North Carolina to Produce Flood Insurance Rate Maps in Partnership with the Federal Emergency Management Agency (FEMA)

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The State of North Carolina, the Federal Emergency Management Agency (FEMA), and numerous other federal, state, and local agencies have entered into a Cooperating Technical State (CTS) agreement, whereby the state will assume primary ownership of, and responsibility for, the National Flood Insurance Program (NFIP) maps for all North Carolina communities. This project will include conducting flood hazard analyses and producing updated, digital Flood Insurance Rate Maps (FIRMs).

Congress established the NFIP, which is administered by FEMA, in 1968 in response to escalating costs to taxpayers for flood disaster relief. In support of the NFIP, FEMA identifies flood hazards, and publishes and updates FIRMs for more than 18,000 communities. The FIRMS are used primarily for determining flood insurance requirements and for floodplain management. FEMA makes flood insurance available in communities which adopt and enforce floodplain ordinances that meet NFIP regulations. In accordance with the Flood Disaster Protection Act of 1973, flood insurance is required for insurable structures within floodprone areas as a condition of receipt of federal or federally backed financing. The goal of the floodplain management regulations is to minimize future flood damage. Compliance with these regulations saves an estimated $770 million annually in building and contents damage.

Hurricane Floyd revealed limitations of North Carolina's flood hazard data and maps. Approximately 55 percent of North Carolina FIRMs are at least 10 years old, and approximately 75 percent are at least 5 years old. Although a basic tenet of the NFIP is to provide communities with the most accurate, up-to-date flood hazard information available,

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FEMA's mapping budget is finite. On average, North Carolina receives only one updated flood study for one county per year. The CTS partnership between North Carolina and FEMA will maximize the use of state and federal funds to meet North Carolina's map update needs while maintaining national standards.

FEMA's Cooperating Technical Partner (CTP) Initiative

The CTS partnership agreement is part of FEMA's CTP initiative. This initiative is an innovative new approach to meet the challenge of maintaining up-to-date flood maps for over 18,000 communities. The flood maps need to be updated for several reasons. Natural and man-made changes in the floodplain alter flooding conditions. Also, development creates new streets and alters road networks. In addition, most of FEMA's flood map inventory was produced using manual cartographic methods. Although these methods were state of the art at the time, modern technology now supports digital production of the maps. Users need digital maps for automated geographic information systems applications. The digital format also allows for more efficient future map updates, as well as for online distribution. Current, accurate flood maps are critical to reduce potential loss of life and property, reduce NFIP and disaster costs, and protect the natural and beneficial values of floodplains. Nationwide, 63 percent of the maps are at least 10 years old, and 84 percent are at least 5 years old or older.

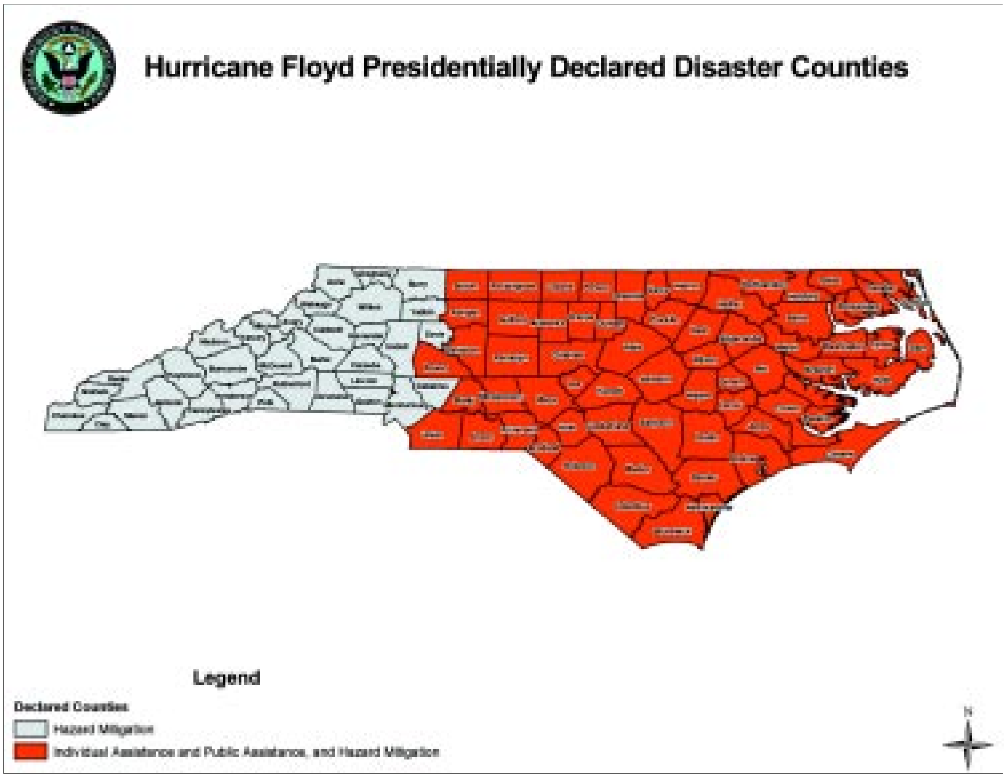
In 1997, FEMA designed a plan to modernize its flood map inventory. Over time, the objective is to eliminate the existing backlog of outdated maps and to convert all the maps to a digital format. One of the key objectives of the modernization plan is to increase local involvement in, and ownership of, the flood mapping process. Therefore, FEMA developed the CTP concept. As technologies have increased dramatically, many states, regional agencies, and local communities have become increasingly sophisticated and have invested significant resources in flood hazard identification. The CTP initiative will recognize the contributions of these communities and agencies and fully integrate them into the flood mapping process.

