Risk Mapping for Strategic Planning of Shelter Response in Tijuana, Baja California, México

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Report

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Project Participants

Overall Coordinators
Carlos Villacis, Ph.D., MPA
Coordinator
Global Risk Identification Programme (GRIP)
Bureau for Crisis Prevention and Recovery
United Nations Development Programme

Mr. Esteban Leon
Disaster Management Specialist
UN-HABITAT Geneva Office

Technical Coordinators
Luis Humberto Mendoza Garcilazo, M.Sc.
Leader team of the Laboratory of Seismology applied to Engineering, Earth Sciences Division, of the Center for Scientific Research and Higher Education of Ensenada (CICESE) in Ensenada, Baja California, Mexico.

Antonio Rosquillas Navarro
Director of Civil Protection Office in the Municipality Tijuana

Project Participants
Ernesto Rocha Guerrero (CICESE)
Ena del Carmen Gámez Balmaceda (CICESE)
Ana María Frías León (CICESE)
Orlando Granados Hernández (CICESE)
Rogelio Reyes Serrano (CICESE)
Sergio Vázquez Hernández (CICESE)
Octavio Méndez Stoever (DMPCR)
Mario Rodríguez Corella (DEPC)
Ramón Moldrano Salgado (DMPCT)
José Luis Ledezma (DMPCT)

Municipal Civil Protection Board in Tijuana (DMPCT)
Integral Family Development (DIF)
Urban Administration Board DAU)
Municipal Planning Institute (IMPLAN)
Municipal Civil Protection Board in Rosarito (DMPCR)
Civil Protection State Board (DEPC)
Infrastructure and State Urban Development Board (SIDUE)
Main Administrative Office (OM)
National Defense Board (SEDENA)
Red Cross - Municipal (Tijuana and Rosarito) and State
Volunteers - Rotary Club
Comisión Estatal de Servicios Públicos de Tijuana (State Utilities Commission of Tijuana) (CESPT)
RADIUS Tijuana Group

Executive Summary

The city of Tijuana is located in a seismically active region due to its location on the boundary of the North American and Pacific tectonic plates, with the presence of the Secondary System of the San Andreas Fault System that transmit the slip main movement between the North American and Pacific plates. Under the current conditions of the city, future earthquakes represent an intensive risk; that would affect mostly the low-income population that lives in areas with high population density, in badly built houses, and on land with a higher exposure to risk.

The objective of this project is the preparation of a pre-disaster emergency shelter plan for earthquakes. The plan should ensure timely provision of roof; food and safety to people that have lost their houses. This report describes the methodology and criteria adopted for the selection, planning and activation of provisional shelters. A damage scenario for a 6.5 earthquake on the La Nacion fault 15 Km from the border of the U.S. with Mexico was selected for the preparation of the plan. Calculations for this scenario, through the simulation of RADIUS tool, indicate that 50,192 people would lose their houses and they would need emergency shelters.

The developed shelter plan has identified some areas and facilities that could be used for shelters provision. It includes a list of Junior-High-School buildings that might be used as a first option for provisional shelter, as long as an evaluation finds them structurally safe. Also, another list included parks and sport fields that are suitable as provisional shelters or for emergency camps. The methodology developed in this study can be applied to other cities in the country, given the expertise and skills and lesson learned from this project.

The results should be used to perform earthquake drills with the participation of authorities, institutions and the community. This project promotes increased the seismic risk awareness of the community and its leaders, with the aim of reducing risk to disasters, by incorporating the various sectors of society.

Acronyms and Abbreviations

CCO	Cerro Colorado
CEN	Centanario
CESPT	Comisión Estatal de Servicios Públicos de Tijuana (State Utilities Commission of Tijuana)
CFE	Comisión Federal de Electricidad (Federal Electricity Commission)
CICESE	Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California (Center for Scientific Research and Higher Education at Ensenada)
CMOE	Centro Municipal de Operaciones de Emergencia (Municipal Center for Emergency Operations)
CTO	Centro
CVE	Cueros de Venado
DAU	Dirección de Administración Urbana (Urban Administration Board)
DEPC	Dirección Estatal de Protección Civil (Civil Protection State Board)
DIF	Desarrollo Integral de la Familia (Integral Family Development)
DMPCR	Direccción Municipal de Protección Civil Rosarito (Municipal Civil Protection Board in Rosarito)
DMPCT	Dirección Municipal de Protección Civil Tijuana (Municipal Civil Protection Board in Tijuana)
DNPC	Dirección Nacional de Protección Civil (National Civil Protection Board)
EDAN	Evaluación de Daños y Análisis de Necesidades (Damage Evaluation and Analysis of Needs)
GRT	Grupo RADIUS Tijuana (Group RADIUS Tijuana)
IDNDR	International Decade for Natural Disaster Reduction
IMPLAN	Instituto Municipal de Planeación (Municipal Planning Institute)
INEGI	Instituto Nacional de Estadísticas y Geografía (National Institute of Statistics and Geography)
LICONSA	Programa de Abasto Social de Leche (Social Program for Milk Supply)
LME	La Mesa
OM	Oficialía Mayor (Main Administrative Office)
OTA	Mesa de Otay
PLA	Playas
PMCT	Plan Municipal de Contingencias para Terremotos (Municipal Contingency Plan on Earthquakes)
PRE	La Presa
PS	Refugios Temporales (Provisional Shelters)
Rotarios	Club Rotario (Rotary Clubs)
SAB	San Antonio de los Buenos
SEDENA	Secretaría de la Defensa Nacional (National Defense Board)
SEGOB	Secretaría de Gobernación (Government Board Office)
SEGPUB	Secretaría de la Seguridad Pública (Public Safety Board)
SIDUE	Secretaría de Infraestructura y Desarrollo Urbano del Estado (Infrastructure and State Urban Development Board)
TAB	Sánchez Taboada
TELNOR	Teléfonos del Noroeste (Northwest Telephone Company)
TGN	Transporte de Gas Natural (Natural Gas Transport)

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1. Introduction

1.1 General background of Tijuana

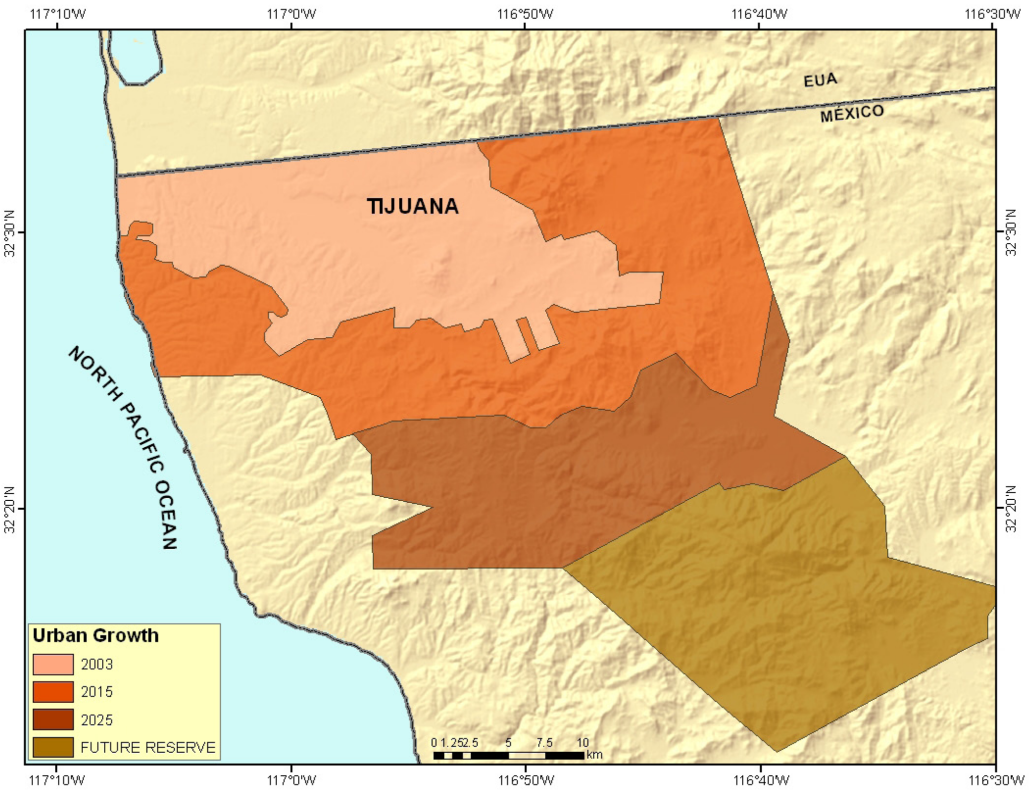
The city and municipality of Tijuana is located in the state of Baja California, to the northwest of Mexico. It is bordered on the north by the state of California of the United States, on the south by the city of Rosarito, on the east by the city of Tecate, and on the west by the Pacific Ocean.

The metropolitan area of Tijuana City is of 879.2 square kilometers. The total population, as of 2010, is of 1,300,000 people, which amounts to 50% of the total state population. Due to its geographic location in regards to the United States, Tijuana is a great migratory, tourist and commercial attraction. Tijuana's GDP per capita (USD 16,600) is above the national average. In fact, according to the INEGI (National Institute for Statistics and Geography), its GDP per capita is the third in Mexico after Cancun and Mexico City.

Table 1: Census population

Year	Population
1950	65,364
1960	165,690
1970	340,583
1980	461,257
1990	747,381
2000	1,210,820

Figure 1. Urban area growth in Tijuana



Tijuana is divided into ten municipal districts, shown in figure 2:

1. Centro (CTO)
2. Playas (PLA)
3. San Antonio de los Buenos (SAB)
4. Sánchez Taboada (TAB)
5. La Mesa (LME)
6. Mesa de Otay (OTA)
7. Centenario (CEN)
8. Cerro Colorado (CCO)
9. La Presa (PRE)
10. Cueros de Venado (CVE)

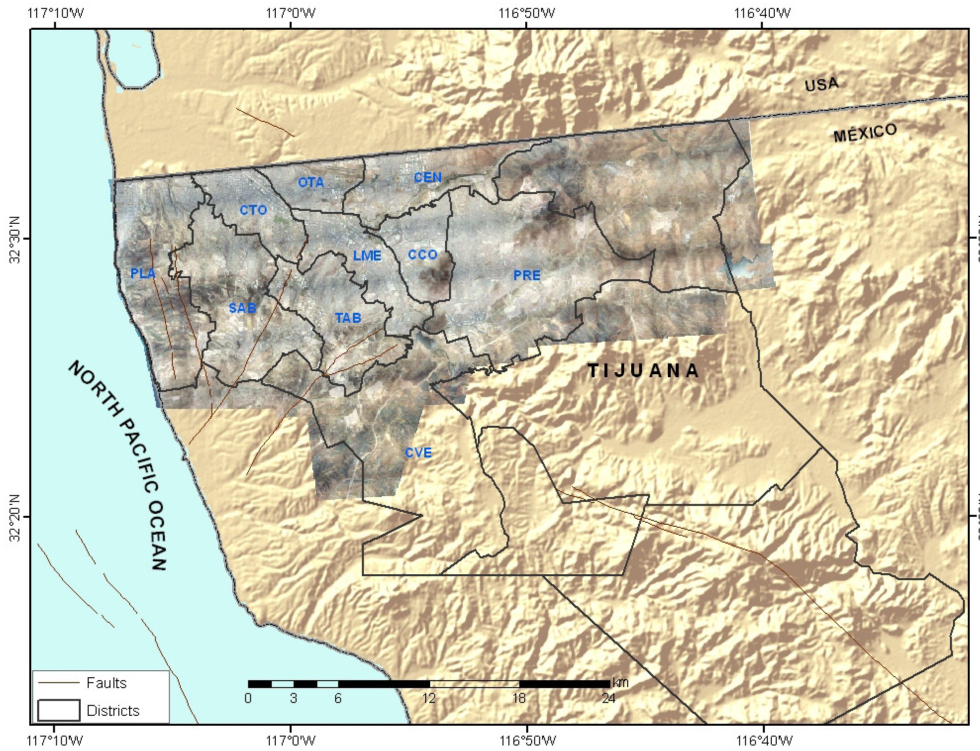
1.2 Hazard profile of Tijuana

The city of Tijuana is located in a region subject to a high seismic risk due to its location bordering the North America and Pacific tectonic plates. These plates have a significant relative sliding movement of 56 mm/year, producing high effort concentrations in the earth's crust (Legg & Kennedy, 1991).

The interaction between the tectonic plates suggests that part of this movement is being absorbed by Secondary Fault System of the San Andres System on the west portion that include Coronado, Silver Strand, Rose Canyon, San Diego depression, La Nacion, Vallecitos and San Clemente faults. All these faults are at a close distance to Tijuana; therefore they pose an intensive risk for people and present buildings (Mendoza et al; 1992)

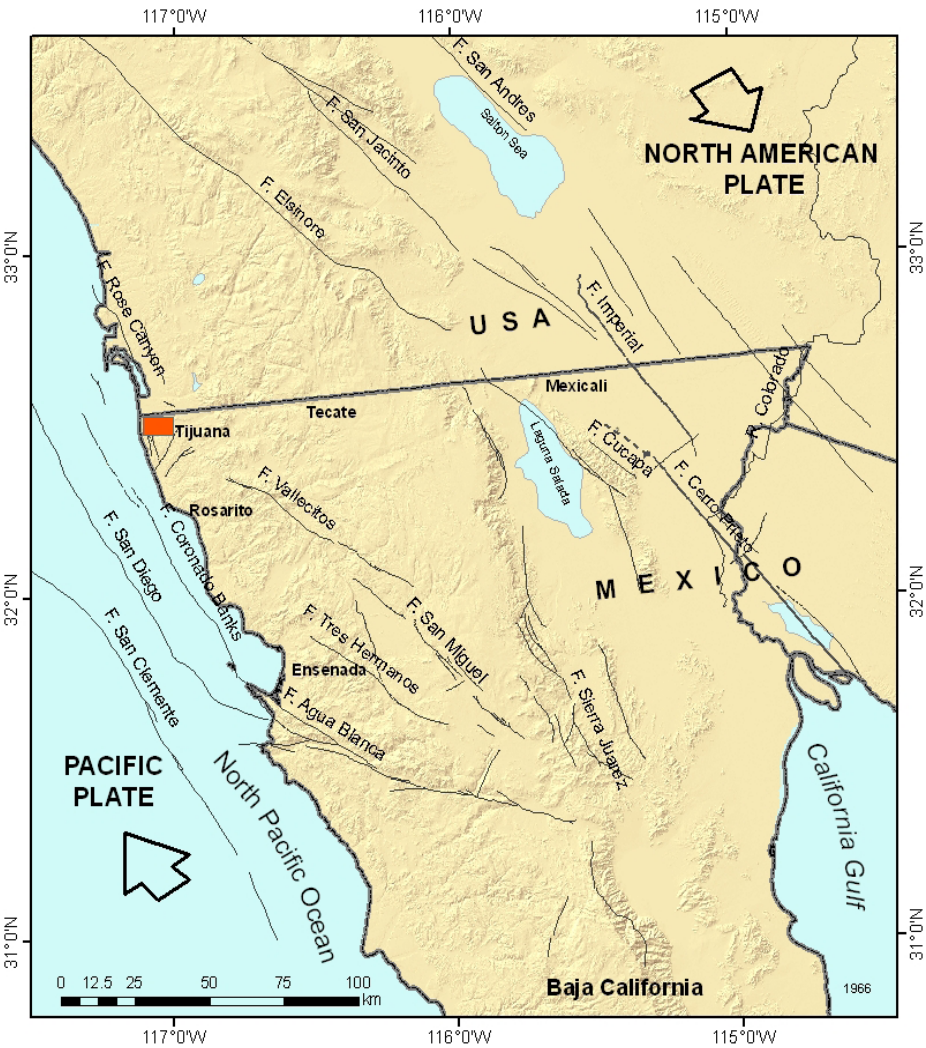
Figure 3 presents the Tectonic Frame of the northern region of Baja California and shows the main faults associated with the relative movement of the plates.

Figure 2. Districts of Tijuana



Centro (CTO)
Playas (PLA)
San Antonio de los Buenos (SAB)
Sánchez Taboada (TAB)
La Mesa (LME)
Mesa de Otay (OTA)
Centenario (CEN)
Cerro Colorado (CCO)
La Presa (PRE)
Cueros de Venado (CVE)

Figure 3: Tectonic set up of Baja California



Part of the seismic hazard in Tijuana is known by the evidence of the seismic activity on the principle faults that surround the city: Rose Canyon and La Nacion (Lindvall, et al. 1990). There exist, however, other faults on alluvium deposits or urban zones that are pretty much unknown and which are seismically quiet.

The relative seismic quietness prevents the releasing of accumulated energy due to the relative movement of the faults. These energies continue to accumulate until, at any given moment, they come to exceed the natural resistance capacity of that part of the crust, resulting in it breaking up and releasing the accumulated energy in a seismic event.

1.3 Earthquake risk in Tijuana

Since its foundation, Tijuana has not suffered any damaging effects due to earthquakes, however, as it was described in hazard profile of Tijuana, the hazard is known by the evidence of the seismic activity on the principle faults that surround the city and by the relative seismic quietness.

In a seismic hazard study implemented in Tijuana, it is shown the highest seismic intensity of IX produced from an earthquake of Mw = 6.5 (Acosta and Montalvo, 1997). The results of this study represent a high risk in Tijuana. Considering these results, in case of an earthquake, under current situation of the city, people and building exposed are vulnerable.

Proportionally more people of lower income will be affected due to their higher number and the fact that they live in higher density population zones, in badly built homes and on land with a higher risk exposure. The majority struggles daily just to survive and they don't have the time, the knowledge, or the energy to worry about natural hazards of a remote and unpredictable occurrence. They cannot build houses that are seismically safe with the appropriate materials and better adapted to the local ground conditions in accordance with seismic micro-zoning studies and in compliance with building codes. The cost of construction prevails over the safety of their lives and assets.

On the other hand, there is no doubt that government actions for the preparation of emergency aid response to the acute phase in a possible disaster will continue to be of importance; with the need to reinforce them in time if there are no parallel preventive actions to reduce the daily growth of risks.

1.4 Past efforts in disaster risk reduction

Since there is not a history of past earthquake disasters in Tijuana, its vulnerability has been increasing along the years due to the rapid growth of the city, bad individual decisions, and other decisions that are not taken at a governmental level. The population has not had experiences to learn about disasters of their own city and there is no awareness.

In the 90's the United Nations implemented the "International Decade for Natural Disasters Reduction" (IDNDR) to reduce the loss of life, damage to properties and economic unrest caused by natural disasters.

As part of this initiative, the UN launched Project RADIUS from 1998 to1999, encouraging the promotion of activities to reduce seismic disasters in urban areas, especially in developing countries, and to create tools available to humankind. Tijuana was one of the nine cities in the world that were selected for the implementation of case studies that include the estimate of seismic damages in the event of a probable seismic event and for the preparation of a Action Plan based on the understanding of the seismic risk to manage the urban seismic risk.

From the RADIUS project, since 1998 the RADIUS Tijuana Group (GRT in Spanish) maintains a process of positive and firm political and social awareness. The GRT promotes an increase in awareness, knowledge and inter-institutional associations to break through the present reckless passivity, caused more by lack of knowledge on the subject than the ability to cope. It is proven that the reduction of urban risk should be a consistent succession of efforts and decisions in different areas of social, economic, governmental and professional activities. It seeks an increase in involvement of all community sectors, particularly the ones with higher economic and social exposure.

Besides RADIUS initiative to reduce risk, there have been studies about hazards in Tijuana, like reports, maps, scientific articles and conferences that have not been understood, much less used, by the community. Very few concrete actions have resulted from those studies and there is hardly any progress in incorporating the community in the risk reduction process.

Up to now, there is a wrong and general perception in the community that earthquakes (and other natural disasters) are "technical" problems and should only be handled by the technical or governmental community.

1.5 Importance of this project

This Project is the continuation of past efforts on disaster risk reduction. Its methodology contributes to the awareness raising in the community for reducing risk. Its products are useful to improve the city planning and to the decision making, with the participation of several sector of the community.

This report presents the process adopted, as well as the results obtained, in the preparation of a Pre-Disaster Shelter Plan to attend the needs of people left homeless by an earthquake affecting Tijuana. This project was implemented as part of a global initiative to develop a methodology for Pre-Disaster Shelter Planning based on the experiences of three pilot cities: Tijuana, Kathmandu in Nepal and Maputo in Mozambique. The Global Risk Identification Programme (GRIP) of the United Nations Development Programme (UNDP), in collaboration with UN-Habitat and the International Federation of the Red Cross, provided coordination and technical advice for the project implementation.

The goal of this project is to establish sustainable long-term initiatives to manage disaster risk.

Scope and objectives
The objective of this work is the strategic planning of provisional shelters in the event of an earthquake; to provide shelter, food and safety to those people that have lost their homes. This objective generates the following products:

a) Method for the development of strategic response plans in shelters after an earthquake;
b) Strategic Plan Response in Shelters for Tijuana;
c) Training of personnel at a local level for the application of the tool and Plan development;
d) Developed guidelines for a large scale response;
e) Long term strategy to be repeated in other cities;
f) Increased knowledge and awareness of the present risk with the use of the method, in regards to government and humanitarian professionals;
g) Reports that summarize backgrounds, findings and recommendations for future risk assessment projects and action plans to develop them.

Main stakeholders
The project was coordinated by the Municipal Board for Civil Protection of Tijuana and by personnel of Center for Scientific Research and Higher Education at Ensenada (CICESE), Seismology Department, Seismology group Applied to Engineering.

The project was shown to GRT from the start and during the development, results were produced and ideas and comments were received (meetings # 91, 92, 94, 95, 101, 102, 105, 106). In all, the development was completed with close interaction with the following stakeholders:

- Municipality:
  - Municipal Civil Protection Board in Tijuna (DMPCT),
  - Integral Family Development (DIF)
  - Urban Administration Board (DAU)
  - Municipal Planning Institute (IMPLAN)
  - Municipal Civil Protection Board in Rosarito (DMPCR)
- State:
  - Civil Protection State Board (DEPC)
  - Infrastructure and State Urban Development Board (SIDUE)
  - Main Administrative Office (OM)
- Federation:
  - National Defense Board Red Cross (SEDENA)
  - Municipal (Tijuana and Rosarito)
  - State Volunteers: Club Rotario (Rotary Club)

Methodology to follow
To reach the objectives of this project the following activities were performed:

- Use of the tool RADIUS99.xls for the Evaltion of Damage by earthquake in Tijuana. This tool is described in attachment A, which has been used in previous projects of seismic risk in Tijuana. With this tool the following results are obtained:

  - Number of houses and estimate of damage level;
  - Estimated number of affected people that need support in provisional shelters;
  - Shelter needs evaluated in a pre-disaster situation;
  - Tested and calibrated tool for Tijuana;
  - A generic guide to identify the needs for provisional shelters regarding the results of risk analysis for institutes related to handling shelters, local governments and community organizations;
  - Lessons learned.

- Develop a guide to identify the needs for provisional shelters regarding the results of risk analysis for institutes related to handling shelters, local governments and community organizations;

- Submit the general subjects in shelter planning regarding the risk evaluation and contingency plans, as well as the use of the tool RADIUS to facilitate the planning.

2. Risk Assessment

2.1 Selection of the scenario earthquakes

To establish a plan for the necessity of provisional shelters, it was necessary to assess the seismic risk of the city based on a hypothetical scenario of damage by earthquake.

The earthquake damage scenario was estimated from six probable earthquakes generated by three active faults that, due to their closeness to Tijuana, have a higher damage potential. The locations of these probable earthquakes are: north and south sections of the Silver Strand fault, located west of Tijuana; north and central sections of the Vallecitos fault, located southeast of Tijuana; and north and south sections of the La Nacion fault, located north of Tijuana. Table 2 shows the location of the scenarios in the various faults used for all the districts.

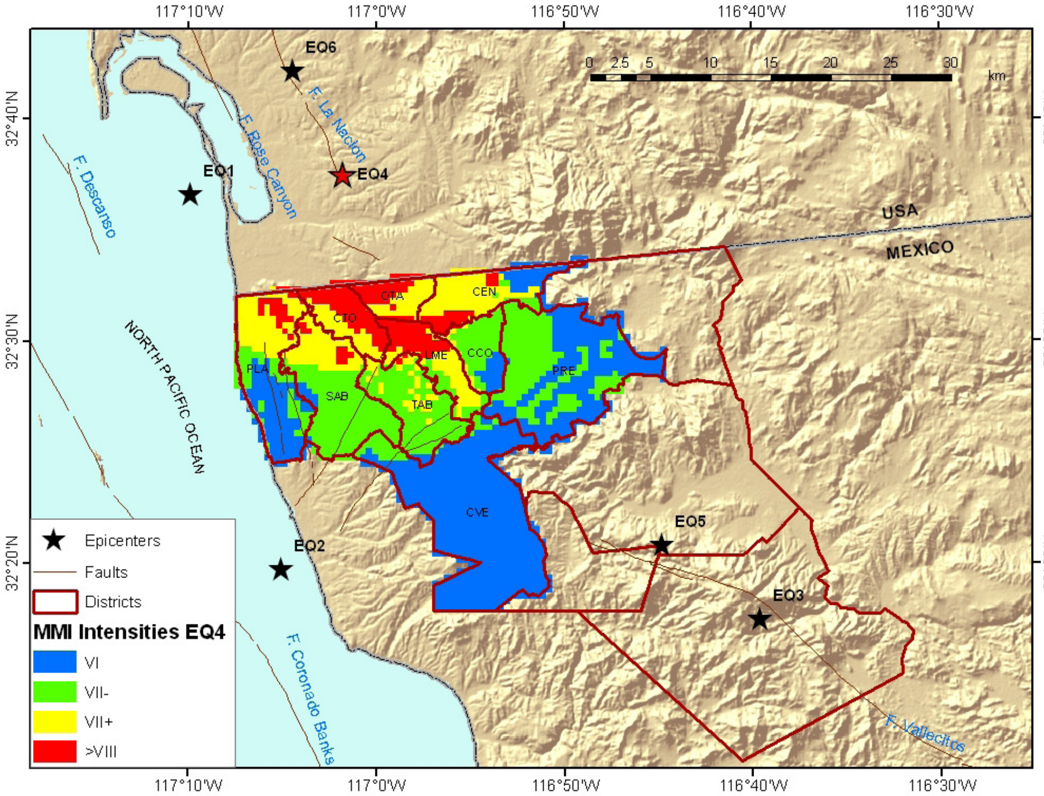
The six damage scenarios were estimated through RADIUS99 tool, and based on them, to define the previous activation activities of provisional shelters. Out of the 6 scenarios estimated, the one with the highest level of damage was caused by an earthquake on the south segment of the La Nacion fault, located 8 km from the Mexico/U.S. border (earthquake EQ4). The location of the epicenter and the intensity results in the Modified Mercalli Scale for this scenario are shown in Figure 4.

