The Role of GIS in Emergency Management

by Ross Prizzia

Hawaii's use of geographic information systems (GIS) illustrates the potential use this technology has for assisting other localities with emergency management response and recovery efforts.

The primary government agency for disaster response in the State of Hawaii is the Oahu Civil Defense Agency (OCDA), a department in the City and County of Honolulu. The Mayor acts as the CEO of OCDA and has the power to declare a disaster. Disasters are county specific. Each county—Honolulu, Maui, Kauai, and Hawaii—determines what constitutes a disaster. For example, the island of Hawaii may have volcanic eruptions listed as natural disasters, whereas Honolulu would not. Disasters also can be localized to certain areas within a county and designated to the Local Emergency Planning Committee (LEPC), which is part of the City and County of Honolulu, as opposed to the State's Emergency Response Commission, which oversees the Hawaii State Civil Defense (HSCD) system.

The state's primary responsibility is to provide leadership in rapid assistance during a disaster, with a full range of resources and effective partnerships. All city departments follow the directives outlined in the City and County of Honolulu's Emergency Operations Plan (EOP). Once the EOP draft for a specific emergency is approved by the mayor and city council, all county departments and coordinating county agencies adopt and follow the plan. Most of Oahu's medical centers play a crucial role in disaster preparedness and response. In particular, Queen's Medical Center (QMC), with its 560 beds, is the largest and oldest hospital and main trauma center in Hawaii. QMC is instrumental in coordinating disaster response, and it plays an active role in Honolulu's Disaster Committee.

Coordination of Public and Private Sector Organizations

The OCDA facilitates public agency coordination through communication, training, procedures, and information within the City and County of Honolulu. In addition, OCDA coordinates disaster responsibilities among various private organizations and educates the public about emergency preparedness. It also has hundreds of volunteers. Interviews with OCDA personnel revealed that they are continuously reviewing, revising, and testing procedures outlined in the EOP. The administrator of OCDA works closely with the mayor and acts as an advisor for disaster preparedness and emergency management.

The Emergency Operations Center (EOC) is designed to facilitate agency coordination emergency response, including establishing operational policy, providing logistical and resource support, and facilitating communications.

Specifically, the EOC houses the communications system for the Emergency Broadcast System and provides a meeting place for the City and County of Honolulu's Disaster Committee. The EOC also houses the geographic information systems (GIS) and radio devices for federal, state, and county agencies, such as the emergency medical services (EMS), hospitals, police, fire, and utility companies.

Former Honolulu Mayor, Jeremy Harris, recognized the importance of Hawaii's reliance on GIS in a keynote speech stating that "Before GIS, we lacked the fundamentals for good decision making and good urban governance. And all that has changed with the invention of GIS. So we have it deployed in an enterprise wide operation of the city. Everything we do in the city takes advantage of GIS. Every decision that we make really affects every other decision... GIS gives us the opportunity to see our city; to understand it; and to understand how it works" (Frencica).

Ross Prizzia, *PhD, is professor of public administration at the University of Hawaii-West Oahu in Pearl City, Hawaii. He can be reached at rprizzia@hawaii.edu.*

GIS Application to Natural Hazards in Hawaii

GIS application to such natural hazards in Hawaii as volcanoes, earthquakes, tsunamis, hurricanes, and flooding varies in scope and effectiveness. GIS application to volcanoes has been primarily at Volcano National Park on the island of Hawaii and involves mapping rare and endangered plants and invertebrates in the park. These data are then overlaid with maps of vegetation, lava flows, and climate change to provide information on habitat requirements.

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Also, real time fire mapping using the global positioning system (GPS) from within a helicopter is downloaded into ArcView. This information is then overlaid with maps of fuels, rare plants, archeological sites, structures, and so forth to assist in developing fire suppression strategies.

Several forms of computerized models for volcanic eruptions and their associated hazards have been developed, but not often linked to interactive GIS systems that could assist in the prediction of or preparation for eruptions.

GIS application to earthquakes in Hawaii focuses on mapping and assessing damage data in the aftermath of a quake, as in the case of the October 2006 earthquake. Hawaii County was hit hardest by the initial 6.7 magnitude quake, followed by a second 6.0 quake and numerous aftershocks. Oahu experienced structural damage, as well as the loss of electricity for more than 24 hours in some areas.

The Pacific Disaster Center (PDC) assisted the HSCD in mapping the damage data from spreadsheets using ARCGIS, USGS, ArcScene, and other advanced technology. GIS and other available technology have had difficulty in creating effective models for predicting earthquakes.

GIS application to tsunamis in Hawaii involves coordination with the National Tsunami Hazard Mitigation Program of the National Oceanic and Atmospheric Administration (NOAA). This program is designed to reduce the damaging effects of tsunamis through hazard assessment, warning guidance, and mitigation.

The essential first step in assessing a tsunami hazard is to produce Tsunami Inundation Maps. The Center for Tsunami Inundation Mapping Efforts (TIME) within

the Pacific Marine Environmental Laboratory (PMEL) of NOAA was created to develop, maintain, and upgrade maps that identify areas of potential tsunami flooding. The PMEL maintains large databases related to the research and exploration of hydrothermal vent processes and applies GIS to integrating multidisciplinary data sets to create both a map gallery and an Internet site.

