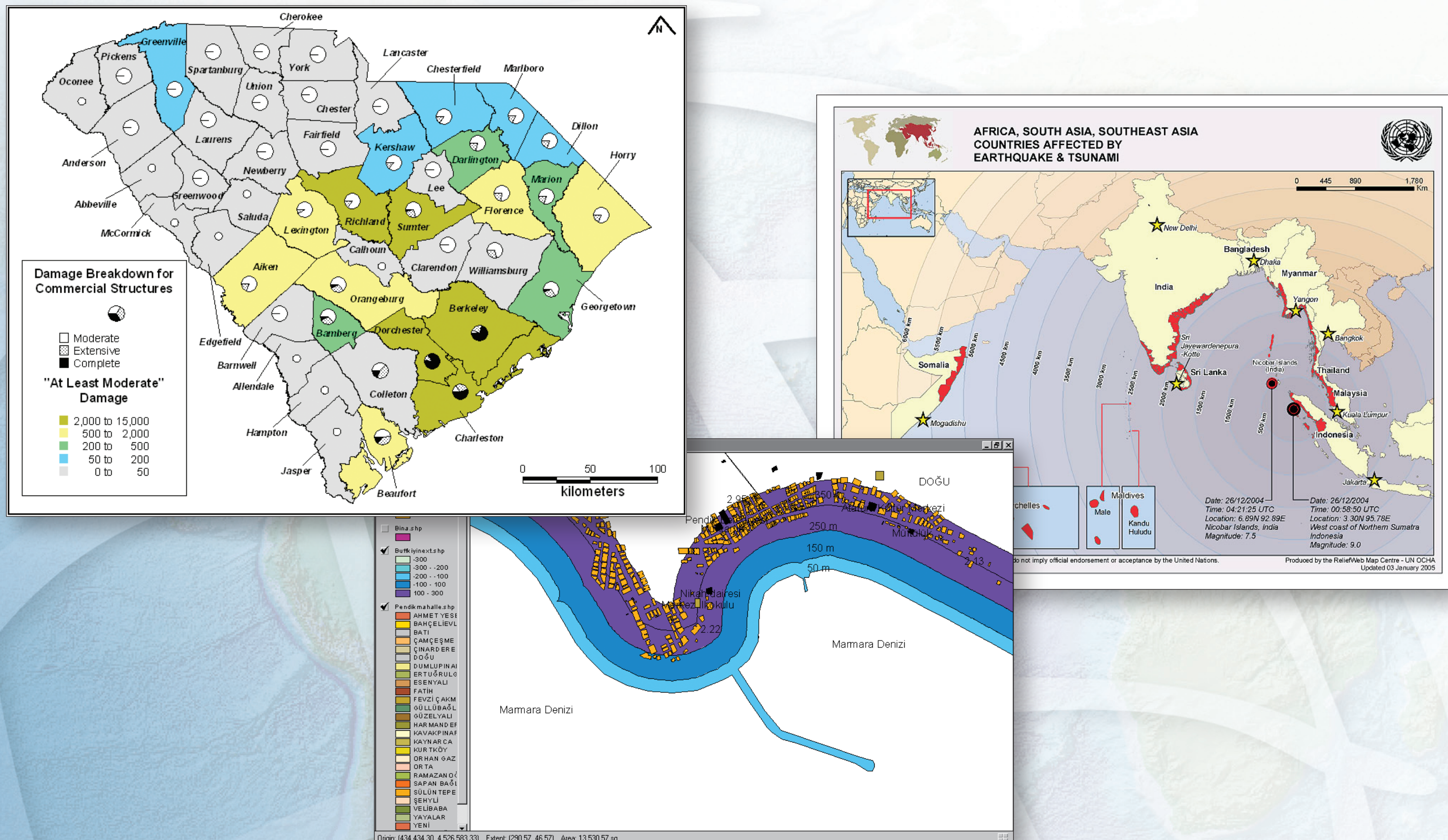
GIS Best Practices

GIS for Earthquakes



February 2007

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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

GIS for Earthquakes

Emergency management professionals are responsible for assessing risks and hazards and identifying potential emergencies and disasters. Emergency operations personnel recommend appropriate prevention or mitigation strategies that can reduce the impact of potential emergencies.

Large, complex emergencies such as earthquakes often affect multiple departments or multiple agencies and require data to be collected and assembled from a variety of locations quickly under adverse conditions. Part of the Emergency Operations Center (EOC) role is to understand the details of the emergency, order the required response resources, coordinate with adjoining agencies, and determine the immediate actions necessary to contain the incident.

Emergency personnel use GIS to help manage the impact of earthquakes and other disasters by

- Assessing risk and hazard locations in relation to populations, property, and natural resources
- Integrating data and enabling understanding of the scope of an emergency to manage an incident
- Recommending preventive and mitigating solutions
- Determining how and where scarce resources should be assigned
- Prioritizing search and rescue tasks
- Identifying staging area locations, operational branches and divisions, and other important incident management needs
- Assessing short- and long-term recovery operations

In Japan, Niigata Chuetsu Earthquake Damage Assessment Data Is Gathered More Efficiently Using GIS

GIS Portal Helps to Quickly Share Disaster Data

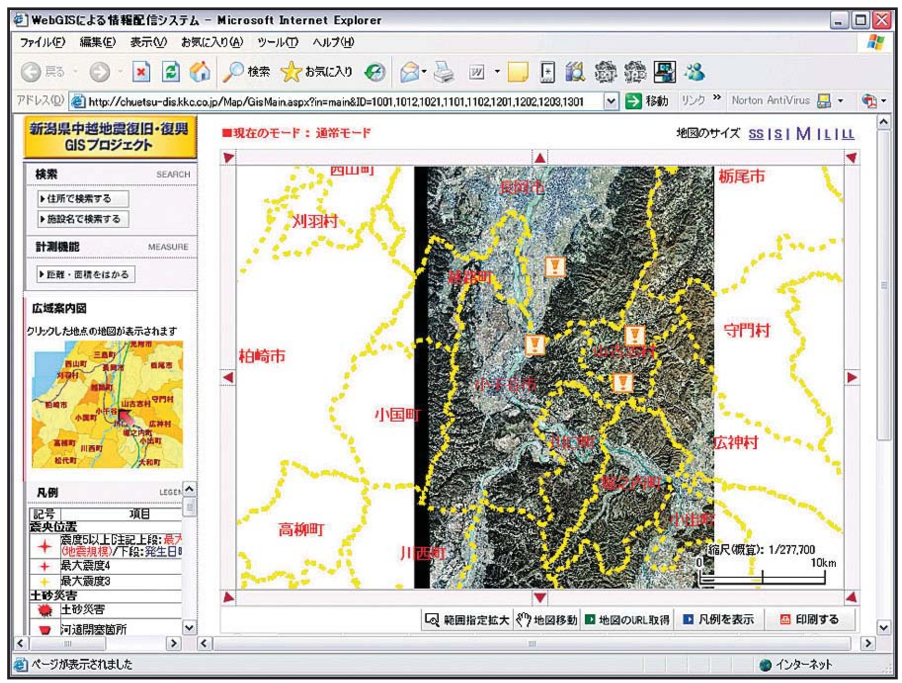
A powerful earthquake with a magnitude of 6.8 shook the Chuetsu region of Japan's Niigata prefecture on October 23, 2004. The Niigata Chuetsu earthquake, named after the location of the epicenter, became the largest disaster in terms of scale and impact since the 1995 Great Hanshin-Awaji (Kobe) earthquake. The earthquake caused large-scale destruction of properties in the region, particularly affecting older structures, and resulted in 46 deaths, 4,793 injuries, and the evacuation of more than 100,000 residents from their homes. Among the municipalities affected, the city of Ojiya (population: 41,461; households: 12,266) suffered the severest damage as it was closest to the epicenter.

The Niigata Chuetsu earthquake caused large-scale destruction.

Soon after the earthquake occurred, professor Haruo Hayashi from the Disaster Prevention Research Institute of Kyoto University and his research team helped develop three GIS applications that were important contributions to the disaster response. These applications were a GIS portal site for quickly sharing disaster-related GIS data, an efficient method of accessing and recording damage in the field throughout the city, and customized GIS systems to speed up the issuance of damage certificates.

GIS Portal Site

This GIS portal project had great significance because it gathered various organizations from the national, local, educational, and private domains together and built a framework in which geographic information could be shared in real time to support disaster response activities. The establishment of the project initiated a foundation that would be carried on and utilized in future disaster events.



More than 40 key organizations joined the project to build an Internet GIS site (chuetsu-gis.nagaoka-id.ac.jp) to provide valuable information and maps.

The goal was to build an Internet GIS site so organizations involved in postdisaster events, most of them scattered throughout the country, could readily upload and/or download GIS data. The team, along with ESRI Japan Corporation, developed the site (www.geographynetwork.ne.jp/disasters/explorer.jsp) based on the Japanese version of ESRI's Geography Network. Because of the adoption of the Geography Network framework, the team was able to build the site in less than 10 days and could easily start providing data many organizations were anxious to get.

Damage Assessment

Hayashi's research team had been in the city of Ojiya since the day after the earthquake occurred and was asked to help conduct damage assessments because the team had done extensive research in the past on structural damage assessment processes.

Evaluation results of the damage assessments were recorded on paper survey sheets, but to streamline the data entry process and increase data accuracy, ArcPad PDA applications were also developed following the same procedures used in the manual process.

