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Building Geographic Information System (GIS) from the Ground Up:
Experience in Disaster Planning in Caracas

The author based this paper on his presentation at the BCRP program in the Spring quarter 2004. He shows us the importance of incorporating Geographical Information Systems in planning for natural disasters through a project in Caracas, Venezuela, a city constantly exposed to the risk of earthquakes, floods and mudslides.

THE EXISTING CONDITIONS IN CARACAS AND THE PROJECT

Caracas is the capital city of Venezuela with the population of 3.1 million and area of 303 sq. miles. It experienced several large scale earthquakes since its modern history began in 16th century. There are two large earthquake that hit Caracas: in 1812 an earthquake with magnitude 6.3 killed around 10,000 of the population, while the most recent earthquake occurred in 1967, where about 1,800 buildings were damaged and 274 people died. Caracas also has a history of frequent sediment disasters. In December 1999, Caracas was hit by a heavy rainfall caused by cold weather front from Caribbean Sea and debris flow was generated in the mountain streams which caused death of around 100 people. Similar debris flow had occurred in February of 1951.

Despite the frequent and devastating natural disasters there is lack of resources and planning for natural disasters both among population as well as response agencies. As a significant part of the Caracas low income population live in high density conditions, and many people live in the same household, in case of natural disaster this could lead a large number of casualties even when only a few buildings collapse.

Figure 1: Caracas, a city with a population of 3.1 Million (2001)

In this presentation I will describe how a Geographic Information System (GIS) was designed and put in place as part of the mitigation and disaster preparedness plan effort for the metropolitan district of Caracas. The purpose of the GIS system was to develop risk vulnerability maps for present conditions and to permit new information to be added on to update them (see figure 2).

Table 1
Comparative Population and Housing Units in Los Angeles, Caracas and Bogota

Geographic area	Population	Housing Units (HU)	Total Area Sq. miles	Pop Density	HU Density
Bogota, Colombia	6,437,842	955,991	488	13192	1959
Los Angeles City	3,694,820	1,337,706	498	7877	2852
Caracas, Venezuela	3,162,759	684,643	303	9118	2260

Source: US Census Bureau ; National Census, Colombia ; National Census, Venezuela

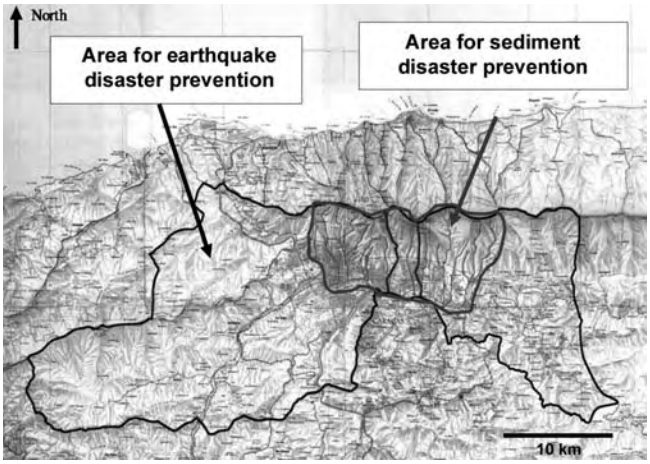

Figure 2. Project areas

GIS APPLICATION IN THE PROJECTS

The GIS implementation in the project was challenging tasks as there were following implementation issues were at stake.

- Too little compatible data set
- Few resources (Economic/ Human)
- High expectations
- Immediate result seeking
- Poor system maintenance
- Poor system continuity

On May 7 2003, the project started with two months' deadline for data collection and their incorporation in GIS. The following opportunity and risk were present at that time.

OPPORTUNITY

- Risk Map Project was done recently by the National Cartography Institute
- This project was a grant project from Japan
- Recent Disaster event in Dec. 1999 has led awareness

CHALLENGES

1. Too little GIS development in Govt. Sector
2. Private sector (utilities companies) were not ready to share data with any outside agencies
3. Fragile political situation led to little or no coordination among national and local governments
4. No universal GIS standards and process were in place
5. The available data were in many different formats
6. There were huge requirements of data for a disaster management project
7. Data paradox: Too little data and sometimes too many data but little information

Looking at this scenario, the study team first elaborated GIS and database standards to be applied for the projects. These standards included system platform to data input as well as output formats. These standards were discussed with counterpart Venezuelan agencies.

