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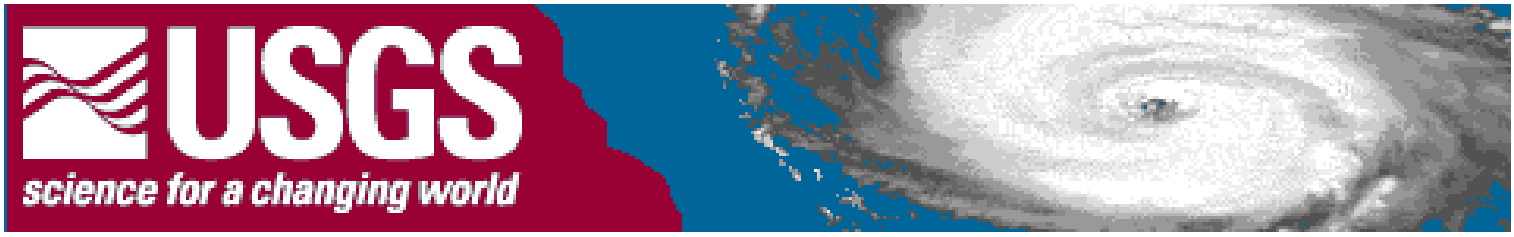

Activities in Nicaragua In Support of the Hurricane Mitch Reconstruction Program

A Final Report Submitted to
The U.S. Agency for International Development

by the

U.S. Geological Survey

May 2002

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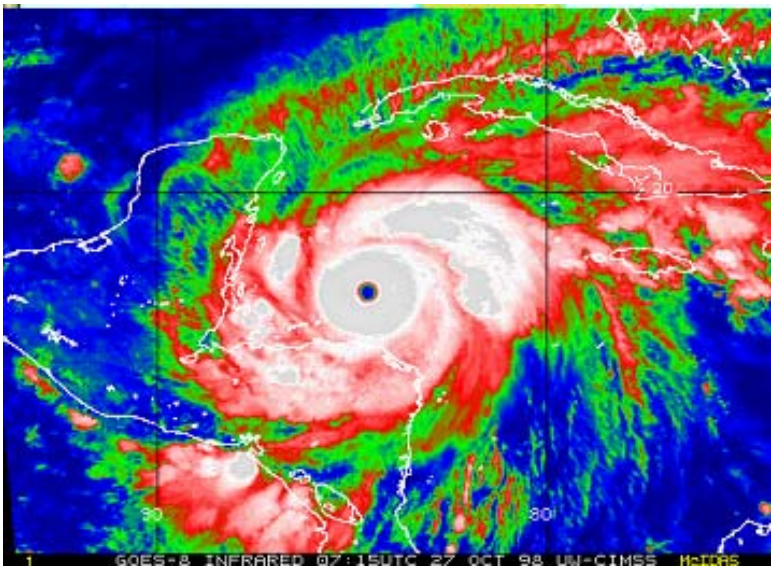
Overview

Raphael Rodriquez



On October 21, 1998, a tropical depression formed in the southern Caribbean Sea. One day later, the storm became a tropical storm and was given the name "Mitch". Tropical Storm Mitch moved very little over the next few days, drifting to the northwest, and gathering strength. On October 24 Atlantic Tropical Storm Mitch was upgraded to a hurricane that developed into one of the strongest and most damaging storms to ever hit the Caribbean and Central America. At its height on October 26 and 27, the hurricane had sustained winds of 180 mph and dumped heavy rains over Central America. The image above, taken by the NOAA GOES satellite, shows the position of Hurricane Mitch on October 28, 1998.

Hurricane Mitch was the worst natural disaster in Nicaragua's history. An estimated 3,000 people died and 870,000 people (18 percent of the total population) were affected by the storm. Catastrophic floods in the northern Atlantic coastal area and in the provinces of Madriz, Nueva Segovia, Esteli, Jinotega, Matagalpa, Chinandega, Leon, Granada and Rivas, and numerous landslides caused unparalleled destruction.

The productive sector was particularly hard hit. An estimated 11,550 hectares were permanently destroyed. Another 308,000 hectares (25 percent of the country's total cropland) was seriously damaged. Potable water and wastewater systems serving an estimated 804,000 people suffered over $560 million worth of damage. Ninety health centers and over 400 health posts were damaged. Over 500 primary schools were structurally damaged. Total damages are estimated at US $1.5 billion – 70 percent of the 1998 Gross Domestic Product of Nicaragua.

The Nicaraguan government estimated that nationwide more than 30,000 houses had been either totally or partially destroyed and as many as 870,000 people were estimated to have been

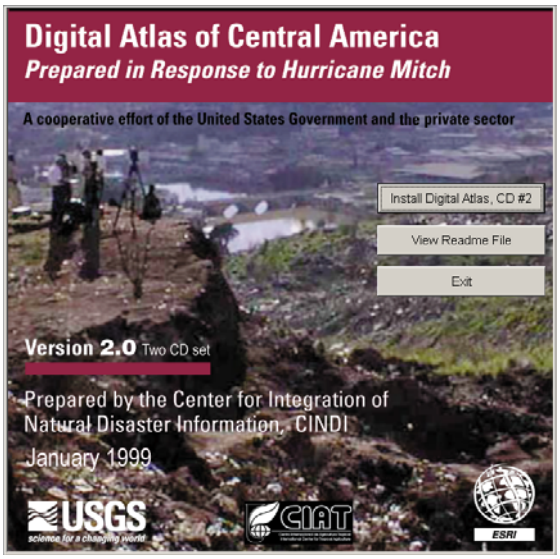
displaced. Transportation officials reported on that 70% of the roads were unusable and at least 71 bridges had been destroyed or heavily damaged

Man-made factors and management deficiencies aggravate the effects of natural disasters, such as Hurricane Mitch, in Central America. These include poorly developed and maintained infrastructure, poor watershed management, inappropriate situation of population centers, and limited capacity to anticipate and respond to extreme climate events.

To manage and eliminate these and other weakness, USAID and the Government of Nicaragua (GON) developed a series of national level reconstruction activities in public health, economic reactivation, soil conservation, repair and reconstruction of infrastructure, flood control and disaster mitigation through better land-use planning and watershed management.

A wide variety of data, information, expert analyses, and capacity building and technical assistance were needed to successfully plan and implement the recovery and reconstruction effort facing by the Central America countries. Detailed maps, aerial photographs of key areas, damage inventories, and continued assessment of potential flood, landslide, and other hazards needed to

be made available, not only to plan the reconstruction efforts, but also to mitigate the human and economic impacts of future natural disasters.



As part of this effort, the USGS's Center for Integration of Natural Disaster Information (CINDI) provided integrated geologic, geographic, hydrologic, and biological information needed to support emergency managers and international relief organizations and enable them to understand and respond effectively to the devastation on the ground. Within weeks following the tragic event, the CINDI created a digital atlas communicating more than 60 different types of geospatial information in a form that can be manipulated for analysis. The new maps showed the locations of landslides and floods, damage to roads, bridges, and other infrastructure, precipitation information, and impacts on agricultural lands. The information was extracted from satellite images, existing geologic maps, airphotos, and dozens of other digital and paper sources. This integrated information has continued to be critical for allocating resources for understanding the disaster's long-term impact on ecosystems, and for planning the region's economic recovery and reconstruction.

The U.S. Geological Survey brought its expertise, resources, and capabilities to bear in a cooperative effort with USAID, other U.S. Government agencies, and Nicaraguan national and local agencies to assist in the reconstruction following Hurricane Mitch. This effort, which began in September 1999 and ended in December 2001, encompassed both short-term and long-term goals. It was intended not only to support relief and reconstruction activities already under way but also to assist in developing Central America capacity and the developing strategies for long-term sustainability and the mitigation of vulnerability to natural hazards.

