6 PROCESSES OF TOPOGRAPHIC MAPPING (1/5,000)

6-1 Existing Data Collection

The Study Team collected necessary material for the topographic mapping with 1/5,000 such as color aerial photograph, aerial-triangulation results and Digital color ortho-photographs from Managua city government with cooperation of INETER.

6-2 Ground Control Point Survey

In the initial plan, although the control point surveying using GPS was planned. But since it became clear that the Managua city government owned aerial-triangulation results, the GPS survey seemed unnecessary. However, the existing aerial-triangulation results were later found to be inadequate for 1/5,000 topographic mapping, since it was based on the ortho-metric heights using results from the geoid model. Therefore, leveling was decided to be implemented.

6-3 Changes of Mapping Scope

INETER had requested the southern mountainous area of the Managua City which has about 100 km^2 in addition to the originally planned 200 km^2 to be included in the 1/5,000 topographic mapping area. It was pointed out that the area included a dam and reservoir development in the flood control plan of Managua City. In order to satisfy the request, the Study Team presented a proposal to compile the data of 1/50,000 prepared in the first year for the purpose. Finally, the study area for the 1/5,000 mapping area became 300 km^2. The change of the area is shown in Figure 6-1 and Figure 6-2.

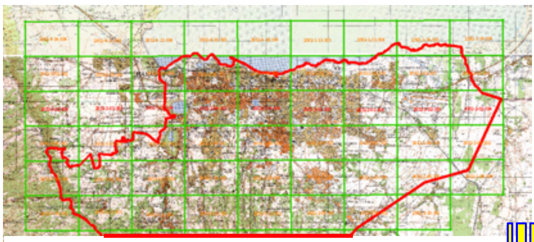

Figure 6-1 Original Planning Area

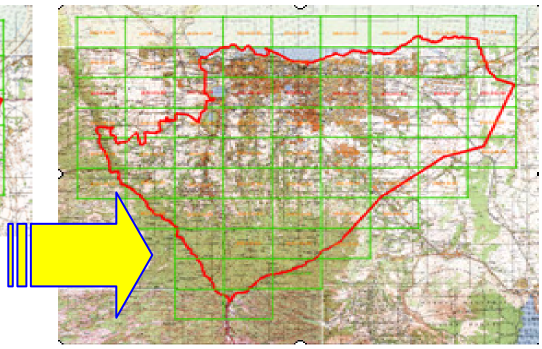

Figure 6-2 Final Mapped Area

6-4 Aerial Triangulation

New aerial triangulation was conducted based on the existing results of aerial triangulation and the results of the control point survey. 623 aerial photographs for the scale of 1/5,000 were used and 610 models were observed. The block adjustment was conducted by the bundle method (PAT-B). The standard of precision was based on the specifications agreed with the INETER side. Table 6-1 shows the control-point Residual of aerial triangulation.

Table 6-1 Control-Point Residual (RMS)

	RMS control points in photo	Max.
X	0.108 m	0.286m
Y	0.117 m	0.255m
Z	0.123 m	0.297m

Note: Specified accuracy is 0.2‰X Flight altitude (800m)

6-5 Field Identification

The field identification for 1/5,000 topographic mapping was carried out in accordance with the discussed map symbols. It was conducted using digital-ortho maps which were provided by the Municipality of Managua. The work was conducted for annotating for public buildings, churches, factories, schools and other small objects and for identifying geographic names.

6-6 Plotting

Based on the "1/5,000 New Map Symbols and Application Rules", detailed plotting was performed, using base data from the results of former and new aerial triangulation, aerial photography interpretation, and field identification. The interval of the intermediate contour is two (2) meters and. supplementary contour lines with an interval of one (1) meter were inserted. The format of final data to be delivered was the DXF format which was the general format commonly accepted by end users such as INETER, the Municipality of Managua, and ENACAL and others.

6-7 Field Completion for Topographic Mapping

The field completion was performed for The secular changes. The annotations were very important information; therefore, spelling, location, types were carefully examined. The secular changes were examined using the aerial photographs taken in 2004 and other reference materials because photographs used for the plotting work was taken by 2000. The work was conducted from May 9, 2005 to June 22, 2005. The ortho-images and plotted draft maps were used during the work.

6-8 Final Data delivery of Topographic map at a scale of 1/5,000

The Study Team delivered the final digital data of Topographic map at a scale of 1/5,000 for being checked by INETER in November, 2005. The Study Team delivered two types of Topographic mapping data. One type of data showed the all outlines of buildings. The other type is generalized for built-up area as polygon data.

