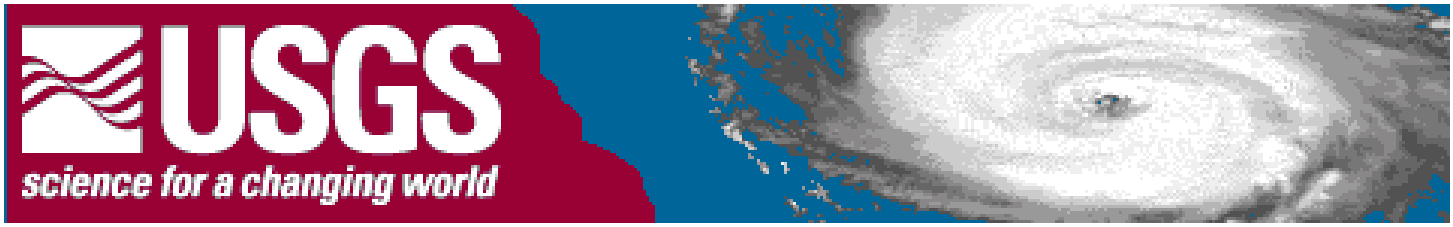

Activities in El Salvador
In Support of the
Hurricane Mitch
Reconstruction Program

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

by the

U.S. Geological Survey

May 2002

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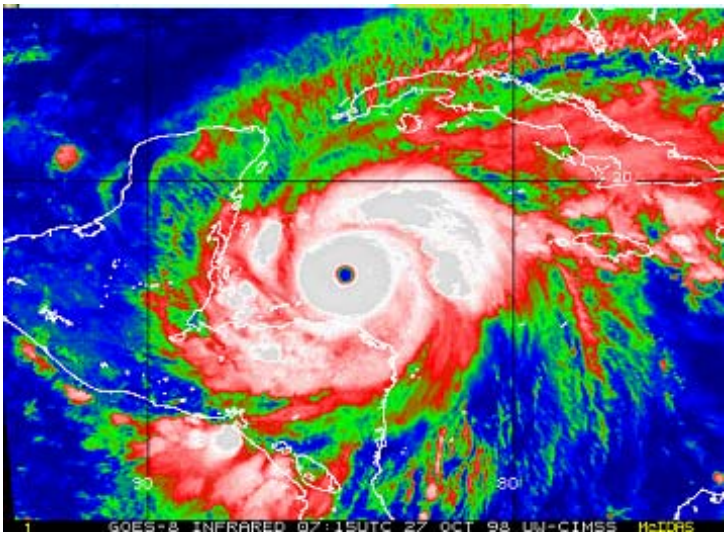
Overview

Rafael Rodriguez

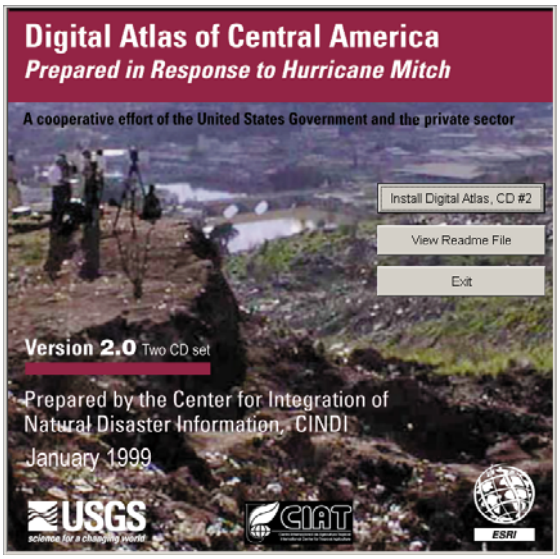


On October 25, 1998, Hurricane Mitch, the fourth most intense Atlantic Ocean hurricane on record, slammed into the Central American coastline. At is height on October 26 and 27, the hurricane had sustained winds of 180 mph and triggered 4 days of heavy incessant rains. The devastation wrought across a broad portion of Central America was unprecedented. This short-lived extreme event set back economic development in the most affected countries by perhaps more than a decade. The figure to the right is an image from the NOAA GOES satellite, showing the position of Mitch on October 28, 1998.

The flooding and landslides in El Salvador from Hurricane Mitch resulted in 374 deaths and 55,864 displaced. Twelve of the country's 14 departments suffered significant damage, but the hardest-hit areas were in the low-lying coastal zones, particularly those bordering the Rio Lempa and the Rio Grande de San Miguel. Roughly 163,000 acres were flooded, and 15 major bridges were damaged or destroyed. The Government of El Salvador (GOES) estimated the total damage at $132.5 million, making it one the worst natural disaster to affect the country since the 1986 earthquake. The flooding as a result of Hurricane Mitch was felt most in rural areas, particularly in the departments of San Vicente, Usulutan and San Miguel -- some of the poorest areas of the country. These were also areas where people affected by the civil war had recently been resettled, ex-combatants had been given land, and where many land reform cooperatives were located.

To manage and eliminate these and other weakness, the U.S. Agency for International Development and the Salvadoran government proposed to carry out 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 these recovery and reconstruction efforts. Detailed maps, aerial photographs of key areas, damage inventories, and continued assessment of potential flood, landslide, and other hazards were required 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, the Salvadoran national government, municipalities, other U.S. Government agencies, and other foreign donors to assist in the reconstruction following Hurricane Mitch. This effort began in September 1999, was completed in December 2001, and 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 El Salvador's capacity and the developing strategies for long-term sustainability and the mitigation of vulnerability to natural hazards.

The USGS program in El Salvador included the following projects:

1) **Development of Digital Topographic Maps**

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

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

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

5) **Landslide Hazard Assessment**

6) **Volcano Hazard Assessment**

7) **Municipal GIS Development**

The USGS program also involved substantial capacity building through purchase of equipment and software for counterpart agencies and both formal and on-the-job training of specialists from counterpart agencies.

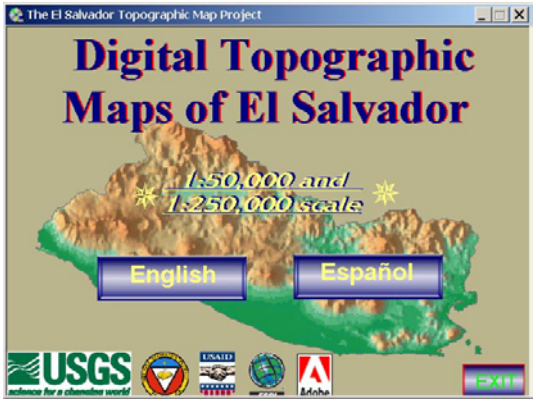
Digital Topographic Maps

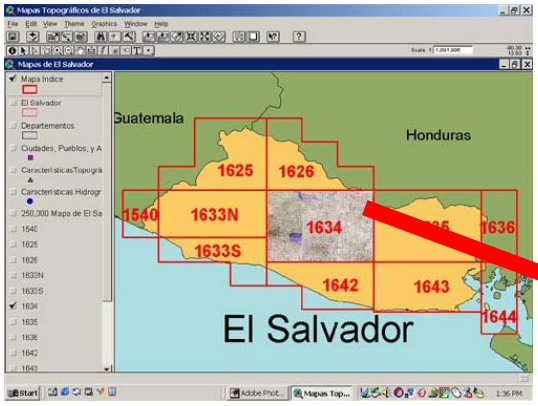
Sharon Hamann and Cassandra Ladino

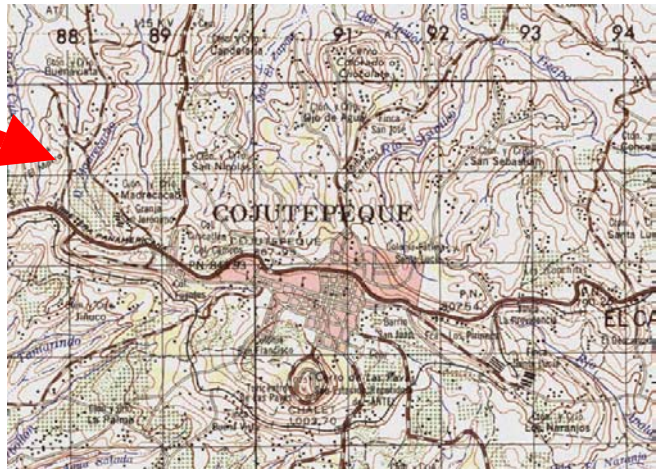
Objectives: One of the most important basic tools needed to support reconstruction and hazard mitigation activities were accurate topographic base maps showing topographic contours, locations or rivers and streams, roads, and layouts of cities, towns, and villages. Although paper topographic maps at 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.



