THE RADIUS FULL STUDY CASE IN GUAYAQUIL CITY

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Abstract:

RADIUS (**R**isk **A**ssessment tools for **Di**agnosis of **U**rban areas against **S**eismic disasters) was a project of the United Nations **IDNDR/ISDR** Secretariat sponsored by the Government of Japan, carried out during 1998 – 1999 in 9 cities around the world and conducted in Guayaquil by its City Government with the technical support of IIFIUC/Universidad Católica and the supervision of Geohazards International.

The key aspects of the Guayaquil full study case are presented in this paper. The study case included the preparation of a seismic scenario of damage and an Action Plan for managing the risk. The scenario was based on an hypothetical earthquake of intensity VIII MM. In the preparation of the Action Plan more than 50 institutions where involved and its execution is on charge of the recently created Municipal Office for Disaster Preparedness.

The world wide project information can be found at: http://www.geohaz.org/radius, http://www.unisdr.org. and http://www.ucsg.edu.ec/centros/iifiuc/iifiuc.htm.

INTRODUCTION

Outline of Guayaquil

Guayaquil is located on the west margin of the Guayas River, on both soft alluvial soils and sedimentary volcanic rock deposits. Guayaquil has grown to the south by filling with gravel obtained from rock deposits the ocean estuaries, originally crowded of mangle trees. It is placed at the end of the Guayas River basin, bounded in the east by the Andes mountains, and in the west by the Chongón-Colonche mountains. This mountains end at Guayaquil city reaching 800 meters in altitude.

The weather is warm and humid with two seasons well defined: the rainy season from January to May and the dry season from June to December. The average temperature is 21° C with extremes of 18° C to 36° C. The relative humidity is 50 % and, in the months between January and May, it reaches 97 %. The dominant winds have a south-west direction. The mean annual precipitation is near 1,000 mm, and the extremely high values related to El Niño are greater than 4,000 mm.

The urban area of Guayaquil city is 33,825 ha. the entire region (which includes rural areas) is 500,706 ha. The population for the whole metropolitan area is 2,129,000 in habitants. The recent annual growth rate of population is 3.54 %. Guayaquil is the major industrial and commercial city of Ecuador, concentrating more than 40% of the 100 major commercial companies and industries of the country. The GNP of the city was US$ 2,782 million in 1995, almost 20% of the gross national product of the country. The city also has the main port of Ecuador where 60% of import and export merchandise is in transit.

Guayaquil Downtown.- This is the area of the highest seismic risk as a result of four factors: 1) High construction density; 2) High vulnerability due to great amount of old buildings and infrastructure built without seismic design provisions. 3) Great value of buildings, infrastructure and equipment used in commercial and financial activities; and 4) High population density during commercial hours.

The objectives of Radius

a) To evaluate the seismic risk and to develop an hypothetical earthquake scenario of damage,
b) To prepare an Action Plan based upon the results of the seismic risk evaluation and community representatives participation,
c) To increase public awareness in citizens and governmental authorities about seismic risk,
d) To initiate an institutionalization process to support mitigation efforts and the seismic risk management.

EARTHQUAKE SCENARIO OF DAMAGE

Seismic hazard evaluation

An evaluation of the Seismic Hazard of Guayaquil was conducted. The following items were covered extensively:

a) Gathering of relevant information: historical records and chronicles, seismic catalogues and strong motion records of soil (accelerograms);
b) Description, zoning and interpretation of historical damage caused in Guayaquil by the seven most significant earthquakes to strike the city;
c) Estimation of the seismic hazard using probabilistic models, corresponding to the three seismogenetic sources of Ecuador with a capacity to produce earthquakes with Mercalli Intensity greater or equal to VII in Guayaquil;
d) The selection of the adopted EQ for the "Seismic Scenario of RADIUS", equal to an EQ of magnitude Ms = 8.0 next to the northern coast of Ecuador;
e) The "distribution of expected intensities in Guayaquil" during the adopted earthquake, on the three type of soils, as shown in figure 1;
f) The study of the associated risks and the identification of the "susceptible zones to landslides as a collateral effect of the earthquake", as shown in figure 1.

Preparation of GIS and Database

With the contribution of the information given by many city institutions to the Municipal Government, and with the results generated by the Project, RADIUS has compiled a "Database" quite complete and up to date for the buildings and infrastructure of the city for the diagnosis of the Seismic Risk. The majority of the information is run in a Geographic Information System (GIS), which is a very important tool for the management of the seismic risk of the city.