The USGS program in Nicaragua included the following projects:

1) **Development of Digital Topographic Maps**

2) **Acquisition and Distribution of Satellite Imagery and Aerial Photography**

3) **Development of an Internet Data Clearinghouse**

4) **Streamflow Monitoring and Hydrologic Data Collection and Management**

5) **Landslide Hazard Assessment**

6) **Volcano Hazard Assessment**

7) **Biological Assessment of Damage to Coastal Resources**

8) **Municipal GIS Development**

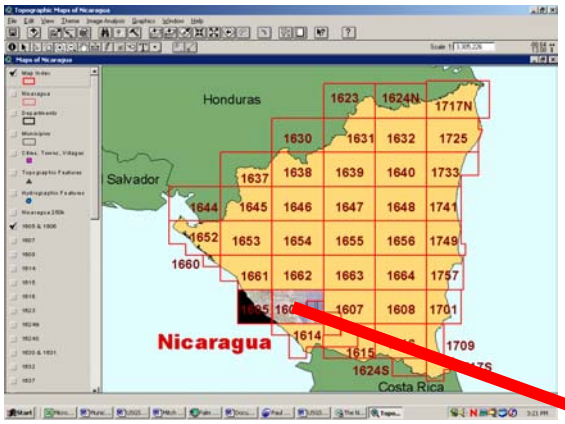
Digital Topographic Maps

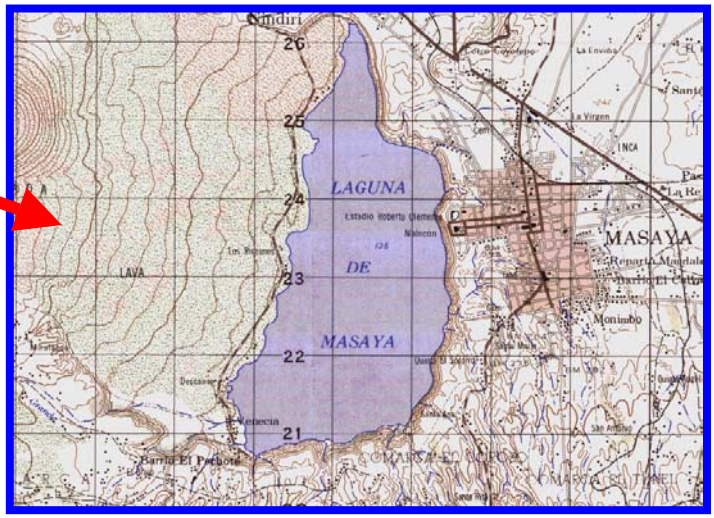
Sharon Hamann and Cassandra Ladino

Objectives: One of the most important basic tools needed to support reconstruction and hazard mitigation activities were accurate topographic base maps showing topographic contours, locations or rivers and streams, roads, and layouts of cities, towns, and villages. Although paper topographic maps at scales of 1:250,000 and 1:50,000 had been available in El Salvador for some time, these maps were not available in digital form at the time Mitch occurred in 1998.

Digital maps allow much more rapid and accurate measurements of distances and surface areas, and provide the base upon which to add additional information in the development of geographic information system (GIS) products. The objective of this project was to compile and package digital topographic maps for Guatemala in a compact convenient format and assist the Government of El Salvador in making these maps publicly available.

Activities: The USGS, working through the U.S. National Imagery and Mapping Agency (NIMA), compiled and packaged digital maps for El Salvador at scales of 1:250,000 and 1:50,000. The equivalent of approximately 40 individual map sheets were mozaicked and indexed.





The maps were digitally compressed and packaged on a single CD-ROM together with GIS software to view the maps, make measurements, and print copies of selected areas.

These maps have been delivered to INETER, who will assume responsibility for their distribution These products will significantly increase access to large-scale topographic maps for Nicaraguan government agencies and the general public. This represents a major step forward in getting basic products such as this into the hands of the public and educating them as to their potential applications. These maps will be used as the basis for a national disaster-preparedness GIS for Nicaragua, and are also serving a host of other applications, including risk assessments, road building, watershed analysis, and urban development.

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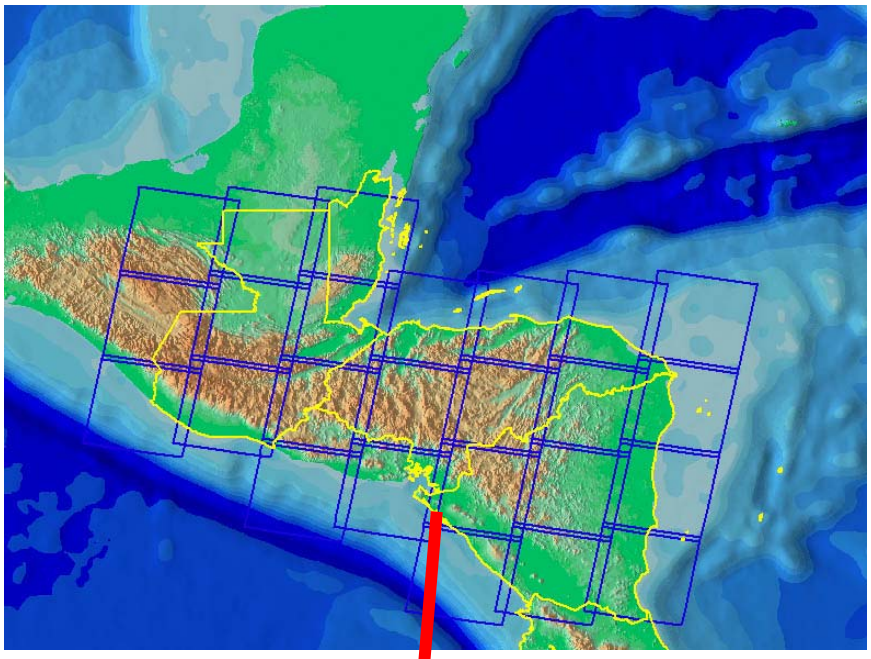
Satellite Imagery and Aerial Photography

Mike Crane and Ron Risty

Although topographic maps are essential for providing a geographic frame of reference, the information they contain is only as current as their dates of publication. The best alternative to doing extensive observations on the ground is acquiring imagery of priority areas from satellites or aircraft.

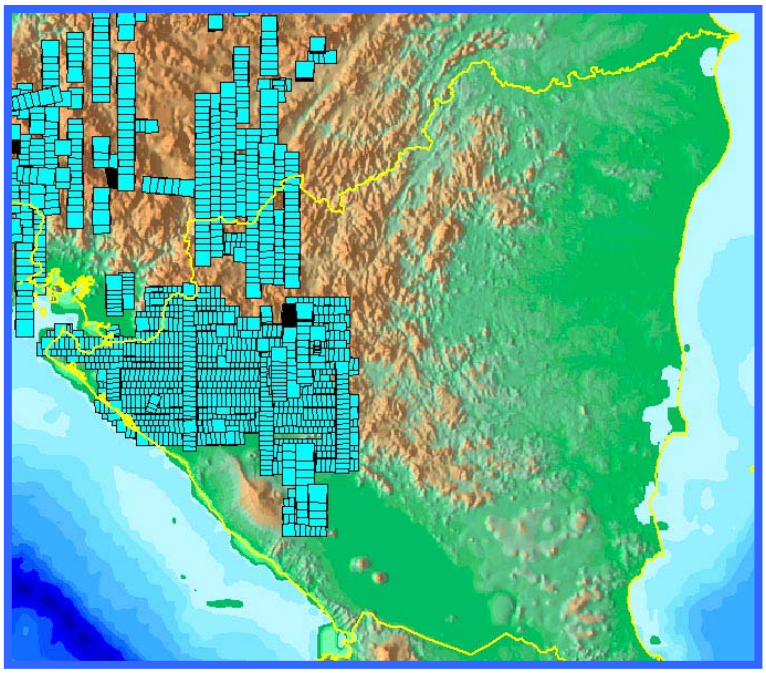


Landsat satellite imagery provides 15-30 meter resolution and the ability to detect subtle differences in vegetation and land cover. The figure to the right shows the location of individual Landsat images (scenes) covering the Mitch-affected countries. The USGS compiled and mozaicked complete Landsat satellite imagery coverage for El Salvador, Belize, Honduras, El Salvador, and Nicaragua, both in digital form on CD-ROM, and as large format prints.

The sample Landsat image to the right shows the area around the Estero Real estuary, in western Nicaragua. Landsat mage products were provided to U.S. and Nicaraguan counterpart agencies participating in USAID-funded Hurricane Mitch relief activities, and are also now available to the public and private sector on a cost-of-reproduction basis. This imagery is being used for a wide variety of applications, including

land-use and land-cover analysis and assessment of agricultural areas.