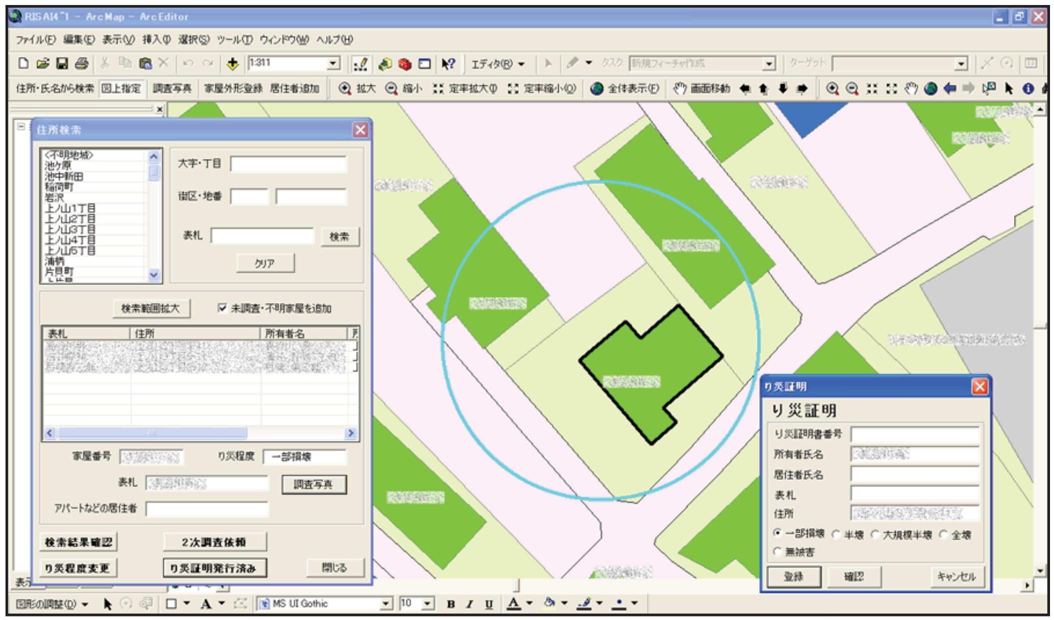
The following summarizes the benefits of utilizing ArcPad for damage assessment:

- The results are calculated automatically and entered on-site, avoiding errors associated with manual data entry (miscalculation, etc.). Also, the assessment results are properly linked to the corresponding buildings. One of the biggest issues the team had to resolve in developing the database for damage certificates was the large number of mismatches that occurred between the results and building polygons. This problem arose mainly because a parcel with a single address would often contain multiple buildings (house, garage, warehouse, workshop, etc.), and it was difficult to identify the correct building for the assessment once the survey was completed. However, once the team began using the ArcPad PDA solution, it didn't have such problems because the results were entered into the correct polygon at the time of the assessment.
- A great number of investigators were out-of-town volunteers and not familiar with the city. Furthermore, they often had to go to places where there were neither street signs nor nameplates. However, the PDAs with GPS devices attached allowed ArcPad to automatically zoom in to the point so the investigators knew exactly where they were.

Customized Applications for Issuing Damage Certificates to Victims

Damage certificates are issued to victims of a disaster to officially acknowledge their losses. These certificates determine eligibility for receiving various kinds of relief measures, such as distribution of relief money, tax exemptions, and a reduction on their national health insurance premiums, so it was important to process the assessment results as quickly and correctly as possible.

Early on, it was decided to digitize the assessment results from paper survey sheets into a database where the information could be managed and retrieved accurately and efficiently. Once the base datasets were prepared, the damage assessment results were linked to the building footprints of the Property Tax layer, and photographs of the damage were linked to the building polygons.



Customized applications for issuing damage certificates.

Once the database was built and ready to be deployed, several customized ArcGIS applications were developed to streamline the process of issuing damage certificates. The goal was to build a GIS database system that would improve the efficiency of the distribution process so that the city could issue as many damage certificates as possible while simultaneously providing satisfactory services to disaster victims.

The system meets the following goals:

- Develop the applications based on the specific needs of the damage so city personnel can perform their tasks effectively.
- Design a user interface that is as simple as possible so city personnel can access the necessary functions as quickly as possible (ArcObjects was used for customization), since most city personnel had never used GIS before.
- Make the system as simple as possible. The team was given less than one week to develop the whole system, so it was particularly important to make the development work uncomplicated. It was also important to make the system straightforward and trouble free so the tasks could be carried out successfully.
- It was essential to develop the system on a server/client configuration so the same information could be shared among everyone, and any edits that were made could be reflected in real time (ArcEditor, ArcSDE, and Oracle9*i* were used to support this).

The Property Tax Department started issuing damage certificates on November 21, 2004, and more than 3,200 certificates—which amounted to one-quarter of the households in the city of Ojiya—were issued during the first four days without any disruption. Most of the Property Tax Department personnel, as well as supporters from adjacent cities, had never used GIS before, but all of them were able to use the system with less than one-half hour of training and were completely comfortable in using GIS to process their work.

Conclusion

The GIS system certainly played an important role in producing damage certificates. Without it, the city of Ojiya could not have achieved as much as it did in such a short time. Damage certificates were issued for a full year, proving that the system is stable. The project indeed demonstrated the value of utilizing GIS technologies in emergency response and illustrated the importance of data integration.

For more information, visit Kyoto University's Web site (www.drs.dpri.kyoto-u.ac.jp/top.html)

(Reprinted from the Winter 2005/2006 issue of *ArcNews* magazine)

Urban Information Systems for Earthquake-Resistant Cities

By Ozge Yalciner, Gazi University, Ankara, Turkey

Current, accurate information assists decision makers in normal planning and monitoring tasks. For emergency planning and response, this type of dynamic information is even more important. The information gathered during the hours, days, months, and years following a disaster can lead to improved policies and practices that reduce risks and enhance the effectiveness of emergency planning, awareness, preparedness, and recovery.

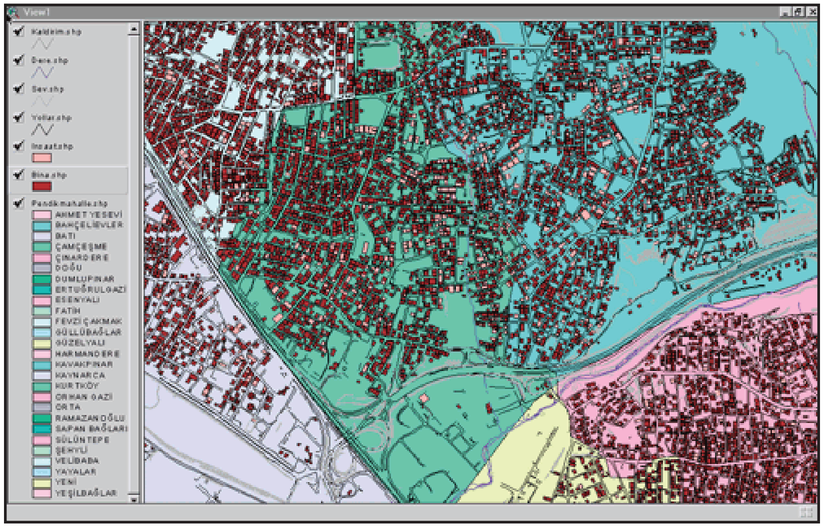
ArcView 3D Analyst was used to extrude buildings for a three-dimensional view of the pilot study area.

Earthquakes, one of the oldest enemies of mankind, can now be mapped and analyzed. GIS helps national, regional, and local emergency organizations plan and manage preparedness programs. Urban information systems, a subspecialty of GIS, are used to analyze the location of both populations and infrastructure. This article, describing an earthquake-preparedness study of a district in Istanbul, Turkey, illustrates how the effects of earthquakes can be minimized, emergency response planned, and an urban inventory created using GIS.

Pendik, an administrative district located in eastern Istanbul, has a population of 389,000 and stands at the gateway to Istanbul. Important highways pass through the district, and one of Istanbul's two airports is located there. As a result, many leading companies have located in Pendik. Its strategic location has caused rapid population growth. The resulting population pressure has contributed to the lack of planned development in the district.

GIS has proved a powerful tool for assessing the risk and prioritizing needs in Pendik. ArcView, versions 3.2 and 8.1, were used to produce detailed risk maps, perform queries, and generate analytical reports. After collecting the municipal data describing the district's land, residents, and infrastructure, digitizing and editing were done using ESRI products.

A database structure was created and table links and joins were created to make data kept in Microsoft Excel accessible to ArcView. Some of this data was also kept in Microsoft Access files and ArcView attribute tables.



Datasets for hospitals and health centers, schools, governmental buildings, police and fire stations, industrial buildings, and gas stations were created as separate themes.

After preparations were completed, thematic maps could be created for the Pendik Urban Inventory. Data for hospitals and health centers, schools, governmental buildings, police and fire stations, industrial buildings, and gas stations was created as separate themes. Geological maps and infrastructure maps were produced. Chart maps produced in ArcView were used to make comparisons between neighborhoods and identify areas where earthquake preparedness could be improved.

One neighborhood was selected for a pilot study. Using information gathered during a field study of this neighborhood, thematic maps were built by querying the database. Information on area housing, which included the occupancy type for the ground floor and other floors as well as number of stories, construction type, and the number of flats in the apartments, was shown in different views.

Mapping and spatial analysis have helped authorities make better decisions and formulate more effective policies for local emergency bureaus. Working with geographic data can answer questions such as "where is...?", "what intersects...?", and "what if...?" Analyzing the location of various structures in relation to hazardous conditions highlighted significant dangers. Querying the building theme to find all buildings located on earthquake faults identified 255 such buildings. Many residential buildings and industrial plants are located on alluvial ground. [Loose soils amplify and prolong shaking.] Thirteen schools are located on unstable land. Potentially explosive natural gas main pipes and tanks as well as 56 companies that produce hazardous materials and 76 gas stations are located on unstable land. Several unauthorized buildings are located under high voltage power lines.