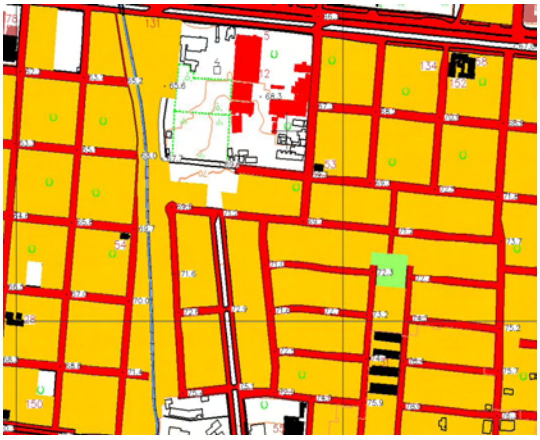

Figure 6-3 Generalized Built-Up Area

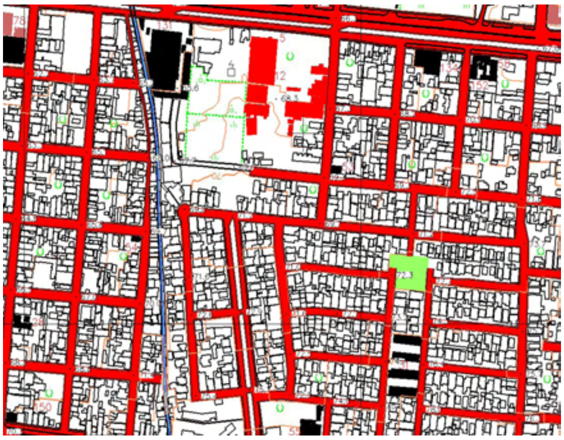

Figure 6-4 No Generalized Built-Up Area

7 GIS DATABASE OF INFRASTRUCTURES FOR DISASTER MITIGATION

GIS Database of Infrastructures for Disaster Mitigation was prepared using ArcGIS Necessary infrastructures data such as City halls, Fire stations Red Cross, Hospitals, Schools, Police stations, Gas stations, Wells, and Bridges were finally included for creation of GIS database.　The existing 1/250,000 scaled Digital Topographic Raster was used as background data. The system displays all the information by clicking at feature symbol. In case of Hospital data, the database shows number of bed and doctor.　Similarly, the attached photo (image) is displayed using Hyperlink button or Information button and then clicking on the desired photo item.