Aerial photography – The USGS acquired approximately 1700 frames of black and white aerial photography over Nicaragua (see figure to the right). This photography was utilized for fine-scale analysis and mapping of landslides and flood inundation patterns, and also provided the base for municipal information systems developed for 40 Honduran cities. All photography has been catalogued, indexed, and archived at USGS's EROS Data Center and is available to the public for the cost of reproduction.



The aerial photos below were taken shortly after the catastrophic debris flow on the flanks of Casita Volcano, triggered by the intense rainfall during Hurricane Mitch. This event completely buried two towns and resulted in the deaths of over 2500 people. Photography like this was used in initial assessments of landslides and flooding throughout Nicaragua. Most of the aerial photography flown over Honduras was flown at a scale of 1:40,000, however high-resolution scanning of negatives produces images with resolutions of 2-3 feet, equivalent to much larger scale photography.

Internet Data Clearinghouse

Eric Van Praag

Project Objectives

The Mitch reconstruction and planning activities in Nicaragua by USAID, the United States and Nicaragua government agencies, and other donor organizations have generated a tremendous amount of spatial data and information, to complement the spatial data holdings already held by national institutions. The ability to search for and locate these data sets, the ready accessibility by local governmental agencies and various aid agencies, and the distribution of these data and information are critical elements of both short-term reconstruction efforts and longer term planning. To facilitate management and access to relevant data, this project has implemented a national Clearinghouse node and associated WEB Site in Nicaragua, with the following main objectives:

- Facilitate discovery and access of spatial data;
- Reduce duplication of efforts in the production of spatial data;
- Facilitate evaluation of data quality, suitability and accessibility;
- Foster better communications and cooperation amongst data producing agencies.

Project description

Prior to the project, Nicaragua lacked the means to catalog and describe their spatial data holdings or make them easily available. Data was simply produced and stored in national agencies, leaving the burden of finding it, assessing its value or acquiring it entirely to the user - who was often unable to even localize the data he was searching for.

Based on the model provided by the U.S. Federal Geographic Data Committee's (FGDC) pioneering work in spatial data cataloging and standardization, and on previous EDC projects in the region administered jointly with the Pan-American Institute of Geography and History and the United Nations Environment Programme, project staff assisted partner institutions to establish a Clearinghouse node and Clearinghouse WEB Site. The Clearinghouse node supports a spatial data catalog, registered on the International Clearinghouse system, accessible through several Internet "gateways" (search engines specializing on spatial data catalogs) in the world, and containing all data descriptions (metadata) developed by partner agencies in Nicaragua and by USGS projects in Central America. The WEB Site complements the Clearinghouse node by providing: access to the data catalogs - either by topic or by institution, access to institutional spatial data inventories, Internet Map Services, download spatial data options, and an assorted gamut of other services.

Five national organizations have participated in the project: National Institute for Terrestrial Studies (INETER), Forestry and Agriculture Ministry (MAG-FOR), Ministry of Environment (MARENA), Alistar Foundation, Ministry of Public Works

Work was coordinated by a Steering Committee featuring one representative from each participating institution, plus the regional USGS project coordinator. A technical coordinator at INETER was hired half-time by the project. Each partner agency developed a project workplan and a metadata development plan, produced digital spatial data inventories, cataloged all – or most – of their spatial data holdings, and participated in the development of the Clearinghouse node and associated WEB Site. EROS provided training and capacity building in Clearinghouse implementation, GIS and WEB programming and design; a methodological framework; basic hardware and software needed to construct the node; technical assistance and overall coordination.

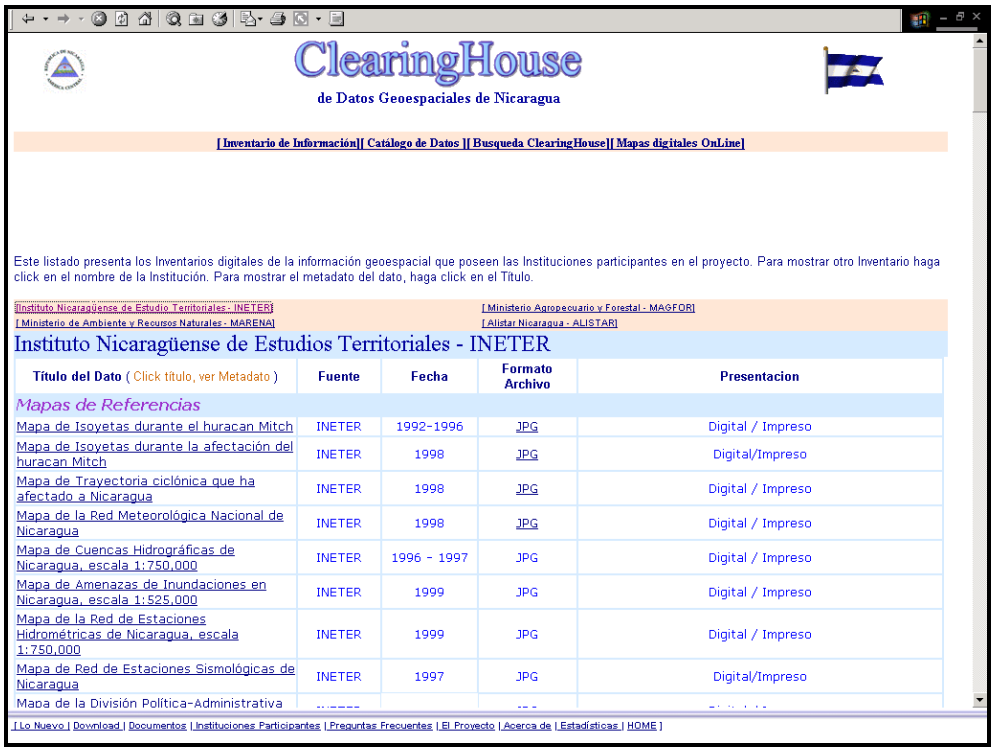
Results and Accomplishments

Nicaraguan partners implemented and made operational the two systems described above: a Clearinghouse data catalog node and its associated WEB Site. More than 430 spatial data sets were described and cataloged inside metadata records and carefully validated - with a significant proportion featuring links to browse graphics. The WEB Site features two browse sections for metadata consultation, and will in the near future host an Internet Map Service offering basic GIS functionality and access to public data holdings (now under construction). The physical

Clearinghouse server computer - featuring the Clearinghouse node and Web Site - is located at INETER.

The project has proven the benefits of working cooperatively to reach common objectives, and propagated and reinforced the value of data sharing amongst spatial data producers– although still being far from an ideal situation.

All deliverables were designed and built by partner agencies, generating the know-how needed to maintain, improve and adapt these products in the future. INETER and MAG-FOR in particular have a strong commitment to maintain and expand the system.



System maintenance and improvement looks sustainable due to the following considerations:

- Having designed and built the system, partners agencies acquired the resources and know-how needed to maintain and upgrade it;
- Partners appreciate the benefits obtained;
- Maintenance costs are low. The main hardware pieces needed have already being acquired, and all basic software in use is free. Costs of items like Internet connectivity and WEB maintenance are mostly internalized by agencies as part of their operational budgets.
- There is political support to sustain the system.

However, it should be acknowledged that further funding would make certain enhancements to the system possible in the near future:

- Incorporation of new institutions to the network - with the goal of reaching a "critical" mass of data cataloged as to make the system truly sustainable;
- Training in associated technologies and themes: Internet Map Servers, encryption, copyright, legislation, data standards, advanced WEB programming and design, e-commerce;
- Full implementation of an Internet Map Server;
- WEB Site upgrade: feedback mechanisms, statistical tools to track usage, restricted access to Web pages based on level of membership, e-commerce;
- Response to issues of copyright protection and unlawful data distribution;
- Data protection.

Due to the new system put in place public agencies and other users find themselves in a better position to locate, analyze and distribute spatial data needed for important rescue, mitigation and planning efforts needed to respond to natural disasters.

