Hurricane Mitch Recovery

By

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ABSTRACT

The characteristics of Hurricane Mitch, the most destructive storm in the Atlantic Basin in the past 200 years, are described. A summary of Mitch's impact on Central America, including its path and impact on people, infrastructure and the environment are presented. Initial recovery efforts focused on saving people and opening transportation routes. That was followed by assessment of high-risk landslide areas and flood mitigation approaches. The planning approach including the use of geographic information system tools are summarized. Initial results and on-going recovery actions are reviewed.

KEYWORDS: Hurricane Mitch, flooding, flood mitigation, storm track, landslides, geographic information system, aerial photographs, mapping, remote sensing, image analysis

1.0 INTRODUCTION

In the Fall of 19978, the Caribbean Basin and surrounding Central American countries experienced the full fury of a rare level five hurricane: Mitch. From October 27 to November 1, 1998, the most destructive hurricane in the history of the Western Hemisphere hovered off the Honduran coast battering Honduras, Guatemala, Nicaragua, and El Salvador (Figure 1). Mitch's 180+ mph winds and torrential rainfall, varying from one to six feet of water in a 24-hour period, devastated major portion of these Central American countries. In the days following this natural disaster, a multi-national relief effort was launched and is still underway today. Initially, the focus was on locating and evacuating victims to safer areas and providing emergency relief supplies to them. The recovery effort soon expanded to assess the amount and type of infrastructure damage and to develop plans for restoration. In all phases, the application of remote sensing, image analysis, the global positioning system, and geographic information systems were used extensively.

2.0 HURRICANE MITCH STORM TRACK AND CHARACTERISTICS

Hurricane Mitch, the strongest October Hurricane ever recorded, formed in the southwest Caribbean sea from a tropical wave about 360 miles south of Kingston, Jamaica, late on October 21. The system initially moved slowly westward and intensified to a tropical storm (AcuWeather, 1999). Mitch then moved slowly northward. Its course changed to north-northwestward on the 23rd and 24th while gradually gaining strength. Early on October 24, Mitch became a hurricane. Later that day, as it turned towards the west, Mitch began to intensify rapidly. In about 24 hours, its central pressure dropped 52 MB to 924 MB by the afternoon of October 25. Further strengthening took place and the central pressure reached a minimum of 905 MB about 40 miles southeast of Swan Island on the afternoon of September 26. This pressure is the fourth lowest ever recorded in an Atlantic hurricane this century. It is tied with Hurricane Camille in 1969. This is

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also the lowest pressure ever observed in an October hurricane in the Atlantic Basin. At its peak, the maximum winds were estimated to be 180 mph, a strong Category 5 hurricane.

After passing over Swan Island, Mitch began to gradually weaken on September 27 while moving slowly west, then southwest toward the Bay Islands off the coast of Honduras. The center passed very near the Island of Guanaja wreaking havoc there. From mid-day on the 27th to early on the 29th, the minimum central pressure rose 59 MB. The center of the hurricane meandered near the north coast of Honduras from late on the 27th through the 28th before making landfall during the morning of the 29th about 70 miles east of LaCeiba with 100 MPH winds. Mitch moved southward over Honduras, weakening to a tropical storm early on the 30th. Mitch moved slowly over Honduras and Guatemala on September 30-31, gradually weakening to a depression. The storm generated torrential rains over portions of Honduras and Nicaragua where the associated floods were devastating. Some heavy rains also occurred in neighboring countries. Figure 2 shows rain bands associated with Mitch.

Although Mitch originally dissipated near the Guatemala/Southeast Mexico border Sunday afternoon, November 1. The remnants continued to produce locally heavy rainfall over portions of Central America and eastern Mexico for the next couple of days. On November 3, a low-level circulation became evident in the eastern Bay of Campeche and an Air Force Reserve reconnaissance aircraft investigating the system reported tropical storm-force winds and a 99 MB central pressure. Mitch had regenerated into a tropical storm on the afternoon of the 3rd while located about 55 miles west-southwest of Campeche, Mexico. Mitch weakened to a depression early on the 4th as it moved inland over the northwest Yucatan Peninsula. The center re-emerged over the south central Gulf of Mexico by mid-morning on the 4th regaining tropical storm strength. Mitch began to accelerate to the northeast as it became involved with a frontal zone moving through the aster Gulf of Mexico. Mitch made landfall on the morning of the 5th in southwest Florida near Naples with maximum sustained winds near 60 MPH. By mid-afternoon of the 5th, Mitch moved offshore of south Florida and became extratropical. Figure 3 shows the storm track of Hurricane Mitch.

3.0 IMPACTS ON CENTRAL AMERICA

Hurricane Mitch, which has been called the deadliest Atlantic storm since the eighteenth century, carved a week-long path of destruction through Honduras, Nicaragua, El Salvador, Guatemala and Belize. A quote from Daniel Alegria, a reporter for Orfam GB of Nicaragua: "Imagine your worst nightmare. Imagine waking up to something a hundred times worse." Latest reports of the human costs are staggering:

· More than 18,000 people are dead or missing.

· One million homes have been lost.

· More than three million people have lost their livelihoods.

Much of the transportation and communications infrastructure of Honduras and Nicaragua was devastated. In addition to the roads buried by landslides or washed away by floods, towers and bridges were destroyed (Figures 4, 5 6, and 7). Out of 94 known bridges in Honduras, 88 were either destroyed or damaged beyond use.

The crater of Honduran Volcano Casita became rain saturated from the monumental rainfall, causing the southern slopes to slide down the hillside as avalanches of mud, forty feet tall, at sixty miles per hour. Multiple devastating mudslides swept into nearby communities, killing 1900 people. Mudslides reached the town of Posoltega, almost ten miles away from the volcano (Figure 7). The landscape of the entire nation of Honduras has drastically changed—more soil, rock, and sediment was moved in these few days than in the last several hundred years (Collier, 1999).

Of special concern is the severe destruction of the public health infrastructure coupled with severe flooding which has generated favorable conditions for widespread gastrointestinal and respiratory diseases and increased frequency of vector-borne diseases. Respiratory, diarrhea and skin diseases, along with eye infections can spread rapidly in large segments of the population left without homes, water, hygiene and sewage disposal. In southern Honduras, extensive flooding destroyed two pesticide factories containing over 400 barrels of pesticides and other industrial and agricultural chemicals. In Nicaragua, a large number of cases of respiratory infections, dengue, childhood diarrhea and leptopirosis were reported. Major health concerns continue to face the survivors of the flooding and mudslides.