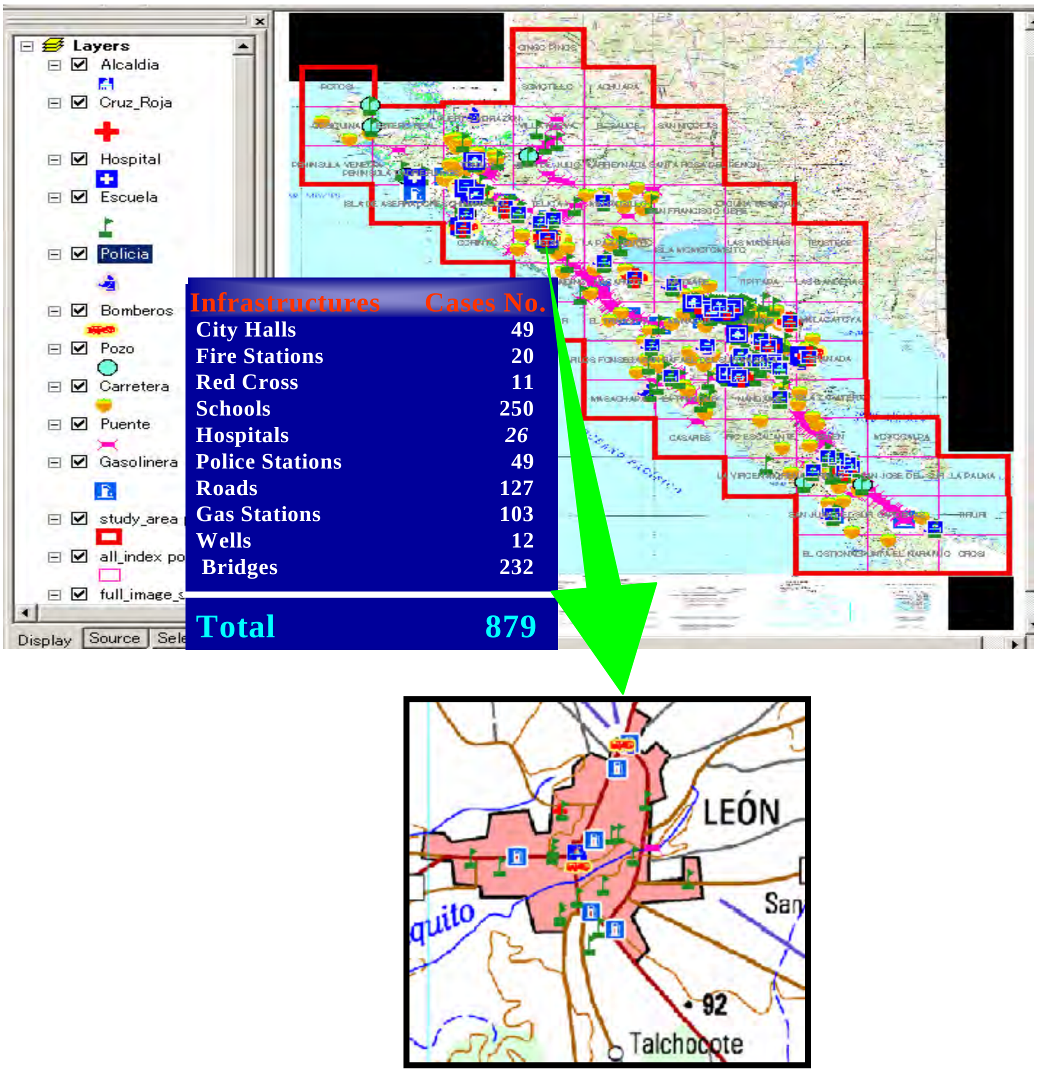

Figure 7-1　GIS Database of Infrastructures for Disaster Mitigation

8 PROCESSES OF THE HAZARD MAPPING

8-1 Earthquake

(1) Basic Policy of Earthquake Hazard Mapping

Earthquake as a natural hazard includes various phenomena such as earthquake ground motion, rupture of surface ground, slope failure / landslide and liquefaction. Hazard potential of these phenomena shall be the subject of the hazard mapping. Among these phenomena, mapping of earthquake ground motions addresses one of the most fundamental aspects of future seismic hazard assessment. Earthquake ground motions are affected by several factors such as source, path and site effects. An assessment of ground motion therefore depends on the following:

a) Regional seismicity;
b) Attenuation of ground motion intensity;
c) Local site effects on ground motion.

Figure 8-1 illustrates the fundamental flow of analysis and key parameters for the ground motion calculation.

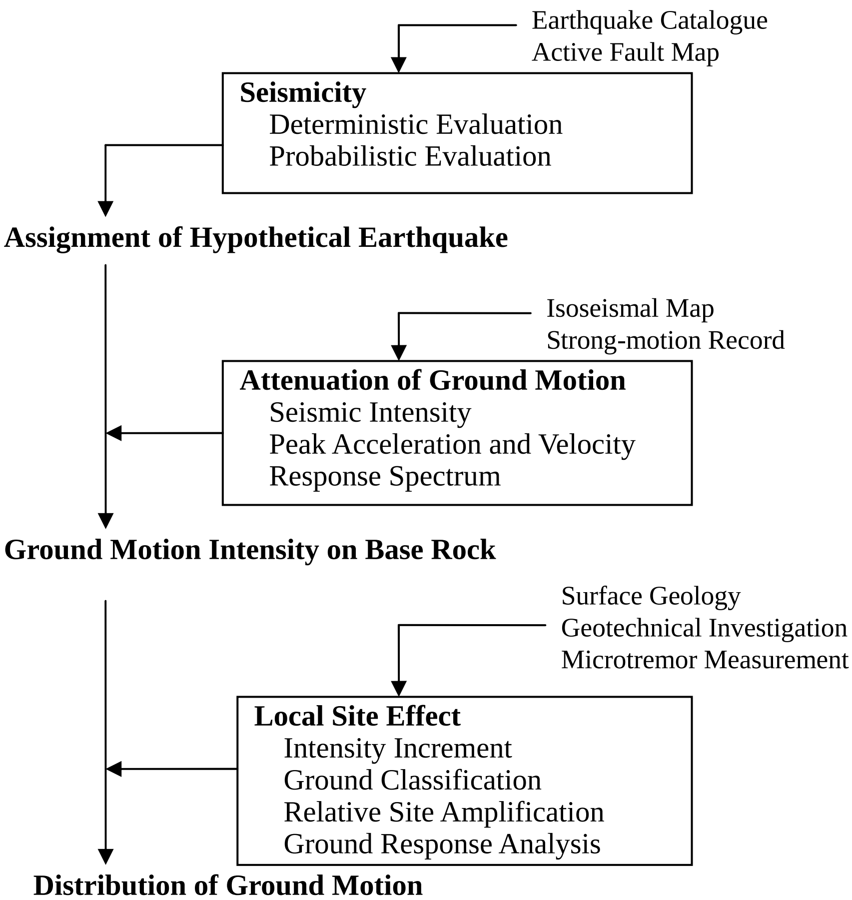

Figure 8-1 Fundamental Flow of Analysis for the Ground Motion Calculation.