The Nicaragua Clearinghouse WEB Site is located at http://www.clearinghouse.gob.ni/. The Clearinghouse metadata catalog node can be searched by choosing the "America Central Clearinghouse Nicaragua" node from the list of servers in a given gateway (i.e. http://130.11.52.184/servlet/FGDCServlet)

Streamflow monitoring, Hydrologic Data Collection, Storage and Analysis

Mark Smith

As part of the Hurricane Mitch Supplemental Program, the U.S. Geological Survey (USGS) provided technical assistance in the area of surface-water hydrology to counterpart agencies in Nicaragua. Objectives of the USGS hydrologic program were:

1. Reconstruction and improvement of the national hydrologic monitoring network (streamflow and rainfall);
2. Development of a centralized hydrologic database for storage and analysis of hydrologic data collected;
3. Introduction of basic tools for the implementation of a flood-inundation mapping program in Nicaragua;
4. Intensive training and capacity-building within counterpart agencies to provide them with skills to independently collect, store, and analyze hydrologic data for use in flood forecasting and water-resources management; and
5. Implementation of nationwide (and region wide) quality-control standards for hydrologic data collection, storage, and analysis.

In conjunction with Objective 5, the USGS emphasized the value of sharing basic hydrologic data among government agencies, municipalities, and the public. The USGS counterpart in Nicaragua was the Instituto Nicaragüense de Estudios Territoriales (INETER), the GON agency primarily responsible for maintenance of the nationwide hydrologic monitoring network and storage of hydrologic data. The USGS provided equipment, training, and technical support to INETER as part of the surface-water hydrology program in Nicaragua.

National Hydrologic Monitoring Network

The hydrologic monitoring network in Nicaragua suffered heavy damage as a result of Hurricane Mitch; half of the 54 existing stream gages in Nicaragua were destroyed. The monitoring network was in desperate need of repair if it was to be useful for early flood warning and in planning for disaster preparedness and mitigation. To help address this need, the USGS worked closely with INETER (and with other USG agencies such as NOAA) to identify critical areas where stream flow data are needed to mitigate future damage and deaths from flooding and to enhance management of water resources.

One of the most critical areas lacking adequate hydrologic information was the Escondido River basin of eastern Nicaragua. USGS and Nicaraguan counterparts at INETER installed a total of five[1] state-of-the-art hydrologic monitoring stations in the basin as part of the Hurricane Mitch program (fig. 1). The Río Escondido flows to the Caribbean Sea and supports the only seaport on the east coast of Nicaragua. The monitoring stations are part of the Escondido River Forecast System developed by NOAA/NWS and INETER. Monitoring and management of water

[1] Five streamflow-monitoring stations were installed by the USGS and INETER; funding for one of the stations was provided by NOAA.

resources in the Escondido River basin are deemed critical to the economic well-being of the country.

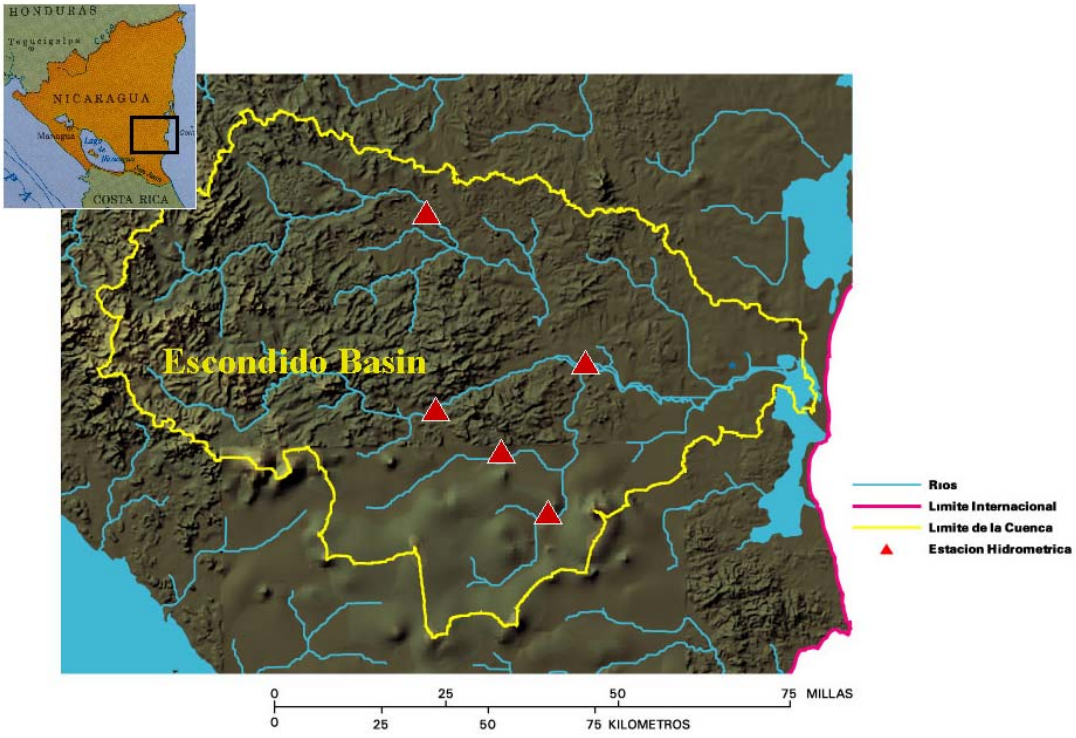


Figure 1. The USGS and GON counterparts installed 5 hydrologic monitoring stations in the Escondido River basin of eastern Nicaragua.

Real-time transmission of data from hydrologic monitoring stations is new to Nicaragua – the technology implemented in Nicaragua is essentially the same as that used by the USGS in the United States. Each station transmits hydrologic data via satellite, which is received in real-time by downlink stations in Nicaragua and Puerto Rico. There are two modes of operation: 1) normal mode, in which hydrologic data collected every 15 minutes are transmitted via satellite at 3-hour intervals; and 2) emergency mode, in which hydrologic data are transmitted as frequently as every 5 minutes during periods of flooding or heavy rainfall. An example of the streamflow gaging stations installed as part of the USGS program in Nicaragua is shown in Figure 2. Table 1 at the end of this report shows a complete listing of hydrologic monitoring stations that were installed in Nicaragua.

Figure 2. Streamflow monitoring station Río Siquia at Salto Grande.

Hydrologic data from the telemetric monitoring stations are being used by government agencies, municipalities, and private interests involved with flood warning, disaster mitigation and water-resources planning in Nicaragua. The USGS cooperated closely with NOAA/NWS and its contractors in developing the hydrologic monitoring network. Hydrologic data from the Escondido monitoring stations are incorporated into the river forecast system implemented by NOAA/NWS in the Escondido basin. Accurate river stage and flow data are critical to the success of river-basin forecasting models used by NOAA/NWS.

Problems and future needs

INETER hydrologists and technicians are well-trained and competent. As a result of formal and on-the-job training by the USGS, INETER quickly became capable of installing, operating, and maintaining the electronic monitoring equipment used in the gaging stations. Cooperative planning by USGS, NOAA/NWS, and other international donors has resulted in the procurement of enough spare equipment to support the hydrologic monitoring network in Nicaragua for the next 1-3 years.

Program continuity and maintenance of trained technical personnel at INETER will be critical to continued success of this program. Adequate operating budgets for maintenance of the monitoring network (vehicles, fuel, staff perdiem, and routine repair costs) need to be maintained within the agency. Based on an analysis of operating costs by USGS and INETER personnel, the estimated net annual cost (not including staff salaries) to operate and maintain the 5 streamflow monitoring stations in the Escondido basin is $10,000.

Centralized Hydrologic Database

INETER is responsible for collection, analysis, and storage of hydrologic data throughout Nicaragua. In order to accurately apply and statistically manipulate hydrologic data to determine discharge values, historic and current hydrologic information needs to be available in a comprehensive, centralized database. The existing computer database used by INETER was obsolete and did not meet the needs of their hydrologic program.

To this end, the USGS worked with INETER to implement the USGS surface-water database system, NWIS/ADAPS, in Nicaragua. The USGS provided INETER with a SUN workstation, capable of supporting 15-20 users, and advanced hydrologic-analysis software used by the USGS in the United States. Computer specialists at INETER are responsible for maintenance of the computer system, while INETER hydrologists and technicians are responsible for data entry, analysis and storage using the NWIS/ADAPS system. Real-time data from each station are stored on computer systems at INETER and at the USGS in Puerto Rico. These data are displayed via the World Wide Web at the USGS site in Puerto Rico:

http://pr.water.usgs.gov

Hydrologic information recorded by each station is displayed in graphical and tabular for the previous seven days (fig. 3).