GIS was also used for other emergency preparedness activities.

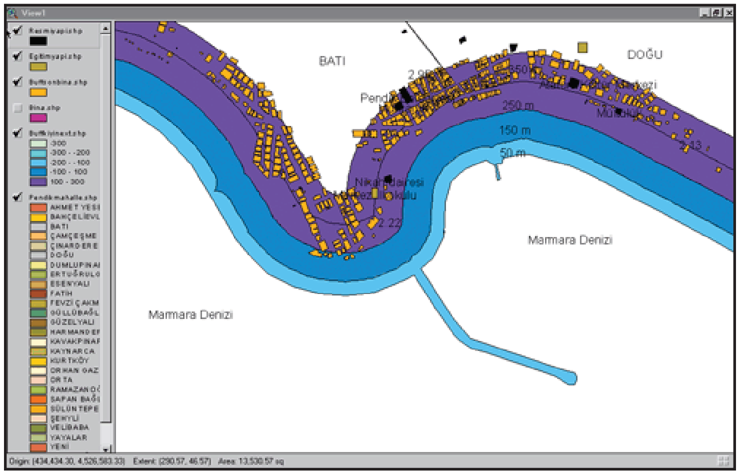
- Experience has shown that an earthquake's death toll can be multiplied by follow-on disasters such as tsunamis and fires. To predict the damage that might result from a tsunami, a buffer analysis was made along the coast initially using a 50-meter buffer and then creating additional 100-meter buffers farther inland.
- Service area analyses of hospitals and fire stations identified routes that provided the quickest response.
- "What-if" scenarios were used to predict the effect of road and highway closures. Using ArcView Network Analyst, alternate routes were generated.
- ArcView 3D Analyst was used to extrude buildings for a three-dimensional view of the pilot study area. Buildings with more than five stories, buildings situated on alluvial land, and wooden and masonry buildings are most vulnerable to earthquakes. These structures were

located by query and mapped. Buildings with mixed commercial and residential use (i.e., commercial facility on ground floor with many flats on the upper floors) are at greater risk for floor collapse and evacuation problems.

- Strategic databases, such as a pharmacy database for medical supplies, were created.

Conclusion

Urban information systems help automate analysis, share information, and encourage teamwork. By visually displaying information, GIS enhances risk evaluation and performs analyses that would not otherwise be possible. Real-time information updates in GIS support better decision making and improve earthquake management. Creating an urban inventory, thematic maps, and queries also helped identify Pendik's most vulnerable areas and "what-if" scenarios helped in planning mitigation measures such as retrofitting and relocation. ESRI products have helped develop new applications to support emergency preparedness. GIS technology manages vast quantities of information quickly in an emergency and helps authorities formulate strategies that mitigate the effects of future earthquakes.



Follow-on disasters such as tsunamis can multiply the damage from earthquakes. To predict the damage that might result from a tsunami, a buffer analysis was made along the coast initially using a 50-meter buffer and then creating additional 100-meter buffers farther inland.

(Reprinted from the July–September 2002 issue of *ArcUser* magazine)

South Carolina Devises Earthquake Preparedness Plan With GIS

U.S. Federal Emergency Management Agency Lends a Hand With HAZUS

By Kevin P. Corbley

One hundred seventeen years ago, on August 31, 1886, one of the strongest earthquakes to strike the continental United States in recorded history hit Charleston, South Carolina. The 7.3-magnitude quake and subsequent fires killed 60 people and significantly damaged every building in what was then a city of only 49,000 people.

Damage from the 1886 Charleston earthquake.

In the past century, Charleston and its surroundings have grown considerably, and a major earthquake today could prove devastating to the half million people who live and work there. As can be expected, however, with very little seismic activity occurring in South Carolina in recent memory, earthquakes are no longer on the minds of average citizens.

But the South Carolina Emergency Management Division (SCEMD) hasn't forgotten 1886, and it is prepared for another quake just as strong.

Planning for and responding to disasters of any kind fall under the purview of the SCEMD. An arm of the state adjutant general based in Columbia, SCEMD develops and continually fine-tunes procedures for disaster mitigation, preparedness, response, and recovery with the objective of saving lives, reducing suffering, and minimizing property loss.

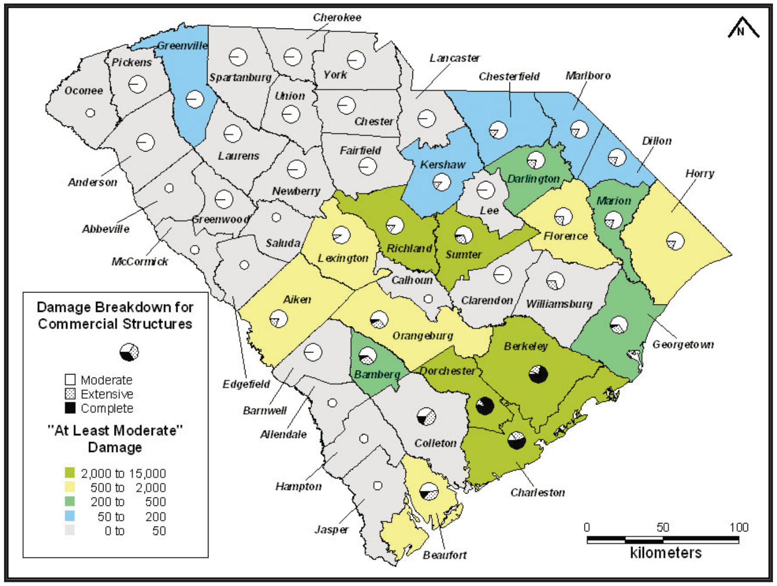
In 2000, SCEMD revamped its hurricane evacuation procedures and emergency shelter assignments to accommodate shifting demographics within the state. With so many real-life storm experiences to draw upon, SCEMD was readily able to predict where emergency resources would be needed under a variety of hurricane intensity and landfall location scenarios.

"We felt ready to manage a hurricane, but we asked ourselves, 'What would our emergency needs be if an earthquake struck?'" says John Knight, risk assessment coordinator for SCEMD. "Given South Carolina's history, this question required serious answers."

Other than seismic records from a century ago, South Carolina had little information on how a major quake would impact the state. Questions were posed such as "What buildings will be damaged?" and "How will transportation and utility infrastructure be affected?" Without these answers, SCEMD found it difficult to select evacuation routes, stockpile emergency supplies, and designate relief shelters in preparation for a major seismic event that could strike anywhere in the state with no warning.

Why HAZUS?

To answer its earthquake questions, South Carolina looked to the U.S. Federal Emergency Management Agency (FEMA) in Washington, D.C. In 1997, FEMA released Hazards U.S. (HAZUS), a GIS-based software program that estimates and maps the regional damage and losses resulting from an earthquake of a given location and intensity. The results support planning for natural hazards mitigation and response by state, regional, and local governments.



HAZUS estimates the degree and geographic extent of earthquake building damage across the state based on inputs of building use, type, and construction materials.

GIS is the ideal environment for earthquake loss modeling because it has the ability to analyze spatially distributed data such as demographics, the built environment, and infrastructure with a vast number of different attributes including quake magnitude, geological conditions, and structure type. Spatial analysis is essential to the mathematical and empirical vulnerability models of HAZUS, which require substantial processing power for the analysis of spatially distributed information. The first release of HAZUS was built on the ArcView 3.x platform.

HAZUS-MH

For the development of HAZUS Multi-Hazard (HAZUS-MH), an enhanced version that will be released in February 2003 with flood and wind models added, FEMA chose the ArcGIS platform. FEMA opted to use ArcGIS for the new version because the state-of-the-art Component Object

Model (COM) technology provides a framework that allows HAZUS users to build upon the basic software, if they desire, by integrating additional applications from a variety of vendors.

In addition, the ArcGIS Spatial Analyst extension provides the multidimensional analysis capabilities essential for the new software to model flood behavior and estimate flood losses in the built environment. ArcGIS Spatial Analyst enables users to conduct cell-based GIS operations on data sets to determine the depth and extent of floodwaters at specific points within a hazard study area.

Sobering Results

Knowing that an earthquake could strike anywhere in the state, South Carolina has simulated numerous size/location quake scenarios with HAZUS. SCEMD's Knight typically runs scenarios on his desktop computer, a Pentium IV with 512 megabytes of RAM operating on Windows 2000 Professional.

With SCEMD selecting earthquake size and epicenter location, the software provides results geographically on a map as well as in tabular lists and text descriptions. Results include estimates of

- Number of buildings damaged
- Number of casualties
- Degree of damage to transportation
- Disruption of power and water
- Number of people displaced from homes
- Cost to repair damage

The scenario that has been refined and studied most closely by SCEMD is a repeat of the 1886 Charleston earthquake.

"The results are sobering," says Knight. "It became clear we must devise substantially different mitigation, response, and recovery plans for an earthquake than for a hurricane."

If Charleston were struck by a 7.3-magnitude seismic event today, the software estimates that at least 800 bridges would be rendered impassable and 250 fires would be ignited. More than 300,000 households would be without power while 80 percent of residences would have no water service. Losses could be as high as $20 billion with 75 percent of the damage localized in Charleston, Berkeley, and Dorchester counties.

Based on inputs of recent data on area building uses, occupancy classes, and construction type, the analysts estimated 69,000 homes would be uninhabitable, 30 of 108 hospitals would be too damaged to operate, and more than 25 percent of schools and 34 percent of fire stations would be closed by damage. Unreinforced masonry buildings would be hit hardest.

