THE ALL-HAZARD SITUATION ASSESSMENT PROTOTYPE

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ABSTRACT

The Federal Emergency Management Agency has established its vision for the future. A key element of the new direction for the Agency is to ensure that Governments and private organizations have proven effective plans, necessary resources, and rigorous training for disaster response.

Specifically FEMA has established the following goals that are pertinent to this direction:

To create an emergency management partnership with other Federal agencies, state and local governments, volunteer organizations, and the private sector.

To establish, in concert with FEMA's partners, a national emergency management system that is comprehensive, risk-based, and all-hazards in approach.

To provide rapid and effective response to any disaster, a comprehensive situation assessment capability is required.

If FEMA is successful in achieving these goals, decision making in support of disasters will have access to information on estimated and assessed effects of an emergency event. Thus, situation assessment can provide support for preparedness, response, recovery, and mitigation.

This situation assessment capability is being achieved through the All-Hazard Situation Assessment Prototype (ASAP). This system combines models and databases in a Geographic Information System (GIS) which allows the estimation and assessment of the effects of natural and technological disasters. Currently, the ASAP is operational at Headquarters FEMA for hurricanes. In prototype, the ASAP includes floods, storm surges, chemical spills and releases, earthquakes, urban and wildland fires, and chemical releases. These capabilities will be made operational at Hq FEMA in the immediate future.

The following discussion will describe how the system works, the models that have been incorporated into ASAP; the databases that have been installed; and the applications of the GIS. In concert, these processes will enable FEMA to estimate the extent of damage and the population at risk from these natural and technological disasters.

1. Introduction

Responding to the criticism following Hurricane Andrew the Federal Emergency Management Agency instituted the ASAP. This initiative was undertaken by FEMA in response to Congressional recognition that the Nation must be better prepared to respond to natural disasters. As a result ASAP was initiated to acquire the software, computer hardware, and databases that would allow FEMA to estimate the potential damage to housing, businesses, and other resources from natural and technological emergencies.

The steps which are necessary for complete damage estimation and assessment are: model development; message receipt; analysis; and product generation. For example to estimate the damage from hurricanes, Headquarters FEMA receives messages from the National Hurricane Center transmitted by the Weather Service's Family of Services. These message are automatically processed to provide input to models that estimate the extent of potential damage. The resulting regions of estimated damage, "damage bands", are input to the GIS. Already stored in the GIS are databases that locate and describe the population and housing as well as a plethora of facilities, resources and assets. The GIS allows the emergency managers to intersect the damage bands with databases in order to determine the assets and population at risk.

2.0 HURRICANES

The ASAP is developing the capability to estimate in real-time the civil resources and population at risk from threatening hurricanes. This system provides sufficient lead time to allow emergency planning, readiness actions, and prepositioning of appropriate types and amounts of relief supplies.

The hurricane damage and at-risk population estimation module automatically reads the National Hurricane Center's Maritime Advisory Messages using the National Weather Service's Family of Services. The message is automatically parsed for current and forecast hurricane characteristics, e.g., current position, maximum wind speed, forecast positions, radii of wind speeds.

Using existing analytical techniques, the module generates complete wind profiles (wind speed vs. distance from storm center) for the current and forecast positions. The module adjusts the profile such that the gust velocity is the maximum wind speed, not the sustaining one-minute winds. These wind profiles are converted to dynamic pressures. Accepted structural response modeling techniques have been incorporated for determining the susceptibility of approximately 20 different structural types to the hurricane's dynamic pressure. Vulnerability criteria show the threshold dynamic pressures needed to cause severe, moderate, and light damage. The regions on the ground for severe, moderate, and light damage to each of the different structural types are calculated for the current position and each of the forecast positions. The damage typically represent a seventy-two hour forecast of potential damage.

The damage bands have been integrated with the ARC/INFO Geographic Information System (GIS) and numerous databases created by the Census Bureau and U.S. Departments and Agencies. Business databases are also included. Using automated, integrated system of models, databases, and GIS, the hurricane's damage potential to resources and assets as well as population at-risk can be anticipated.

A Predeployment Report automatically calculates the amount of relief support that will be required based on the estimated damage. With this information the sources of the needed support and the logistics required for prepositioning can be identified.

The initial operational capability of the hurricane damage estimation system was announced on June 1 1993. The system was in place for Hurricane Emily and proved to be completely functional for FEMA personnel utilization. Estimations of damage to residences based on the forecasts proved to be acceptably close to published damage assessments.

The on-going development activities include incorporating tidal surge damage estimations using the National Weather Service's Maximum Envelope of Water (MEOW) contours and best available digital elevation models (DEMS). In addition, hurricane track uncertainties are being added to the track information promulgated by the NWS in the Maritime Advisory Messages. Additional work on the structural response models is continuing particularly with attention to validation.

3.0 FLOODS

Responding to the immediate real-time demands of the Mid-West flood crisis situation the ASAP was able to provide valuable information to FEMA regarding the extent of flood damage. At the direction of the FEMA program manager the software developers provided the necessary set of techniques that would allow FEMA to determine the population and resources at risk due to the flood conditions.

In an effort to obtain more comprehensive information on the extent of the river flooding, FEMA initiated an investigation to determine if the NOAA satellites (NOAA 9, 10, 11, 12) could quickly determine the extent of areas flooded using AVHRR imagery. With this information, FEMA could then estimate the resources and assets and the number of people, houses and businesses at risk. FEMA was able to apply this technology because of its acquisition of a AVHRR ground station anticipating its use in a variety of disaster situations. The feasibility of using the NOAA satellites in this way had been demonstrated very early in the ASAP program during Arizona floods but had never been fully tested.