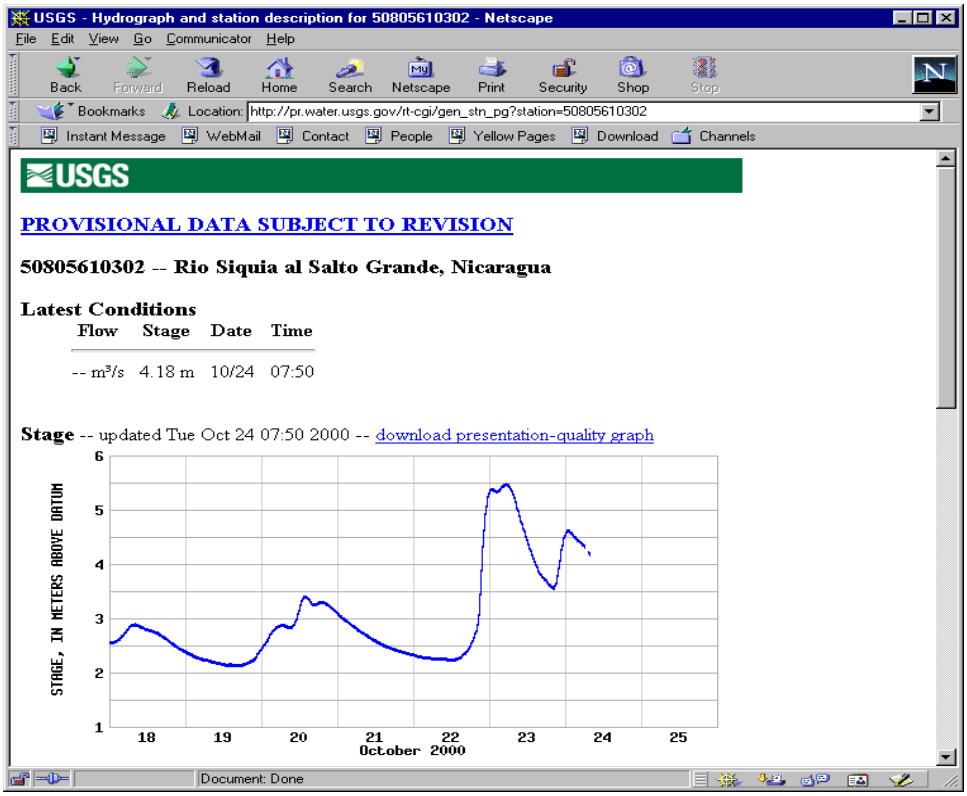


Figure 3. Graphical display of river stage for the Río Siquia at Salto Grande, Nicaragua.

As part of the database program, the USGS purchased a small satellite receiving station for INETER. The receiving dish is 1 meter in diameter, simple to install, and can be moved with relative ease. The transmission and data-processing system, called EMWIN (Emergency Managers Information System), is operated by NOAA and provides reliable, real-time access to meteorologic (and now hydrologic) information via the receiving platform and a PC computer. The program in Central America is the first use of the EMWIN system for transmission of hydrologic data via the network.

EMWIN can be used for primary data reception, or as a backup if a larger receiving station is installed in Nicaragua. The system is highly reliable even during storms and flooding.

Problems and future needs

The USGS provided intensive formal and on-the-job training of counterparts at INETER in the analysis of hydrologic data using the NWIS/ADAPS system. Counterpart data analysts showed they were very capable of learning and implementing the technology provided. However, certain

equipment defects led to substantial system down time, which slowed the learning curve of INETER technicians. The computer system and software components are complex, so that equipment problems necessitated extensive troubleshooting efforts by USGS experts.

INETER systems administrators are capable of providing normal maintenance to the Sun workstation. INETER has assumed the routine costs of operating and maintaining at the site.

Flood Inundation Mapping

USGS personnel provided basic training to hydrologists at INETER in techniques used for flood-inundation mapping. A wide range of techniques was presented, whose use depends on the data available in a given area and on the accuracy of mapping desired. Use of digital methods (GIS) was emphasized.

INETER wants to develop floodplain mapping capabilities. Methods introduced by the USGS emphasized approximate methods that could be conducted inexpensively, rather than detailed, FEMA-type floodplain mapping. Digital GIS methods can be incorporated in either type of study. It was hoped that USGS and INETER hydrologists could complete approximate flood-inundation maps at one or two pilot sites. However, critical data components were not available. Instead, USGS training focused on methodology, data needs, and detailed tutorials developed by the USGS for study sites in Honduras. Funding for this component was extremely limited and precluded collection of new data; however, hydrologists at INETER absorbed the concepts presented by USGS personnel and probably will be able to apply these concepts once the necessary data becomes available.

Counterpart Training

USGS personnel conducted on-the-job training of INETER personnel (hydrologists and technicians) during each visit to Nicaragua. As of December 31, 2001 counterpart personnel were well-trained to conduct routine streamflow measurements, gage construction, gage operation and maintenance activities, and basic troubleshooting of electronic equipment. INETER staff proved to be highly capable of absorbing the new technology. The USGS views this as a significant factor in the sustainability of the program.

Formal and informal training in the areas of streamgage operation and maintenance, hydrologic data collection, data analysis using NWIS/ADAPS, and computer-system maintenance was conducted on a regular basis in Nicaragua; counterparts from the cooperating agencies participated in all formal courses presented by the USGS. Personnel from INETER also participated in regional USGS courses that included participants from the four Mitch-affected countries. Regional training was successful in promoting uniform standards for data-collection methods in each country, sharing of scientific information, and professional camaraderie among peers in each country. A summary of formal training courses presented to Nicaraguan counterparts is shown in Table 2.

Program Successes

INETER hydrologists have monitored the real-time data from gages in the Escondido basin during periods of flooding for the past two years. The Nicaraguan Civil Defense has relied on INETER to provide early warning information based on gage data and to provide river forecasts using the gage data and the river forecast system implemented by NOAA.

During the passage of Tropical Storm Michelle in October 2001, real-time data from the streamgages in the Escondido basin were monitored closely by INETER and the civil defense agency. Early warning provided by streamflow and rainfall stations in the basin was instrumental in the mitigation of flood-related loss of life and damages in affected areas.

TABLE 1. Hydrologic Monitoring Stations in Nicaragua (December 31, 2001)

Number	Station	Type	Lat N (dec deg.)	Long W (dec deg.)	Date Operational
	ESCONDIDO RIVER BASIN				
50805610105	Rio Escondido at El Rama II	Stage, Rainfall	12.1613	84.2145	March 2000
50805610302	Rio Siquia at Salto Grande	Streamflow, Rainfall	12.4903	84.5412	March 2000
50805610201	Rio Mico at M. de los Buelles	Streamflow, Rainfall	12.0775	84.5290	March 2000
50805610102	Rio Plata at Piedra Fina*	Streamflow, Rainfall	11.8450	84.2869	June 2000
50805610104	Rio Rama at Valentin	Streamflow, Rainfall	11.9706	84.3925	June 2000

* Funded by NOAA

TABLE 2. Summary of Formal Training Provided by the USGS

Course	Location	Dates	Participants
Station Operation and Maintenance			
Operation of the Sutron DCP, and Topographic Leveling at Gaging Stations	INETER/Hídricos, Managua	7-8 September, 2000	INETER/Hídricos
Installation and Operation of Electronic Monitoring Equipment (Sutron and Design Analysis) Used in the Gaging Stations	INETER/Hídricos, Managua	5-6 June, 2000	INETER/Hídricos
Concepts in Hydrology and Hydraulics			
Introduction to Flood Inundation Mapping - Hydrologic, Hydraulic, and Digital (GIS) Methods	INETER/Hídricos, Managua	19-22 June, 2001	INETER/Hídricos
Basic Concepts of Hydrology and River Hydraulic Analyses	INETER/Hídricos, Managua	27 Nov - 1 Dec, 2000	INETER/Hídricos
Compilation and Analysis of Data using NWIS/ADAPS			
Computation of Hydrologic Records and Analysis of Discharge	UNITEC/SERNA, Honduras	3-7 December, 2001	INETER/Hídricos
Computation of Hydrologic Records and Analysis of Discharge	INSIVUMEH, Guatemala	20-24 August, 2001	INETER/Hídricos
Computation of Hydrologic Records and Analysis of Discharge	UNITEC/SERNA, Honduras	14-18 May, 2001	INETER/Hídricos
Introduction to the Computation of Hydrologic Records (Review)	SMHN, El Salvador	11-15 December, 2000	INETER/Hídricos
Introduction to the Computation of Hydrologic Records	USGS, Puerto Rico	31 Jul - 11 Aug, 2000	INETER/Hídricos