For the strategic shelter plan we chose scenario EQ6 as a hypothetical scenario which corresponds to the north segment of the La Nacion fault located 18 km from the border of Mexico with the U.S. It is the most manageable because of the availability of resources to respond to the emergency.

Table 2: Location of seismic scenarios for Tijuana

Name	Mag	EQ	Longitude	Latitude
Strand North	6.5	EQ1	-117.16	32.61
Strand South	6.5	EQ2	-117.08	32.33
Vallecitos South	6.5	EQ3	-116.66	32.29
La Nacion South	6.5	EQ4	-117.03	32.63
Vallecitos North	6.5	EQ5	-116.75	32.35
La Nacion North	6.5	EQ6	-117.07	32.70

Figure 4: Location of the 6 epicenters used to obtain the scenario of damages



The EQ4 is the scenario that shows more damages.

2.2 Expected damages

In Seismology, a measurement used to classify the horizontal ground movement is the Peak Ground Acceleration (PGA). It is used for its relation to inertia forces, since regularly the dynamic forces induced in structures are closely related to PGA.

The predictive relations for parameters that diminish with distance (like PGA) are called attenuation relations for different geographic and tectonic environments. On the West part of North America, the relation of Joyner & Boore (1981) is commonly used. Additionally, PGA can be correlated to seismic intensities (MMI) (Trifunac & Brady, 1975). The RADIUS99 tool uses these parameters to classify the horizontal ground movement and to get an estimate of damages.

The RADIUS99 software estimates de PGA values first and then after an empiric relation changes to MMI values and with the damage observation relations, sends these values to damage percentages (MDR). The description of the MMI scale is shown in Annex (A).

Classification of buildings was necessary for the estimate of damaged buildings with the RADIUS99 program, based on material type, use, age, structure type and existent construction code. The data detail used in the RADIUS99 tool and the results obtained from PGA, MMI and MDR for all scenarios is shown in Annex (B)

The result of intensities for the hypothetical case chosen for the selection of shelters (earthquake #6, La Nacion fault North section), is shown in figure 5. It was estimated that 50,192 people would need a provisional shelter caused by an earthquake of a 6.5 magnitude in the La Nacion fault. This estimate was done with the number of damaged buildings estimated by RADIUS99 for each district. The details of the estimate of shelters for this scenario are shown in table 3.

Other data from RADIUS tool results are 31,397 injured, 1,576 dead and 37,654 damaged homes. The needs of refugees implies a minimum of 120 provisional shelters or organized camping places, each for 400 people, with personnel for management, equipment, furniture, food, hygiene supplies, drinking water, health, safety, psychological care, kitchen, stoves, etc., acquired whether inside or outside the city. Additionally, the city may be able to immediately take care of 1200 affected people, that is if the army, the community and the local Red Cross do not incur damages and are able to install the shelters first hand, and taking into consideration that the next ones should be installed with the help and support of the Federal and State Governments.

Table 3: Number of people with shelter needs according to EQ6 earthquake scenarios for each district

District	Direction	Epic_dist. (Km)	Damage Blds	Blds*4pers	Persons/3
SAB	N	28.50	5,449	21,795	7,263
CEN	NW	23.17	3,805	15,222	5,073
CTO	N	22.30	5,092	20,370	6,788
CCO	NW	23.37	2,359	9,438	3,145
CVE	N	31.81	844	3,376	1,125
LME	N	22.37	3,858	15,431	5,142
PRE	NW	23.08	5,469	21,877	7,290
OTA	N	19.42	3,353	13,412	4,469
PLA	NE	23.17	3,474	13,895	4,631
TAB	N	25.85	3,950	15,801	5,266
Total number of people in provisional shelters for EQ6					50,192

Figure 5: Intensity values of Mercalli Scale, for scenario 6, selected as the hypothetic scenario for the creation of provisional shelters

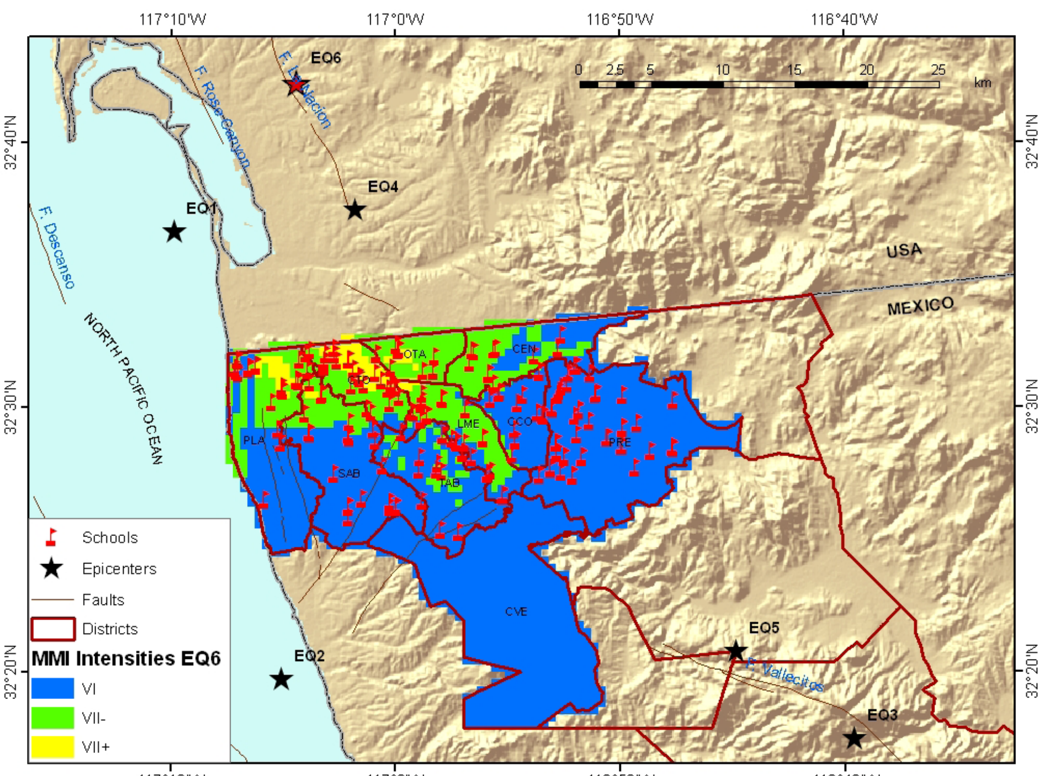


Table 4: Number of people in provisional shelters vs. the location of the earthquake

	CTO	PLA	SAB	TAB	LME	OTA	CEN	CCO	PRE	CVE	Total
EQ1	9,182	8,432	10,475	6,407	6,035	5,220	5,348	3,298	7,676	1,311	63,384
EQ2	6,504	5,011	12,389	10,170	7,263	3,336	4,536	3,585	8,836	3,703	65,332
EQ3	1,893	1,107	2,747	3,672	2,790	1,265	2,779	2,396	8,698	1,303	28,651
EQ4	11,910	8,224	12,543	10,313	10,156	8,139	9,663	6,141	12,959	1,714	91,761
EQ5	2,984	1,953	5,469	6,468	5,375	2,031	4,767	4,344	17,186	2,451	53,028
EQ6	6,788	4,631	7,263	5,266	5,142	4,469	5,073	3,145	7,290	1,125	50,192

Table 5: Number of injured people vs. the location of the earthquake

	CTO	PLA	SAB	TAB	LME	OTA	CEN	CCO	PRE	CVE	Total
EQ1	4,583	5,067	7,632	9,328	3,923	3,975	3,179	1,762	4,258	516	44,223
EQ2	2,857	2,464	8,400	17,785	4,895	2,210	2,446	1,995	5,414	2,334	50,800
EQ3	449	220	829	3,779	1,293	458	1,139	1,036	5,290	499	14,992
EQ4	6,631	4,899	9,771	18,246	7,856	7,419	8,908	4,237	9,680	792	78,438
EQ5	954	587	2,461	9,723	3,343	1,039	2,677	2,605	14,522	1,311	39,221
EQ6	3,049	2,297	3,898	6,896	3,167	3,220	2,944	1,632	3,895	399	31,397

Table 6: Number of deaths vs. the location of the earthquake

	CTO	PLA	SAB	TAB	LME	OTA	CEN	CCO	PRE	CVE	Total
EQ1	483	399	448	374	213	249	232	95	135	25	2,655
EQ2	225	122	762	1,102	284	95	155	114	169	255	3,284
EQ3	19	6	54	103	32	12	57	49	190	25	548
EQ4	861	380	658	1,162	627	656	663	414	451	38	5,910
EQ5	37	15	119	346	156	27	175	172	942	94	2,081
EQ6	256	103	234	225	149	176	201	86	125	21	1,576

Table 7: Number of damaged buildings vs. the location of the earthquake

	CTO	PLA	SAB	TAB	LME	OTA	CEN	CCO	PRE	CVE	Total
EQ1	6,888	6,326	7,858	4,807	4,527	3,916	4,012	2,474	5,759	984	47,550
EQ2	4,879	3,759	9,294	7,629	5,448	2,503	3,403	2,689	6,628	2,778	49,011
EQ3	1,420	831	2,061	2,755	2,093	949	2,085	1,797	6,525	977	21,494
EQ4	8,935	6,169	9,409	7,736	7,619	6,106	7,249	4,607	9,722	1,286	68,838
EQ5	2,239	1,465	4,103	4,852	4,032	1,524	3,576	3,259	12,893	1,839	39,781
EQ6	5,092	3,474	5,449	3,950	3,858	3,353	3,805	2,359	5,469	844	37,654

3. Emergency Shelter Needs Identification

Tijuana is located at the North-Western corner of the Mexican Republic; the nearest cities are Tecate on the east and Playas de Rosarito to the south, both with a big shortage of strategic resources for disaster emergencies. Ensenada and Mexicali could provide human resources and supplies in the following hours; however, there it would be the need to evaluate the roads for damages.

In the event of an earthquake, among other actions, one would be the need to install provisional shelters to provide shelter, food and safety to those people that have lost their homes. Therefore, it is urgent to be prepared with a protocol that eases the installation of provisional shelters.

In case of a destructive earthquake, provisional shelters are essential and the project has the purpose of providing a list of places that may be used as shelters along with their locations, as well as a list of previous requirements and the activation guidelines. It is important to mention that due to the impossibility of predicting the location and magnitude of a tremor, the buildings chosen as shelters in this list will be appropriate to be used and free of damages.
This document shows the list of junior high schools to be used after an earthquake as a first option for provisional shelters - as long as they do not show structural damages after an evaluation - as well as parks and sport fields which should be conditioned as provisional shelters or organized camps.

Based on the hypothetical damage scenario, schools located in areas with Mercalli intensities below VII were chosen as provisional shelters. An average of 300 people's capacity was considered per school. Open fields (sport fields and parks over 1000 m2) located in areas with lower or same intensities to VII will be used as shelters in organized camps with tents. The locations of these sites are shown in Figure 8 and they are listed in annexes C and D.

It is assumed that population will show up to the open areas by themselves, and that the government will provide the immediate needs to these people. Some of them will be there because they are afraid their houses would collapse and others because their houses were damaged to such degree they became uninhabitable, The later ones are who finally will receive provisional shelter. Additionally, the government should consider supporting people that would like to go back to their place of origin or go to nearby cities in search of work or shelter.

4. Emergency Shelter Planning

4.1 Legal and institutional frameworks for emergency shelter provision

The earthquake itself should activate the Municipal Civil Protection System. Immediately and independently, all members should work on the actions defined in the Municipal Contingency Plan for Earthquakes (PMCT) that includes the installation of provisional shelters.

According to PMCT, Municipal DIF is in charge of the Provisional Shelters and Social Aid Board and the development of specific plans for this activity.

In theory, the responsible people for activating the provisional shelters in Tijuana are the personnel from DIF in direct coordination with the Municipal Districts, with the support of the Municipal Center for Emergency Operations (CMOE) from the Municipal Civil Protection System. However, to this date (July 2009), if the CMOE facilities do not have all the necessary risk-reduction and operational capacities ready before an earthquake occurs, the CMOE might not respond as it should, and this document should be used only as a guide to activate provisional shelters from their offices or tent operation centers. Offices located out of the city could access the document on the Internet, as this service could be off in the city because of the earthquake.

This document by itself will not open shelters and much less explain in detail which ones to open and the moment at which they should open. It will all depend on the training and knowledge of the people in charge. But training and preparing them does not guarantee their reliance and effectiveness at the time of the response since they are also subject to changes in government administrations. The only thing that can be done is to prepare the City Council personnel every three years and prepare the State and Federal personnel every 6 years.

According to the practice established in Mexico, the National Defense Department, with its DNIII-E Plan, has the presidential order of responding to emergencies by self-activation. This gives a guarantee to the population and a relief to the civil authority because, while public officers establish an agreement and try to align to work on the disaster, the Army will already be acting along with firemen and rescuers in the immediate rescue operations, and the partial administration of provisional shelters.

It is important to realize that this document does not define the manner in which the authorities from DIF, Municipal Districts, National Defense Department, Navy Department, Social Development Department, National Civil Protection System, among others, will provide the supplies, personnel and equipment for these shelters. These actions should be listed in their disaster response programs. This document only has the purpose of offering information regarding the location of provisional shelters according to the possible damages to the city and the basic steps for the operation and administration.

4.2 Criteria for acceptable level of risk

There is no known document that describes officially the criteria on acceptable seismic risk levels in the Mexican Republic, Federation States and Cities.

4.3 Description of process of emergency shelter planning

The City Council has elaborated instructions to be followed before opening of provisional shelters (PS) and the camping places to be used as shelters:

1. Council for Provisional Shelters and Social Services are the commissioned for the opening, operation and management of the PS;

2. It is necessary to have enough personnel for the initial opening of the PS;

3. Personnel in the administration of PS must have the necessary training according to the Sphere Project;

4. It is necessary to have trained personnel specialists on the structural evaluation of the PS premises;

5. It is necessary to have a team of prepared people for the evaluation of damages and estimation of necessities (EDAN);

6. The County Deputy must be notified of his responsibility regarding the actions described above in opening and activating the PS;

7. The steps for the shelters activation must be well defined in a guideline, which has to be acknowledged by the prepared personnel about the installation, operation and administration of the provisional shelters and camping places to be used as shelters;

8. The prepared personnel for the shelter activation has to locate the PS through Google Maps and verify the information list where address and coordinates are specified;

9. A list of governmental and civil organizations that operate the PS must be provided; they must be authorized and previously coordinated by the Board of "Provisional Shelters and Social Aid" of the Municipal Civil Protection Council;

10. Based on the situation of the earthquake impact, it is necessary to estimate the period of time in which the PS will work or will be open;

11. Have in mind the opening of PS in open spaces and all the work needed doing so;

Steps for the opening and activation of the provisional shelters:

1. Automatically activate the protocol by means of the Board of Provisional Shelters and Social Aid:
   a. By the Municipal Districts and in direct cordination with its staff;
   b. Recall previously trained personnel in the administration of the PS;
   c. Define the responsible administrators for the PS;
   d. Create teams to provide for the PS, 24 hours a day;
   e. Recruit volunteers and organize them.

2. Permanent coordination with the Municipal Center for Emergency Operations (CMOE);

3. Evaluate the disaster situation and estimate the necessities;
   a. Recruit and activate the team EDAN.

4. Locate the zones with more victims;

5. Make contact with the personnel of the 28th Infantry Battalion for support with the PSs;

6. Coordinate with civil Society Organizations that have agreed to help in the operation of the PSs;

7. Predefine the closest PSs to be used;

8. Certify by means of the Board of Damage Evaluation, the structural security of the closest facilities that will be used;

9. Coordinate with the vital service providers in order to supply drinkable water, electricity, trash collection services; security, communication, information, health and

hygiene services, and all that are listed in detail in the Sphere Project;

10. Inform the population about the PS already in operation and the ones opening for service;

11. Be prepared to receive State and Federal support by means of the CMOE;

12. Install Collection and Resource Administration Centers;

13. Coordinate the collection/distribution of equipment and consumables for the PS operation with the following Institutions:
    a. LICONSA;
    b. Secretary of Economy;
    c. State and Federal DIF (Integral Family Development);
    d. Civil Society Entities.

14. International Support
    a. Installation of camp sites for the external support groups. Finally, sites will be enabled by independent humanitarian support groups from this and other countries. It is important to emphasize that these support groups will adjust to the protocols and criteria established in the Humanitarian Letter recorded in the Project Sphere Manual of the International Red Cross (2004), which promotes the fundamental humanitarian principles of population assistance in case of disasters or armed conflicts.

15. Evaluate the possibility of the necessity to open PSs or Organized Camps;

16. Initiate the necessary adjustments of the opened PSs for service and minimum obligatory equipment:
    a. Equipped kitchen;
    b. Drinkable water, electricity installation;
    c. Bathrooms or latrines;
    d. Showers;
    e. Camping tents;
    f. Soup kitchens.

17. Location of local and foreign provisions in case it becomes a long term organized camp site:
    a. Materials for construction, brick or concrete housing;
    b. Semi-permanent installations of drinkable water and electricity;
    c. Public services.

Subsequent follow-up of the reconstruction processes and resumption of normal activities based on the learned experience and improvement for the future.

4.4 Identification of emergency shelter

4.4.1 Criteria for emergency shelter selection

4.4.1.1 Criteria for the selection of the closest provisional shelters

Considering that schools should not be used as provisional shelters (PS) for several reasons, as that children should return as soon as possible to a normal scenario, Elementary Schools should not be used as PS. Due this reason, only Junior High Schools of the State Educational System have been considered with the understanding that these also must return to their normal activities as soon as possible. So it is important to use open spaces before using schools for shelter provision. These schools, as before mentioned, must be evaluated in their structural security before using the as PS.

For this exercise, we have divided them in Mercalli Intensity Zones, although this has not been determined as definitive; it only complies with the adopted scenario according to the Radius99 software. The project recommended the CMPC to have a laptop computer with the necessary database to run RADIUS 99, because in the event of an earthquake and having its hypocenter location and magnitude, RADIUS99 can be ran and in a matter of minutes demarcate areas of PGA, IMM and MDR as shown in annex B.

Note: It will be extremely important to locate the epicenter and magnitude of the earthquake as well as the already identified damages in the city before using these facilities.

4.4.1.2 Selection criteria for the proposed sites as Open Provisional Shelters

For the selection of the open spaces that will serve as PS, it is recommended that at least the following criteria be met:

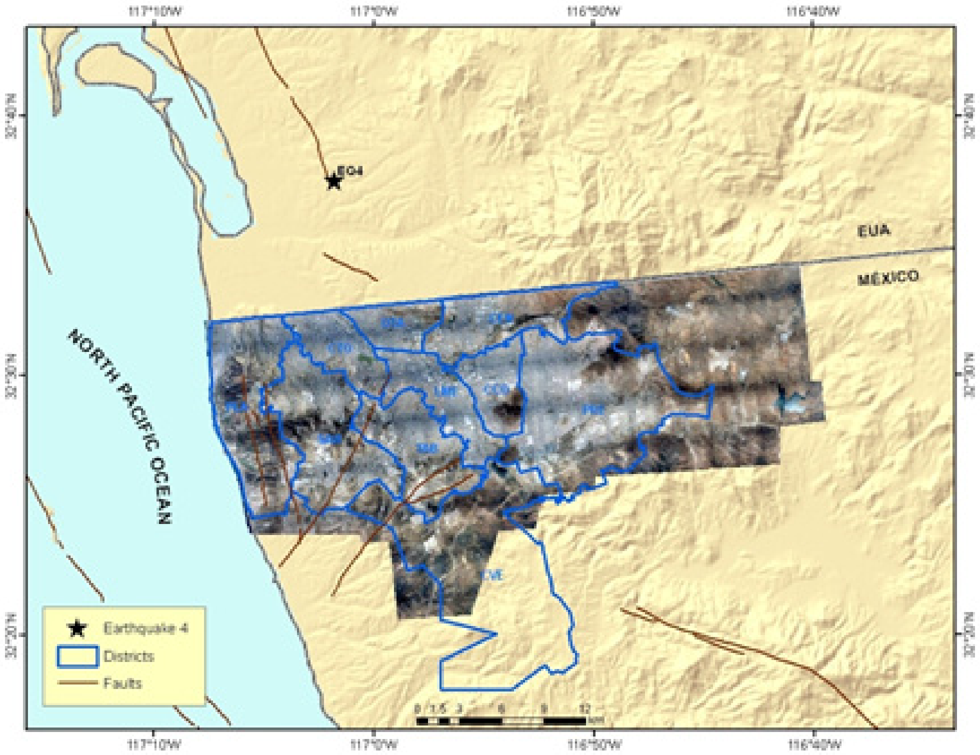
- That they are located on a site with a good drainage system.
- Not prone to seasonal flooding, collapses, tsunamis, high tide or any other hazards.
- Easy access via roads, schools, health care, markets,
- It must be close to the area of the affected population.
- Have a minimum capacity for 250 people.
- Access to water
- Open spaces with possibilities of changing them into Organized Camping Sites.
- Security
- Has (possibility of) good sewer system or access to toilets/bathrooms/washing place

4.4.2 Some maps

The following maps show the expected percentage of damages for the worst scenario (EQ4) and for the hypothetical scenario (EQ6). Overlapping the map of intensities for EQ6, the proposed site locations to be used as provisional shelters are shown.