Source: TC4 Manual

(2) Study on Regional Seismicity

In order to determine the scenario earthquake, following information / data are collected and studied:

- Earthquake Disaster History
- Tectonic Setting of the Region
- Active Fault in Managua Area
- Earthquake Catalogue

The earthquake catalogue in the region is improved based on the existing following two basic catalogues.

a) Historical earthquake catalogue by INETER (1505 - 1992)
b) Instrumental earthquake catalogue by INETER (1993 - 2001)

(3) Determination of Scenario Earthquake

Based on the studies and discussions with experts of the Counterpart, it was decided that the deterministic approach would be adopted for the simulation of the seismic motion caused by the active faults and volcanoes. Probabilistic base rock motion also adopted for 100 years return period. Following three (3) types of earthquakes are considered, and finally 5 kinds of scenario earthquakes are estimated and determined.

a) Earthquake by Active Fault

Estadio and Tiscapa Fault are already moved recently. Following two faults those exist in the east of Managua city are modeled.

- Aeropuerto Fault
- Cofradia Fault

b) Volcanic Earthquake

The largest earthquakes that occurred around following active volcanoes are modeled. Through the study of newly developed volcanic earthquake catalogue, it is found that the magnitude of volcanic earthquakes larger than 5.5 should be reduced 0.5 to 1.0 after the analysis by Dr. Katayama.

- Apoyeque M=6.0 (1852 year)
- Masaya M=6.0 (1772 year)

Table 8-1 Parameter of Scenario Earthquake

			Active Fault				Volcanic	
Name			Aeropuerto		Cofradia		Apoyeque	Masaya
			Northern Line	Southern Line	Northern Line	Southern Line		
North End	Latitude		12.300	12.156	12.332	12.152	12.242	11.984
	Longitude		-86.175	-86.183	-86.107	-86.111	-86.342	-86.161
	UTM Zone16, WGS84	N	1359877	1343917	1363451	1343494	1353401	1324923
		E	589675	588856	597041	596734	571566	591341
South End	Latitude		12	12	12	12		
	Longitude		-86	-86	-86	-86		
	UTM Zone16, WGS84	N	1343917	1334844	1343494	1333711		
		E	588856	584720	596734	594564		
Length	(km)		16.0	10.0	20.0	10.0	0	0
Total Length	(km)		26.0		30.0		0	0
Width	(km)		8.0	5.0	10.0	5.0	0	0
Dip Angle	(deg.)		90		90		0	0
Depth	(km)		8.0	5.0	10.0	5.0	0	0
Type			oblique-normal		normal		point source	point source
Magnitude	Mw		6.7		6.8		6.0	6.0

c) Probabilistic Base Rock Motion

An analysis to establish a probabilistic scenario earthquake of Managua city is conducted. For this study, the newly improved earthquake catalogue is used and analyzed. Through the B-value analysis and hazard curve analysis, the maximum acceleration of 100-year-return period is obtained as 110 gals with the standard deviation of 28 gals.

(4) Selection of Attenuation Formula

Some empirical attenuation laws for maximum ground motions are tested whether they can properly explain the past historical disaster and recorded ground motion intensities at Managua city. In selection of attenuation laws, laws which were used in the past for the seismic hazard of Managua, and laws which are the most current and considered as conceivably appropriate in light of characteristics of earthquake source region in and around Nicaragua including Managua city were selected. Then, it is concluded that combined Joyner-Boore and Young law is considered as appropriately applicable to the recorded accelerations of both non-volcanic and volcanic events.

(5) Ground Model for Subsurface Amplification

In order to construct the ground model for the subsurface amplification, following data and information are collected and studied:

- Topography of Study Area
- Geology of Managua Region
- Compilation of Existing Geological Data

Geological data is compiled based on existing 170 boreholes data. Four geological profiles are prepared in East-West direction and three profiles in South-North direction based on the existing surface geological map with the existing borehole data.