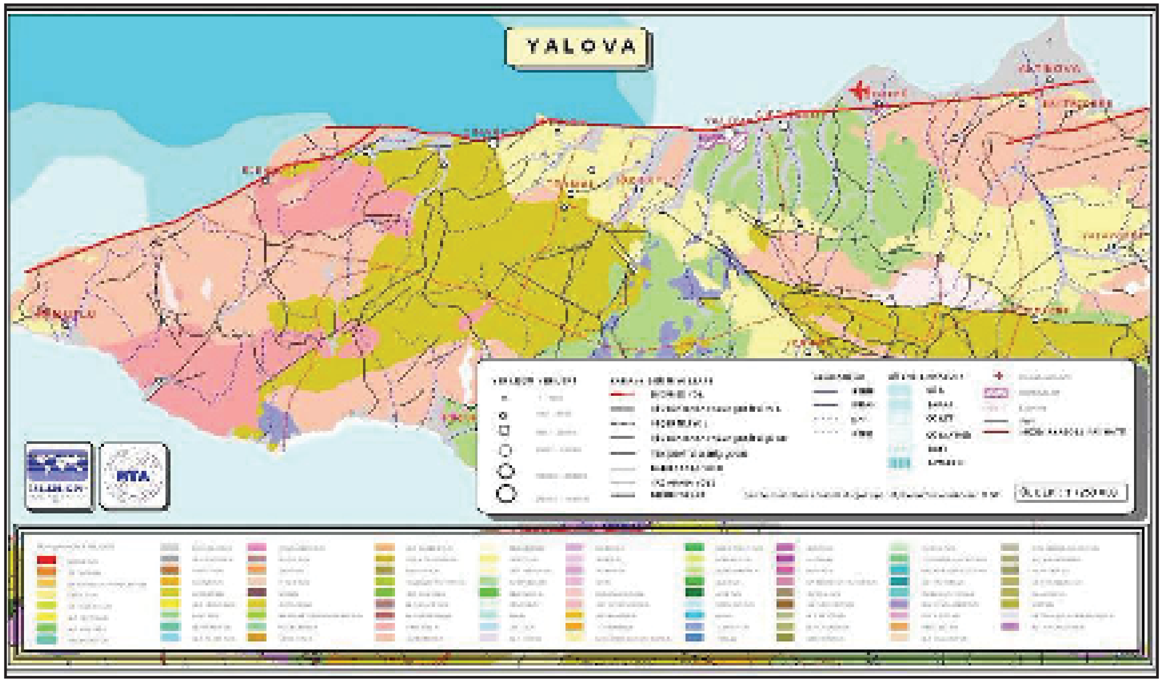
"We obtained an excellent overview of impact to the community as well as estimates of localized damage," says Knight.

SCEMD has used these results to create a mitigation, preparedness, and response plan specific to earthquakes. This new earthquake plan is 95 percent complete and is being distributed to emergency personnel statewide along with maps generated by the GIS program showing evacuation routes over highways and bridges least likely to have sustained damage.

(Reprinted from the Winter 2002/2003 issue of *ArcNews* magazine)

Turkish Government Bases National Emergency Response System on GIS

August 17, 1999, will forever remain etched in the minds of the Turkish people. That day, a 7.4 earthquake struck western Turkey, leaving more than 17,000 dead, 44,000 injured, and 320,000 homes and businesses lost. More than 300,000 people became instantly homeless from a disaster that caused more than $3 billion in damage.



Geological map of Yalova Province prepared from the Geological Data Base of General Directorate of Mineral Research and Exploration.

This catastrophic event was surpassed only once in the 100 years that Turkey has been recording earthquake data. On December 27, 1939, a 7.9 quake struck, killing nearly 33,000 people and damaging 117,000 buildings.

These are not, however, isolated incidents. According to Turkish seismic records, 66 major earthquakes (5.5 or greater on the Richter scale) have struck Turkey during the past 100 years, almost half of which were 6.5 or greater. Scientists who study the causes of earthquakes say that there are so many deadly temblors in this region because it is located at a point, known as the Anatolia fault, where several of the earth's tectonic plates meet.

In addition to the ever-present danger of living in a high-risk earthquake zone, Turks are also vulnerable to other common natural and man-made disasters such as fire, flood, and terrorism.

To develop an integrated response to potential national disasters, the Republic of Turkey tasked its Ministry of Environment, a longtime user of GIS technology, with developing a national emergency response center, designated as the Emergency Center Project (ECP).

The ministry turned to Islem Geographic Information System & Engineering Ltd. (Islem GIS), ESRI's software distributor and GIS integrator in Turkey, for technical help with the project. It was decided to initially implement a pilot project in the Kocaeli and Yalova Provinces.

According to Yalcin Akkas, head of the Section of Industrial Accidents Control, Ministry of Environment and Forestry, ECP was developed to "analyze the effects of accidents and natural disasters on Turkey's strategic commercial and industrial installations."

After extensive study, GIS-based environmental predictive models were integrated into the ECP system to provide the necessary analytic capabilities.

The data for the database was processed using the ArcView Image Analysis extension (a collaborative effort between ERDAS and ESRI), and ArcInfo, ArcView, ArcView 3D Analyst, ArcView Spatial Analyst, and ERDAS IMAGINE.

The team chose two models to incorporate into ECP. One is the Areal Locations of Hazardous Atmospheres (ALOHA) that was developed by Environmental Software and Services of Gumpoldskirchen, Austria. ALOHA is an environmental model used to simulate the dispersion of specific chemicals in the atmosphere. The other model, Risk Management Plan (RMP–HazMat) from the U.S. Environmental Protection Agency, creates dispersion models for land- and water-based spills. These models, which require atmospheric and geographic data input, can predict with great accuracy the affected areas in the event of a large industrial accident.

To test and refine the models, environmental studies were conducted on two factories that were severely damaged in the August 1999 earthquake. The team prepared accident reports, environmental pollution assessments, and mitigation studies on AKSA, a synthetic fiber and textile factory, and Tupras, a petroleum refinery, and analyzed them in detail to generate model parameters.

In addition, a wide variety of data was processed to generate the geospatial database necessary for ECP. The data includes soil and land capability maps (1:100,000 scale), topographic maps (1:25,000 scale), Landsat TM images, SPOT PAN images, aerial photography, and a digital elevation model. Also included was information from Turkey's Industrial Site Establishment Information Questionnaire, which details production and consumption amounts, the location of hazardous materials on-site, NACE Codes (a pan-European classification system), CASNOs (lists in descending order of concentration) of chemical agents, and an industrial site location map at a scale of 1:25,000.

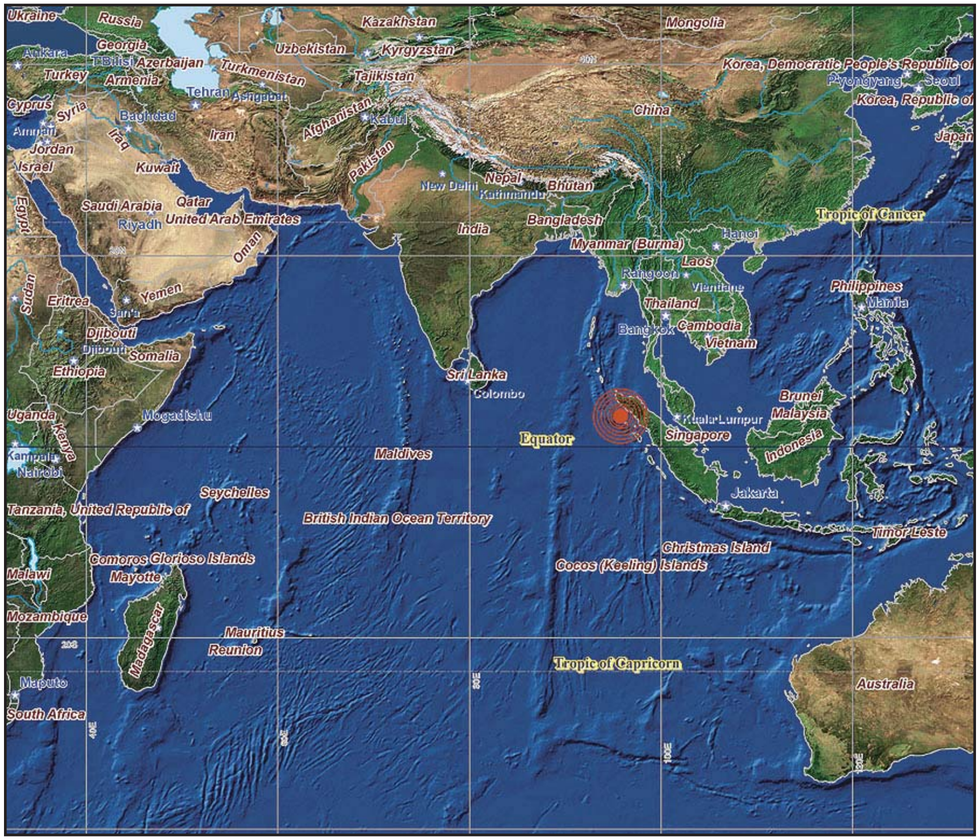
Concludes Akkas, "Phase one of the Emergency Center Project is now complete. In the next phase, we will set up an ArcSDE server to manage the data with ArcIMS to allow the distribution of our National Environmentally Hazardous Industries database via the Web, which will allow our emergency response agencies to react more quickly in times of disaster."

(Reprinted from the Summer 2004 issue of *ArcNews* magazine)

GIS Supports Indian Ocean Tsunami Disaster Relief

Assessment and Coordination of a Complex Emergency

The devastating Indian Ocean earthquake and tsunami resulted in one of the world's most damaging and complex natural disasters in recent history. Estimates of nearly 300,000 casualties; 143,000 missing; nearly a dozen countries affected; and billions of dollars in international aid provide just a glimpse into the enormous impact of the terrible catastrophe. Entire cities and regions were destroyed, and landscapes and shorelines were changed forever.