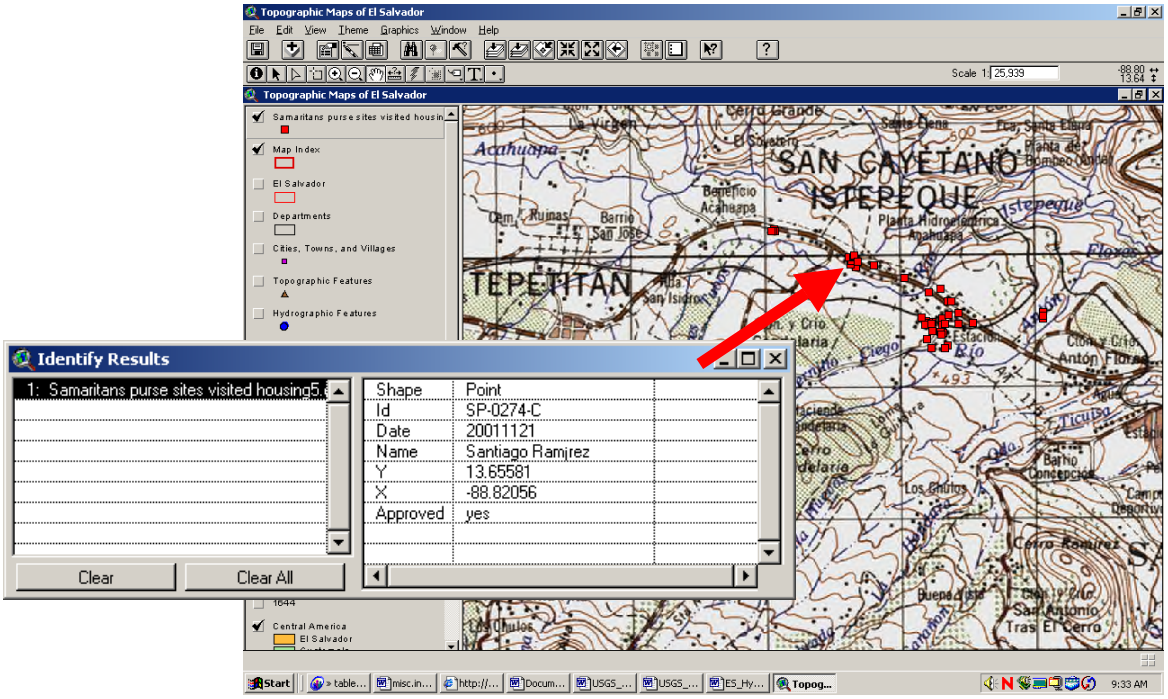




The maps were digitally compressed and packaged on a single CD-ROM together with GIS software to view the maps, make measurements, and print copies of selected areas.. These maps have been delivered to the Instituto Geografico Nacional, who will assume responsibility for their distribution.

These products will significantly increase access to large-scale topographic maps for Salvadoran government agencies and the general public. This represents a major step forward in getting basic

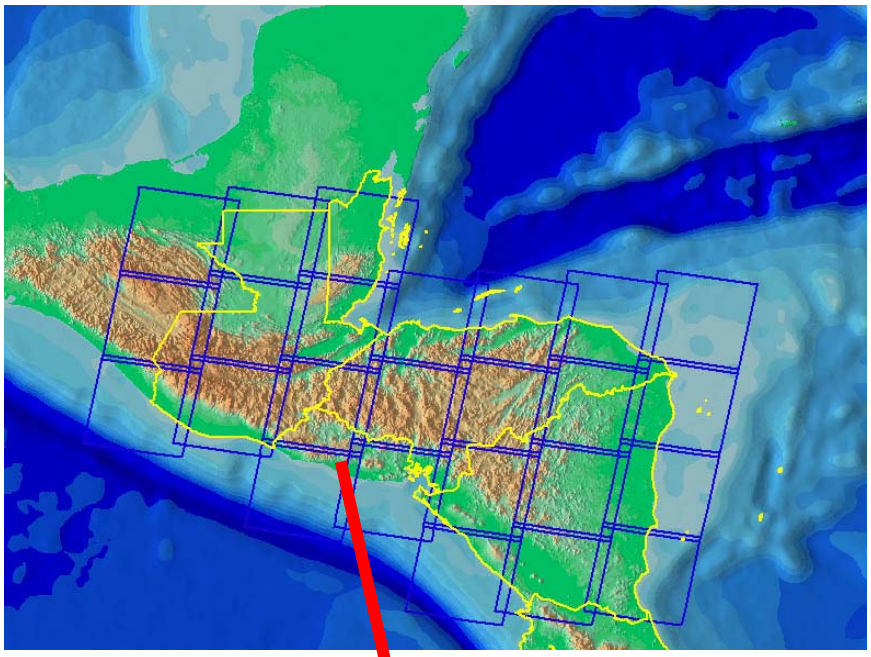
products such as this into the hands of the public and educating them as to their potential applications. These maps will be used as the basis for a national disaster-preparedness GIS for El Salvador and are also serving a host of other applications, including risk assessments, road building, watershed analysis, and urban development. The maps are also being used by the USAID Mission in San Salvador to plot and evaluate the locations for proposed new housing under USAID's Earthquake Reconstruction Program. Site locations collected with USGS-provided GPS units are e-mailed to the Mission, which plots them on the base maps together with other hazard assessment data. This technology allows the Mission to quickly evaluate each site and, together with the field reports, make a decision on whether to approve or disapprove.



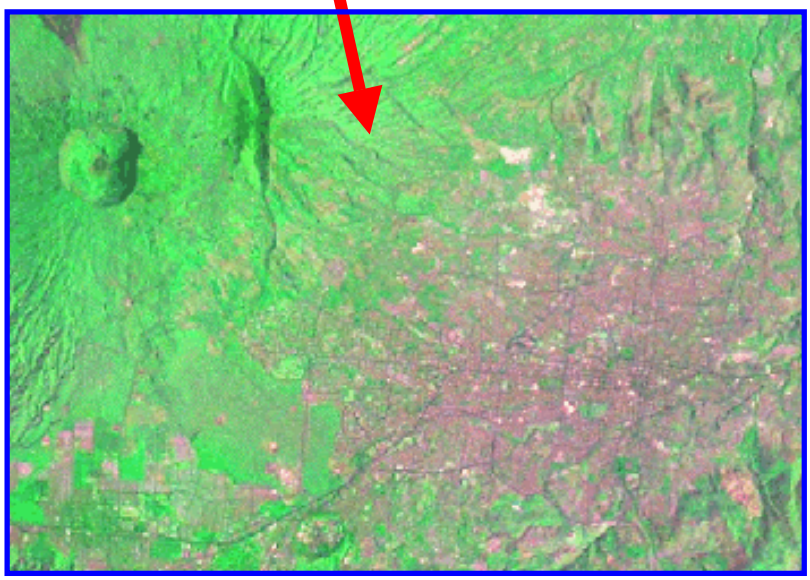
Satellite Imagery and Aerial Photography

Mike Crane

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.

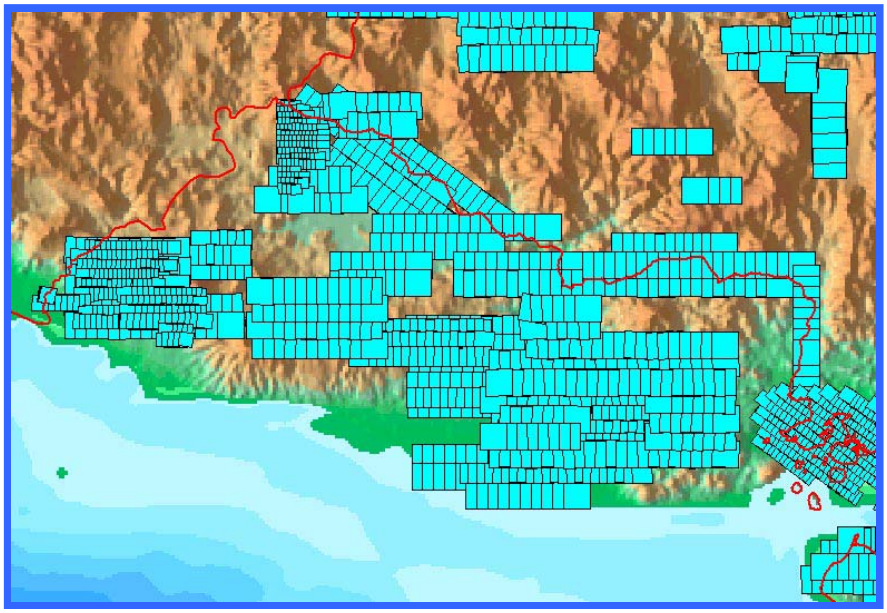


Landsat satellite imagery provides 15-30 meter resolution and the ability to detect subtle differences in vegetation and land cover. The figure to the right shows the location of individual Landsat images (scenes) covering the Mitch-affected countries. The USGS compiled and mozaicked complete Landsat 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 city of San Salvador and Volcan San Salvador to the west. Landsat mage products were provided to U.S. and Salvadoran 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 1500 frames of black and white aerial photography over El Salvador (see figure below). 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 several El Salvadoran 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 figure to the left shows a bridge over the Rio Ticuisa in the town San Vincente. Most of the aerial photography flown over El Salvador 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.