Landslide Hazard Assessment

Eugene Schweig

Project Objectives: The primary objective of the Nicaragua Landslide Mapping project was to develop a comprehensive inventory of landslides in seven small study areas that can be used to identify areas still threatened by landslides and to assess the potential impact of failure of slopes that remain unstable. These areas were chosen because they were heavily impacted by landslides and were near areas with substantial human impact. We also chose areas with different surficial geological materials. This objective was substantially reduced from the original scope because we were not able to obtain the aerial photography that we hoped for. Involvement of scientists from the Geophysics group at INETER (Instituto Nicaragüense de Estudios Territoriales) in as many aspects of the project as possible and GIS training of the scientists was another objective that we met successfully.

Accomplishments: We completed detailed mapping of landslides and related effects in and adjacent to downstream drainages that occurred in response to the torrential rainfall that accompanied Hurricane Mitch in seven study areas: Jinotega/San Rafael del Norte; El Sauce/San Nicolas; Sébaco/San Nicolas; La Fundadora; Matagalpa; Dipilto; and Cinco Piños (Figure 1). All of these areas are in northwestern Nicaragua in the Central Highlands physiographic province (Figure 1). Although landslide activity occurred in other areas in Nicaragua during Hurricane Mitch, we selected these study areas based on their differing geological conditions, proximity to populated areas, and availability of aerial photography. Our results are detailed in a U.S. Geological Survey Open-File Report 01-0412-A, which contains 7 plates at 1:50,000-scale showing maps of hurricane-induced landslides.

Graziella Devoli of INETER spent two weeks of training at USGS offices in Memphis, Tennessee, and Golden Colorado, learning GIS techniques while actually working on the Nicaragua landslide maps. We have purchased both a powerful CPU and ArcInfo GIS software for INETER so that they may continue to apply the techniques learned.

Resulting Benefits: Our original intent was to create both landslide inventory and landslide susceptibility maps. The susceptibility maps, however, would have required much greater aerial photography coverage than was available and good geological maps, which do not exist. Nonetheless, the landslide inventory maps and report should be very useful in understanding in a general way the types of slope failures that occurred and how they are distributed. For example, there seemed to be a positive correlation between landslide density and hydrothermally altered volcanic rocks. As more data become available on the detailed geology of the region, researchers will be able to return to the maps and further compare landslide density with geological characteristics. Within the areas that were actually mapped, local planners and emergency managers will be able to see where the hazard was during Hurricane and avoid those areas or ones like them in the future.

The GIS training that we did for INETER will have lasting effects on the institute's capabilities to respond to future hazardous events.

Success Stories: Beyond the landslide maps themselves, our greatest success was in forming an integrate USGS-INETER team to work on this project. This is reflected in the results, the Spanish translation, the report authorship, and even having the INETER logo on all documents. We are hopeful that this will have lasting benefits in terms of future links between our two countries and agencies.

Collaboration Efforts: Throughout this project, we have maintained steady communication and strong collaboration with INETER colleagues and officials at the USAID mission in Nicaragua. We also reviewed a landslide hazard report from the U.S. Forest Service for USAID and INETER. We remain in communication today and are planning future exchanges of information.

Formal Reports:

Cannon, S. H., Haller, K. M., Ekstrom, I., Schweig, E. S., III, Devoli, G., Moore, D. W., Rafferty, S. A., and Tarr, A. C., 2001, Landslide response to Hurricane Mitch rainfall in seven study areas in Nicaragua: U.S. Geological Survey Open-File Report 01-0412, 21 p., 7 oversized plates. ** This report is available on the web at http://greenwood.cr.usgs.gov/pub/open-file-reports/ofr-01-0412-a/

Visuals:

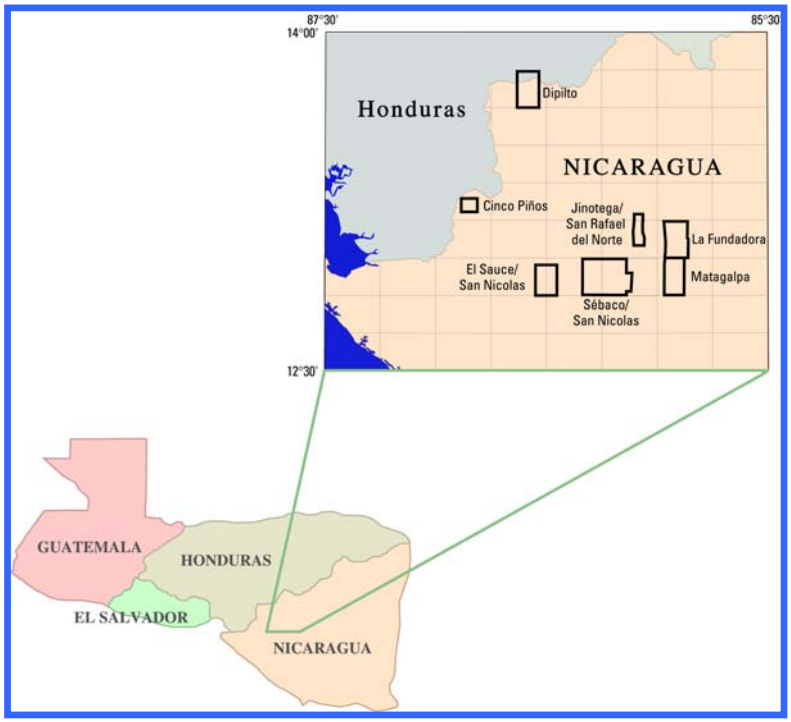


Figure 1. Map showing locations of seven study areas in Nicaragua.

Figure 2. Structures destroyed by debris flows behind hospital at La Trinidad.

Figure 3. Deep-seated, slow-moving earth flow on road to Jinotega. The road crossing this feature was disrupted in many places and was under extensive repair.

Figure 4.
Toe of the earth flow at San Simón de Palcila. House on the left was destroyed by movement on the earth flow. An active lobe of the earth flow is impinging on the house at the right.

Volcano Hazard Assessment

Jim Vallance and Steve Schilling

1. The chief objectives of the Nicaragua volcanoes project were: (a) to conduct an analysis of lahar (large volcanic debris flow) hazards at target volcanoes identified in consultation with INETER and the local USAID mission, (b) to produce maps depicting zones of potential inundation from lahars, and (c) to train local geoscientists and engineers to conduct lahar-hazards analyses. The maps identify hazardous areas as well as provide information on the probability of varying size lahars flowing over areas around volcanoes.

Figure 1. Photograph showing scarp and part of the avalanche of October 30, 1998 that occurred at Casita during Hurricane Mitch.

Particular objectives of the project were selected primarily in response to the disaster at Casita volcano, Nicaragua. At Casita, Hurricane Mitch triggered a 1.6-million-cubic-meter landslide that transformed into a rapidly moving debris flow that destroyed two villages and killed about 2500 people (Figures 1 and 2). If field investigations and lahar-hazard analyses had been conducted at Casita volcano prior to Hurricane Mitch, they would have shown that the towns destroyed were located in an active lahar pathway that was extremely hazardous (Figure 2). Experience at other volcanoes worldwide shows that population centers and infrastructure located near volcanoes are at risk from a variety of hazardous events--both related and unrelated

to volcanic eruptions. The 1998 tragedy at Casita volcano illustrates hazards associated with volcanoes even when they are not erupting.

