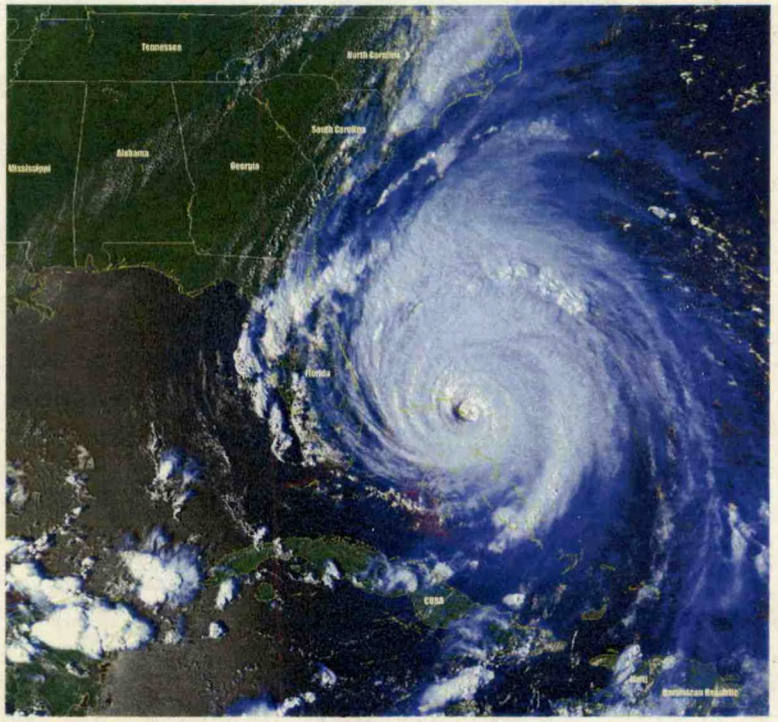
Lessons Learned Regarding the Use of Spatial Data and Geographic Information Systems (GIS) During Hurricane Floyd



NOAA Coastal Services Center
LINKING PEOPLE,INFORMATION, AND TECHNOLOGY

For additional information, contact
Russell Jackson, Coastal Hazards Specialist
NOAA Coastal Services Center
2234 South Hobson Avenue
Charleston, SC 29405-2413
(843) 740-1188
www.csc.noaa.gov
Russell.Jackson@noaa.gov

Citation: U.S. National Oceanic and Atmospheric Administration. Coastal Services Center. 2001. *Lessons Learned Regarding the Use of Spatial Data and Geographic Information Systems (GIS) During Hurricane Floyd.* NOAA/CSC/20119-PUB. Charleston, SC: NOAA Coastal Services Center.

LESSONS LEARNED REGARDING THE USE OF SPATIAL DATA AND GEOGRAPHIC INFORMATION SYSTEMS (GIS) DURING HURRICANE FLOYD

TABLE OF CONTENTS

List of Figures

LESSONS LEARNED

THE USE OF SPATIAL DATA AND GEOGRAPHIC INFORMATION SYSTEMS (GIS) DURING HURRICANE FLOYD RESPONSE AND RECOVERY EFFORTS

EXECUTIVE SUMMARY

Hurricane Floyd, which made landfall along the North Carolina coast on September 15, 1999, was a devastating and tragic event. The massive size and strength of the storm, combined with significant rainfall, caused federal, state, and local emergency management personnel along the entire east coast of the United States to prepare, respond, and, if necessary, recover from the effects of Hurricane Floyd. The response and recovery activities associated with the storm highlight how advances in technology have enhanced the ability to deal with disasters.

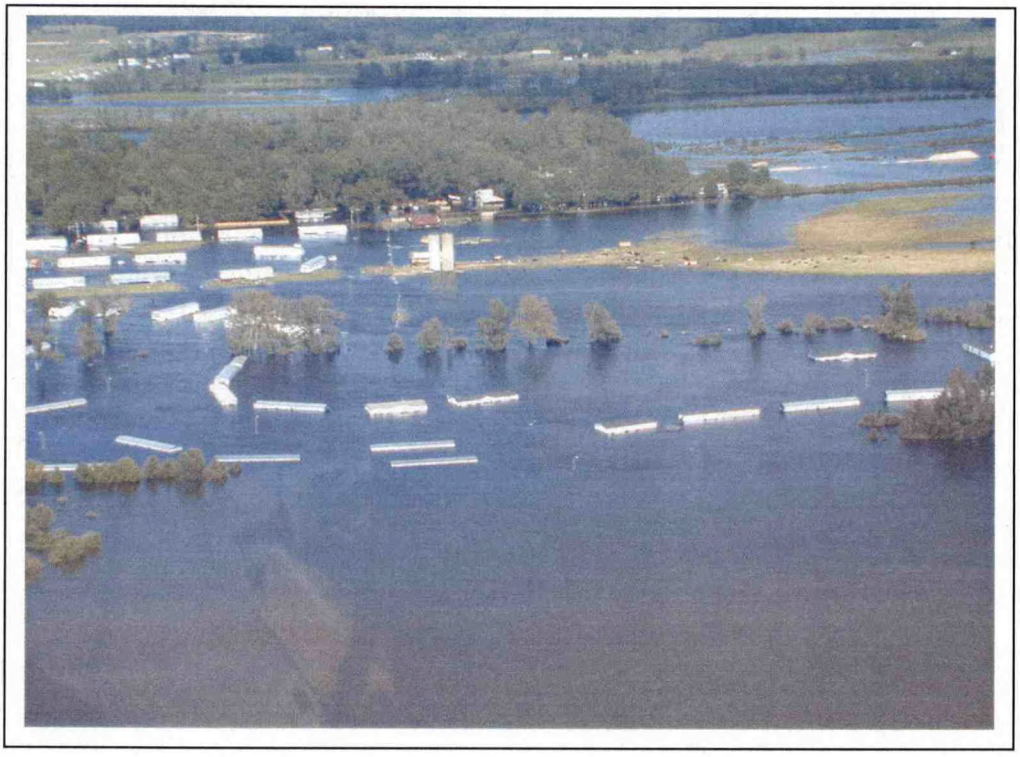


Figure 1. Hurricane Floyd-Related Flood Inundation, (FEMA)

The hurricane response efforts at the federal, state, and local levels for Hurricane Floyd were the first to rely heavily on spatial data and geographic information systems (GIS) technology. Compared to previous hurricanes, many of these response and recovery efforts were carried out more effectively and efficiently through the use of these tools. Many of the preparedness activities, such as forecasting potential flood inundation areas and disseminating forecasts, hinged on GIS and the use of Internet mapping applications. GIS was also used to monitor and track real-time road conditions and damage locations to ensure that responders could quickly be routed to areas in most need of assistance. During the long-term recovery phase, satellite imagery was combined with the Federal Emergency Management Agency's National Flood Insurance Program Digital Flood Insurance Rate Maps and analyzed with GIS to assist with the

largest Hazard Mitigation Buyout Program in U.S. history. The "lessons learned" from these and many other successful uses of spatial data and GIS during Floyd are summarized in this report.

The use of spatial data and GIS during Hurricane Floyd response and recovery activities also helped to uncover many issues and areas of concern. Some of the issues were related to hardware and software limitations, such as the lack of proper equipment and storage capacity to handle large spatial data sets. Interoperability issues arose when trying to share data between various levels of government. Other areas of concern related to data availability, data limitations, and data acquisition requirements. For example, proper procedures were lacking for collecting and incorporating damage assessment data into the National Emergency Management Information System database, which would have ensured easy conversion into GIS. Some other areas of concern arose when new data sources were utilized for the first time or when existing data sources were used in new ways. The use of satellite imagery for the first time to map the extent of flood inundation associated with Hurricane Floyd raised many data acquisition and accuracy issues.

Several articles, assessments, and "lessons learned" papers have been produced to document the operational practices of the response and recovery efforts of the emergency management community during Hurricane Floyd. For example, an assessment of the evacuation effort has been produced in a Federal Emergency Management Agency and U.S. Army Corps of Engineers publication entitled "Hurricane Evacuation Study Program: Status Report on Lessons Learned." The National Weather Service (NWS), a line office of the National Oceanic and Atmospheric Administration, has produced a report entitled "Service Assessment: Hurricane Floyd Floods of September 1999" to document how NWS forecasts and products assisted in the response efforts. Several other documents have also been produced at the state and local levels. This publication focuses specifically on how the use of spatial data and GIS was, and continues to be, a tremendous asset in the response and recovery efforts. While this report highlights numerous positive aspects about the use of spatial data and GIS, it also identifies some of the problems encountered.

BRIEF HURRICANE FLOYD OVERVIEW

Hurricane Floyd made landfall along the North Carolina coast the morning of September 15, 1999. The storm, with its massive size and strength, combined with the significant rainfall it produced, impacted the majority of the East Coast of the United States from September 14 to 17, 1999. Major river and urban flooding was the result of torrential rains from the Carolinas to New England. Flood damage estimates range from $4.5 billion to over $6 billion. There were 56 deaths directly attributed to Floyd, 91 percent of which were flood related. The hurricane forecast track resulted in the evacuation of nearly three million people from the coastal areas of Florida, Georgia, South Carolina, and North Carolina.

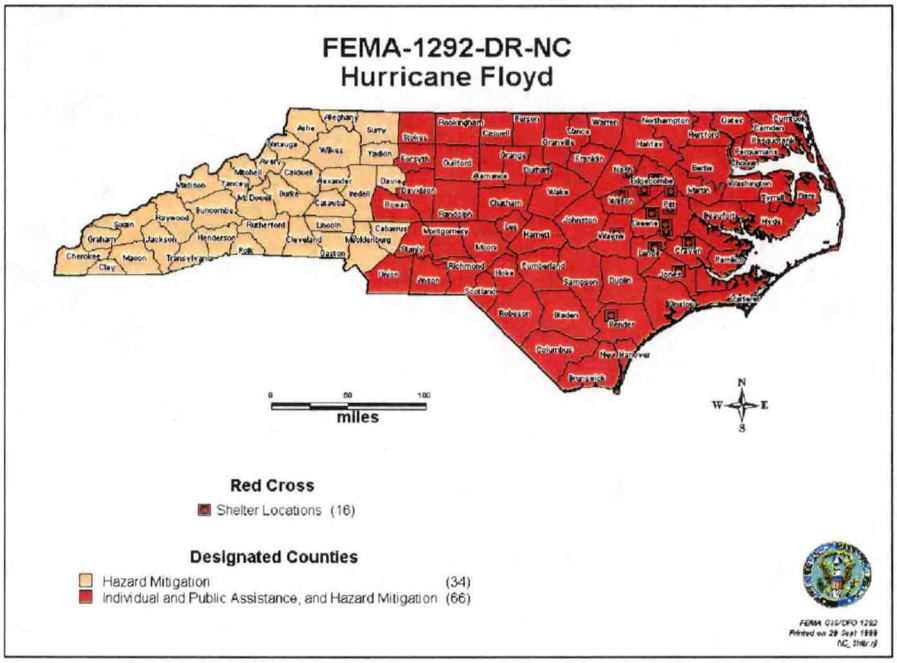


Figure 2. Presidentially Designated Counties in North Carolina

Hurricane Floyd caused damages throughout the entire eastern seaboard. Significant erosion was experienced in Florida and the Carolinas, high winds impacted the Carolinas, and torrential rains caused flood inundation and flash flood problems from northeast South Carolina through eastern North Carolina, eastern Virginia, eastern Maryland, Delaware, eastern Pennsylvania, New Jersey, eastern New York, and parts of the coastal New England states. The most substantial damages occurred in eastern North Carolina. The widespread inland flooding and coastal damages experienced in North Carolina led to loss of life; destruction of personal property, businesses, infrastructure, livestock, and crops; and disruption of commerce and tourism.

North Carolina has had its share of hurricanes and tropical storms. Since 1995 portions of North Carolina have been impacted by a total of seven hurricanes/tropical storms (Tropical Storms Josephine and Opal, and Hurricanes Bertha, Fran, Bonnie, Dennis, and Floyd), causing billions of dollars in economic and environmental damages. Hurricane Floyd is the worst natural disaster in North Carolina's recorded history; the storm brought as much as 22 inches of rain to some locations. Combined with rains from Hurricane Dennis just weeks earlier and post-hurricane rains, Floyd caused unprecedented

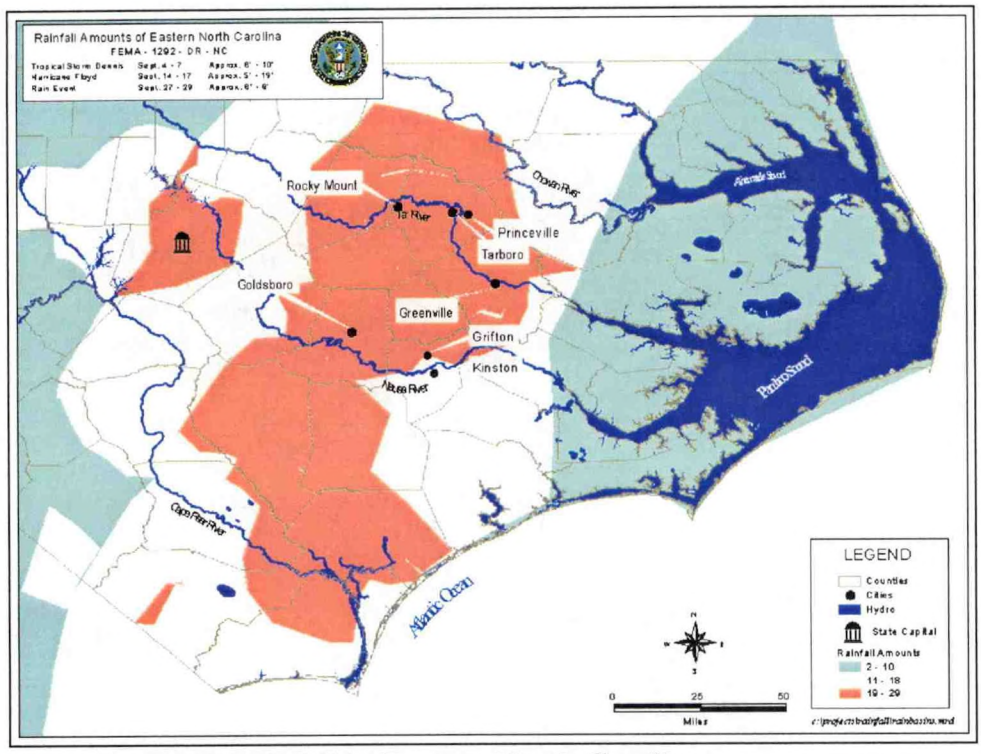


Figure 3. Total Rainfall in Eastern North Carolina

flooding in central and eastern North Carolina. River crests were observed as much as 24 feet above flood stage. Sixty-six of North Carolina's 100 counties received a Presidential Disaster Declaration due to the unprecedented flooding. Much of the damages occurred in economically distressed counties in the eastern portion of the state. Many communities were isolated, water systems were contaminated, and more than one million individuals were left without electricity. Contaminated flood waters containing raw sewage, pesticides, agricultural wastes, and dead farm animals hampered rescue efforts and resulted in the condemnation of thousands of homes.

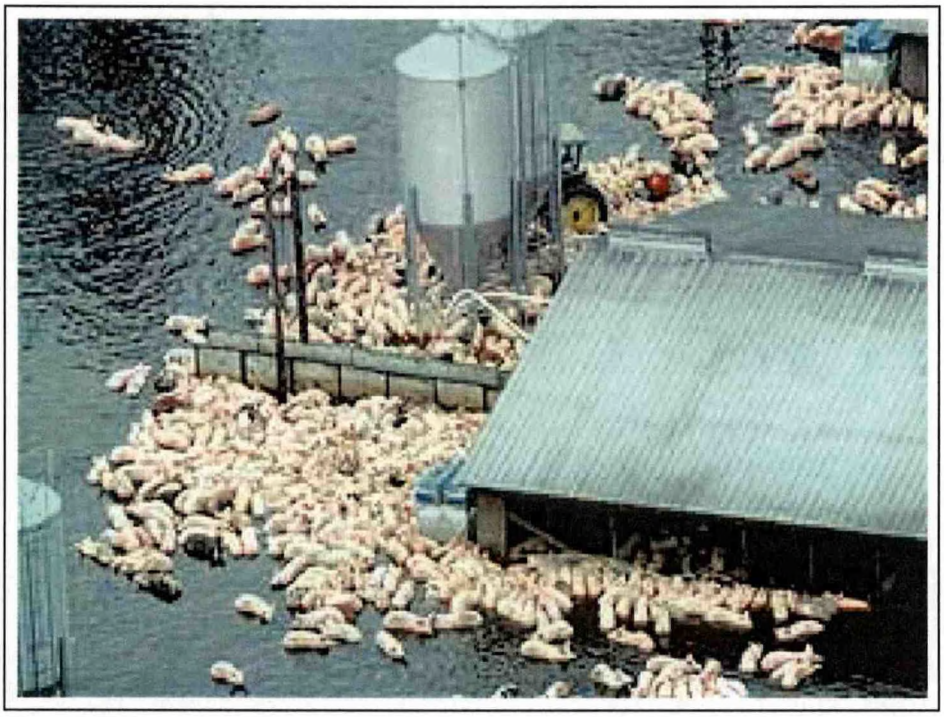


Figure 4. Hog Farm Impacted by Hurricane Floyd-Related Flood Inundation (FEMA)

Although Floyd was a devastating and tragic event, the response and recovery activities associated with it highlight how advances in technology have enhanced the ability to deal with disasters. When compared to previous hurricanes, many of the response and recovery efforts at the federal, state, and local levels associated with Floyd were carried out more effectively and efficiently through the use of spatial data and geographic information systems (GIS) technology.

SPATIAL DATA AND GIS USE AT THE FEDERAL LEVEL DURING HURRICANE FLOYD

FEDERAL EMERGENCY MANAGEMENT AGENCY

Most disasters and emergencies are handled by local and state responders. The federal government provides assistance when a major disaster or emergency overwhelms the ability of state and local governments to respond effectively to save lives; protect public health, safety, and property; and restore their communities. The Federal Response Plan outlines how the Federal Emergency Management Agency (FEMA), acting through the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended, coordinates the delivery of federal disaster assistance to state and local governments. The majority of the examples highlighted will focus on the use of spatial data and geographic information systems (GIS) at FEMA Region IV's Regional Operations Center in Atlanta, Georgia, and the Disaster Field Office in Raleigh, North Carolina.