4.0 GEOSPATIAL SUPPORT OF RECOVERY ACTIVITIES

4.1 Initial Emergency Response Efforts

U.S. military forces were some of the first international support units on the ground conducting recovery operations. As a result, a number of requirements for geospatial products were identified early in the operation (Operations Summary, January 1999).

In support of these requests maps, country studies, water areal appraisals and other available materials were collected and provided to the U.S. Army Corps of Engineers (USACE) Operations Center for use in immediate recovery operations, planning any additional deployments and future reconstruction efforts.

Separate requests for ground water resource data were received from support elements of the Second Mare Expeditionary Force and two Air Force Red Horse Squadrons (well drilling units) in Honduras. Maps and water areal appraisals were provided to two Marine Expeditionary Forces. Water detection data was also provided to the Air Force unit.

Initial analytical activities focused on assessing road and bridge damage in Honduras. Satellite imagery was reviewed and road and bridge assessment data were tabulated and served over the communication links. These data were keyed to a regional map, provided by the National Imagery and Mapping Agency (NIMA), to which a grid was added as an orientation aid for the user (Figure 9).

Photo maps of the Soto Cano Air Base and a slide area along the Chaluteca River in Tegucigalpa were also prepared and provided to the Army Corps of Engineers Operations Center.

The 30th Engineer Battalion, also in Honduras, requested specific Digital Topographic Data, and loan of high-capacity hard drives to process data. The Topographic Engineering Center imbedded current imagery data on the affected areas onto 14 CDs and provided them to the 30th Engineers. These CDs contained landsat and Spot imagery.

4.2 Joint Government and Private Sector Support

A cooperative effort of U.S. Government agencies and the private sector developed a Digital Atlas of Central America to assist in recovery efforts and planning for reconstruction. The geographic information sytem (GIS) based product provided a framework for displaying and organizing information in multiple layers useful to those responding to the disaster. Figure 10 is a sample product showing the path of Hurricane Mitch over a map with country boundaries and terrain elevation color coding (Digital Atlas, January 1999).

4.3 Geospatial Technology Applications

For the initial reconstruction phase, a number of geospatial products are needed to enhance planning and project execution (Hearn, February, 1999). Some of these information products include:

4.3.1 Topographic Base Maps

Virtually all activities associated with the reconstruction effort required large-scale (high-resolution) base maps showing topography, drainage, and the location of roads, bridges, and other infrastructure. This included 1:50,000 scale (I inch – 4000 feet) topographic maps in digital form – scanned and provided on CD-ROM with software to view and print the maps. In their simplest form, paper copies of these maps could be produced at data centers in Honduras and distributed to Honduran agencies, municipalities, and other agencies. The digital maps were also "georeferencd," so that when read by GIS software, precise geographic coordinates could be determined for any point on a map. Similarly, additional data or observations having geographic coordinates were added to the base map in a GIS. It is also important that hand-held Global Positioning System (GPS) units be available to allow USAID and Honduran agencies to readily determine location on the ground and be able to relate directly to map information.

4.2.2 Aerial Photography and Satellite Imagery

While base maps are essential to provide a geographic frame of reference, the information they contain is only as current as the date of the maps' publication. The best alternative to extensive observations on the ground is acquiring imagery of priority areas from satellites or aircraft. For large areas (e.g., agricultural areas), assessing the impact of floods and landslides was best done using medium-resolution satellite imagery. Landsat TM imagery provides 30 meter resolution and the ability to detect subtle differences in vegetation and ground cover. The highest-resolution and most convenient source of imagery for assessing dame to infrastructure was aerial photography. Aerial photographs allow rapid identification and assessment of damage infrastructure and can be used to prioritize and plan reconstruction activities. Photography acquired by the U.S. Air Force's Open Skies Program was available for most of the areas impacted by Mitch. The goal is to digitize and make available all existing photography for 123 municipal areas. Additional photography may be required for Tegucigalpa and other sites where there is either no coverage or where existing imagery is not acceptable due to cloud cover.

4.3.2 Geographic Information Systems (GIS)

GIS technologies allow base maps, imagery, data from landslide and flood risk assessments, water-quality data, site-reports, an other information to be integrated into comprehensive data bases that provide the same geographic frame of reference (Figure 11). For example, combining estimated floodplain boundaries with maps an aerial photography allows derivative maps to be quickly produced showing recommended no-build areas. Similarly, integration of base maps, satellite imagery, and ground-based observations in a GIS would allow rapid assessment of flood damage to agricultural areas. For this interim effort, a comprehensive GIS of Tegucigalpa at 1:10,000 scale, will be developed and technical assistance will also be required for the Honduran agencies.

4.3.3 Assessment of Landslide Hazards

Mitch-related landslides and flooding in Honduras were intricately interrelated, and the two processes interacted with each other in numerous places (Figure 12). Many of the landslides that caused loss of life and property were caused by stream-bank erosion and, conversely, major flooding was also triggered by landslide damming of rivers. Agricultural lands, population centers, transpiration corridors, and engineered structures such as dams and ports have been severely impacted by landslides and fluvial processes. USACE is assisting USAID and Honduran authorities with mapping and topographic analysis and evaluation of landslides affecting critical populated areas, facilities, transportation corridors, and engineered structures to assist authorities in the assessment of mitigation options.

5.0 RECONSTRUCTION IN THE AREA OF TEGUCIGALPA, HONDURAS

One of the large urban areas hardest hit by Hurricane Mitch in Honduras was the city of Tegucigalpa. The creation of a natural dam by massive sediment deposits from the flooded Rio Choluteca Rier within the city limits is of particular concern with the fast approaching rainy season. Also a major landslide during Mitch has left a large area of unstable ground immediately above the city. Figure 13 is an airborne image of the landslide area, and Figure 14 is a GIS layered data base illustrating the area of unstable earth (Digital Atlas, 1999).

Because of the vulnerability of the city of Tegucigalpa to additional flooding and landslides during the upcoming rainy season and the limited time available to put protection measures in place; the majority of the effort in developing this action plans was placed on the short-term phase. The long-tern solutions to the flooding and landslides are conceptual at this time and will require substantial data gathering and engineering analysis to determine the most cost-effective solutions.

