CHECK-2:
THE AUTOMATED HEC-2 REVIEW PROGRAM

Zekrollah Momeni
Moe Khine
Dewberry & Davis

Introduction

Since 1974, Dewberry & Davis (D&D) has served as a technical evaluation contractor for the Federal Emergency Management Agency (FEMA) in administering the National Flood Insurance Program. One of our major functions is to ensure the technical accuracy of flood hazard analyses used to prepare and/or revise Flood Insurance Studies (FISs). Most FISs were prepared utilizing the U.S. Army Corps of Engineers' HEC-2 hydraulic backwater model to analyze riverine flood hazards. Therefore, D&D established a procedure for evaluating and reviewing HEC-2 models to ensure that flood hazards are analyzed accurately and within the Corps' guidance outlined in the *HEC-2 User's Manual.* This procedure, used successfully for many years, involved the creation of several spreadsheets that helped reviewers identify areas of potential concern within a given HEC-2 model. D&D is now developing a computer program that automates the HEC-2 review that was historically performed manually. This program, CHECK-2, is described below.

The Program

CHECK-2 consists of five different programs (modules) running under one menu:

The J3 Program
The NVCE Check Program
The XSEC Check Program
The FLOODWAY Check Program
The BRIDGE Check Program

The J3 Program

In order to retrieve certain specific information for each check, it was necessary to create a program that would insert "customized" J3 records into a HEC-2 input file and produce new output files with the customized summary tables. There are three specific summary tables that were created in order to retrieve the appropriate data to perform the checks. The variables in each J3 record are:

```
J3  SECNO   CLASS   XLCH   CWSEL   HV      EG     HL     OLOSS   10K*S   EGLWC
EGPRS       EGOC    EGIC
J3  SECNO   QPR     QWEIR  QCULV   Q       QCH    ELMIN  XNCH    XLBEL   RBEL
ELLC        ELTRD   .01K
J3  SECNO   DIFKWS  CRIWS  TOPWID  KRATIO  TELMX  SSTA   STENCL  STCHL   STCHR
STENCR      ENDST   AREA
J3  200
```

This program also deletes any J5 records in the HEC-2 input file.

The NVCE Check Program

This module checks HEC-2 input data files only. The other three modules (XSEC, FLOODWAY, and BRIDGE) check both the HEC-2 input and output files. The NVCE module checks the following items in a HEC-2 input file:

- Cross Section Table (identifies structures)

  Creates a table showing the "n" values used for the channel and overbanks and the contraction and expansion loss coefficients at each cross section. It also identifies those cross sections where a structure is modelled.

- Summary of Statistics Table

  Creates a table listing the maximum and minimum channel and overbank "n" values, and contraction and expansion coefficients for the HEC-2 file being tested.

- Roughness Coefficient Check

  Produces messages when "n" values for the cross sections fall outside the following limits:

	Minimum	Maximum
Channel	0.025	0.075
Overbanks	0.040	0.200

- Starting NC Record Check

  Checks for a complete NC Record at the beginning of the HEC-2 input file

- NC and NH Record Check

  Checks that NC records (or another NH record) exist immediately following a cross section using NH records.

- NV Record Check

  Reads the input file and identifies cross sections where an NV record is used.

- Transition Coefficient Check

  Checks that transition (contraction and expansion) coefficients at structures modeled using normal and special bridge and special culvert routines following guidelines set in the *HEC-2 Users Manual*, Table 1, Page III-17.

The XSEC Check Program

This program checks the HEC-2 input and output files for a given profile and checks the following:

- Type of Bridge Check

  Lists whether special bridge, normal bridge, or special culvert routines were used to model a structure.

- Spacing Check

  Checks velocity head change, conveyance ratio, and top width ratio between cross sections to see if additional cross sections are required. The following criteria are used:

  1. Difference in velocity head is more than 0.5 foot
  2. Conveyance ratio is outside the range of 0.7 and 1.4
  3. Top width changes by more than a factor of 2.0

- Ineffective Flow Area Check

  Reads input file and identifies cross sections in the natural (unencroached) profile that use ET and X3 records to define areas of ineffective flow.

- Location Check

  Checks the location of a cross section upstream of a cross section where critical depth occurs.

- Discharge Check

  1. Checks whether or not discharges decrease in upstream direction.

  2. Checks whether or not discharges upstream and downstream of a structure are equal.

- Starting WSEL Check

  Checks whether starting slope is too steep or too mild.