The Regional Operations Center, managed by FEMA and staffed by other federal agency representatives, was responsible for coordinating the federal response efforts during the early stages of the Hurricane Floyd disaster. Among other things, it handled prepositioning and delivery of response and recovery supplies, assisted with initial damage assessments, and established disaster recovery centers. Once the Disaster Field Office was established, it was responsible for coordinating and providing necessary assistance directly to state officials.

The Regional Operations Center was opened on August 26, 1999, to respond to Hurricane Dennis and, due to Hurricane Floyd, remained continuously opened until September 21, 1999. Spatial data and GIS were used to assist the operations center's decision makers; however, as noted by observers from the U.S. Army Corps of Engineers (USACE) and the National Oceanic and Atmospheric Administration (NOAA), the use was somewhat limited during the response phase. USACE was tasked by FEMA to observe and make suggestions for improvement of GIS use at the operations center during Hurricane Dennis, and NOAA was given a similar task related to Hurricane Floyd. Based on their observations, the limited use was likely due to the lack of knowledge by Regional Operations Center personnel of the capabilities of GIS, the limited GIS staff, and non–user friendly data organization.

The GIS personnel provided support to the Regional Operations Center decision makers by providing products such as maps depicting storm track forecasts, precipitation forecasts, real-time river gauge data, forecasts of river peak crest elevations and locations, critical transportation routes, and demographic distribution data. Several of the beneficial uses of spatial data and GIS by FEMA are highlighted in the following sections. However, there are numerous other instances where GIS and spatial data were utilized to enhance the federal response and recovery efforts coordinated through FEMA. **Appendix A** contains some of the other GIS products produced by FEMA, as well as descriptions of how each product was utilized by decision makers.

FEMA Disaster Recovery Center Locations

One of the examples of the beneficial use of GIS by the Regional Operations Center included the utilization of data sets from various sources to provide an estimate of significant damage impact areas through predictive modeling. GIS personnel used flood forecast maps and cumulative rainfall maps to identify the areas most likely to experience flood inundation problems. These maps, produced by the NOAA Southeast River Forecast Center (SERFC), included precipitation from Hurricanes Dennis and Floyd, and the storm event of September 27-29. Spatial analysis of this information, combined with

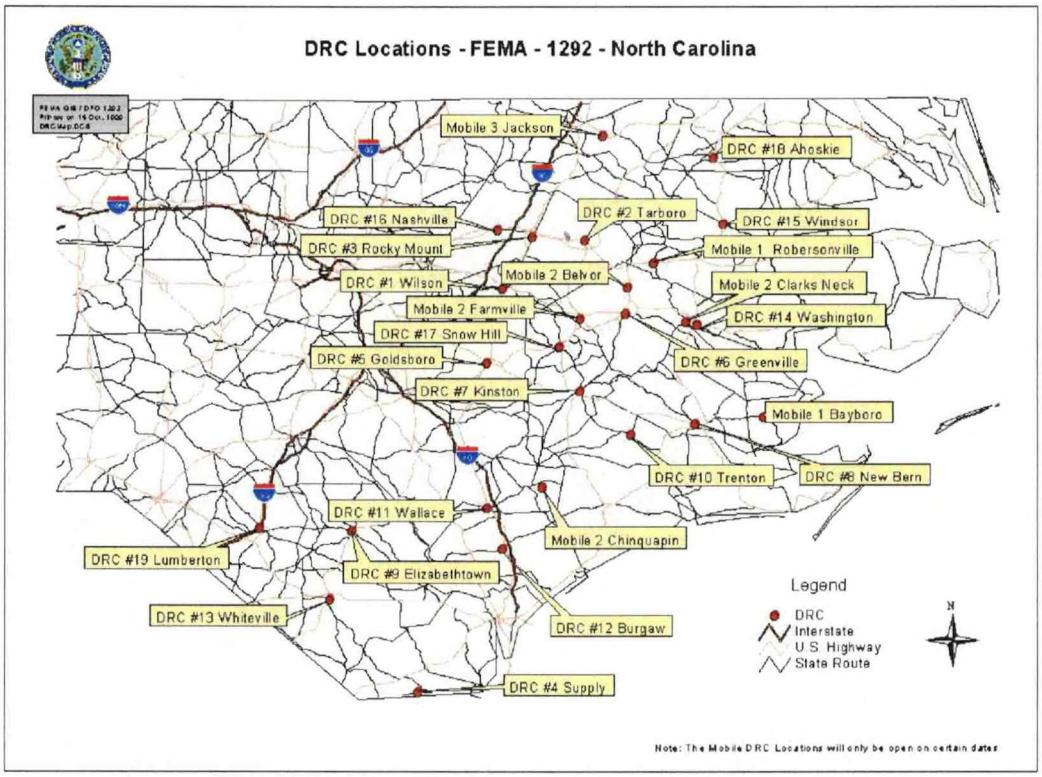


Figure 5. FEMA Disaster Recovery Center Location Map

demographic data, road network data, critical facilities, infrastructure, and emergency shelter locations helped Regional Operations Center decision makers locate 23 Disaster Recovery Centers. The location of these recovery centers was critical to ensure that federal emergency supplies and resources would be able to reach the impacted areas in the most efficient manner. Using GIS for this function was a simple task, but a vital step to ensure the success of the long-term recovery process.

FEMA Emergency Support Functions

The Federal Response Plan organizes the Regional Operations Center into 12 Emergency Support Functions. Each function is headed by a primary federal or nonprofit agency designated on the basis of its authorities, resources, and capabilities. These Emergency Support Functions support one another in carrying out their respective missions. In fact, many of the areas relied on spatial data and GIS analysis provided by the operations center GIS staff, which is a part of Emergency Support Function 5, Information and Planning.

Emergency Support Function 11, Food, which is headed by the U.S. Department of Agriculture (USDA) used GIS products to identify low income areas likely to be impacted by Hurricane Floyd. This information was utilized to plan in advance where it would need to provide emergency food stamps and assistance to the federal/state social services program known as the Women, Infants, and Children program.

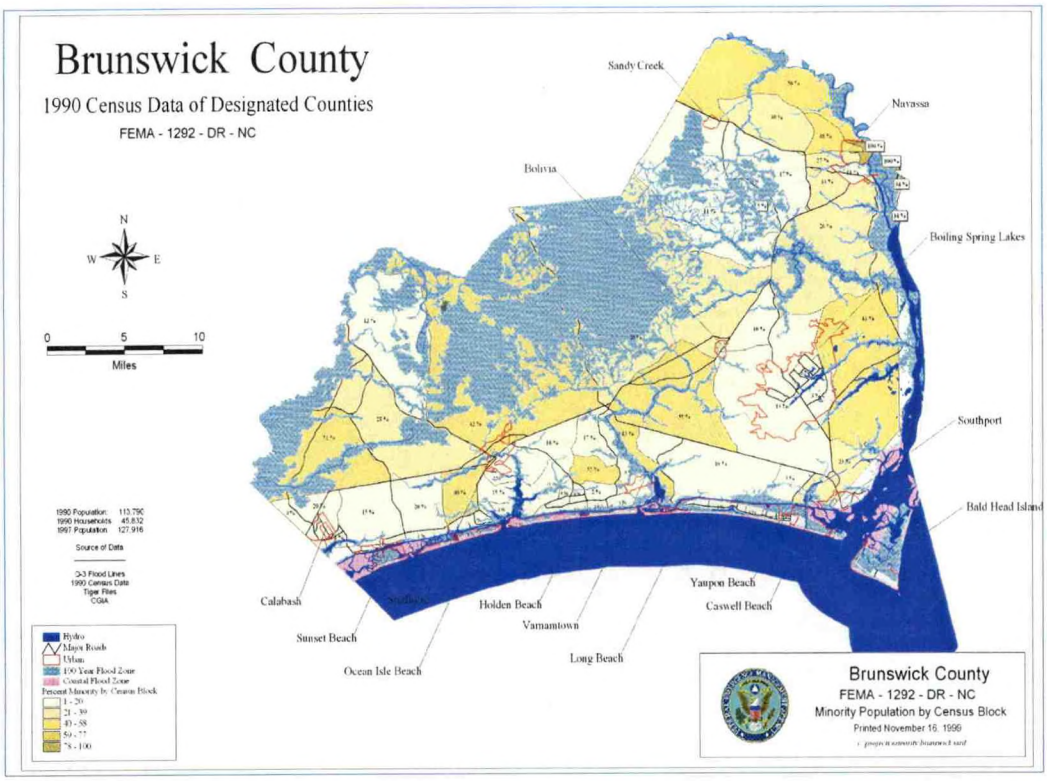


Figure 6. Demographic Data of a County Impacted by Hurricane Floyd

The Red Cross, which heads Emergency Support Function 6, Mass Care, used GIS to assist with its transportation planning needs. Personnel identified potential transportation issues by analyzing shelter locations in relation to population distribution data, elderly care facilities, and road status data.

FEMA Use of Real-Time Traffic Data

Emergency Support Function 1, Transportation, headed by the U.S. Department of Transportation (US DOT), provided real-time highway evacuation status data to GIS personnel within Emergency Support Function 5, Information and Planning. This information was then provided to the Regional Operation Center's operations manager and other support functions for use in their planning and decision-making processes. Issues such as traffic flow conditions on major evacuation routes, or roads being impassible due to flood inundation or debris, were addressed utilizing US DOT information combined with other data sets within the GIS.

The ability to update and analyze real-time road conditions in a digital environment greatly enhanced the ability of the decision makers within the Regional Operations Center to distribute emergency supplies and resources to the disaster locations from staging areas such as Shaw Air Force Base in Sumter, South Carolina, and Fort Gillem in Atlanta, Georgia. Initially, a significant amount of the data came in handwritten format, for example, the South Carolina road status data. This data had to be converted into digital format by GIS staff. Later they used a North Carolina Department of Transportation (NC DOT) Internet site to monitor road conditions within the heavily impacted areas of North Carolina. The NC DOT Internet site provided real-time data through the use of an application that allowed map or text querying. Data from NC DOT could be imported directly into the FEMA GIS for analysis, which substantially enhanced the operation center's ability to make timely and accurate decisions.

FEMA Flood Inundation Mapping Using Satellite Imagery

Early in the recovery phase it was critical for FEMA to have an idea of the extent of flood inundation associated with Hurricane Floyd. For the first time, FEMA utilized satellite imagery timed to coincide with peak flood stages to map the extent of flood inundation. The flood extent maps were utilized to help prioritize recovery efforts and to identify areas eligible for potential mitigation measures.

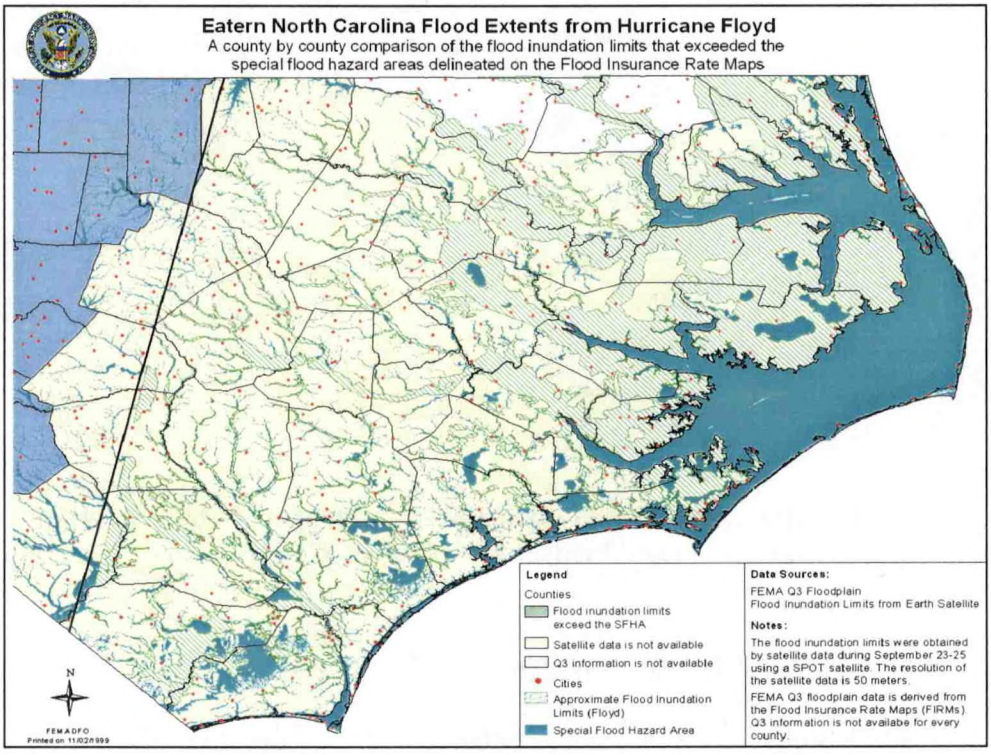


Figure 7. Comparison of Flood Extent Data Interpreted from Satellite Imagery and the FEMA Flood Insurance Rate Maps

For many areas throughout North Carolina, the Flood Insurance Rate Maps (FIRM), which define the 100- and 500-year floodplains, are 10 to 20 years old. Rapid growth and development throughout much of the state have caused the floodplains to change over the years. The flood extent maps enabled FEMA to identify areas outside the currently defined 100- and 500-year floodplains that had experienced inundation problems. These areas could be analyzed through hindcast models to evaluate exactly what frequency of storm event had occurred at each area in question. Through GIS analysis, FEMA identified locations where inundation had occurred outside of the FIRM-defined floodplain and where the frequency of storm event had not exceeded either the 100- or 500-year storm. This analysis helped to identify potential deficiencies in the existing FIRMs.

The acknowledgment of deficiencies in the FIRMs was critical for long-term mitigation activities. Due to flood-related damages from Hurricane Floyd, FEMA is currently working with North Carolina on the largest Hazard Mitigation Buyout Program in U.S. history. For a flood-damaged property to be eligible for the buyout program, it must be located within the floodplain. Numerous properties impacted by the flooding were located outside of the FIRM-defined floodplain. The acknowledgment of deficiencies with the FIRMs was justification to include many of these properties in the buyout program.

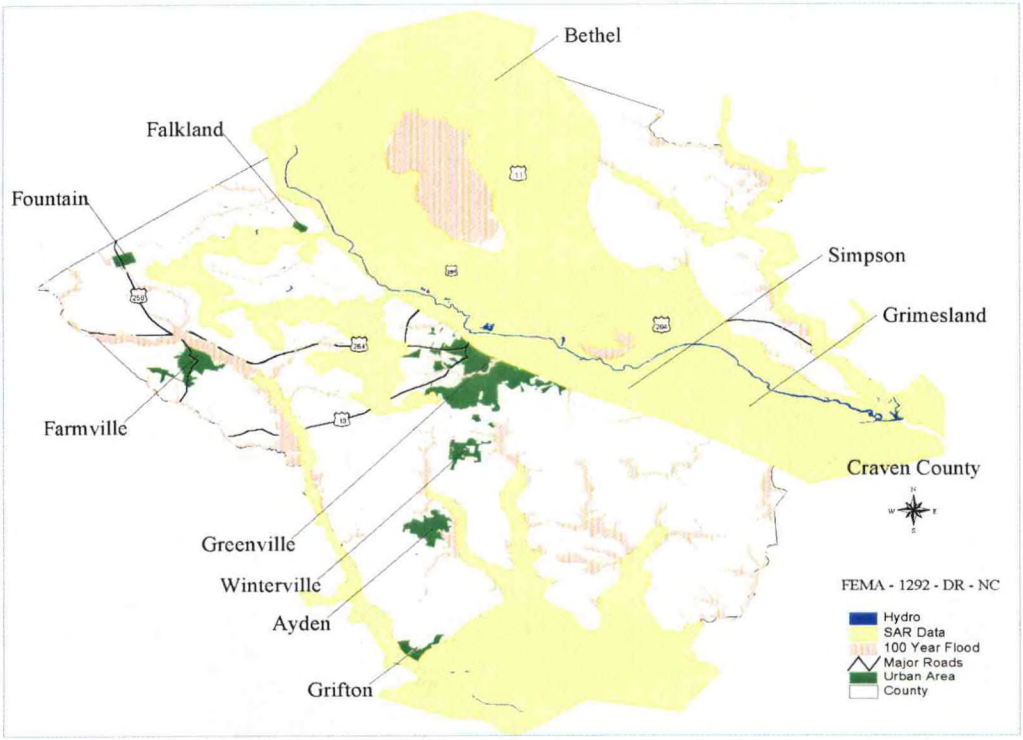


Figure 8. Comparison of Flood Extent Data Interpreted from Satellite Imagery and the 100-Year Floodplain in Craven County, North Carolina

FEMA Use of the National Emergency Management Information System

For the first time since its implementation, the National Emergency Management Information System (NEMIS) was utilized as a source for creating real-time GIS disaster products. NEMIS is a FEMA-wide system of hardware, software, telecommunications, and applications that provides a new technology base to FEMA and its partners to carry out emergency management efforts. NEMIS expedites disaster response and recovery activities by providing standard workflow procedures, automated business processes, and an enterprise database (a network of distributed databases across different computing platforms) that allows personnel at different locations to use and share data. Various elements of the enterprise database are stored in formats that enable easy export to GIS.

As damage assessment data were compiled they were entered into the NEMIS system using a standardized format. The housing damage entries contained several data fields that were very useful for enhancing the response and recovery efforts through the use of GIS. Since each entry contained either a street address or location coordinates obtained with Global Positioning System instrumentation, the data could be located on a map. Street address locations were linked to a geographic location through the process of address geocoding. Geocoding is a process of identifying a location by one or more latitude and longitude coordinates from another location description such as an address. Once each NEMIS housing damage entry had been linked to a geographic location, beneficial GIS maps could be created through spatial analysis of the other data fields.

