UNESCO-RAPCA project

# Deterministic seismic hazard and physical vulnerability analysis for the city of Cañas, Costa Rica

This case study has been developed within the framework of the ITC - UNESCO project *Regional Action Program for Central America (RAP-CA),* which is a subprogram of the programme **"***Capacity Building for Natural Disaster Reduction Program" (CBNDR),* funded by the Netherlands government through UNESCO. This program, launched in 1999, focuses on capacity building for natural disaster reduction. For more information visit the following link http://www.unesco.org/science/earthsciences/disaster/disasterRAP-CA.htm


### Summary

The main objective of this exercise is to introduce a methodology for making a basic seismic hazard map and the use of this for estimating seismic vulnerability and losses. Seismic hazard scenarios are defined based on a deterministic approach. Peak Ground Acceleration values for rock and soil site conditions are calculated using the attenuation law of Climent et al (1994). The acceleration values are then transformed to an intensity scale (Modified Mercalli Intensity). The expected seismic intensity zonation map is used together with elements at risk data to define the vulnerability scenario and to estimate the expected damages. Data available for this exercise are from the municipality of Cañas, Costa Rica.


### Disclaimer

The material in this exercise is for training purposes only. The results should not be used in actual planning of the city of Cañas as ITC does not guarantee the accuracy and precision of the input data and adequacy of the methodology developed during the exercise.

The GIS software that will be used in this exercise is the Integrated Land and Water Information System (ILWIS), version 3.x, developed by the International Institute for Geo-Information Science and Earth Observation (ITC). Information: www.itc.nl

### Introduction

Seismic hazard scenarios can be defined using either deterministic or probabilistic approaches. In both cases available historical seismic records and geological data (neotectonics studies) are used to identify and characterize main seismic sources relevant to the site of interest concerning their earthquake potential. The difference between these two approaches lies in the way the seismic scenarios are defined. The probabilistic scenario is defined as the likelihood for a specified Peak Ground Acceleration (PGA) value to be exceeded within a certain time frame. The deterministic approach commonly produces a worst-case scenario, defined by a controlling earthquake, without given an indication on how likely that given scenario is to occur. See XX for a more detailed explanation of these methodologies.

In this exercise a set of seismic hazard scenarios are drawn, using a deterministic approach for the municipality of Cañas, Costa Rica. Controlling earthquakes are derived from the existing historical seismic records and the available tectonic data. The seismic hazard parameters (PGA) are calculated using the attenuation law for the Central America region derived by Climent et al. (1994). This attenuation relation was drawn from strong

motion data observed in both México and Central America. A total of some 218 such measurements have been used in the least squares derivation of this attenuation model. The Climent et al. (1994) attenuation relation is:

$$\ln A = -1{,}687+0{,}553*M-0{,}537*\ln(r)-0.00302*r+0{,}327*S+\ln\in$$

Where

**M** is the moment magnitude
**r** is the distance to the hypocenter (from Pythagoras $r^2$ =earthquake-depth$^2$ + epicentre-distance$^2$)
**S** amplification factor, which has a value of 0 for rock site conditions and 1 for soils
**ln∈** is a term related to the error estimation factor equal to 0.75

From the previous equation we have:

***Lnarock( rock site conditions)*** = -1.687+0,553*7,7-0.537*ln(r)-0.00302*r+0.75

***Lnasoil (soil site conditions)*** = -1.360+0,553*7,7-0.537*ln(r)-0.00302*hyp(r)+0.75

From the previous maps it is possible to calculate

***arock*** (expected acceleration for rock site conditions) = exp(***lnarock*** )

***asoil*** (expected acceleration for soil site conditions) = exp (***lnasoil***)

Seismic hazard scenarios are compared against existing vulnerability data for the Cañas city centre to develop qualitative preliminary damage scenarios

The city of Cañas is located in the Guanacaste province, North-western Costa Rica.

## Objectives and practical application

- Create deterministic macro seismic hazard scenarios for the city of Cañas, Guatemala
- Assessment of the building's physical vulnerability regarding defined hazard scenarios
- Produce qualitative damage scenarios based on existing vulnerability data

## Expected outcomes and outputs

- ✓ Several deterministic seismic hazard scenarios for the municipality of Cañas
- ✓ Expected seismic intensity map (MMI) for the municipality of Cañas
- ✓ Seismic hazard vulnerability maps for the different types construction materials

## Instructions

### 1.1 Selecting the "controlling earthquakes"

Based on historic records and geological studies seismic sources are located and characterized in terms of their earthquake potential. Following a deterministic approach, once all the different sources have been analysed a decision is made regarding the selection of the "controlling earthquake". The controlling earthquake is in most cases the one that represents the worst-case scenario: the maximum magnitude value and the shortest distance to the site of interest.