5.1 Short Term Phase

The short-term solutions are divided into five areas: 1. Restrict the use of the floodplain and landslides areas; 2. Clear and excavate the Rio Choluteca channel at the El Berrinche site; 3. Stabilize the El Berrinche an El Reparto landslides; 4. Repair broken sewer collection system near the river; and 5. Initiate topographic surveys and subsurface exploration of the slides and river channel (Duffy, April, 1999).

5.1.1 Restriction of Land Use

Government of Honduras/City of Tegucigalpa should condemn the properties on the landslide and in the floodplain, and should relocate the residents to an approved reconstruction site. Strict land use plans must be developed, implemented, and enforced by the city. To implement this action, relocation sites must be identified; water, electrical and sewerage infrastructure must be developed at the relocation sites, and the relocated property owners must be compensated for their losses of property due to condemnation.

This is the simplest, most direct action that can be taken to reduce the potential for loss of life and property resulting from flooding or landslides. However, politically it may be the most difficult to implement. The government institutions in Honduras and the City of Tegucigalpa must demonstrate the will to develop and implement this action. The City and Government of Honduras should clearly announce there would be no indemnification of losses in the future for those who build in these no-build areas. The costs associated with this action reflect the cost to acquire the relocation site, develop the site access, water and sewer systems. Also included in the cost is the compensation to the property owners for the loss of their property on the landslide or in the floodplain.

5.1.2. Clearing and Excavating the Rio Choluteca Channel

Excavate the Rio Choluteca channel to restore as much channel capacity as possible prior to the onset of the rainy season. The primary focus of this effort will be the El Berrinche landslide site since this is a choke point for the Rio Choluteca. The channel capacity will be increased by removing landslide material and by removing structures along the street parallel to the river. Excavated material will be disposed of in an area outside of the floodplain. Some of the building materials resulting from the demolition of the gymnasium and other structures will be used to protect the toe of the landslide from erosion during the upcoming rains (Preliminary Action Plan, February, 1999).

It is believed that some excavation can be performed at the toe of the El Barrinche slide prior to conducting a geotechnical investigation without undue risk of causing further movement of the slide. However, due to the scarcity of survey data, the initial excavation amounts cannot be accurately determined. Therefore, the initial excavation will be directed in the field, with a series of slopes and berms approximately twenty feet in height.

5.1.2 Stabilize the Landslide Sites

The El Berrinche and El Reparto landslides will be re-graded to seal open cracks, improve drainage and reinforce the toe of the slope. A waterproof membrane will be installed near the tope of the slide to prevent rain from entering the slide mass.

Stabilizing the landslide can best be accomplished by preventing water from entering the landmass during the rainy season. This will prevent the landslide mass from becoming saturated and unstable. Preventing water from entering the landslide can be accomplished by grading the upper portion of the slide to allow rain falling on the slide to flow on the surface and down to the river without penetrating the land mass. Installing a waterproof membrane, similar to that used to line landfills and ponds, near the top edge of the slide can further enhance this. If this is done, steps must be taken to prevent the membrane from being removed (stolen) and restrictions must be enforced to prevent human activities on the membrane and sloped areas.

5.1.3 Repair Sewers

Repair the major breaks in the sewage collection system along the Rio Choluteca near the El Berrinche site.

Raw sewage is draining into the river channel from the sewer collection system. Many breaks were experienced during the flood and landslide creating a highly unsanitary situation after the storm. The work will involve repairing as many of the breaks as possible during the time prior to the rainy season to reduce the amount of sewage entering the river near the city. The repair work will concentrate on the main collection system located near the river.

5.1.4 Initiate Surveys and Subsurface Explorations

Develop topographic and subsurface information for use by the engineers to develop long-term solutions to the flooding and landslide problems. Acquire the topographic survey, prepare risk-zone maps, install river-monitoring system and establish control point to monitor slide movements. The most important information needed for an engineering analysis of the flooding and landslide problems is topographic and subsurface data. Without this information, very little engineering can be accomplished with any assurance that the solutions are viable. It is recommended to initiate these actions as part of the short-term actions since the data is critical to any follow-on engineering activities.

5.2 Long Term Phase

5.2.1 Data Collection and Analysis and Recommendations

A detailed analysis is used to address the long-term solutions to the flooding and landslides associated with the Rio Choluteca in the vicinity of Tegucigalpa. This will require comprehensive data collection and analysis of the water resource problems, subsurface conditions an infrastructure needs including the following:

A. Hydrologic and hydraulic investigation
B. Determine proper flow relief for bridges
C. Landslide recovery
D. Sedimentation analyses to estimate production of sediment and movement of sediment in the floodplain
E. Develop mapping to delineate the 100-year floodplain
F. Analysis of alternative solutions to flooding problems including levees, channel modification, stream bank stabilization, multi-reservoirs, and other options.

It is estimated to take three years to complete these actions. Once these investigations are complete, design and construction of the most effective and efficient measures can begin.

5.2.2 Tegucigalpa Sewer System

A study is required to determine the cost of providing a sanitary sewer system to serve the

City of Tegucigalpa. The study would involve sending a two-man team to Tegucigalpa for a period of 30 days to gather information. Topographic maps and existing sewer system plans would be reviewed. The service area and potential locations of the treatment plant should be addressed on this initial site visit. After making the site visit, the report should be prepared. The report should provide a plan showing the preliminary layout of the sewage collection system, pumping station locations, and location/alternate locations for the treatment plant. The report would address alternate treatment plant processes and the reason for selecting a particular process. The report would be coordinated with city officials and three design review meetings would be held at Teguigalpa. It is estimated that the report would take 12 months to prepare.

6.0 CONCLUSIONS

Hurricane Mitch was a natural disaster of epic proportion to Central America. The recovery and reconstruction efforts have also been of a magnitude not encountered before in that region. For the first time in a major disaster, extensive application of geospatial technology was used to assist in all phases of the recovery. A digital atlas and Geographic Information System was created for the impacted area to form a framework to integrate new data and information over time in a systematic manner. Satellite, aircraft, and ground information sources were used to collect data and information to support the recovery activities. A variety of products were successfully generated tailored to user needs in the field and higher level decisionmakers in the recovery effort.