The BRIDGE Check Program

This is the most complex module to develop because it tests for the many types of flow that may occur at a structure. This module tests for the following:

- Channel Bank Station Check

  Checks stations on BT records against channel bank stations defined in the X1 record.

- Maximum Low Chord Elevation and Minimum Top of Road Check

  Checks that values calculated from the BT record match values specified on the X2 record.

- X3 Elevation Check

  Checks that the limiting elevations used at upstream and downstream of a structure are not outside the maximum low chord and minimum road elevation range from the BT data.

- Low Flow Check

  Checks type of flow, pier coefficient value (XK value between 0.9 and 1.25).

- Pressure Flow Check

  Checks type of flow, orifice coefficient value (XKOR computed matches specified XKOR value in SB record), X3 record elevation.

- Weir Flow Check

  Checks whether weir length (WRLEN) is equal to top width (TOPWID).

- Normal Bridge Check

  Checks for type of flow by comparing CWSEL to maximum low chord elevation.

- Manning's N Value Check

  Checks for "n" value changes, and contraction and expansion coefficients at bridge sections.

- Special Notes and Messages

  The following messages are searched for from the detailed printout and printed:

  1. Downstream energy of X higher than computed energy of Y
  2. Possible invalid solution, 20 trials of EG not enough.
  3. Bridge deck definition error at stations X and Y.

The FLOODWAY Check

Checks HEC-2 "with floodway" (encroached) profile and compares to 100-year natural profile for the following:

- Encroachment Method

  1. Whether each cross section has an encroachment method selected.

2. Whether bridge cross sections have bridge encroachment option (a value of 0.01 added to the code on the ET record that describes the method of encroachment).

- Starting Water Surface Elevation

  Checks that the starting WSEL of the floodway profile be equal to the WSEL of the natural profile plus the specified target surcharge value on the first ET record.

- X5 Records

  Checks for the use of X5 records in the input file.

- Floodway Width

  Checks that:

  1. Floodway top width does not exceed unencroached 100-year flood top width at any cross section.

  2. Encroachment stations are not set inside of defined channel bank stations.

  3. X3 record exists that overrides encroachment stations specified on ET record at a cross section.

- Surcharge Value Check

  Checks whether:

  1. Maximum allowable surcharge value for a specific state or within the FEMA maximum of 1.0 foot has not been exceeded.

  2. Negative surcharges exist.

Conclusion

We believe that this program will enhance Dewberry & Davis' ability to evaluate flood hazard analyses and hence allow FEMA to conduct and review FISs in a more efficient and accurate manner. This program will also be made available to any other users of the HEC-2 program including FEMA study contractors and revision requesters. Use of this program by study contractors and revision requestors will ensure that HEC-2 models are checked before they are submitted to FEMA. This, in turn, will lead to reduced costs to all parties involved, as it should eliminate the resubmission of models for inaccuracy or incompleteness. It must be noted that this program does not replace sound analyses and common sense, but rather it is intended to highlight areas of potential modelling problems for further investigation and scrutiny.

D&D is testing and finalizing the program and anticipates releasing a BETA version of the CHECK-2 program in July 1994. A copy of the BETA version can be obtained for review by writing directly to Mr. John Magnotti, III, Federal Emergency Management Agency, Mitigation Directorate, Hazard Identification Branch, 500 C Street, S.W., Washington, D.C. 20472.

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DIGITAL FLOOD INSURANCE RATE MAPS: STANDARDS FOR SHARED DATA

Alan A. Johnson
Federal Emergency Management Agency

David P. Preusch
Michael Baker Jr., Inc.

Introduction

The Federal Emergency Management Agency (FEMA) is working on a multi-year project of converting Flood Insurance Rate Maps (FIRMs) prepared using manual graphic processes to computer digital format using Geographic Information System (GIS)-based software. FIRMs will be available in digital format for a limited number of communities starting in 1994. The Study Contractors (SCs) who perform Flood Insurance Studies (FISs) and restudies for FEMA will be required to submit floodplain maps in digital format in the near future to facilitate preparation and storage of information as a digital FIRM (DFIRM). SCs, communities, or private property owners who prepare revisions to FIRMs to incorporate floodplain changes due to channel improvements, flood-control projects, better data, improved models, or other reasons may use available digital information or supply new digital data. New digital data supplied to FEMA must be horizontally controlled and prepared in a format that allows (1) ready use for converting the digital data into a standard, formatted DFIRM, (2) separation of flood data into four themes, and (3) separation of base map information from flood information.