The housing damage information entries in NEMIS contained a field for describing the magnitude of the damage for each home. To standardize the information, each entry was assigned one of four categories:

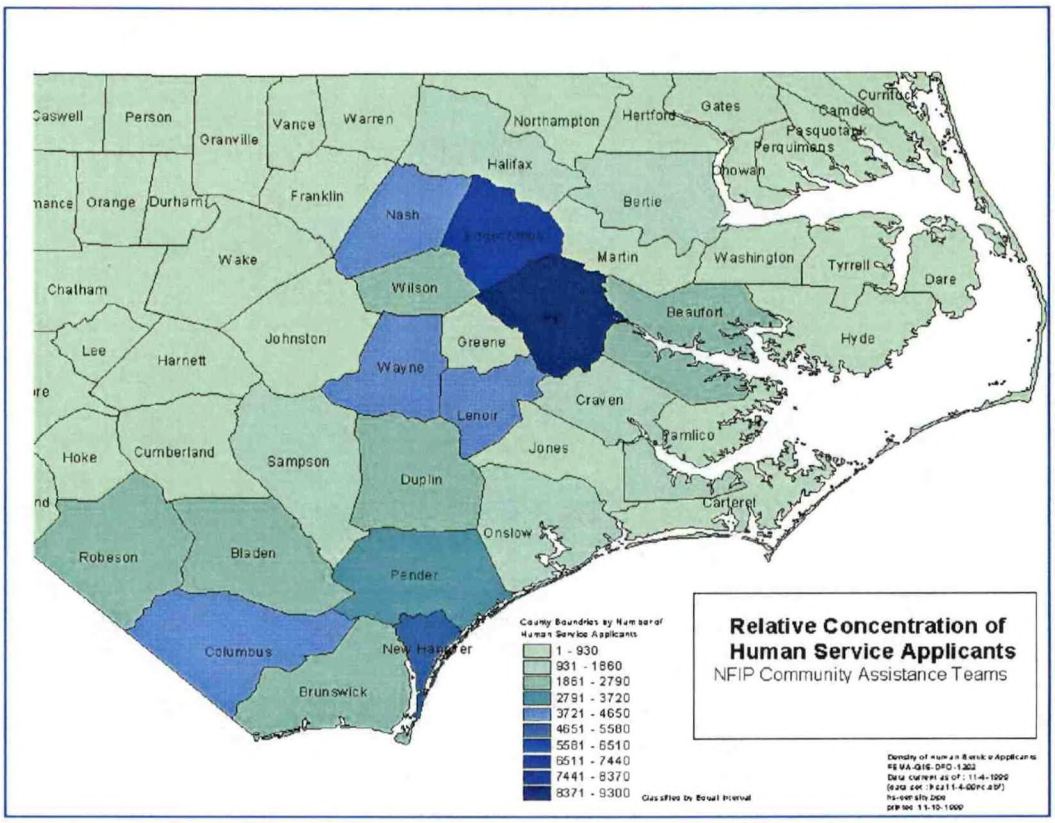


Figure 9. Map of Human Service Applicants from NEMIS

minor, moderate, severe, or destroyed. Using this information, combined with the geographic location, enabled FEMA to create maps depicting substantially damaged buildings. The maps were used to determine and prioritize resource needs such as manpower, temporary housing facilities, and temporary housing assignments. The maps also helped assess the need for buyouts and other hazard mitigation programs, and ultimately helped to determine how much mitigation funding would be needed. Once the buyouts had been determined, the data were used to assist the planning process for demolition operations.

FEMA Temporary Housing Facility Location

The flood inundation caused by Hurricane Floyd left thousands of people homeless in North Carolina. To help alleviate some of the homelessness, FEMA and the State of North Carolina created several temporary housing facilities. Their goal was to locate the facilities as close as possible to the areas most impacted by the flooding. At the same time, they also wanted to locate the facilities outside of the floodplain, away from endangered species habitats, and on soils suitable for development. Spatial analysis enabled them to address all of these issues when considering potential sites. The analysis was accomplished by utilizing a GIS that incorporated the following data sets: floodplain data, endangered species habitat locations, soils type, archeological data, substantial damage locations, land use data, and road network data.

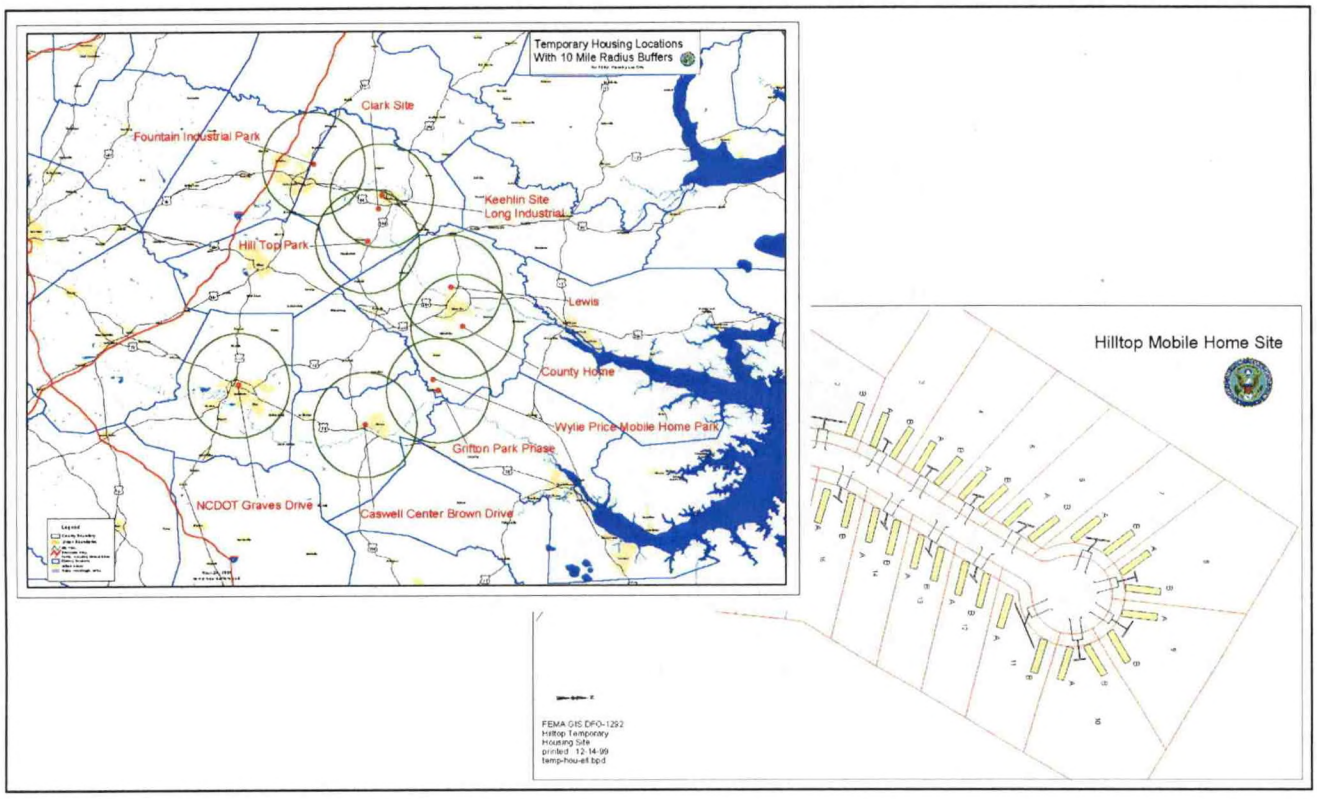


Figure 10. Temporary Housing Facility Maps

U.S. Army Corps of Engineers

After Floyd made landfall, the massive rainfall accompanying it caused the emergency operations to shift quickly from hurricane response to floodfighting. The U.S. Army Corps of Engineers (USACE), under Public Law 84-99, as amended, has authority to conduct flood emergency operations in cooperation with state and local efforts. The following examples demonstrate how the Charleston District of USACE effectively utilized GIS to assist in the flood fight decision-making process in Horry County, South Carolina. Horry County is located along the northeastern coast, along the South Carolina and North Carolina border.

Predictions for river crests significantly above flood stage in Horry County were the result of heavy rains within the county, combined with even greater rains in the upstream portions of the river basins located in North Carolina. Assistance from USACE was requested by the county to help identify potential flood impacts. By identifying locations likely to be impacted, the county and USACE could focus their response and mitigation efforts.

USACE acquired flood height predictions for the Waccamaw River in both Longs and Conway, South Carolina, from the National Oceanic and Atmospheric Administration (NOAA) Southeast River Forecasting Center (SEFRC). SEFRC does not predict floods in the coastal zone where tides influence flooding. Therefore, USACE engineers used GIS platforms to project downstream flooding using terrain slope values. Inundation maps based upon the flood projections were created and used to brief the governor of the state through on-screen digitization, illustrating flood areas on digital US Geological Society (USGS) 24,000-scale, 7.5-minute quadrangle maps in ArcView. ArcView is an off-the-shelf GIS software produced by the Environmental Systems Research Institute (ESRI). The final flood maps

spanned 35 USGS quadrangle sheets (132 square miles) and included flooding on the Lumber, Little Pee Dee, Pee Dee, and Waccamaw Rivers, as well as portions of the Atlantic Intracoastal Waterway.

The flood map data along with general data that included minor and major roads, cities, and hydrography was made available to other federal, state, and local agencies and the general public through the use of an Internet map server, ArcView IMS. The Internet site received over 18,000 hits during floods related to Hurricane Floyd. By utilizing an Internet map server, decision makers and the general public, without GIS software or experience, could access and utilize the data.

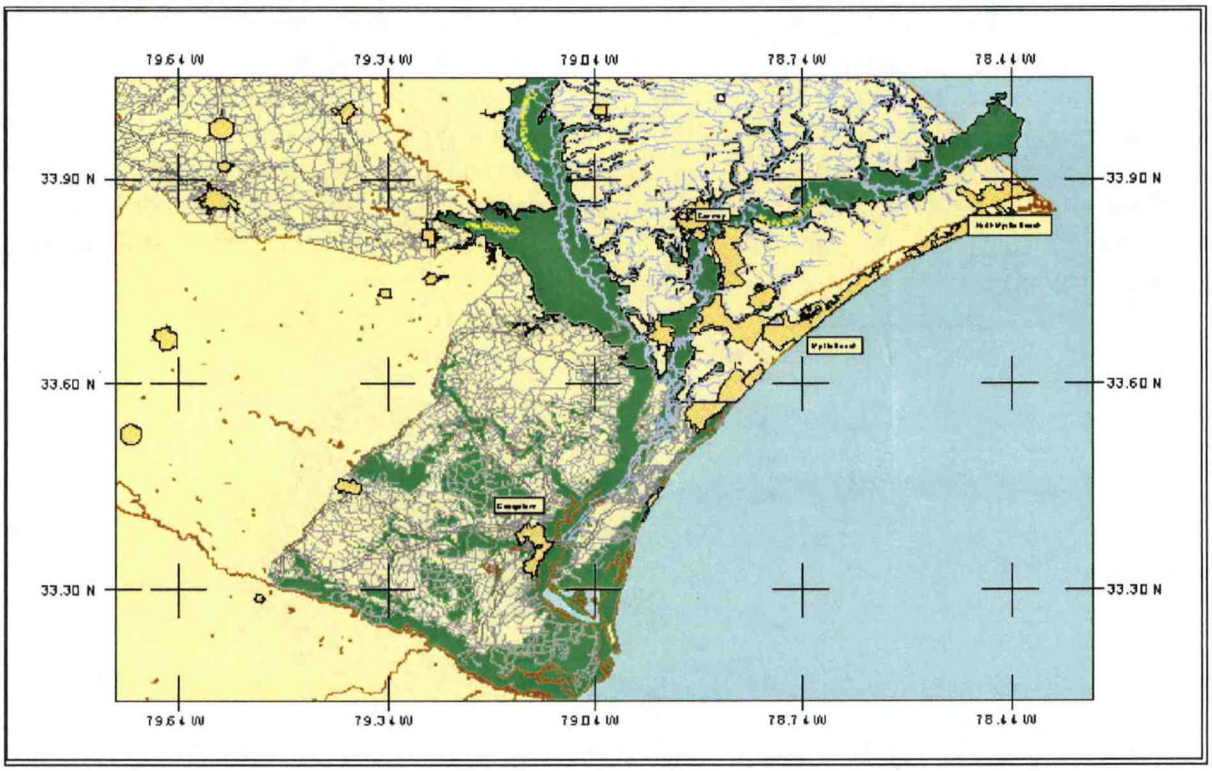


Figure 11. Horry County, South Carolina, Flood Forecast Map Produced by the Charleston District of the U.S. Army Corps of Engineers

The river peaks did not occur until a week after the rains had stopped. Therefore, the maps of the probable flood inundation areas helped decision makers prepare for and lessen the impacts of the flooding. They utilized GIS to combine the flood maps with housing data to identify which areas to evacuate. This helped decrease the number of stranded homeowners once the flooding occurred. It also helped to target search and rescue efforts during the actual flooding. USACE also used GIS to identify critical resources likely to be inundated. This helped them target sandbagging efforts to protect critical resources such as water and sewage treatment facilities. Another significant use of the potential flood inundation map, when combined with other GIS data, was the identification of areas along vital transportation routes where temporary levees would be needed. Based on GIS analysis, USACE and its contractors built temporary levees along portions of US Highways 501 and 9 to ensure that vital access remained available.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION SOUTHEAST RIVER FORECASTING CENTER

The function of the National Oceanic and Atmospheric Administration (NOAA) Southeast River Forecasting Center (SERFC) is to produce timely hydrologic daily forecasts, as well as flood forecasts. In the SERFC area of responsibility, record flooding occurred in the Cape Fear, Chowan, Neuse, Pee Dee, Tar, and Waccamaw River Basins. The hardest hit were the Tar and Neuse River Basins. New record floods were recorded in the Tar River Basin at Louisburg, Rocky Mount, Enfield, Tarboro, and Greenville, North Carolina. Tarboro, Rocky Mount, and Enfield all encountered greater than a 500-year flood event. SERFC forecast products helped numerous federal, state, and local agencies and private industry plan their response activities.

SERFC was very proactive in relaying information to potential users before and during the warning period. As Hurricane Floyd approached the U.S. coast and made its initial landfall, much of the attention was focused on the potential damaging high winds and storm surge. In an attempt to focus additional attention on the inland flood threat, SERFC contacted CNN, The Weather Channel, NOAA National Weather Service Eastern and Southern Region Headquarters, and the FEMA Hurricane Liaison Team. They also initiated daily conference calls in an effort to bring together NOAA Weather Forecast Offices (WFOs), FEMA, USACE, USGS, and Divisions of Emergency Management in North Carolina, South Carolina, and Virginia.

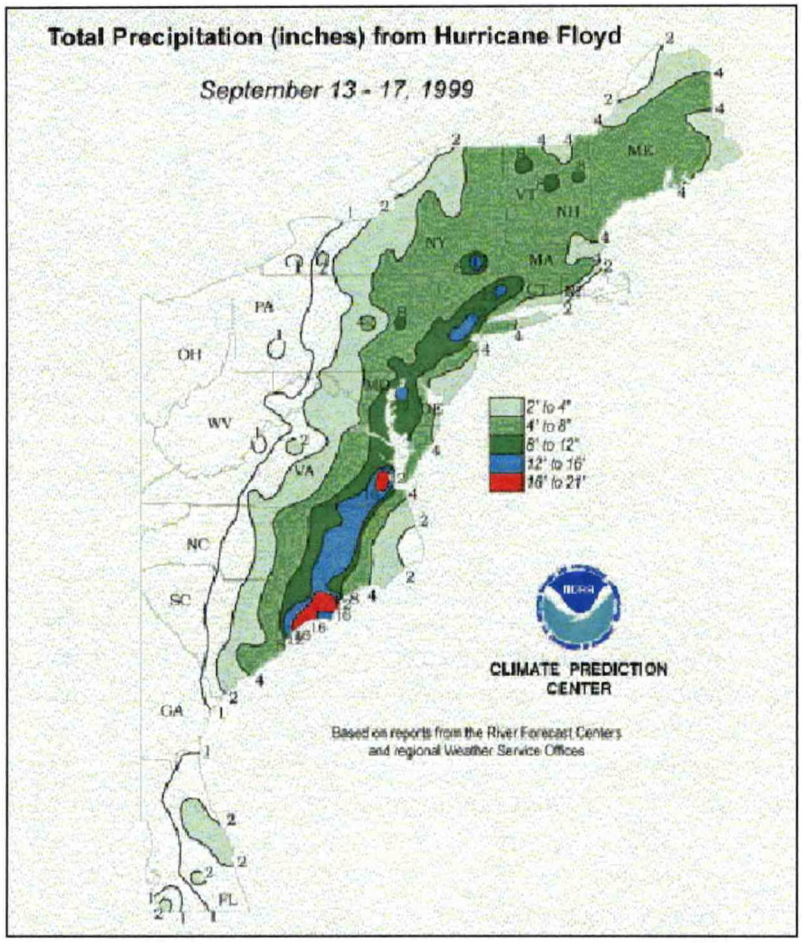


Figure 12. Map of Total Precipitation from Hurricane Floyd Produced by SERFC

SERFC provided information on flood potential through the use of GIS, and produced over 50 graphic depictions of flood potential. The graphics pinpointed the threat of "widespread and major flooding," days in advance of heavy rains. The information that was disseminated via a SERFC Hurricane Floyd Internet site could be downloaded and incorporated into the user communities' GIS. The flood forecast products were well received by customers, especially emergency management personnel within FEMA , USACE, and Horry County, South Carolina.

U.S. Fish and Wildlife Service

Hurricane Floyd caused significant erosion along the coast from Florida to the Carolinas. Since Hurricane Floyd occurred during the sea turtle nesting period, the erosion and any potential response and restoration activities could impact the sea turtle nesting areas along the coast. By having sea turtle nesting areas in its GIS, the U.S. Fish and Wildlife Service could easily and quickly identify any negative impacts of proposed emergency measures and permanent restorative work. This information provided the necessary backup information to disapprove any permit application that would negatively effect the nesting sites.

Issues and Lessons Learned

GIS Capability at the Disaster Field Office

Following Hurricane Floyd, FEMA Headquarters conducted a survey to determine if having full GIS operations physically located at the Disaster Field Office was successful. Based on the survey results, the advantages of having full GIS capability at the field office were as follows:

- Products were produced and delivered faster.
- Interaction with those requesting data resulted in more useful maps. GIS specialists need to discuss what the maps will be used for, what maps are currently available, and the capabilities of GIS mapping, including issues of usefulness and display.
- Real-time data being produced by field office staff could be identified and utilized in GIS mapping.
- It was easier to ascertain what local data (state and local data, educational facility data, state GIS data clearinghouse organizations, etc.) were available, and once identified, it could be obtained quickly.
- Coordination with state personnel was easier, and this coordination provided new and improved avenues for acquiring data. The field office level coordination also provided the opportunity for state staff to learn more about NEMIS and what data were available for their use.
- Interactive work with field personnel was possible and relatively easy via phone or upon their visits to the Disaster Field Office. This often entailed pulling maps up, giving data/answers directly over the phone, and then producing the map for future reference.
- Work with local educators, via hazard mitigation outreach projects, was possible. Disaster Field Office GIS staff provided demonstrations/presentations to magnet schools with GIS programs, and

were able to share data with local and state educational facilities that should prove useful in their teaching curriculum. Several of the educators plan to use the data as the basis for future studies that will provide or improve available data at the state level, as well as enhance GIS capabilities for future disasters.