North Carolina's CTS Flood Mapping Program

North Carolina is the first state to enter into a CTS partnership with FEMA. North Carolina's interest in updating its flood maps is understandable. The state faces extreme risk and damage from hurricanes and flooding. Since 1989 there have been 14 federally declared disasters in North Carolina. Damages from Hurricane Floyd alone have reached $3.5 billion. With Hurricane Floyd, 4,117 uninsured and under-insured homes were destroyed. The state's vulnerability to hurricanes and flooding make it crucial that communities and property owners have accurate, up-to-date information about the flood hazard. The updated digital FIRMs produced through the CTS program will help to protect the lives and property of North Carolina citizens and contribute to their general well being.

In August 2000, the North Carolina General Assembly allocated $23 million to the flood-mapping project. FEMA has contributed an additional $6 million toward the project. The State of North Carolina is pursuing the remaining $4 million from other federal CTS partners. In addition to its cash contribution, FEMA has pledged in-kind contributions of engineering, mapping, and program management services through its Mapping

Coordination Contract with Dewberry & Davis LLC, a private architectural/engineering firm. Based on the General Assembly's directive, work has begun on Phase I, which includes the six eastern river basins—Cape Fear, Lumber, Neuse, Pasquotank, Tar-Pamlico, and White Oak—most affected by Hurricane Floyd. These river basins account for approximately one-half of the state, affecting 48 counties (in whole or in part) and approximately 21,200 linear miles of streams and rivers. Phase I has an aggressive schedule of completing the basin studies for Lumber, White Oak, and Tar-Pamlico by August 2001 and for the other three basins by August 2002. Phase II, which will include five basins in central North Carolina, will be initiated in 2001, and Phase III, which will include the final six basins in western North Carolina will be initiated in 2002. The goal is to have the entire state remapped by the end of 2005.



Hurricane Floyd: Presidentially declared disaster counties.

Production of Digital FIRMs Involves Overlaying Topography and Flood Data on a Base Map