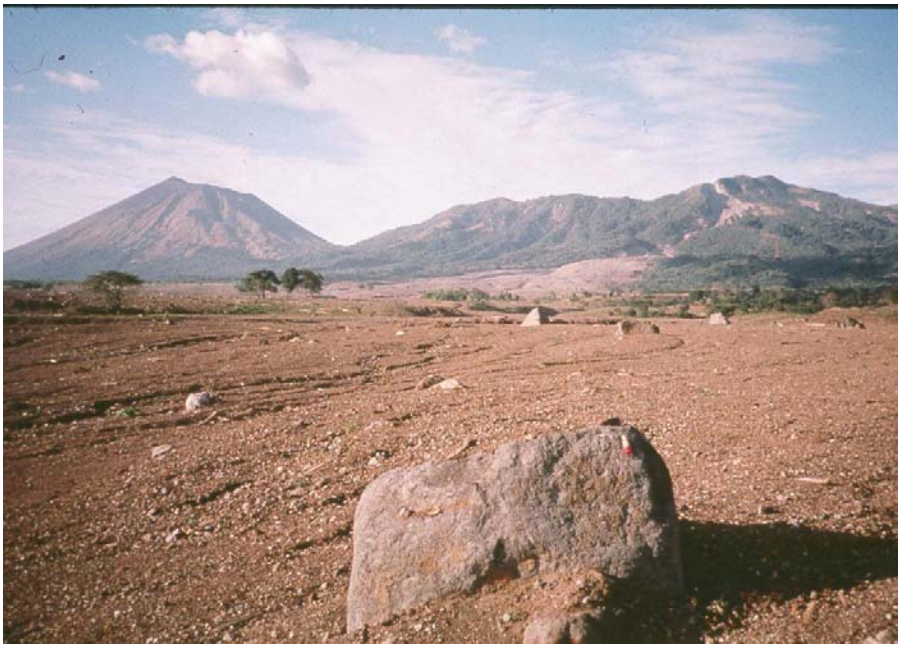


Figure 2. Photograph showing the devastation of the Casita lahar from a site near the two destroyed towns of El Porvenir and Rolando Rodriguez.

In Nicaragua, communities are located at the bases of large, active volcanoes, and encroach onto the volcanoes' flanks. Thus, significant numbers of people are at risk from hazardous events at Nicaragua's volcanoes. In the course of this study, we learned that older dissected volcanoes whose rocks have been weakened by hydrothermal alteration were most susceptible to failure-generated lahars of the type that occurred at Casita. Lahars at younger more active volcanoes were susceptible to smaller lahars during rainy periods after eruptions blanketed surrounding areas with ash. The USGS is attempting to provide information that can help prevent a Casita-type disaster by identifying areas subject to volcanic hazards, particularly identifying areas subject to inundation by lahars of various sizes. The planned impact of this project was to identify, for the first time, areas subject to hazardous lahars of various sizes, and to provide some sense of the likelihood of occurrence of these types of events.

2. Key accomplishments of the project are threefold: a) development of formal reports on hazards at the target volcanoes; b) transfer of technology; and c) development of in-country capability.

Formal reports: The project produced three formal reports that identify hazards at 4 volcanoes:

Vallance, J.W., Schilling, S.P., Devoli, G., and Howell, M.M., 2001, Lahar Hazards at Concepción Volcano: USGS Open-File Report 01-457, 7 p. Available on the web at http://vulcan.wr.usgs.gov/Volcanoes/Nicaragua/Publications/OFR01-457/framework.html

Vallance, J.W., Schilling, S.P., and Devoli, G.., 2001, Lahar Hazards at Mombacho Volcano: USGS Open-File Report 01-455, 8 p. Available on the web at http://vulcan.wr.usgs.gov/Volcanoes/Nicaragua/Publications/OFR01-455/framework.html

Vallance, J.W., Schilling, S.P., Devoli, G., and Howell, M.M.., 2001, Lahar Hazards at Casita and San Crostóbal Volcanoes: USGS Open-File Report 01-468, 15 p..

Each report contains maps that depict hazard zones related to lahars and other volcanic phenomena (*eg*., http://vulcan.wr.usgs.gov/Volcanoes/Nicaragua/Publications/OFR01-455/OFR01-455_plate_1_color.pdf), and all reports and maps were translated into Spanish. Versions of the reports and maps will be posted on the USGS Cascades Volcano Observatory web page by late February. They will also be accessible through the Hurricane Mitch clearinghouse website. The project also produced a compact disk (CD) that contains digital elevation models of 1:50,000 scale topographic maps of the target volcanoes and surrounding areas. The CD also includes vector files of the transportation network, hydrology, and contours.

Technology transfer: The project convened a one-week workshop for about one dozen Central American scientists from El Salvador, Guatemala, and Nicaragua on volcano hazards and GIS. A key element of the workshop included training on a recently developed GIS-based model, LAHARZ, for objectively, and reproducibly, producing hazard maps that depict zones of inundation by lahars having various volumes. Workshop participants learned about the statistical basis for the model, how the model is coded and implemented within GIS, the input information and elements needed to run the model, the output information given by the model, the limitations of the model, how to run the model, and the computer hardware and software necessary to run the model. Each participant was given copies of the scientific literature (translated into Spanish) that describes the basis of the model as well as a copy of the model software. Representatives of INETER (Instituto Nicaraguense de Estudios Territoriales) were selected as most appropriate for transferring the technology to a wide scientific audience within the country.

Development of in-country capability: To develop in-country capability to conduct lahar hazard analyses and other GIS applications, the project purchased a computer workstation for Instituto Nicaraguense de Estudios Territoriales (INETER), the national geosciences agency. The landslides project aided us in this effort by providing ARCINFO software. This computer hardware and software, along with the training described above, provides in-country counterparts the capability to conduct lahar and volcano hazards analyses on their own. Investment in this capability can be protected through the Central American mitigation initiative (CAMI) and subsequent projects funded by OFDA through the USGS Volcano Disaster Assistance Program by ensuring that INETER maintains core capability in GIS, that they maintain the annual updates to the ARCINFO license, and that they periodically update the computer hardware. (We

purposely purchased a very high-end computer workstation that should maintain capability for several years). Periodic funding may be needed to help INETER maintain necessary computer hardware and software capability. USGS will help maintain in-country capability by periodically providing updates to the lahar simulation software.

3. As a result of the project, the government of Nicaragua and the local USAID mission now have probabilistic assessments of lahar hazards at Casita, San Cristóbal, Mombacho, and Concepción volcanoes. In addition to these probabilistic assessments, the country now has maps that clearly outline zones of hazard, particularly lahar hazards. The country also has, for the first time, in-house capability to produce these types of hazards assessments and maps. The maps produced by the project, and future maps produced by INETER, will greatly aid reconstruction efforts by identifying zones of particular hazard. The reports produced also discuss hazard warnings and forecasts, and what communities can do to protect their citizens. This information is being widely distributed to the affected municipalities, and it will provide information regarding hazards, hazardous areas, and mitigation strategies.

4. During the course of the project, we collaborated with the local USAID mission, in particular with Dr. Margaret Harritt. She was instrumental in helping us identify target volcanoes, and in transferring technology to counterpart agency, INETER. We did not interact with other USG agencies or other donors during the course of the project

Biological Analyses of Coastal Resource Damage and Recovery

Edward Proffitt

Project Objectives:

The U.S. Geological Survey (USGS) biology projects in Nicaragua were developed at the request of USAID and Nicaraguan government agencies responsible for natural resources and shrimp farming, which is one important component of the Nicaraguan economy. The USGS coastal resource damage and recovery projects had as its primary objective to evaluate the degree to which Hurricane Mitch allowed nuisance burrowing crustaceans to invade and disrupt shrimp aquaculture ponds. To meet these objectives we contracted with Dr. Darryl Felder of the University of Louisiana at Lafayette to conduct a study. Dr. Felder is a recognized expert in crustaceans and has previously worked with nuisance crustaceans in shrimp ponds in Colombia.

Accomplishments:

Extensive natural populations of the burrowing crustaceans were found in several estuaries in Nicaragua. However, the species that occurred in Nicaragua are different from the species that caused problems in Colombia, in that they do not appear to inhabit areas of very low oxygen and thus do not contribute to mobilization of organic degradation products from sediments into the water column. Also, the larvae do not appear to inhabit low oxygen sediments and so there is a reduced chance for invasion of shrimp ponds. Since low population densities of these crustaceans have been shown to be beneficial to shrimp farms, the recommendation was made that the widespread use of pesticides to control for invasions be discontinued.