- Interaction with field office staff created an opportunity to identify disaster planning and disaster field work that could be augmented or improved through GIS mapping. It gave field office staff a chance to learn about GIS and what its capabilities were, or could be through future cooperative efforts between their section and the GIS branch.

- Disaster response and relief funding provided an opportunity to improve GIS capabilities through hardware, software, and data acquisition.

- The opening of Disaster Field Offices provided an opportunity to hire local people/staff, especially college students, who had knowledge of, and skills with, the most current GIS technologies and data. These local hires also had knowledge of local resources and local contacts, which are invaluable.

- Having GIS staff physically located at the field office provided an easy means of coordination with other field office staff regarding available data (and therefore, possible products), especially as new data were acquired.

As previously identified, there were numerous examples illustrating the benefits of using spatial data and GIS by federal agencies to complete their Hurricane Floyd response and recovery missions. However, the response and recovery activities also helped to uncover many of the data limitations, data needs, and areas of improvement related to spatial data and GIS.

Data Availability

- Prior to Hurricane Floyd there was a lack of time spent on planning the development of GIS capability at FEMA Region IV. Therefore, the spatial data housed and available for Regional Operations Center and Disaster Field Office operations lacked organization. In addition, many of the response and recovery activities created new spatial data which added to the clutter. Significant resources were spent researching data availability, locating data, and converting data into usable formats. This created problems for providing timely GIS support.

  - In an effort to improve Regional Operations Center data organization and GIS capabilities, FEMA solicited recommendations from other federal agencies and Dewberry & Davis, its private GIS consultant. The Louisville District of USACE provided some guidance following Hurricane Dennis. The NOAA Coastal Services Center provided additional recommendations following Hurricane Floyd. Dewberry & Davis provided recommendations following both Hurricanes Dennis and Floyd.

  - To address data organization and availability, FEMA GIS staff developed a Data Catalog. The Data Catalog has helped to improve spatial data organization. The Data Catalog contains brief descriptions and thumbnail images of the available data. It can be accessed via the FEMA Intranet, which has helped to enlighten non-GIS operations center and field office personnel of the availability of spatial data.

- The availability of predictive modeling data such as precipitation and flood forecast data from SERFC was virtually unknown to FEMA Region IV prior to Hurricane Floyd. Based on the highly beneficial use of SERFC data, FEMA Region IV has been working to strengthen its relationship with SERFC.

  - The realization that other significant data and modeling tools may also be available from other nontraditional partners has led FEMA Region IV to initiate ongoing efforts to improve collaboration and data dissemination with several other federal agencies. Some of the agencies involved include USACE, NOAA, USGS, and the Environmental Protection Agency (EPA).

  - FEMA Region IV now has more efficient and effective tools through the use of predictive models developed to export data in a GIS format. As a direct result of Hurricane Floyd, a Traffic Demand Forecast Model is being developed to monitor traffic conditions during evacuations throughout Region IV. The results from the model can be directly formatted for use in a GIS.

  - Although not a direct result of Hurricane Floyd, the newest version of HURREVAC 2000, a hurricane decision assistance and planning tool developed by FEMA and USACE to assist emergency management personnel, now has an export feature for GIS.

- Hurricane Floyd provided the means for further development of a pilot "Repetitive Loss Program" put together in Mississippi after Hurricane Georges. Through the use of a contract programmer, FEMA was able to have the program updated to create a seamless link between the GIS software and the database software utilized to track structures that have repetitively suffered losses from flooding, making it a truly interactive program. This step of development was essential and has paved the way for the final step, formatting the program for use in any state. Through this program, hazard mitigation field staff will have an interactive means of accessing and updating information on repetitive flood loss structures, as well as a spatial display of the structure and its surrounding features. All of the program data will be available for GIS manipulation, providing managers with tools for analysis.

Data Acquisition

- For the first time since it's implementation, the National Emergency Management Information System (NEMIS) was utilized as a source of data for real-time GIS disaster products. This created some problems because there are no procedures at FEMA regional or headquarter levels for such data utilization. Headquarters staff lacked guidelines for what data to extract, how to extract it, and even whether it was permissible to provide such data to field personnel. Due to lack of experience and procedures, some of the data that was extracted was not in a format readily useable by GIS. This required GIS staff to spend hours "scrubbing" the data. This had a definite affect on production because of the additional time required to make the data useable.

- Remote sensing data, such as satellite imagery and aerial photography, played an important role in the response and recovery efforts of FEMA. However, the imagery acquisition process highlighted several issues that need to be addressed. Floyd was the first time remote sensing acquisition was done at the FEMA regional level. Acquisition has traditionally been done at the FEMA headquarters level. Deciding where FEMA needed to deploy the satellites or planes for imagery was a critical issue. The following are several questions that needed to be answered. What are the key inputs to making these decisions? Who should provide the input, the Regional Operations Center or FEMA state liaisons?

- *Remote Sensing in Federal Disaster Operations 9321.1-PR,* the standard operating procedures for FEMA, was published in June 1999. The report outlines the policies, procedures, and responsibilities associated with the use of ancillary data to support and facilitate disaster and emergency response operations. It directly supports and is applicable to all federal departments and agencies operating under the Federal Response Plan. Since Hurricane Floyd occurred shortly after the publication date of the report, FEMA Region IV was not familiar with all of the procedures outlined in the document. However, the document should help to guide future acquisition of remote sensing data.

- Initial guidance from the FEMA headquarters remote sensing point-of-contact was to collect 1:10,000 scale remote sensing aerial photos to get 1-foot pixel resolution. When the operations center inquired to the USGS Earth Resources Observation Services Data Center, FEMA's executive agent for the acquisition and coordination of non-National Technical Means and non-Department of Defense aerial and satellite imagery during disaster response operations, they were told that 1-foot pixel resolution was more than what was needed for initial damage assessment and would be too expensive. Thus, they decided to go with 2-foot pixel resolution. These data were good enough for initial damage assessment and were not used for other purposes such as identifying debris quantities. The photography was mostly used as a backdrop and combined with Global Positioning System data from field inspectors to make damage assessments.

- Satellite imagery timed to coincide with peak flood stages was utilized to identify critical flood inundation areas. As previously mentioned, the imagery helped to identify some of the flooding that took place outside of the 100- and 500-year floodplain. While trying to develop an acquisition plan for the satellite imagery, FEMA GIS staff received some initial imagery instructions from FEMA headquarters. The instructions were then augmented by the operations center. Finally, input from the State of North Carolina caused them to amend the imagery needs for a third time. Each time the plans were adjusted they had to change the mission assignment paperwork to reflect the changes in flight paths in a very short turn-around time. Better communication between all parties from the outset could have prevented the confusion and saved some time.

- There was a delay in the use of state data when FEMA first deployed to the Disaster Field Office. Data projections was an issue. Most of the FEMA data were in North American Datum of 1927 latitude/longitude, while data from the state GIS resources such as the NC Center for Geographic Information Analysis and the NC Department of Environment and Natural Resources were in State Plane North American Datum of 1983 feet. Therefore, any data sharing between FEMA and the State of North Carolina required time-consuming data conversions.

Data Limitations

- The satellite imagery used to identify the extent of flood inundation was very beneficial. However, there were some faults and limitations associated with the data. Due to the nature of river flooding, not all segments of the river reached peak flood crests on the same day. Subsequently, not all of the imagery acquired coincided exactly with the flooding for portions of the river basins. As a result, sections in the maps that were produced contained data gaps or erroneous data. Field verifications of the maps proved that the method of utilizing satellite imagery for this purpose was fairly accurate in areas where the imagery and peak flooding coincided. However, in some areas where the imagery date did not match the flood peaks, the full flood extents were underrepresented. Underrepresentation of the flood extents could have a negative impact on the potential for acquiring sufficient disaster

relief funding. Fortunately, field verification data, highlighting the underestimation areas, were utilized to augment initial disaster impact assessments.

- The flood extent data produced by utilizing satellite imagery also had other limitations. The data lacked any information regarding flood depths. Thus, an area identified as "flooded" on the map could mean 1 inch of flooding or 15 feet of flooding. Realizing the limitations of the data and in an effort to fill some of the data gaps, FEMA issued a mission assignment to USACE and USGS to collect and document high water marks. USACE Charleston District worked with USGS to produce a CD-ROM entitled "Hurricane Floyd High Water Marks and Inundation Mapping." The CD-ROM product contained a final report in a PDF format and an ArcView Project. Data on the CD-ROM includes high water mark location information, and inundation maps for the State of South Carolina based on these high water marks. USACE Wilmington District and USGS also produced a similar high water marks report for North Carolina.

- The USACE flood forecast map for Horry County, South Carolina, was produced from the original SERFC forecast. The map was not updated with subsequent SERFC forecasts. The latter forecasts produced by SERFC called for lower peak flood elevations compared to the initial forecast. Thus, the USACE flood forecast map was an overestimation of actual flooding based on preliminary estimates. However, it was still a useful tool to determine areas vulnerable to potential flooding, especially since overestimation of flood potential is preferred to underestimation.

- The flood forecast maps produced by USACE were created utilizing USGS digital elevation model data combined with some site-specific survey data. Utilizing a similar method, ESRI and one of Horry County's contractors later developed a similar map with a higher level of detail. They used preliminary topography captured from orthophotography (2-foot contours) to delineate the inundation areas. Through better coordination regarding data availability and data needs, USACE and Horry County could have initially focused their combined efforts on producing the higher detailed map.

Hardware and Software Limitations

- The GIS server at the Regional Operations Center had only moderate capacity and was somewhat slow.

- Output devices needed to be upgraded. The older plotters housed in the operations center slowed the output process for GIS products. These plotters put pressures on the workstation servers because they were not able to handle the conversion of map data to pixel images. This caused many "out of memory" errors for the plotters. Therefore, personnel had to convert the vector data to raster images on the workstations instead of the plotter doing it on the fly. The new HP1055 plotter, once received, provided a much needed improvement in plotting speed and quality of the product.

- Having a color printer at the operations center and field office that can produce 11x 17 inch prints would increase speed and save resources. A tremendous amount of plotter paper was wasted when producing 11x 17 inch maps.

- The first immediate problem encountered in the Disaster Field Office was related to the GIS hardware. GIS hardware was shipped from the FEMA Central Distribution Center in Mt. Weather, Virginia. All of the five GIS suites available were outdated. Each GIS suite include a server with a 66 Megahertz (MHz) processor, a 2 Gigabyte (GB) hard drive, and 64 Megabytes (MB) of Random Access Memory (RAM); and two workstations with a 90 MHz processor, a 1 GB hard drive, and 32 MB of RAM. The

limitations of the GIS server caused GIS staff to share the Disaster Field Office's regional server which burdened the system.

  - In the field, realizing the limitations of the existing hardware, field office personnel decided on the first day to purchase a new server, two new workstations, and a plotter. The new server had a Pentium III 600 MHz processor with lots of RAM and memory. The new plotter, which wasn't received until November, was an HP1050 Plotter, a high-speed plotter designed for GIS. It was five times faster than the HP750 they initially were using. Later, realizing the need for more workstations, they expanded from five to seven. The workstations were manned by three contractors from Dewberry & Davis, two FEMA GIS contract reservists, and two local hires.

- FEMA's agency-defined GIS platform is MapInfo, which created a problem in sharing data. Some of the data had to be converted or translated before it could be shared, since most of the other federal, state, and local agencies utilize ESRI GIS software.

  - Recognizing this problem, FEMA Region IV ran and created data in both ArcView and MapInfo. However, this required additional manpower by doubling data update times, and it also created storage problems.

Spatial Data and GIS Use at the State Level During Hurricane Floyd

North Carolina Division of Emergency Management

In 1996 Hurricanes Bertha & Fran caused significant damage to North Carolina. At that time the North Carolina Division of Emergency Management (NC DEM) had no geographic information systems (GIS) capability. Following the Hurricane Fran response and recovery activities, NC DEM realized the potential benefits of utilizing spatial data and GIS to enhance its capabilities. As a result the Technical Services Branch was created. The State of North Carolina has an abundant amount of spatial data available from several state agencies, such as the North Carolina Department of Transportation, the North Carolina Department of Environment and Natural Resources, and the North Carolina Center for Geographic Information and Analysis. The Technical Services Branch has the ability to tap these agencies and other federal and local agencies to acquire and share spatial data.

During the early response phase NC DEM relied mainly on the Technical Services Branch for all of its GIS needs. Once the Disaster Field Office was established, NC DEM utilized spatial data and GIS products produced by both the state and FEMA. The field office was staffed by both the state and FEMA personnel. NC DEM utilized many of the same GIS products previously identified in FEMA's GIS-use section. There are numerous examples of how GIS was utilized to enhance NC DEM's ability to respond to and recover from the impacts of Hurricane Floyd. However, this section will only focus on a few cases.

One of the most significant uses of GIS from the State of North Carolina's perspective was the ability to rapidly portray damage information to legislative officials. The ability to graphically display the magnitude of impact greatly enhanced the disaster assistance request package. The Information and Planning Section of NC DEM prepared a report describing the impacts of the storm, which was sent to the legislature along with its request for disaster assistance funds. The report contained three pages of text and 15 GIS maps. Don Heard, manager of the Technical Services Branch, believes the maps contained in

the report were "significant in the acquisition of disaster recovery funds." To date, $836 million in state funds and $2.2 billion in federal funds have been appropriated for disaster recovery.

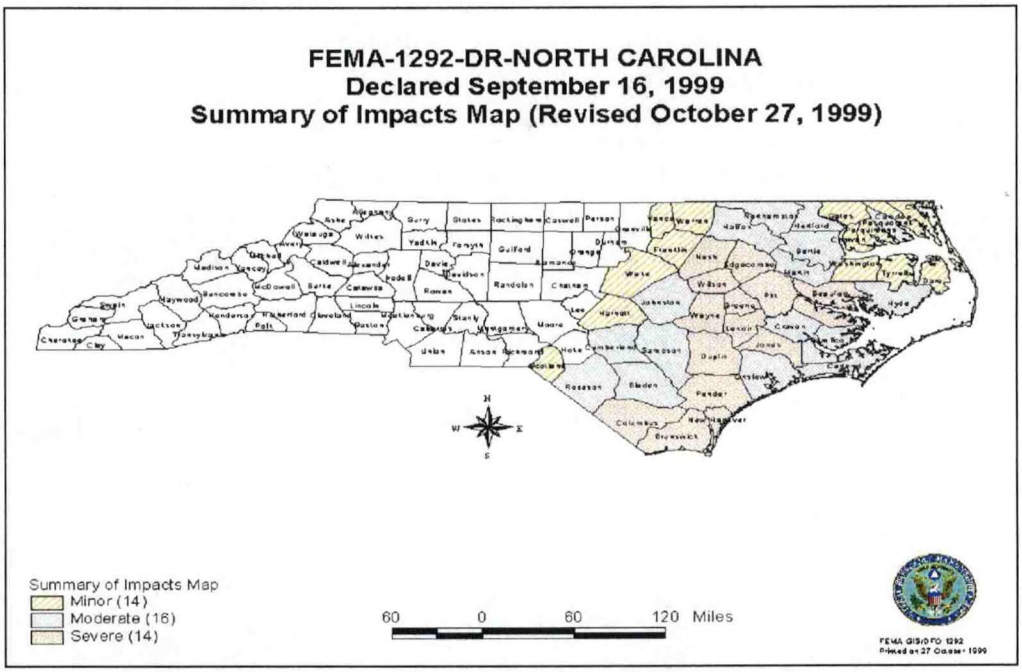


Figure 13. Map of Disaster Impacts in North Carolina

As previously mentioned, the use of NEMIS by FEMA greatly enhanced the efficiency of the federal response and recovery efforts. The use of spatial data from NEMIS was also very beneficial for NC DEM efforts. Before damage assessments were completed by field personnel, NC DEM relied on data from NEMIS to assist in the identification of damage areas. Many of the initial damage claims data in NEMIS were obtained from residents calling the National Tele-registration System to report flooding and flood-related damage. This information was used to prioritize search and rescue efforts, allocate resources, and to target mitigation efforts.

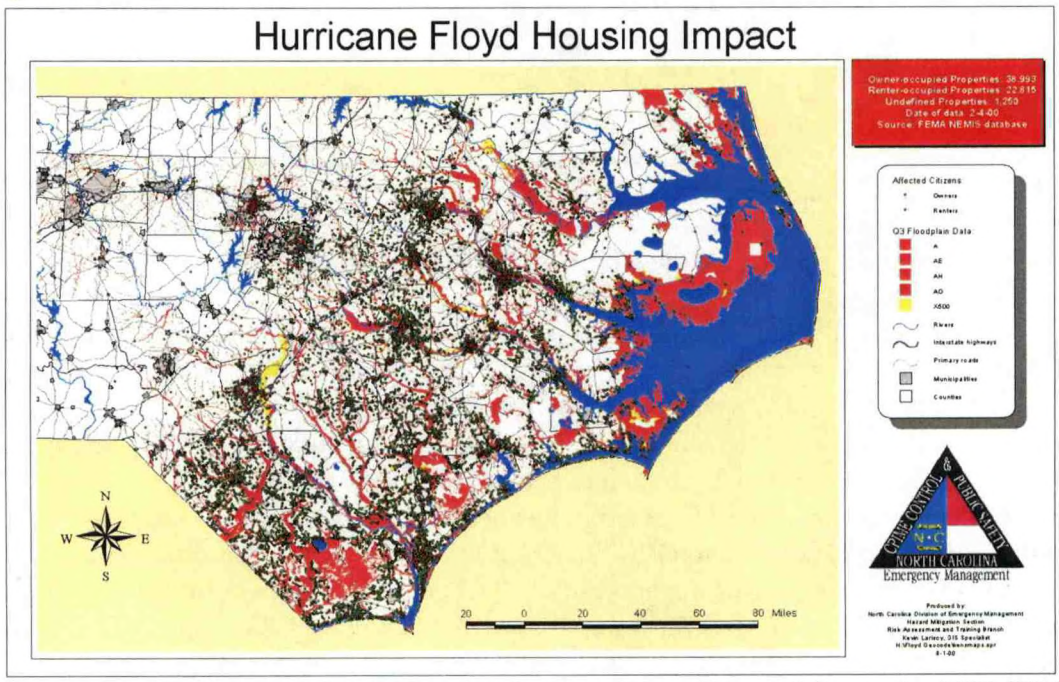


Figure 14. Hurricane Floyd Housing Impact Map Created from the NEMIS Database

Damage assessment data collected by field personnel were also added to the NEMIS database. The residential damage information could easily be extracted and geo-coded for use in GIS. GIS analysis of the data helped to determine which buildings were potentially eligible for the Hazard Mitigation Buyout Program. Historically, the identification process of structure location coupled with precise eligibility requirements pose lengthy waiting periods for funding. With the benefits of GIS, funding was maximized while timeframes were greatly decreased.