The building stock of the city is composed of near 350,000 of buildings divided into 12 construction types that where defined for the estimation of the seismic risk. Figure 2 shows how GIS allows the displaying of the amount and geographical distribution of one type of building stock according to the city sectors.

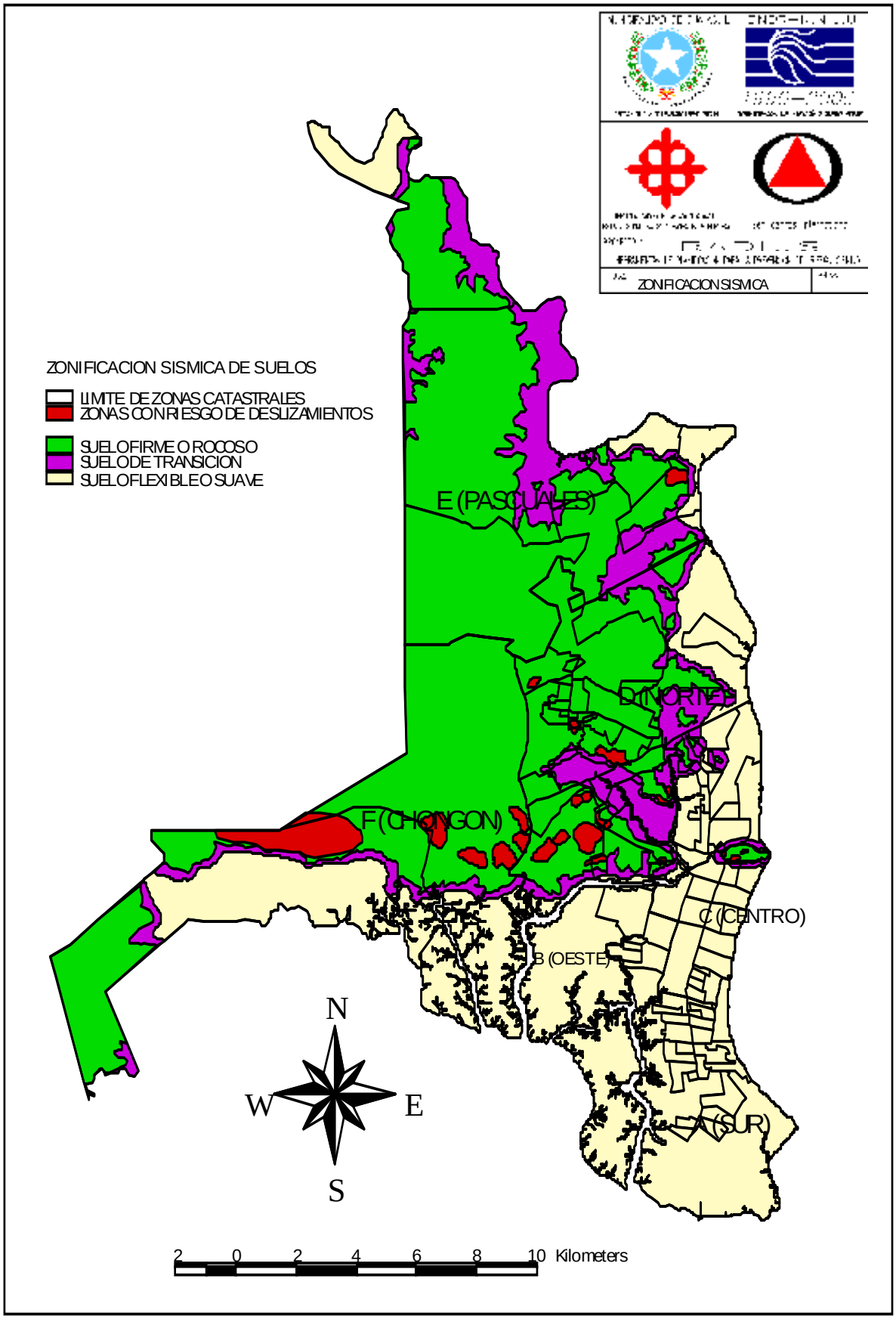

Figure1. Distribution of expected intensities for the adopted earthquake and susceptible zones to landslides in Guayaquil as a collateral effect.

The inventory of the city's lifeline infrastructure includes all important facilities (seaport, airport, bridges, electricity substations, pumping stations of sewage water, potable water plant and reservoirs, etc.) and main networks. There is also an inventory of essential facilities such as hospitals, schools, churches, emergency centres (fire stations, police stations, etc.) and government buildings.