Streamflow Monitoring and Hydrologic Data Collection

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 El Salvador. 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. 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
4. Implementation of nationwide (and region wide) quality-control standards for hydrologic data collection, storage, and analysis.

In conjunction with Objective 4, the USGS emphasized the value of sharing basic hydrologic data among government agencies, municipalities, and the public. The USGS worked closely with the following Salvadoran agencies involved with hydrologic data collection and analysis:

- Servicio Meteorológico y Hidrológico Nacional (SMHN)
- Comisión Ejecutiva Hidroeléctrica del Río Lempa (CEL)
- Programa Ambiental de El Salvador (PAES)

SMHN is the GOES agency primarily responsible for maintenance of the nationwide hydrologic monitoring network and storage of hydrologic data in El Salvador. The USGS provided equipment, training, and technical support to SMHN in order to implement the surface-water hydrology program in El Salvador.

National Hydrologic Monitoring Network

The hydrologic monitoring network in El Salvador was damaged by Hurricane Mitch, but also has long been in a state of disrepair as a result of past warfare. The network was in desperate need of improvement 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 SMHN, CEL, and PAES (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. The bilateral program in El Salvador overlapped considerably with the regional (Lempa) program, because the Lempa River basin covers much of El Salvador and is the principal river system in the country.

USGS, NOAA, and Salvadoran experts determined that critical areas lacking adequate hydrologic information included the Lempa and Grande de San Miguel River basins. USGS and Salvadoran counterparts installed 2 state-of-the-art hydrologic monitoring stations in the Grande de San Miguel River basin as part of the bilateral program, and 4 monitoring stations in the Lempa River basin as part of the regional program (fig. 1). The monitoring stations are part of flood-alert and river-forecast systems

implemented by NOAA/NWS in each basin. Ongoing monitoring and management of water resources in these river basins are deemed critical to the safety and economic well-being of the country.

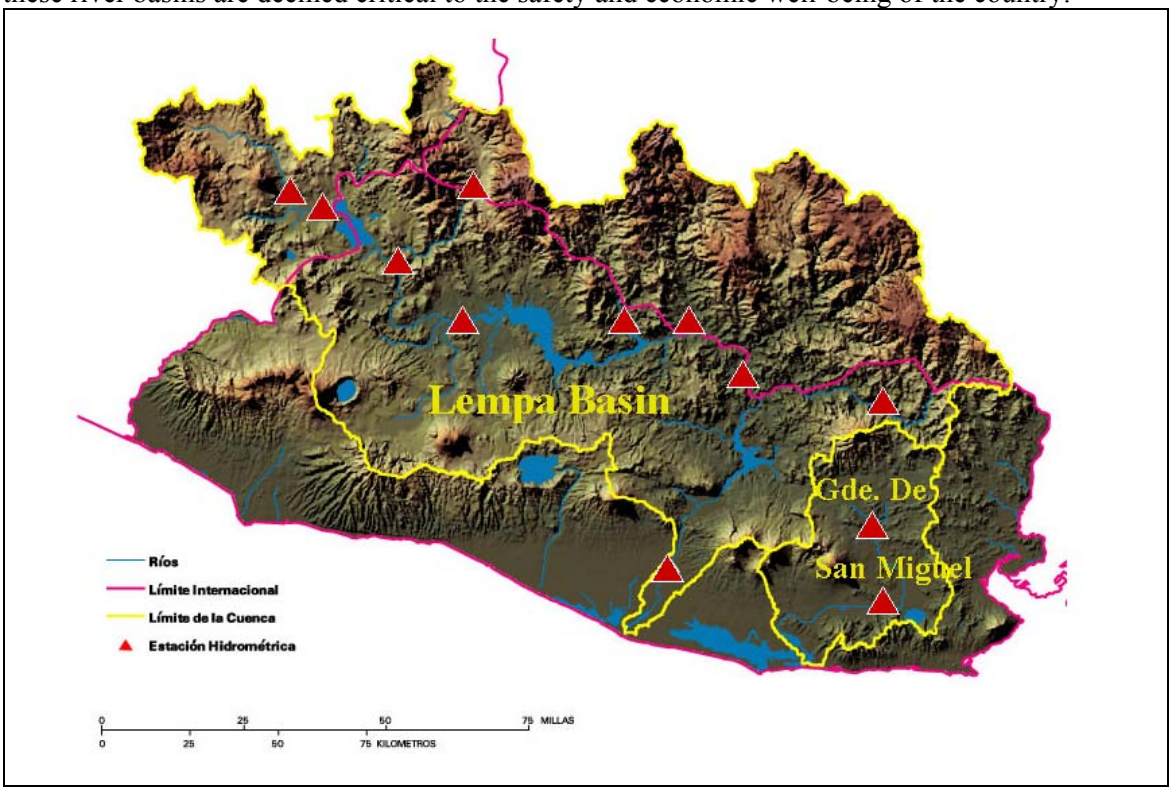


Figure 1. Hydrologic monitoring stations, each equipped with satellite telemetry, operational in El Salvador and the transnational Río Lempa basin.

Real-time transmission of data from hydrologic monitoring stations is new to El Salvador – the technology implemented in El Salvador is 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 El Salvador 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 El Salvador is shown in Figure 2.

Figure 2. Streamflow monitoring station Río Lempa near San Gregorio.

Table 1 at the end of this report shows a complete listing of hydrologic monitoring stations that were installed in El Salvador. 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 El Salvador. The USGS cooperated closely with NOAA/NWS and its contractors in developing the hydrologic monitoring network. Hydrologic data from the hydrologic monitoring stations are part of river forecast and flood-alert systems implemented by NOAA/NWS in the Lempa and Grande de San Miguel basins. Accurate river stage and flow data are critical to successful river-basin forecasting models used by NOAA/NWS.

Problems and future needs

As a result of intensive formal and on-the-job training, counterparts at SMHN generally are capable of installing, operating, and maintaining the electronic monitoring equipment used in the gaging stations; CEL and PAES personnel also participated in USGS-sponsored training. In addition, cooperative planning by USGS, NOAA/NWS, and regional agencies such as SICA, has resulted in the procurement of enough spare equipment to support the monitoring network for the next 2-5 years.

However, program continuity and maintenance of trained technical personnel within each agency 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 established and maintained within each agency. Currently, the operating budget for hydrologic monitoring at SMHN is inadequate, and is subject to wide fluctuation. Implementation of a new earth sciences institute (Servicio Nacional de Estudios Territoriales – SNET) within the Ministry of Environment should eventually provide for a more stable budget; however, the complete transition may take up to a year. Based on an analysis of operating costs by USGS and SMHN personnel, the estimated net annual cost (not including staff salaries) to operate and maintain the 6 streamflow monitoring stations in El Salvador is $12,000.

Centralized Hydrologic Database

SMHN (and eventually SNET) is primarily responsible for collection, analysis, and storage of hydrologic data in El Salvador. 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 SMHN was obsolete and did not meet the needs of their hydrologic program.

To this end, the USGS worked with SMHN to implement the USGS surface-water database system, NWIS/ADAPS, in El Salvador. The USGS provided SMHN with a SUN workstation, capable of supporting 15-20 users, and advanced hydrologic-analysis software used by the USGS in the United States. SMHN 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 SMHN and at USGS offices 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).