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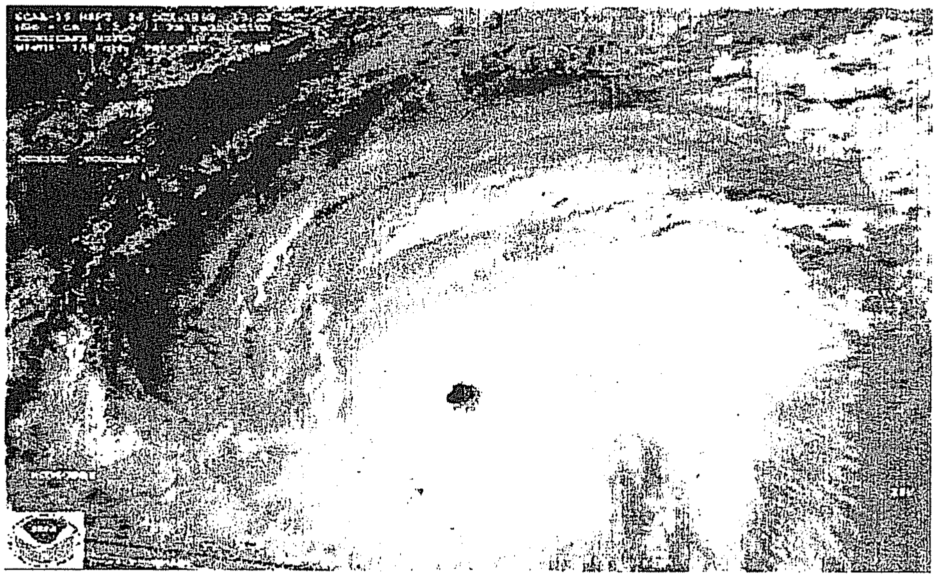