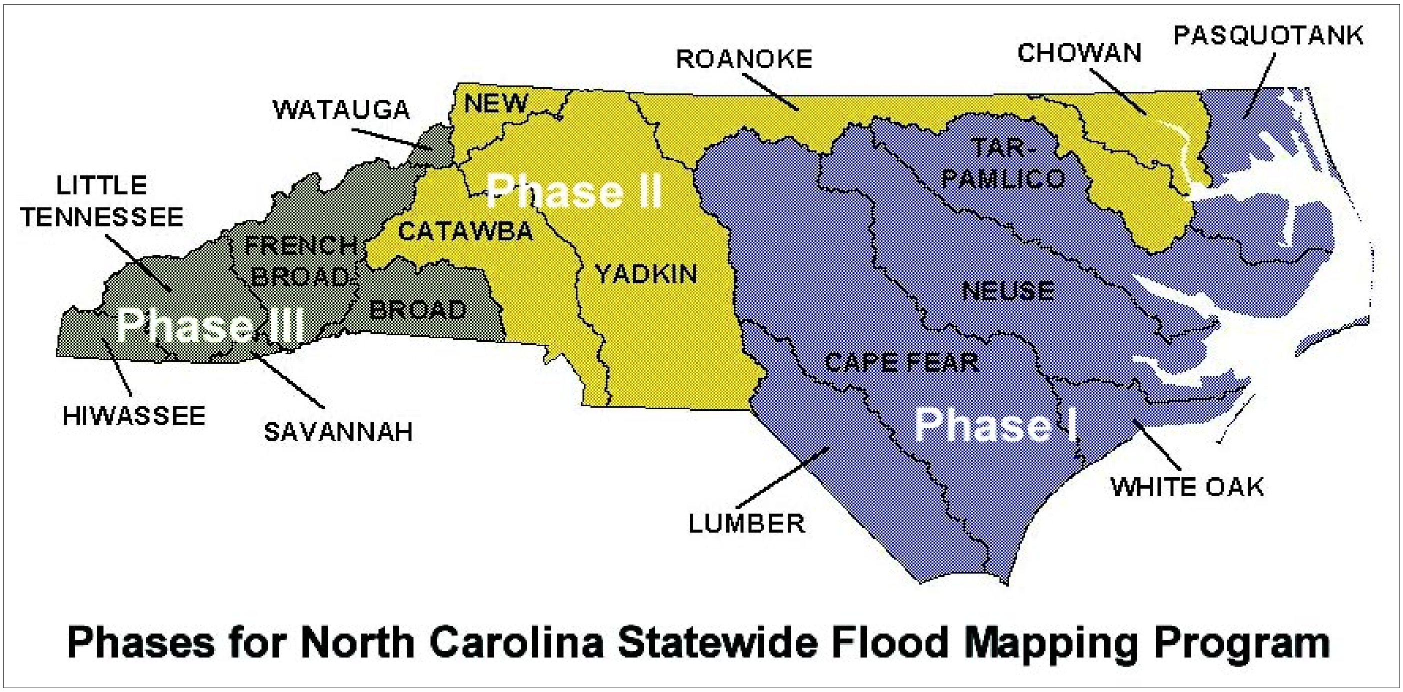
Digital Orthophoto Quarter Quadrangles (DOQQs) produced in partnership by the State of North Carolina and the U.S. Geological Survey (USGS) using updated 1998 aerial photography will be used as the primary base map. In areas where there is a locally produced base map that is more current or more accurate than the DOQQs, the locally developed map may be used as the base. The base map covers the entire geographical area and is used as the source for physical features—most notably roads and road names, railroads and railroad names, streams, and corporate limits. Map users utilize these features to locate properties and structures relative to floodplains. DOQQs also show the location of individual structures.

The North Carolina CTS program will entail the acquisition of high-resolution topographic data and development of accurate Digital Elevation Models (DEMs). The DEMs will be used to perform engineering studies to develop up-to-date, accurate flood hazard data and floodplain mapping. Additionally, because the DEMs will be "wall-to-wall," they will have great value for other engineering and planning applications beyond flood mapping.