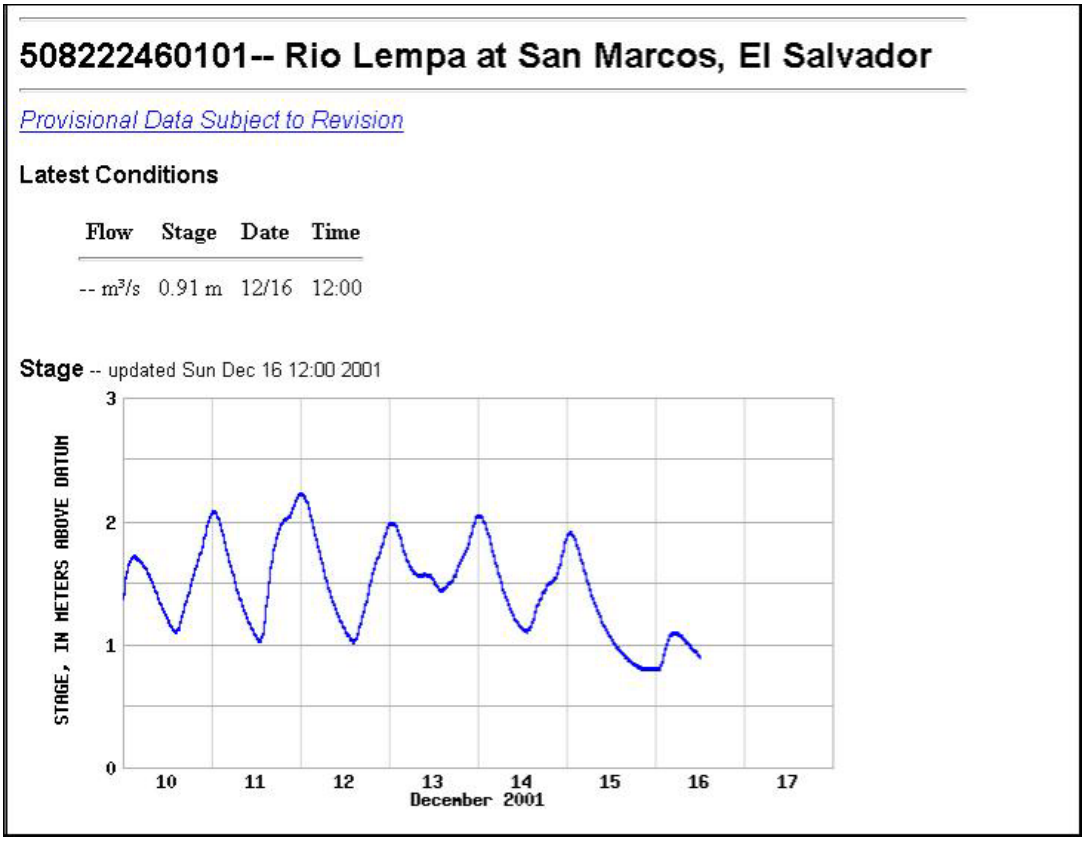


Figure 3. Graphical display of river stage for the Río Lempa at San Marcos Lempa , El Salvador.

As part of the database program, the USGS purchased a small satellite receiving station for SMHN. 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 provides primary data reception for the NWIS/ADAPS system at SMHN, and also as a backup for the main receiving station installed at the Río Lempa River Forecast Center in Santa Tecla. The EMWIN 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 SMHN in the analysis of hydrologic data using the NWIS/ADAPS system. Counterpart data analysts showed they were capable of learning and implementing the technology provided. However, a number of factors hindered the effectiveness of this program component:

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

2. SMHN has been without a designated systems administrator since CY2000. Maintenance of the Sun workstation and NWIS/ADAPS system requires an expert in computer and systems maintenance. Equipment problems were compounded by the lack of experienced personnel to address these issues. It is anticipated that SNET, the new earth resources institute, will provide the necessary support.

3. The existing facilities at the SMHN location in Soyapango are minimally adequate to support the complex computer equipment for the hydrologic database. Frequent power fluctuations and outages have adversely affected system performance. Inconsistent environmental conditions (room temperature, etc.) also may have affected the performance. Again, redeployment of the equipment to more appropriate facilities at SNET should improve this situation.

Availability of a systems administrator, proficient in the operation and maintenance of UNIX operating systems and local area networks, is desperately needed at SMHN and/or SNET. Other recurring costs to maintain the database will be salary for the data analysts at SMHN/SNET, and service costs to maintain the phone line and modem connection for internet access.

Counterpart Training

USGS personnel conducted on-the-job training of SMHN personnel (hydrologists and technicians) during each visit to El Salvador. As of December 31, 2001 counterpart personnel were adequately-trained to conduct routine streamflow measurements, gage construction, gage operation and maintenance activities, and basic troubleshooting of electronic equipment. 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 El Salvador; counterparts from the cooperating agencies participated in all formal courses presented by the USGS. Personnel from SMHN 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 Salvadoran counterparts is shown in Table 2.

Program Successes

SMHN hydrologists and CEL hydropower analysts have monitored real-time data from gages in the Lempa and Grande de San Miguel basin during periods of flooding for the past two years. Hydropower managers at CEL have used the real-time data extensively, to help determine reservoir releases for flood control and for optimal power generation.

The following email exchange (translated to English) documents the use by CEL of USGS stream-gage data in El Salvador to help prevent flooding in the Lower Lempa Basin during Hurricane Keith (October,

2000). Internet access to the real-time hydrologic data helped CEL to optimize reservoir releases throughout the basin and prevent flooding of low-lying population centers near the Pacific coast:

Rodolfo Cáceres of CEL says that information for the stations installed in the Lempa have helped to make gradual reservoir releases and that has avoided flooding in the Lower Lempa Basin during the passage of Hurricane Keith.

Other regions of El Salvador in Ahuachapan, Río Grande de San Miguel, and La Union have experienced problems with flooding during this period.

We hope that with the information that is generated that reservoir releases of the Río Lempa can continue to be adequately managed through the end of this rainy season.

Congratulations on your efforts to install these stations in a timely manner.

Rosa Maura Gattas de Mayorga
SpO Team Leader, USAID/El Salvador

---------- Original Text ----------

From: hgproduccion@salnet.net, on 10/6/00 5:38 PM:
To: Rosa MayorgaNatl Disasters@San Salvador

Resending for your information regarding the use of this new tool.
Sincerely.
R.Cáceres.

----- Mensaje original -----
From: "Patricia Ramirez O. >" < <probando@sol.racsa.co.cr>
To: <rcaceres@tmmail.telemovil.net>
Sent: Martes 19 de Septiembre de 2000 10:25 AM
Subject: RE: ADVISORY CEL-COEN:SPILLWAY RELEASES OF WATER FROM THE HYDROELECTRIC FACILITIES

> Esteemed friends of CEL,
>
> Many thanks for the information you have sent me regarding the new advisory service
> of reservoir releases in the reservoirs that no doubt will contribute to
> a better protection of the residents downstream. I congratulate you for the
> initiative and the quick application of the new tools. The meteorologic information
> is also of great interest for those interested in the
> evolution of the atmospheric conditions across the region.
> Cordial Regards
> Patricia Ramirez
> CRRH

TABLE 1. Hydrologic Monitoring Stations installed by the USGS in El Salvador (December 31, 2001)

Number	Station	Type	Lat N (dec deg.)	Long W (dec deg.)	Date Operational
	LEMPA RIVER BASIN				
508222461401	Rio Sumpul near San Jose de las Flores	Streamflow, Rainfall	14.0440	88.8093	August 2000
508222460701	Rio Torola near Osicala	Streamflow, Rainfall	13.8401	88.1485	August 2000
508222460101	Rio Lempa at San Marcos Lempa	Streamflow, Rainfall	13.4258	88.6977	August 2000
508222460120	Rio Lempa at Cantón San Gregorio	Streamflow, Rainfall	13.9329	88.5074	December 2001
	GRANDE DE SAN MIGUEL RIVER BASIN				
508222480105	Rio Gde. de San Miguel at Villarias	Streamflow, Rainfall	13.5184	88.1757	November 2000
508222480103	Rio Gde. de San Miguel near El Delirio	Streamflow, Rainfall	13.3279	88.1476	December 2000

TABLE 2. Summary of Formal Training Provided by the USGS

Course	Location	Dates	Participants
Station Operation and Maintenance			
Streamflow Measurement Techniques at Gaging Stations (Wading Measurements Using a Current Meter)	SMHN, Soyapango	17-21 August, 2001	SMHN, PAES, CEL
Basic Operation of Electronic Monitoring Equipment (Sutron and Design Analysis) Used in the Gaging Stations	Station Río Lempa at Tamarindo	27 July, 2001	SMHN
Introduction to Discharge Measurements in Natural Streams	SMHN, Soyapango	20 July, 2001	SMHN
Installation and Operation of Electronic Monitoring Equipment (Sutron and Design Analysis) Used in the Gaging Stations	SMHN, Soyapango	2-5 April, 2001	SMHN, PAES, CEL
Concepts in Hydrology and Hydraulics			
Basic Concepts of Hydrology and River Hydraulic Analyses	INSIVUMEH, Guatemala	13-17 August, 2001	SMHN
Compilation and Analysis of Data using NWIS/ADAPS			
Computation of Hydrologic Records and Analysis of Discharge	UNITEC/SERNA, Honduras	3-7 December, 2001	SMHN
Computation of Hydrologic Records and Analysis of Discharge	INSIVUMEH, Guatemala	20-24 August, 2001	SMHN
Computation of Hydrologic Records and Analysis of Discharge	UNITEC/SERNA, Honduras	14-18 May, 2001	SMHN
Introduction to the Computation of Hydrologic Records (Review)	SMHN, El Salvador	11-15 December, 2000	SMHN
Introduction to the Computation of Hydrologic Records	USGS, Puerto Rico	31 Jul - 11 Aug, 2000	SMHN