Standards for shared digital data are not intended to specify the usage of any data capture procedure, production system, or software. The standards are primarily intended to assure that the captured data are compatible with many production systems to facilitate interchange of data, to support automation of DFIRM production, and to support automated spatial data analysis.

Background

FEMA will prepare DFIRMs in its Countywide Format, in which the FIRM depicts the floodplains in both the unincorporated and incorporated areas of the county. Corporate limits for the incorporated areas are shown. Consequently, unincorporated and incorporated areas will be mapped at the same scale on any given panel. DFIRM panels will be printed at scales of 1" = 2000', 1" = 1000', and 1" = 500'. Map paneling will conform to the U.S. Geological

Survey (USGS) 7.5-minute series topographic quadrangle maps. Quadrangles will be quartered and further quartered depending on the printed map scale of the DFIRM.

Flood information is to be stored as continuous data for the entire county across the corporate limits and panel boundaries. When new information is received for part of the county, it is to be sewn into the master file of the entire county. During final DFIRM processing, panel boundaries are to be used to break the information into separate map panels.

All linear and curvilinear features on a DFIRM, such as stream center lines, floodplain and floodway boundaries, corporate limits, and panel boundaries, are to be represented as series of lines or vectors (line strings). Curvilinear lines are to be drawn by making a series of very short lines by "zooming in" on the area. These short lines, when printed at the map scale, appear as curvilinear lines. No nonlinear geometric functions are used to represent these data. These line strings are connected to form polygons, which represent an area of flood data. No two lines can cross without breaking and there can be no free endpoints on a line string. A FIRM is, therefore, subdivided into areas or zones. Each area contains a centroid, and attributes are assigned to each area that define characteristics such as flood zone designation and base flood elevation (BFE). An exception to this is the hydrography, which includes the stream center lines. This information is stored as linear features and does not have to form polygons. All linear features are defined by their attribute codes.

Roads are to be shown on the DFIRM as single lines, representing the road center line. Therefore, roadway width and right-of-way information will not be needed.

Thematic Layers of Data

To facilitate the use of digital information, data in digital files must be separated into different themes by using layers (levels) or by assigning attributes to individual data. Each theme is stored in a separate file. The four themes are:

1. Political Areas: Jurisdictional boundaries such as city, county, and state boundaries;

2. Map Panel Areas: Edges of FIRM panels that correspond to the USGS quadrangle maps;

3. Hydrography: Stream centerlines, water-control structures, and cross sections; and

4. Flood Hazard Zones and Floodways: Floodplain and floodway boundaries that outline inundated areas and floodways. Inundated areas are assigned attributes such as flood zones and BFEs.

These four themes of data comprise the DFIRM-DLG file, which is a separate data file of jurisdictional flood information. Base map information, such as roads and other planimetric features, is not included on the DFIRM-DLG file. The DFIRM-DLG file is the digital product that will be available to the public. For data supplied to FEMA, no floodplain screening or floodway cross hatching is necessary. These will be added by FEMA during final processing of the DFIRM.

Data Formats

Data files used to store FIS/FIRM information may be exported in one of the following formats: (1) DLG (Digital Line Graph), (2) DXF (Drawing Exchange Format), (3) ARC/INFO export format, (4) Microstation (DOS or UNIX) Design Files, or (5) AutoCADD Drawing Files. These files are to be created by segregating the data into the themes shown above.

Specifications for DFIRM-DLG file format are contained in *National Flood Insurance Program, Standards for Digital Flood Insurance Rate Maps* (FEMA, 1993a), which specifies the type of information stored on each layer/level, attribute codes, file header information, file naming conventions, and National Flood Insurance Program symbols. FEMA coordinated with the National Mapping Division of the USGS to establish a topological structure for DFIRMs consistent with USGS DLG-3 specifications.

For the other file formats (i.e., DXF, ARC/INFO, Microstation, and AutoCADD), specifications are given in Appendix 7 of *Flood Insurance Study Guidelines and Specifications for Study Contractors* (FEMA, 1993b), which specifies the same type of file formatting as discussed in the previous paragraph. It also presents three options for file formatting. One option may be more suitable or efficient for use with specific hardware or software than another.

