# LIVING WITH GEOHAZARDS. A STRATEGIC CONTRIBUTION TO ITS MITIGATION: THE GEOLOGICAL HAZARD MAP OF CATALONIA 1:25 000

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## INTRODUCTION

The high density of urban development and infrastructures in Catalonia requires geo-thematic information for planning. Geo-hazard mapping is a fundamental part of this information. Despite some tests having been carried out with wide land recovery (Mountain Regions Hazard Map 1:50000 [DGPAT, 1985], Risk Prevention Map of Catalonia 1:50000 [ICC, 2003]), in 2006 the Catalan government made a strong commitment to produce the Geological Hazard Prevention Map of Catalonia (MPRGC).

The MPRGC is a 1:25000 scale map where terrain is zoned according to geological hazard. The purpose of this tool is to support urban, road and infrastructure planning. The map is intended to enable government and individuals to have an overview of the territory, with respect to geological hazards, identifying areas where it is advisable to do detailed studies in case of action planning. At the same time a database is being implemented. It will incorporate all the information coming from these maps. In the future it will become the Geological Hazard Information System of Catalonia (SIRGC).

## GEOLOGICAL HAZARD PREVENTION MAP OF CATALONIA

In the MPRGC, evidence, phenomena, susceptibility and natural hazard of geological processes are represented. These processes are generated by the external geodynamics (such as slope, torrent, snow, coastal and flood dynamics) and the internal Geodynamics (earthquake). Those areas likely to generate hazard due to human causes are not considered.

The phenomena considered in the map are:

- slope movements (rock-falls, landslides, complex movements, flows ...)
- Sinking (subsidences and collapses).
- Avalanches
- Floods
- Earthquakes

The information is distributed on different maps at different scales on the published sheet (Figure 1). The main map is at scale of 1:25000. Landslide, avalanche and flood hazard (according to geomorphologycal approach) is represented. Several complementary maps at 1:100000 scale show the different phenomena hazard, separately in order to facilitate their understanding. Two additional maps, flooding and seismic hazard, represented at 1:50000 and 1:100000 respectively, are added on the sheet.

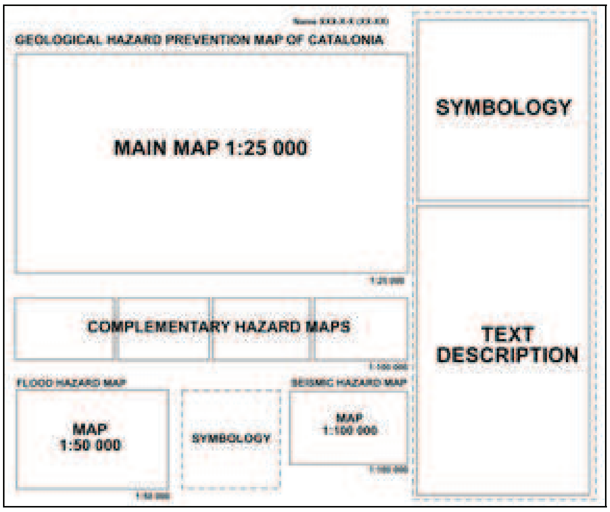


*Figure 1 – Outline sheet. It shows the distribution of the different maps.*

## MAIN MAP

The methodology used to work is synthesized in the following phases:

1. Mapping Inventory

1.1. Bibliographic and cartographic search: the information available into archives and databases is collected.

1.2. Photointerpretation: carried out on vertical aerial photos of flights from different years (1957, 1977, 1985, 2003, etc.). The observation of the topography and the vegetation allows the identification of areas with instability signs coming from the identification and characterization of events that occurred recently or in the past, and from activity indicators.

1.3. Field survey consists of checking and contrasting on the field, the elements identified in the previous phases. Field analysis allows a better approach and understanding, and therefore identifying signs and phenomena not observable through the photointerpretation.

1.4. Population inquiries: the goal of this stage is to complement the information obtained in the earlier stages, especially in aspects such as the intensity and frequency. It is done through a survey to witness who lives and/or works in the study areas.

2. Determination of the susceptibility

Areas susceptible to be affected by the phenomena are identified from the starting zone to the maximum extent determinable at the scale of work. Their limits are drawn taking into account the inventory of phenomena, signs of activity geomorphological indicators, and from the identification of favourable lithologies and morphologies of the terrain. This phase includes the completion of numerical models to support the determination of the starting and run-out zone.

3. Determining hazard

Based on the analysis of the magnitude and frequency of the observed or potential phenomena, susceptibility areas are classified according to hazard matrix represented in Figure 2.

Hazard zones are represented as follows: in white, areas where no hazard was detected, in yellow, zones with low hazard, in orange, the medium hazard zones, and in red, areas with high hazard.