Internet Data Clearinghouse

Larry Tieszen and Eric Van Praag

Project Objectives

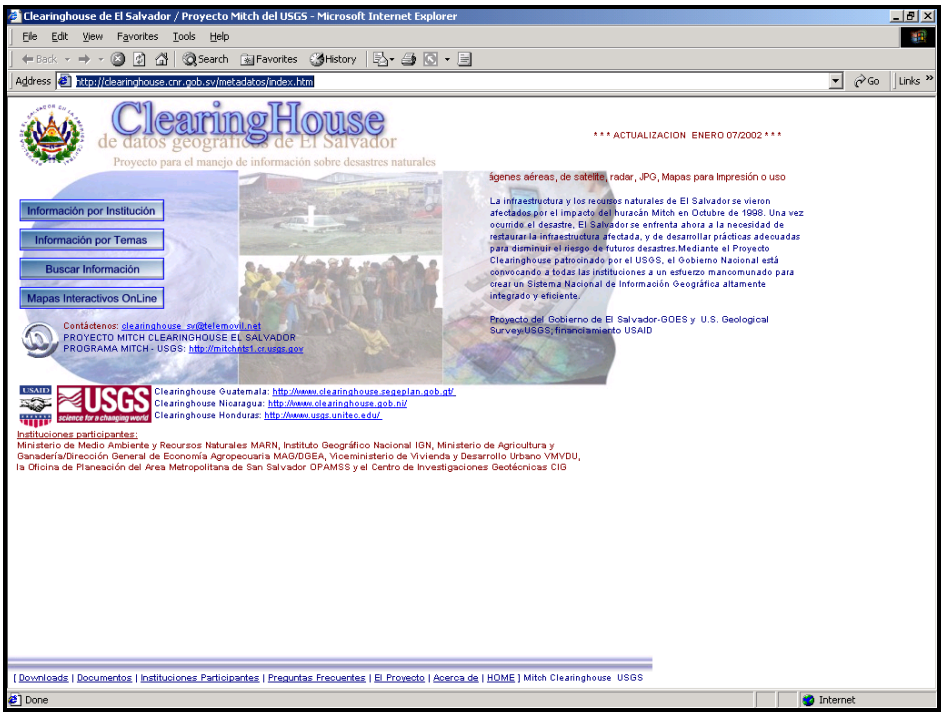
The Mitch reconstruction and planning activities in El Salvador by USAID, the United States and El Salvador government agencies, and other donor organizations have generated a tremendous amount of spatial data and information, to complement the spatial data holdings already held by national institutions. 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 El Salvador, 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, El Salvador 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 El Salvador 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.



Six national organizations have participated in the project: National Geographic Institute, Ministry of Environment, Ministry of Agriculture, Planning Office for San Salvador, Strategic Planning Office at the Ministry of Housing, Center for Geotechnical Research, 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 the Ministry of Envirnonment 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

Salvadorean partners implemented and made operational the two systems described above: a Clearinghouse data catalog node and its associated WEB Site. More than 500 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 an Internet Map Service offering basic GIS functionality and access to public data holdings. The physical Clearinghouse server computer - featuring the Clearinghouse node and Web Site - is located at the National Geographic Institute.

The earthquakes that hit the country in early 2001 allowed the government agencies to realize the usefulness and applicability of the Clearinghouse system, and regretfull at this event was, it helped the Clearinghouse gain considerable ground with senior governmental authorities.

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. The Ministry of Environment and the National Geographic Institute in particular have a strong commitment to maintain and expand the system.

Project involvement varied considerably: the National Geographic Institute, the Ministry of Environment, the Ministry of Agriculture and the Planning Office for San Salvador became active project participants, while the Strategic Planning Office at the Ministry of Housing and the Center for Geotechnical Research at Ministry of Public Works were less involved.

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 El Salvador Clearinghouse WEB Site is located at http://clearinghouse.cnr.gob.sv/metadatos/index.htm. The Clearinghouse metadata catalog node can be searched by choosing the "El Salvador – Clearinghouse Nacional de Datos Geoespaciales" node from the list of servers in a given gateway (i.e. http://130.11.52.184/servlet/FGDCServlet)

Landslide Hazard Assessment

Anthony Crone

Project Objectives: The El Salvador Landslide Mapping project had two primary objectives: a) to develop a comprehensive inventory of storm-induced landslides in selected parts of the country that were most heavily impacted by the hurricane, and b) identify places in these study areas where unstable slopes may continue to pose a hazard to lives and property. We also sought to involve Salvadoran geoscientists in our studies, but there is virtually no landslide expertise in the Salvador national government. Through our studies and collaboration with Salvadoran counterparts, and through similar interactions of other USGS scientists and Salvadoran colleagues, we have stimulated a new awareness in the Government of El Salvador (GOES) of the need for high-quality and objective earth science information to respond to and deal with hazardous natural events.

To meet our objective of providing useful landslide information, our products are in bilingual format and in digital form, which will accelerate distribution of the products and increase their utility throughout El Salvador. The digital products will be available on CD-ROMs and via the web.

Accomplishments: We completed detailed mapping of landslides and slope failures in five widely separated study areas throughout the country (Figure 1). There study areas were initially defined on the basis of recommendations from Salvadoran colleagues and officials, but they were further enlarged when we obtained aerial photographs that covered larger areas than those originally defined as study areas. In total, we thoroughly examined photography that covered an area of 11,490 km^2, which is more than 50 percent of the country (Figure 1). Ultimately, we prepared a report and 11 plates at 1:50,000-scale showing maps of hurricane-induced landslides.

The formally designated study areas include:

The *Santa Ana-Ahuachapan* study area, which encompasses approximately 2,600 km^2 between Lago de Coatepeque on the east and Ahuachapan and the Río Paz along the Guatemalan border on the west.

The *San Ignacio-Tejutla* study area, which covers approximately 2,650 km^2 between Nueva Concepcion and El Paraiso on the south to San Ignacio and northward across the Honduran border.

The *Berlin-San Miguel* study area, which covers approximately 5,000 km^2 and extends from the eastern slopes of Volcàn San Miguel and the nearby volcanoes on the east to the western flank of Volcàn de San Vicente on the west.

Two additional study areas, designated the ***Embalse Cerrón Grande*** and the ***Embalse 15 de Septiembre*** study areas, were included at the request of Salvadoran officials because of concerns about landslides affecting the country's infrastructure for its hydroelectric power generation. These two added study areas covered an additional 1,240 km^2.

As we proceeded, we expanded the mapping outside of our originally defined study areas to include all areas where we had aerial photographic coverage (Figure 1). This expanded coverage

is mainly around the eastern and southern margins of the *San Ignacio-Tejutla* study area in north-central El Salvador and in the Berlin-San Miguel area.

Following our initial mapping, we examined selected features in the field to better characterize the landslides and to assess their impact on the landscape. GOES geoscientists joined us during this field review to acquaint them potential remaining problems associated with some of the larger landslides, including El Zompopera and El Pinar landslides (Figures 2 and 3)

During the course of this landslide study, El Salvador was struck by two major earthquakes (January 13 and February 13, 2001) that caused thousand of fatalities and injuries, and widespread destruction. Much of the human toll and destruction was related to earthquake-induced landslides. Because of our existing association with Salvadoran geoscientists, government officials, and USAID-ES, we responded to both earthquakes and provided advice and recommendations to government officials concerning steps to mitigate continuing hazards and to avoid potential future hazards. Within a few weeks of our field studies, we completed and published reports summarizing our observations and recommendations.

These earthquakes emphasized the vulnerability of the country to a multitude of natural hazards, and stimulated an awareness throughout all levels of government in El Salvador that basic earth-science information is a valuable and vital asset that is necessary to have in responding to natural disasters and in planning to mitigate their impacts.

Resulting Benefits: The adverse impact of Hurricane Mitch was not a strong in El Salvador as it was in neighboring Honduras and Nicaragua, but the storm and the subsequent earthquakes created a profound awareness in El Salvador that geoscience expertise and information are vital resources that can benefit the Salvadoran people. The hurricane and earthquake disasters have stimulated the Salvadoran government to create a national earth science agency in the Ministry of the Environment (MARN). This agency, named Servicio Nacional de Estudios Territoriales (SNET), has two directorates, one that is responsible for geological studies and a second that is responsible for hydrological and meteorological studies. The creation of this agency and the unification of these services are a major and important step forward in serving the needs of the country.