Figure 6: a) Earthquake 4 located 8 km from the Mexico/U.S. border; b) Average value in percentage of severe damaged buildings for earthquake 4

a)



b)

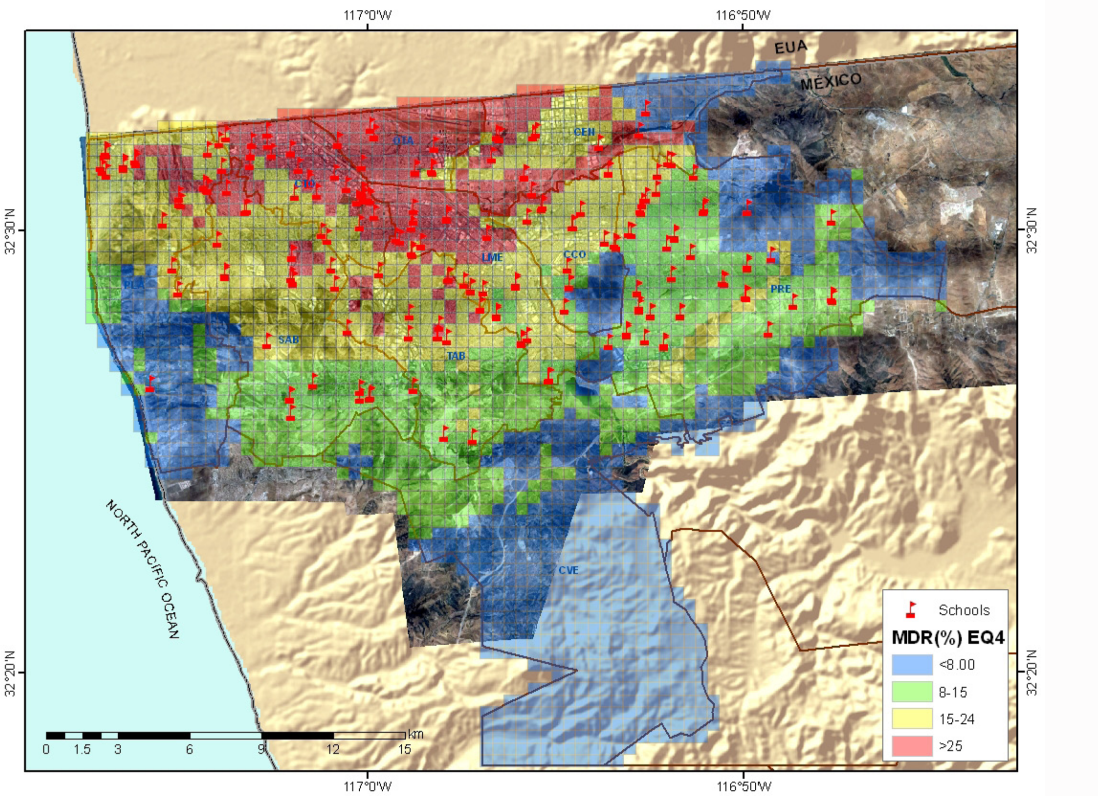
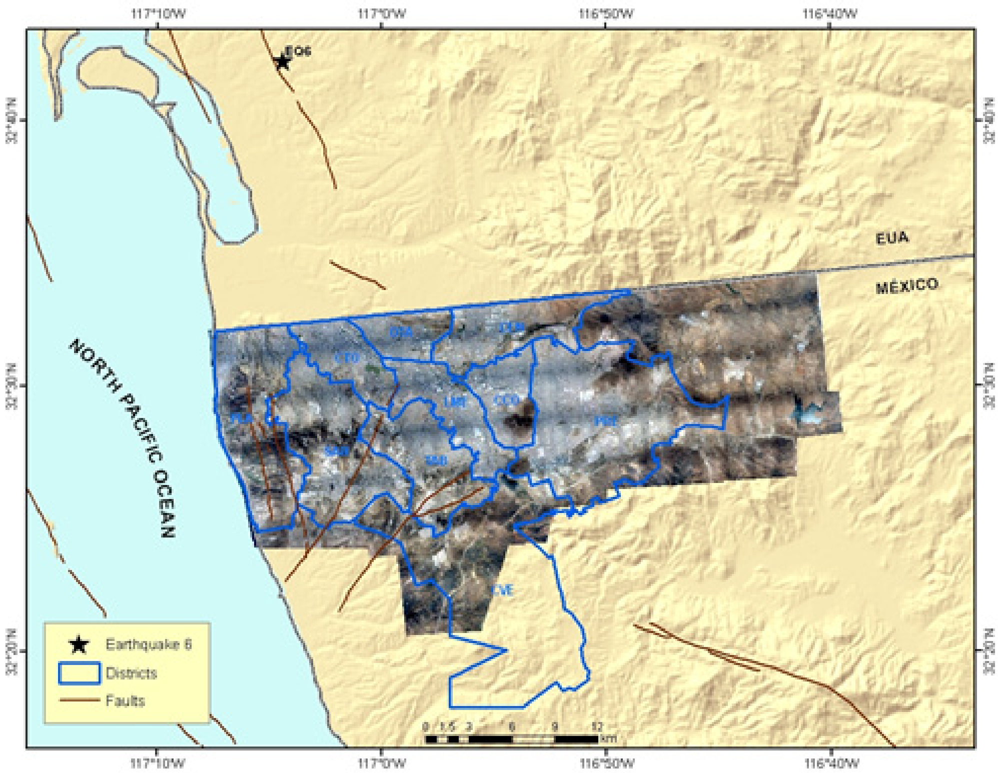


Figure 7: a) Earthquake 6 located 18 km from the Mexico/U.S. border; b) Average value in percentage of severe damaged buildings for earthquake 6

a)



b)

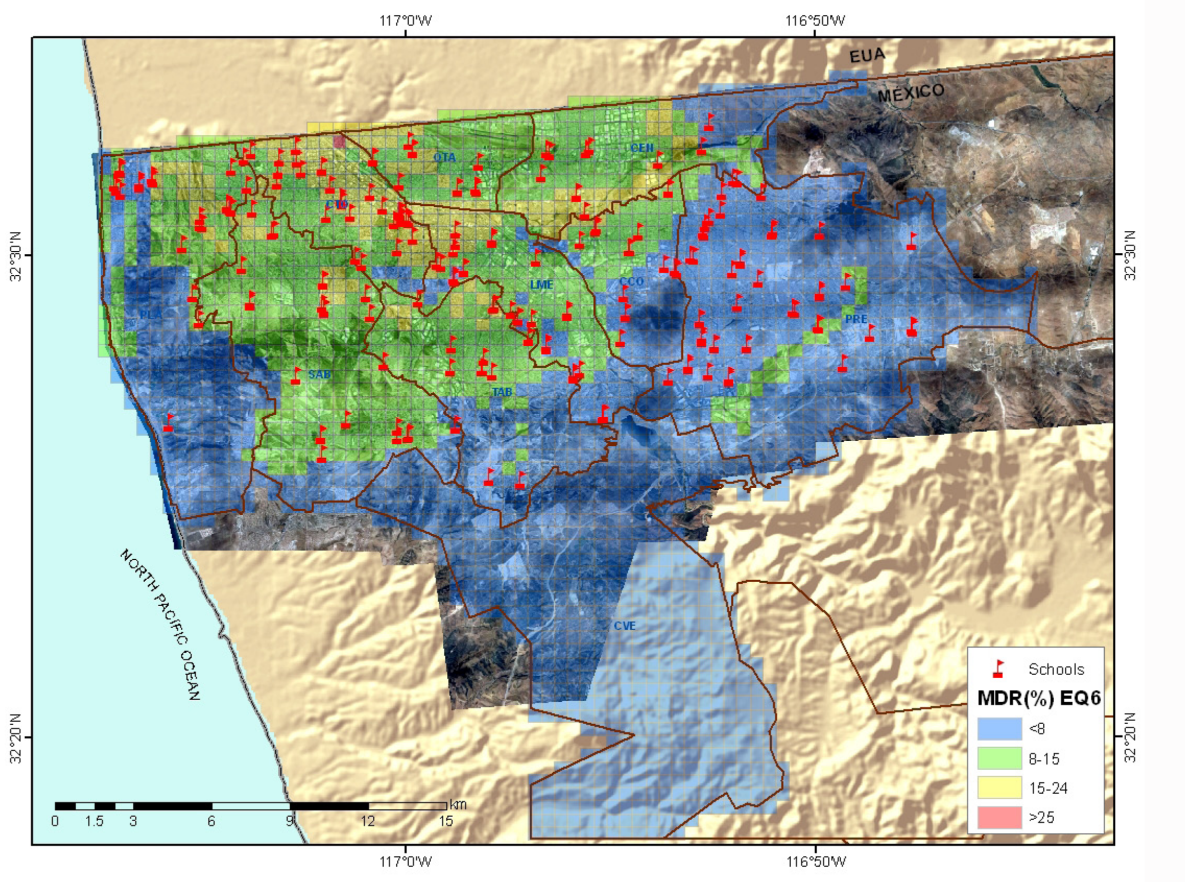
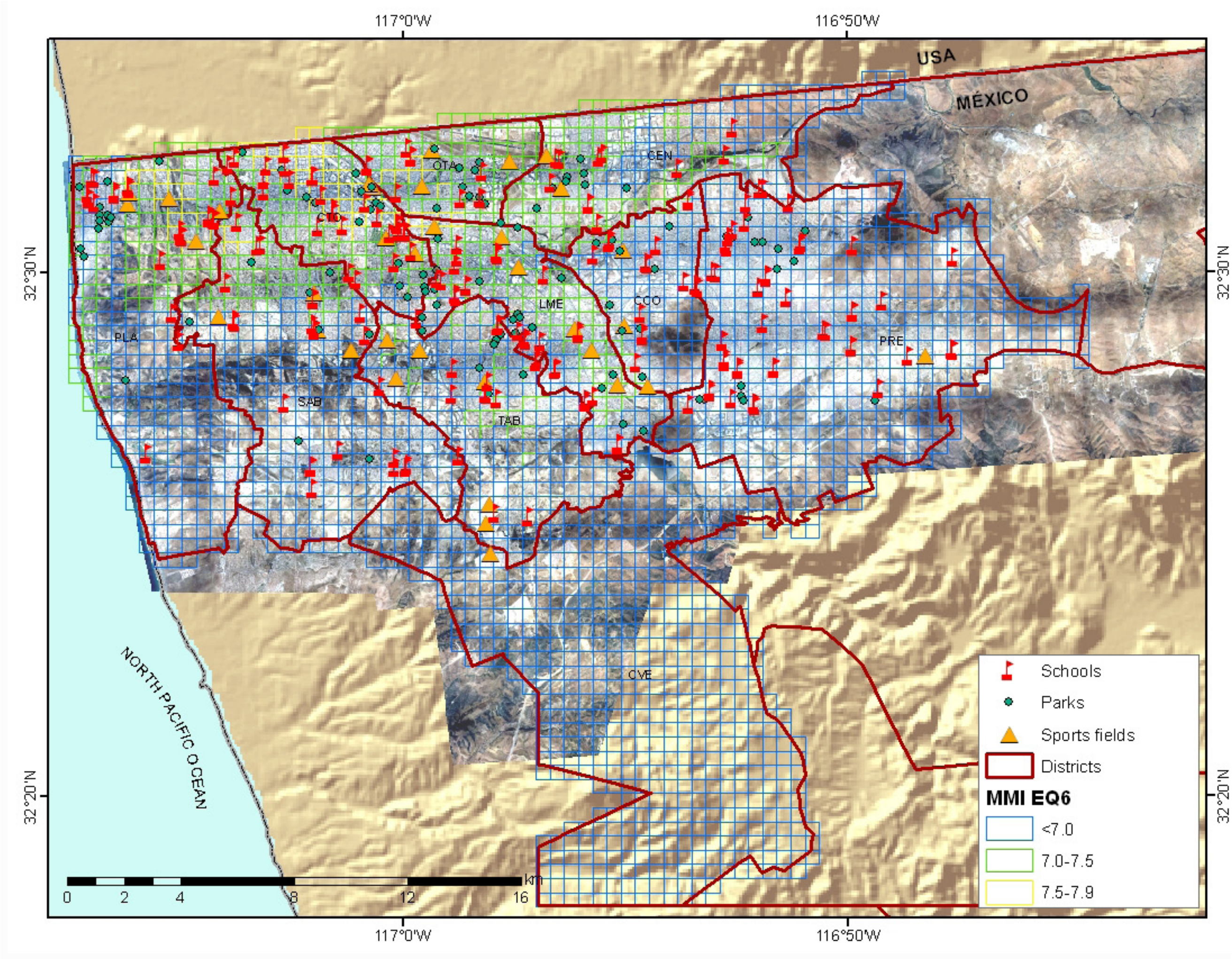


Figure 8: Location of sites to be used as provisional shelters over MMI for EQ6



4.5 Coordination mechanisms

It is expected that the provisional shelters will activate more efficiently days after the earthquake has hit. By then civil authorities will have a more realistic perception of the damages and necessities. It will be at that time the Army and the Municipal, State or Federal authorities meet to define when and which provisional shelters will be implemented.

This Guideline will not give any details on how actions will be taken. We must understand that each Office, Institution or Organization will have their own action plans. For example, it will not be stated how CESPT will provide drinking water for the shelters. It is their obligation to have a pre-defined plan in place, the same goes for Health Services or the Energy Company.

5. Impact and Lessons Learned

5.1 Immediate impacts

The development and project results were presented at the GRT monthly meetings, with the participation of different sectors of the society. This project served as basis for the organization of an earthquake drill in Tijuana on September 18 of 2009, commemorating the earthquake that occurred in Mexico City in 1985. With the help of the RADIUS99 tool and adjusting it for the soil conditions in Tijuana, several tests were done for different magnitudes and epicentral distances to see how the damages would differ and EQ5 was selected for the drill. EQ5 is located south of Tijuana on the Vallecitos Fault, and it was chosen because if would affect three cities: Tijuana, Tecate and Rosarito. With these estimates, we sought the collaboration and communication among the Municipalities.

The drill consisted of the emergency to the different representatives of the Tijuana, Rosarito and Tecate cities; the greater representation was by Tijuana, among which DMPCR, SEGPUB, Red Cross, Public Works, TGN, CESPT, CFE, Fire Stations, TELNOR, were present. Once the earthquake had occurred, the question was how would these sectors respond to care for people affected and repair the damages. The job was divided into several Working Groups: Health Group and Humanitarian Attention, Safety and Rescue Group, Power Lines and Strategic Services Group, which responded to 72 incidents in all Districts of Tijuana. The incidents covered in the drill can be checked at the following URL address:
http://radius-tij.cicese.mx/simulacro09/simulacro2009.htm

The drill was presented to the different media in all Baja California cities. The following pictures on figure 9 show the Groups working during the earthquake drill.

5.2 Future expected impacts

The methodology used for choosing the scenario and provisional shelters can be used for other risk studies and earthquake drills in other cities of the State of Baja California or the country as was done for the drill in the city of Tijuana in September of 2009.

5.3 Lessons learned

RADIUS99.xls program is a simple tool with high utilization potential by people who are decision makers associated with seismic risks in urban regions. It provides a good approximation and an idea of what can happen in housing facilities subject to earthquakes of considerable magnitude. Comparisons in this exercise were made with the results for Tijuana using RADIUS99 vs. more sophisticated estimations (Acosta y Montalvo, 1997); other comparisons were made for Mexicali and two earthquakes (Gámez, 2008). With the reliance of this tool and the training of government and private companies' personnel, other institutions can manage damage estimates for earthquakes of different distances and magnitudes. The training given on March of 2009 already presented this possibility.

On the other hand, the results obtained show great potential losses for Tijuana. That compels a person to take this phenomenon seriously and react responsibly. It is clear that the people who came into contact with this project and its results are now more aware of this problem and they are participating with more insight about the situation.

Figure 9: Executive Boards responding to the emergency for the earthquake drill

6. Conclusions and Next Steps

Before this project, Tijuana lacked any document that could identify the need to develop a Plan for Provisional Shelters after an earthquake occurred. Most importantly this document is created with the consensus of local and regional institutions. In order to continue with these efforts and implement them as a public policy for a sustainable development, it is necessary to define an Acceptable Criteria of Seismic Risk for the city of Tijuana, based on previous studies and with the involvement of the community.

The following actions are recommended for the above:

1. Continue training the municipal government personnel in the use of the RADIUS99 tool (new administration for 2010-2013);

2. Evaluation for Junior high schools that are listed in this first stage of the Plan (Annex C). The revision must include the availability of accesses, services, structural safety and with a low risk level of other natural hazards;

3. Promote the city council's compliance with the indications and obligations listed on point 4.c of this document;

4. Define and furnish a Prevention and Emergency Operation Center where all the preventive information and all the facilities responding to any high energy natural phenomenon are given;

5. Provide maps which have resulted from the seismic micro-zoning of Tijuana showing the more vulnerable zones to the passing of the seismic waves be used. This tool shows that the major damages expected are located in areas with lower seismic wave propagation velocity.

Annex A. RADIUS Methodology

A.1. Overview of Earthquake Damage

A large scale earthquake can affect a wide area in many different aspects. In such an earthquake, for example, the area near the epicenter will be shaken severely and some slopes may fail. The direct disaster of the ground shaking caused by earthquakes is called Earthquake Hazard. Earthquake Hazard can inflict damage on a wide variety of structures. The damage to buildings is the most obvious and important damage.

Casualties can be a result of building damage as well as fires which may ignite after an earthquake. The main cause of deaths during earthquakes is building collapse. About 160,000 buildings collapsed or damaged and 15,000 lives were lost in the case of the 1999 Turkey earthquake.

Earthquake Hazard also affects lifeline facilities such as railroads, highways, bridges and water, sewage, electric power and gas networks. Lifeline damages can significantly hamper recovery efforts aimed at the damaged area. For example, after the 1995 Kobe earthquake, it took the city several years to recover completely because of the extensive damage due to the transportation network (e.g. railroads and roads). Also, many people were forced to live inconveniently for several months because water and sewage services were interrupted. Moreover, damage sometimes causes indirect economical losses in addition to direct physical damage. For example, in the case of the 1999 Taiwan earthquake, the impact to economy by the shutdown of a damaged semiconductor factory was greater than the impact due to lifeline damages.

Earthquake damage can affect many fields which are correlated to each other. The most universal and basic damages are building damage and human casualties.

In order to reduce earthquake damage, a first step by an earthquake prone city should be to understand what would happen if a significant earthquake were to strike the city. As a second step, effective earthquake risk management activities and measures that would aid in damage reduction, and that are based on the findings of the first step, should be identified. Assessing the magnitude of potential damage should not be thought of as the final goal of the damage estimation process, but rather as the beginning of the earthquake disaster management planning.

Figure 10: Slope failure in Nishinomiya city (Kobe earthquake, Japan, 1995)

Figure 11: People trapped in collapsed buildings (Chi-Chi earthquake, Taiwan, 1999)

Memories for 100 years, TVBS, 1999

Figure 12: Damaged transformer substation (Chi-Chi earthquake, Taiwan, 1999)

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A.2. Outline of Damage Estimation

Scenario earthquakes, ground conditions, demographic data and vulnerability functions are critical input data for the earthquake damage estimation.

To begin, a scenario earthquake for the area should be decided on. Reoccurrence of a past damaging earthquake or active fault earthquake is commonly assumed. The epicenter, magnitude, occurrence time (day or night) should also be determined. Usually, ground shaking intensity or PGA (peak ground acceleration) at the site generally becomes greater as the magnitude becomes larger or the distance from the site to the epicenter becomes smaller. Ground shaking is also greatly influenced by the ground conditions of the site.

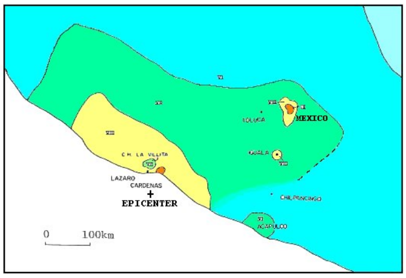
Thus, Earthquake Hazard will be estimated from the parameters of the scenario earthquake and ground conditions. Damage will be estimated from hazard and the existing structures in the area and depends on not only the number of structures but also types of the buildings or lifeline facilities, using vulnerability functions derived for each type of structure. Vulnerability functions reflect the relationship between seismic intensity and the degree of damage to the structure. Casualties such as deaths and injuries are also estimated if the population distribution is known. Thus, the total amount and distribution of damage can be estimated if the chosen scenario earthquake were to occur.

Using a simplified method, this Tool can be used to calculate seismic intensity (shaking) distribution, building damage, number of casualties and lifeline damage

A.3. Zoning of the Area

Usually Damage Estimation is carried out by subdividing the area in question. The RADIUS

Figure 13: Seismic intensity (MMI) distribution around Mexico city (Michoakan earthquake, Mexico, 1985)



Japan Society of Civil Engineers, 1986

Tool introduces a simplified method to evaluate ground conditions. Subdivision of the area in question into mesh units or irregular shapes.

The larger the magnitude of an earthquake or the nearer the seismic source is to the site in question, the greater the ground shaking intensity or PGA experienced at the site. However, the ground conditions at the site also affect the intensity or PGA. For example, the damage observed in the city of San Francisco in the 1989 Loma Prieta earthquake was concentrated in areas of thickly deposited bay area mud. Similarly, the damage experienced by Mexico City due to the 1985 Michoacan earthquake was great even though the distance from the city to the epicenter was 400 km.

The observed damage was a result of not only the weakness of buildings but also topography of the basin in which the city is located; the basin is characterized by very thick deposits of soft soils. As mentioned above, the target area has a wide variety of characteristics, such as ground conditions, that are considered in the process of damage estimation.

For planning and executing mitigation measures against future catastrophic earthquake damages, the subdivided units of the city are often zoned according to existing ground conditions and administration boundaries (city block, city sector, etc.).

Ground classification/zoning should be done for every subdivided unit area because ground conditions can be different at different sites of the city. For example, some soil types can be found homogeneously spread over a wide area while other soil types are distributed over narrow areas such as old river courses. In order to model these conditions, the mesh system is frequently used. Treating irregularly shaped areas as groups of mesh unit areas in the computer is convenient and easy.

A GIS (Geographical Information System) can treat irregularly shaped area boundaries without using a mesh system. However, the cost of most GIS is currently still high and training is necessary to use it.

A.4. Scenario Earthquake

In this section, how to decide on and set the parameters of a scenario earthquake is explained. Input data for parameters are Magnitude, Epicenter, Depth and Occurrence Time. Distance from the epicenter can be calculated with the locations of the epicenter and target area.

For the scenario earthquake, the reoccurrence of a past damaging earthquake or an active fault earthquake is commonly adopted. Although hypothetical earthquakes can be used as the scenario earthquake, it is important to be careful that the hypothetical earthquake model is valid from a seismological point of view. For example, the magnitude should not exceed 8.5. However, since the degree of damage is the function of the magnitude of the event and distance of the target area from the epicenter, it is meaningless to use an excessively small magnitude event or a large distance from the epicenter. The historical earthquakes supplied

Figure 14: Zoning with large mesh

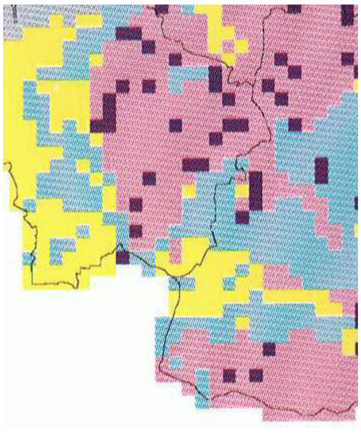


Figure 15: Zoning with small mesh

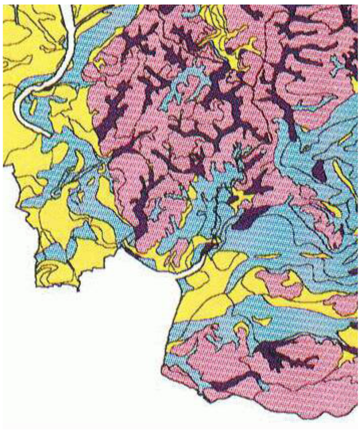


Figure 16: Zoning with GIS

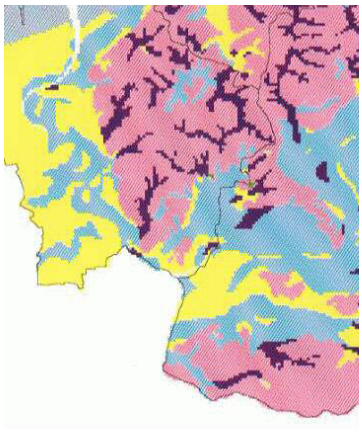
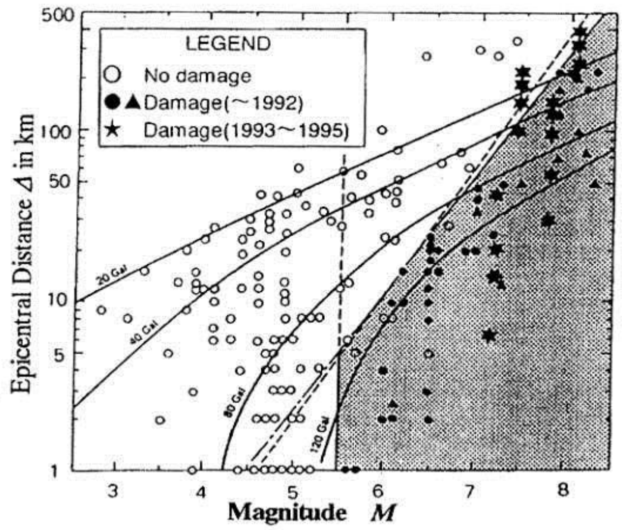
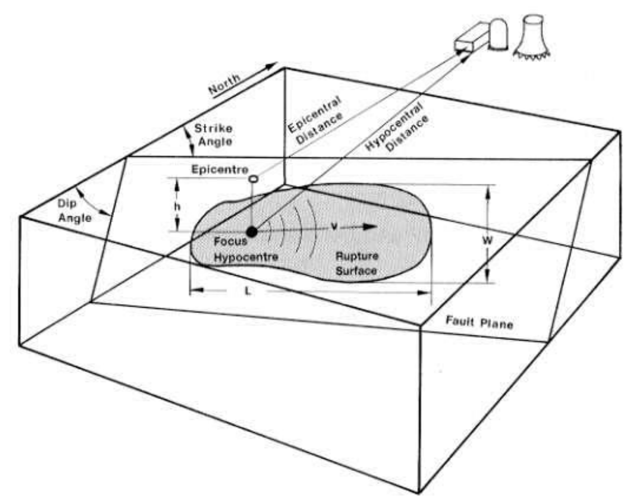


Figure 17: One example of Magnitude, Epicentral Distance - Damage relation

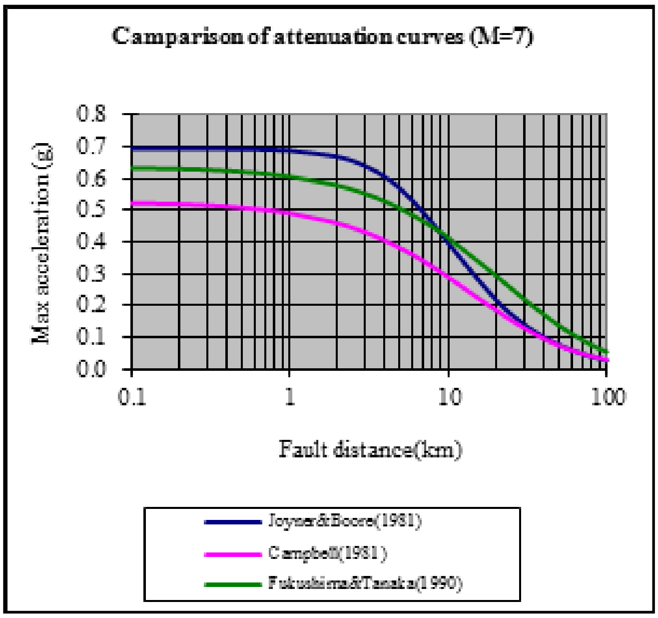


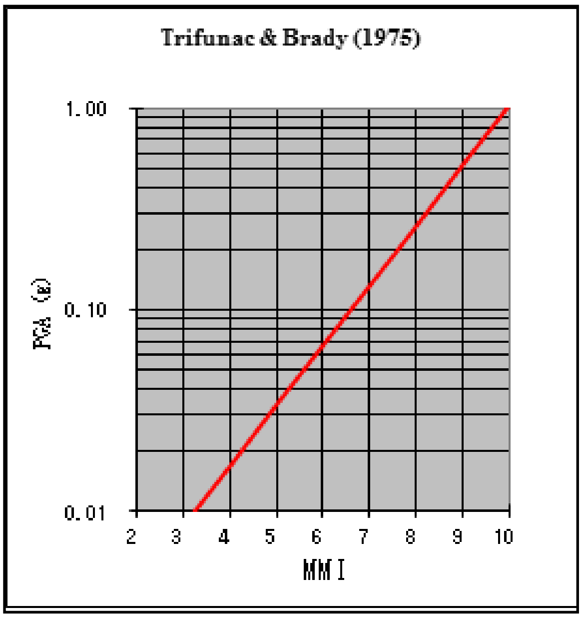
Nakamura Y.; Real time information system for hazard mitigation, 11WCEE, 1996

Figure 18: Simple model of an earthquake source



Earthquakes and volcanic eruptions; Swiss Re, 1992.





in this Tool are helpful when deciding scenario earthquake parameters. Input parameters for the scenario earthquake are location, depth, magnitude and occurrence time (hour during the day or night when the event strikes) of the earthquake. The user is required to specify the time of occurrence for the scenario earthquake because casualty count depends on whether the earthquake occurs during the night or day.