Figure 1: Visual Image of Hurricane Mitch October , 1999

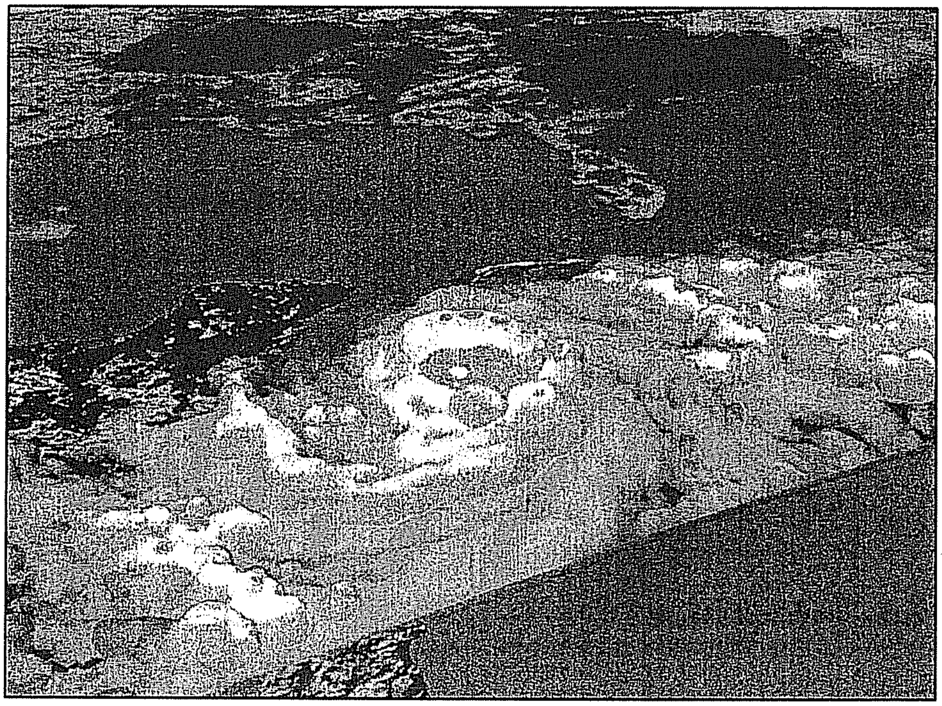

Figure 2: NASA Rain Density Model of Hurricane Mitch

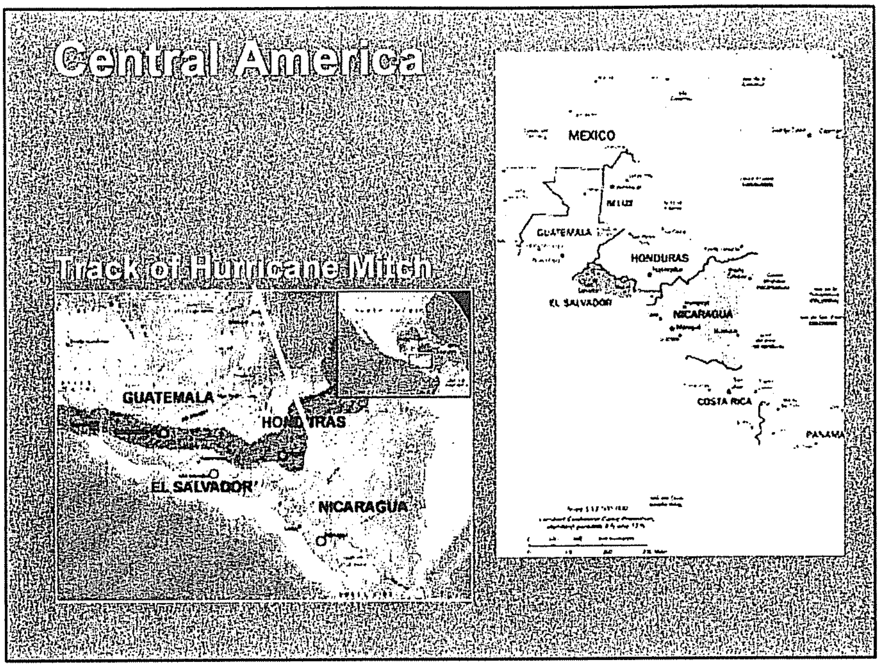

Figure 3: Storm Track of Hurricane Mitch

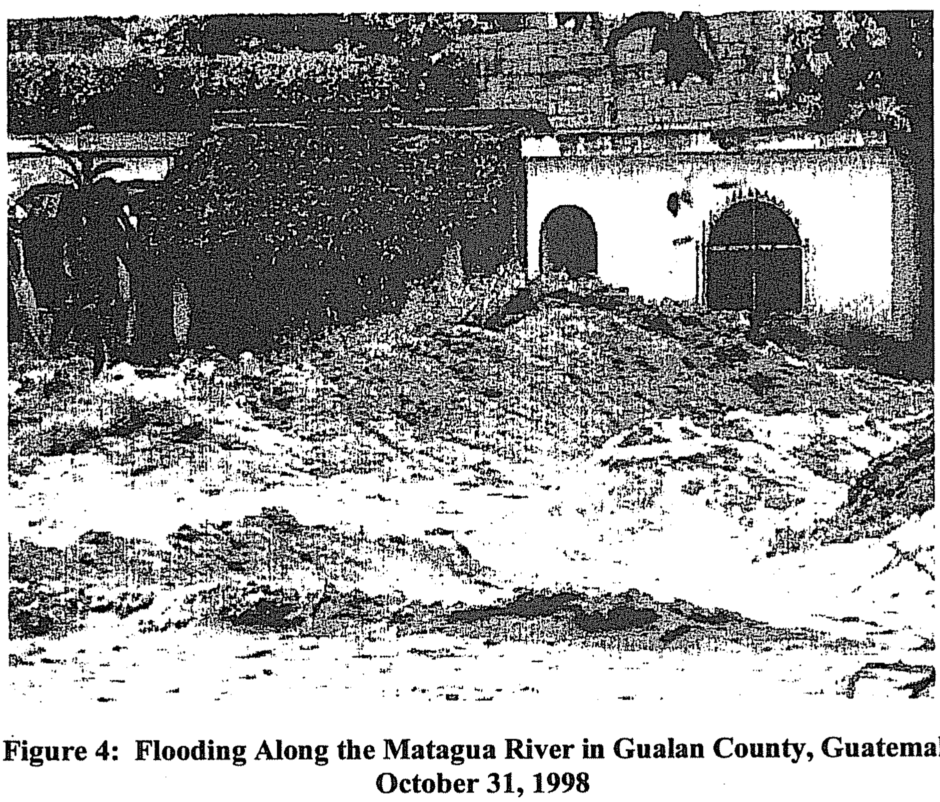

Figure 4: Flooding Along the Matagua River in Gualan County, Guatemala October 31, 1998