Horizontal Control and Accuracy

The lack of horizontal control on manually produced FIRMs required lenders and floodplain managers to use "due diligence and good faith" in determining the location of a property with respect to the 100-year floodplain (Special Flood Hazard Area). This is done using the relative location of hydrographic features and roads with or near the floodplain, using additional information such as land parcel maps overlaid on the FIRM. FEMA makes determinations by comparing the first-floor elevation with a BFE obtained from the flood profiles presented in the FIS report.

DFIRMs are horizontally controlled (within the floodplain and at the four corners of the panel) with USGS quadrangle maps, which are mapped using Universal Transverse Mercator (UTM) coordinates. The quadrangles are prepared at a scale of 1:24,000 (1"=2,000') and meet National Map Accuracy Standards, which specify that "90% of all points tested must be accurate to within 1/50 of an inch at the printed map scale." Therefore, the quadrangle maps are accurate to within 40 feet.

Base map information as well as floodplain information provided to FEMA as a result of a study or restudy performed by an SC for FEMA or a map revision request performed by a local agency or consulting firm must meet or exceed these specifications in order for FEMA to accept the work as digital information. Most coordinate systems can be converted easily to UTM by existing software. Therefore, coordinates such as State Plane coordinates are acceptable and will be converted to UTM before they are incorporated into the DFIRM.

Maps that are enlarged or reduced to a scale of 1:24,000 may not meet the National Map Accuracy Standards for 1:24,000-scale maps. The accuracy of the map at the original scale is critical. For instance, USGS quadrangles at a scale of 1:100,000 are accurate to within 167 feet (1/50 inch at the printed map scale). Enlarging these maps to a scale of 1:24,000 does not improve the horizontal accuracy and would, therefore, not meet the DFIRM standard. Additionally, DFIRM users cannot use the scale of the published FIRM as the basis for estimating the horizontal accuracy of the flood data.

Base Mapping

Base mapping includes all planimetric features, such as roads, railroads, airports, bridges, and contour lines. This information must be stored in a separate file or files to allow FEMA to easily separate the flood information from the base mapping. Additionally, individual base map features, such as roads, railroads, contours, spot elevations, and bridges, must be isolated on separate layers/levels or by attribute because not all of these features are shown on the printed DFIRM.

New photogrammetric data may be necessary along a restudied stream. Information obtained by field surveys or photogrammetry or from other sources must meet National Map Accuracy Standards and must be plotted on a geographic projection or control grid (State Plane Coordinates or UTM).

Existing base map data for other areas may be available from other base map sources. Sources of digital base mapping include USGS quadrangle maps, U.S. Census Bureau TIGER files, and other data available locally.

Not all USGS quadrangle maps have been digitized by the USGS. USGS 1:100,000-scale digital data are available, but they may not meet the horizontal accuracy standards of a 7.5-minute quadrangle, which is the standard for a DFIRM. Additionally, the USGS 7.5-minute quadrangles do not have all the names of streets in the floodplain, which is necessary for final processing of the DFIRM.

The TIGER files have variable horizontal accuracy and would have to be controlled before they could be used. The advantage of the TIGER files is that they have an associated database of road names, street addresses, and zip codes, which could be used for other GIS applications. In addition, road names can be placed on the final DFIRM using an automated process that eliminates labeling each road.

Data obtained locally, for example from a community GIS, can be used but these data again must meet National Map Accuracy Standards and must be plotted on a geographic projection or control grid. The primary advantage of using community-furnished data is that the resulting flood overlay will be compatible with community base maps in a GIS environment to perform spatial analysis using flood data. This will be an extremely useful tool for local planners and floodplain managers.

When proprietary base map information is obtained from the community or other source and used to develop the DFIRM, only a printed copy of the DFIRM and the DFIRM-DLG data file will be provided upon request to interested parties. Only when the community has "explicitly waived" any objection of release of this data will these digital base map data be made available to the general public.

Summary

Setting standards and specifications for the use of shared data with FEMA will allow for efficient use of supplied data in preparing the final product—the DFIRM. If data are not supplied in a standardized format, it may be too costly for FEMA to separate and format the data. The available format options do not require the use of any specific production system, hardware, or software. Finally, data must meet horizontal accuracy standards and be mapped on a control grid in order for the flood information to be accurately overlaid with other digital information for spatial data analysis.