Epicenter of magnitude 9.0 Indian Ocean earthquake occurring on December 26, 2004
(Credits: WorldSat International, Inc., and ESRI Data & Maps *CD 2002).*

In the immediate aftermath, countless international organizations, relief organizations, and nations around the world responded, offering monetary donations, supplies, personnel, equipment, services, and much more. GIS played a pivotal role in the response activities for many of these organizations. The United Nations and U.S. government agencies that traditionally focus on international humanitarian emergencies were initially challenged to estimate the scope and extent of the disaster. From the beginning, GIS technology played a critical role in guiding emergency responders to affected areas and, once there, mapping the enormous impact of the event to coordinate the relief effort.

The United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) was tasked with not only providing on-the-ground support and guidance for relief workers but also globally disseminating information on the event for the international community. UNOCHA established two Humanitarian Information Center (HIC) offices, one in Sri Lanka and the other in Sumatra. Each office made extensive use of GIS in the production of maps for humanitarian workers, such as maps of injured populations, damage assessments, and internally displaced persons.

Among the most valuable products that HIC produces is the "Who Is Doing What Where" maps and database. These products are invaluable in communicating to relief workers which organizations are already addressing problems in a given area and where help is potentially still needed. More information on active Humanitarian Information Centers around the world can be obtained at humanitarianinfo.org. To promote the dissemination of information on global humanitarian events, UNOCHA maintains the ReliefWeb site (www.reliefweb.int). ReliefWeb is the world's most visited humanitarian information portal with more than one million hits a day. The ReliefWeb Map Centre is a repository of published maps on humanitarian events around the world. In addition to situation maps produced by UNOCHA, the Map Centre includes products from a diverse array of international sources.

Another entity that has used GIS extensively in tsunami response activities is the United Nations Joint Logistics Center (UNJLC). UNJLC is an interagency facility whose mandate is to coordinate and optimize the logistics capabilities of humanitarian organizations during large-scale emergencies. UNJLC employed GIS to produce a detailed atlas of the damage to the transportation infrastructure of northern Sumatra; the atlas identified 178 damaged or destroyed bridges. With support from technical staff from the Vietnam Veterans of America Foundation, UNJLC used spatial analysis to determine that 41 of the identified bridges should be considered a priority in the redevelopment effort.

Other United Nations agencies that used GIS technology in their response to the Indian Ocean tsunami disaster include the Food and Agriculture Organization of the United Nations, the United Nations Children's Fund (UNICEF), the United Nations High Commissioner for Refugees, the United Nations World Food Programme, UNOSAT, the World Health Organization (WHO), and others.

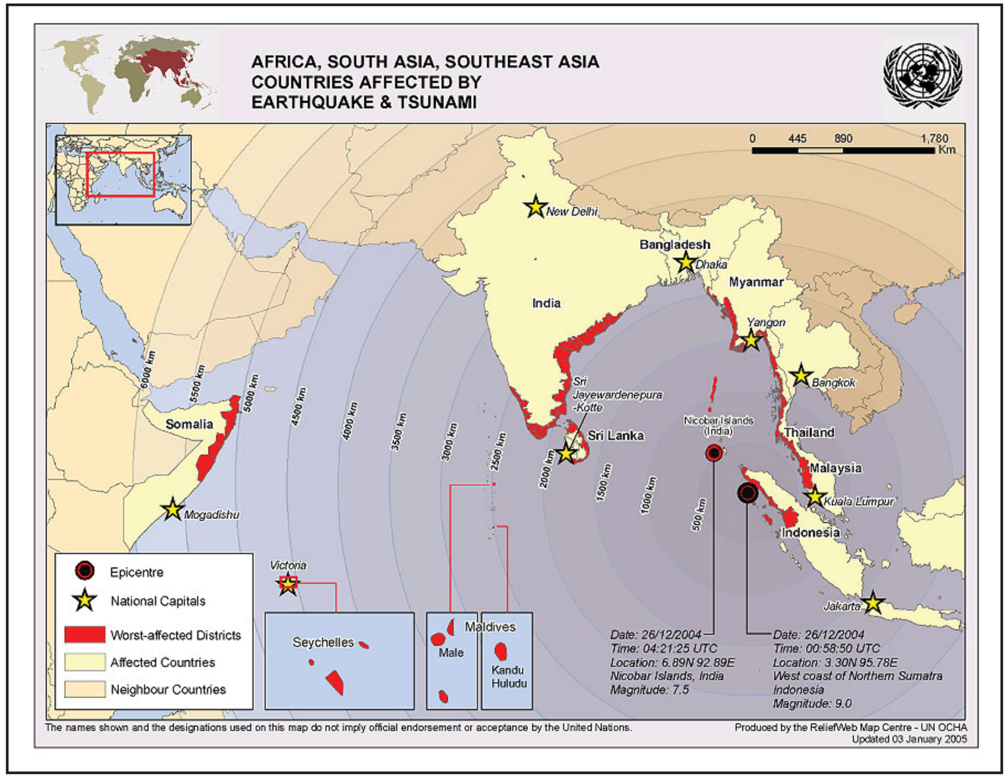
U.S. government agencies played an enormous role in the response to the Indian Ocean tsunami disaster. The National Oceanic and Atmospheric Administration was one of the first to publish detailed animations of the tsunami that swept across the Indian Ocean. This and other products allowed responders to quickly realize the enormity of the event. In addition to deploying disaster assistance response teams to affected countries immediately following the event, the U.S. Agency for International Development (USAID) used GIS to produce maps of affected countries and related U.S. government programs in the area. The U.S. Department of State Humanitarian Information Unit, an interagency working group, used GIS to estimate the inundated areas of the tsunami as well as produce common operating picture maps that include economic impact, infrastructure damage, and U.S. government assistance. The U.S. Geological Survey disseminated a wide array of GIS products related to the tsunami via *The National Map*'s Hazard's Data Distribution System (gisdata.usgs.gov/website/tsunami/). Many other U.S. government agencies played an active role in the tsunami response, including the Federal Emergency Management Agency and the U.S. Pacific Command's Joint Task Force/Civil-Military Operations Center.

Unlike many previous international humanitarian emergencies, existing GIS infrastructure was able to rapidly meet the demands of the disaster response. One such example is the Pacific Disaster Center (PDC) whose existing GIS capacity was able to rapidly support the dissemination of valuable data, products, and imagery to the global response community. The PDC's mission is to provide research and analysis for the development of more effective disaster management and humanitarian assistance in the Asia Pacific region. In the wake of the tsunami disaster, PDC immediately embarked on several GIS-related activities, including the deployment of an ArcIMS software-based Map Viewer and its underlying service: the South East Asia and Indian Ocean Tsunami Response Map Viewer. The Map Viewer is designed to serve site visitors and GIS users and displays Landsat imagery, Shuttle Radar Topography, mission-derived shaded relief images, LANDSCAN-derived population density, detailed coastlines, damage polygons, and high-resolution imagery received from the U.S. government's Commercial Satellite Imagery Library. PDC also launched the Indian Ocean

Tsunami Response Geospatial Information Service, an ArcIMS map service, supporting the GIS needs of emergency managers by providing direct access to data in the Map Viewer via ArcInfo software's ArcMap application, as well as convenient downloadable data to support field applications. This service is part of the PDC-hosted Asia Pacific Natural Hazards Information Network (apnhin.pdc.org). Although PDC has been a long-time user of ArcSDE, ArcIMS, ArcInfo, and other ArcGIS software, ESRI sent technical staff to provide on-site assistance to help PDC ensure high availability of these critical information services in light of the extremely high traffic that they generated.

Another example of existing GIS infrastructure that played a supporting role in the disaster response was the Geospatial One-Stop. A dedicated channel for the disaster was created on geodata.gov to catalog data sources, map products, and dynamic mapping services related to the tsunami. The geodata.gov Map Viewer allows users to integrate diverse ArcIMS and Web Map Server mapping services into a dynamic browser and produce maps that can be saved or shared with others. The architecture of the Geospatial One-Stop was well suited to information about nonspatial resources, as well as such volunteer organizations, local GIS firms, international organizations, and commercial companies that were interested in providing support.

As in countless previous humanitarian emergencies, the nongovernmental organizations (NGOs) played an enormous role in responding to the tsunami disaster. One such NGO is MapAction, a United Kingdom-based international charity that specializes in applying GIS to mapping of disaster areas and supplying GIS products and information to support humanitarian relief operations. MapAction worked actively to map the damaged areas in Sri Lanka in support of the Sri Lankan government. Some of the valuable products that MapAction provided to the Sri Lankan government included maps of land mine hazards, damaged bridges, damaged schools, and camp locations of internally displaced persons.



Map courtesy of ReliefWeb Map Center, United Nations Office for the Coordination of Humanitarian Affairs. The names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

In support of its users around the globe, ESRI and many of its international distributors quickly mobilized to provide support to international organizations, governments, and individuals responding to this complex emergency. One such distributor was ESRI (Thailand) Co. Ltd. whose volunteers conducted damage assessments and assisted in the search for casualties. Using ArcGIS, the volunteers produced an atlas of the affected area—which included a one-kilometer reference grid—that allowed search and rescue personnel to effectively survey the damaged area. The survey team's observations were integrated into a daily situation map that was distributed to diverse organizations, such as the Rural Highway Department, the Telephone Organization of Thailand, local governments, and other volunteers. In addition, ESRI (Thailand) employed video mapping technology, which coupled video shot from vans and helicopters with GPS data. Video mapping technology helped the response team rapidly estimate damaged areas over a large spatial extent. Another volunteer team from ESRI (Thailand) assisted the Ministry of Natural Resources and Environment in the development of an ArcIMS service used to publish the geospatial data of the damage area in the southern part of Thailand. GIS data in the map service includes imagery, damaged areas, disaster operation centers, and recommended routes to affected areas and uses ArcData Thairoad as the basemap. The Web mapping application also provided an input mechanism for submitting information on the location of victims of the tsunami disaster.