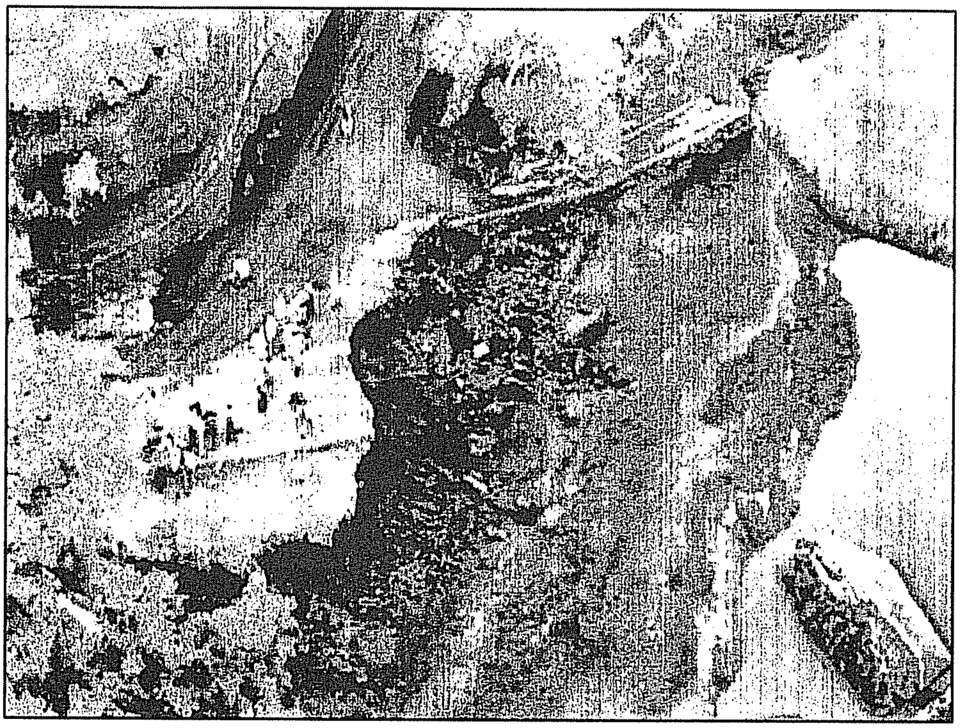

Figure 5: Flood Damaged Bridge and Road in Honduras

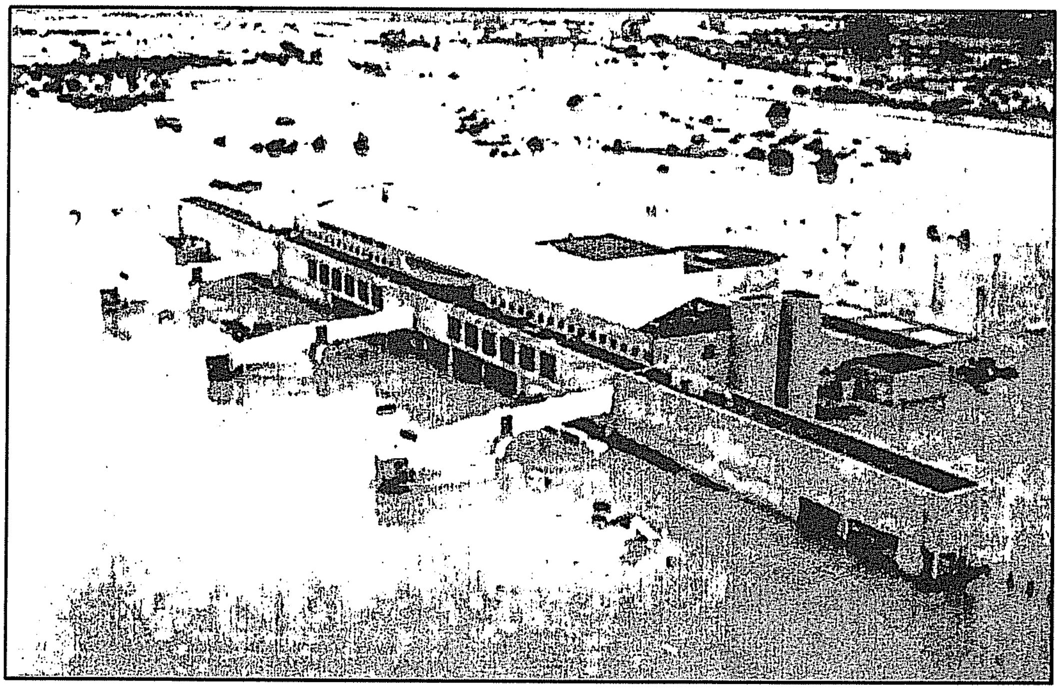

Figure 6: Flooded San Pedro Sula Airport, Honduras

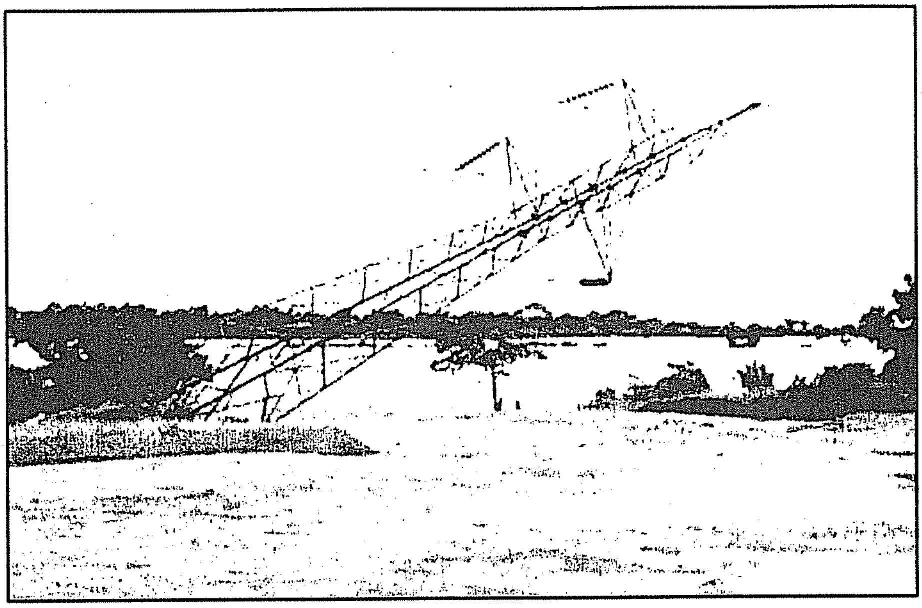

Figure 7: Damaged High Voltage Transmission Line on the Choluteca River

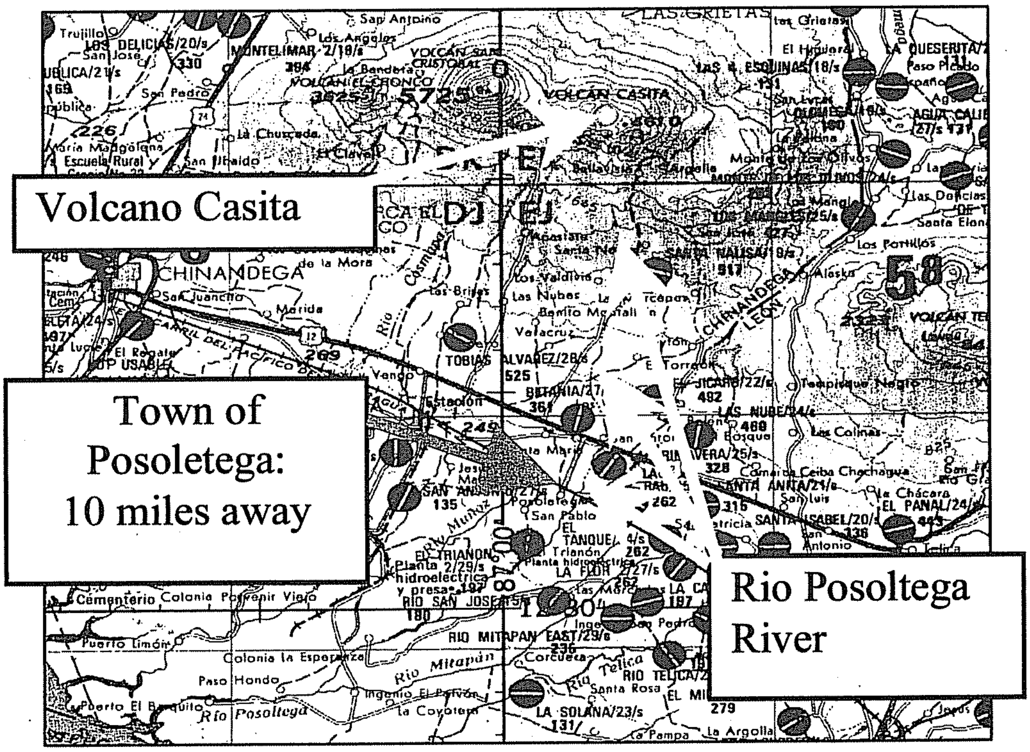

Figure 8: Map Showing Location of Landslide to Posoletega