Hawaii, California, Oregon, Washington, and Alaska participate in the PMEL Tsunami Program that works to mitigate tsunami hazards by developing improved tsunami inundation maps, hazard assessment tools, and advanced technology to increase the speed and accuracy of tsunami forecasts and warnings. Tsunamis, like earthquakes, are difficult to predict, but their inundation zone along the coastline can be mapped and early warnings are possible.

GIS application to hurricanes in Hawaii includes the GIS-based Consequences Assessment Tool Set (CATS), developed by Science Applications International Corporation (SAIC), which enables Hawaii to coordinate with FEMA to predict the effect of impending disasters such as hurricanes, and quickly mobilize a well-coordinated and directed response. CATS provides the capability to pinpoint critical evacuation areas, as well as make accurate damage predictions for phenomena such as storm surge and wind damage that facilitates a quick recovery (Corbley, 1999).

GIS application to flooding involves the Hawaii Statewide GIS Program working with FEMA to scan and create Digital Flood Insurance Rate Maps (DFIRMS) and to collect digital flood data for the islands of Niihau, Kauai, Oahu, Maui, Molokai, and Hawaii. Flood zones can be mapped, and floods can be predicted with some degree of accuracy.

In 2009, the State of Hawaii began to implement a statewide emergency management system that integrates real-time information, satellite imagery, and other geospatial information into a comprehensive GIS. The system is managed by HSCD. The State of Hawaii and HSCD contracted with 21st Century Systems in August 2008 to develop this GIS-based EMS system.

GIS Coordination in Hawaii

The Hawaii Statewide GIS Program and the Office of Planning GIS Program lead a multi-agency effort to establish, promote, and coordinate the use of GIS technology among government agencies in the state. The State Office of Planning is responsible for planning and coordinating activities that are critical to the state's GIS. A primary goal of the Statewide GIS Program is to improve overall efficiency and effectiveness in government emergency management decision-making.

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Pacific Tsunami Warning Center

Supported by GIS located at disaster and research centers in Hawaii, advanced warning systems facilitate agency coordination in response to a wide range of natural hazards that threaten Hawaii and the Pacific region. The Pacific Tsunami Warning Center (PTWC), established in 1949 in Ewa Beach, Hawaii, provides advance warnings of likely tsunamis to most countries in the Pacific Basin. It is continually upgraded with the most sophisticated technology, including access to NASA's Earth Observing System (EOS) data.

The PTWC also plays a crucial role in agency coordination in disaster response in Hawaii and throughout the Pacific region. It was the first agency to provide prior warning of the devastating tsunami in South East Asia on December 26, 2004. The PTWC monitors a real-time reporting deep-ocean system that communicates with weather-resistance surface buoys that surround the Hawaiian Islands, and are sensitive enough to detect tsunami vibrations throughout the Pacific (EOSDIS, 2005).

Pacific Disaster Center

The PDC, located in Kihei on the island of Maui in Hawaii, assists the network of emergency managers in Hawaii and throughout the Pacific region to make informed decisions in times of crisis. The PDC's mission is to provide applied information research and analysis support for the development of more effective policies, institutions, programs, and information products for the disaster management and humanitarian assistance communities of the Asia Pacific region.

In 2003, the PDC developed an Integrated Decision Support System (IDSS) designed to allow humanitarian assistance and disaster management groups to log situational awareness, provide input to planning and analysis models, and gain access to tools, experts, data sources, and organizations in ways that were never before possible. A key component of this system is the Geospatial Collaboration and Awareness System (GeoCAS).

The GeoCAS system is based on a distributed data-sharing network. The GeoCAS component of IDSS enables crisis planners and decision makers to access a reliable and easy-to-use set of web-based tools that automatically map information about hazards (such as hurricane tracks and intensities), overlays the maps with possible impacts to critical facilities (such as roads and hospitals), and provides sharing of other hazard analyses (such as risk and vulnerability assessments, mitigation and preparedness, and planning information).

The collective efforts to forge a seamless, integrated homeland security system entail strategies that necessitate cooperation and coordination supported by GIS and other advanced technology.

In November 2005, the State of Hawaii was awarded a major grant for Pacific emergency preparedness that made GIS software available to the Hawaii school system, from K-12 through the college level. A similar initiative, Environmental and Spatial Technologies (EAST), which supported GIS projects in Hawaii, helped one Maui High School graduate to obtain an internship at the PDC.

Geo-Conferencing

In 2005, the PDC began using geo-conferencing, which allows multiple participants in various locations to collaborate in viewing and editing geospatial data that are useful to crisis managers, such as homeland security or disaster responders and teams of emergency specialists from multiple, disparate organizations who often need to share maps, GPS locations, and related data (Judd, 2005).

Also in 2005, the Research Corporation of the University of Hawaii (RCUH), in coordination with the PDC, HSCD, Pacific Command for U.S. Department of Defense (DOD), FEMA, and other disaster management organizations, developed the automatic production of cloud-free base images using full-resolution Landsat 7 data.