In this study, the ground type is classified by Average Shear-wave Velocity over the upper 30 m (AVS30). AVS30 is authorized on “Recommended Provisions for Seismic Regulations for New Buildings and Other Structures,” (1997 edition, FEMA-302, 303; BSSC, 1997) by NEHRP (National Earthquake Hazards Reduction Program) in U.S.A.

Ground type is classified five types as Lower plane, Middle plane, Hill area, Mountain area and Crater area by Satellite image as shown in Figure 8-2.

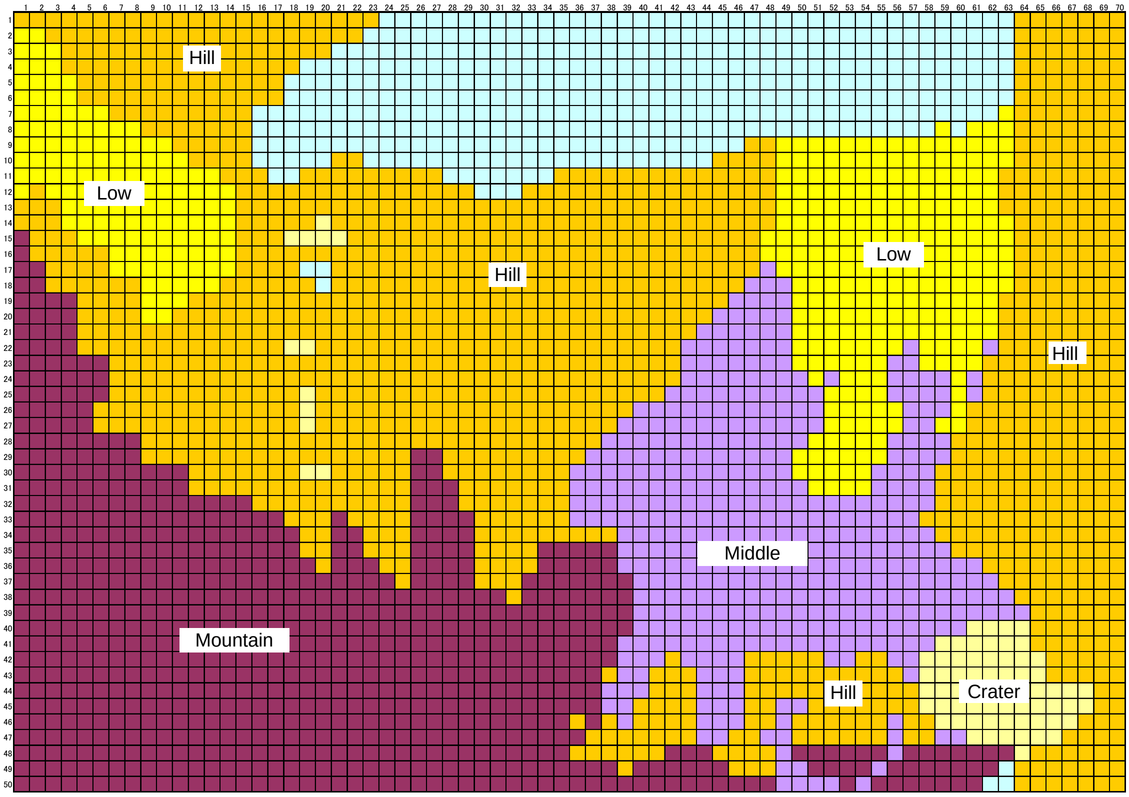

Figure 8-2   Ground Model of the Study Area

(6)   Preparation of Earthquake Hazard Map

The end user of the earthquake hazard map shall be scientists, researchers and engineers who are involved in the building design, construction, city planning and disaster management.

The earthquake hazard map will be distributed to the assumed end users.   However, the map will not be used for the actual determination of the seismic code, city planning nor disaster management plan.   In order to conduct these actual works, more detailed information, such as location of the objective building, location of disaster prevention resources, land use map and existing city planning map are necessary.   Therefore, the role of the map is to inform the end users that the PGA distribution map is available in GIS database in INETER and these users can utilize the database for their objectives. We determine the size of the map to be 17x22 inches.

The contents of map are determined as followings through the discussion with counterpart:

- Distribution of peak ground acceleration (PGA)

- Earthquake source parameters

- Adopted attenuation formula

- Meaning of PGA in terms of seismic intensity.

(7) Example of Earthquake Hazard Map

Figure 8-3 shows an example of earthquake hazard map which is in case of Aeropuerto Fault.