The mapping and field observations from this study provide first-order information on the susceptibility of the steep slopes of volcanoes and other mountainous areas of the country to landslides. The most susceptible areas are where the bedrock is highly fractured, deeply weathered, or where the near-surface substrate is composed of poorly consolidated volcanic deposits. Landslide masses moving down steep slopes commonly transform into rapidly moving debris flows and may travel hundreds or thousands of meters before stopping on gently sloping ground. Channel areas downstream and downslope of steep slopes are areas of potential inundation by debris flows and should be carefully evaluated prior to siting homes, businesses, or infrastructure. The information gathered in the course of this project provides a starting point for guiding future development in landslide-prone areas.

The general observations regarding some of the controls on landslides in El Salvador can be tested by further analysis. The landslide inventory generated by this project can be used as the first step in developing a more comprehensive analysis of landslide hazards. For example, GIS-based analysis of the distribution of landslides in relation to different geologic units would be useful to determine if specific types of bedrock are more susceptible to landsliding. This kind of susceptibility information can then be

combined with a GIS-analysis of slope angles determined from digital elevation models. The merger of slope-angle information and the failure susceptibility of various rock types and surficial materials can be merged to yield landslide susceptibility maps. With additional geotechnical data and the application of slope failure models, it would be possible to estimate landslide-travel distances and develop maps of potential debris-flow inundation zones. Such maps would be valuable tools to help identify areas where future development should be restricted or avoided, and should be developed to help mitigate landslide hazards in parts of the country where urbanization is occurring.

Success Stories: The most serious and hazardous landslide threats in El Salvador were related to effects from the 2001 earthquakes. The 13 February, 2001 earthquake caused large landslides and rockfalls throughout central El Salvador. Large landslides dammed two major rivers and created landslide dams containing hundreds of thousand to millions of cubic meters of debris. As part of the USGS response effort, we provided immediate advice and recommendations concerning the stability and hazards posed by these dams. Examination of the landslide dam on the Rió El Desagüe indicated that this dam was not hazardous. In contrast, the landslide dam on the Rió Jiboa was creating a large deep lake that could cause a catastrophic failure of the dam. Such a dam failure would produce a huge, potentially devastating flood. In collaboration with Salvadoran colleagues, we evaluated mitigation options and presented recommendations to government officials. The officials quickly executed our recommendations to mitigate the hazard and avert an additional potential disaster.

Collaboration Efforts: Throughout this project, we have maintained steady communication and strong collaboration with Salvadoran colleagues in various agencies and with staff and officials at the USAID mission in El Salvador. During the course of this study, we worked with Salvadoran colleagues in the Centro de Investigaciones Geotécnicas (CIG), Geotérmica Salvadoreña (GESAL), and the newly formed Servicio Nacional de Estudios Territoriales (SNET).

Formal Reports:

Crone, A.J., Baum, R.L., Lidke, D.J., Sather, D.N.D., Bradley, L.-A., and Tarr, A.C., 2001, Landslides induced by Hurricane Mitch in El Salvador—An inventory and descriptions of selected features: U.S. Geological Survey Open-File Report 01-0444, 23 p., 11 oversized plates. **Available on the web at:** http://greenwood.cr.usgs.gov/pub/open-file-reports/ofr-01-0443/

Jibson, R.W., and Crone, A.J., 2001, Observations and recommendations regarding landslide hazards related to the January 13, 2001 M-7.6 El Salvador earthquake: U.S. Geological Survey Open-File Report 01-141, 19 p.

Baum, R.L., Crone, A.J., Escobar, D., Harp, E.L., Major, J.J., Martinez, M., Pullinger, C., and Smith, M.E., 2001, Assessment of landslide hazards resulting from the February 13, 2001, El Salvador earthquake: U.S. Geological Survey Open-File Report 01-119, 20 p.

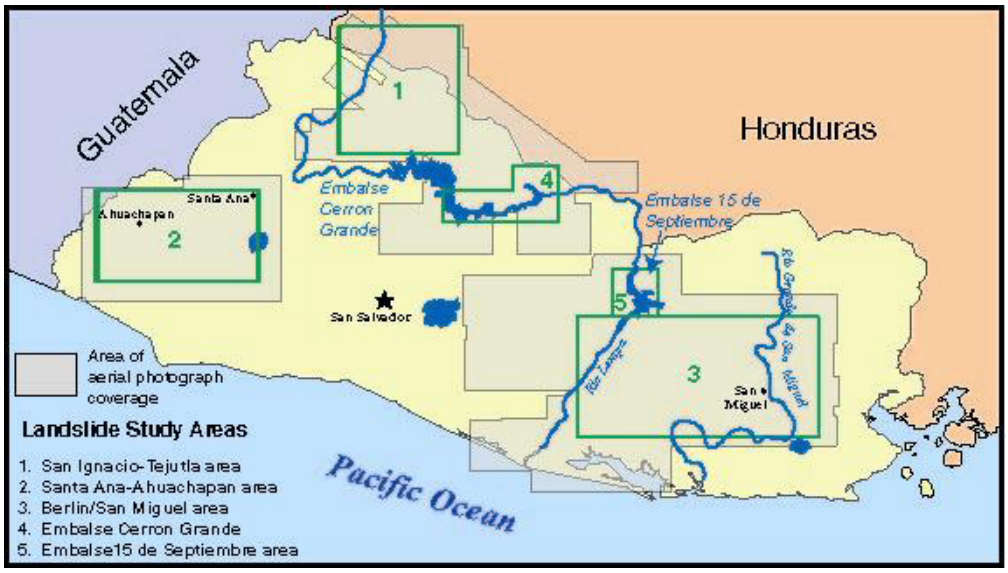


Figure 1. General location map of El Salvador and the landslide study areas. Areas 1, 2, and 3 were the initially defined study areas, areas 4 and 5 were added because of concerns about the possible effects of landslide on two large reservoirs Shaded areas show the coverage of aerial photographs that were examined in this study.

Figure 2. View to the northeast of the upper part of El Zompopera landslide. The collapse of unstable blocks in the upper part of the landslide destroyed a road at the crest of the ridge. Many unstable blocks remain in the upper part of the slide and a catastrophic collapse of those blocks could potentially dam the Río La Palma at the bottom of the valley. A catastrophic failure of a landslide dam could cause flooding and damage in the downstream town of La Palma.

Figure 3. View of the El Pinar landslide and the abandoned school. A new road has been graded across the head of the landslide, which slid into the valley of the Río La Palma o Las Pozos on the right. Future movements on the landslide will likely disrupt the new road

Volcano Hazards Assessment

Jon Major and Steven Schilling

Objectives - The El Salvador volcanoes project had two primary objectives: a) Conduct an analysis of lahar (volcanic debris flow) hazards at target volcanoes identified in consultation with the local USAID mission, GOES, and NGO's and produce maps depicting zones of potential inundation from lahars of various sizes. The maps were to identify hazardous areas as well as provide information on the probability of occurrence of lahars of various sizes. b) Train local geoscientists and spatial data analysts on recently developed methodologies for conducting lahar-hazards analysis. Secondary objectives of the project included a broader analysis of general hazards at the target volcanoes and production of maps that showed areas of volcanic hazard.

Particular objectives of the project were selected primarily in response to the disaster at Casita volcano, Nicaragua. At Casita, Hurricane Mitch triggered an approximately 2 million cubic meter landslide that transformed into a rapidly moving debris flow that destroyed two villages and killed more than 2000 people. If a lahar-hazard analysis had been conducted at Casita volcano prior to Mitch, it would have shown that the destroyed towns were located in an extremely hazardous area. 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, and a recent rainfall-triggered debris flow at San Vicente volcano in El Salvador that killed residents of Guadalupe, poignantly illustrate hazards associated with volcanoes even when they are not erupting.

In El Salvador, the three largest population centers--San Salvador, San Vicente, and San Miguel--are located at the bases of large, active volcanoes, and outlying communities and coffee plantations encroach onto the volcanoes themselves. Thus, the population density and distribution in El Salvador potentially put large numbers of people at risk from hazardous events at the country's volcanoes. Near San Salvador volcano, for example, tens to hundreds of thousands of people live in areas that could be affected by a variety of volcanic events. 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.