The data collection phase was geared up to have the following data base and GIS subcomponents.

DATABASE COMPONENTS

- Building Inventory
- Population Distribution
- Social Vulnerability
- Damage Estimation
- Public Facilities
- Open Spaces
- Road Networks
- Bridges

GIS COMPONENTS

- Base Map (1:25000) -26 layers/15 sheets
- Working Base Map (1:5000, 1:1000) -26 layers/ 45 Sheets
- Scanned Basemap (1:5000, 1984) – 45 Sheets
- Aerial Photos(17) / Satellite Images (6)
- Boreholes
- Lifelines (Water Supply/Telephone)
- Road Networks
- Evacuation Places
- Open Spaces
- Public Facilities (8)
- Landuse
- Microzone
- Administrative Boundaries (6)
- Important Faciliies
- Hazard Map (9+2 Sediments, 2 Earthquake)
- Risk Map (9 +1 Sediments, 2 Earthquake)

Different GIS analysis was performed and more than 200 map layers were produced. Some of them are outlined below.

EARTHQUAKE DISASTER SIMULATION

Damage scenarios for four hypothetical earthquakes were simulated and shake maps were produced. Also, risk maps such as building damage, human injury and death, damage to utilities networks and damage to infrastructure were simulated.

SEDIMENT DISASTERS SIMULATION

For the sediment disaster, three components were analyzed: landslides, potential risky slopes, and flood and debris flow. Landslides and potential risky slopes were mapped using aerial photos and field visits, and they were analyzed with existing building and population distribution to determine the risk. Past hydrological data were carefully analyzed and two dimensional water and debris flow were calculated using the simulation software Flo-2D. Calculation results were expressed in flood velocity and depth. Large part of existing urban are were found to be vulnerable to flooding. Flood risk map was created by overlaying existing building distribution and flood damage due to flood velocity and flood depth.

SOCIAL VULNERABILITY STUDY

The aim of the social vulnerability study was to find the vulnerability and resilience of the population for natural disasters. This study was conducted for 15 homogenous sub-areas in the study area where 4,800 houses were surveyed

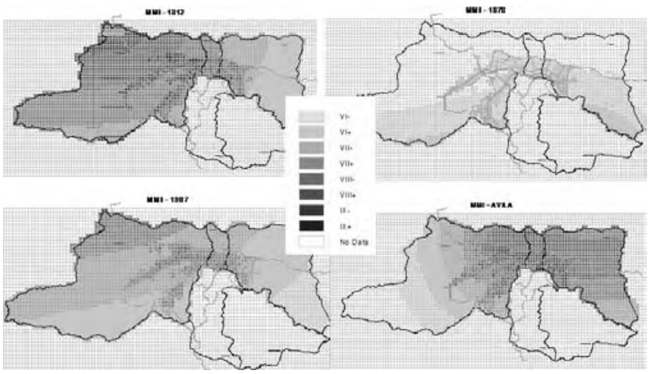

Figure 3. Earthquake intensity in Modified Mercali Intensity (MMI) scale for four earthquake scenarios