This advanced technology and Landsat 7 data enable users at remote sites to evaluate the quality and coverage of images using browse data prior to ordering the full resolution scenes. The images are generated on-demand using the most recent data available for the area, which extends over much of the Pacific and Indian Oceans. As a result, disaster managers can obtain an essentially cloud-free high resolution satellite image of their geographic area of concern.

U.S. Pacific Command

Improved GIS and other relevant technology in disaster prevention and management have been implemented successfully at the county, state, federal, regional (for example, Asia-Pacific), and international levels. These improvements facilitate and support inter- and intra-agency coordination in the management of man-made and natural hazards in the State of Hawaii.

The National Geospatial-Intelligence Agency (NGA) and NGA team supporting the U.S. Pacific Command (USPACOM or PACOM) is fully integrated with its partners. Most of the NGA employees are assigned to the PACOM NGA Support Team (NST). The demanding work of the NST varies widely and changes constantly.

The NST acts as the NGA director's single point of representation and contact to the combatant commander and subordinate unified and service component commands. In this role, the NST provides flexible, in-depth, and predictive regionally focused geospatial intelligence (GEOINT) analysis at PACOM Headquarters and the Joint Intelligence Operations Center (JIOC) in Hawaii, at U.S. Forces Korea in Seoul, at US Forces Japan outside Tokyo, and at other commands in the Pacific region.

Support to the Special Operations Command Pacific (SOCPAC) is provided by an NGA liaison in Hawaii who extensively trains Military Liaison Element (MLE) representatives before their deployment. Because this training is often the first exposure the MLE has to working with geospatial data, MLE personnel learn the basic functions of FalconView and ARCGIS to prepare them to do basic geospatial work while in the field.

The MLEs also learn how to order commercial imagery for cases when intelligence materials of operational value need to be shared with local military and police forces. In addition, the NGA SOCPAC liaison assists in planning preparedness exercises by contributing geospatial graphics and expertise, which help to create more realistic, life-like disaster scenarios.

The support the PACOM NST provides to mission partners from its base in Hawaii is critical because the Pacific region is home to several of the world's largest armed forces and has been the victim of 60 percent of the world's natural disasters over the past 30 years.

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Recommendations

Not all states or regions are equally challenged by the specter of natural or man-made disasters. Hawaii's isolated location in the middle of the Pacific and its heavy reliance on shipped goods and products make it especially vulnerable to acts of terrorism via air and sea, as well as natural hazards.

However, there are also advantages associated with Hawaii's geographic isolation, such as tighter control and access, a large military presence with a military commander in chief, and the four armed services and the United States Coast Guard (USCG) in close proximity, already accustomed to working with local, state, and federal agencies and officials. In addition, the spirit of "ohana," or family, helps people in Hawaii transcend normal bureaucratic and cultural barriers (Prizzia, 2008).

The threats to homeland security compel public and private sector agencies and organizations on the local, state and national levels to cooperate and coordinate human, physical, and technological, especially GIS, resources to efficiently and effectively protect the island State. Simply put, the collective efforts to forge a seamless, integrated homeland security system entail strategies that necessitate cooperation and coordination supported by GIS and other advanced technology.

In some ways, Hawaii can be considered a model for reasonably effective disaster preparedness and response. Hawaii's emergency management and intergovernmental agency coordination at the federal, state, county, and even community levels appear to be relatively effective in response to natural hazards such as tsunamis, hurricanes, earthquakes, and flooding.

The effectiveness of disaster response coordination is supported and enhanced by the PDC, PTWC, FEMA, and PACOM and includes advanced GIS technology and state-of-the-art warning systems at disaster centers and research facilities throughout the state.

Finally, efforts to establish, maintain, and strengthen coordination and cooperation and improved GIS and related training among emergency managers at the state, federal, county, and community levels before, during, and after disasters should be common practice. In spite of the extreme complexity of inter-organizational communication and the use of rapidly changing GIS technology to plan for and respond to disasters, I'm optimistic that Hawaii is meeting the challenge and that other jurisdictions and regions of the country can learn from Hawaii's example.

References

Corbley, Karl P. 1999. *Fleeing from Floyd: GIS in the Eye of the Storm*, Geo Info System. 9(10): 28 – 35.

EOSDIS. 2005. Synergy IV: Improving access to and application of EOA data, Final Report. Raytheon Company, Upper Marlboro, Maryland, July. http://edhsl.gsfc.nasa.gov/waisdata/complete/hold/803end002.pdf.

Frencica, Joseph. 2004. Exclusive Interview with Mayor Harris. *Directions Magazine*, August 20.

Judd, Damon D. 2005. Geocollaboration Using Peer-Peer GIS. *Directions Magazine*, May 08.

Prizzia, Ross. 2008. The Role of Coordination in Disaster Management. Chapter 5, Section I. Introduction, Theoretical Constructs, and Conceptual Foundations. *The Disaster Management Handbook*, ed. Jack Pinkowski. 76-98. Taylor and Francis Publishers.