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THE USE OF GEOGRAPHIC INFORMATION SYSTEMS TO MANAGE NEW JERSEY'S HISTORICAL SHORELINE DATA

Mark N. Mauriello
New Jersey Bureau of Coastal Regulation

Introduction

Historical shoreline data are becoming increasingly important for coastal planning and regulatory programs, as well as for public information purposes, throughout the U.S. coastal zone. With the prospect of new federal flood insurance legislation, including erosion zone mapping provisions, the management of long-term historical shoreline data will become even more critical in the future. The use of geographic information systems (GIS) provides a means to digitally map coastal features through the use of verifiable shoreline data and enhanced computer graphics. This has yielded the highest quality data on shoreline movement, which can be accessed on a user-friendly, menu-driven personal computer. The New Jersey Department of Environmental Protection and Energy (DEPE) GIS has proven to be the most efficient way to compile, compare and display shoreline data of varying forms, scales, and sources, dating from the 1840s to the present.

Coastal Dynamics

Coastal shorelines are very dynamic areas that are subject to significant long-term and short-term changes resulting from sea level rise, altered sediment supply, tidal inlet processes, storms, and human intervention. These landforms are extremely mobile and are subject to both gradual and avulsive change, making oceanfront shorelines quite vulnerable to damages from storm surges, storm waves, and associated flooding. The patterns and rates of shoreline change are not uniform, and vary locally depending on the nature and magnitude of coastal processes operating within specific shoreline segments. Because of these dynamics, coastal shoreline management, particularly along the oceanfront, has become a major focus for local, state, and federal agencies, as well as for coastal residents and property owners.

Comprehensive coastal shoreline management is dependent on the availability of accurate historical shoreline data, which is used to evaluate past shoreline changes and to project future changes. These data are critical to the understanding of coastal processes and the impacts of human intervention on these processes and associated shoreline response.

Data Sources

Historical shoreline data are reflected in the large number of maps and surveys of oceanfront areas, which have been compiled since the mid-1800s. These map data include hydrographic and topographic surveys at varying scales, prepared by the U.S. Coast and Geodetic Survey, the National Ocean Survey, the U.S. Army Corps of Engineers, and the New Jersey State Geological Survey. Aerial photographs produced since the 1940s also provide a valuable source of shoreline data, although these photographs require rectification before being used as part of the historical shoreline data base.

Prior to the use of GIS for shoreline mapping and data management, the only method available to the DEPE for compiling and comparing historical shoreline data involved the use of photo enlargements and zoom transfer scopes. Although these two techniques are simpler and less expensive than digital mapping and analysis, the final products are hand traced maps that do not meet National Map Accuracy Standards. While these techniques may be acceptable for evaluating general shoreline change patterns, they are not well suited for quantitative shoreline analyses, due to the degree of error associated with the mapping techniques (Leatherman, 1983). Therefore, GIS represents the most reliable method available for the mapping, compilation, and comparison of shoreline data, and for the production of accurate shoreline change maps.

GIS Applications for Shoreline Data Management

To evaluate this large volume of shoreline data for use in regulatory, planning, and educational programs, the DEPE has developed a GIS that allows for the compilation, comparison, and display of large amounts of shoreline data. Such comparisons are required to establish historical shoreline change rates, to define erosion and accretion areas, and to develop erosion hazard area maps for use in planning and regulatory programs. In addition, this GIS capability facilitates the production of maps and overlays for use in public information and education programs undertaken by the DEPE and other agencies at all levels of government, as well as by academic institutions.

The primary use of this historical shoreline mapping program is to implement the Department's Rules on Coastal Zone Management (N.J.A.C. 7:7E-1.1 et seq.), specifically the Erosion Hazard Areas rule (-3.19). This rule requires that most types of development be located landward of the defined erosion hazard area for the proposed development site. The application of this method for calculating historical shoreline change rates and construction setbacks was previously described in detail by Mauriello (1991), and has been approved by the Federal Emergency Management Agency for use by the DEPE in making imminent collapse certifications pursuant to the Upton-Jones Amendment to the National Flood Insurance Program. The long-term historical shoreline data are jointly evaluated with other information such as past or on-going shore protection activities, navigational dredging projects, and past storm events, which may help to explain the change rate determinations.

This shoreline mapping and comparison procedure also allows for shoreline change map plots to be overlaid on a base photograph or survey, so that a property owner can have the benefit of visually understanding the history of shoreline movement for that specific area. This is important in helping to educate the public in the area of hazard identification and management, and in explaining how the history of shoreline changes in an area can be examined and used to project future changes. With the ability to combine other data layers onto these shoreline change map plots, the final map products can be annotated to make them easier to interpret and understand.