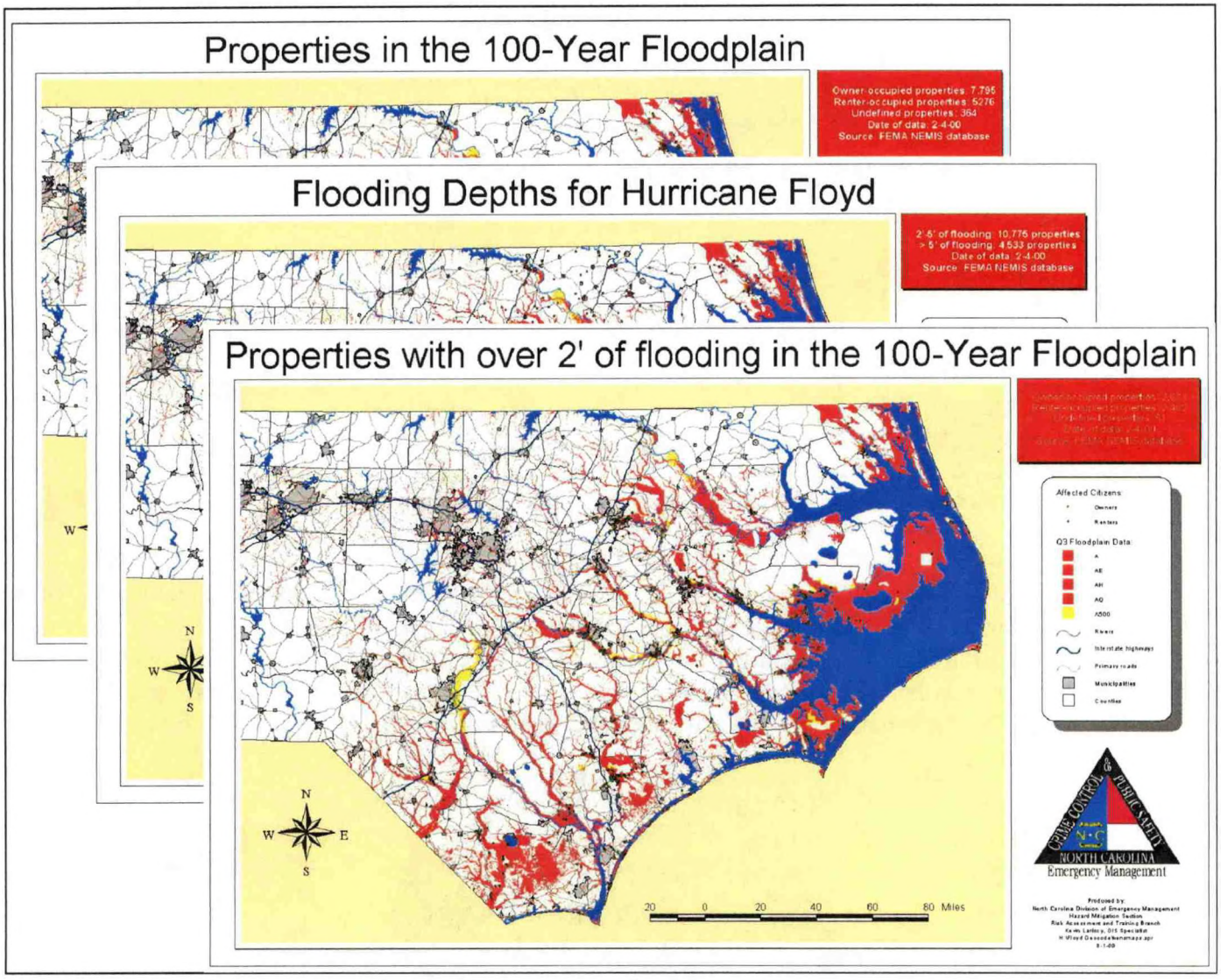


Figure 15. GIS Maps Used to Determine Eligibility for the Hazard Mitigation Buyout Program

The use of GIS also provided new opportunities to compare the impact of Hurricane Floyd with historical damage data from previous hurricane events. In an effort to evaluate the performance of past mitigation measures and to promote new mitigation measures, historical damage data could be analyzed and compared to the impacts of Hurricane Floyd. For example, during Hurricane Fran, two separate neighborhoods in Goldsboro, North Carolina, had been approved to participate in the Hazard Mitigation Buyout Program. However, only one of the neighborhoods chose to partake. Through the use of the NEMIS residential damage database and GIS, NC DEM could easily compare the damages sustained in both neighborhoods from Hurricanes Fran and Floyd. The analysis, which demonstrated the benefits of the buyout program, provided concrete information to convince the neighborhood, which originally chose not to participate in the buyout program, to partake in the program after Hurricane Floyd. The ability to

compare Hurricane Floyd impacts with previous storm event impacts provided a new ability to document the lessons learned from implementing hazard mitigation measures.

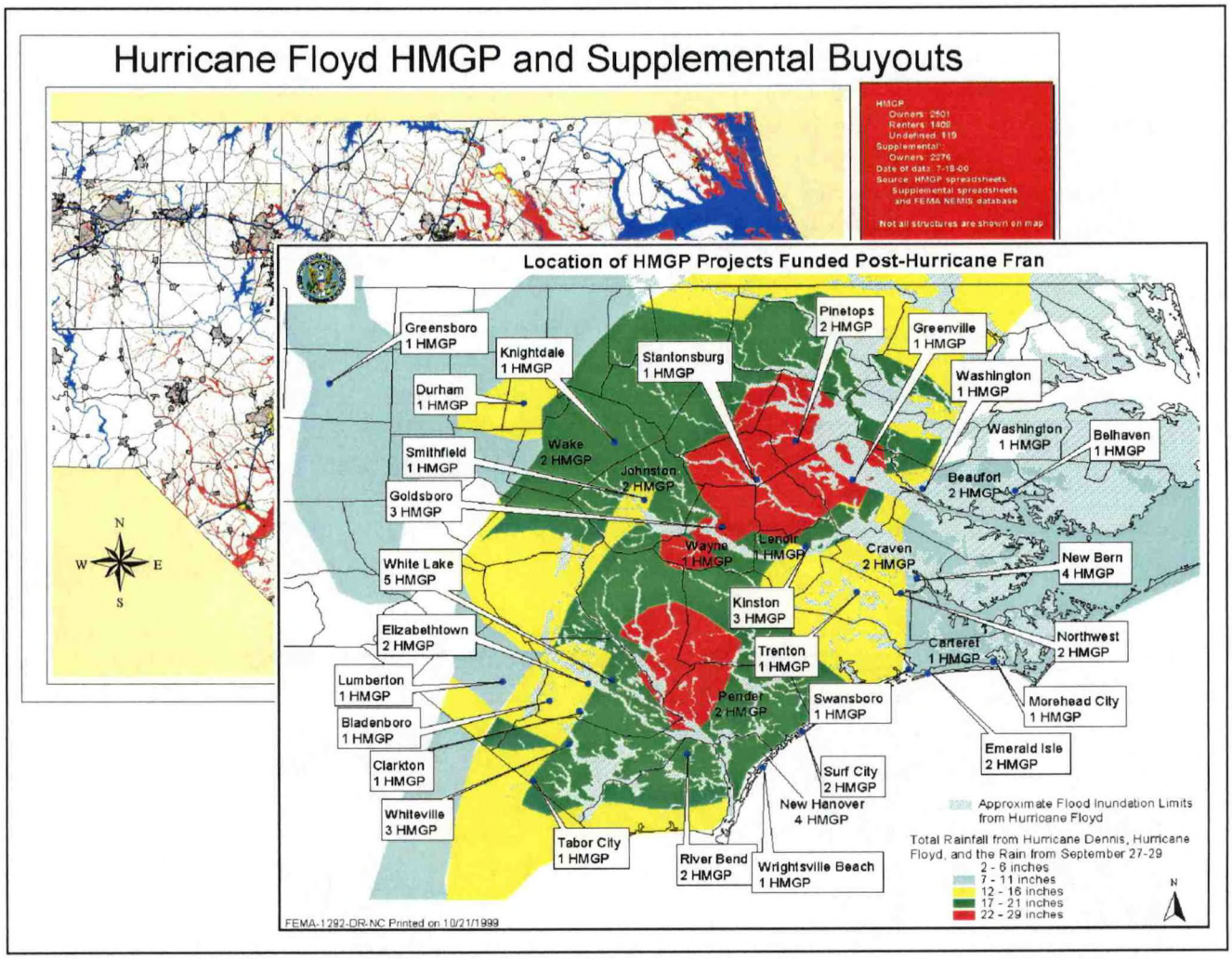


Figure 16. Maps Utilized by NC DEM to Assess the Impacts on Past Hazard Mitigation Grant Program Projects

Following Hurricane Floyd, GIS maps were used in the Disaster Field Office, staffed by NC DEM and FEMA, to aid in the recovery efforts. The Public Assistance Section, which funds the restoration, replacement, and mitigation of public facilities and infrastructure, used GIS maps for resource allocation and programmatic compliance measures. GIS-based maps were used to determine whether all eligible municipal applicants had submitted their applications for federal assistance. Global Positioning System (GPS) data of all cities, towns, and villages in the declared disaster areas were plugged into maps. Recovery operations were improved, as flood levels and damage assessment information were used to identify impact levels (i.e., destroyed, severe, major, minor) and adversely impacted critical facilities. This helped to plan immediate recovery actions that required resource allocation and staffing decisions (e.g., environmental specialists, civil engineers, emergency medical responders, etc.).

Environmental policy compliance processes were improved by plotting areas of environmental concern. For example, the Coastal Barrier Resource Act (CBRA) Zones were plotted for Brunswick, Cateret, Currituck, Dare, Hyde, New Hanover, Onslow, and Pender Counties. This information was used

to ensure that sensitive environmental resources were not impacted by permit applications for reconstruction and recovery efforts.

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

As documented in the media, the threat of Hurricane Floyd caused the largest peacetime evacuation in U.S. history. Federal, state, and local emergency management agencies, law enforcement agencies, and North Carolina Department of Transportation (NC DOT) field personnel all relied on real-time road condition data to help ensure that all evacuees could successfully get out of harm's way. Information dissemination was also a high priority for NC DOT to keep individual motorists informed about current road conditions. Following the passage of Hurricane Floyd, emergency service providers utilized real-time road condition data to identify which routes could be used to aid in disaster recovery.

During the height of the flooding following Hurricane Floyd's landfall, over 1,500 roads were closed in North Carolina. Information about roadway conditions was vital to ensuring the success of emergency response and recovery activities. The NC DOT Customer Service hotline (1-800-DOT-4YOU) typically handles about 700 calls per week. On the busiest day following landfall, they received over 50,000 phone calls. During the crisis they answered over 175,000 calls. The major challenge was finding improved ways of getting the information to customers. The NC DOT Information Systems Technology and GIS Units worked together to create a new and improved system virtually overnight. Road condition information was added to its Internet site for use by emergency management personnel and the public.

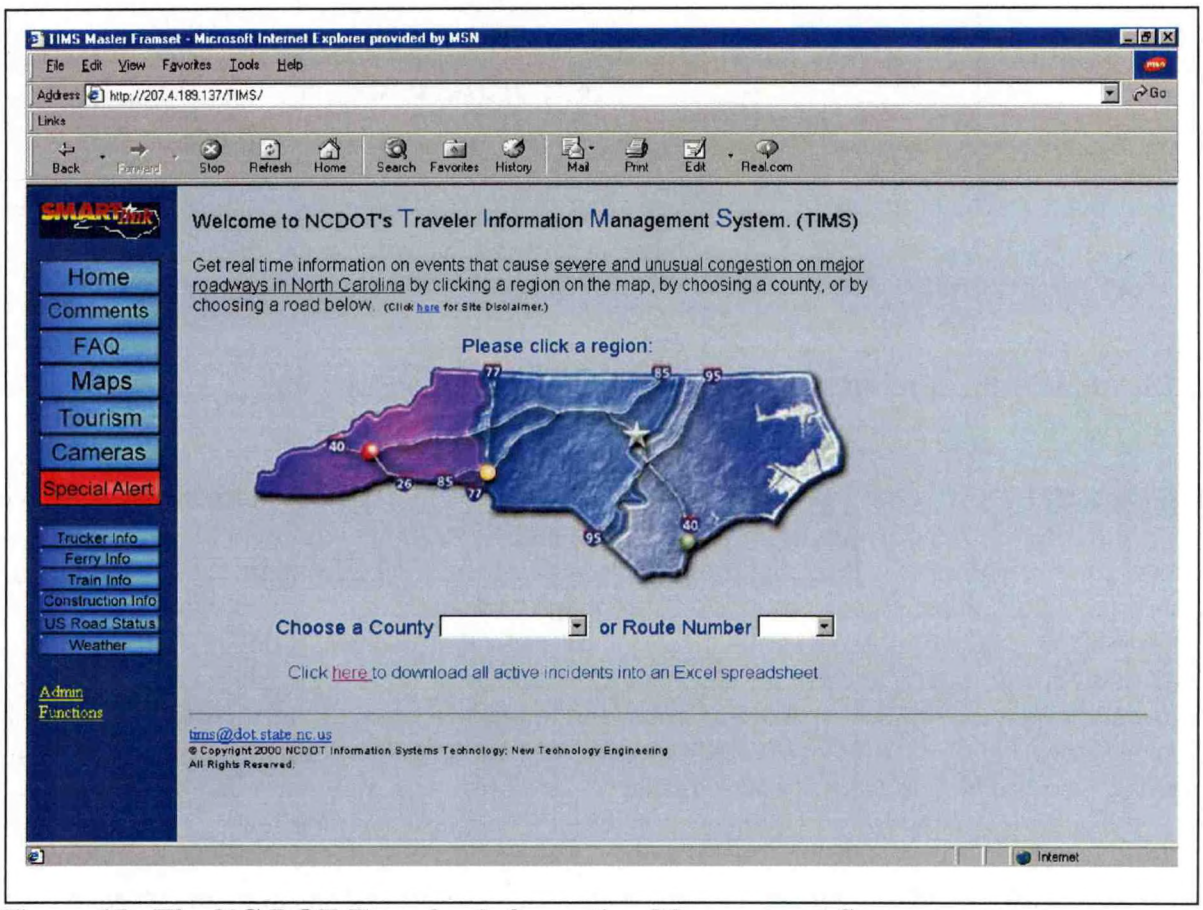


Figure 17. The NC DOT Traveler Information Management System <http://207.4.189.137/TIMS/>.

The NC DOT Internet site allowed users to locate road closures either by using text or GIS maps. On a typical day NC DOT's Internet site receives approximately 15,000 to 17,000 daily hits. During the Hurricane Floyd disaster the Internet site received nearly two million total hits. On the busiest day it received over 250,000 hits. Emergency management agencies at the federal, state, and local levels used the Internet site extensively to route emergency responders and to plan response and recovery missions. In many cases, the GIS maps, as produced by NC DOT, were used as decision-making tools by emergency management personnel. In other cases, the GIS maps were incorporated with other spatial data, such as damage assessment data, allowing improved decision making through further GIS analysis.

The on-line GIS maps were also very beneficial for improving the efficiency of NC DOT recovery missions. Within the State of North Carolina approximately 2,100 sites on the state's highway infrastructure were damaged. NC DOT utilized the GIS maps to prioritize road repair efforts and to route repair crews to damage locations.

The NC DOT Internet site and hotline both served as valuable resources to reduce the workload of emergency management personnel. Emergency management agencies at both the state and local levels were inundated with calls from other agencies and the public inquiring about road conditions. Once the NC DOT Web site and hotline were publicized, the call volume to the emergency management agencies significantly decreased. This allowed them to dedicate more of their manpower and resources to actual emergency response and recovery activities.

ISSUES AND LESSONS LEARNED

There were numerous examples illustrating the benefits of using spatial data and GIS by state agencies to complete their respective Hurricane Floyd response and recovery missions. There were also numerous cases where state agency-produced spatial data and GIS products were effectively utilized by other federal, state, and local agencies. On the other hand, many of the data limitations, data needs, and areas of improvement related to spatial data and GIS were revealed by the response and recovery activities. Many of the issues and lessons learned identified at the state level were similar to those identified at the federal level.

Data Availability

- The North Carolina Center for Geographic Information and Analysis (NC CGIA), the state GIS data clearinghouse, has a tremendous amount of data and spatial analysis capabilities that could potentially enhance NC DEM's response and recovery operations. However, during Hurricane Floyd there was no mechanism or plan in place detailing how the two agencies would work together. Realizing this limitation they are currently working on a plan detailing how future collaborative efforts will be accomplished.

- When Floyd hit, the state Information Technology Services group informed NC CGIA that all state servers, except the state Emergency Operations Center's server, would be taken down. The servers remained down for approximately 1 1/2 days. Therefore, there was no access to NC CGIA's spatial data for a brief time. The EOC's server had some spatial data, but not the full range of GIS data that would be available from NC CGIA.

- A GIS data layer containing rural water and sanitary sewer information was used extensively in the aftermath of Hurricane Floyd. No agency is responsible for its maintenance, and no new strategy has

evolved as to who should have the responsibility. Many agencies want the data and used the existing data, but no one wants to pay for its maintenance.

- The North Carolina State Historic Preservation Office has expressed the need to develop a GIS database containing the locations of the historic properties in North Carolina. This would expedite damage assessment efforts and recovery funding to state and local governments for any historic property impacted by disaster events.

- NC DOT was very successful disseminating roadway conditions on the Internet utilizing GIS maps. Some of the barrier islands of North Carolina are only accessible by ferry, and others have very limited alternatives for access besides the ferries. Participation by the North Carolina Ferry Division could have greatly improved the availability of real-time information.

- Prior to Hurricane Floyd, NC DOT had considered developing a real-time traveler information Internet site. The volume of road condition requests received during and following the disaster verified the need for such an Internet site. NC DOT is currently developing the Transportation Information and Management System to provide roadway condition information. The new system will address the information collection and dissemination problems encountered during Hurricane Floyd. The system will be utilized for day-to-day events that affect local travel, as well as for major events, such as Hurricane Floyd. Once in place, NC DOT plans to highly publicize the system to increase awareness of its availability.