A.5. Seismic Intensity

How earthquake hazard is calculated and presented is discussed. Seismic intensity scale and PGA (Peak Ground Acceleration) are popular measures. Although there are various formula, MMI for seismic intensity scale and PGA is adopted in the Tool derived from popular empirical formula. PGA is calculated by one of three most popular attenuation formulas and converted to MMI using empirical formulae in the Tool.

The seismic intensity scale is the most familiar index to indicate the strength of ground shaking and/or how an area will be affected by an earthquake. Several types of intensity scales exist and different types are used throughout the world. The most commonly used scale is the MMI (Modified Mercalli Intensity) scale and is used in this Tool. PGA (Peak Ground Acceleration) is also used for the convenience of engineers since this parameter is used in the design or analyses of structures. Velocity or displacement parameters are used for specific purposes, but are not used in this Tool. These parameters present only the maximum values of the ground shaking time history, but there are other precise parameters that can be used to indicate the intensity of shaking depending on frequency, such as Fourier Spectrum and Response Spectrum. If precise data for the seismic source and ground conditions are available, precise parameters can be estimated.

In this Tool, PGA can be calculated using one of three attenuation formulas: Joyner & Boore (1981), Campbell (1981) or Fukushima & Tanaka (1990). PGA is converted to MMI using the empirical formula of Trifunac & Brady (1975). These formulas are popularly used worldwide.

A.6. Soil condition

Classification or zoning of ground conditions is important in the earthquake damage estimation process because ground conditions directly affect seismic amplification of ground shaking. When classifying ground conditions, a vast amount of soil data is required. This Tool adopts a simple classification, which divides the ground into 4 classes with corresponding amplification factors.

Since the differences in ground conditions have a great influence on the observed seismic intensities, precise ground classification is desirable. However, detailed databases as well as complex analyses are necessary for precise classifications because ground conditions. For example, let us assume a sand layer exists from the surface to some depth, which differs 5 to 15 m continuously. To precisely model the ground to a one-meter resolution scale, at least 11(eleven) models need to be established. It is possible to make more precise classifications considering the composition of soil layers, but the preciseness of ground classifications should depend on the quality and quantity of available data. This Tool adopts four ground classifications based on the surface soil, namely, "Hard Rock," "Soft Rock," "Medium Soil," and "Soft Soil." These classifications correspond to the amplification factors of each soil type. In addition, user may choose "Unknown" if he does not know the soil condition

"Hard Rock" corresponds to volcanic rocks, such as granite or basalt, and sedimentary rocks, such as pre-tertiary sand and mud stones. The amplification factor for "Hard Rock" is specified as 0.55, but can be changed by the user. "Soft Rock" corresponds to tertiary sand and/or mud stones and conglomerates. The corresponding amplification factor is set to 0.7. "Medium Soil" corresponds to diluvial soil and stiff alluvial soil etc. The specified amplification factor for "Medium Soil" is s set to 1.00 as a standard. "Soft Soil" corresponds to soft alluvial soil, reclaimed land and landfill etc. The amplification factor for "Soft Soil" is set to 1.30. If the soil condition is unknown, 1.0 is used as the amplification factor. The value of all the amplification factors can be changed by users.

A.7. Building Damage

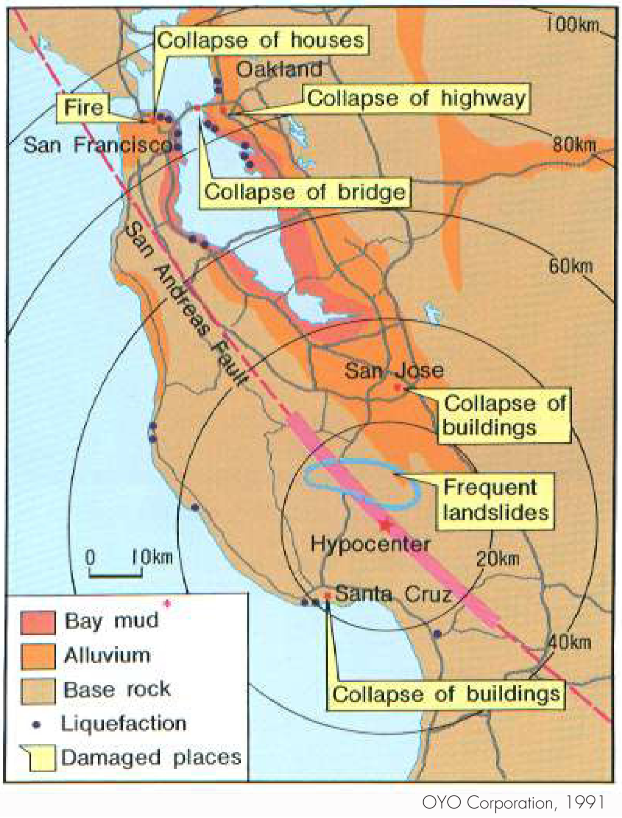
In this section, the importance of damage to buildings caused by earthquakes is discussed. For an effective estimation of damage to buildings, a building classification is necessary. Buildings may be classified according to various parameters. For example, building may be classified according to their material types, usage, age, structural types and local building codes, etc. This Tool adopts a simple building classification which categorizes buildings as one of 10 types, based on a classification used by some Latin American cities. Moreover, vulnerability functions are used for each building type which have been derived from past samples. The user inputs the percentage of each building type for each mesh area. The user also specifies the "Mesh Weight," which is defined as the relative density of buildings in each mesh unit. Thus, combining the above factors with the estimated seismic intensity distribution, building damage can be estimated.

Building damage caused by earthquakes

contributes to disasters and causes casualties and fires. Earthquake damage to buildings is greatly influenced by the types of buildings. There are various ways to classify buildings, namely by materials, construction type, building age, story or height and usage, etc. It is desirable to adopt the classification based on the factors that closely correlates to observed past damages. However, since detailed building information is not available in many cases, a general classification is often used. This Tool uses the following 10 classification categories, adopted by sample Latin American countries. This classification was determined based on the building material, construction type, applied code, usage and number of stories, etc. Also, the following classification considers that this Tool will be mainly used in developing countries.

- RES1- Informal construction: mainly slums, row housing etc. made from unfired bricks, mud mortar, loosely tied walls and roofs;
- RES2 - URM-RC composite construction: substandard construction, not complying with the local building code provisions. Height up to 3 stories. URM = Unreinforced Masonry, RC = Reinforced Concrete;
- RES3 - URM-RC composite construction: old, deteriorated construction, not complying with the latest building code provisions. Height 4 - 6 stories;
- RES4 - Engineered RC construction: newly constructed multi-story buildings, for residential and commercial purposes;

Figure 19: Distribution of ground types and damage around San Francisco in the Loma Prieta earthquake, 1989



OYO Corporation, 1991

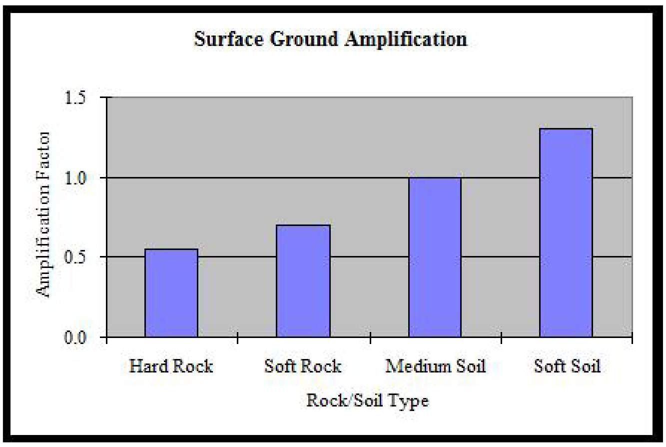


Figure 20: Typical pancake-type collapse of reinforced concrete structure (Kocaeli earthquake, Turkey, 1999)

Figure 21: Collapse of reinforced concrete structure (Kobe earthquake, Japan, 1995)

Figure 22: Collapse of masonry structure (South Italy earthquake, Italy, 1980)

Earthquake Damages: The Mother of Earthquake Engineering;
Hakuno Motohiko, Kajima Institute Publishing, 1992

Figure 23: Collapse of wooden structure (Kobe earthquake, Japan, 1995)

Figure 24: Collapse of prefabricated structure (Spitak earthquake, Armeniya, 1990)

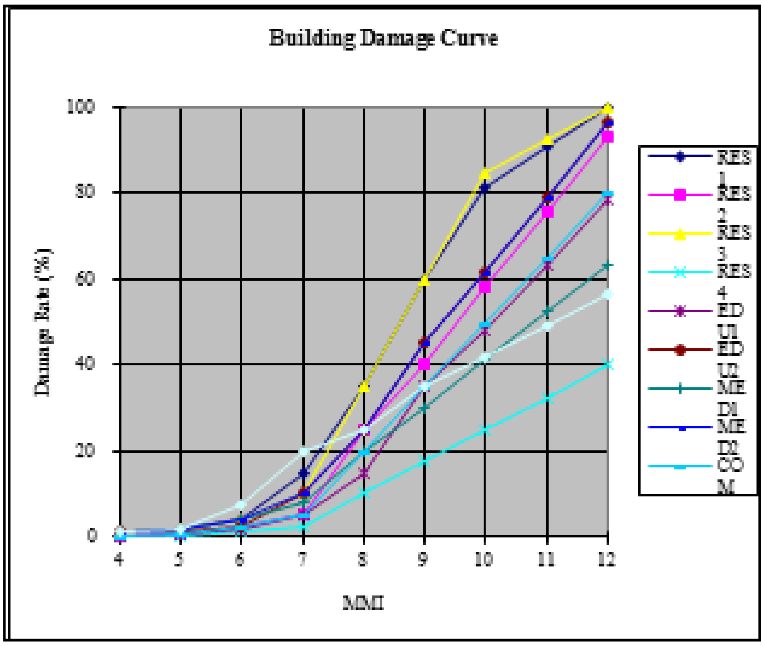
Earthquake Damages: The Mother of Earthquake Engineering;
Hakuno Motohiko, Kajima Institute Publishing, 1992

Figure 25: Collapse of adobe structure (Chile earthquake, Chile, 1985)

Earthquake Damages: The Mother of Earthquake Engineering;
Hakuno Motohiko, Kajima Institute Publishing, 1992

Figure 26: Collapsed overpass of freeway (Northridge earthquake, USA, 1994)

1994 Los Angeles Earthquake; Los Angeles Times, 1994



- EDU1 - School buildings, up to 2 stories: generally, the percentage of this type of building should be very low;
- EDU2 - School buildings, greater than 2 stories: office buildings should also be included in this class; generally, the percentage of this type of buildings should be very low;
- MED1 - Low to medium rise hospitals: generally, the percentage of this type of building should be very low;
- MED2 - High rise hospitals: generally, the percentage of this type of building should be very low;
- COM - Shopping Centers
- IND - Industrial facilities: both low and high risk.

Vulnerability functions which define the relation between seismic intensity and damage rate for structural types are determined as the function of acceleration/MMI based on damage observed during past sample earthquakes. The damage levels considered in this Tool are collapse and heavy damage. Slight damage is not considered. The number of buildings in each mesh unit is necessary to calculate the total damage amount. Since it is usually difficult to determine the precise number of buildings in each mesh unit, this Tool estimates the number of buildings in each mesh unit from a specified total number of buildings in the target area and the relative density of each mesh which is called "Mesh Weight." The Mesh Weight can be specified as "Very High", High", Medium", or "Low". The weight (relative density of building counts) is set as 3.0, 2.0, 1.0 and 0.5, respectively. These values can be changed by the user, though "medium" will be considered as the average of the other specified weights.

A.8. Lifeline Damage

If lifelines such as water, electric power, or transportation networks are affected by an earthquake, when estimating damage it is necessary to consider not only the direct loss and recovery efforts, but also the interruption of activities and daily life. Since estimation methods are often complex and need detailed input data, this Tool instead adopts a simple method which estimates total damage using a total count of lifelines in the target area. For further analyses, accurate estimations should be conducted through detailed studies.

Lifeline facilities include water, sewage, electric power, gas supplies and transportation networks, namely roads and bridges, etc. If an earthquake greatly affects lifeline facilities, not only will emergency response and recovery activities be hampered, but daily life and activities will also suffer. A database including information on location, structure and attributes of these facilities is necessary to accurately estimate the damage of lifeline networks, but, in many cases, it is difficult to gather complete data. This Tool roughly estimates the average damage amount and damage ratio for the total number of facilities in the target area. Vulnerability curves for each lifeline are determined as the function of acceleration/MMI based on observed damage to lifeline facilities in past sample earthquakes. For further analyses, accurate estimations should be conducted through detailed studies.

A.9. Casualties

Casualties caused by earthquakes are main "damages" and their reduction is targeted in disaster planning and preparedness. Building collapse is a main cause of casualties during earthquakes. Therefore, information on the number of people inside buildings when the earthquake occurs is necessary for casualty estimations. Moreover, day and night populations are different. The estimation method used by this Tool is based on past examples.

Casualties caused by earthquakes are main "damages" and their reduction is targeted in disaster planning and preparedness. The collapse or heavy damage of buildings is considered as the main cause of death and injury during an earthquake. Casualties can be calculated from the number of damaged buildings. Information on the number of people

Figure 27: People are waiting for emergency water distribution (Kobe earthquake, Japan, 1995)

Figure 28: Damaged water distribution pipeline (Chi-Chi earthquake, Taiwan, 1999)

Figure 29: Rescue team try to find trapped people in the rubble (Northridge earthquake, USA , 1994)

1994 Los Angeles Earthquake; Los Angeles Times, 1994

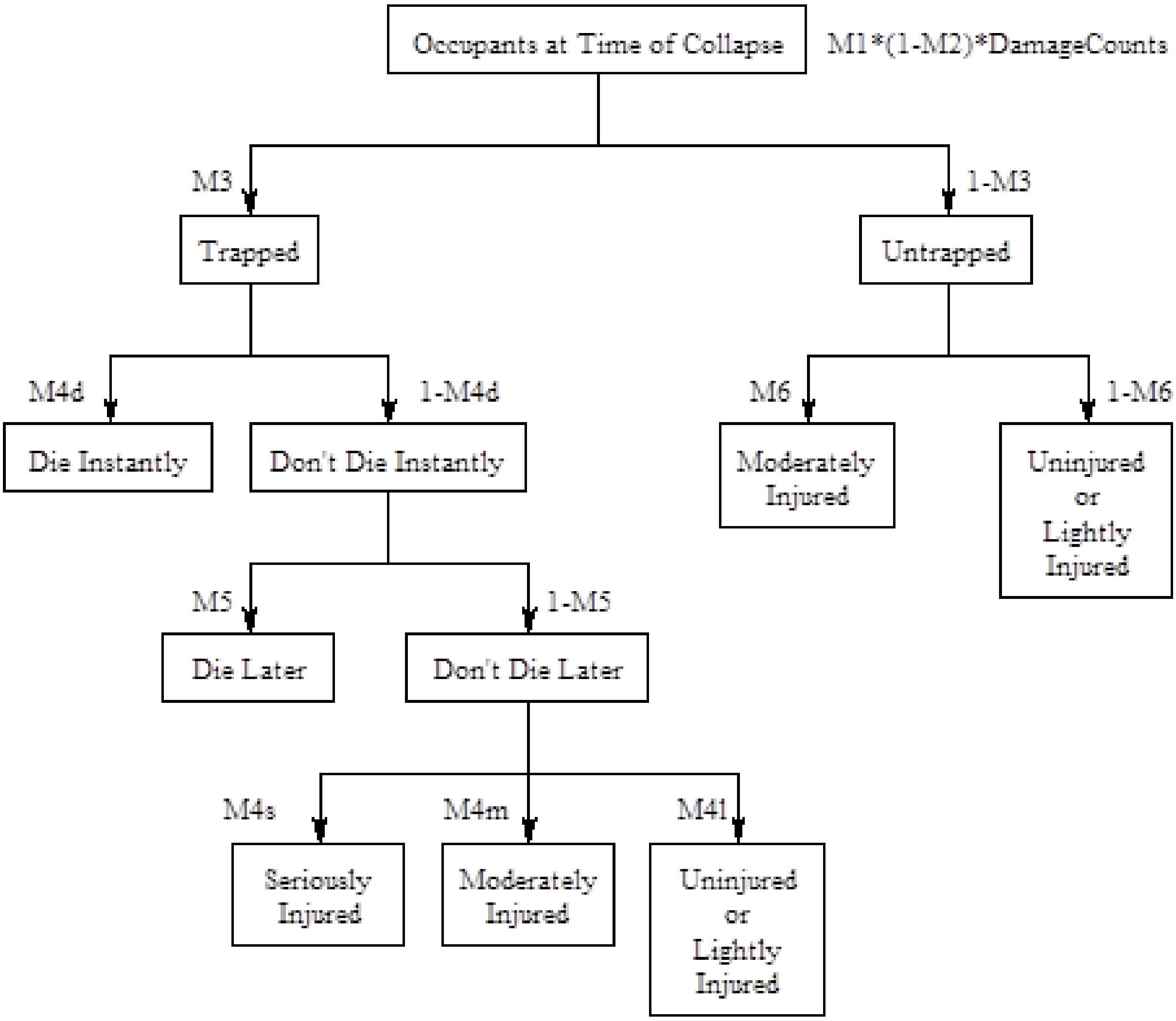
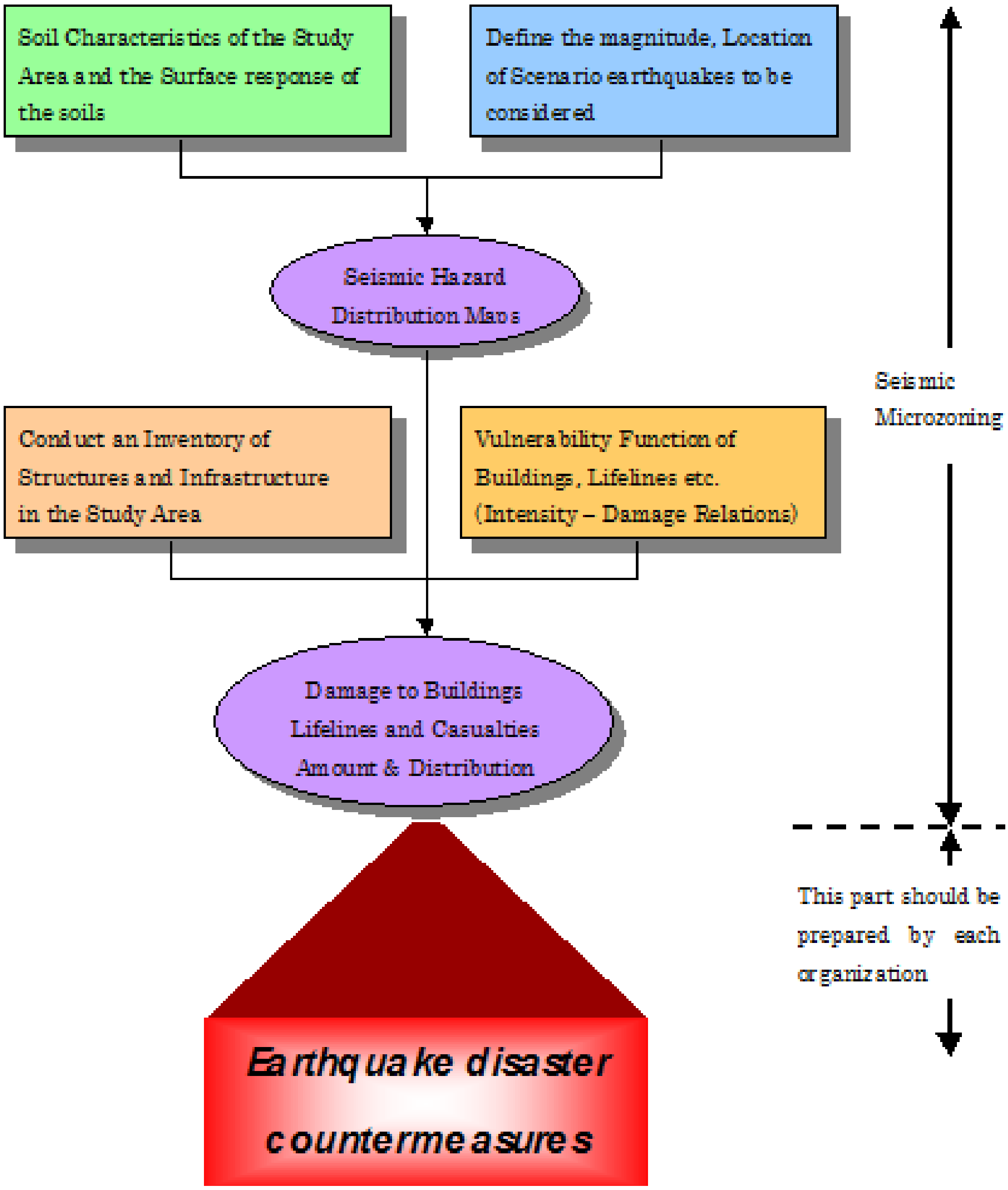


Figure 30: Flowchart of seismic microzoning study for earthquake disaster reduction. All organizations are supposed to prepare their own earthquake disaster countermeasures on the basis of the microzoning study



found inside buildings during the earthquake is necessary for casualty and injury calculations. The number of people inside buildings during the day and night is usually not the same since the ratio of usage of buildings is different. For example, day population is smaller than night population in residential dwellings. Alternatively, school and office populations are higher during the day and almost non-existent during the night. In this Tool, the day and night populations are estimated individually for each type of building classification. Day time is defined from 6 AM to 6 PM and night time is defined from 6 PM to 6 AM. Users can change the day time and night time definitions.

A.10. How to use the Damage Estimation

Although the damage estimations provided by this Tool are rough, the results of the program can be used in various ways. Through using this tool, users can gain a better understanding of earthquakes and the disasters associated with them. The potential extent of damage and the vulnerable points of the city are highlighted by the use of this Tool. It should be noted that the calculations of the damage amount should not be considered as a final goal of earthquake damage estimation, but instead as a starting point for seismic disaster reduction.

Damage Estimation leads to the knowledge/awareness of the extent of damage which the city will incur if the scenario earthquake were to occur in the city. It is possible to know not only the total amount of the damage but also the weak points of the city through the analysis. This information is very important to manage effective seismic disaster reduction measures, including preparedness, emergency response activities, and seismic retrofit and recovery actions and policies. Often, however, the budget and efforts that are readily available to implement seismic disaster reduction actions are limited in almost all countries of the world. Therefore, the knowledge of what will happen if an earthquake were to occur is indispensable for earthquake-prone cities since this information can help to set priorities in using these limited resources. To merely calculate the damage amount is not the goal of the earthquake damage estimation. The damage estimation should serve as a starting point for effective seismic disaster mitigation.

A.11. Earthquake terminology

PGA: PGA stands for peak ground acceleration, which represents the ground shaking acceleration in terms of g (acceleration due to gravity of the earth = 9.81 m/sec/sec) or any acceleration unit. PGA can be measured using an accelerograph.

MMI: MMI stands for Modified Mercalli Intensity. The other popular earthquake intensity scales are JMA, MSK, Rossi-Forrel and Chinese ones etc. MMI is one of the most widely accepted and used earthquake damage estimation scales. MMI scale is not based on any scientific basis, rather it has evolved based on experiences from observed damages in the aftermath of earthquakes. Many researchers have proposed relationships between PGA and MMI. RADIUS Program is using the one given by Trifunac and Brady (1970). The MMI scale ranges from 1 – 12, although any damage could be expected only at MMI greater than or equal to 4.0, and this is the reason why MMI values less than 4.0 are ignored in this program. Following is a description of the MMI scale (after UNESCO Working Group).