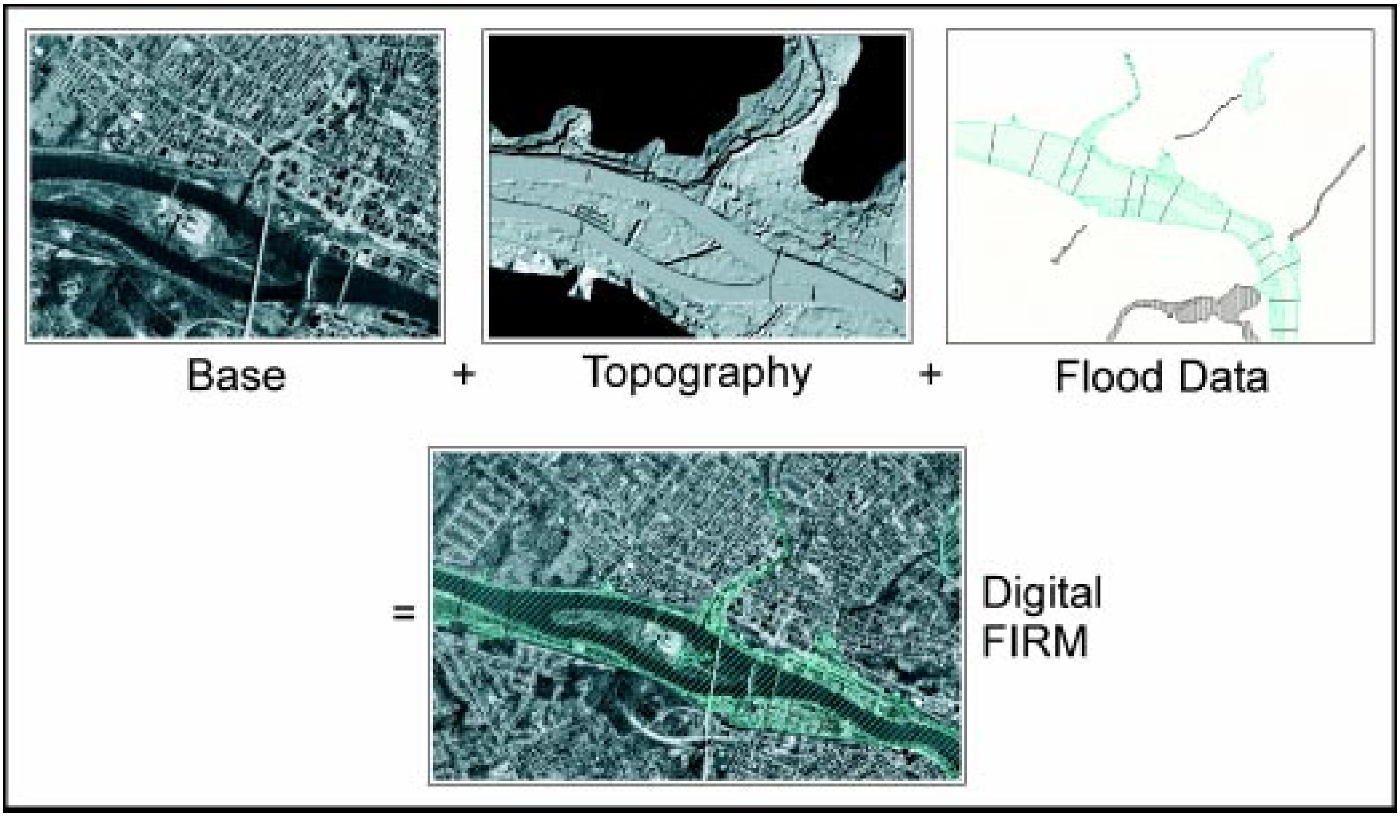
The development of updated digital FIRMs for the six eastern basins has begun with a comprehensive "scoping" phase for each basin. Because flooding sources frequently affect many counties and/or municipalities, it is most efficient to conduct the updated analyses and mapping on a basin-wide basis. The scoping process entails researching and inventorying all available elevation, flood hazard, and digital base map data that may be useful for preparing updated digital FIRMs. Flood hazard data (e.g., flood elevation profiles, floodplain boundaries, floodways, and coastal hazard zones) already on the FIRMs are assessed for adequacy. Where the existing flood hazard data are inadequate, the most appropriate technical method to develop up-to-date flood hazard data is determined and a priority level established. Face-to-face meetings are being conducted with counties and communities to determine needs for updating the FIRMs. Data that need to be developed or acquired—such as digital base maps, DEMs, or field surveys of stream channels, hydraulic structures, and coastal transects—are identified. The proposed scales and paneling scheme for digital FIRM production are determined. Finally, a schedule will be developed for the completion of updated flood hazard data and for digital FIRM production. The results of this scoping research and coordination are consolidated and synthesized to produce "Basin Plans" tailored to the needs of all the counties and communities within the basin.

After scoping comes the map production phase. Using the basin plans developed during the scoping phase and the DEMs being developed, work on updated engineering analyses and floodplain mapping begins. Updated flood hazard data and floodplain mapping will be used to produce seamless digital FIRM coverage for the entire State. Digital FIRMs will be produced on a countywide basis, whereby the county and its incorporated municipalities are shown on the same set of maps. The vertical reference for elevation data on the FIRMs will be converted to the North American Vertical Datum of 1988 (NAVD 88). The North Carolina Geodetic Survey will work with communities and counties to implement the use of NAVD 88 and to convert between NAVD 88 and other datums (e.g., locally established datums).