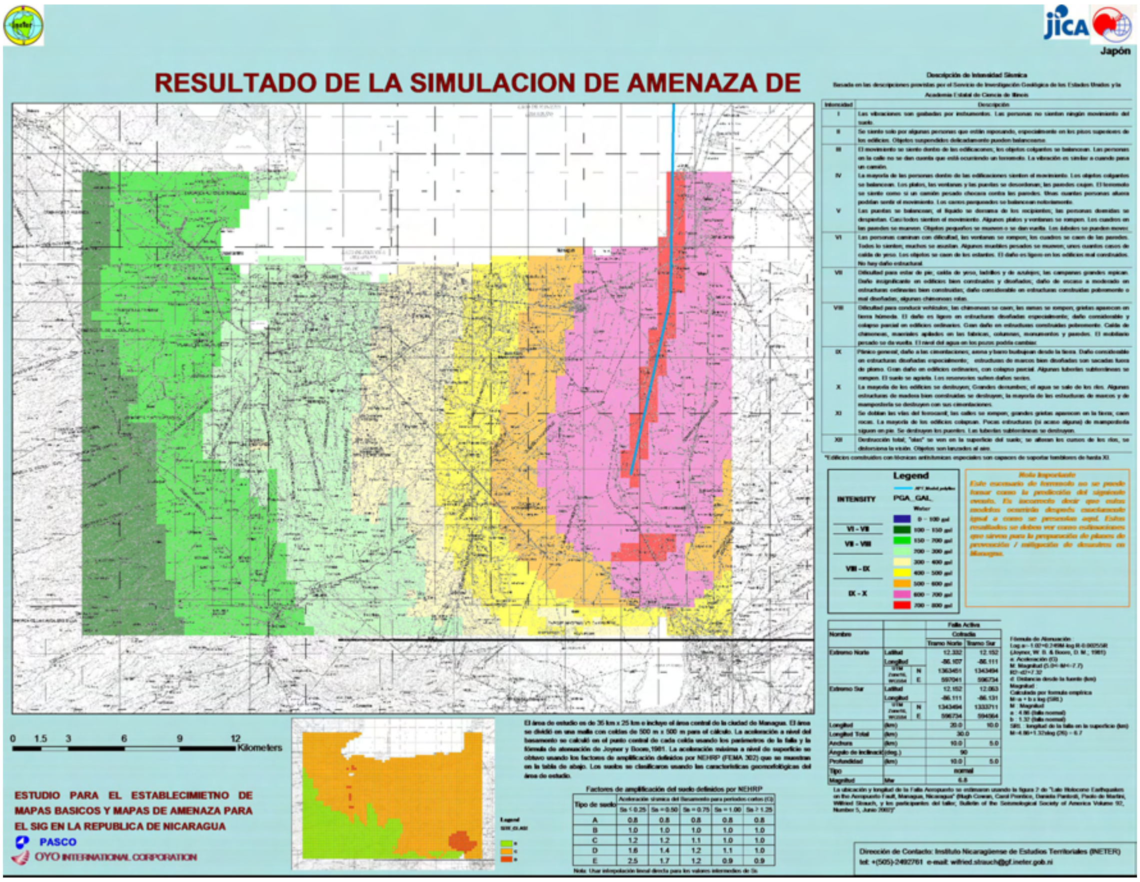

Figure 8-3 Example of Earthquake Hazard Map (Cofradia Fault)

In addition to the map shown in Figure 8-3, four other scenarios are mapped and printed 500 copies each, thus 2,500 sheets in total.

8-2 Volcano

8-2-1 Target Area

The target area for the volcanic hazard study is an area of 1,300m^2 of the Telica-El Hoyo volcanic complex.

8-2-2 Target Phenomena

The target phenomena of volcanic hazard are: 1) lava flow; 2) pyroclastic flow; 3) bomb (ejecta); 4) tephra fall (ash fall); and 5) lahar.