Accomplishments - 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:

Major, J.J., Schilling, S.P., Sofield, D.J., Escobar, C.D., and Pullinger, C.R., 2001, Volcano Hazards in the San Salvador Region, El Salvador: USGS Open File Report 01-366, 17 p. This report is available on the web at http://vulcan.wr.usgs.gov/Volcanoes/ElSalvador/Publications/OFR01-366/framework.html

Major, J.J., Schilling, S.P., Pullinger, C.R., Escobar, C.D., and Howell, M.M., 2001, Volcano-hazard zonation for San Vicente Volcano, El Salvador: USGS Open-File Report 01-367, 15 p. This report is available on the web at: http://vulcan.wr.usgs.gov/Volcanoes/ElSalvador/Publications/OFR01-367/framework.html

Major, J.J., Schilling, S.P., Pullinger, C.R., Escobar, C.D., Chesner, C.A., and Howell, M.M., 2001, Lahar-hazard zonation for San Miguel Volcano, El Salvador: USGS Open-File Report 01-395. This report is available on the web at: http://vulcan.wr.usgs.gov/Volcanoes/ElSalvador/Publications/OFR01-395/framework.html

Each report contains maps that depict hazard zones related to lahars and other volcanic phenomena, 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 early February. They will also be accessible through the Hurricane Mitch clearinghouse website.

The project also produced a compact disk that contains digital elevation models of 1:50,000 scale topographic maps of the target volcanoes and surrounding areas.

Technology transfer: The project convened a week-long 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 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. Participants from El Salvador included representatives from USAID, Ministerio de Medio Ambiente y Recursos Naturale (MARN), Servicio Nacionale de Estudios Territoriales (SNET), Geotermica Salvadorena (GESAL), and Servicio Meteorologico e Hidrologico Nacionale (SMHN). Representatives of these agencies were purposely selected to transfer the technology to a wide scientific audience within the country and to begin fostering communication among agencies that have various scientific strengths.

Development of in-country capability: To develop in-country capability to conduct lahar hazard analyses, the project purchased a computer workstation and an ARCINFO license for Servicio Nacionale de Estudios Territoriales (SNET), the national geoscience agency. 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.

Furthermore, communications among a variety of counterpart agencies fostered during the workshop described above ensure that the capability to conduct hazard analyses can be distributed and shared among relevant agencies. Investment in this capability can be protected by ensuring that SNET 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 SNET 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 El Salvador and the local USAID mission now have probabilistic assessments of volcano hazards at San Salvador and San Vicente volcanoes, and a probabilistic assessment of lahar hazards at San Miguel volcano. 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 SNET, 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. If this information can be widely distributed to the affected municipalities, it will provide significant information regarding hazards, hazardous areas, and mitigation strategies. The host government, as well as the local USAID mission, should take steps to ensure that this information is disseminated as widely as possible to the appropriate people. Recurring costs for maintaining the new technology are discussed above.

4. In response to landslides triggered at San Vicente volcano by the February 2001 earthquake, the local USAID mission as well as representatives from SNET requested that we expedite the lahar hazard analysis for San Vicente volcano. We sent them an advance map of the hazards analysis, and they used this map to discuss areas of potential hazard in the village of Guadalupe as residents rebuilt in the aftermath of the earthquake. Such discussions may have been partly responsible for minimizing the number of fatalities from a landslide/lahar triggered by rainfall in September 2001.

5. During the course of the project, we had very close collaboration with the local USAID mission, in particular with Lic. Ana Elizabeth De Gonzalez. She was instrumental in helping us identify target volcanoes, in obtaining clear-film copies of topographic maps that we needed to generate digital elevation models, in arranging meetings with counterpart agencies, in arranging the final debriefing meeting in which we discussed the reports, and in helping disseminate the information in reports. She also actively participated in the technology transfer workshop. We did not interact with other USG agencies or other donors during the course of the project.

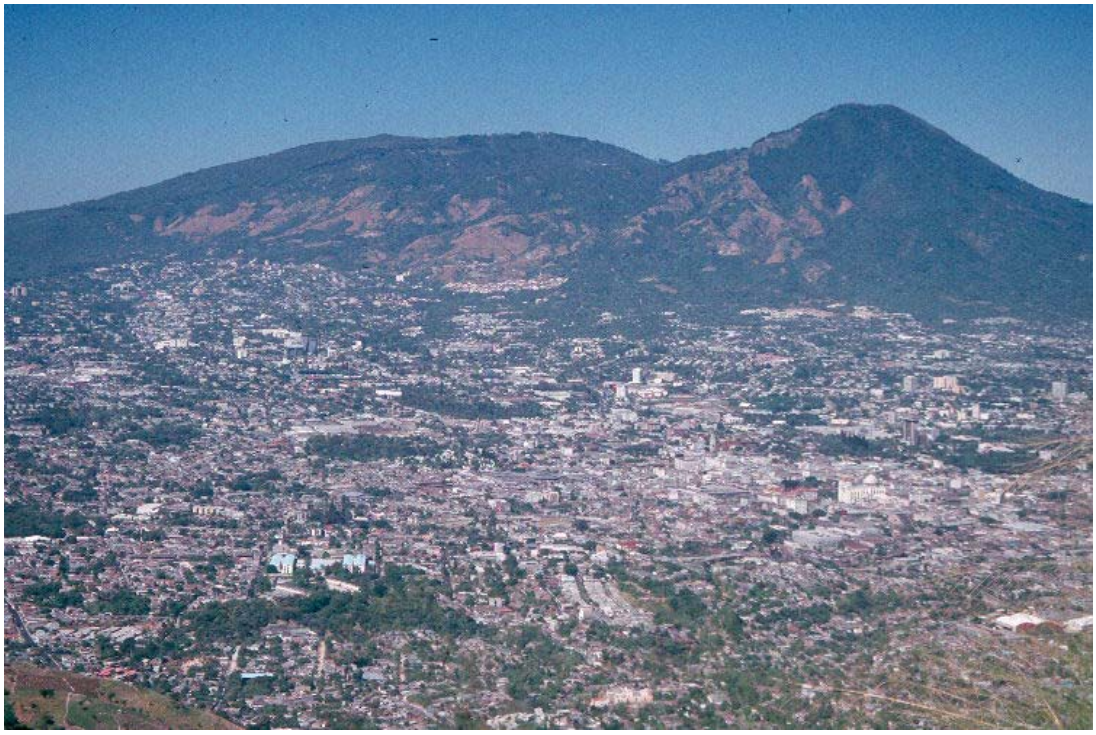


Figure 1 –Photo of San Salvador volcano with city in foreground

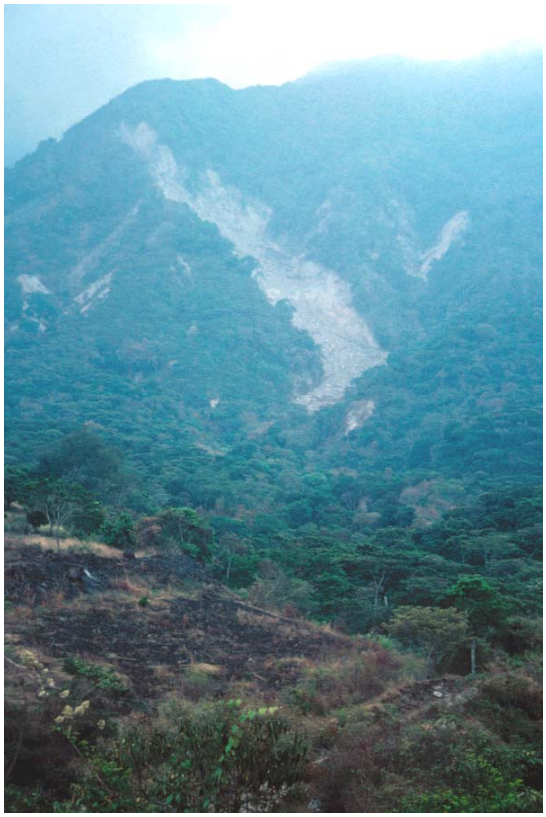


Figure 2 - photo of landslide at San Vicente volcano triggered by Feb 2001 earthquake