The preliminary countywide digital FIRMs will be issued to each county and its communities for review and comment. The state will hold a meeting in each county subsequent to the issuance of its preliminary digital FIRM to present the maps and give the county, its communities, and citizens an



Phases I, II, and III of the North Carolina Flood Mapping Project.

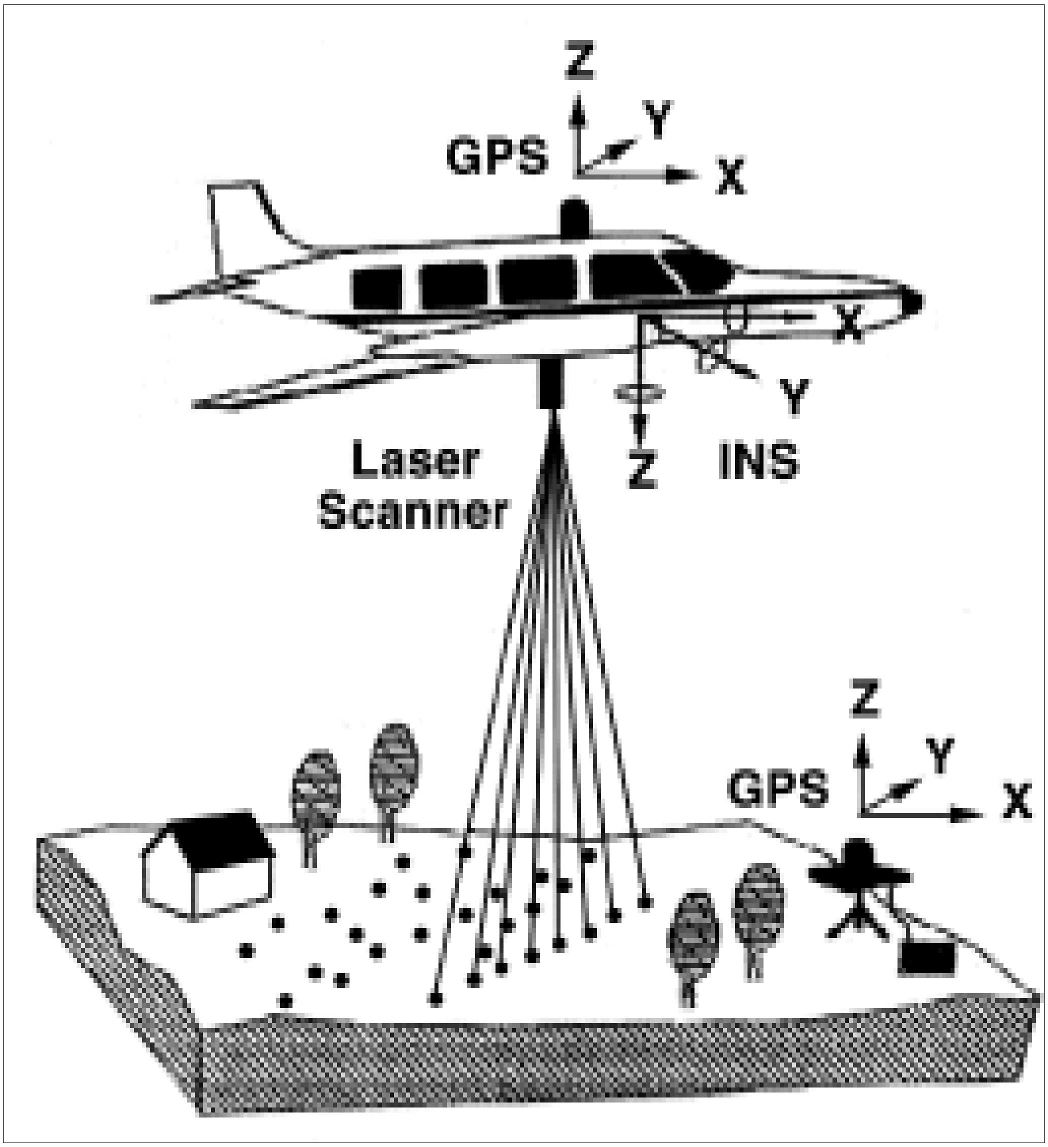


Component parts of digital flood insurance rate maps.

opportunity to comment on the maps. After the meeting, a statutory 90-day appeal period will be provided. During this appeal period, the affected county, communities, and/or citizens will have the opportunity to submit scientific or technical data refuting or contesting the results of the preliminary digital FIRM.