Many other ESRI distributors in the affected areas contributed to the tsunami disaster response, including EMSO Limited (Sri Lanka), ESRI Australia Pty. Ltd., ESRI South Asia, and NIIT-GIS Ltd. (ESRI India). ESRI distributors who were not in the affected area, such as ESRI Geoinformatik AG (Switzerland), ESRI Italia, ESRI Sweden, and ESRI (UK) Ltd., became active in the response by supporting relief agencies in their regions.

GIS professionals are increasingly making themselves available to support international development and humanitarian programs through volunteer organizations. The Urban and Regional Information Systems Association GISCorps was founded to coordinate short-term, volunteer-based GIS professional services for international programs. GISCorps (www.giscorps.org) was founded in 2003 as a not-for-profit volunteer organization aimed at matching interested and qualified GIS professionals with programs in need around the world. In response to the tsunami disaster, GISCorps provided volunteers and remote support to a variety of programs including Global MapAid, MapAction, Map Relief, Sustainable Environment and Ecological Development (India), and Vietnam Veterans of America Foundation.

Within hours of the devastating Indian Ocean earthquake and tsunami, ESRI began directly supporting many United Nations organizations, government agencies, and disaster responders with GIS software; mapping; GIS professional services; data collection, management, and dissemination; and industry expertise. "This was one of the largest disasters in history," says Russ Johnson, ESRI's public safety industry manager, "and one of the immediate needs we recognized was the ability to identify what data was needed, where it was located, and which data needed to be built instantly. Getting the right data to the right people in the easiest, most efficient manner became a paramount concern. Mapping is important during the response and recovery stage of a disaster. It is critical in positioning facilities and services, determining a triage method to repair infrastructure, and determining loss in order to begin work on recovery.

ESRI and many of our business partners, including EarthSat, IBM, and Trimble, were ready to help with these efforts."

Recovering from the tsunami disaster and returning the affected communities to their preevent condition will likely take decades. As the acute humanitarian risks are mediated, the long-term challenges of sustainable development, repatriation, relocation, and sanitation will need to be addressed. "Development activities will take place for months and years," says Johnson, "and GIS has a role to play here. Information will provide government officials and others with the support they need for addressing a myriad of concerns. The reconstruction, economic, and social factors involved all have a time and space component. GIS provides an invaluable framework for building an information base and providing the best decision support, communication, and collaboration possible."

In addition to the long-term mitigation strategies, preplanning for future events is also underway. Discussions are taking place to evaluate and learn from current activities and to develop new processes and methods for rapid response for future emergencies of this scale. This involves identifying in detail how technology supported rescue, recovery, and rehabilitation; understanding where these implementations occurred; and describing how GIS technology can assist in preventing loss of life and property in future catastrophes. "There is a lot we can learn to be more prepared in the future," adds Johnson.

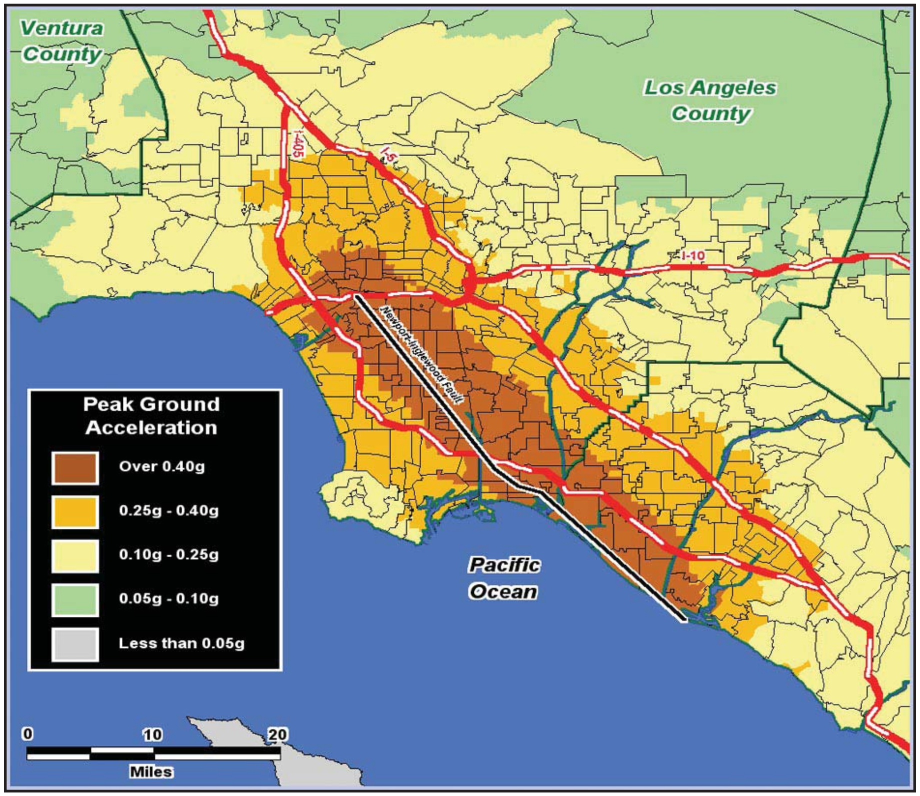
Adversity can bring out the best in the human spirit as was demonstrated by the outpouring of support from around the world following the tsunami disaster. It should be duly noted that countless individuals and organizations put tremendous effort into responding to the disaster; clearly it was only possible to mention a fraction of them in this article. "GIS professionals really responded to the call and made a difference in the immediate, short-term, and long-term rescue and recovery efforts," says Jack Dangermond, president of ESRI. "There were so many vital contributions; there's just not enough that can be said about the nations, agencies, volunteers, and others who helped when needed. In the aftermath of this disaster, organizations are looking at long-term spatial technology strategies that will aid in preevent planning and postevent rescue and recovery efforts for years to come."

(Reprinted from the Spring 2005 issue of *ArcNews* magazine)

FEMA and Local Governments Battle Hazards With a New GIS Tool

HAZUS-MH Standard for Multihazard Risk Assessment on the National Stage

Nationwide, the recognition of hazard vulnerability is growing. As a result, planners are reevaluating their communities' exposure to risks and considering proactive hazard mitigation measures. Such planning was given a boost in October 2000 when the Disaster Mitigation Act (DMA) was signed into law.



Showing ground acceleration relative to the Newport–Inglewood Fault.

DMA 2000 encourages and rewards predisaster planning, calling for increased coordination between state and local governments. Interim final regulations published in February 2002 require communities to complete mitigation plans in order to receive hazard mitigation funds.

Often the greatest challenge in developing such plans is their scope. Reaching an understanding of how to prepare for, mitigate, respond to, and recover from hazards is a complicated journey. And as all aspects of hazard planning are interrelated, data compilation, evaluation, maintenance, and standardization create an imposing hurdle.

Comprehensive community planning relies on understanding risks to the physical, social, and economic components of a community. Only communities that understand their vulnerability to natural hazards can make informed decisions.

The Federal Emergency Management Agency (FEMA) latest risk assessment and loss estimation software package, HAZUS-MH (Multi-Hazard), can help answer complex hazard planning questions. By using their existing GIS in conjunction with HAZUS-MH tools, planners can integrate and analyze earthquake, hurricane wind, and flood information.

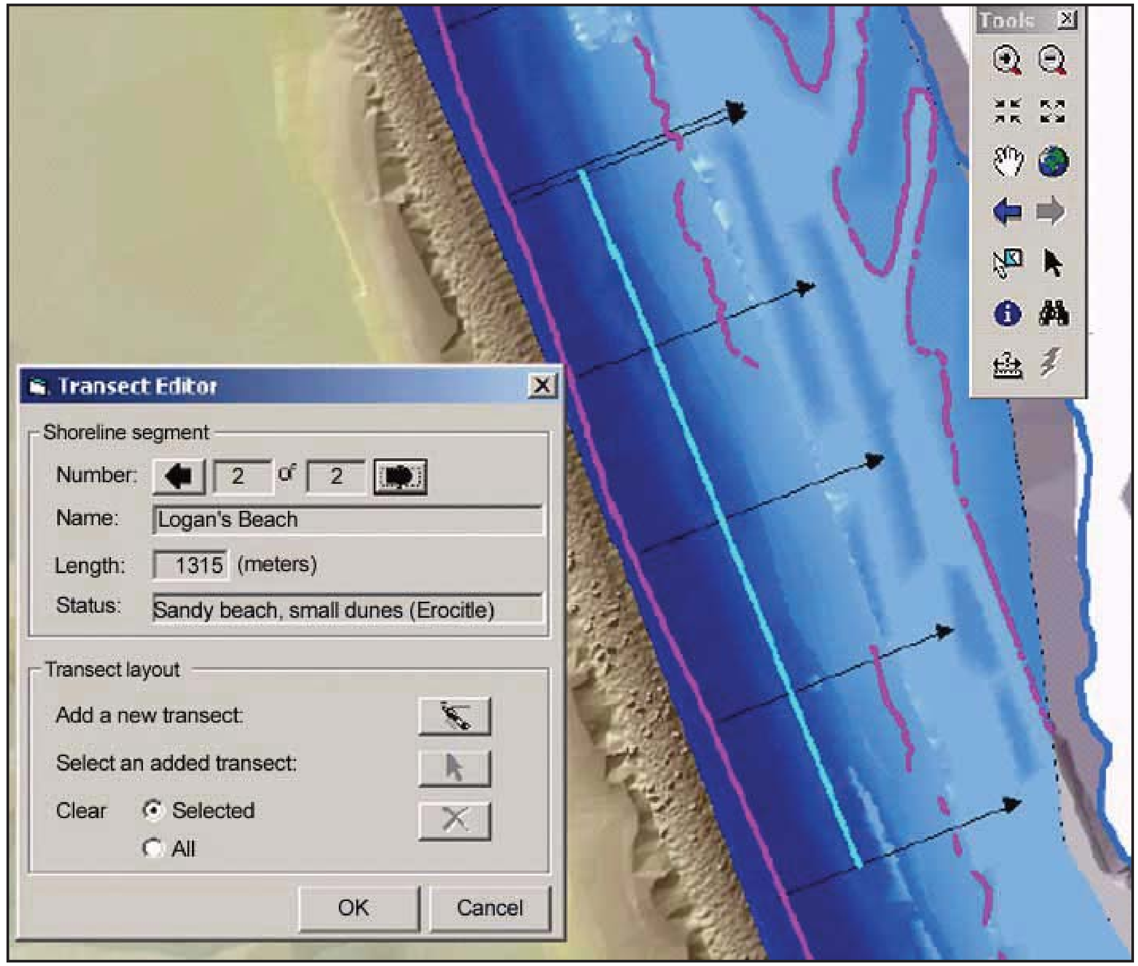
HAZUS-MH maps and displays hazard data, facilitating real-time support for natural disaster response and recovery as well as economic loss estimates for buildings and infrastructure. While a previous version of this software was made available in 1999, the upgraded HAZUS-MH provides emergency managers with new loss estimation tools for hurricane wind and flooding while taking advantage of the ArcGIS software platform.