GIS Flexibility

As mentioned above, another benefit of managing historical shoreline data through a GIS is the ability to overlay other data layers onto a map containing the shoreline data. For example, a map that displays historical shoreline locations can be annotated to include additional information such as geographic coordinates, streets and roadways, county and municipal boundaries, flood hazard area boundaries, soils, regulatory boundaries, and much more. The capability to combine historical shoreline map data with other data in this manner makes the information usable for a greater number of applications. In addition to the large number of data sets which can be accessed and displayed through the use of GIS, perhaps the greatest benefit of using GIS to manage historical shoreline data is the ease and speed at which information can be processed.

Summary

The use of GIS has proven to be the most efficient method for mapping, compiling, comparing, and displaying historical shoreline data of various scales, forms, and sources. In addition to the ease with which this information can be accessed and displayed, the digital historical shoreline data files are very easy to distribute to other agencies involved with coastal management in New Jersey. With the advent of less expensive, high powered personal computers and plotters, this digital data will become even more useful in the future, since more people will have the capability to access data that were previously very difficult to compile and compare.

In addition, it allows for periodic updating of the digital shoreline data files, as more recent shoreline data are generated, thereby allowing the program to remain current. The ability to overlay additional data layers with the shoreline data also expands the scope of potential users, and therefore provides a greater overall return on the GIS investment.

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GIS TO THE RESCUE: GIS AND THE MISSISSIPPI RIVER FLOODING

Sue Hoegberg
Dewberry & Davis

Much has been written about what went into predicting, tracking, analyzing, and cleaning up after the floods in the Midwest last summer, and about how geographic information systems (GISs) played a role in this effort. One of the most encouraging things to have come out of the response to the disaster is the true cooperation among the many parties using GISs to identify and solve these problems. A disaster of such monumental proportions just cannot be handled by any single agency or entity.

The Federal Emergency Management Agency (FEMA) is the lead federal agency for disaster assessment and assistance, and its mission is to coordinate real-time response to disasters and to cooperatively fund the recovery efforts. In the agency's role of coordinator, it was able to pull together software, hardware, data, and personnel, both at headquarters in Washington, D.C. and in the field, to use GIS as part of the response. FEMA maintains a GIS data base called the All-hazards Situation Assessment Prototype GIS data base, or ASAP for short. FEMA is putting together a GIS that will allow for the collection, integration, and analysis of satellite imagery, transportation data files, point elevations, demographic data, and locations of critical features. These data can then be used for real-time analysis and relief planning.

FEMA and the U.S. Army Corps of Engineers collected up-to-date satellite imagery for use in the relief planning. The Corps obtained hard copy maps for use in the field. These were 32"x44" georeferenced images with a plotted latitude and longitude grid. FEMA obtained georeferenced vector files that had been converted from the raster imagery, showing the extent of the flooding.

As would be expected, conventional aerial photographs were also provided to the Corps of Engineers. Four hundred river miles were flown daily at approximately 12,000 feet above ground level for 60 days, beginning July 8, 1993. These photographs allowed for constant monitoring of the situation by the Corps and will also allow for historical comparisons with similar photos taken in 1973. While these photographs were essential to the Corps' needs, the cloud cover was quite extensive in many of them, and they were not able to be georeferenced, so they were not particularly useful for GIS applications.

FEMA and the National Aeronautic and Space Administration (NASA) also gathered radar imagery. The radar was used to penetrate the cloud cover that was so extensive and continuous, identifying the flooded areas by what the return was from the water as opposed to the dry land. The extent of the flooding was mapped by extracting the water classification from the radar images. These data were provided to FEMA, the National Oceanic and Atmospheric Administration, the Illinois Department of Energy and Natural Resources, as well as to NASA. NASA then merged the radar images with satellite imagery to allow viewers to see both the flooded areas and the underlying terrain.

The sharing of this type of information is critical to our ability as a nation to respond to emergencies, and we need to keep the vehicle for data exchange in place for situations like this. The events in the Midwest last summer forged some new relationships that will be kept alive. In fact, a similar response was experienced when the Laguna Beach, California, fires of October and November 1993 were raging. These 26 fires destroyed over 200,000 acres of land and thousands of people were displaced from their homes. Many private and government entities worked together to assemble a fire response team, with contributions of equipment, software, data, expertise, photography, imagery, and more.