Data Acquisition

- As previously mentioned, there were interoperability issues related to data sharing between FEMA and NC DEM. The State of North Carolina utilizes ArcINFO and ArcView, GIS software created by ESRI, and prefers to work with data projected in NAD83 State Plane (feet) format. The standard GIS software platform for FEMA is MapInfo; FEMA prefers to work with data in NAD27 Latitude/ Longitude. Therefore, any data sharing would warrant a large number of data conversions.

- NC DEM requested NC CGIA to explore avenues for acquiring satellite imagery to delineate the extent of flooding. After spending a significant amount of time researching the issue, the agency discovered that FEMA had an existing agreement with the USGS Earth Resources Observation Services Data Center for remotely sensed data. Had they known ahead of time about the agreement, the agency would have saved some time and devoted the resources to other emergency response activities.

  - NC CGIA now has a copy of *Remote Sensing in Federal Disaster Operations 9321.1-PR*, the standard operating procedures for FEMA. The document should help guide any future acquisitions of remote sensing disaster data.

- NC DEM had contracted with a private firm for the acquisition of digital aerial photography; however, the data were not properly aligned or mosaiced. Some of the areas appeared to be off by as much as 500 feet. In some cases, double images of the same building would be visible in the overlap areas. Therefore, other vector data layers, such as roads, utility lines, or shelter locations, could not be used with the aerials. If the aerial mosaic had been properly assembled, the resolution of the photography would have been very beneficial for identifying individual properties outside of the floodplain that had been inundated.

Data Limitations

- The flooding associated with Hurricane Floyd highlighted the inadequacies of the existing FEMA Flood Insurance Rate Maps (FIRM). In some cases, the FIRMs, which define the floodplain, are significantly outdated. Significant growth and development in some areas has altered the floodplain. In other areas, the defined floodplain is based on estimates created with poor topographic data. As a result, many areas located outside of the currently defined floodplain were inundated as a result of Hurricane Floyd. The floodplain maps are used nationwide as a basis for setting flood insurance rates. They are also essential tools for guiding local land use planning and development and environmental management. Having inadequate floodplain maps greatly impacts the ability to properly enact and enforce floodplain management efforts and other potential mitigation measures.

  - Due to a lack of resources, FEMA has often been unable to update the flood hazard maps. To help address this issue, FEMA has created a Cooperating Technical Communities program. The program shifts the responsibility for maintaining the flood maps to local governments. As part of the program FEMA provides some seed funding and technical assistance. Realizing the importance of having up-to-date and accurate flood hazard maps, the State of North Carolina has gone a step further and became the first Cooperating Technical State. North Carolina worked with the National Partnership for Reinventing Government (NPR), FEMA, and other federal agencies to develop a partnership agreement. The goal of the agreement is to update and digitize the FIRM's for the entire state, utilizing 2-foot contour topographic data or better. North Carolina plans to make the updated maps available to the public through the Internet. The updated maps will allow local communities to manage their floodplains more effectively.

  - As part of the agreement, a Cooperating Technical State Committee, made up of representatives from the state, participating communities, FEMA, NPR, and 15 other federal agencies, was established. The committee was formed to improve coordination and cooperation between all relevant agencies and communities by sharing technical capabilities and resources. The State of North Carolina has set aside $23 million for the project, and FEMA is providing approximately $6 million.

- NC DEM had reservations about the flood extent data interpreted from satellite imagery by FEMA. The imagery utilized by FEMA was only from September 23 and 25, 1999. Since rivers crest at different times for different reaches, FEMA was unable to properly map all of the maximum flood extent from the limited imagery it had acquired. Some of the field verifications of the flood inundation estimates from the satellite imagery proved to be significantly off in some locations. At one point FEMA displayed some of the interpreted flood extent maps on its Internet site. NC DEM, having knowledge of the errors in some locations, requested FEMA to remove the data from its Internet site. NC DEM had concerns that displaying the flood extent map, which underestimated the inundation in some areas, could potentially impact its ability to obtain adequate disaster assistance funding.

- Some of the satellite data they had acquired was collected at 25-meter resolution and some at 50-meter resolution. A composite mosaic was created from the data even though they were at differing resolutions. Trying to use the mosaic for analysis purposes was very complicated since it was difficult to differentiate whether the resolution was 25 or 50 meters in any particular area of concern.

- When data on residential, commercial, and public property damages were collected for input into the NEMIS database, there were no procedures in place to ensure that the data could be easily

georeferenced for spatial analysis. Data collection efforts were done somewhat haphazardly in the initial phases. Some of the data lacked adequate address information, such as zip code, exact street address, or GPS location coordinates. First attempts to georeference the damage locations resulted in an approximate match for only 50 percent of the properties. Therefore, significant efforts to obtain more precise location information were required.

  - As a result of Hurricane Floyd, North Carolina has developed a standard form for disaster damage data collection. The form will ensure that all data will have a street address and a zip code. This will allow all damage data to be easily georeferenced, thus allowing for easy import into GIS for further analysis.

- During Hurricane Floyd, there was a lack of real-time flood predictability data within North Carolina. NC DEM is working with the National Weather Service and the Southeast River Forecast Center (SERFC) to address this issue. SERFC is working to add visualization (maps) to forecasts. Instead of relying on written advisories stating river crest elevations, SERFC plan to show maps depicting the areas forecasted to be inundated when the river crests.

- At the height of the flooding, over 1,500 roads were closed within North Carolina, including federal, state, and local roads. Thus, several agencies had responsibility for reporting and disseminating road condition data. During Hurricane Floyd, NC DOT and the State Highway Patrol were responsible for determining the status of the state-maintained roads. At times the two sources provided conflicting data. "Hurricane Floyd Lessons Learned," a document created by NC DOT, highlighted the need for having one agency responsible for disseminating roadway condition information.

- Another issue concerned roadway closure information related to emergency vehicles. During the disaster, the GIS maps provided by NC DOT simply depicted roadway closures. Some of the roads identified as being closed were completely inundated and impassable by any type of vehicle. On the other hand, some roads could still be navigated, but were closed to ensure the safety of the public. In many cases these roads could still be utilized by emergency vehicles. This led to some confusion since NC DEM personnel questioned whether road closure status applied to emergency vehicles.

  - Realizing the need to address this issue, NC DOT has created a new reporting distinction. The new reporting distinction, known only to emergency personnel, will be utilized in any future event.

Hardware and Software Limitations

- At the Disaster Field Office, both the state and FEMA had set up their own local area network (LAN). The state's LAN allowed all state computers to share data across the network. However, since the state and FEMA LANs were not connected, they could not easily share data. Any exchange of data had to be accomplished through the use of CD-ROMs or zip disks. A connection between the two networks would have enhanced efficiency by reducing the time and effort required for data sharing.

SPATIAL DATA AND GIS USE AT THE LOCAL LEVEL DURING HURRICANE FLOYD

The use of spatial data and geographic information systems (GIS) varies greatly at the local level. Some local governments have very sophisticated GIS systems, while others have no GIS capabilities. Several North Carolina and South Carolina local governments severely impacted by Hurricane Floyd have provided feedback on their use of spatial data and GIS during the response and recovery phases. In addition, several GIS projects have been completed or are in progress as a result of Hurricane Floyd.

CITY OF KINSTON, NORTH CAROLINA

During the response phase, GIS capabilities were used for evacuation and re-entry procedures, search and rescue operations, the establishment of law enforcement checkpoints, and preliminary damage assessment. Comparisons were made between city GIS maps and data provided on a USGS Internet site to successfully predict rising floodwaters 24 hours in advance. This information was invaluable in apprising residents of which areas were going to be inundated, allowing them to get out of harm's way.

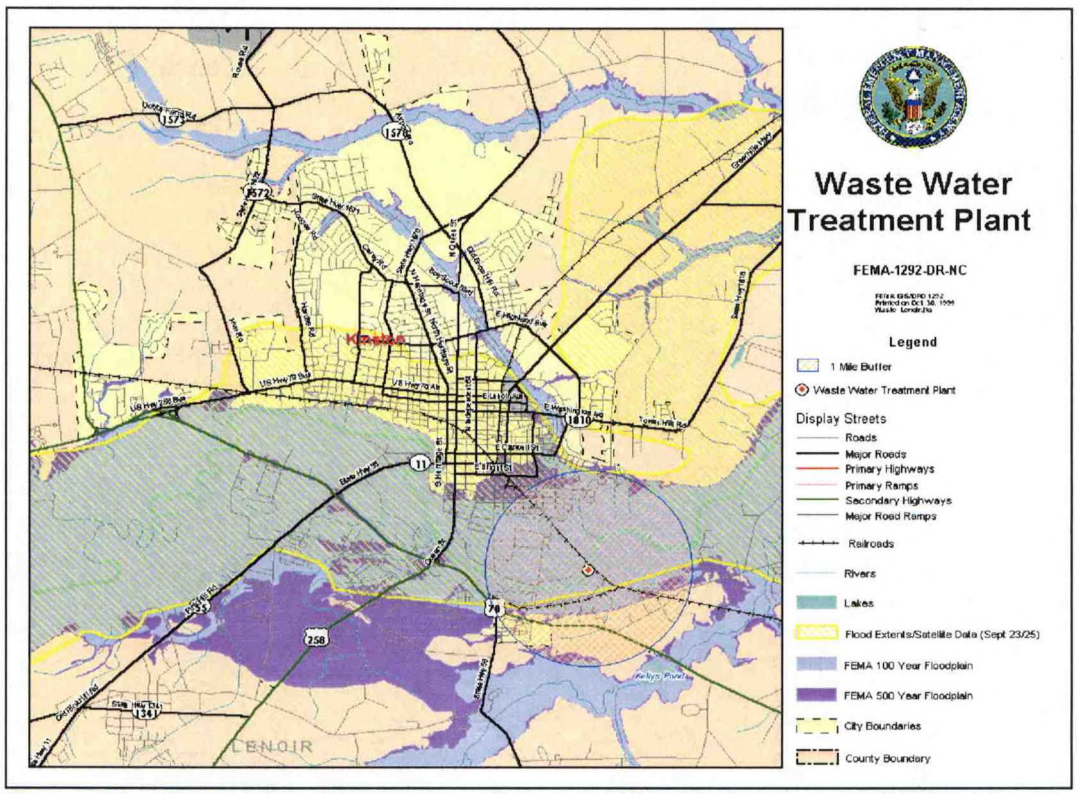


Figure 18. Map of the Wastewater Treatment Facility Likely to be Impacted by Hurricane Floyd Inundation

During the recovery phase, GIS is being used by the City of Kinston to record the locations of damaged structures that are being bought out under the FEMA Hazard Mitigation Grant Program. GIS is also being incorporated into the city's disaster plan. Prior to Floyd, the city had mapped critical facilities, utilities, and water and sewer systems. The city is currently working on adding the locations of emergency shelters, schools, and elder-care facilities. These efforts will enhance its ability to plan for its future disasters.

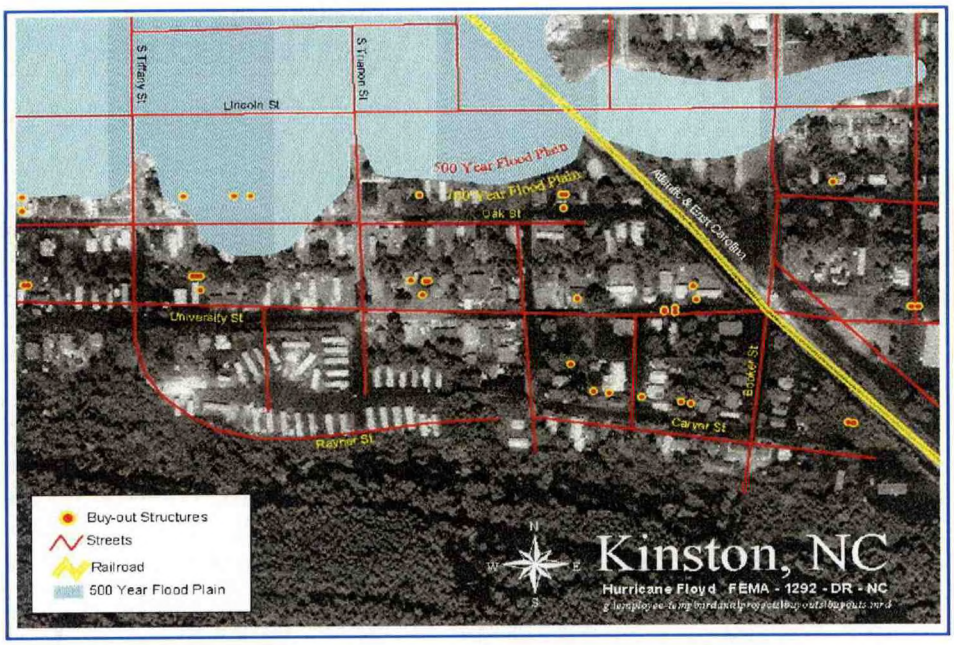


Figure 19. Map of FEMA Hazard Mitigation Grant Program Buyout Structures in Relation to the 500-Year Floodplain

TOWN OF PRINCEVILLE, NORTH CAROLINA

The Town of Princeville, North Carolina, as the first city in the United States founded by former slaves, holds a highly significant place in our nation's history. Princeville was devastated by severe floods that accompanied Hurricane Floyd. By executive order, the President's Council on the Future of Princeville, North Carolina, was created to assist with efforts to repair and, to the extent possible, rebuild Princeville in a manner more resilient to future flooding.

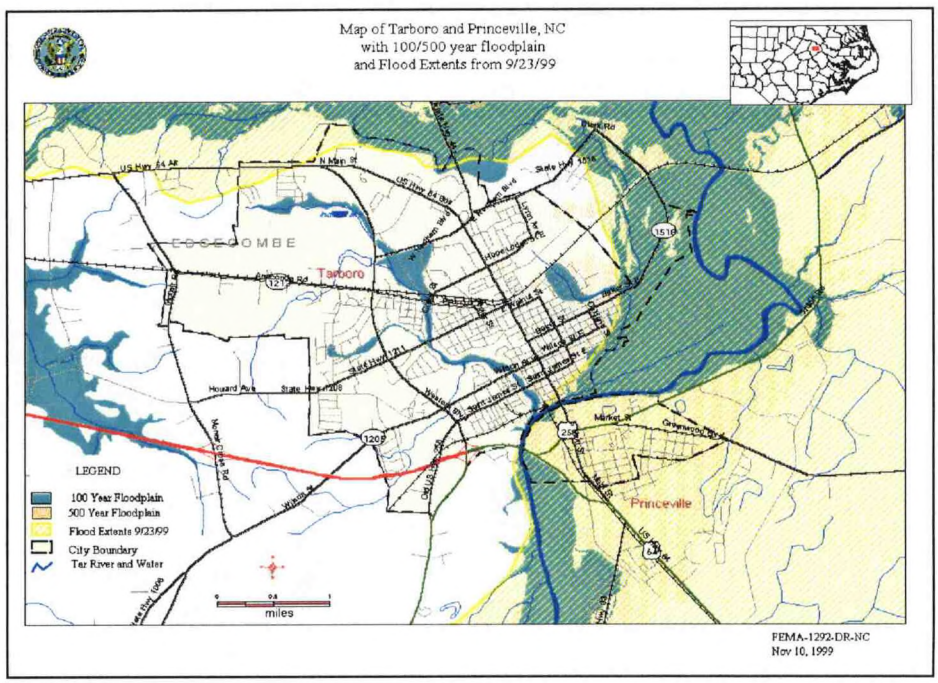


Figure 20. Map of the Hurricane Floyd Flood Extent and the 100- and 500-Year Floodplain in Princeville, North Carolina

GIS technology was utilized to help create the restoration plan for Princeville. GIS layers containing spatial data such as utilities, zoning, repetitive flood loss properties, and floodplain delineation are helping to ensure that reconstruction efforts occur either outside of the floodplain or at heights above the 100-year flood elevation.

HORRY COUNTY, SOUTH CAROLINA

Prior to Hurricane Floyd, Horry County, South Carolina, had very little GIS capability. In the aftermath of the storm, the South Carolina Emergency Preparedness Division donated the services of the Environmental Systems Research Institute (ESRI) to Horry County. ESRI employees were able to help the county build and use a GIS system geared towards emergency response. They utilized various data sets, ESRI software, and the employees of Horry County to build the GIS system in two day's time.

Since Horry County had no GIS system in place, initial efforts focused on data collection. Topographic elevations, floodplain delineation, road centerline files, tax parcel data, building footprints, and hydrologic data were some of the critical data sets needed for the GIS system. The data were acquired from various private and public sources, including FEMA, USACE, Dewberry and Davis, Waccamaw Regional Planning Council, and ESRI. Given that the data came from various sources, they had to be converted into a similar format. All of the data was projected to the state plane coordinates for South Carolina.

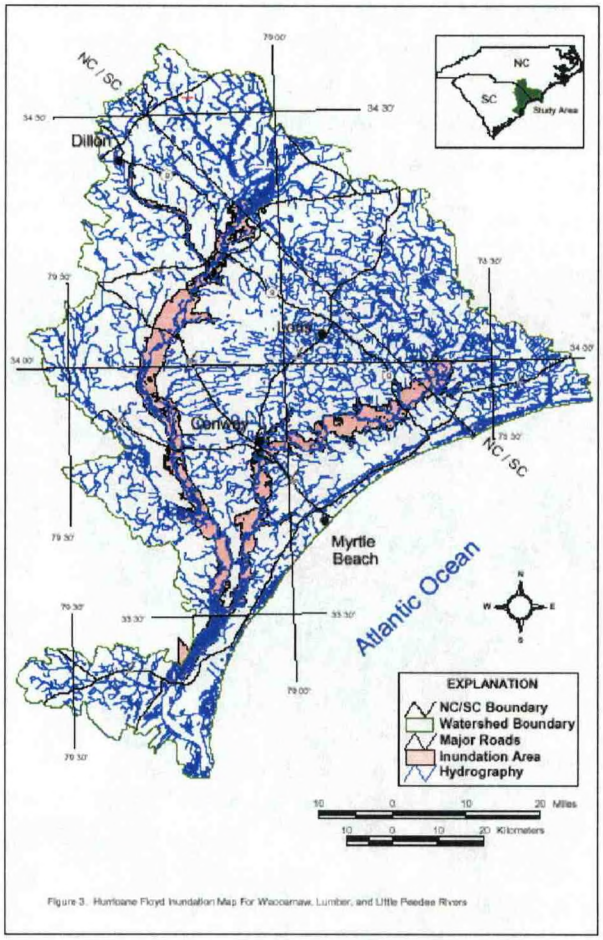


Figure 21. Hurricane Floyd Inundation Map for Horry County, South Carolina

Once all of the data layers had been incorporated into the GIS, modeling was used to project the flood inundation areas for the county. ESRI personnel instructed Horry County staff how to build the necessary models using the data sets and ESRI technology. With ESRI assistance, Horry County staff created maps by combining the model results with the road centerline data, building footprints, and tax parcel data. The maps were used to make emergency management decisions, such as where to close streets, how to delineate high-risk flood areas, and which critical public utilities would need sandbag protection to ensure continuos operation.