Interviews to important organisations

Twenty (20) operators of important institutions of the city were interviewed for the preparation of the "Seismic Scenario". These institutions are related to the management of an emergency during an earthquake. The accomplished goals were the followings:

a) To identify specific characteristics of the system and its performance,
b) To gather data to be used for the "Scenario of Seismic Damage",
c) To study the potential of mitigation, response and recovery capacity after an earthquake,
d) To establish the feasibility of starting actions of risk mitigation,
e) To inform about the project
f) To educate and awake interest about Seismic Risk

The gathered information was useful to produce a diagnosis about the capacity of response and recovery of the city in case of an earthquake. An example is shown in table 1.

Table 2. Diagnosis of lifeline systems

ITEMS	WATER	SEWAGE	ELECTRICITY	TELEPHONES
1. CRITICAL VULNERABLE ITEMS	* New Plant * Santa Ana Tanks *Acqueduct 42" *Primary Network in soil transition *Distribution Network Downtown	* Pump Stations *Primary Network Parsons *Cross with bridges *Secondary network downtown	*Links to inter-connected system *Substaciones *Primary Network in soil transition *Networks downtown *Light posts	*Tower Cerro del Carmen *Downtown Station *Primary Network *Cable from Downtown to Tower Cerro Carmen *Cable Downtown to a Satellite Station
2. DEPENDENT OF	*EMELGUR *Daule Highway	*EMELEC *PETROCOMERCIAL	*INECEL *PETROCOMERCIAL	*Private Sector *ECAPAG
3. SYSTEM REDUNDANCE	*Good	*Bad	*Good	*Bad
4. RESPONSE TO EARTHQUAKES	*Variable *Hours-days-weeks	*Slow *Days-weeks	*Very Fast *Hours	*Fast *Hours-days
5. RECOVERY CAPACITY	*Slow *Days-weeks	*Very Slow *Weeks-months	*Fast *Hours-days	*Variable *Days-weeks-months
6. EMERGENCY CAPACITY	*None	*None	*Some	*None
7. EARTHQUAKE PLANNING	*None	*None	*None	*None