MMI	DESCRIPTION
4	Largely Observed - The earthquake is felt indoors by many people, outdoors by a few. Here and there people wake up, but no one is frightened. The vibration is similar to passing of a heavily loaded truck. Windows doors and dishes rattle. Floors and walls creak. Furniture begins to shake. Hanging objects swing slightly. Liquids in open vessels are slightly disturbed. The shock is noticeable in standing motor cars.
5	Awakening - The earthquake is felt indoors by all, outdoors by many. Many sleeping people wake up. A few run outdoors. Animals become uneasy. Buildings tremble throughout. Hanging objects swing considerably. Pictures knock against walls or swing out of place. Occasionally, pendulum clocks stop. Unstable objects may be overturned or shifted. Open doors and windows are thrust open and slam back again. Liquids spill in small amounts from well-defined open containers. The sensation of vibration is similar to the falling of a heavy object inside the building.
6	Frightening - Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons lose their balance. Domestic animals run out of their stalls. In few instances dishes and glassware may break and books fall down. Heavy furniture may possibly move and small steeple bells may ring.
7	Damages to Buildings - Most people are frightened and run outdoors. Many find it difficult to stand. Persons driving motor cars notice the vibration. Large bells ring.
8	Destruction of Buildings - Fright and panic. Also persons driving motor cars are disturbed. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are damaged in part.
9	General Damage to Buildings - General panic. Considerable damage to furniture. Animals run to and fro in confusion and vocalize.
10	General Destruction of Buildings - Critical damages to dams and dikes and severe damages to bridges. Railway lines are bent slightly. Underground pipes broken or bent. Road paving and asphalt show waves. In ground, cracks up to a width of several cm, sometimes up to 1m. Broad fissures appear parallel to watercourses. Loose ground slides from steep slopes. Considerable landslides are possible near riverbanks and steep coasts. In coastal area displacement of sand and mud; change of water level in wells; water from canals lakes, river etc. thrown on land. New lakes appear.
11	Landscape Change - Practically all structures above and below ground are greatly damaged or destroyed. The surface of the ground is radically changed. Considerable ground cracks with extensive vertical and horizontal movements are observed. Falls of rock and slumping of river banks over wide areas; lakes are dammed; waterfalls appear and rivers are deflected. The intensity of the earthquake requires special investigation.
12	MMI > 11 is impractical, as everything gets destroyed at MMI = 11.

Annex B. Maps and Google addresses

B.1. Data maps RADIUS

The RADIUS tool aims to facilitate preliminary estimation of earthquake damage. The tool takes into account that city administrators are likely to have only a vague idea of the seismic susceptibility of a city. The tool aims to be practical, mainly for promoting awareness of earthquake risk. It is not to be used for accurate engineering analysis or detailed risk assessment. To apply the RADIUS tool, it was necessary to divide the city into a mesh of small areas. For this project, of the size of the mesh was 500x 500 m using aerial photos, as shown in Figure 1 of this Section, which in turn are represented by marked spreadsheet cells called meshes. These meshes are generated to enter generic information on demographics, relative density of buildings, soil type, and inventory information related to buildings.

The mesh weight by population density was generated for each district using aerial photo, as shown in Figure 2 of this Section.

The soil type distribution in Tijuana for each mesh was generated using a geological map, shown in figure 3, following the criteria from this tool: 0 for unknown soil type (considered as average in the software), 1 for hard rock/ bed rock, 2 for soft rock, 3 for medium or average stiff soil and 4 for soft soil/land fill/reclaimed land. These classes are matched with their amplification factors during the analysis: 0.55, 0.7, 1.0 or 1.3 for soil types of 1, 2, 3 or 4 respectively.

The building classes adopted for this study were selected only for residential building from RES1 to RES4. The data for building inventory that most closely matches the building classes in the software was obtained from Civil Protection Municipal System, Shown in figure 4. This software adopted the classification of ten types with the vulnerability function for each class that was derived from past samples. Counts at each mesh are estimated from total counts entered by the user, and mesh weight indicates relative density of buildings in each mesh. Through the combination of these factors with estimated seismic intensity scale, building damage can be estimated.

The six earthquake scenarios were defined by researchers from CICESE, following the criteria and parameters of this tool. The six epicenters are associated to three faults close to the city, shown in Figure 5.

Figure 31: Mesh 500x500 meter. Example: San Antonio de los Buenos district

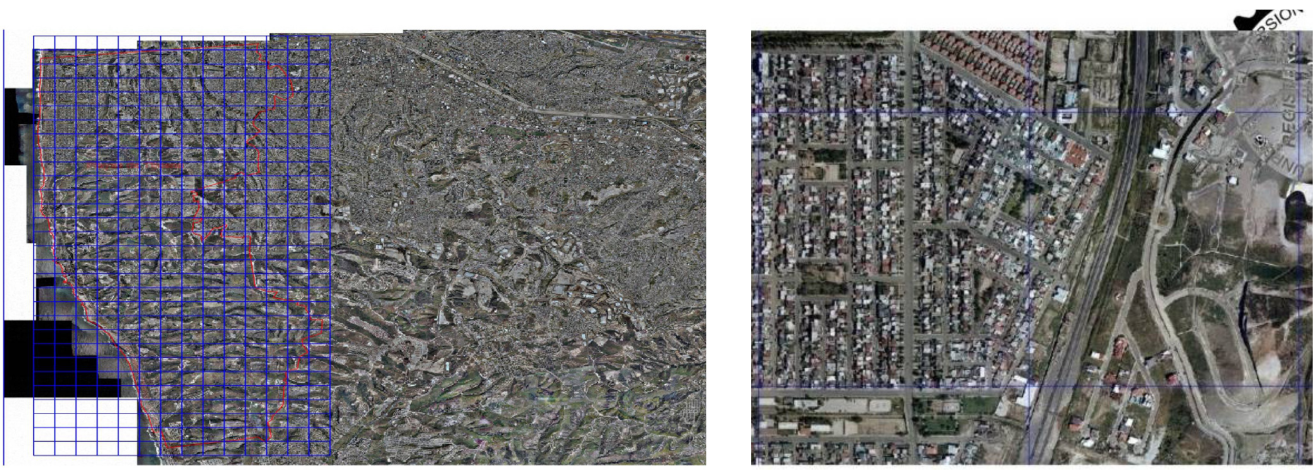


Figure 32: Population distribution in Tijuana

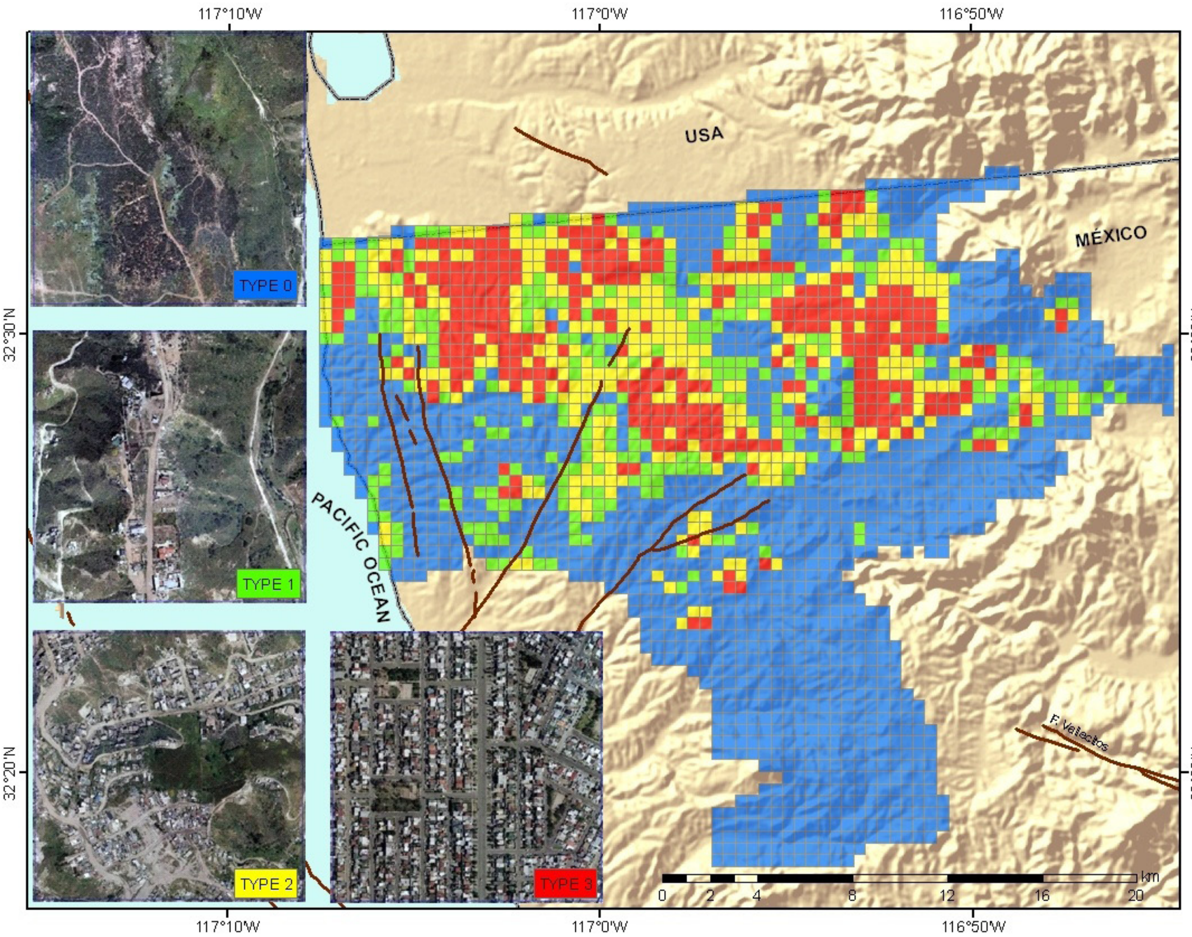
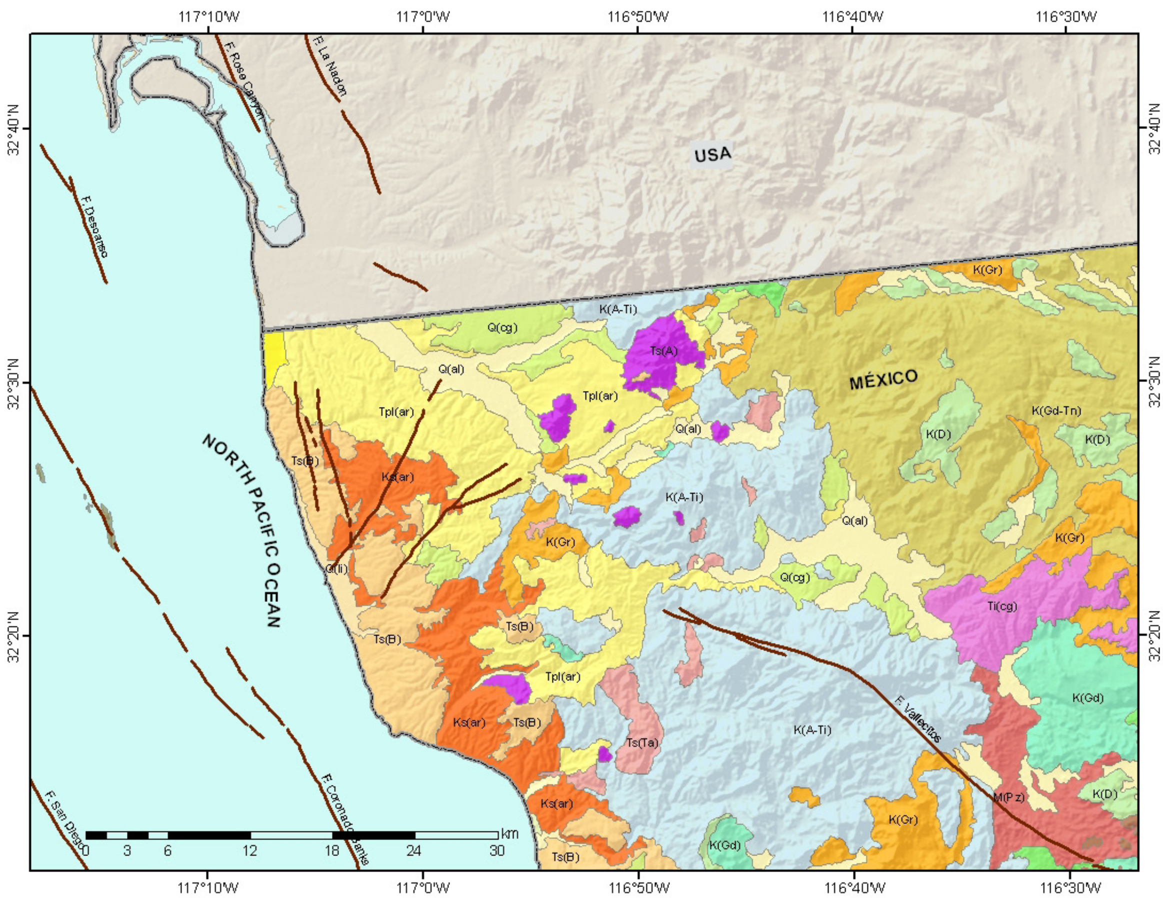


Figure 33: Types of soil distribution in Tijuana urban zone



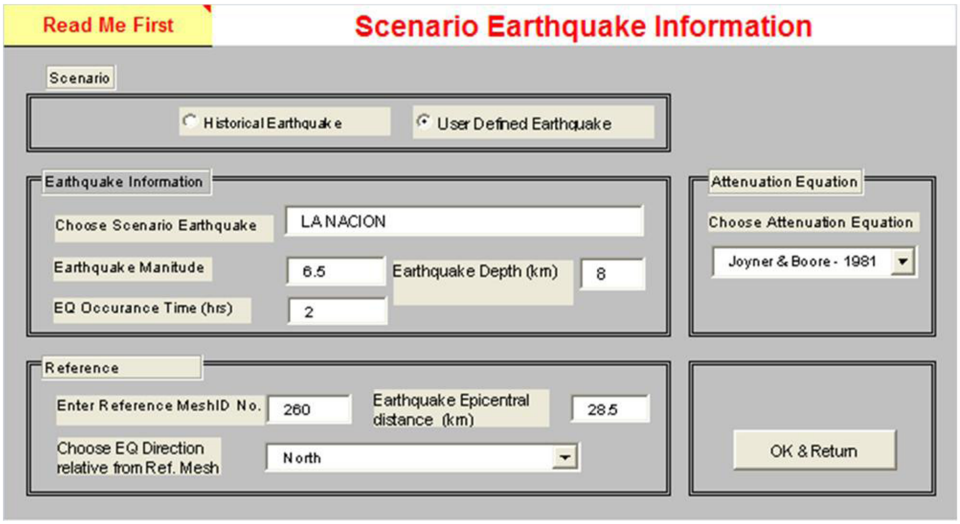
The software RADIUS99 first estimates PGA parameter values and next through an empiric relation, changes to MMI values and with the observation relations passes to damage percentages. The results are presented in that sequence: PGA, MMI and MDR (mean damage ratio) of buildings. These results can be viewed graphically in ArcGIS, to provide a better understanding of the results of earthquake damage estimation by presenting data in the form of maps. The earthequake scenarios below show the results for the 6 Scenarios.

Figure 34: San Antonio de los Buenos district

Figure 35: Buildings classes explanation by districts. The picture shows typical construction of SAB.

Area ID	Area Name	RES1 (%)	RES2 (%)	RES3 (%)	RES4 (%)	Sum (%)
1	SAB	60	35	0	5	100
2	CEN	55	40	0	5	100
3	CTO	30	60	0	10	100
4	CCO	45	50	0	5	100
5	CVE	40	60	0	0	100
6	LME	15	50	20	15	100
7	PRE	35	40	20	5	100
8	OTA	20	40	30	10	100
9	PLA	20	40	15	25	100
10	TAB	30	30	35	5	100

Figure 36: Earthquake scenario EQ6 for SAB district, reference mesh #260 to 28.5 km of epicentral distance



2. Results of PGA, MMI and MDR for 6 evaluated scenarios

Figure 37: Earthquake 1 in north segment of the Silver Strand Fault (a) and its PGA values and school locations (b)

a)

b)

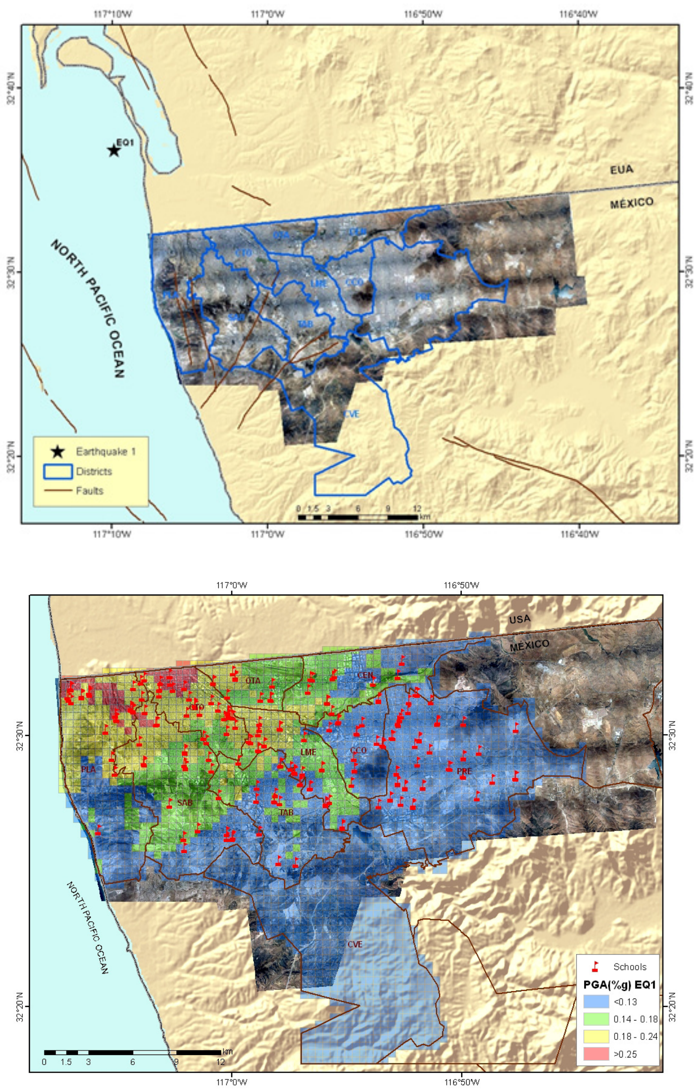


Figure 38: Earthquake 1 Modified Mercalli Intensity values

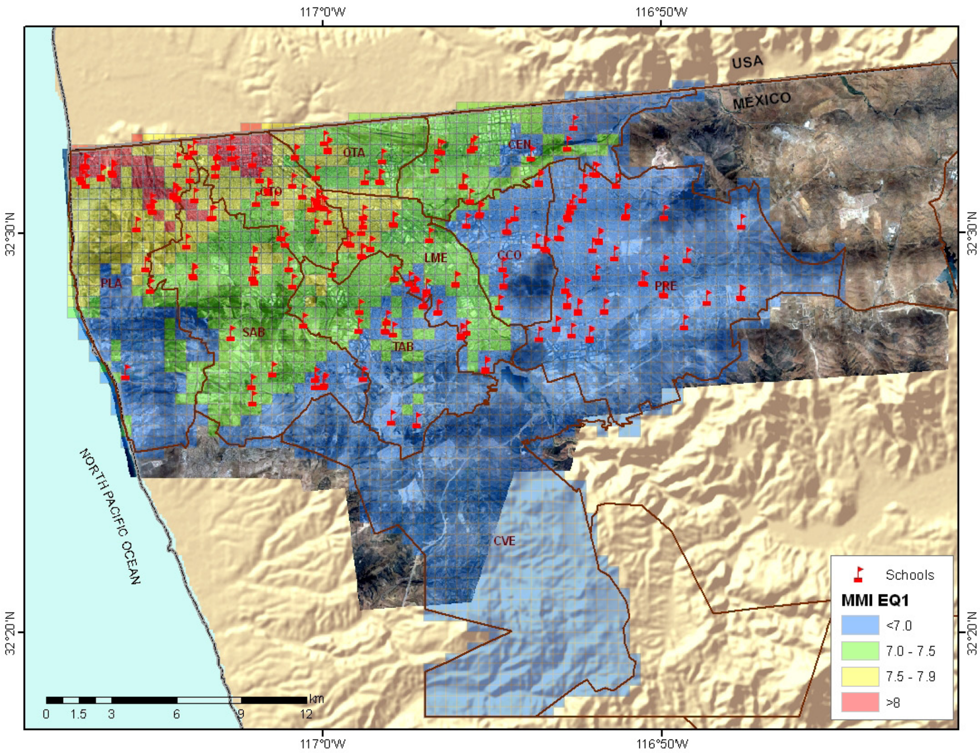


Figure 39: Earthquake 1 and average percentage values of buildings with severe damages

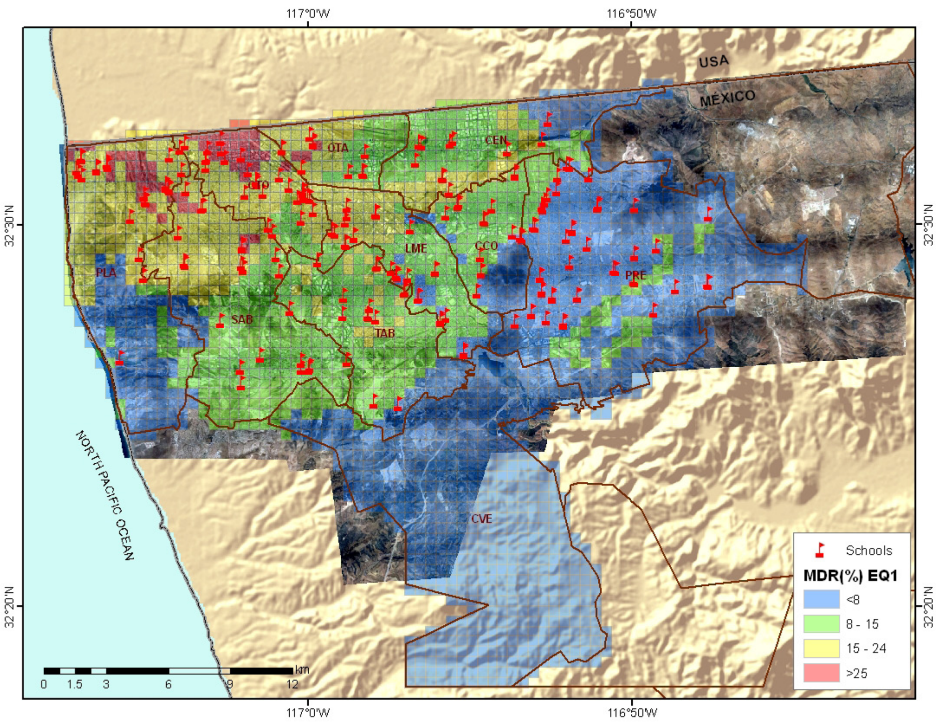


Figure 40: Earthquake 2 in Silver Strand fault (a) and its PGA values in school locations (b)

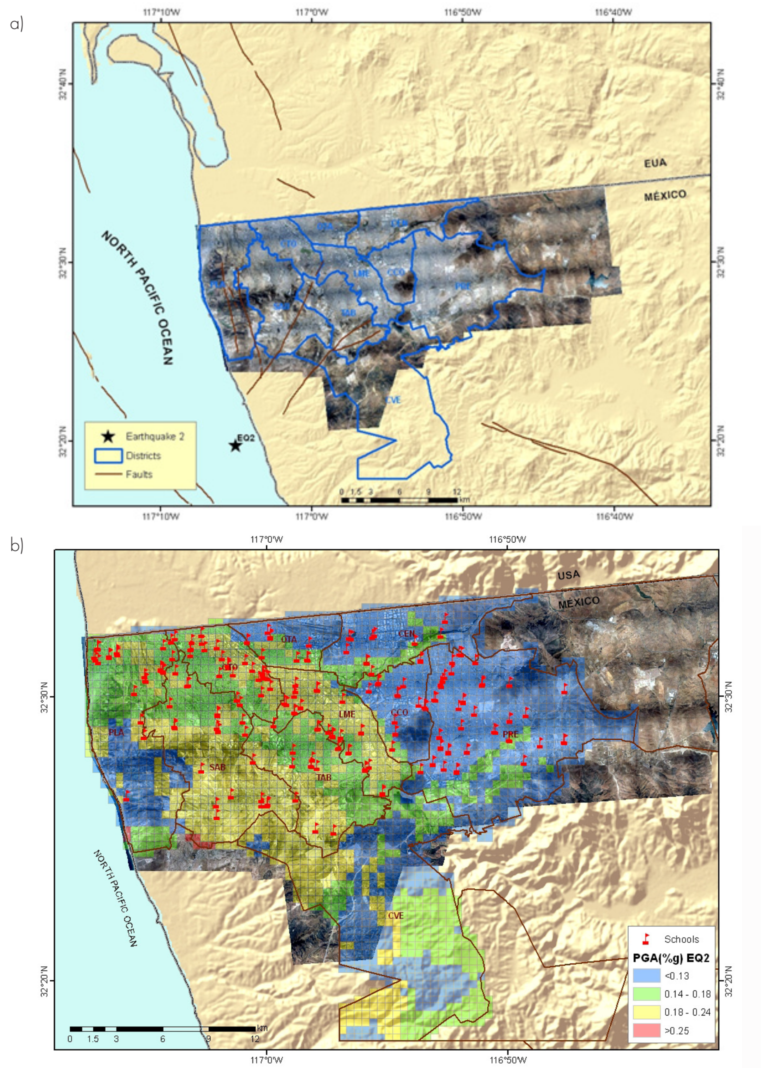


Figure 41: Modified Mercalli Intensity values for earthquake 2

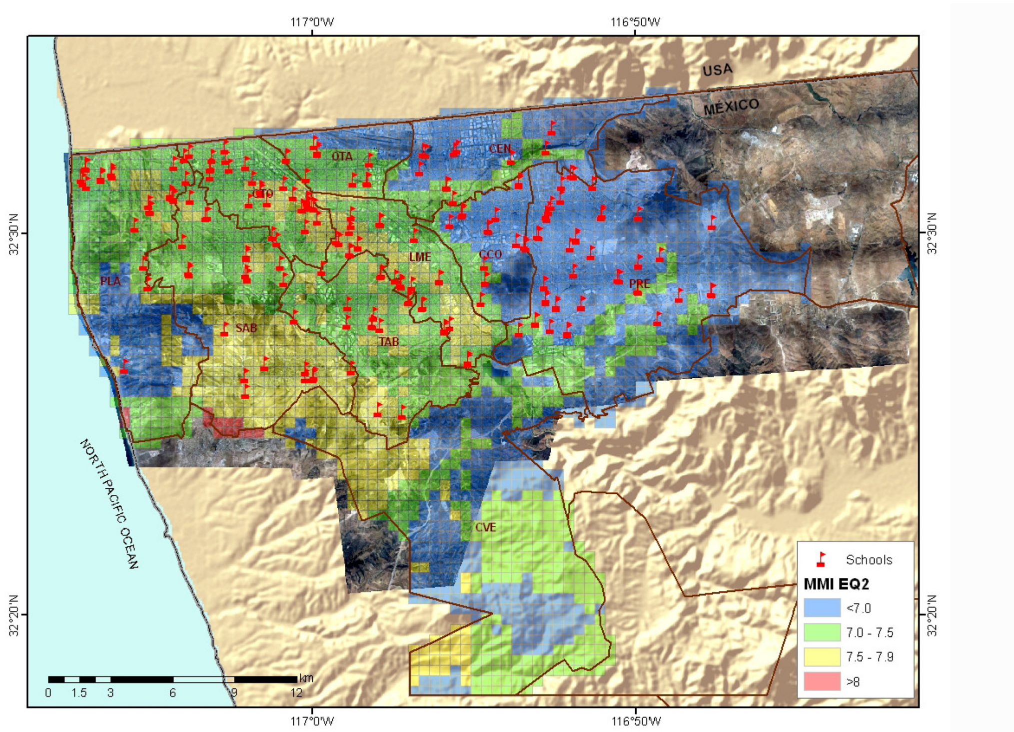


Figure 42: Average percentage values of buildings with severe damage of earthquake 2

