies occurring in actual events (Foster, 1980, p. 158). The introduction of false and spontaneous information should be re-evaluated for applicability of emergency function testing.

Other problem areas encountered during the exercise include shelter management, agency supply inventories, generator availability, cross-coordination with non-governmental entities, and landing sites for

air transport. Most of these issues could be resolved or could have solutions facilitated through agency cooperation and agreements prior to any functional simulation, perhaps exercised through organizational meetings and drills. Ultimately, HURREX '97 resulted in the illumination of specific, chronic problems for hazard management to address.

Testing new procedures

The simulation itself constituted a new procedure for the USVI, and given the complications and solutions during the exercise, the simulation proved to be a promising new tool for hazard management in the islands. Given the newness of simulation applications in the USVI, no new procedures for hazard management were tested within the game play. Future simulations should test changes in policy and procedure resulting from the experiences of HURREX '97 and the new leadership at VITEMA and the St. Thomas/St. John Red Cross.

Development of corrective actions

Whether or not feasible corrective actions are developed as a result of the simulation largely remains to be seen. A good deal of activity involving interagency coordination occurred shortly after the simulation and much of this activity was fueled by the experiences of HURREX '97. Specific actions included initiatives for community and business involvement, interagency meetings for formal coordination and cooperation agreements, proactive Red Cross involvement in agency coordination, and the reassessment of sheltering and supply facilities within the islands. The impacts of HURREX '97 have not been field tested as of this writing. This lack of field testing necessitates the continuation of simulated exercises to test and revise response policies and procedures.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Properly conducted and assessed, simulations such as HURREX '97 can be extremely beneficial to the USVI hazard management system. Given the chronic shortage of financial resources and the need to prepare for a variety of hazards over four distinct islands, simulations could provide the most effective method of critical analysis of hazard management in the USVI. Through simulations, officials will be exposed to necessary elements of insular management in a structured fashion, thus facilitating appropriate activity in their respective agencies. Communication between agencies will be improved through regular meetings and game play. Simulation activity can heighten public awareness of the hazard, contributing positively to public education. Strengths and weaknesses of policies and procedures may be identified by failure or success of the simulation, and corrective actions can be developed and tested in small, less costly drills.

Potential problems involved in simulation activities include the threat of complacency of officials in misinterpreting a successful exercise as an indication that the territory is prepared for an actual event, the augmentation of power struggles already present within the territory (struggles that often lead to counterproductive actions), and the exercise of ill-prepared simulations. It is possible that mistakes may be repeated in the absence of proper post-simulation assessment, thereby ingraining ineffective responses into the response system. These problems may be abated or prevented through use of two or more outside referees, whenever financially possible.

Recommendations

In order to maximize the benefits of simulations, the following recommendations, specific to the USVI are provided, based on the experience of HURREX '97. First, these simulations should become part and parcel of the regular agenda for hazard and disaster management of VITEMA. This is

necessary to continually improve upon policies and procedures and to keep new agency representatives current on hazard management and field operations.

Second, a variety of orientations, drills and tabletop exercises should occur to further agency operations to acceptable preparedness and response levels. Simulated exercises need to continue regularly, perhaps at the tabletop level, telescoping scale for optimal resource expenditure. The agencies of the Virgin Islands clearly need to begin with organizational meetings and drills, leading up to a simulation at time of year conducive to all possible participants and field play. FEMA's goal is to reduce jurisdictional dependence on Federal or other outside resources, and the USVI government and VITEMA should work toward this end as well, utilizing CEP and other FEMA resources.

Third, the business community and general population should be involved in the overall process, perhaps within the scope of activities such as drills, and most definitely with hazard education. The proportionality of impacts experienced from any individual storm can be significant, reaching deep into the community. Thus, all activities should ultimately involve the business community, social organizations and ideally, the general public for optimal preparedness. A great deal of work needs to be done to further hazard education at the individual and household level. Without this involvement, activities at the managerial level ultimately will be forced to use excessive resources and may result in failure.

Fourth, all exercises should simulate the experience of real life. The USVI has the advantage of assessing multiple recent events for real life variables, such as communications failures and resources shortages. USVI representatives should work with FEMA to ensure the reflection of actual disaster conditions. Contextual variables should be included to reduce the gap between emergent norms of action by the public and bureaucratic norms assumed by hazard managers and public officials.

Fifth, all efforts should be made to codify agency involvement. Given the frequency of hurricanes and tropical storms in the region and the occurrence of government elections, the agency rather than the individual should be paramount. Roles and responsibilities of each agency should be clearly

documented and assimilation of such information should be a mandatory responsibility of incoming elected representatives. It is also imperative to improve interagency communication, perhaps through formal mutual aid agreements.

Sixth, there needs to be concerted efforts to follow up simulations with corrective actions. Formal decisions must be based on simulation experiences. For example, if the simulation illuminates the need for additional generators for indispensable purposes, e.g. a clinic, steps should be taken to procure the machinery. A formal local debriefing and analysis needs to be conducted to give agencies a chance to assess and respond to the simulation. Without this feedback, interagency coordination for corrective actions will be problematic.

These are general recommendations for simulation application and efficacy in the USVI. Finer points of analysis would complement these broader assessments. These analyses are essential, as with continued vulnerability and rising costs of recovery it is imperative that significant preparedness efforts are employed in the USVI. Flexible, creative preparedness measures can contribute to reducing overall vulnerability, with a priority for preparedness measures that can be adjusted according to social, political, financial and natural climates. The experience of HURREX '97 demonstrates that hazard simulation is one technique that can be used to achieve these ends.

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