DARE COUNTY, NORTH CAROLINA

Prior to Hurricane Floyd, Dare County, North Carolina, had utilized GIS to map its critical facilities, water lines, turnoff valves, and property values. The ability to conduct GIS analysis of the existing data combined with flood prediction and damage location data would have greatly enhanced Dare County's ability to respond and recover from Hurricane Floyd. However, the county did not have adequate staffing to utilize GIS technology following Hurricane Floyd.

EDGECOMBE COUNTY, NORTH CAROLINA

During the response phase in Edgecombe County, North Carolina, GIS capabilities that were in place prior to the impact of Hurricane Floyd were inaccessible because the county building housing the GIS server was severely flooded. However, the County GIS coordinator was able to copy some of the GIS data onto a laptop. The data were then utilized by the County Emergency Operations Center. GIS maps containing streets, residential property, and other pertinent data were printed to assist the North Carolina National Guard with general navigation and search and rescue operations.

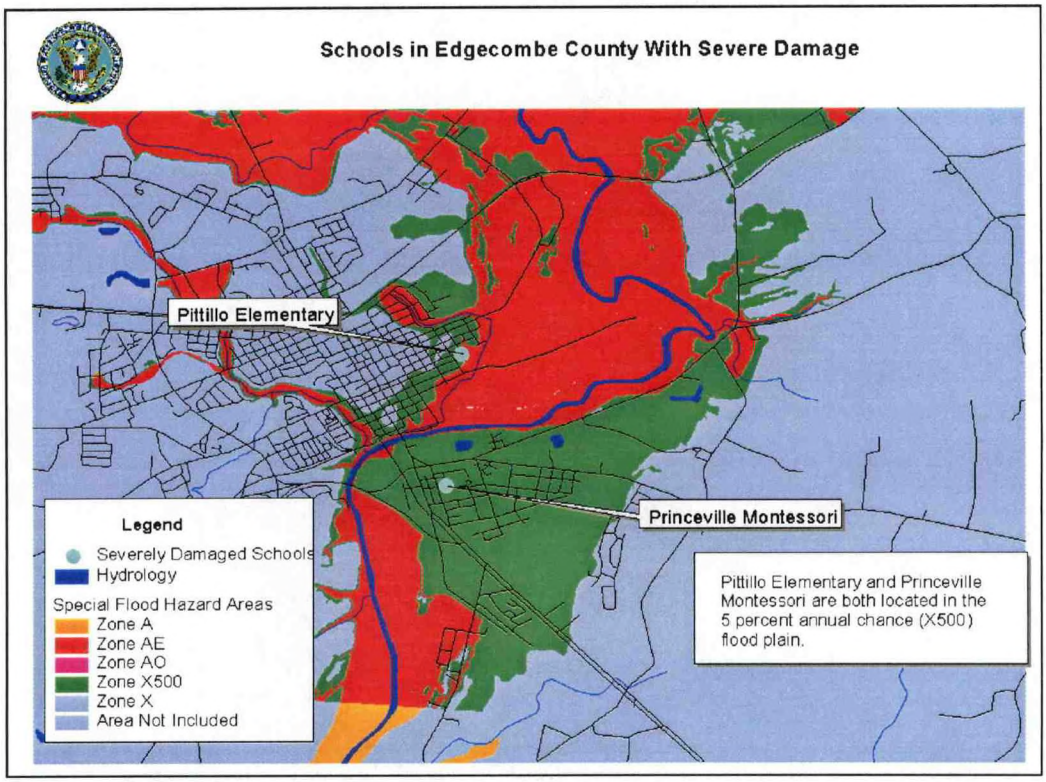


Figure 22. Map of Schools in Edgecombe County with Severe Damage

During the recovery phase, GIS was used for general damage assessment. GIS is also being used to identify the locations and track the status of damaged structures that are being bought out under the FEMA Hazard Mitigation Grant Program.

NEW HANOVER COUNTY, NORTH CAROLINA

Prior to Hurricane Floyd, New Hanover County, North Carolina, utilized GIS to conduct a comprehensive community hazard risk and vulnerability assessment. The results of the assessment were used to identify and prioritize potential hazard mitigation measures. Having gone through the process of conducting the assessment, New Hanover County possessed a wealth of spatial data that could have been utilized to enhance their response activities. However, GIS was unable to be used in the County Emergency Operations Center due to a lack of space. During the response phase, GIS was used by field personnel to assist with damage assessment.

PITT COUNTY, NORTH CAROLINA

Prior to landfall, GIS was used by Pitt County, North Carolina, personnel to plan for the impending disaster. Through the use of GIS, county staff identified potential impacts by comparing flood-prone areas with the locations of critical facilities, populations with special needs (diabetics and respirator-dependent individuals), fire hydrants, fire responders, rescue responders, bridges, rail systems, residential properties (zones and subdivisions), and utilities. The GIS analysis helped the county prioritize response activities.

During the response phase, Pitt County incorporated a GIS module into its Emergency 911 calling system. Upon receiving a call, a map was generated to plot the location of the call. The maps were given to search and rescue teams to enhance their ability to locate residents in need of assistance. During the recovery phase, GIS is being used to record the locations and track the status of damaged structures that are being bought out under the FEMA Hazard Mitigation Grant Program.

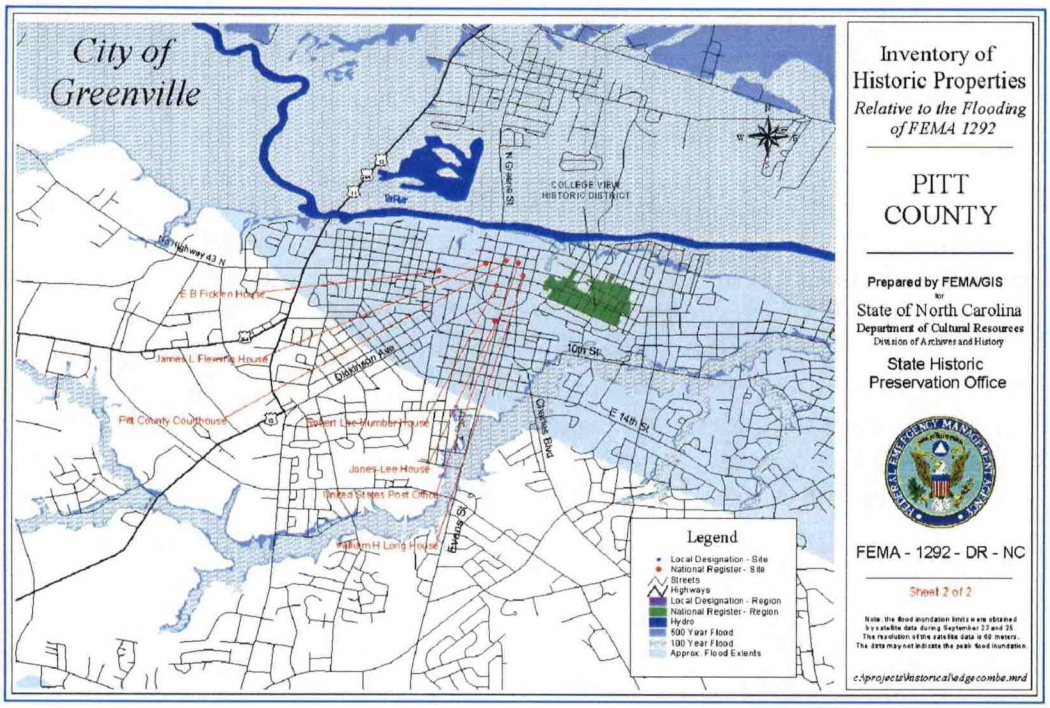


Figure 23. Inventory of Pitt County Historic Properties Relative to Hurricane Floyd Inundation

NORTH CAROLINA LEAGUE OF MUNICIPALITIES

The North Carolina League of Municipalities (NC LM) partners with local, state, and federal agencies during the response and recovery phases of disasters to coordinate mutual aid resource management. One of the main challenges of this process is the proper identification and efficient transmittal of resources. NC LM has been charged with maintaining an Internet site to foster intergovernmental trading of resources. NC LM is working closely with NC DEM and NC CGIA in the planning stage, with consideration to develop an application that will incorporate GIS, using ArcInfo, with EM-2000 (NC DEM resource assignment and tracking software) to track local resources.

ISSUES AND LESSONS LEARNED

- The experiences of Dare County, North Carolina, during Hurricane Floyd help to stress the need for pre-identifying what resources will be necessary for utilizing GIS during disasters. Dare County had numerous spatial data sets that could have enhanced its ability to respond to the disaster. Unfortunately, the county lacked the manpower to utilize GIS technology following Hurricane Floyd. During emergency response and recovery operations, many local government employees are required to take on additional responsibilities. Therefore, it is critical for local governments to develop emergency response and recovery plans that ensure sufficient staff resources will be dedicated to the utilization of GIS.

- As evident by the New Hanover County, North Carolina, experience, other critical resource issues can dictate whether GIS is successfully utilized during disaster response and recovery operations. New Hanover County's GIS system was unable to be used in the County Emergency Operations Center due to a lack of space. To ensure that GIS can be utilized by local governments during disaster operations, response and recovery plans should address all resource issues related to GIS, including manpower, space, and equipment.

- The unforeseen flooding that impacted Edgecombe County, North Carolina, also highlights the need to have detailed emergency response and recovery plans, including contingency plans, in place prior to a hazard event. GIS capabilities that were in place prior to the impact of Hurricane Floyd were inaccessible because the county building housing the GIS server was severely flooded.

- The GIS system rapidly developed in Horry County, South Carolina, during the Hurricane Floyd response phase provided several key lessons. When developing a new GIS system, some of the critical elements are data collection, data verification, and data maintenance. Local governments should devote adequate resources to ensure that all are accomplished. The importance of interoffice/interdepartmental cooperation was also a critical element to ensuring the success of the GIS development. It is critical to have all departments involved with the initial development to ensure that all data sources have been identified and to ensure that the GIS will meet the needs of all potential users. Once a GIS system has been developed for a local government, many departments besides the emergency management division will also benefit from the system.

BIBLIOGRAPHY

Bishop, Sally. 2000. Open-File Document. "Hurricane Floyd GIS Products, North Carolina DFO – Raleigh, FEMA-1292-DR-NC." Federal Emergency Management Agency, Region IV. Atlanta, Georgia. June 21.

Colby, Jeffery D., Karen Mulcahy, and Yong Wang. 2000. "Hurricane Floyd Flood Mapping Integrating Landsat 7 TM Satellite Imagery and DEM Data." National Science Foundation. *(http://www.colorado.edu/hazards/qr/qr126/qr126.html).*

Corbley, Kevin. 1999. "Fleeing from Floyd: Internet GIS in the Eye of the Storm." *GeoInfo Systems.* Volume 9. Number 10. Pages 28 to 35.

Dow, Kirstin, and Susan L. Cutter. 2000. "South Carolina's Response to Hurricane Floyd." National Science Foundation. *(http://www.colorado.edu/hazards/qr/qr128/qr128.html).*

Dymon, Ute J. 1999. "Effectiveness of Geographic Information Systems (GIS) Applications in Flood Management during and after Hurricane Fran." National Science Foundation. *(http://www.colorado.edu/hazards/qr/qr114.html).*

Economic Development Administration. 2000. *Economic Impact Assessment of Hurricane Floyd for North Carolina.* DR-1292-NC. Federal Emergency Management Agency. January.

Environmental Systems Research Institute, Inc. 1999. "GIS for Emergency Management, An ESRI White Paper." Environmental Systems Research Institute Press. Redlands, California. July.

Federal Emergency Management Agency. 1998. *NEMIS Concept of Operations (Operations and Maintenance).* Federal Emergency Management Agency. May 15.

Federal Emergency Management Agency, and North Carolina Emergency Management Agency. 2000. "Joint Federal Emergency Management Agency - North Carolina, FEMA Situation Report #82, State Situation Report #88." FEMA-1292-DR-NC. FEMA-3136-EM-NC. Raleigh, North Carolina. March 7.

Federal Geographic Data Committee. 2000. "Improving Federal Agency Geospatial Data Coordination." Federal Geographic Data Committee. May 11.

Johnson, Russ. 2000. "GIS Technology for Disasters and Emergency Mangement, An ESRI White Paper." Environmental Systems Research Institute Press. Redlands, California. May.

Marcy, Doug. 2000. Open-File Document. "USACE Hurricane Floyd Flood Mapping Effort Using GIS." U.S. Army Corps of Engineers, Charleston District. Charleston, South Carolina. June 27.

National Climatic Data Center. 2000. "Climate Watch, September 1999." *(http://www.ncdc.noaa.gov/ol/climate/extremes/1999/september/extremes0999.html).* May.

National Weather Service. 2000. *Service Assessment, Hurricane Floyd Floods of September 1999.* National Weather Service. Silver Spring, Maryland. June.

National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. 2000. Interview Regarding the Lessons Learned from GIS Use by the Federal Emergency Management Agency (FEMA) during Hurricane Floyd. Between Russell Jackson, Coastal Hazards Specialist, and David Lawson, GIS Specialist, FEMA. June 6.

NOAA Coastal Services Center. 2000. Interview Regarding the Lessons Learned from GIS Use by the North Carolina Center for Geographic Information and Analysis (NC CGIA) during Hurricane Floyd. Between Russell Jackson, Coastal Hazards Specialist, and Jeff Brown, GIS Specialist, NC CGIA. June 15.

NOAA Coastal Services Center. 2000. Interview Regarding the Lessons Learned from GIS Use by the North Carolina Center for Geographic Information and Analysis (NC CGIA) during Hurricane Floyd. Between Russell Jackson, Coastal Hazards Specialist, and Karen Siderelis, Director, NC CGIA. June 15.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by New Hanover County during Hurricane Floyd. Between Lisa Flax, Coastal Hazards Specialist, and Brenda Coffee, Assistant Director of Emergency Management, New Hanover County. August 3.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by the Town of Princeville during Hurricane Floyd. Between Lisa Flax, Coastal Hazards Specialist, and Brad Gair, Deputy Federal Coordinating Officer, FEMA.
August 3.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by the North Carolina Division of Emergency Management (NC DEM) during Hurricane Floyd. Between Lisa Flax, Coastal Hazards Specialist, and Steven N. Glenn, Deputy State Coordinating Officer, NC DEM, August 24.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by Pitt County during Hurricane Floyd. Between Lisa Flax, Coastal Hazards Specialist, and Robert E. "Bobby" Joyner, Director of Emergency Management, Pitt County. August 2.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by the City of Kinston during Hurricane Floyd. Between Lisa Flax, Coastal Hazards Specialist, and Tommy Lee, Director of Building Inspections and Code Enforcement, City of Kinston. August 2.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by Edgecombe County during Hurricane Floyd. Between Lisa Flax, Coastal Hazards Specialist, and James Mercer, Director of Emergency Management, Edgecombe County. August 3.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by Dare County during Hurricane Floyd. Between Lisa Flax, Coastal Hazards Specialist, and Nathaniel H. "Sandy" Sanderson, Director of Emergency Management, Dare County. August 2.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by the North Carolina League of Municipalities (NCLM) during Hurricane Floyd.

Between Lisa Flax, Coastal Hazards Specialist, and John Spurrell, Environmental Policy Analyst/GIS Coordinator, NCLM. August 3.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by the North Carolina Division of Emergency Management (NC DEM) during Hurricane Floyd. Between Lisa Flax, Coastal Hazards Specialist, and Dr. Kenneth Taylor, State Hazard Mitigation Officer, September 5.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by the North Carolina Department of Emergency Management (NC DEM) during Hurricane Floyd. Between Russell Jackson, Coastal Hazards Specialist, and Don Heard, Technical Services Manager, NC DEM. June 20.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use during Hurricane Floyd. Between Russell Jackson, Coastal Hazards Specialist, and John Spurrell, Environmental Policy Analyst, NC League of Municipalities. June 20.

NOAA Coastal Services Center. 2000. Record of Telephone Conversation Regarding the Lessons Learned from GIS Use by the North Carolina Department of Emergency Management (NC DEM) during Hurricane Floyd. Between Russell Jackson, Coastal Hazards Specialist, and Kenneth Taylor, State Hazard Mitigation Officer, NC DEM. August 13.

Neumann, Charles J., and others. 1999. *Tropical Cyclones of the North Atlantic Ocean, 1871 - 1998, Historical Climatology Series 6-2*. NOAA National Climatic Data Center and Tropical Prediction Center. Asheville, North Carolina. October.

North Carolina Center for Geographic Information and Analysis. 2000. "Hazard Mitigation Planning Initiative: Supporting the Initiative with Geographic Information Systems." North Carolina Center for Geographic Information and Analysis. Raleigh, North Carolina. May.

North Carolina Center for Geographic Information and Analysis. (draft). "GIS Preparation Plan: Strategic Geographic Information for Emergency Response, Recovery, and Mitigation." North Carolina Center for Geographic Information and Analysis. Raleigh, North Carolina.

North Carolina Department of Transportation. 2000. "Hurricane Floyd Lessons Learned." North Carolina State Highway Administration. Raleigh, North Carolina. April 5.

Radke, John, and others. 2000. "Challenges for GIS in Emergency Preparedness and Response, An ESRI White Paper." Environmental Systems Research Institute Press. Redlands, California. May.

U.S. Army Corps of Engineers, Charleston District, and U.S. Geological Survey, South Carolina Water Resources Division. 2000. *Hurricane Floyd High Water Marks and Inundation Mapping*. Federal Emergency Management Agency, Region IV. May.

Wilson, Joey. 2000. Open-File Document. "Emergency Preparedness in South Carolina." Environmental Systems Research Institute, Inc. Charlotte, North Carolina. August 24.

Zagier, Alan. 2000. "North Carolina Regroups." *American Planning Associaton*. Volume 66. Number 2. Pages 8 to 11.