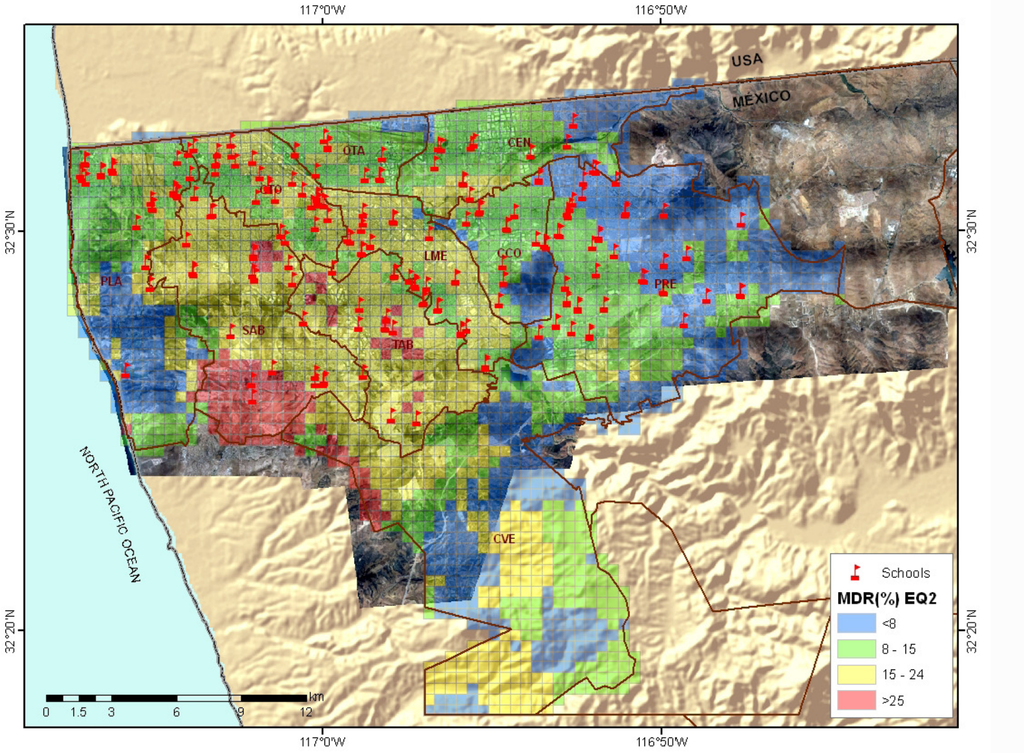
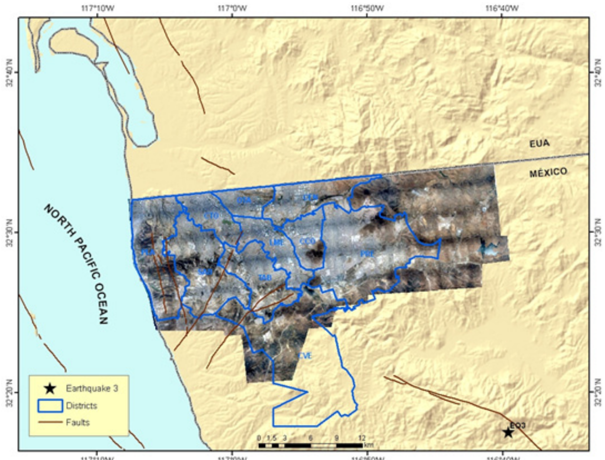


Figure 43: Earthquake 3 in south segment of Vallecitos Fault (a) and its PGA values in school locations (b)

a)



b)

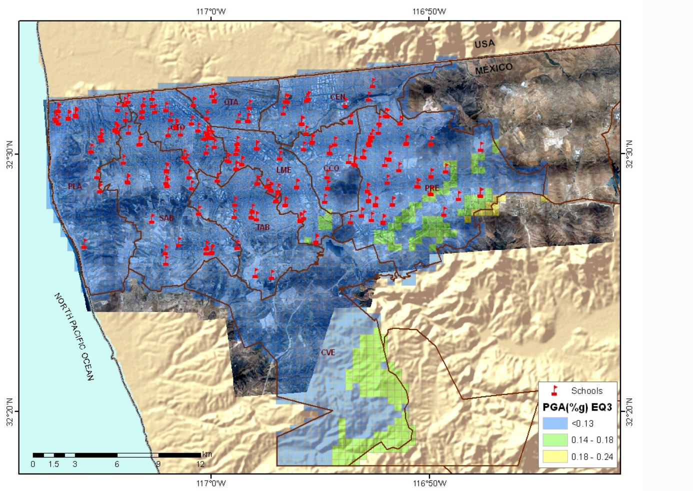


Figure 44: Modified Mercalli Intensity values of earthquake 3

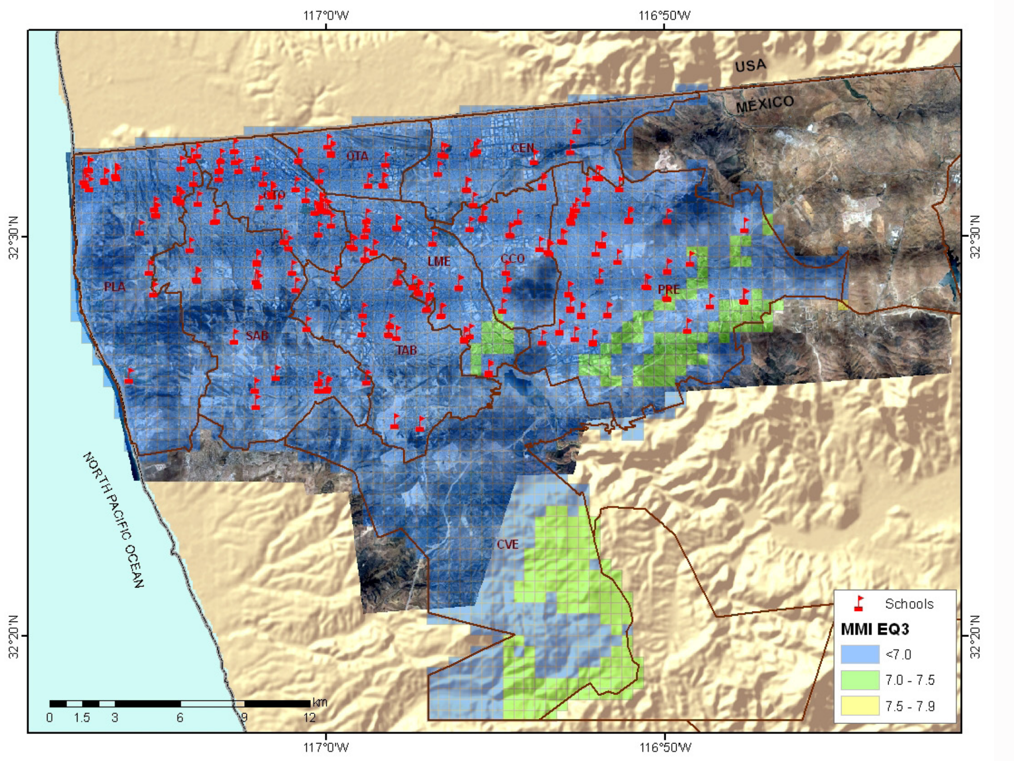


Figure 45: Average percentage values of buildings with severe damage of earthquake 3

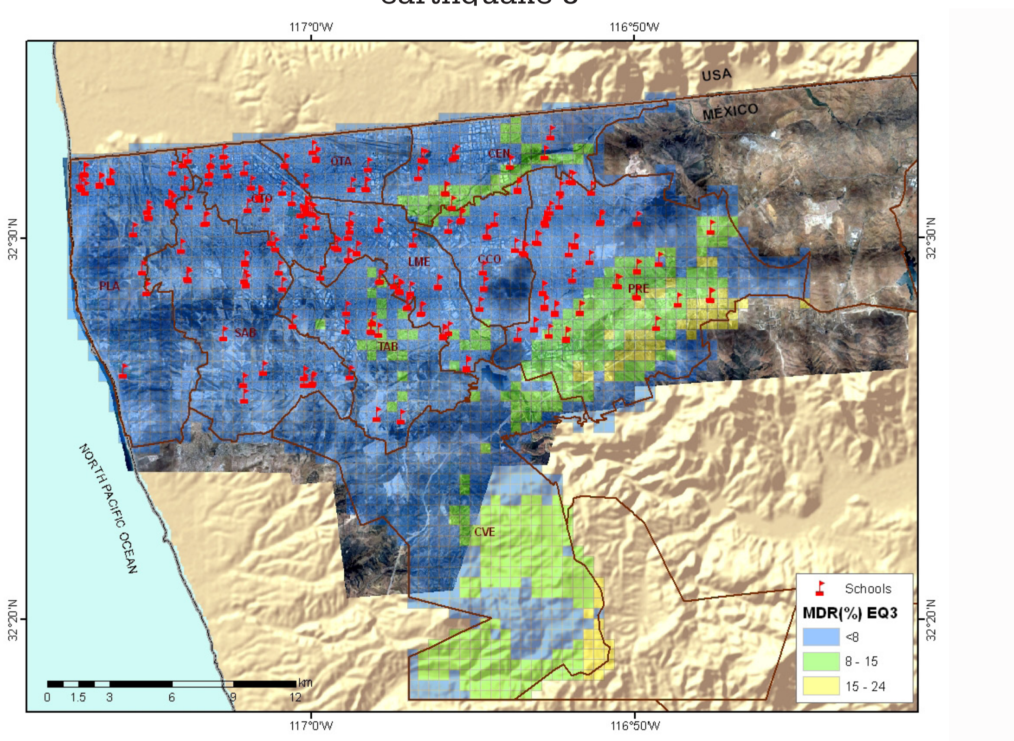


Figure 46: Earthquake 4 in south segment of La Nacion Fault (a) and its PGA values in school locations (b)

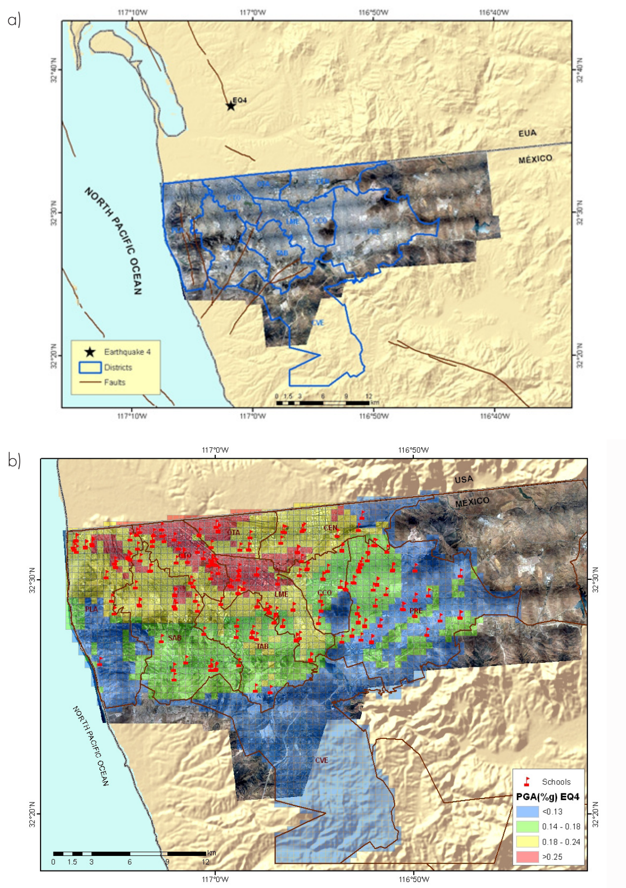


Figure 47: Modified Mercalli Intensity values of earthquake 4

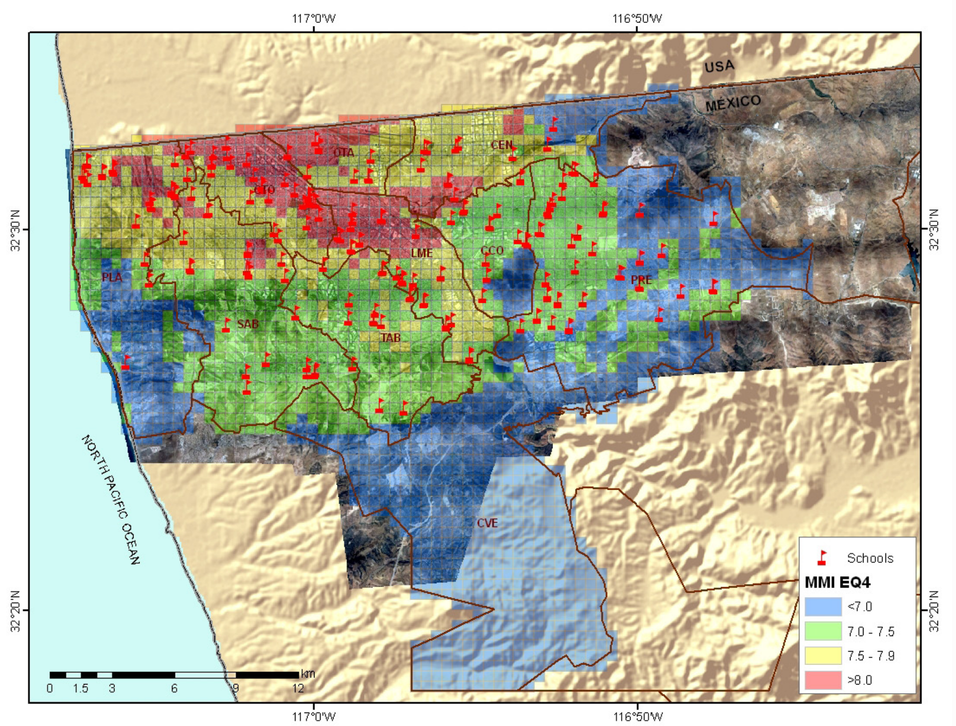


Figure 48: Average percentage values of buildings with severe damage of earthquake 4

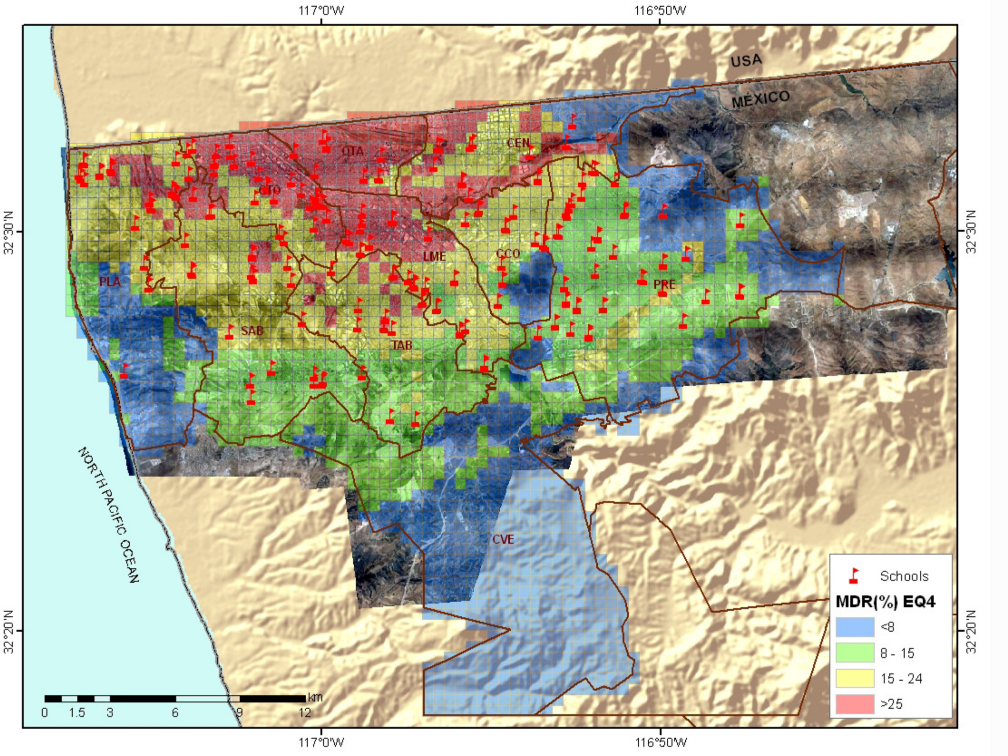


Figure 49: Earthquake 5 in north segment of the Vallecitos Fault (a) and its PGA values with school locations (b)

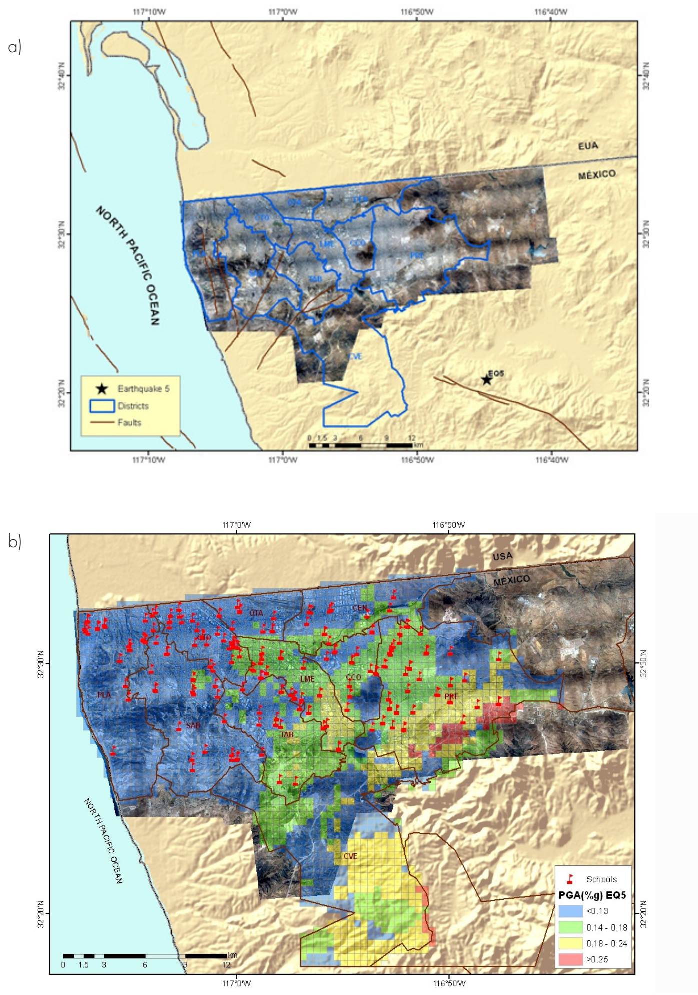


Figure 50: Modified Mercalli Intensity values for earthquake 5

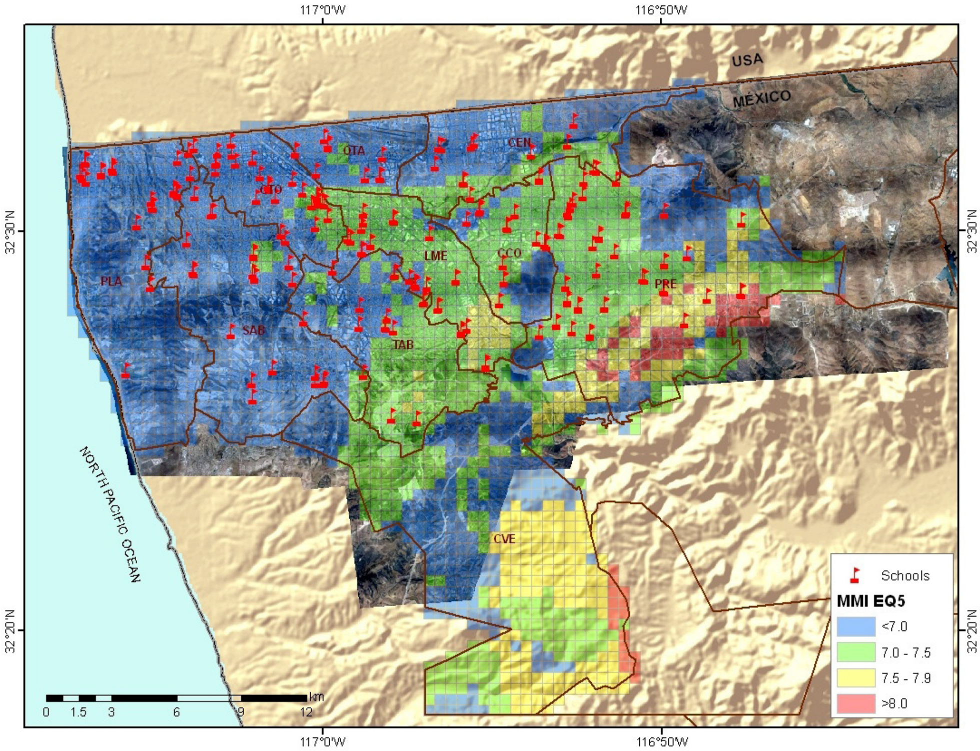


Figure 51: Average percentage values of buildings with severe damage of earthquake 5

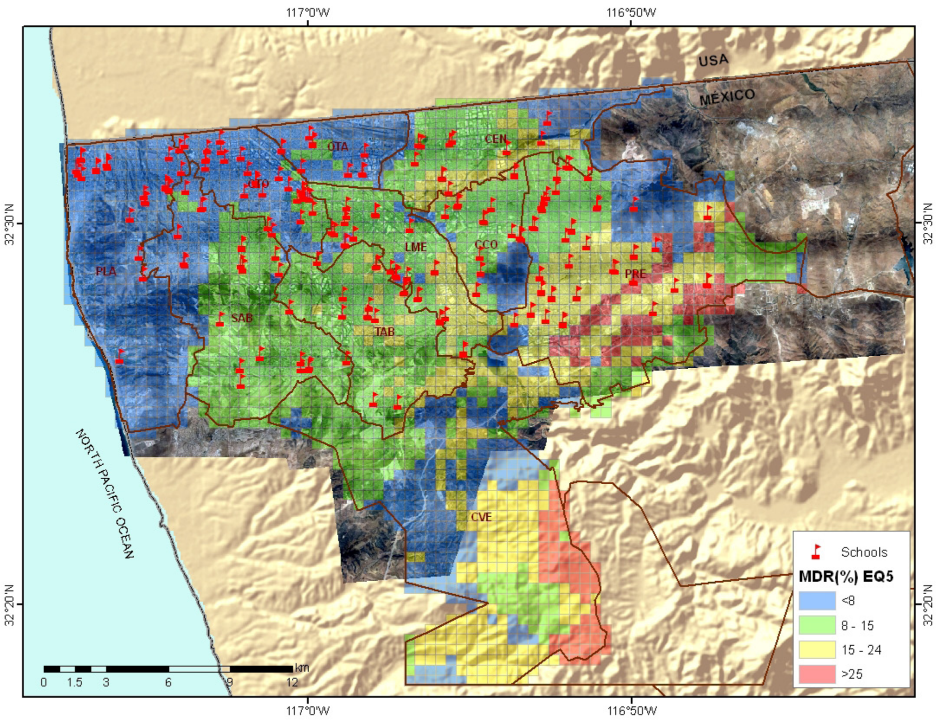


Figure 52: Earthquake 6 in north segment of La Nacion Fault (a) and its PGA values in school locations (b)