Slob et al. (2003) suggested that, based on the available historical seismic records and tectonic data for the Costa Rica's north-west region, it is possible to define a least four seismic sources that might strongly affect the municipality of Cañas. These seismic sources are:

- The Nicoya seismic zone (subduction zone): where an earthquake 30 Km deep having 7.7 Mw (moment magnitude?) may occur under the Nicoya peninsula.

- The Papagayo seismic zone (subduction zone): where an earthquake 40 km deep having 7.7 Mw (moment magnitude?) may occur.

- The other two seismic sources would be defined by the local fault's system. In this case the controlling earthquake would occur 12 km deep and have a 6.5 Mw (moment magnitude?)

Having into account Slob et al.(2003) suggestion, analyse the available seismic sources information and select four controlling earthquakes.

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- Use the data provided on seismic sources (epicentres map – tectonic settings) and select four (4) "controlling earthquakes" for the municipality of Cañas. Select two earthquakes from the epicentre's map, one representing a shallow source and one representing a deep source. Analyse the fault's map and select the remaining two earthquake sources. Bear in mind the concept of "controlling earthquake" as defined from a deterministic viewpoint.

### 1.2 Defining the deterministic seismic hazard scenario

Once the controlling earthquakes have been selected the expected acceleration values can be calculated. Several attenuation relations are available for the Central America region. Before using the one suggested for the exercise, Climent et al. (1994), search the web for other attenuation laws. Explain why Climent et al. (1994) is considered as most appropriate. The following link can be useful for this purpose
http://geohazards.cr.usgs.gov/paigh/mapsabs.html

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- Use Climent's 1994 attenuation law to produce the different seismic hazard scenarios both at macro and micro-zoning level for the city of Cañas.

- Produce seismic intensity maps by transforming the ground acceleration values to the Mercalli Modified Intensity scale (MMI).

### 1.3 Analysis of vulnerability aspects

The seismic hazard assessment main objective is to provide the seismic scenario to which buildings and infrastructure in the site of interest would be exposed. If suitable data on the physical characteristics of the elements at risk exist then a vulnerability analysis could be carried out. In many cases, however, data on physical characteristics of the elements at risk is limited. This situation could easily lead us to the idea of abandoning the project or waiting until the required data are available. On the other hand, funding for collection of new data is sometimes only granted when public awareness has been raised through preliminary studies showing how serious the situation could be. Preliminary studies could also be used to efficiently allocate already scarce resources.

Analyse the existing elements at risk data and select some of the attributes that could be used for the vulnerability analysis concerning seismic hazard.

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- Use existing elements at risk data to prepare qualitative seismic vulnerability assessment maps for the city of Cañas. Consider different vulnerability aspects such as collapsing buildings (construction type, roof type), fire (kitchen type could give some info on this aspect), etc.

## References

Slob, S. et al. In UNESCO - ITC Capacity Building for Natural Disaster Reduction (CBNDR) Regional Action Program for Central America (RAPCA). Amenaza Sísmica y Vulnerabilidad Física en la ciudad de Cañas, Guanacaste, Costa Rica. August 2003

**Materials**

| **Basic data/map name** | **Format** | **Description** | **Comments** |
|---|---|---|---|
| CSCostarica | Coordinate system | Coordinate system projection for Costa Rica | |
| choroteg | Georeference | Georeference for Guanacaste | |
| Cañas | Georeference | Georeference Cañas and surroundings | |
| Curvasnivel50m | Segments | 50 m Contour lines map | Cañas basin (some of the contour lines at the level of the city of Cañas are not complete, this creates artefacts in the DEM derived) |
| Rios | Segments | Drainage network | |
| Redvialcañas | Segments | Roads map around Cañas | No attributes. |
| ContornoCR | Segments | Boundary map Costa Rica North zone | |
| Condmec | Polygon | Soil's mechanic conditions around Cañas. | No attribute table |
| cuencaña | Polygon | Cañas basin | |
| Geolcr | Polygon file | Regional geology map? | Attribute table: geological units are coded but there is not code description |
| **Hazard data/map name** | **Format** | **Description** | **Comments** |
| SismSub, SismSup | Point maps | Seismic catalogue | 9 and 6 records respectively. Moment Magnitude (?) |
| Epicenters | Point | Location of earthquake epicentres | |
| FallasCañas | Segment | Quaternary and tertiary faults in the Guanacaste region | Incomplete attribute table |
| **Vulnerability data /map name** | **Format** | **Description** | **Comments** |
| Sub-parcels | Polygons | Census data linked to blocks map | Only for the central part of the municipality |
| Escuelascercanas | Points | Nearby Cañas municipality schools | |
| Ciudades | Points | Urban centers Canas basin and surroundings | Apparently there is a shift in the map: the location of the Cañas city does not coincide with its location in the roads map (?) |