FEMA's technical evaluation contractors are currently contracted to provide FEMA with digital Flood Insurance Rate Maps. Both CADD and GIS software packages are used to do this work, and one of the first things done was to digitize floodplain information in the affected areas from the hard copy maps. They also did some data conversion of maps showing the extent of the flooding in local areas. In addition, they were called upon to help incorporate these and other types of data into FEMA's all-hazards GIS data base. In addition to the technical evaluation contractors, many other companies and agencies were directly involved with FEMA, supplying hardware, software, data, and personnel for the preparation of situation reports and briefing graphics of map data.

FEMA's all-hazards GIS data base was first established in 1992 during the Hurricane Andrew cleanup efforts. As part of this effort, FEMA has been building a nationwide data base of critical features that need to be monitored during the response to a disaster. Developing a data base of this magnitude is no small task and this one will likely be added to and improved for a very long while to come.

In order to try to provide meaningful figures and analysis, FEMA started by amassing as much data as possible for the affected areas. State and county boundaries, rivers, cities, and statistical attributes were gathered. In addition, road and railroad locations, street names, and street types were added. FEMA also had certain types of point features that had been worked with for quite a while in the ASAP GIS. These included airports, chemical plants, dams, electric power plants, General Services Administration facilities, hospitals, interstate highway bridges, and tank farms. Each of these features has database information such as facility name, address, type, etc. attached to it. Additional point features were created for public buildings such as fire stations, police stations, prisons, and many government agencies. These features also came with attribute data filled in for facility name, address, type, etc. FEMA had also previously created point coverages of census block centroids from the U.S. Census Bureau STF1A data files. These point coverages contained a useful distillation of the enormous amount of information contained in the Census files. These data were being used for reports of housing units, both occupied and unoccupied, total population, and number of families affected by the flooding.

So FEMA had all of this data and wanted to know what was being impacted by the flooding. To do that, the agency needed an outline of the area of flooding. Several sources were combined over the course of time, as the flood kept increasing and as newer data became available. One interesting thing that could be done is to date-stamp the data, to show how the flooded area was changing. However, at the time, FEMA's primary concern was the maximum extent of the flooding. Sources of the flooded areas data included data that were digitized from Corps and U2 imagery, as well as polygons generated by a Thermal InfraRed Observation Satellite (TIROS). The TIROS data are collected by daily satellite passes as raster imagery, which must be georeferenced, interpreted, and vectorized. The images were analyzed to separate the water cover from the drier land.

The TIROS data were very "blocky" looking because of the resolution and pixel size of the raster imagery and the size of the grid cells that were used. In addition, on many days the cloud cover was so extensive that the ground was obscured too much to make an evaluation of the extent of the flooding. Therefore the TIROS data were augmented with data from other sources. The polygons generated from the TIROS imagery were subsequently combined with the other digital files showing extent of flooding, to make one big flooded-areas polygon. In addition, for certain analysis requests, this flooded-areas polygon was buffered by a given distance to create a new area of concern. For instance, one request was to identify the population at risk of mosquito infestation within 5 miles of the flooding, so the flooded areas were buffered by 5 miles.

This question and other similar ones are answered by using the GIS to overlay the points or roads with the flooded-areas polygon, and then to count the number of features within the area of concern. GISs are very good at doing this task, and the output can be summarized and formatted into a table or report. Thus, FEMA was able to generate reports of all sorts of data within a reasonably short period of time, including the number of acres of land affected by the flooding, the number of miles of different classes of roads that were affected, and the number of bridges, schools, hospitals, etc. affected. These types of data were being requested almost hourly by people preparing situation reports and briefings. This data set acquisition, manipulation, and report generation was going on at a fast and furious pace. In addition, plots showing these data in various combinations and permutations and at various scales were also being output at a comparable pace.

Improved data on the extent of the flooding continued to become available over time. This allowed for more detailed and accurate assessments to be made from all of these data sources that FEMA had collected. The work with the data sets that were gathered has continued to this day, and some of these data are being distributed to emergency planners for their real-time use. Digital photographs were taken of some of the flood-damaged structures and integrated into the GIS data base. This allows people who are remote but need to assess the damage to see the effects of the flooding without getting their feet wet. It also makes for some truly robust GIS applications.