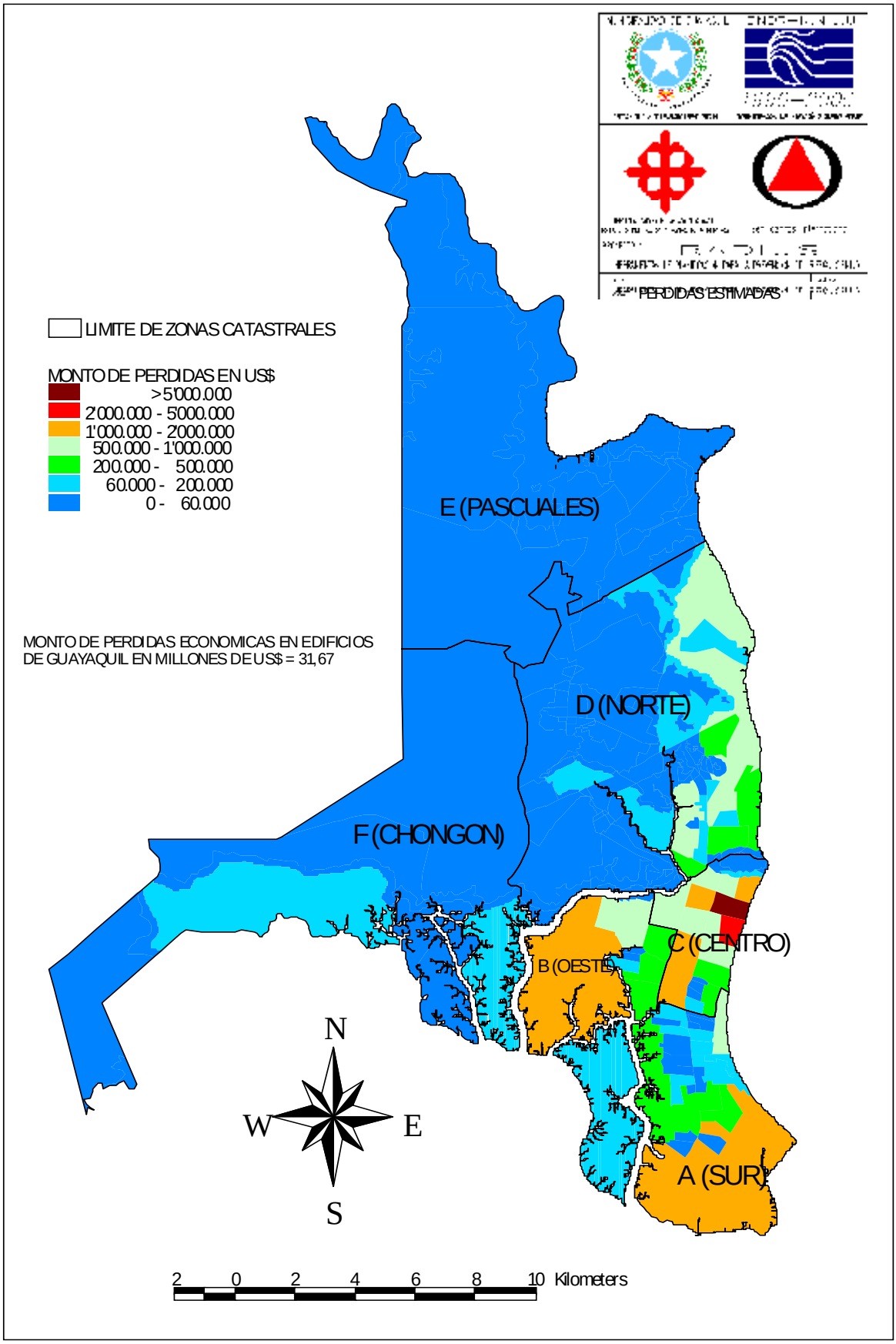

Figure 2. Geographical distribution of losses in buildings in Guayaquil due to the adopted earthquake.

Estimate of losses in buildings

The direct economic losses were obtained by combining the distribution of intensities, vulnerability functions based on inspection to buildings and historical data and the building stock and its estimated. Considering current market values, the amount of direct losses would be nearly US$ 200 million. Geographical distribution of losses are shown in figure 2.

The Seismic Risk

"The results of the damage estimation indicate that there is a 53% probability that, in the next 50 years, economic losses in excess of US$ 1,000 millions will occur in Guayaquil, as a result of an earthquake of magnitude Ms 8 or greater, with its epicentre in the coastal zone of Ecuador".

Estimate of damage to lifelines

Damage to lifeline were obtained by combining the distribution of intensities and the ATC-13 vulnerability functions. From the estimated damage the recovery of essential services of the city will be affected by different situations that are foreseeable; the most important ones are:

1. Up to 75% of hospitals could be non-operational after the earthquake due to the vulnerability of their facilities. There is an important deficit of public hospitals and welfare hospitals with emergency services (4), ambulances and beds for hospitalisation;

2. The provision of temporary or permanent shelter for those affected (up to 20.000) would be very slow, because of the lack of an executive organisation. The schools will be used as shelters for more time than normally recommended (one week), but, it must also be considered that up to 10% of the school infrastructure might be severely affected;

3. There might be a partial and significant suspension of basic services during the first week following the earthquake as shown in table 2.

Table 2. Recovery of life lines after an earthquake

LIFE LINES	**TIME OF RECOVERY TO THE ORIGINAL CAPACITY OF**		
	30%	60%	100%
ELECTRICITY	2 – 3 days	1 week	2 – 3 weeks
WATER	1 week	1 month	3 months
TELÉPHONE	2 – 3 days	1 week	1 – 2 months
SEWAGE SYSTEM	2 weeks	2 – 3 months	6 months – 1 year
ROADS	1 week	2-3 weeks	1 – 2 months

Estimation of casualties

Using factors that depend upon the damage percentage of building types and considering the population density, 22,461 deaths and 90,114 people injured were estimated. Results are shown in figure 3.

Micro-zoning the risk

Base upon a geographical combination of damage estimations in buildings and lifelines with the estimation of causalities the seismic risk was micro-zoned. Results are shown in figure 4.

THE ACTION PLAN

Two workshops were conducted for reviewing the Scenario of Damage (January 1999) and preparing The Action Plan to mitigate and manage the seismic risk (July 1999). More than 50 institutions were actively involved in the workshops as well as in focal meetings organised to accomplish the various project goals.