In addition to the production of digital FIRMs, the North Carolina Flood Mapping Program also includes implementation of a state-of-the-art, dynamic information technology (IT) infrastructure to analyze, maintain, and archive maps and associated flood hazard data. This system will also present and distribute mapping data (DEMs, engineering analyses and models, base maps, digital FIRMs, study reports) and associated documents to the public via the Internet. Finally, the project plan includes the eventual development of a real-time flood forecasting and inundation mapping capability.

A cornerstone of the project is the State of North Carolina CTS Committee. The Committee, in close collaboration and coordination with the North Carolina Division of Emergency Management and FEMA, will be responsible for strategic planning; providing input regarding data and products; facilitating multi-level government coordination; providing technical and programmatic expertise and advice; and reviewing and concurring on Mapping Activity Statement Agreements. The CTS Committee is comprised of stakeholders from more than 20 federal, state, county, and local government agencies, as well as several North Carolina professional associations and the academic community. As examples, J. Dean Slate (President of the North Carolina Society of Surveyors) and Tom Morgan (also of the Society of Surveyors) are on the CTS Committee.



LIDAR sensor.

The State of North Carolina has selected two private firms to conduct the work: Greenhorne & O'Mara and Watershed Concepts. The work will include two major components: (1) conducting hazard analyses and producing updated, digital FIRMs for the six eastern basins; and (2) designing and implementing the IT infrastructure for the mapping program, as discussed earlier.

DEMs To Be Produced by Light Detection and Ranging (LIDAR)

When the State of North Carolina issued a Request for Qualifications, it called for high-resolution DEMs at an accuracy level of 20-cm vertical root-mean-square error (RMSE), without stating how those DEMs should be produced. All responses proposed the use of LIDAR in lieu of traditional photogrammetry. Greenhorne & O'Mara will use 3Di as its main LIDAR firm. Watershed Concepts has EarthData as its main LIDAR firm, with support to be provided by TerraPoint & 3001. The State of North Carolina intends to initiate work by early December 2000.

LIDAR is considered by many to be the "latest and greatest" technology in the toolbox of the surveying and mapping community—at least to those in the business of producing DEMs. (In this article, the term "DEMs" is used in a generic sense to represent randomly spaced elevation points that form a Triangulated Irregular Network [TIN] as well as uniformly spaced elevation points in a gridded DEM. The uniform grid is interpolated at precise x,y coordinates from surrounding TIN points.) Normally mounted in the camera port of a mapping aircraft, LIDAR sensors emit up to 25,000 laser pulses per second in a circular or zig-zag pattern beneath the aircraft. Eye-safe laser spot sizes can vary (from inches to meters in diameter), and the flying height, airspeed, and scan angle control the density of laser spots (pulses) that hit the ground or features thereon. There are invariably gaps between individual laser spots on the ground.

Each laser pulse normally receives a "first return" and/or a "last return," and some LIDAR sensors can also receive intermediate returns. The "first return" is from the first thing hit by a laser pulse; e.g., a rooftop or a treetop. First-return LIDAR data are used to produce Digital Surface Models (DSMs) of forest canopies, for instance. When a laser pulse hits a treetop, a portion of the laser beam will continue through the tree to hit subsequent targets

Post-processing leaves uncleaned artifacts.

beneath the tree canopy. The "last return" is from the last measurable surface hit by a laser pulse, hopefully the bare-earth terrain beneath the trees; but this is far from certain since it is possible that a laser pulse might never penetrate the dense foliage to reach the ground. If you cannot see the sky while walking through a forest, laser pulses from aircraft flying overhead will not be able to see the ground either. Intermediate returns hit tree branches or other features between the first and last returns.