8-2-3 Collection and Analyses of Existing Sources on Volcanic Geology

(1) Outline

Fundamental reference materials that can be useful for volcanic hazard map preparation are listed as follows:

1) Martha Navarro(2002) Fichas de los Volcanes de Nicaragua, INETER
2) Martha Navarro(1994) Peligro Volcanico "Volcán Telica", INETER
3) Gardner, C. A., et al.(2004) Hazard Assessment for Volcán Telica, Nicaragua., USGS, Open File Report 2004-1046
4) Havlicek, P., et al.(2000) Estudio geológico y reconocimiento del la amenaza Geológica en el area de Leon, La Paz Centro y Malpaisillo, Nicaragua, Servicio Geológico Checo(CGU) en cooperacion con INETER
5) Brittain, E. H. et al.(1998) 1995 eruptions of Cerro Negro volcano, Nicaragua, and risk assessment for future eruptions., Geol. Sc. Am. Bull, v.110, no.10, p.1231-1241

(2) Analysis of Reference Materials

Analyses of the reference materials revealed the following facts.

a. The stratigraphy of the stratum which constitutes a volcano object has not been established.
b. There is no data on dates. Therefore, there is no time-series data.
c. Availability of volcanic-activity data are limited in general in 1850 and afterwards.
d. There are almost no written data on each volcanic phenomenon (lithofacies, stratum).
e. There are no fundamental written data on each stratum.
f. Although there are hazard maps already available for certain volcano, INETER is not capable of processing all the procedure of preparation.

(3) Analysis of Basic Reference on Hazard Mapping

In order to obtain basic reference for hazard mapping, following references were analyzed.

1) Tephra fall (volcanic ash)
2) Upper layer meteorological data

8-2-4 Volcanic Aerial Photograph Interpretation

The Study Team conducted geomorphologic interpretation in the volcanic areas using color aerial photographs at a scale of about 1/20,000 taken by the Study Team.

8-2-5 Field Identification on Volcanic Geomorphology/Geology

The Study Team conducted field identification for hazard mapping based on the aerial photograph interpretation and organization/analysis of existing reference materials. Figure 8-4 shows the geological map prepared for the study area.

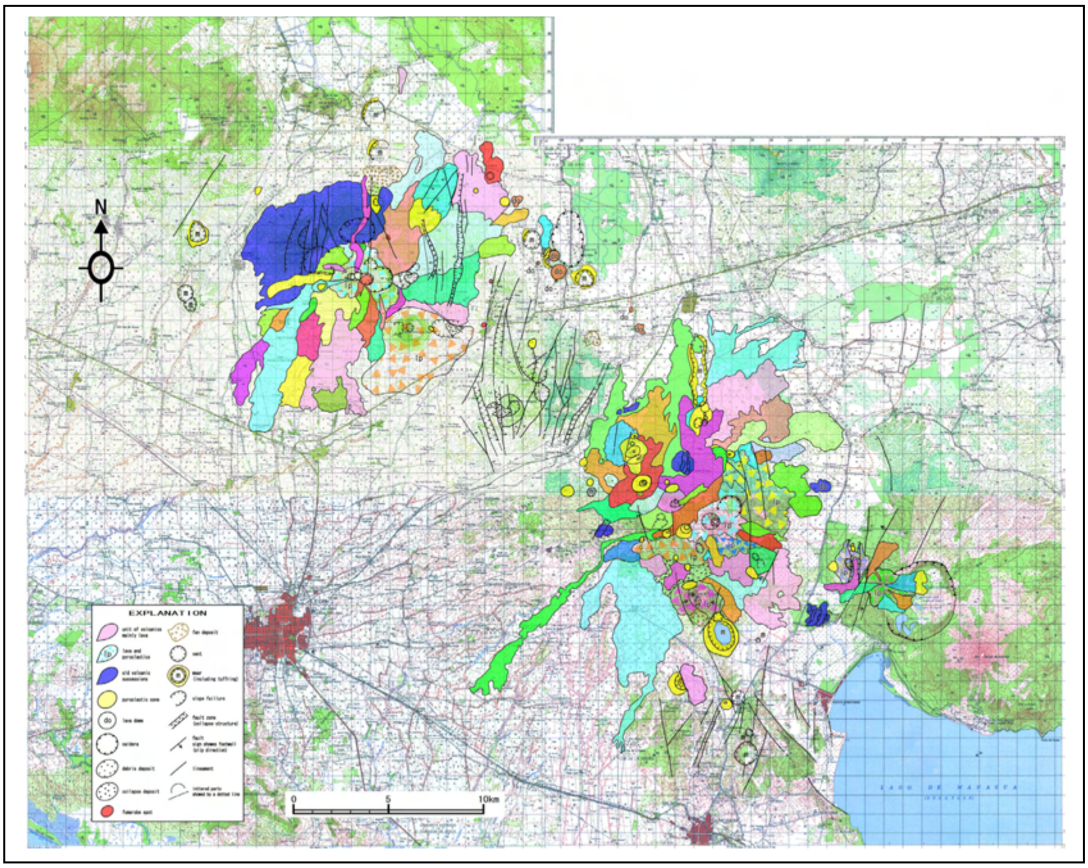

Figure 8-4 Geological map of Telica – El Hoyo volcanic complex area

8-2-6 Volcanic Hazard Simulation

(1) Theoretical Foundation for Numerical Analysis and Model Development

Simulation models on volcanic phenomena were created based on theoretical papers that were the foundations.