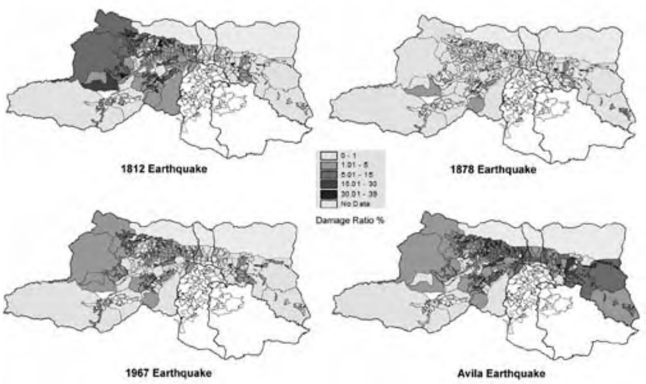

Figure 4. Heavily damaged building ratio in four earthquake scenarios

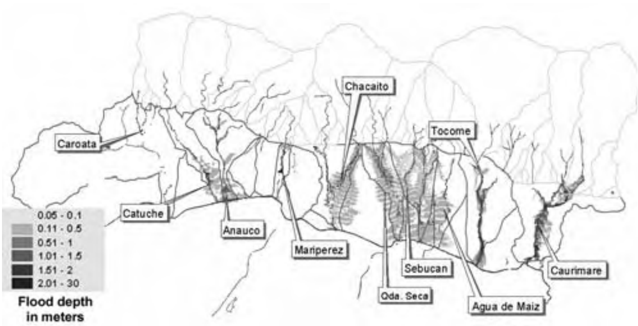

Figure 5. Flood depth in the urban area

Figure 6. The high density unplanned development of a Caracas Barrio (Photo by W. Siembieda)

and 38 different questions were asked regarding social vulnerability.

These survey results were sub classified among five different categories: Knowledge, Demography, Economy, Facility and Community Organization. GIS maps were produced for each of these indices as well as combined social vulnerability index and overlaid with earthquake hazard maps. The combined result was expressed as integral vulnerability index.

Also simulation was done for the building damage with or without master plan implementation as well as evaluation of resources (like open space/ evacuation routes).

FINAL GIS IMPLEMENTATION

All of these input maps as well as results were grouped in a single ArcView project and a custom user interface was developed (using Avenue programming) for easier viewing and printing of these maps. ArcView 3.2 was chosen as it was the software used by almost all of the government agencies at that time. A training course was performed for the GIS users in Caracas. A detail Metadata was created in FGDC format and web-based HTML maps were also produced for the users who otherwise do not have access to ArcView system.

These GIS data were placed in a central server and the participating institutions were connected to it through VPN. Data can be shared in this secure private network. A blueprint for Disaster Management Information System (DMIS) in Caracas was elaborated based on the information gathered on this project and with the anticipation of the future participation by different institutions.

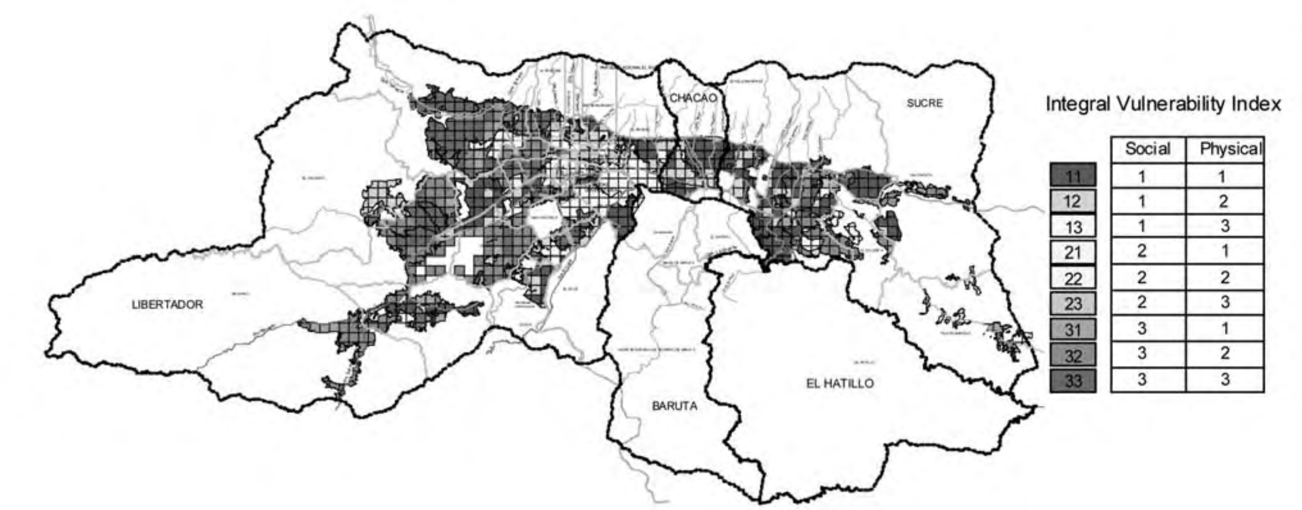

Figure 7. Integral Vulnerability (Social and Physical Vulnerability)