None of the analyses or applications described here is pushing technical boundaries. But they are pushing agencies to work together and communicate and share data. The machines and the people are talking to each other and that is what is really needed. The next step in the evolution of this type of data base is to continue with data acquisition and improvement. The entire United States needs to be covered by all of the data sets that FEMA wants to analyze. Undoubtedly as this happens, the questions people want to answer will grow and the amount of information needed to answer those questions will grow as well. In addition, the location of all of the features to be analyzed will be improved as the data sets evolve.

As digital orthophotos become available for the entire United States, individual structures will be precisely located as point features, and attribute data can be attached to them. The U.S. Geological Survey plans to have Digital Orthophoto Quarter Quads available for the entire country within five years. These raster images will be used for locating point, line, and polygon vector features with a great deal of accuracy. Census data could be attached to each house location in the United States in a massive data base (or series of data bases). Roads, bridges, flood control structures, etc. could be equally precisely located and attributes attached. As the use of global positioning systems increases, field data will also be transmitted back to the master data bases for continuous updates.

FEMA's data base is not at this level of precision yet, but a wonderful start has been made, and through the collective efforts of many players, it will keep growing.

USING GPS/GIS TO INVENTORY DAMAGED STRUCTURES

Eric Berman
Federal Emergency Management Agency

Introduction

The Great Flood of 1993 caused catastrophic damages to the Midwest. Four hundred and twenty five counties in nine states were declared disaster areas by the President of the United States. What made this disaster different was the geographic size and the duration of the area that was affected. In earthquakes and hurricanes, the area that is usually affected is only a few counties at most and the event is over in hours. This flood lasted for months. This may not have been the most costly disaster but the area it covered was one of the largest areas that was ever handled by this agency.

Problem

The Federal Emergency Management Agency's (FEMA) role is not limited to disaster assistance. The Federal Insurance Administration (FIA) is also a part of FEMA and one program under the FIA is the National Flood Insurance Program (NFIP). For a community to participate in the NFIP it must adopt sound floodplain management principles. This essentially means that the community does not allow any new development or substantial improvement in the floodplain.

With the great number of damaged structures after the 1993 flood, many communities were overburdened with requests for building permits and pressured by citizens to start getting their lives back to a pre-disaster state. To assist them with this, an inventory of potential substantially damaged structures was developed by FEMA.

Method

The old way to develop this inventory was to have teams of trained floodplain management personal drive the floodplain in automobiles. A list of the addresses for structures they believed to be substantially damaged would be developed. This tabular list than could be placed in a database for easier management and the product was then presented to the community.

With this disaster a new way of developing an inventory was implemented. Using new technologies, not just a tabular list but also mapping and digital photos were developed for the Mississippi River area within the State of Illinois.

The need to have teams in the field to collect this data had not changed but the team members and the equipment had. Now each team consisted of an information specialist from GeoResearch, Inc. of Billings, Montana, and a general adjuster from the NFIP. Teams were equipped with a Global Positioning System (GPS) receiver to georeference each location. Also, information about the structure was recorded for each location on a lap-top computer. Each team also had a digital camera to capture a photographic image of each structure. These images were then added to the database of location information.

After this information was collected it was downloaded into a geographical information system (GIS) at the Rock Island District of the U.S. Army Corps Of Engineers. The data were then combined with other geographic features to develop other products.

Products

The main products developed from the inventory were maps, data sheets, and a database. A map was developed for each county along the Mississippi River and smaller scale maps were also produced for every incorporated community within the county. The map not only showed the location of the inventoried structures but also their relationship to the floodplain. This application demonstrates the use of GIS technology at showing how different types of data can be related to each other.

Another product was the observation data sheet. Each data sheet is comprised of three elements; a location map, the observed data, and a digital image of the structure. The location map shows the general area with a square for the location of the structure. With the location map the coordinates of the structure were also shown. This gives anyone the ability to locate the structure in the field using a GPS receiver. The observed data consists of the following; location (street address, city, county), depth of flooding, type of use, displaced from foundation, number of stories, and type of construction. The final part of the data sheet was the digital image. This image was probably the most effective in getting the message across to the local official. A byproduct of the data collection is a database of damaged structures. This database is now being used as a base for the mitigation projects database for Illinois.

Conclusion

The goal of this project was to help local officials in administering their floodplain ordinances. This was proven on August 26, 1993. The *Quad City Times* had an article on rebuilding after the flood. One of the pictures had a building inspector using an observation data sheet with a home owner to help in the determination of substantial damage. This shows that the product was being used and was helpful to the local official.