Almost all commercial LIDAR sensors in use today are topographic LIDARs. Topographic LIDAR laser pulses that hit a water surface are usually absorbed by the water, leaving data voids with no returns. Some returns may be received, but they are often unreliable as to whether they represent the water surface elevation, the terrain beneath the water, or some aberration. It is common to use imagery to identify the outline of water areas, and to discard topographic LIDAR elevations within those areas as unreliable. Bathymetric LIDARs with multiple wavelengths can penetrate clear water, but their use is limited in muddy, murky waters.

For each and every laser pulse, a LIDAR sensor must track the x, y, and z coordinates of the sensor in the air; the roll, pitch, and yaw angular rotations of the sensor about the x, y, and z axes; and the laser scan angle of each laser pulse; and then measure the time that each laser return is received back at the sensor in order to compute the distance down and back. This enables the State Plane or UTM x, y and z coordinates to be computed for the surface points mapped by the laser pulses.

Normally, last-return LIDAR measurements are used to produce bare-earth DEMs. However, a great deal of post-processing is required before this can happen. The LIDAR sensor data must first be merged with airborne Global Positioning System (GPS) data and with roll, pitch, and yaw measurements from the inertial measuring unit of the inertial navigation system. As with all GPS surveys, the latest National Geodetic Survey (NGS) geoid model must be used to convert ellipsoid heights into orthometric heights. Still, the DEMs at this stage do not necessarily represent the bare earth.

Automated post-processing is performed with computer algorithms to remove points that are inconsistent with surrounding elevation points. For example, a single DEM spike could be caused by a telephone pole, a single isolated boulder in a field, a rooftop, or a tree too dense to be penetrated by a laser pulse. It is very difficult for computer algorithms to perform this task flawlessly. In this example, we want the computer to remove spike points on telephone poles, rooftops and trees but leave the point on the boulder; the problem is, they could all look the same to the computer. The computer tries to determine when a slope is unrealistic, but in doing so it might erroneously delete points on a levee or stream bank that need to be there. Similarly, it is hard for a computer to determine if points on steep hillsides represent the bare-earth terrain or points that failed to penetrate the vegetation; a point at the top of a tree on a steep hillside might have the same elevation as a point on the ground at the adjoining laser point a few feet away.

Automated post-processing normally leaves a percentage of "uncleaned artifacts" (i.e., elevation points that do not represent the bare-earth terrain). This percentage is normally somewhere between 5 percent and 20 percent, depending on proprietary algorithms used for post-processing and the characteristics of the vegetation being surveyed. Whereas it is normally preferred to acquire LIDAR data during leaf-off and low-water conditions, this is not always possible. North Carolina projects that there will only be 18 good flying days during the winter of 2000-2001 (leaf-off) flying season, so insistence on low-water conditions might jeopardize the entire data acquisition. The artifacts shown in the figure do not necessarily impact hydraulic modeling of floodplains as most of the artifacts are in the hills outside the floodplains. Nevertheless, DEMs that include such artifacts are less suitable for automated or semi-automated hydraulic modeling than are DEMs that are fully cleaned (at considerably higher costs) of such artifacts.

Manual post-processing is performed by human analysts who compare elevation data with the imagery. The imagery may be acquired from the same LIDAR aircraft. However, because LIDAR is often flown at night and imagery is flown during limited daylight hours to control the sun angle, it is common for imagery to be acquired separately, at a different time and date. Because automated post-processing has been known to delete valid elevation points near escarpments, stream banks, and levees, manual post-processing by an experienced analyst is used to make the ultimate decisions on LIDAR points to be retained or rejected. The major factor here is cost, as manual post-processing could quadruple the cost of a project.

The remote sensing community is developing standard procedures for the calibration of LIDAR systems, but no calibration standard has yet emerged. Meanwhile, North Carolina has specified that test ranges be established near the airports to be used, for daily in-situ calibration of the total LIDAR systems. To supplement the LIDAR data, the state's contractors will conduct field surveys of stream and river channels and bridges and culverts so that hydraulic modeling can be conducted.