Resulting Benefits:

It does not appear as if burrowing crustaceans will become a problem in shrimp ponds in the Gulf of Fonseca. Hurricane Mitch did not enhance their populations in estuaries or shrimp ponds to the extent feared based on historic accounts elsewhere. Habitat preferences of the crustaceans further suggest that they will not form large populations in shrimp ponds, a finding that should save farmers considerable money by reducing the use of pesticides to control burrowing crustacean populations.

Success Stories:

Contract biologists from the university formed professional ties with natural resource managers and shrimp farm mangers of the area. This work, coupled with many studies conducted by USGS in the Honduran waters of the Gulf of Fonseca, will form a good background for future natural resource management decisions by all countries in the gulf area.

Primary Collaboration Efforts:

Collaborations occurred with various shrimp pond officials including Jose Cuesta, Andres Diaz, and Fernando Mantelatto.

Formal Reports:

A Formal technical report (Felder, Nates, and Robles in preparation) is currently in draft stage, and is being peer reviewed. The finalized report will eventually be provided to AID and other interested parties as hardcopy, on compact disk, or on the NWRC or Hurricane Mitch Web sites. In addition, articles for most studies are being prepared for publication in scientific journals, which will broaden the degree of impact of these projects far outside Nicaragua. Also, many of the reports from work in the southern Gulf of Fonseca in Honduras relate to estuarine water quality, gulf circualtion patterns, shrimp farms, natural shrimp populations, and natural resources in Nicaragua as well. A listing of these draft report titles and authors follows.

Nicaragua Report:

Felder, D.L., S. F. Nates, and R. R. Robles. 2002. Hurricane Mitch: Impacts of bioturbating crustaceans in shrimp ponds and adjacent estuaries of coastal Nicaragua. U.S. Geological Survey, Draft report.

Other Gulf of Fonseca Reports of Interest to Nicaragua:

Cahoon, D. R., P. Hensel, J. Rybczyk, and B. C. Perez. 2002. Hurricane Mitch: Impacts on mangrove sediment elevation dynamics and long-term mangrove sustainability: U.S. Geological Survey, draft report.

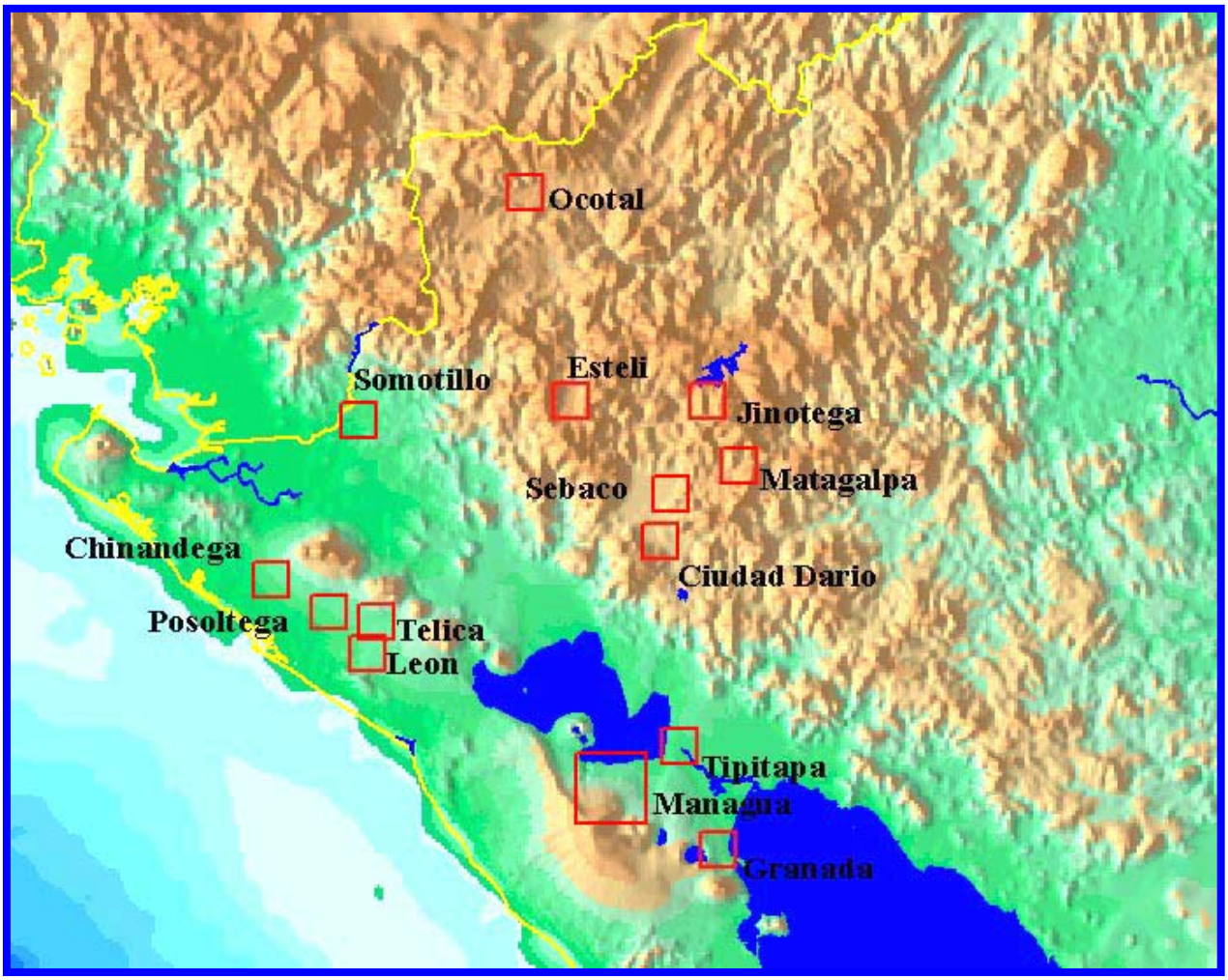
Hensel, P. And C. E. Proffitt 2002. Hurricane Mitch: Acute impacts on mangrove forest structure and an evaluation of recovery trajectories: U.S. Geological Survey, draft report.

McKee, K. L. and T. E. McGinnis. 2002. Hurricane Mitch: Effects on mangrove soil characteristics and root contributions to soil stabilization: U.S. Geological Survey, draft report.

Municipal Geographic Information Systems

Manollo Barillas and Peter Chirico

USGS designed and initiated a project to provide 14 cities in Nicaragua with geographic information systems for use in natural hazard preparedness and mitigation, urban management, and urban planning and development.



Towns chosen to receive GIS systems include

Ocotal	**Esteli**	**Chinandega**	**Jinotega**
Matagalpa	**Sebaco**	**Posoltega**	**Telica**
Leon	**Tipitapa**	**Managua**	**Granada**
Somotillo	**Ciudad Dario**		

Under the Hurricane Mitch program, the following equipment was purchased for each town: computer with monitor and printer/plotter, ArcView license with Spanish kit, GPS unit, and digital camera.

1:40,000 scale aerial photography was acquired, indexed, and digitized.

In 2002-2003, USGS will continue this project under a new agreement (PASA) with the Nicaragua USAID Mission. This continued effort will include the following principal components:

- Develop 1:5,000 scale orthophotomaps for each town
- Deliver and install GIS hardware and software
- Provide each town with USGS hazard assessment data
- Provide training to municipal staff on how to use the GIS systems

Program Budget

USGS HURRICANE MITCH PROGRAM - Nicaragua Summary Budget	
Activity	Funds Expended
Digital Topographic Maps	$87,208
Satellite Imagery & Aerial Photography	$151,407
Streamflow Monitoring Network and Hydrological Databases	$353,187
Internet Data Clearinghouse	$177,832
Landslide & Volcano Hazard Assessments	$422,797
Integrated GIS Products for Municipalities	$144,995
Biological Assessments of Coastal Zones	$109,977
In-country & HQ Management, Staff Support	$324,194
Total	$1,771,598

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