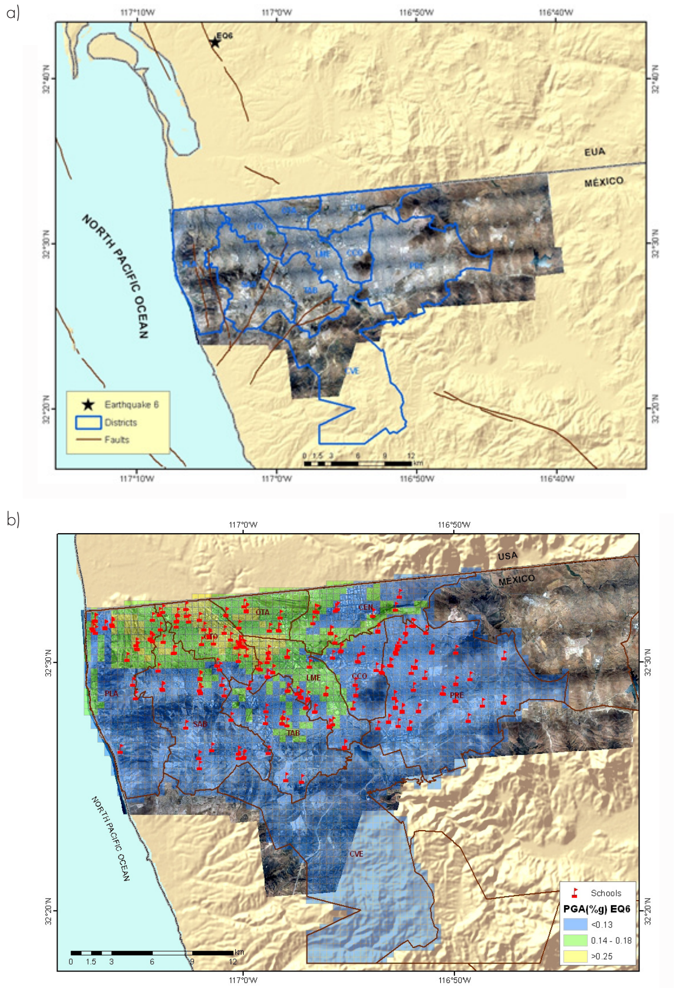


Figure 53: Modified Mercalli Intensity values of earthquake 6

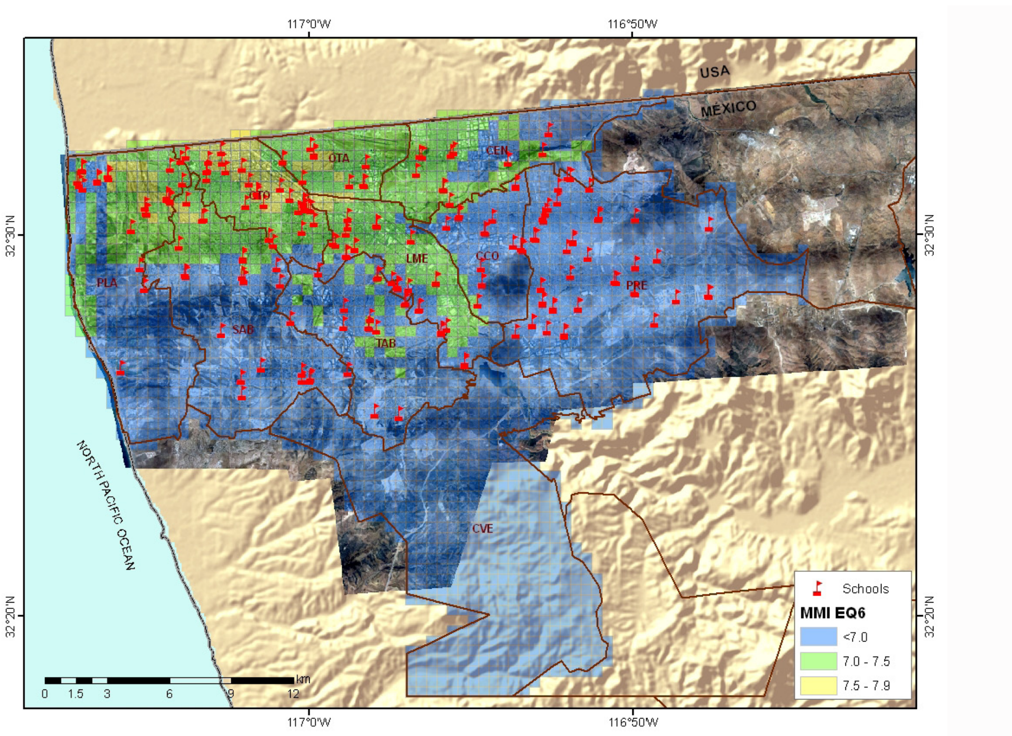
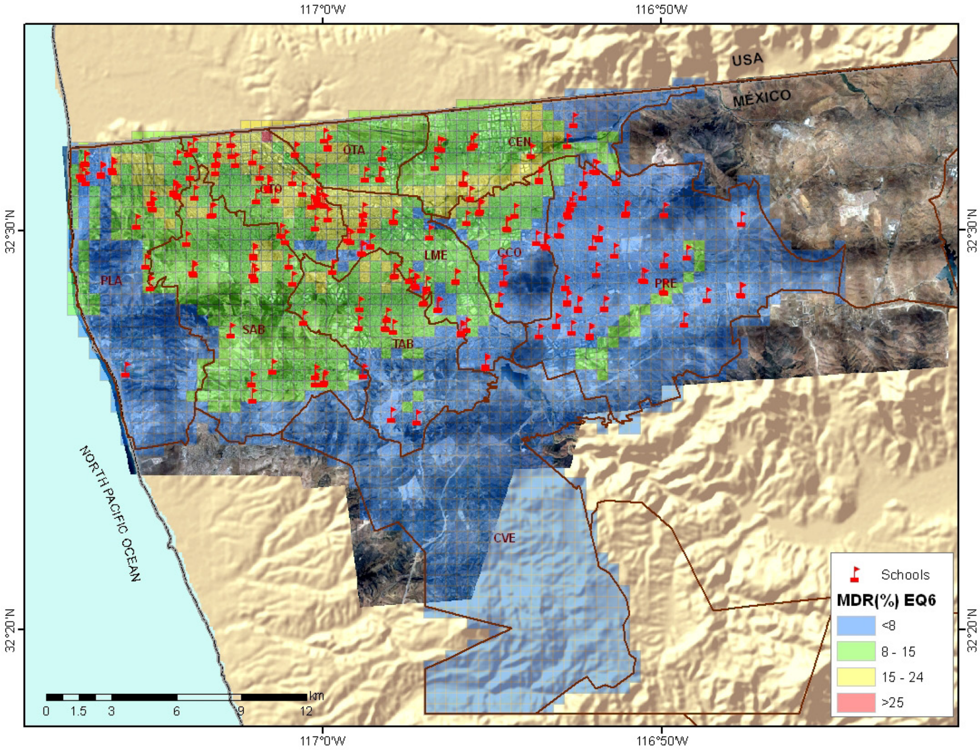


Figure 54: Average percentage values of buildings with severe damage of earthquake 6



B.3. Results by District for EQ4

District results are presented in 500 x 500 m. grids, for EQ4, located 8 km to northern of Tijuana. This earthquake is the worst scenario for the city of Tijuana because of its closeness and population density involved in those distances. The estimate of the number of people who would need shelters was done in terms of the damaged buildings in each district. Tables I and II of this section show the results for the scenario presenting more damages (EQ4) and for the hypothetical scenario EQ6, the direction and closest distance from each district to the Shelters is presented.

The Mean Damage Ratio (MDR) is in % values. The software RADIUS99 considers such value as a percentage (%) of buildings in each grid with severe damage or collapse. Figures 24 – 32 show the MDR results from EQ4 by ten districts of Tijuana, which present an approximate idea of the hazard and vulnerability of the city. These results are useful for people and governments to have an idea of the property damage and human life loss to a city, if a big earthquake would occur, like EQ4.

Table 8: Number of people with shelter needs according to EQ4 earthquake scenario for each district

Districts	Direction	Distances of epi-centers (Km)	Damage buildings	Buildings*4pers	Persons/3
SAB	N	18.50	9,409	37,637	12,543
CEN	NW	15.00	7,249	28,996	9,663
CTO	N	12.39	8,935	35,739	11,910
CCO	NW	15.21	4,607	18,426	6,141
CVE	N	21.81	1,286	5,144	1,714
LME	N	12.37	7,619	30,476	10,156
PRE	NW	14.90	9,722	38,886	12,959
OTA	N	9.42	6,106	24,424	8,139
PLA	NE	15.00	6,169	24,677	8,224
TAB	N	15.85	7,736	30,946	10,313
Total number of people in provisional shelters for EQ4					91,761

Table 9: Number of people with shelter needs according to EQ6 earthquake scenarios for each district

Districts	Direction	Distances of epi-centers (Km)	Damage buildings	Buildings*4pers	Persons/3
SAB	N	28.50	5,449	21,795	7,263
CEN	NW	23.17	3,805	15,222	5,073
CTO	N	22.30	5,092	20,370	6,788
CCO	NW	23.37	2,359	9,438	3,145
CVE	N	31.81	844	3,376	1,125
LME	N	22.37	3,858	15,431	5,142
PRE	NW	23.08	5,469	21,877	7,290
OTA	N	19.42	3,353	13,412	4,469
PLA	NE	23.17	3,474	13,895	4,631
TAB	N	25.85	3,950	15,801	5,266
Total number of people in provisional shelters for EQ6					50,192

Figure 55: Estimated percentage by grid of buildings with severe damages or collapse, in Playas and Cerro Colorado district (earthquake no. 4, M=6.5, southern segment of La Nacion fault)

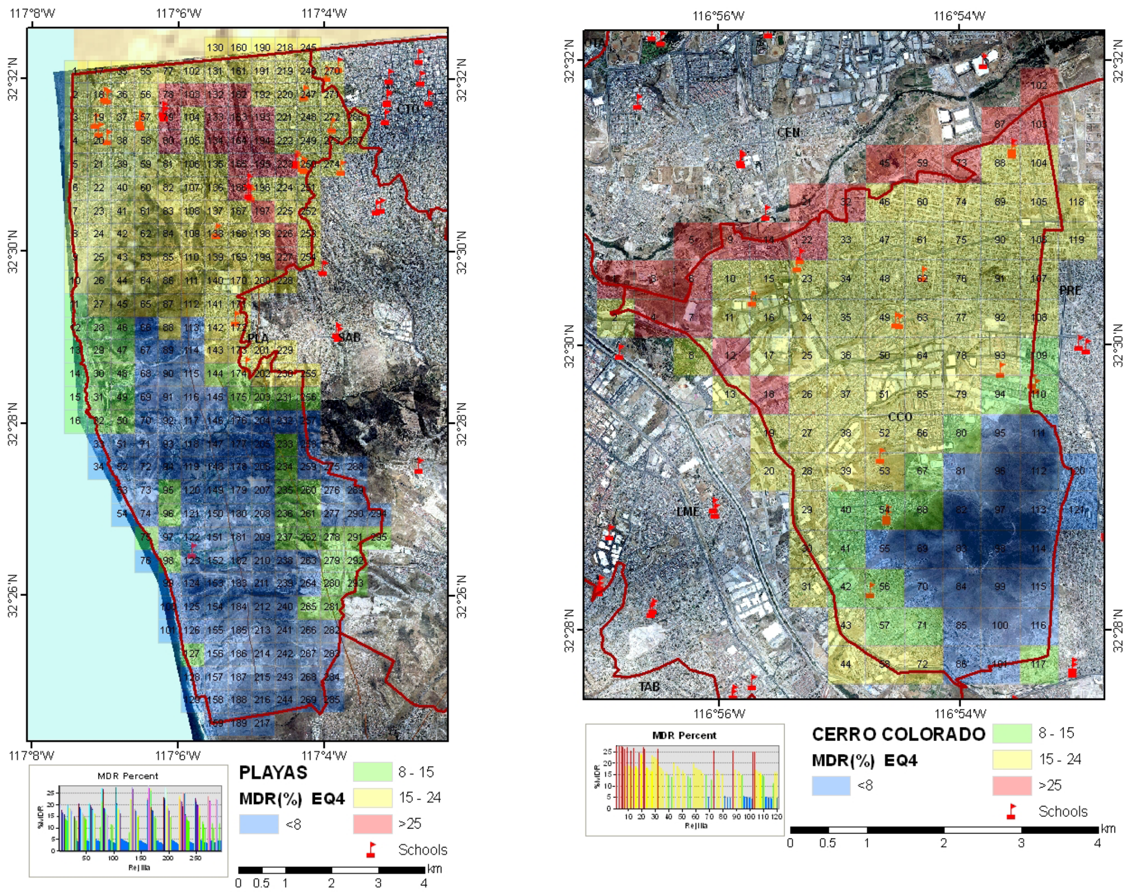


Figure 56: Estimated percentage by grid of buildings with severe damage or collapsed in Centro District

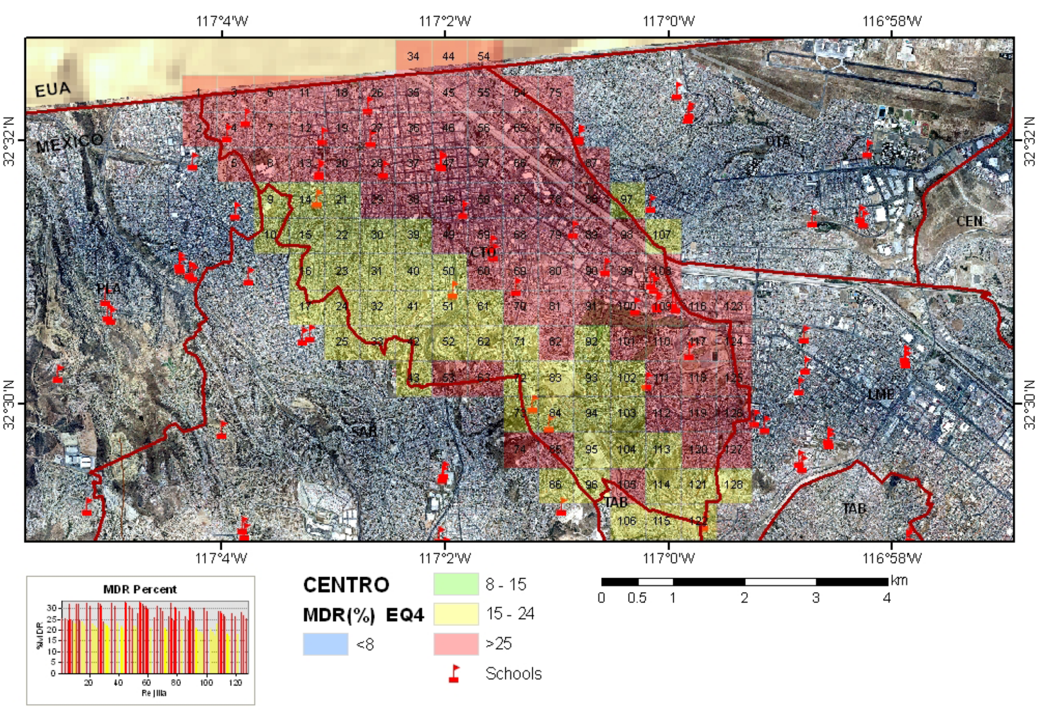


Figure 57: Estimated percentage by grid of buildings with severe damages or collapse, in Otay District

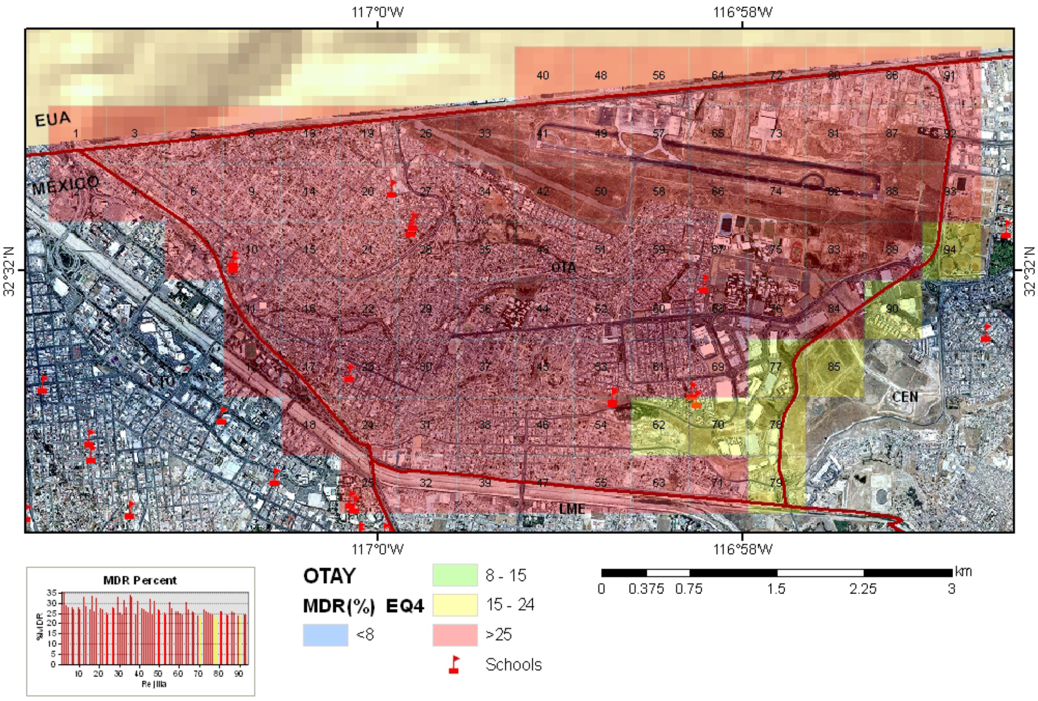


Figure 58: Estimated percentage by grid of buildings with severe damages or collapse, in La Mesa District

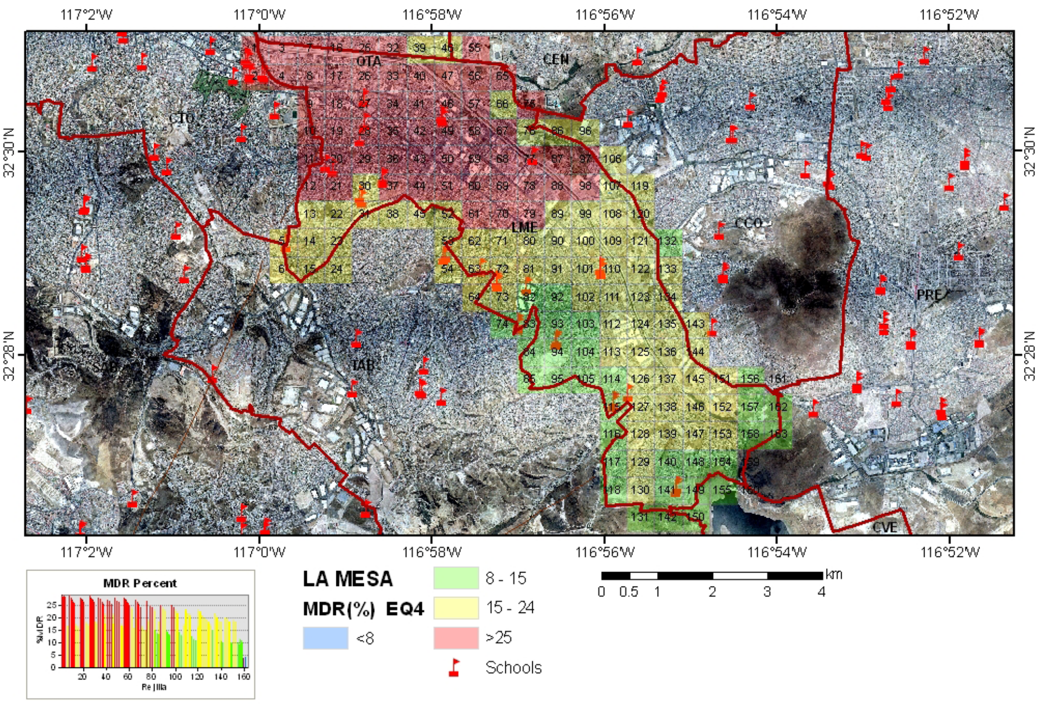


Figure 59: Estimated percentage by grid of buildings with severe damages or collapse, in Centenario District

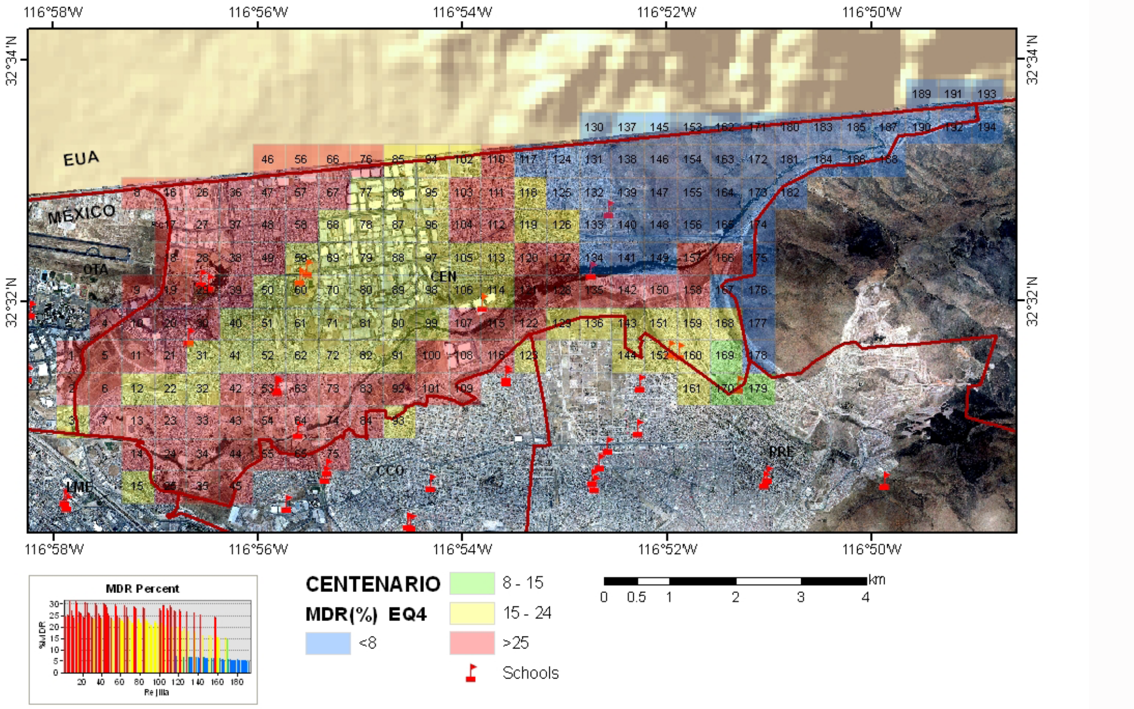


Figure 60: Estimated percentage by grid of buildings with severe damages or collapse, in La Presa District

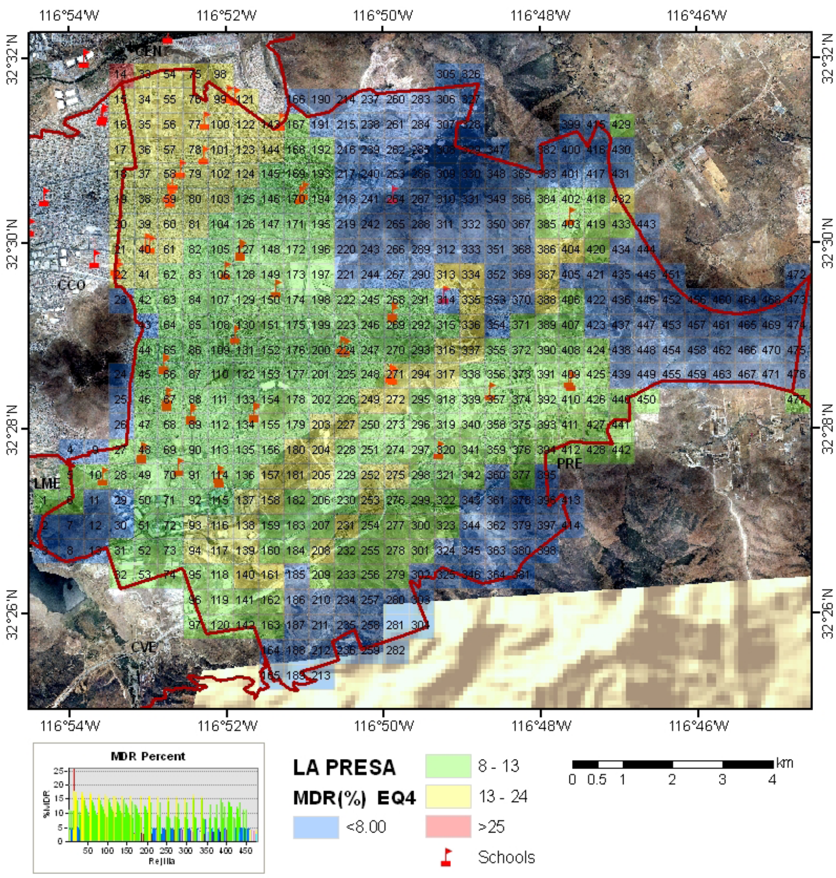


Figure 61: Estimated percentage by grid of buildings with severe damages or collapse in Sánchez Taboada District