A free software package, HAZUS-MH helps states, communities, and businesses prepare for, mitigate, respond to, and recover from hazardous events. To provide estimates of hazard-related damage before a disaster occurs, the software takes into account:

- Physical damage—Damage to residential and commercial buildings, schools, critical facilities, and infrastructure
- Economic loss—Lost jobs, business interruptions, and repair and reconstruction costs
- Social impacts—Impacts to people such as requirements for shelters and medical aid

Unique Features of HAZUS-MH

HAZUS-MH can quantify the risk for a study area of any size, whether for a region, state, community, or neighborhood. Using ArcGIS technology, HAZUS-MH combines hazard layers with national databases, then applies standardized loss estimation and risk assessment methodology. The GIS environment allows users to create graphic presentations, helping communities visualize and understand their hazard risks and solutions.



It is simple to divide shorelines into zones of common physical characteristics.

Nationwide databases built into HAZUS-MH include data sets on demographics, building stock, essential facilities, transportation, utilities, and facilities with a high potential for loss. The software can estimate losses from earthquakes, hurricane winds, and floods. Updated hazard models supplement these new features:

- Earthquake Model—This model provides estimates of damage and loss to buildings, essential facilities, transportation and utility lifelines, and population based on scenario or probabilistic earthquakes. In addition to estimating direct damage, the new model addresses debris generation, fires, casualties, and shelter requirements.
- Hurricane Wind Model—With this model users can consider any possible hurricane winds, as well as historic hurricanes, to estimate potential damage and economic losses to residential, commercial, and industrial buildings in states along the Atlantic and Gulf Coasts.
- Flood Model—Flood risk is determined by nationwide data sets through analyses of possible flooding based on hydrologic information. The Flood Model allows users to characterize flooding and then estimate expected levels of damage to buildings and infrastructure.

Third party hazard models that address hazardous material releases and dam breaks are also accessible with HAZUS-MH.

By providing this software free of charge, FEMA hopes to facilitate effective hazard mitigation. Anticipating the scope of disaster-related damage and identifying areas of special concern can help protect the lives and livelihood of a community.

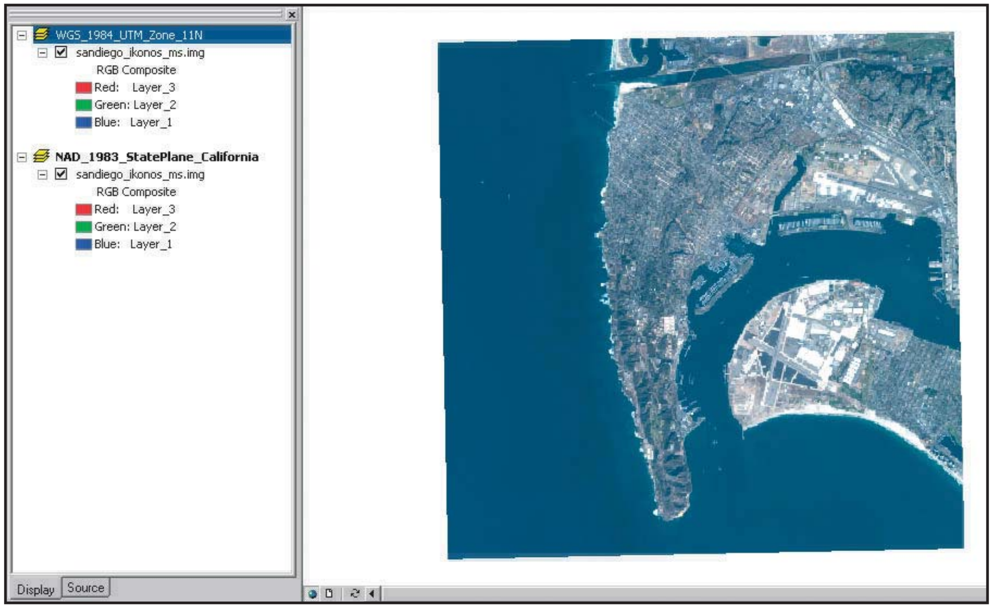
(Reprinted from the Summer 2004 issue of *ArcNews* magazine)

GIS Training for Disaster Relief

By Jared L. Ware, National Geospatial Intelligence School

Disasters in the form of earthquakes, fires, floods, hurricanes, and tornadoes severely impact communities economically, financially, and socially. Most disasters are characterized by short reaction/response times, overwhelming devastation to infrastructure, and a strain on the tangible and intangible resources of the affected community.

Decision makers at local, state, and federal levels are expected to quickly implement plans to restore order and mitigate the aftermath of the disaster. When properly trained, emergency planners and geospatial analysts can take advantage of GIS to aid in tasks such as establishing communications sites, restoring electrical power, and routing emergency supplies to critical facilities. However, in many cases specific datasets will not be available to accommodate every possible contingency that may arise in these operations.



ArcGIS allows geospatial analysts to conduct a wide range of GIS functions on a consistent dataset and provide customer specific datasets in a variety of datums and projections.

The Role of GIS

For geospatial analysts, the challenge is to quickly gather data and accurately fuse it together to support emergency planners. ArcGIS is a powerful mechanism available to emergency planners for collecting, storing, analyzing, and sharing the geospatial information needed by agencies to effectively support operations and restore disaster-affected communities in a relatively efficient manner. For emergency planners, GIS can facilitate critical decision making before a disaster strikes and in the crucial early stages of disaster relief operations.

Geospatial products can provide important information such as locations of critical facilities (e.g., hospitals, water plants), transportation routes (e.g., major highways, harbor charts), and areas affected by follow-on events such as flooding. These products can be used in every stage of a disaster relief operation, but it is necessary to have an existing GIS, a well-trained analyst, and access to credible data sources.

Although imagery typically has an accuracy statement, it is always a good practice to compare imagery against a map source with the same datum, projection, and coordinate system.

Fusing geospatial products, such as remotely sensed imagery with a digital topographic map, can aid response to a tornado by helping determine tornado destruction paths and allocate debris-clearing resources. Vector data can be fused to this product for network analysis to determine the best route to haul generators from a staging area to power up critical facilities. In addition, this product can be fused later with elevation data derived from Light Detection and Ranging (LIDAR) to identify low-lying areas and create image-based flood maps for postdisaster insurance claims. Geospatial analysts trained for disaster relief operations can provide these types of products to emergency planners before (if possible), during, and after disasters have impacted an area.

Requirements for Analysis

To be able to create products and formulate analysis, it is critical that geospatial analysts

- Have access to a GIS, preferably one using a powerful GIS software package with a full range of functionality such as ArcGIS.
- Understand data mining and what data will best support a particular disaster relief operation.
- Understand that data integrity includes data sources, data structure/format, and spatial and/or spectral accuracy.
- Understand the types of products that will need to be produced for decision makers during various stages of the disaster relief operation.

The goal is to develop timely, accurate, and relevant geospatial information that can be easily interpreted by a plethora of end users for a wide range of disaster relief functions. Moreover, the geospatial information must be measurable quantitatively and qualitatively to assure the credibility and integrity of the products produced in support of the disaster relief effort.

ArcGIS provides a full range of functionality to disaster relief operations. Providing a common operating picture is critical to the success of any operation, and defining that picture can be problematic when federal, state, and local officials converge on a community stricken by a disaster. According to the Oklahoma Department of Civil Emergency Management, one of the major lessons learned from the 1995 bombing attack on the Alfred P. Murrah Federal Building in Oklahoma City, Oklahoma, was that "a federal, state, and local cooperative partnership is essential for successful response and recovery operations following a catastrophic disaster."