APPENDIX A

GIS PRODUCTS PRODUCED AT THE DISASTER FIELD OFFICE IN RALEIGH, NORTH CAROLINA, IN RESPONSE TO HURRICANE FLOYD

Following the landfall of Hurricane Floyd, a Disaster Field Office was opened in Raleigh, North Carolina. The Disaster Field Office, headed by FEMA, was staffed by federal and state agencies. The field office consisted of several functional sections which helped to carryout the response and recovery activities. Several of these sections relied heavily on the use of spatial data and GIS to accomplish its mission. These sections are Public Assistance, Individual Assistance, Hazard Mitigation, Community Relations, Public Information, Human Services, and Mobile Homes Operations. The following are examples of how spatial data and GIS enhanced the ability of the field office to carryout its mission.

1. **Severity of Impact Maps**: Maps were created showing the disaster impact on counties, depicted by different colors for minor, moderate, and severe levels of impact. The determination of impact was made using preliminary data collected from various sources. This product was initially produced immediately after Hurricane Floyd made landfall and was subsequently updated as more complete data became available.

   The impact classification was also used to produce maps detailing the demographic characteristics of the most severely impacted counties. The maps depicted critical demographic information such as minority populations, by U.S. Census block group.

   Management Uses: The maps were used to assist all Disaster Field Office management staff in determining the scope of the disaster in order to plan response and recovery activities. For example, the maps helped identify the general size and type of staff needed, the placement of field staff, and the geographic identification of those counties where the greatest response and recovery emphasis should initially be placed (i.e., the prioritization of distribution of emergency food, water, and other provisions).

2. **Potential Substantial Damage Maps**: These maps were created to display the locations of potential substantially damaged structures, flood inundation limits, and FEMA Q3 floodplain data. FEMA Q3 data are a digital form of the basic flood insurance rate map (more information can be found on-line at *http://www.fema.gov/MSC/q3flooda.htm*.

   Action: Disaster Field Office GIS staff combined the National Emergency Management Information System (NEMIS) Human Service inspector database with the Floyd flood-inundation limits and the Q3 floodplain data. This enabled them to

query the inspector database to locate and label structures that were destroyed and structures that were inundated by 5 feet or more of water.

Management Uses: The maps aided Hazard Mitigation personnel in determining the location and magnitude of substantially damaged structures, which in turn was used to assess the need for buyouts and other Hazard Mitigation Programs. The maps ultimately helped to determine what amount of mitigation funding would be needed. After hazard mitigation buy-outs were determined, the data were also used to assist with demolition operations.

3. **Maps of Temporary Living Facilities**: Maps were created to display the locations of temporary living facilities, soil types, floodplains, and endangered species.

Action: Plotted locations of temporary housing sites using Global Positioning System (GPS) coordinates and overlaid other data.

Management Uses: Maps were used by Human Services, Public Assistance, and Public Assistance "Environmental" staff to select temporary living facility sites that were located out of the floodplain, away from endangered species habitats, and on soil suitable for building.

4. **Maps of Temporary Living Facility Parks**: Maps were produced using the site-specific digital plans drawn by the engineering firms hired to develop the park layouts. The maps showed streets and lot numbers.

Management Uses: Provided Human Services Mobile Home Operations office and field staff with a tool to track what units had been filled with housing applicants, what units were empty, what units were completed and ready to be filled, etc. An additional use that was discussed but not developed due to lack of time, was to use these maps in a World Wide Web page environment and tie the page to a database developed by Mobile Home Operations. This would enable staff to see the overall park layout, as well as select individual sites, and view data associated with the site (name of applicant occupying, date unit filled, etc.).

5. **Maps of Temporary Living Facility Parks with a 10-mile Radius Buffer**: The map showed the eastern counties of North Carolina where temporary living facilities had been or were currently being established, with a 10-mile radius buffer drawn around each park.

Management Uses: Assisted Human Services Mobile Home Operations and field staff to determine the assignment of housing applicants to temporary living sites. The determination was based on the proximity of an applicant's

damaged home to a temporary housing site. This information was also used by Community Relations to explain to the public how housing assignments were made.

6. **Maps of Public Assistance Applicants in Relation to the Floodplain**: These maps showed the location of an applicant's structure, Q3 floodplains, and aerial photography of flooding.

   Action: Plotted structure locations based on latitude/longitude coordinates supplied by Public Assistance staff. Overlaid with aerial photography and Q3 floodplains.

   Management Uses: Used to help Public Assistance staff, including Public Assistance Environmental and Historical staff, determine which structures were located in the floodplain, which in turn determined the way each applicant was assisted due to floodplain-specific rules and regulations.

7. **Maps of Human Service Applicants in Relation to ProCD Data**: Maps were created to display Human Services data and ProCD data (residential and business telephone listings).

   Action: ProCD telephone listings were extracted for the designated counties (those included in the disaster declaration) and plotted with the Human Services data from NEMIS. This information was then combined with the Floyd flood-inundation limits and the Q3 floodplain data.

   Management Uses: In an effort to further target Community Relations and Public Information activities, the maps were used by Human Services, Community Relations, and Public Information personnel to identify areas where people may have been impacted by the flooding, but had not yet applied for assistance.

8. **Maps of Human Services Applicants per County and/or City**: These maps illustrated the locations of Human Services applicants by county or city, and were combined with Q3 floodplain data and Floyd flood inundation limits.

   Management Uses: The maps were used by Mitigation and Human Services personnel to identify concentrations of applicants, to determine applicant locations relative to floodplains and actual flooding, and to identify possible floodplain re-study needs. These maps were also used as briefing tools by other Disaster Field Office staff.

9. **Wastewater Treatment Plant Location Maps**: Maps were developed to display the location of wastewater treatment plants in relation to the Q3 floodplain data and Floyd flood-inundation limits.

Action: For planning purposes 1-mile buffers were created around wastewater treatment plant locations, then merged with Q3 floodplain data and flood inundation limits.

Management Uses: The maps were used by Public Assistance staff to identify the relative location of the wastewater treatment plants and to assist with post-storm damage assessments of the plants. The damage assessments included debris fallout potential from the plants within the 1-mile buffer zone.

10. **Maps of Wastewater Treatment Plant Locations and the 100-Year Floodplain**: These maps indicated the relationship between wastewater treatment plant locations and the 100-year floodplain.

Management Uses: The maps were utilized by Mitigation and Public Assistance staff to determine which plants reside within the 100-year floodplain. The plants located within the 100-year floodplain were then assessed as possible hazard mitigation projects.

11. **Drinking-Water Well Location Maps**: Maps created to display the locations of drinking-water wells were combined with Floyd flood inundation limits and Q3 floodplains.

Management Uses: The maps and a data listing were generated to determine which wells (public and private) could have been contaminated by flooding. This information provided a means for Emergency Support Function 8 (Health & Medical) to make initial estimates regarding work volume and a framework to determine work prioritization and assignment. In the case of public wells, the maps provided Public Assistance and Hazard Mitigation staff with a basis for evaluating possible mitigation grant projects.

12. **Census Block Group Data by County Maps**: Maps were generated showing the demographics of impacted areas. The maps displayed distributions of minorities by census block group combined with county boundaries. County boundaries were assigned different colors to reflect the severity of impact (the severity of impact was determined using various disaster data and factors previously addressed).

A second set of county-specific maps was produced showing block groups and the percentage of minority inhabitants within each block group, combined with the

100-year floodplain data. Some of the second set of maps also contained Human Service applicants.

An additional map was produced showing census block group data merged with the "Severity of Impact Map" previously discussed.

Management Uses: The maps gave Human Services, Community Relations, Public Information, Hazard Mitigation, and Congressional Liaison staff a tool to assess the demographic profile of the communities impacted and to determine which areas should receive first attention based on severity of impact.

The second set of county-specific maps was used to further assess heavily impacted areas based on the floodplain, minority densities, and in some instances using the Human Services applicant data plotted over all the other data layers. These data assisted management in identifying services that might be required (Spanish interpretation, etc.) and prioritizing assignment of field staff, as well as providing an initial determination of areas that might require public information targeting.

The additional map with census data and severity of impact data was used by Human Services to determine the most appropriate placement of Disaster Recovery Centers. This determination in turn affected Community Relations and Hazard Mitigation staff assignments.

13. **Map of Total Rainfall for Eastern North Carolina**: This map showed the total rainfall amounts for eastern North Carolina resulting from Hurricanes Dennis and Floyd and the rainfall event of September 27 to 29, 1999.

Action: Disaster Field Office GIS staff received data from the Southeast River Forecast Center and overlaid the files to get a total rainfall amount.

Management Uses: The map was used as a briefing tool by all field office staff to graphically display the scope of the flood event. The map also serves to historically document the event. The map further showed a correlation between the amount of rainfall and the counties determined to be the most severely impacted based on other data. This correlation may seem elementary, but it provides additional support to justify impact determinations.

14. **Maps of Hazard Mitigation Grant Program (HMGP) Projects by City**: These maps display the location of cities with HMGP projects funded after Hurricane Fran, Hurricane Floyd flood-inundation limits, and total rainfall amounts.

Action: GIS staff received a database of the post-Hurricane Fran Hazard Mitigation Grant Program projects and then aggregated them to the city level. They then overlaid rainfall data and flood inundation limits.

Management Uses: The maps were used by Hazard Mitigation personnel to identify the Hazard Mitigation Grant Program project sites most likely impacted by flooding related to Hurricane Floyd. Once these sites had been identified, Hazard Mitigation staff conducted site visits to determine the status of the project. They then evaluated if the project qualified as a success story, determine if there should be any modification to the project based on the recent event, and provide documentation on the site's recurring vulnerability, further justifying its current Hazard Mitigation Grant Program project status.

15. **Maps of National Flood Insurance Program Repetitive Loss Structures**: Maps were created to display the locations of structures that have repetitively experienced flood-related losses from past hazard events.

Action: GIS staff utilized geocoding to geographically locate the repetitive loss database received from FEMA Region IV.

Management Uses: Hazard Mitigation and Public Assistance "Historical" staff utilized the maps as an aid in determining potential areas for participation in the buyout program.

16. **National Flood Insurance Program Policy Information Maps**: Maps were created to graphically display the percentage of National Flood Insurance Program policies per county in eastern North Carolina.

Action: GIS staff utilized geocoding to geographically locate all National Flood Insurance Program policies. Once policies had been assigned locations, they were combined with county boundaries to create the final maps.

Management Uses: The maps were used by the Small Business Administration, Hazard Mitigation, and Congressional Liaison staff to determine the percentage of housing stock that had flood insurance. With this information they could prioritize recovery efforts for those areas with very limited flood insurance coverage.

17. **Maps of River Gauge Locations and Flood Data for Selected Major Drainage Basins**: Maps were created to display the combination of major water bodies, drainage basins, and locations of gauges in the Neuse, Tar River, Cape Fear, and Roanoke River basins. Gauges were labeled showing the 1999 maximum water stages and the approximate recurrence interval for a flood of that magnitude.

Action: GIS staff obtained the location and statistics for each of the gauges from the U.S. Geological Survey. A table was created for each basin. The gauge locations were then plotted and overlaid with major drainage basin boundaries and major water bodies.

Management Uses: These maps were used by Hazard Mitigation to analyze the flood frequency of those areas with the highest historical flooding, with particular interest in those areas where Hurricane Floyd had produced a new historical high. This information was used as the basis for development of the post-storm High Water Mark Survey project conducted by the U.S. Army Corps of Engineers and the U.S. Geological Survey.

18. **Maps of Human Services Applicants in Rural Areas**: These maps displayed the distribution of Human Service applicants in rural areas.

    Management Uses: The maps were utilized by Human Services and Community Relations to assess where additional community outreach efforts might be needed.

19. **Maps of Crop Damage by County**: Maps were created to graphically illustrate the estimated crop damage by county. The maps were based on data provided by the North Carolina State Department of Agriculture.

    Management Uses: The maps provided the Federal Coordinating Officer and Public Assistance, Hazard Mitigation, and Small Business Administration management with additional data to assess the impact of the event and determine what other types of assistance might be needed.

20. **Dam Break Location Maps**: GIS staff created maps containing the locations and names of dams that failed during Hurricane Floyd. The maps also contained the extent of Hurricane Floyd-related flood inundation.

    Action: To create the maps GIS staff plotted the locations of dams using latitude/longitude coordinates supplied by Hazard Mitigation. The dam locations were then combined with Hurricane Floyd flood inundation limits.

    Management Uses: Hazard Mitigation staff utilized the maps to identify areas where Hazard Mitigation Grant Program projects would be needed/feasible.

21. **Environmental Maps: Anadramous Fish Spawning Areas, Endangered Species Areas, Wetlands**: Maps were created on a county-level basis displaying the location of various environmental data.

    Management Uses: Public Assistance "Environmental" field personnel used the county-level maps to determine any potential environmental issues. Once Public Assistance applications were received, more detailed maps were created to check the proximity of the applicant to any significant environmental areas.

22. **Maps of the Small Business Administration Applications Not Returned**: Maps were created to graphically display the locations of all Small Business Administration applications issued but not returned.

    Management Uses: Prior to the application deadline, the maps were utilized by the Small Business Administration staff to determine where additional public information, outreach, and field staff emphasis would be needed.

23. **Maps of the Small Business Administration Business Applicants with Potential Substantial Damage**: These maps showed the locations of confirmed Small Business Administration business applicants with loans exceeding a specific dollar amount. The data were grouped and displayed in various dollar amount ranges (e.g., $20,000-40,000; $40,000-50,000; etc.).

    Management Uses: The Small Business Administration and Hazard Mitigation staff relied on the maps to determine the location and magnitude of the Small Business Administration business applicants who fall in the realm of "potential substantial damage." This information is used to justify disaster recovery funding requests and to assess the need for Hazard Mitigation Grant Program projects and other mitigation measures.

24. **Maps of Historic Preservation Sites, Regions, and Areas (State & National)**: These maps were created to display the location and name of state and national historic preservation sites, regions, and areas with Floyd flood extents and the floodplains overlaid.

    Management Uses: The maps were used by the Public Assistance Program "Historical" staff to identify historic sites, regions, and areas that may have been adversely impacted by Hurricane Floyd. This provided the basis for deciding which sites needed to be assessed in detail. The determination of assessment needs helped to estimate work volume and staff requirements.

The maps also provided staff with a quick reference tool to check an applicant's proximity to the floodplains and ascertain if any additional considerations had to be addressed should they be located within a floodplain.

25. **Map of Cemetery Locations**: These maps showed the locations of cemeteries, with Floyd flood extents overlaid.

    Management Uses: The maps were used by Emergency Support Funtion-8 (Health & Medical) to identify cemetery locations and assess their need for disaster mortuary work. They were also used by Hazard Mitigation staff to identify which cemeteries were in the floodplains and might be candidates for possible Hazard Mitigation activities, such as relocation of a cemetery. In the case of a publicly owned cemetery, all of the above activity would have involved Public Assistance staff.

26. **FEMA Mobilization Centers Map**: Maps were created to display the locations of FEMA Mobilization Centers.

    Management Uses: The maps were used by FEMA operations staff to plan for and track resource movement.

27. **Map of County Seats**: Maps were created to display the locations of county seats.

    Management Uses: The maps were used by Community Relations staff who had to make contact with county officials. They were also used by FEMA programs to identify where to hold community meetings.

28. **National Flood Insurance Program (NFIP) Community Rating System Communites Map**: These maps showed the locations of communities that are members of the NFIP Community Rating System, which makes flood insurance available to residents.

    Management Uses: The maps were used by Hazard Mitigation staff to assess local government compliance with NFIP regulations, as well as to identify those communities affected that were not part of the NFIP but should be. This helped to identify where to assign staff and what work (assessment/solicitation to join) needed to be accomplished.

29. **Coastal Barrier Resource Act Zones (CBRA) Maps**: These maps displayed the North Carolina designated CBRA zones (the zones are a designation within the National Flood Insurance Program).

Management Uses: The maps were used by Public Assistance and Hazard Mitigation staff to identify recovery activities that fall within these special zones and therefore need special attention and monitoring to comply with federal law.

30. **Maps of Hog Lagoons**: These county-level maps showed the location of all Hog Lagoons and the Hurricane Floyd flood extents.

    Management Uses: These maps were utilized by Public Assistance "Environmental" staff and Public Health Service staff to check for and monitor contamination issues.

31. **Maps of Schools with Severe Damage**: These maps displayed all schools along with the Hurricane Floyd flood extents.

    Management Uses: These maps were used by the Public Assistance program to determine the proximity to the floodplain for all schools that applied for assistance. The proximity to the floodplain for each applicant determined recovery activities. These maps were also useful to Hazard Mitigation in identifying possible Hazard Mitigation Grant Program projects.

32. **Maps of Congressional Districts**: These maps displayed each Congressional District along with county boundaries, disaster recovery center locations, temporary living facility locations, Human Services housing applicants, and Hurricane Floyd flood limits.

    Management Uses: The maps were utilized to provide an overview of the disaster impact and recovery operations for congressional staff and other officials. Used by Congressional Liaison staff.

33. **Human Service Applicant Data & Hazard Mitigation "NFIP Community Assistance Team Assignments" Maps**: These maps display NFIP Community Assistance Team assignment areas. Within each assignment area the counties were prioritized and numbered in the order in which they were to be visited.

    Management Uses: The maps were used by Hazard Mitigation managers to determine "team assignment areas" and to prioritize staff work based on applicant densities per county.

34. **Mobile Home Demolition Maps**: These maps show counties grouped into "demolition project areas," the location of structures to be demolished, and the location and names of landfills.

    Management Uses: The maps were used by Public Assistance "Mobile Home Demolition" staff as a quick reference for project areas, but primarily to determine landfill use based on the landfill's proximity to structures tagged for demolition.

Quick Reference Maps: Other Maps produced as quick reference tools for field and office managers and employees:

1. Maps of Counties Designated under the Presidential Disaster Declaration
2. Maps of Designated Public Assistance Inspector Zones
3. Maps of Congressional Districts with County Boundaries and the Names of the Representatives for Each District
4. Maps of Populations within Urban Areas
5. Mosquito Spray Areas Maps
6. Maps of Red Cross Shelter Locations (updated & distributed as they changed)
7. Maps of Disaster Recovery Centers (updated & distributed as they changed)
8. Site-specific Maps using Aerial Photography, with Streets Overlaid. These were used primarily for reports.

NOAA Coastal Services Center
LINKING PEOPLE,INFORMATION, AND TECHNOLOGY

2234 South Hobson Avenue
Charleston, SC 29405-2413
(843) 740-1200
www.csc.noaa.gov
clearinghouse@noaa.gov

U.S. National Oceanic and Atmospheric Administration. Coastal Services Center. 2001. *Lessons Learned Regarding the Use of Spatial Data and Geographic Information Systems (GIS) During Hurricane Floyd.* NOAA/CSC/20119-PUB. Charleston, SC: NOAA Coastal Services Center.