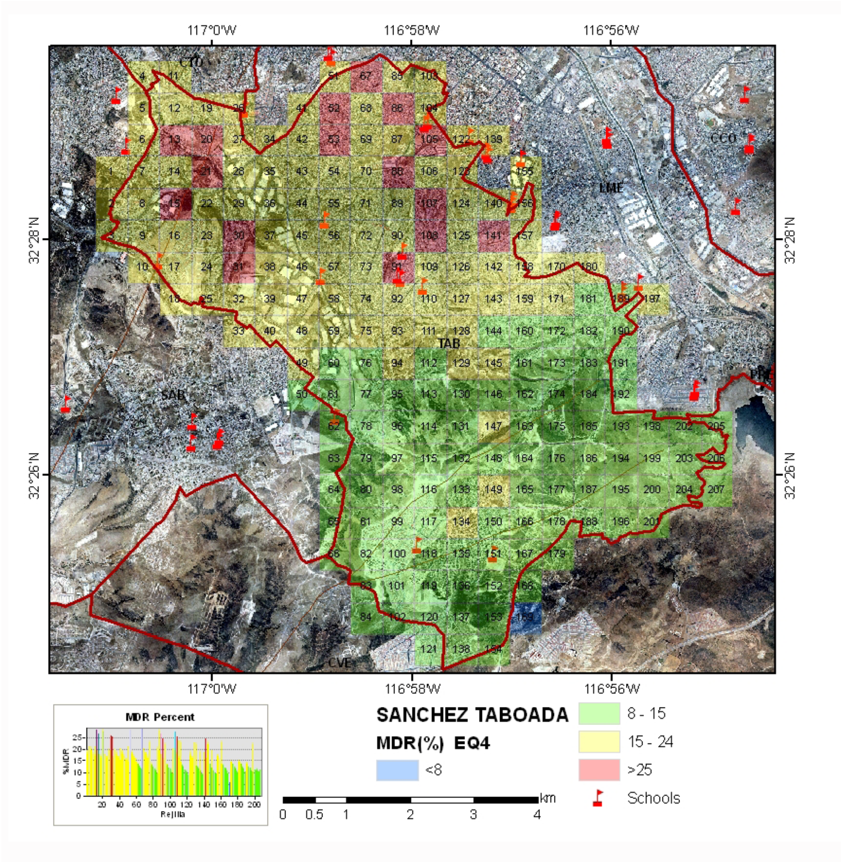


Figure 62: Estimated percentage by grid of buildings with severe damages or collapse, in San Antonio de los Buenos district

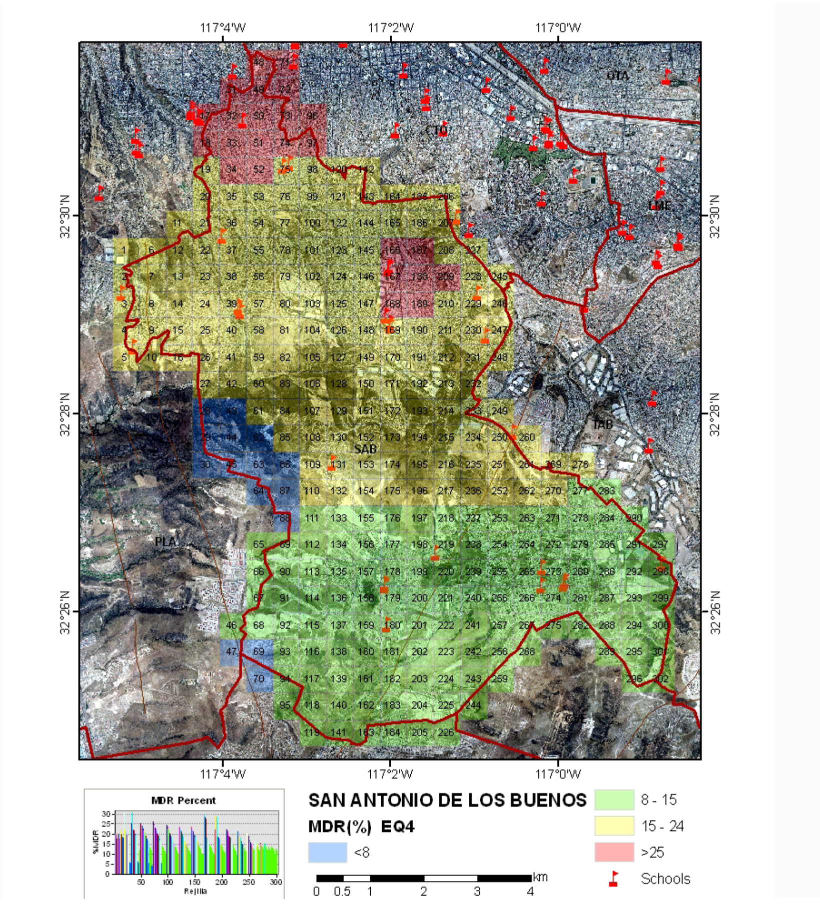
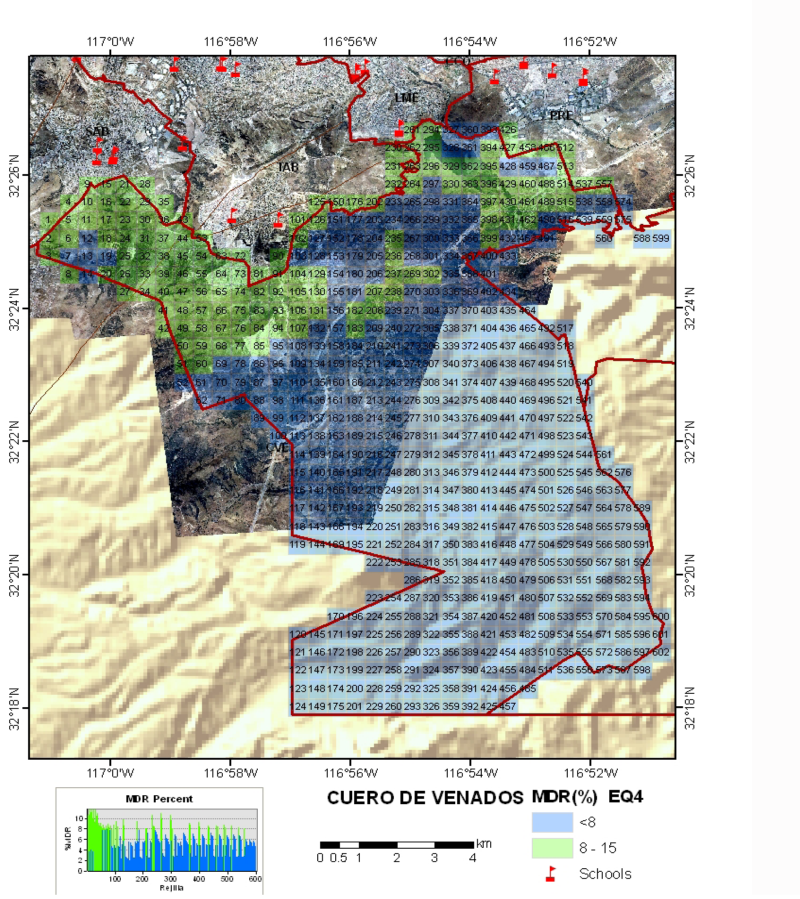


Figure 63: Estimated percentage by grid of buildings with severe damages or collapse, Cuero de Venados District



B.4. Location of proposed sites for provisional shelters in Google maps

The maps showing the locations of provisional close and open shelters can be accessed using the following link: http://maps.google.com/maps/user?uid=103294852585284210499&hl=es&ptab=2 or alternatively by searching for "Tijuana Earthquake shelters" in and clicking on the (title of the page). The list of these spaces along with their addresses is shown in Annexes C and D.

The detail in the open spaces to be used as shelters is shown through aerial photographs shown in figures 65 - 71 below.

Figure 64: Map showing the shelter location through the internet using Google Maps

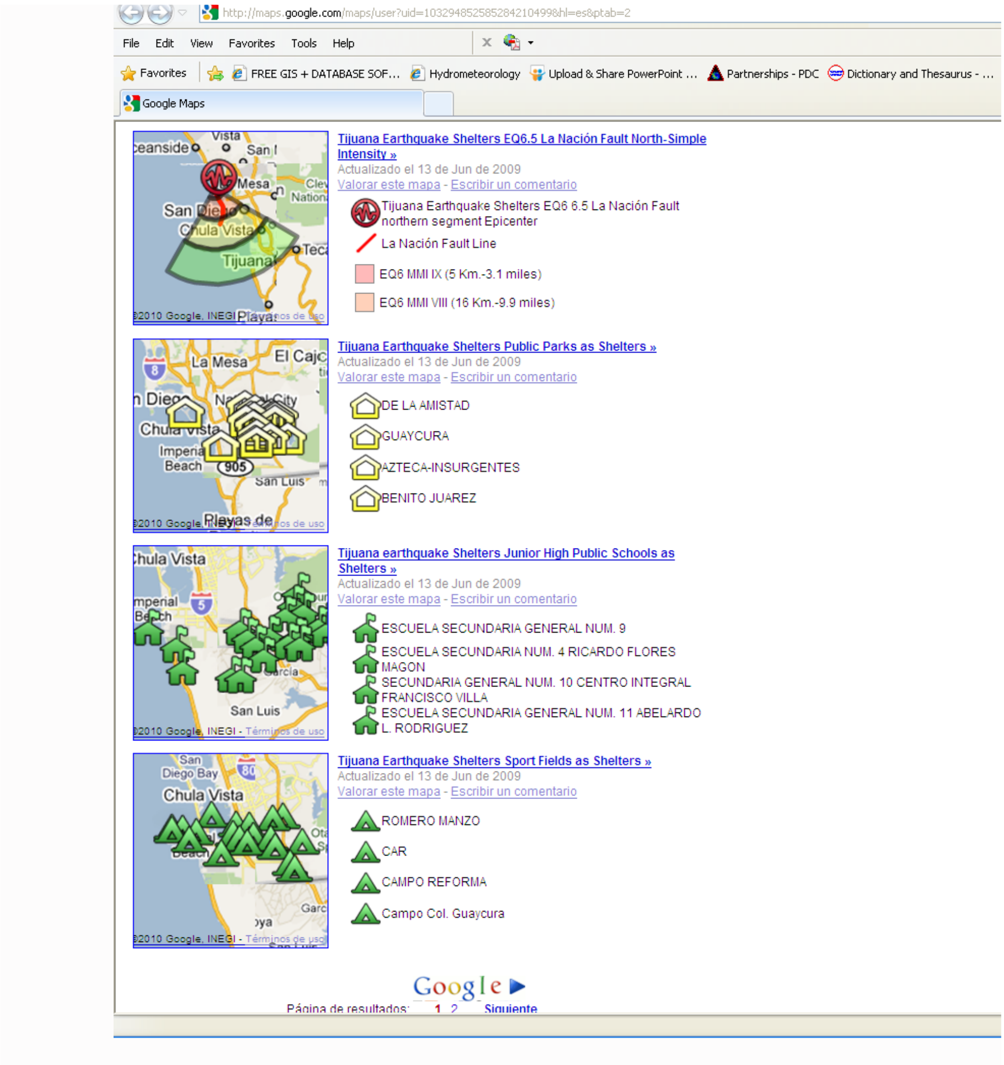


Figure 65: Morelos Park, area = 560 000 m^2, shelter for 1000 people

Figure 66: Alamar river, area = 924 638 m²; shelter for 20 000 people (risk in rainy season)

Figure 67: Golf Course, area = 429 203 m²; shelter for 10 000 people (private)

Figure 68: Airport (open space), area = 593 234 m²; space to receive external supplies

Figure 69: Sport fields, area = 358 115 m²; shelter for foreign teams (near airport)

Figure 70: Race track, area = 362 974 m²; shelter for 7500 people (private)

Figure 71: Military field, area = 1 135 277 m²; supplies

Annex C. List of Schools to be Utilized for Shelters

Table 10: List of location of schools that are in the intensity VII level for the EQ6 scenario

No	Name	Address	District	Area m²	Shelter for (no of people)
1	Secundaria Estatal #69 Rubén Niebla González	Rio Amazonas #7450	CCO	11,000	261
2	Secundaria Técnica #33	Francisco Javier Mina #12200	CCO	12,430	295
3	Secundaria Técnica #21	Paseo de los Pórticos s/n	CCO	15,492	268
4	Secundaria Técnica #36	Sauce #2423	CCO	20,380	482
5	Escuela Secundaria Técnica #15	Alejandro Von Humboldt	CEN	13,205	314
6	Secundaria Técnica #29 Crescencio Lea Ortega	Av. del Parque #1000	CEN	15,314	364
7	Secundaria General José Vasconcelos II	Boulevard Manuel J. Clouthier #114-2	CEN	9,485	226
8	Secundaria General #114	Altiplano s/n Colonia Altiplano	CEN	17,500	216
9	Secundaria General #61	Av. Mar Marmara #5350	CTO	10,000	238
10	Secundaria Municipal #1 Adolfo López Mateos	Mar Báltico #288	CTO	12,600	300
11	Secundaria para Trabajadores #2 Articulo 123 Constitucional	Centro Escolar Agua Caliente	CTO	30,000	714
12	Secundaria Puerta Abierta de Tijuana #128	Sebastián Vizcaíno #4516	CTO	11,299	269
13	Secundaria Técnica #34	Armando Gallegos #100 046	LME	12,931	307
14	Colegio Santa Rosa de Lima	Virgo # 32	LME	23,746	565
15	Secundaria General #12 Miguel de Cervantes Saavedra	Av. Prolongación las Huertas s/n	LME	8,300	200
16	Secundaria General #4 Ricardo Flores Magón	Crisantemo Sur #19	LME	11,000	261
17	Secundaria General #67 Leona Vicario	Leona Vicario #67	LME	20,000	476
18	Secundaria General #44 Ignacio Ramírez	Cajeme #13891	LME	8,300	200
19	Instituto México #25	Av. Las Palmas #5163	LME	10,479	250
20	Secundaria General #25 Libertad	Prolongación Paseo de los Héroes	LME	8,000	190
21	Secundaria #2 Leyes de Reforma	Av. Aquiles Serdán #1277	OTA	9,008	214
22	Colegio Familia #148	Av. de las Brisas #1467	OTA	8,435	201
23	Secundaria Ignacio Manuel Altamirano (#5)	Avenida Parque México Núm. 1210	PLA	13,643	324
24	Secundaria Lic. Milton Castellanos	Everardo Núm. 53	PLA	8,136	200
25	Secundaria Instituto México Miramar # 109	Víctor Parra # 611	PLA	9,100	216
26	Secundaria Prof. Pablo Martínez #30	Miguel Anclan #1500	PLA	10,000	238
27	Telesecundaria #5	Kilimanjaro s/n	PLA	10,000	238
28	Secundaria Técnica #27	Yunque #67	PLA	20,000	476
29	Secundaria Prof. Francisco Cannett Meza #4	Batallón de San Blas y Bahía Kino s/n	PLA	12,450	296
30	Secundaria General #15 Héctor Terán Terán	EncarNacion Ortiz s/n	PRE	11,965	283
31	Secundaria General #17	Av. Paseo del Florido California	PRE	8,124	192
32	Secundaria Técnica #31 José Santos Valdez García	Av. Paseo del Florido California	PRE	15,000	357
33	Telesecundaria #12	Boulevard El Refugio y Nardo s/n	PRE	10,000	238
34	Telesecundaria #17	Hortensia Hernández	PRE	8,100	190
35	Secundaria General #102	Lázaro Cárdenas s/n	PRE	10,000	238

36	Secundaria Técnica #39	Av. las Torres s/n	PRE	11,340	270
37	Secundaria Técnica #45	Av. General Trinidad Rodríguez	PRE	9,300	222
38	Secundaria Estatal #101	Melchor Ocampo s/n	PRE	8,000	190
39	Secundaria General #206	Av. Paseo del Bosque Col. Residencial del Bosque	PRE	14,273	339
40	Secundaria #2 Xicoténcatl Leyva	Lacandones s/n, Manzana 125	PRE	15,996	380
41	Secundaria General #106	Agustín Melgar #3120	SAB	9,500	226
42	Secundaria General #20	Av. Del Faisán s/n	SAB	10,393	247
43	Secundaria Luis Martin Hernández #144	Club de Leones #375	SAB	22,640	539
44	Secundaria Miguel Salceda Heredia #78	Ejido Lázaro Cárdenas s/n	SAB	10,000	238
45	Secundaria Técnica #42	Av. Panamericano	SAB	14,850	353
46	TELESECUNDARIA # 23	Del Roble y Avenida del Ocotes s/n	SAB	8,000	190
47	Secundaria #3 Belisario Domínguez	Obsidiana y Ópalos s/n	SAB	26,636	634

Annex D. List of Open Spaces to be Utilized for Shelters

List of location of open spaces that are in the intensity VII level for the EQ6 scenario

No	Shelter	Name	Address	District	People capacity
1	Sport field	unknown	Av. Rodolfo Sánchez Taboada, Col. Tecnomex	PLA	11,602
2	Sport field	Unidad Deportiva El Mirador	Blvd. Bahía De La Paz Entre Bahía Palmas Y San Lucas, Col. Lomas Del Mirador	PLA	218
3	Sport field	Unknown	Av. Padre Salvatierra Y Av. Padre Ugarte	SAB	881
4	Sport field	Unknown	Av. Mira Flores Y Calle Cabo San Lucas	SAB	651
5	Sport field	Furati	Av. Paseo De Los Héroes Y Av. Gral. Márquez De León	CTO	191
6	Sport field	Crea	Vía Rápida Oriente Y Callejón Aviación, Zona Rio	CTO	377
7	Sport field	Club De Golf Campestre	Blvd. Agua Caliente	CTO	2,193
8	Sport field	Hipódromo	Blvd. Agua Caliente Y Av. Hipódromo	CTO	984
9	Sport field	Club Britania	Av. Club Britania Col. Lomas De Agua Caliente	CTO	237
10	Sport field	Unknown	Av. Salvador Rosas Magallón Y Blvd. Pacifico	TAB	655
11	Sport field	Unknown	Av. Josefina De Contreras Con Av. 76, Centro Urbano 70-76	OTA	490
12	Sport field	Campo Reforma	Guadalupe Ramírez Y Calzada Tecnológico Col. Del Rio	OTA	262
13	Sport field	Car	Calzada Universidad, Atrás De La UABC	OTA	8,218
14	Sport field	Ciudad Deportiva	Vía Rápida Poniente Y Ermita Col. Alfonso Corona	LME	603
15	Sport field	Unknown	Libramiento De Los Insurgentes Con Blvd. Lázaro Cárdenas Norte	LME	245
16	Sport field	Unknown	Constitución Entre Campestre Y Av. Lázaro Cárdenas	LME	280
17	Sport field	Unknown	Vía Rápida Oriente, Antes Del Puente Simón Bolívar, Tercera Etapa Rio Tijuana	LME	772
18	Sport field	Unknown	Vía Rápida Poniente, Tercera Etapa Rio Tijuana	LME	1,052
19	Sport field	Estadio De Los Potros	Calle Prolongación Santo Tomas Y Calle Rio Éufrates	CCO	1,179
20	Sport field	Unknown	Calle Decencia y Bien Común, Col. Valle Verde	CCO	200
21	Sport field	Unknown	Av. Melchor Ocampo Continuidad Con Democracia, Col. Valle Verde	CCO	325
22	Sport field	Unknown	Av. Josa María Velazco Esquina Clemente Orozco, Col. Nueva Tijuana	CEN	341
23	Sport field	Unknown	Entre Calles 3a Y 4a, Col. Roberto De La Madrid	CEN	273
24	Sport field	Campos Romero Manzo	Entre Blvd. Industrial Y Blvd. Lázaro Cárdenas Norte	CEN	7,379
25	Park	Parque México	Av. México norte y Av. México sur, Delegación Playas de Tijuana	PLA	
26	Park	Parque Azteca	Paseo Ensenada y Av. Parque Azteca sur	PLA	
27	Park	Parque Naciones Unidas	Av. Venustiano Carranza y Naciones Unidas	CTO	
28	Park	Parque Independencia	Av. Galeana y Av. Zaragoza	CTO	
29	Park	Parque 18 de Marzo	Av. Ramos Millán y Av. Huitzilac	CTO	
30	Park	Palacio Municipal	Av. Independencia y Paseo Centenario	CTO	
31	Park	Parque de la Comunidad	Calle Lázaro Cárdenas y Calle Francisco G. Lara	SAB	
32	Park	Parque La Gloria	Av. Ensenada, LA GLORIA	SAB	
33	Park	Parque Reacomodo Sánchez Taboada	Calle Virgo y Escultores	TAB	
34	Park	Parque Buena Vista	Juan Ojeda y Av. De las Américas	OTA	

35	Park	Parque Altabrisa	calle Alta Brisa y calle de las Brisas	OTA	
36	Park	Parque de la Amistad	Blvd. Industrial y Blvd. Aztecas norte	CEN	
37	Park	Parque Eco del Prado	Blvd. Federico Benítez López y Av. Ferrocarril	LME	
38	Park	Parque Morelos. Blvd	Insurgentes y Blvd. Bernardo O. Higgins	LME	
39	Park	Parque Terrazas de la Presa	Av. Terrazas y Priv. Ana	LME	
40	Park	Parque Guaycura	Paseo del Guaycura y Pericúe	CCO	
41	Park	Parque Ampliación Guaycura	Av. La Bufadora y Paseo. del Parque	CCO	
42	Park	Parque Grandes Lagos	Calle del Lago de Chapultepec y Lago de Xochimilco	CCO	
43	Park	Parque Azteca-Insurgen-tes	Calle Epatlan y Calle Dinamarca	CCO	
44	Park	Parque Valle Verde	Calle Respeto y calle Educación	CCO	
45	Park	Parque Villa Encantada	Av. Venecia y Av. de la Torres	CCO	
46	Park	Parque Villa Mágica	Calle Pamplona y calle Venecia	CCO	
47	Park	Parque Villa Aventura	Calle Trípoli y calle Landen	CCO	
48	Park	Parque Las Villas	Calle Dos y calle Araunge	CCO	
49	Park	Parque Ejido Matamoros	Calle 2 y calle Instituto Tecnológico	CCO	

Annex E. Contacts of Lead Agencies

C. Antonio Rosquillas Navarro
Protección Civil Municipality director
Institution: Dirección Municipal de Protección Civil
Mail address: 2do piso de Edif. Lic José Federico Benítez López (Edif. A) Av. Guadalupe I. Ramírez y 2ª
Sur S/N Col. del Río Parte Alta Delegación Municipal Mesa de Otay
Tijuana, B. C. 22350
Phone: +52 (664) 683 0908;
607 8945 and 607 7781
Email: arosquillas@tijuana.gob.mx
Website: http://www.tijuana.gob.mx/Dependencias/ProteccionCivil/index.asp

8. References

Acosta Chang. J. G., Montalvo A., J. C.
Intensidades sísmicas para la región de Tijuana, Baja California, a partir del posible rompimiento de la falla La Nacion (Mw=6.5). GEOS. 17(3): 128-138 p. 1997.

Gámez Balmaceda, E.
Sismotectónica y efectos de sitio en la evaluación de la respuesta sísmica en Mexicali, Baja California. Tesis de Maestría. 2008. Biblioteca, CICESE: http://biblioteca.cicese.mx/catalogo/tesis/index.php?query=ena%20gamez.

Gobierno de Baja California, Tijuana
http://www.bajacalifornia.gob.mx/portal/nuestro_estado/municipios/tijuana/Tijuana.jsp

Grupo RADIUS Tijuana
http://radius-tij.cicese.mx

Joyner W. B. and Boore D. M.
Peak horizontal acceleration and velocity from strong motion records including records from the 1979 Imperial Valley, California, earthquake. Bulletin of the Seismological Society of America. 71(6): 2011-2038 p. 1981.

Kaneko Fumio and Shukyo Segawa
IDNDR-RADIUS Project, Geneva, Switzerland OYO Group. 2000.

Legg, M.R. and Kennedy M. P.
Oblique divergence and convergence in the California continental borderland. In: Earthquakes and other perils, San Diego region. (Abbott and Elliot, eds.) San Diego Association of Geologist. 1-16 p. 1991.

Lindvall, S.C., Rockwell, T.K., and Lindvall, E.C.
The seismic hazard of San Diego revised: New evidence for magnitude 6+ Holocene earthquakes on the Rose Canyon Fault Zone, in Proceedings of U.S. National Conference on Earthquake Engineering, Palm Springs, California, Vol 1: Earthquake Engineering Research Inst., p. 679-688. 1990.

Manual Esfera
Carta Humanitaria y Normas Mínimas de Respuesta Humanitaria en Casos de Desastres. Edición revisada. 2004. http://www.sphereproject.org/content/view/27/84/lang,spanishf/.

Mendoza-Garcilazo L. H. y Carlos R. García Flores
Estudio para la estimación del riesgo geológico y sísmico en la Colonia del Río y Anexa en la ciudad de Tijuana, B. C., Reporte Final. Convenio de Colaboración No. 2 entre CICESE y SAHOPE. 1992.

Reichle, M.S., J.E. Kahle, T.G. Atkinson, E.H. Johnson, R.A. Olson, H.J. Lagorio, K.V. Steinbrugge, L.S. Clue T.P. Haney, and J.E. Powers
Planning scenario for a major earthquake: San Diego-Tijuana metropolitan area. Cali@nia Division of Mines and Geology Special Publication 100, 182. 1990.

Sistema Municipal de Protección Civil
Editado por la Dirección Municipal de Protección Civil, XVI Ayuntamiento de Tijuana. 2000. https://www.cia.gov/library/publications/the-world-factbook/geos/mx.html.

Gobierno del Estado de BC
Portal. 2010. http://www.bajacalifornia.gob.mx/portal/nuestro_estado/municipios/tijuana/Tijuana.jsp.

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