Local institutions representatives gave valuable opinions for the better estimation of the impact of an earthquake and the definition of actions to be taken to reduce risks. More than 40 projects were recommended according to the following lines of action:

a) Evaluation and strengthening of buildings and dangerous infrastructure;
b) Training of personnel from basic organisations of citizen's protection;
c) Forming groups specialised in rescue actions, paramedics and emergencies;
d) Creation of a technical unit for disaster preparedness and management in the municipal government;
e) Preparedness of the community through campaigns of prevention and mitigation;
f) Planning of the fast response and recovery of services and lifelines;
g) Preparation of emergency plans;
h) Control of usage, acquisition, rehabilitation, modernisation and maintenance of equipment, services and various systems;
i) Study and monitoring of geological and seismic risks;
j) Evaluation of urban areas, control on the use of soils, issuance of a construction code.

REFERENCE

Argudo J., et al (1999). "The Radius Project in Guayaquil", 10 volumes in 1150 pages and a CD-ROM, The Institute of Research and Development (IIFIUC) of Universidad Católica de Guayaquil – Ecuador.

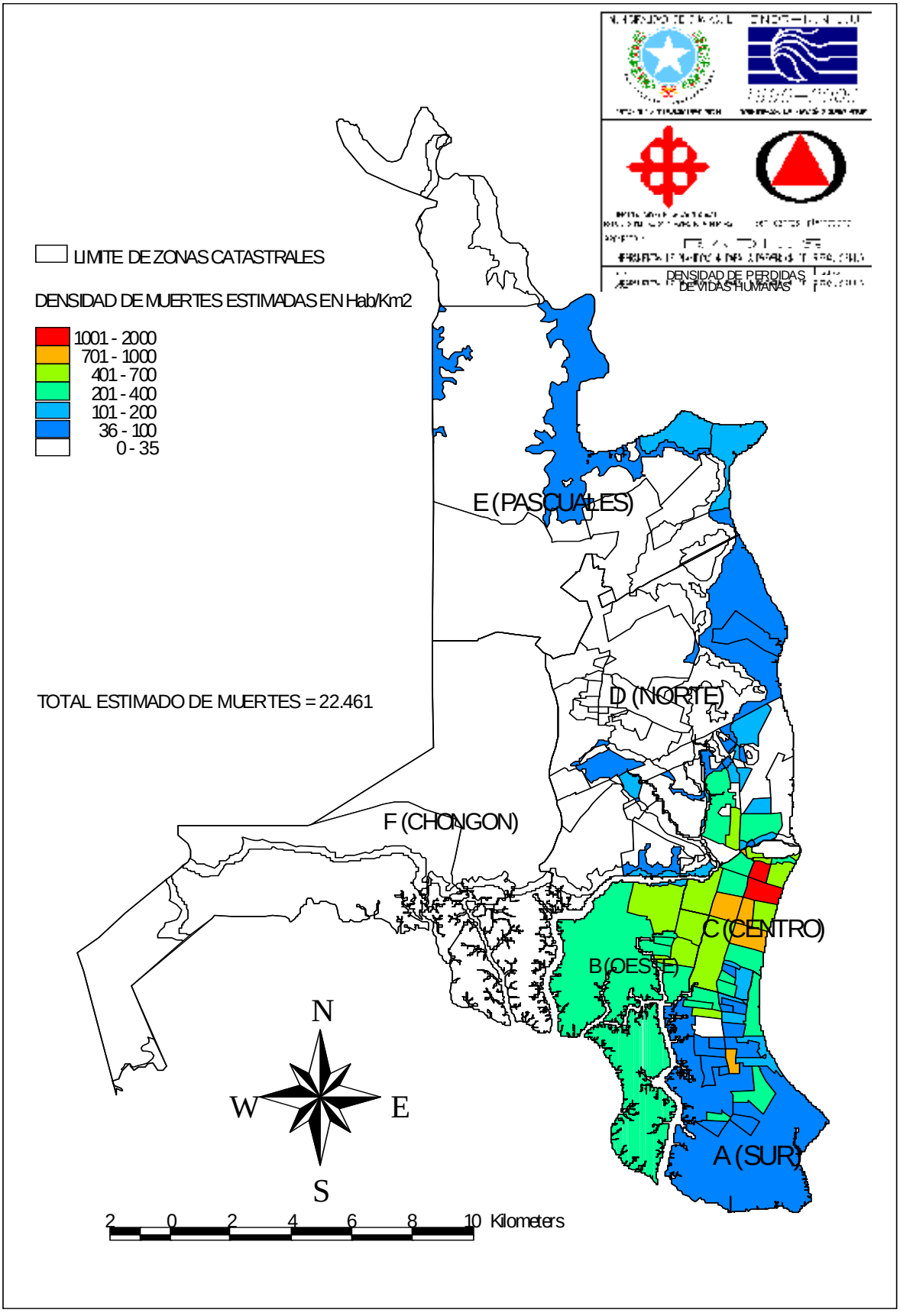

Figure 3. Geographical distribution of causalities in Guayaquil due to the adopted earthquake.