Finally, there is work here also for land surveyors registered in North Carolina. Under the control of the North Carolina Geodetic Survey (NCGS), multiple survey firms are being hired to establish between 60 and 100 survey check points per county (i.e., 20 or more checkpoints in each of three to five major vegetation categories representative of the floodplains in each of the 50+ counties being studied for revised flood insurance studies and digital FIRMs). The objective is to determine whether the LIDAR data achieve a 20-cm vertical RMSE in the major vegetation categories identified for each floodplain being studied. We know that the 20-cm vertical RMSE standard is achievable in open terrain (sand, rock, dirt, short grass), but meeting this standard in dense vegetation and heavy pine forests of North Carolina may be difficult. Note, however, that traditional photogrammetry is also disadvantaged in heavily forested areas because photogrammetrists can determine accurate elevations only when the same points on the ground can be seen from two totally different angular perspectives afforded by stereo photography. LIDAR, on the other hand, needs to be able to see through or between the trees from only a single laser pulse that is looking nearly straight down. To the degree that LIDAR satisfies the 20-cm vertical RMSE standard, hydraulic modeling will also be performed with higher accuracy than in the past, and the new digital FIRMs will be vastly superior for floodplain management.

We do not yet know all the limitations of LIDAR, but we do know that LIDAR appears to offer the potential for generating high-density, bare-earth DEMs that are of higher accuracy and lower costs compared with competing technologies and the ability to do so within the compressed timeframes established for this program. Without LIDAR there appears to be no affordable way to acquire the high-density DEMs needed to revise the obsolete FIRMs throughout North Carolina. The lessons learned here will surely impact the NFIP and initiatives to revise obsolete FIRMs elsewhere in our nation.

Conclusion

This program will benefit North Carolina communities and citizens in numerous ways. The updated flood hazard data will provide current, accurate information to make sound siting and design decisions when rebuilding from flooding disasters, building new structures and infrastructure, and retrofitting existing structures. Indeed, the use of the updated data by communities for floodplain management will dramatically reduce long-term flood losses to the State of North Carolina, its communities, and its citizens. The updated flood hazard data will also alert those at risk of flooding of the need to purchase flood insurance protection. Further, the current, updated base maps and the digital format of the FIRMs will allow users to make more efficient, precise flood risk determinations. Community officials will be able to use the digital FIRMs with geographic information systems for analysis and planning. The DEMs will be useful for almost any engineering or planning application (e.g., site design, stormwater management, transportation planning and design, and spill response). Finally, the digital information system will allow online access to all map users 24 hours a day from a personal computer, without the use of a sophisticated geographic information system.

The North Carolina Office of State Budget, Planning and Management (OSBPM) will oversee and manage the program in close coordination with the North Carolina Division of Emergency Management. The North Carolina Geodetic Survey, a component of OSBPM, will be involved in the acquisition of topographic data and the development of DEMs. The North Carolina Center for Geographic Information and Analysis, also a component of OSBPM, will be involved in the development and acquisition of digital base maps, production of digital FIRMs, and implementation and operation of the digital Information System.

FEMA's Map Assistance Center staff is available to answer questions about the North Carolina CTS Flood Mapping Program, the NFIP, and NFIP mapping. Callers can reach the Center toll free by dialing 1-877-336-2627 (1-877-FEMA-MAP).

Convergence

International LIDAR Mapping Association Established

Created in October 2000, the International LIDAR Mapping Association (ILMA) aims to promote the benefits of LIDAR technology throughout the mapping community.

While not being a pioneering technology, LIDAR mapping has emmerged as a viable commercial alternative for a wide variety of digital mapping programs. LIDAR systems are in operation throughout the world in situations where high-resolution, three-dimensional data sets and quick processing turnaround are required.

LIDAR MAPPING FORUM

The International LIDAR Mapping Association will bring together LIDAR manufacturers, operators, component suppliers, data processors and end users in an inaugural meeting to be held at the Hyatt Regency Downtown hotel in Denver, Colorado, on February 8, 2001.

Sponsored by the Applanix Corporation, EnerQuest Systems LLC, TerraPoint, Inc., and Z/I Imaging, the inaugural LIDAR forum, Mapping Our Future, will include presentations on LIDAR and Digital Image Processing, as well as panel discussion about the issues facing the LIDAR industry, such as technology availability and breaking the conventional mapping mindset.

The creation of the international LIDAR association and its forum come at a time of a growing awareness in the mapping community of the benefits of LIDAR mapping and the need to promote them among potential users. [For more information, contact: Andy Bogle at 281/870-9407; E-mail: andybogle@tms-solutions.com]