Encouraging Partnerships

A successful partnership begins with a common geospatial operating picture that can be established with ArcGIS. ArcMap can supply a common look for geospatial data and, through the use of multiple data frames, display this data in the datums, projections, and coordinate systems that users expect. Local emergency planners in the United States typically use data in North American Datum 1983 (NAD83) and a State Plane projection while initial emergency electrical power responders from the United States Army Corps of Engineer's 249th Engineer Battalion (Prime Power) normally work with the World Geodetic System 1984 (WGS84) datum, the Universal Transverse Mercator (UTM) projection, and the Military Grid Reference System (MGRS). In ArcMap, several data frames can be used to organize one or many layers of geospatial information stacked for analysis within the same geographic extent. This allows geospatial analysts to conduct a wide range of GIS functions on a consistent dataset and provide customer specific datasets in a variety of datums and projections.

Locating Data

Getting the required data is one of the most crucial aspects of disaster relief GIS. Data mining is arguably the most difficult aspect of the process, because it must be done quickly and the data must be able to support a myriad of geospatial products for emergency personnel and their missions. Often, very large geodatabases need to be processed for what could be just a few related facts.

Also, search criteria will often change or be modified depending on the geospatial products required and the stage of the disaster relief operation. Owing to the time constraints of disaster relief operations, geospatial analysts assigned to disaster relief operations should develop a checklist of the data sources needed to support particular disaster relief operations. Table 1 contains a sample predata mining checklist for an earthquake operation.

	Product	Source	Available	Notes
Raster	TLM 1:50,000	NIMA	Yes	
	TLM 1:24,000	USAGA	Yes	
	Imagery, multispectral	Landsat 30m	Yes	From 1998
	Imagery, panchromatic	IKONOS 1m	Yes	
Vector	VMAP 1	NIMA	Yes	On CD-ROM
	VMAP 2	NIMA	No	
	DLG	USGS	Yes	
DEM	DTED1	NIMA	Yes	
	DTED2	NIMA	No	
	LIDAR 1m	RTV	Yes	
	RADAR	RADARSAT	Yes	
Text	GPS Locations	CF-Hospitals	Yes	Latitude/ Longitude
	GPS Locations	CF-C2 Center	Yes	MGRS

Table 1: Sample data mining checklist.

After determining which products are available, data mining begins. The key is to determine what decision makers will need so the correct data can be gathered, and extraneous and irrelevant data is not introduced into the geospatial analysis so that the maximum time and resources are allocated and devoted to supporting the disaster relief operation. Queries should be structured based on these needs while keeping in mind that derived products will eventually be distributed to a number of end users.

Effective Data Searches

One strategy is to narrow the initial searches to trusted Tier 1 databases such as proprietary and government databases (e.g., municipal, state, National Geospatial-Intelligence Agency (NGA) *[formerly the National Imagery Mapping Agency or NIMA],* United States Geological Survey (USGS), and Federal Emergency Management Agency (FEMA)). The effectiveness of data mining can be simulated through geospatial data fusion and the use of the Raster Calculator in ArcMap and the ArcScene application in the ArcGIS 3D Analyst extension.

Geospatial analysts must be able to find the data that best supports a specific disaster relief operation. The data must be in a structure and format accessible to many users. ArcGIS can import and export data in raster, vector, digital elevation model (DEM), and text formats and access data stored in geodatabases, shapefiles, coverages, and CAD files.

Both FEMA and United States Army Corps of Engineers' CADD/GIS Technology Center are in the process of developing a disaster relief product that has two Unified Modeling Language (UML) logical data models for FEMA readiness and response. The submodels will be Spatial Data Standard for Facilities, Infrastructure, and Environment (SDSFIE)-compliant and will reside within a relational database. The goal is to provide a GIS model that eliminates duplication, improves data quality, and saves time in disaster response situations in which critical public assistance data needs to be shared. ArcGIS supports UML for the development of a geodatabase with full topological relationships, integrity rules, and behavior as well as raster, surface, and locational representations.

However, it is unlikely that such a robust data model will be available over a disaster-stricken area in the near future, but the principles required to generate this data are applicable when selecting suitable data for disaster relief operations. For example, if a DEM of the disaster area is required, NIMA Digital Terrain Elevation Data (DTED) Level One, RADARSAT imagery, and LIDAR data could be used as well as contour layers derived from triangulated irregular networks (TINs) generated from known spot heights. A geospatial analyst must be able to determine which product will satisfy the initial requirements and any future requirements.

Quality and Appropriateness

There are many measurements of accuracy for geospatial data, particularly raster data. Digital maps usually have an associated accuracy statement included in the product or in its metadata. Although imagery typically has an accuracy statement, it is always a good practice to compare imagery against a map source with the same datum, projection, and coordinate system.

With this information, the geospatial analyst can determine if the data is accurate enough for disaster relief related GIS analysis. If the information accompanying the data is the only reference source, then a qualitative comparison of the imagery and the existing information should be performed and the differences between the two sources should be analyzed. A truly rigorous quantitative assessment cannot be achieved with the dataset and is probably not attainable given the time constraints of a disaster relief operation.

Another consideration is scale and how it describes geographic data. Geospatial products are created at specific scales and can be displayed at various scales in software viewers. Geospatial analysts should understand how products are developed for an intended scale and potential use at other scales. In most cases, a product derived at a 1:100,000 scale will still be useful with products developed at a 1:50,000 scale, if displayed at a scale of 1:50,000.

Generating the Right Products

Geospatial analysts must understand the different products required for different types of disaster relief operations. For example, in the event of a flood, emergency planners will want to know where the dry areas are located so command/control facilities can be established. Potential products may be maps merged with elevation data and layered with transportation networks and hydrology data. If emergency supplies are being transported to an area, decision makers will want geospatial products that show viable routes into the area; potential heliport locations; and the locations of ports, beaches, and bridges. In the latter stages, planners may want to merge imagery with digital elevation models and vector networks to determine the extent of flooding and postflood modeling. For example, a quick assessment can be done using the elevation data, the transportation network, and a 1:50,000-scale map.

Disaster relief operations provide a range of challenges for geospatial analysts, from getting data in a format that is usable to creating quantitative analysis for the distribution of relief funds. A trained geospatial analyst equipped with ArcGIS and a quality dataset can provide decision makers with the information needed to restore order to a stricken area. The methods and techniques described here will provide a geospatial analyst assigned to a disaster relief operation with some basic tools for developing a training plan that addresses the wide range of operations, from floods to fires, and while taking into account the time-constrained nature of disaster response and relief.

Acknowledgments

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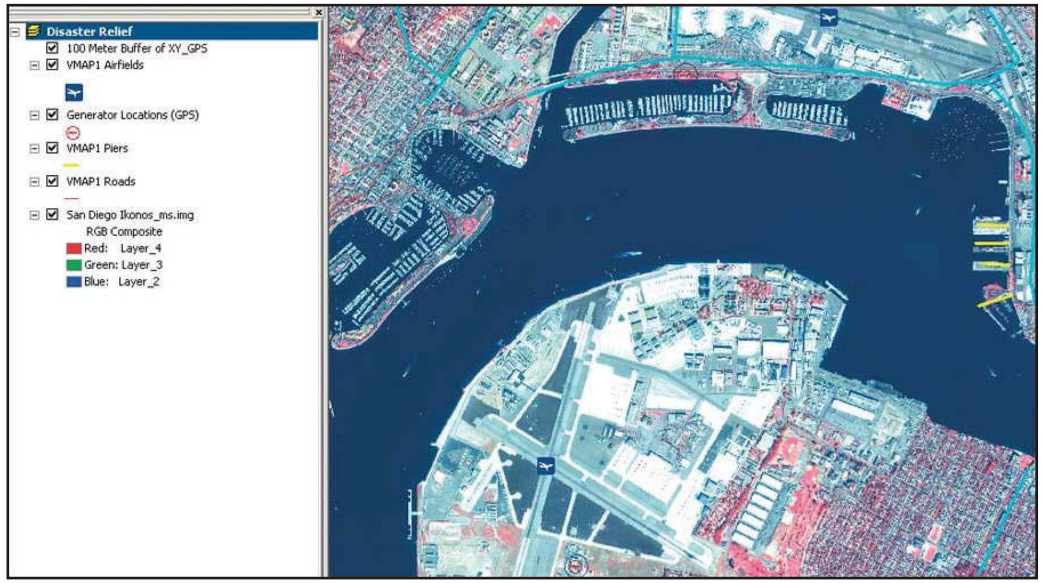

A trained geospatial analyst equipped with ArcGIS and a quality dataset can provide decision makers with the information needed to restore order to a stricken area.

About the Author

Jared Ware is a United States Army engineer officer who teaches geospatial intelligence fusion at the National Geospatial Intelligence School at Fort Belvoir, Virginia. His military assignments have included combat engineering, systems engineering, electrical engineering, and geospatial engineering. He holds a bachelor's degree in geography from the United States Military Academy, West Point, New York; a master's degree in engineering management from the University of Missouri, Rolla, Missouri; and a master's degree in defense geographic information from Cranfield University, Shrivenham, England. He is also a 2001 graduate of the Royal School of Military Survey's Army Survey Course in Hermitage, England. He worked with the United States Army Corps of Engineers and the Federal Emergency Management Agency in disaster relief training and operations for emergency power management from December 1998 to July 2000, when he was the commanding officer of A Company, 249th Engineer Battalion (Prime Power) at Fort Lewis, Washington.

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Since 1969, ESRI has been giving customers around the world the power to think and plan geographically. The market leader in geographic information system (GIS) solutions, ESRI software is used in more than 300,000 organizations worldwide including each of the 200 largest cities in the United States, most national governments, more than two-thirds of Fortune 500 companies, and more than 5,000 colleges and universities. ESRI applications, running on more than one million desktops and thousands of Web and enterprise servers, provide the backbone for the world's mapping and spatial analysis. ESRI is the only vendor that provides complete technical solutions for desktop, mobile, server, and Internet platforms. Visit us at www.esri.com.

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