Figure 3 - Photo of September 2001 debris flow in Guadalupe

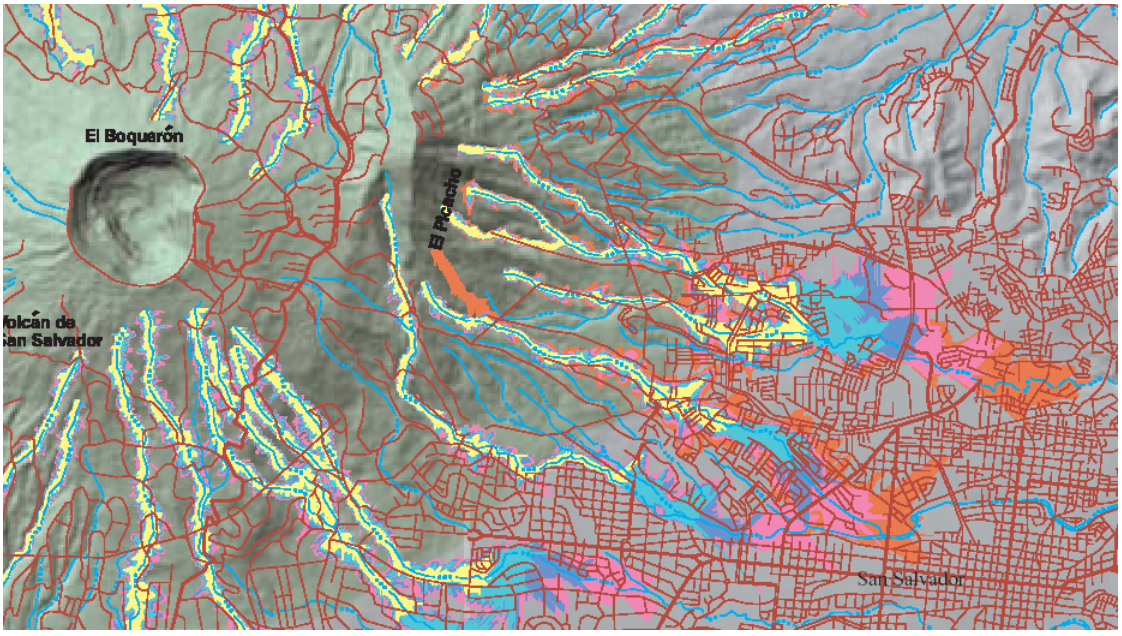


Figure 4 – Portions of a map showing lahar hazards on the flanks of San Salvador volcano (from Major, J.J., Schilling, S.P., Sofield, D.J., Escobar, C.D., and Pullinger, C.R., 2001)

Municipal Geographic Information Systems

Manolo Barillas and Peter Chirico

The national governments of Central America agree that inadequate resources and disaster management capacity in transnational watersheds increase cross-border vulnerability and compromise sustainable development. USAID/G-CAP and SG-SICA, in coordination with other USG agencies addressed this problem by putting in place the conditions necessary for sound management and disaster mitigation in the Río Lempa watershed, which is shared by Guatemala, El Salvador, and Honduras. One of these strategies, consisted on the creation of a Geographic Information Systems (GIS) in various municipalities of the Rio Lempa Watershed.

The main purpose of these Municipal GIS project was to provide municipal governments new maps, aerial photographs, natural hazard data, hardware, software and training for natural disaster preparedness, mitigation and urban development. The four sites chosen for this effort by the SICA and the GOES were San Salvador, La Palma, Jiquilisco, and Berlin (see figure to right).

The principal objectives of the project were:

- Provide decision makers at the local level access to watershed and disaster mitigation/management information.
- Train municipal staff in GIS development and geo-referenced data analysis.
- Provide training on the implementation of disaster response and mitigation plans
- Provide training on access to and use of information for natural disaster management and watershed management.
- Provide GIS analysis for the identification of vulnerable areas, infrastructure, settlements and natural systems.

Activities

- **Project Presentation to Mayors and Municipal Councils**

  Along with officials from the Ministry of the Environment and the Ministry of Agriculture, Municipal Mayors were visited in order to acquaint them with the project's objectives and methodology. Upon these initial efforts to approach them, the Mayors appointed the Municipal officials who were involved in the project and participated in the corresponding training courses.

- **Introductory Training: Arc View and Basic Cartography**

For this activity one group was organized for the cities of La Palma, Jiquilisco, Berlín and San Salvador. At least 20 persons participated in the one-week training course, working full time at the laboratories in the Universidad Centroamericana "José Simeón Cañas" (Central American University).

In this training course the trainees learned about the basic principals of installing, operating and maintaining Geographical Information Systems (hardware and software), basic cartography, aerial photographs, etc. There were also lectures about natural hazards (floods, landslides, earthquakes).

- **Equipment Delivery and On-site Training**

  After the first training session, each municipality was provided with a computer, a GPS unit, and a digital camara, which were personally delivered, installed, and configured on site. Arc View GIS software and other programs were also installed, and on-site training was provided on the use and operation of the digital camera and the GPS portable unit.

- **Info Production and Edition**

  Beside the training sessions and the delivery of the equipment, basic information that will be part of the Municipal GIS was gathered, produced and edited. With a few exceptions, the information produced during the project for each municipality was generally the following:

- ✓ Topographic and vector information at 1:250,000 scale, provided by the GIS at the Ministry of the Environment and Natural Resources (information on over 15 layers)
- ✓ Topographic and vector information at 1:50,000 scale, provided by the USAID-Río Lempa Project (with layers containing contour lines, the hydrographic network, the road network and the population centers).
- ✓ Digital orthophotos at 1:10,000 scale, produced by the USGS Guatemala staff and the USGS Reston staff, with the assistance of project participants.
- ✓ GPS points of critical infrastructure for emergency situations (shelters, police stations, hospitals, etc.) gathered by the project participants and digitalized with the assistance of the USGS Guatemala staff.

- **Intermediate Training: Arc View Applications and Info Analysis**

Intermediate training was provided after the basic GIS had been installed in the Municipalities and the basic information had been generated and edited.

This training included lectures and exercises on the basic applications of Arc View to natural disaster mitigation, especially on issues such as how to create hazard maps (floods, landslides, etc.); how to use orthophotos; how to digitize and prepare databases; how to design layouts; how to print final maps, etc. As in the first training session, the participants worked full time for one week at the laboratories in the Universidad Centroamericana "José Simeón Cañas".

- **Critical Infrastructure Database**

Using orthophotos as a base, information was developed on, for example, location, characteristics, basic services, etc., and a map of critical emergency infrastructure was drawn up. Pending is only the cadastral survey and the development of the corresponding database, since they were only provided with the Cad Tool interface, specifically designed by the Reston staff for that purpose.

- **Product Delivery and Info Integration**

At the end of the project, a meeting was organized in each Municipality in order to deliver the information and products resulting from the process. In most cases, the same Councils and Committees that had been summoned a few months earlier in order to acquaint them with the project were summoned this time. They clearly recognized how much information had been generated by the members of their staff and how much they had increased their technical capabilities.

Significance or Impact of the New Technologies

The Municipal Governments included in this project have made tremendous progress in applying GIS technologies to municipal needs. GIS is now being used by them for inventorying and designing drinking water-systems; identifying flood hazard zones; urban planning, etc. Municipal officials have recognized the value of these technologies and have readily adopted them.

The GIS Municipal Project generated three substantial changes in the participating institutions, organizations and Municipal Governments.

- ✓ **Equipment**: 5 computers, with their corresponding printer; more than 5 Arc View 3.2 licenses; 4 digital cameras, and 4 portable GPS units were delivered in Salvador. All this equipment is also being used for other purposes by Municipal Governments, especially to monitor the progress of their projects and to inventory their resources (drinking water, wells, sewage systems, etc.)
- ✓ **Digital information**: Approximately 20 Gb's of information was provided to Municipal Governments, especially orthophotos, topographic vector and raster information, maps

and databases. This information will considerably increase decision-making and analysis capabilities of Municipal Governments.

- ✓ **Training:** More than 20 technicians were trained in Salvador, among them Municipal officials, governmental agencies, other organizations, etc. The type of training they received will enable them to use GIS for many other purposes within their Municipalities.

Measures to be taken to ensure that the investments are protected and maintained

It will be necessary to identify an organization that will be responsible for following up on and updating the hazards layers for these GIS's. The USGS team recommends that the newly formed Salvadoran Earth Sciences Agency (SNET) is the best institution to follow up the work with the municipalities. The relationship between the Municipalities and the SNET is not yet firmly established because SNET is establishing his GIS department during this year, but this process should be underway shortly.

Also – municipalities will soon receive additional software that will allow them to create cadastral databases, which will assist them in improving their land- and property-tax data management. They have already been provided with training and the necessary tools, and if they were provided with the funds they need to execute the required field work, the sustainability and operation of the Municipal GIS would be ensured.

Collaboration with other agencies.

One of the major successes of the GIS Municipal Project bringing together all the institutions and organizations concerned with mitigating disasters at the municipal level. In El Salvador, UCA (Universidad Centro Americana) played an important role in supporting the training program. They were very helpful in prepare the computer rooms and provided much-appreciated technical assistance.

The Ministerio de Medio Ambiente (National Geographic Institute--IGN in Spanish) provided the digital material that was used in the trainings and gave it to the municipalities. Some of the technicians of MARN went to the municipalities with the USGS team in order to observe the onsite training.

Program Budget

USGS HURRICANE MITCH PROGRAM - El Salvador Summary Budget	
Activity	Funds Expended
Digital Topographic Maps	$86,656
Satellite Imagery & Aerial Photography	$187,900
Streamflow Monitoring Network and Hydrological Databases	$147,444
Internet Data Clearinghouse	$178,764
Landslide & Volcano Hazard Assessments	$247,604
Integrated GIS Products for Municipalities	$126,028
In-country & HQ Management, Staff Support	$218,248
Total	$1,192,643

Program Organization and Points of Contact