FEMA assembled a team of experts from the fields of satellite imagery, computers and geographic information systems (GIS) and put them to work on the problem. What was needed was to incorporate AVHRR images into the ARC/INFO GIS so that the data extracted from the satellite image could be combined with a multitude of databases.

The NOAA satellites are used for meteorological research and produce multi-spectral imagery with a maximum resolution of about 1.1 km. There are currently four satellites broadcasting useful data, and each is able to view a particular area about twice a day. The satellites have the advantages of a wide area of view (approximately two-thirds of the continental US. in one pass) and frequent revisit time, but have a relatively coarse resolution when compared to satellites such as Landsat or SPOT.

The first task was to develop software to determine which areas of the image represented water. This process is called classifying. The software used a variety of techniques to classify each pixel in the image as water, land, cloud or cloud shadow. Since each image is 2048 pixels wide and up to 5000 pixels high and covers 2/3 of the United States, the software would examine a user-selected sub-image which was 512 pixels wide by 512 pixels high.

Next, the software needed to determine the exact ground location of each pixel in the image was adapted. This process is called the image navigation. The software uses a set of complex calculations based on the last known position of the satellite to do the navigation. Outlines of the non-flooded river locations where overlaid on the satellite image to check for the accuracy of the image navigation.

If the river outlines did not line up correctly with the actual locations of the rivers in the image, the navigation was adjusted until the river outlines lined up on top of the rivers in the image.

The software would then transfer the locations of only those image pixels classified as being water to the ARC/INFO GIS.

When the AVHRR data had been successfully processed, the next step was to integrate the information into the ARC/INFO GIS. Polygons representing the extent of the flooding were generated from the point data developed from the image. These polygons were intersected with population and housing and other resource information to produce estimates of flood damage.

4.0 EARTHQUAKES

Experience has shown that in the time period immediately after an earthquake, emergency managers do not know the extent of damage due to broken lines of communication. Thus, responding to the damage and relief requirements of the disaster are often lagging. To improve this situation, Hq FEMA has adapted the USGS model developed by Jack Evernden.

The Evernden model is a collection of computer programs and databases for the calculation and display of various aspects of earthquake-induced ground motion. The model was developed and validated by J.F. Evernden of the National Earthquake Information Center (NEIC) of the United States Geological Survey (USGS). It is intended for the quick assessment of the effects of an earthquake to aid the delivery of fast, efficient, and effective disaster relief.

The model predicts only the ground motion due to shaking. Liquefaction and slumping are not treated by the model. For an earthquake occurring at a specified site, the model can calculate and map the resulting intensity of the event (on the Modified Mercalli Intensity [MMI] scale), the actual ground movement (in terms of its velocity, acceleration, and displacement), and the percent of buildings damaged for a few different building types.

The input parameters and data bases collectively describe the instigating fault rupture, the local ground condition, and the desired type of output. The outputs are maps displaying various ground motion parameters. Further, the value of the ground motion parameter at a particular lat/lon on the map may be determined. estimation in near real-time of the extent of damage from earthquakes FEMA adopted the USGS model developed by Jack Evernden.

The Evernden model requires a minimum of initial conditions, e.g., the earthquake's epicenter location, magnitude. In addition the model requires geologic information (rock type). When merged with a geographic information system and the resource, population, and housing database, the emergency manager can quickly estimate damage and anticipate relief requirements.

During the recent Los Angeles earthquake, FEMA was able to run the USGS model shortly after the quake struck using information from the USGS National Earthquake Information Center. Estimates on the extent and severity of the earthquake were provided to California shortly after the quake struck. The results of these model intensity estimates and the actual damage assessments will be compared.

5.0 CHEMICAL SPILLS AND RELEASES

FEMA has adapted the Army's

approved chemical release model, D2PC, which provides estimates of the spread of toxic chemicals. This model is very easy to use and only requires local weather conditions (wind speed, direction, stability class) and the type and amount of chemical accidently released. The model's output is provided to the GIS. The user sees a visualization of the dangerous areas caused by the spill and, using the geographic information system and the population database, estimates the population at risk.

Examples of the utility of the model, GIS, and databases will be presented.

6.0 FIRES

FEMA pursued several efforts to provide more comprehensive real time information concerning urban and woodland fires to local, state, and federal disaster relief teams. These efforts combine the remote sensing capabilities of the meteorological sensors onboard the NOAA satellites with fire spread simulation models, and geographic information systems (GIS). With this technology the potential fire damage and population at risk can be estimated.

The first task was to develop software to determine which areas of the image represented fire. The software used a variety of techniques to classify each pixel in the image as fire, earth reflections, and normal "hot spots."

Next, software was adapted to determine the exact ground location of each pixel in the image as cited above.

When the satellite data had been successfully processed, the next step was to integrate the information into the ARC/INFO GIS. Polygons representing the extent of the fires were generated from the point data developed from the image. These polygons were intersected with population and housing and other resource information to produce estimates of fire damage. In addition, the satellite-determined fire locations serve as seed points for a simulation model that estimates the spread of the fire. Again, the estimates from the simulation model are integrated into the GIS for analysis of population, housing, facilities, and resources at risk.

References:

Evernden, J.F. and Thomson, J.M., 1988. Predictive model ... great earthquakes. U.S. Geological Survey Bulletin,1838.