(2) Development of Simulation Models

Application for volcanic hazards were redeveloped based on the open source codes for simulation programs. The simulation program is developed in a way to transfer the results to the GIS software.

(3) System Requirement

The required system for executing the simulation are as follows: a). Visual Fortran; b) Visual C^{++}.Net; and c) ArcView.

(4) Implementation of Simulation

An example of the result of the simulation is shown in Figure 8-5.

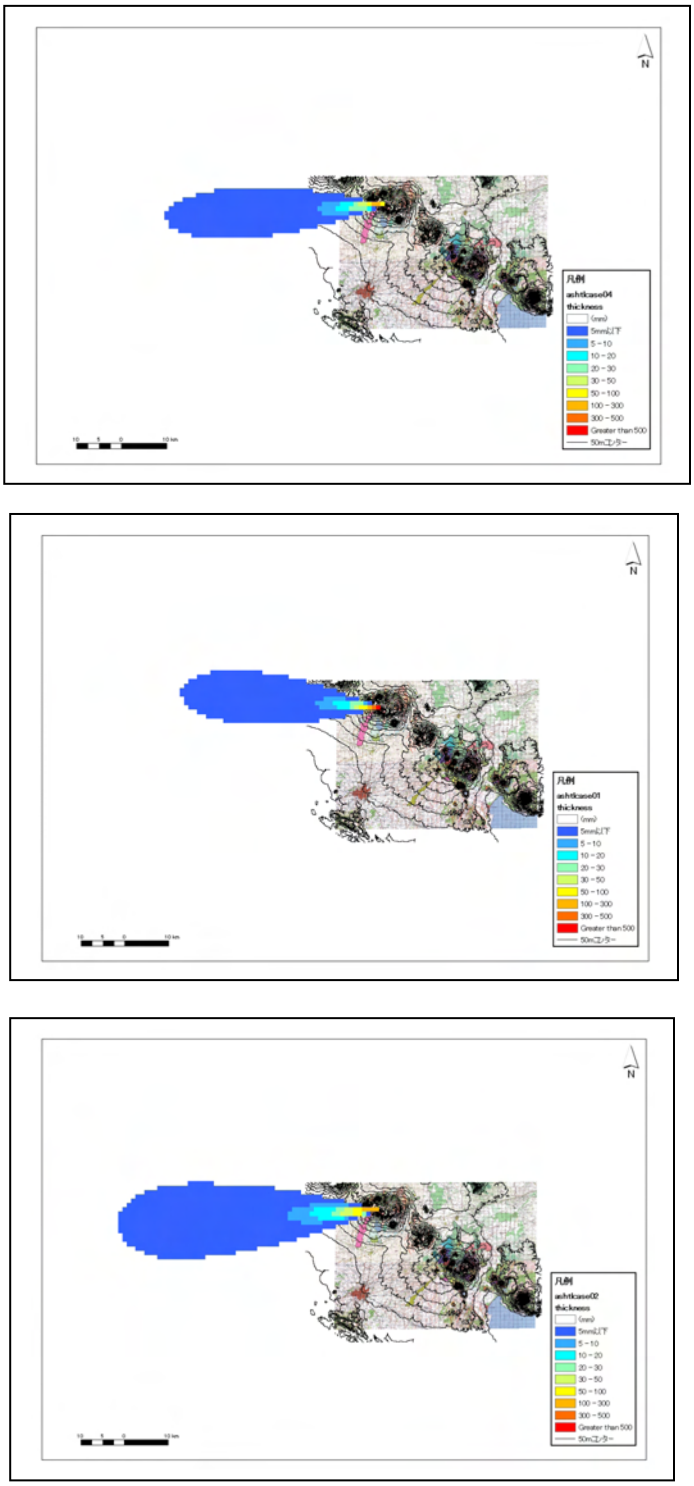

Figure 8-5　Example of Simulation on Tephra fall from the Summit of the Volcán Telica

（Top: The same condition as in Cerro Negro 1995.　Middle: The eruption column is twice as high as in the case of the Cerro Negro 1995 eruption; other conditions are the same.　Bottom:　The amount of pyroclastic objects are twice as large as the case in the Cerro Negro 1995 eruption; other conditions are the same.)