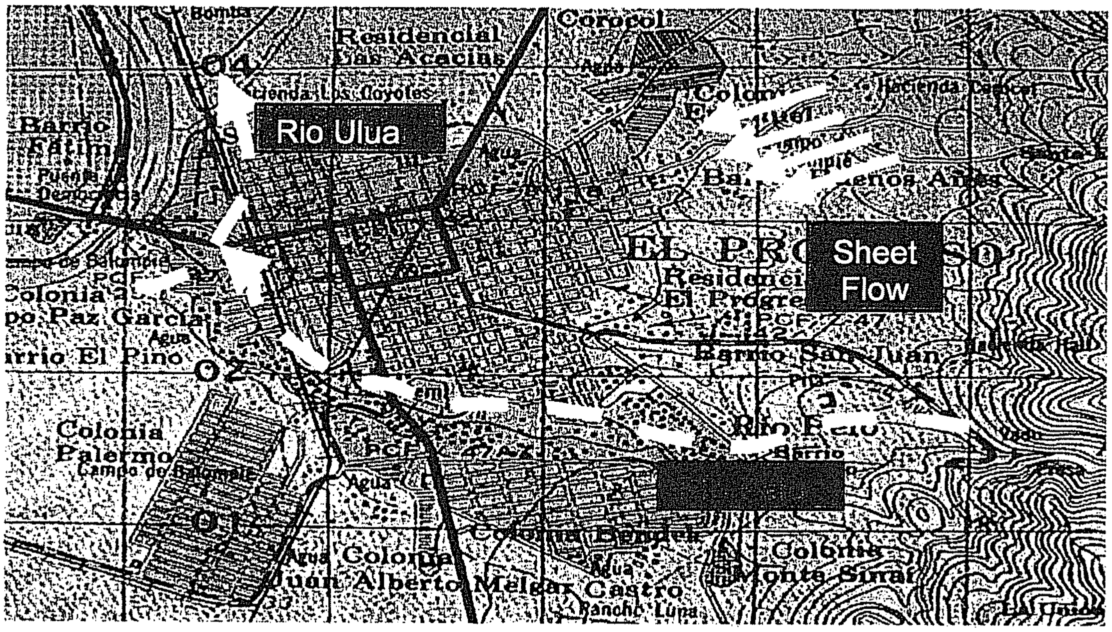

Figure 9: Road and Bridge Assessment Map

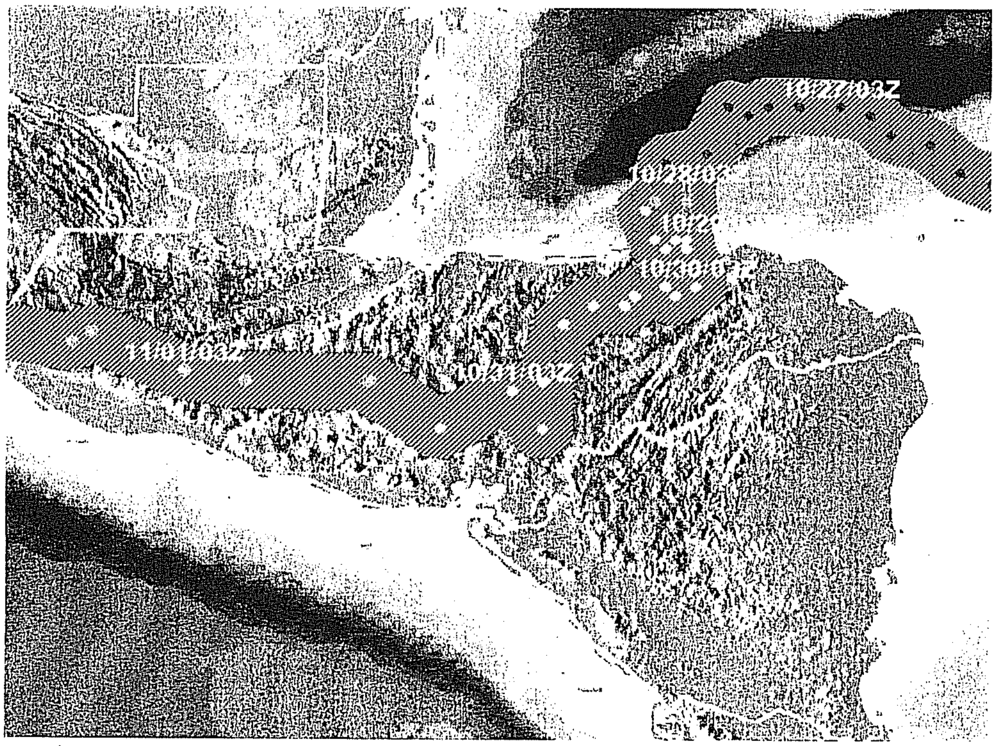

Figure 10: Path of Hurricane Mitch Over Central America From 10/27 – 11/01/98

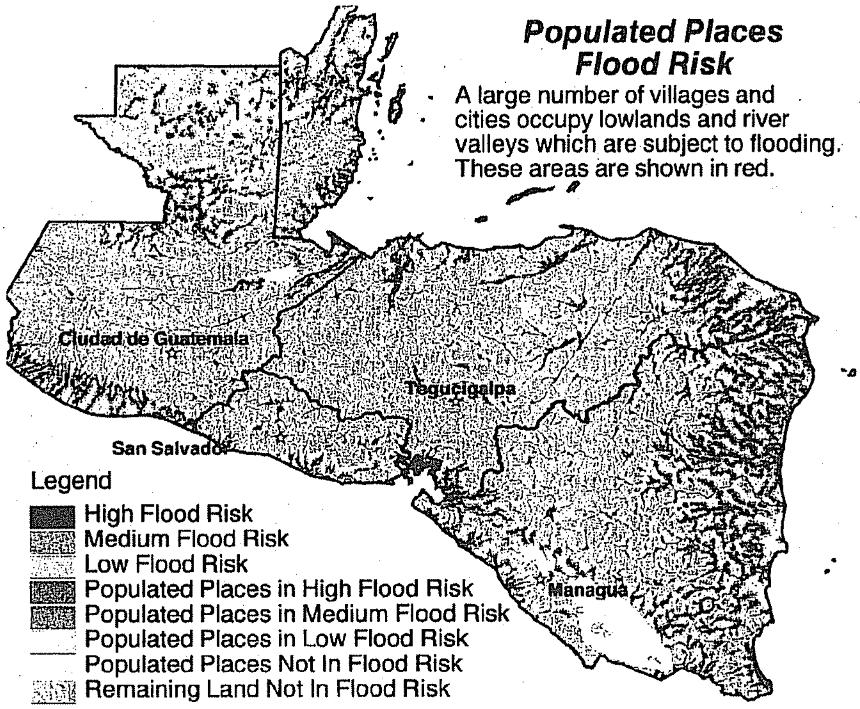

Figure 11: GIS Composite Product Showing Flood Risk in Populated Areas (Digital Atlas, January, 1999)