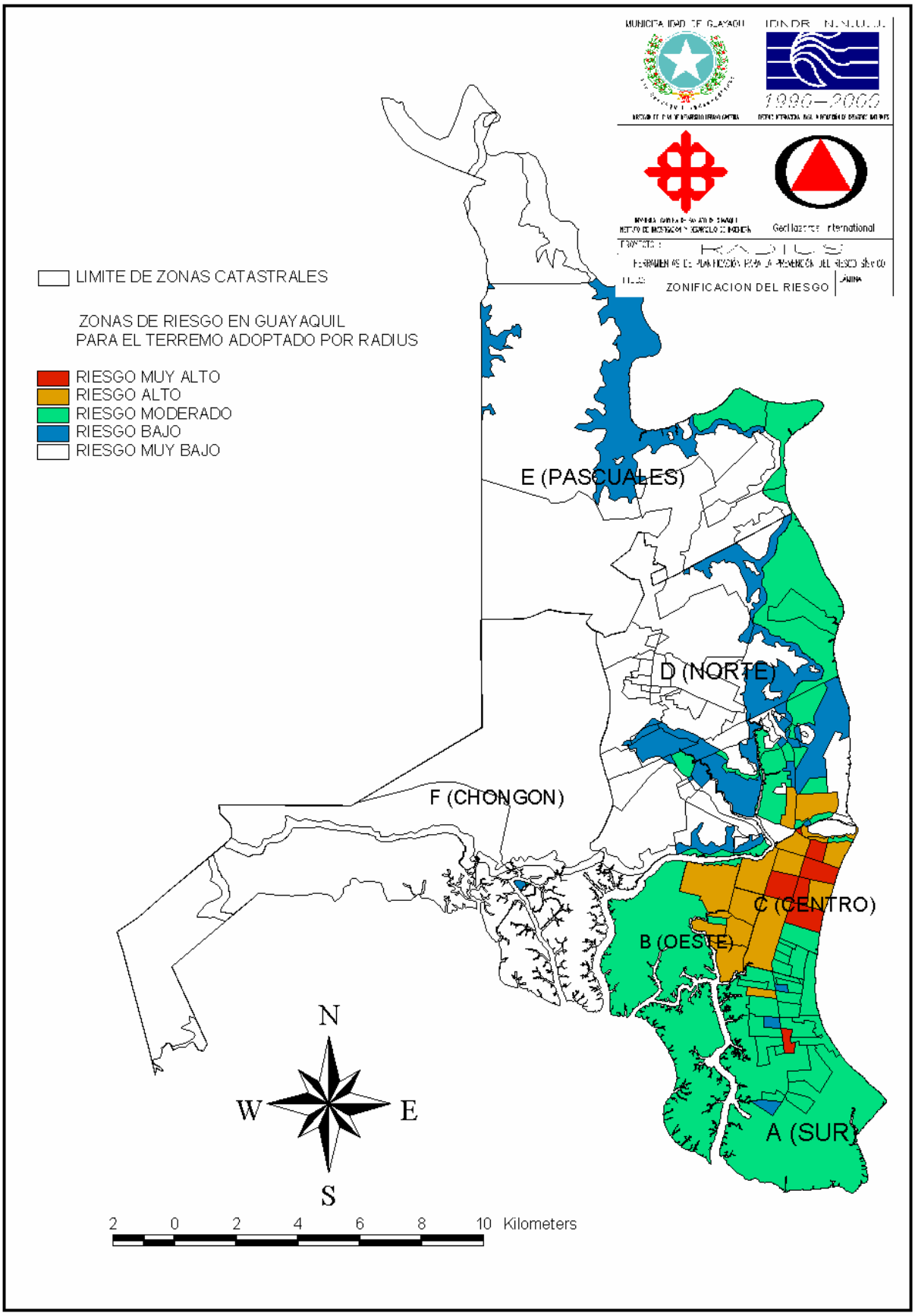

Figure 4. Micro-zoning of seismic risk in Guayaquil - Ecuador.