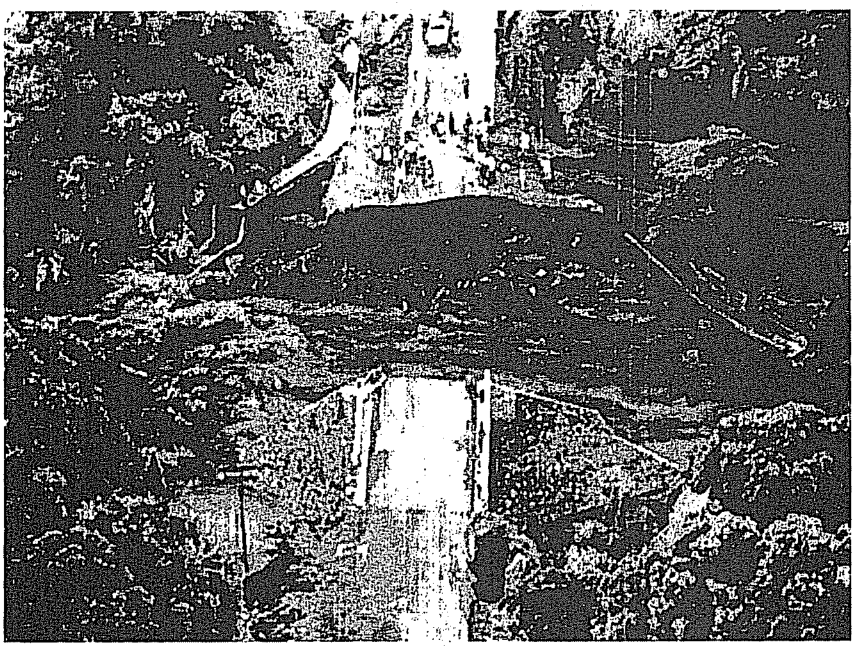

Figure 12: Landslide Damage to Bridge in Honduras

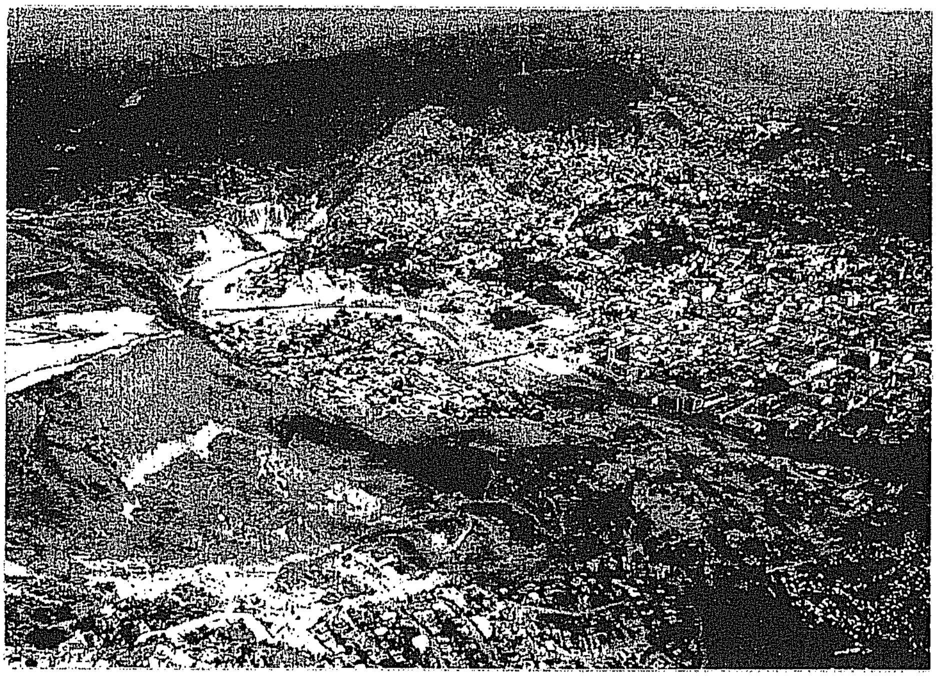

Figure 13: Image of El Berrinche Landslides in Tegucigalpa

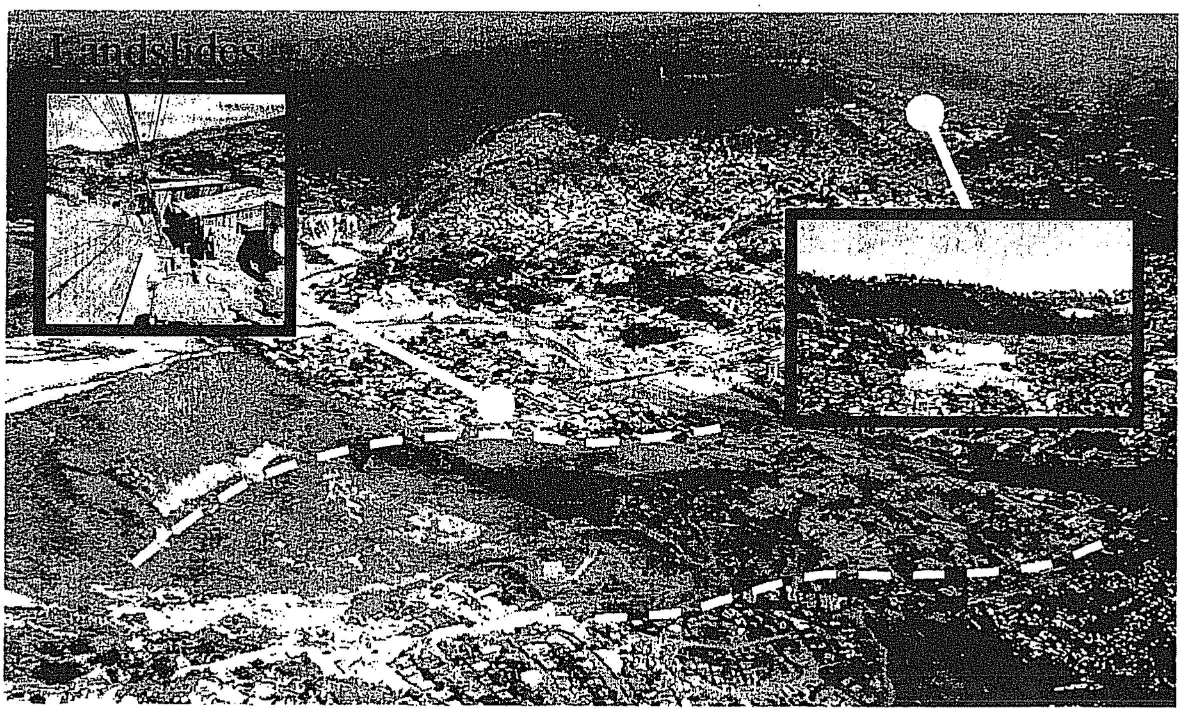

Figure 14: GIS Overlay Showing Location of Landslide Areas