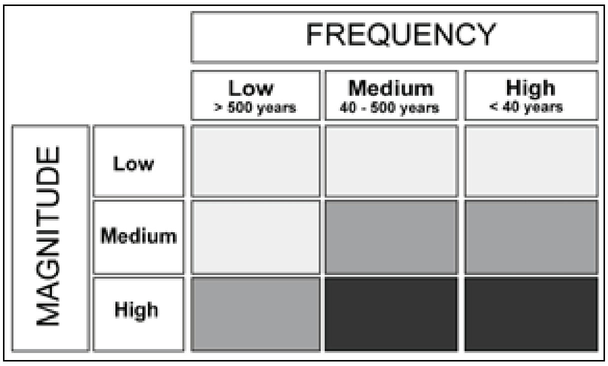


Figure 2 – Hazard matrix (based on Altimir et al, 2001).

Each one of the hazard levels indicates some considerations for prevention. These considerations inform about the need for further detailed studies and they advise about the use of corrective measures.

| | PREVENTION | |
|---|---|---|
| HAZARD | DETAILED STUDIES | HAZARD MANAGEMENT |
| Not observed | ----- | ----- |
| Low | Recomendable | Necessary in certain cases |
| Medium | Indispensable | Necessary in many cases |
| High | Indispensable | Necessary in most of the cases |

*Figure 3 – Prevention recommendations.*

Hazard of each phenomena is analyzed individually. The main challenge of the map is to render the overlapping hazard of different phenomena easily. With this objective a methodology that identifies that this overlap exists has been established. It indicates what the maximum hazard overlapped is (Figure 4), but in any case, not obtaining new hazard values.

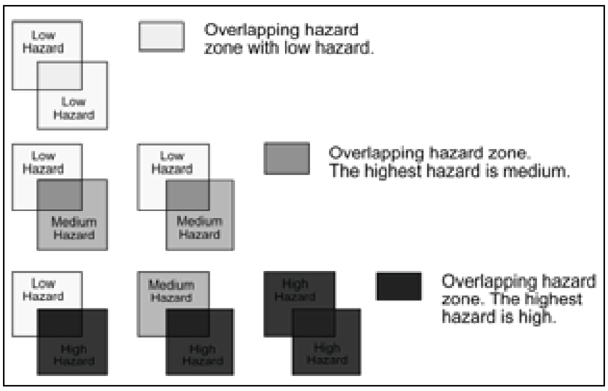


*Figure 4 – Multi-hazard representation.*

To identify which phenomena corresponds with each one of the susceptibility areas, different outline patterns are represented, as shown in Figure 5.

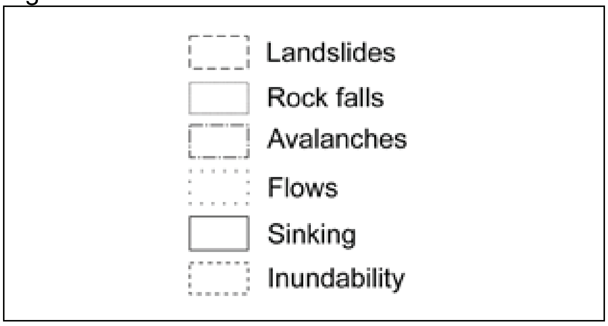


*Figure 5 – Outline patterns identifying at what phenomena the hazard belongs.*

Figures 6 and 7 show the final outcome of the procedure.

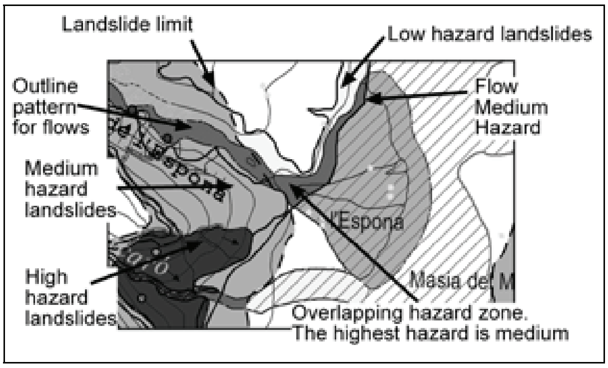


*Figure 6 - Example of multi-hazard representation.*

*Figure 7 – Main map 1:25000, which includes landslides, avalanches, sinking and flooding according to geomorphologic criterion.*

**COMPLEMENTARY MAPS**

Complementary maps represent the hazard determined for each individual phenomena at 1:100000 scale. The purpose of these maps is to facilitate the interpretation of the main map. Depending on the type of phenomena identified in the main map, the number of complementary maps can vary from 1 to 6.

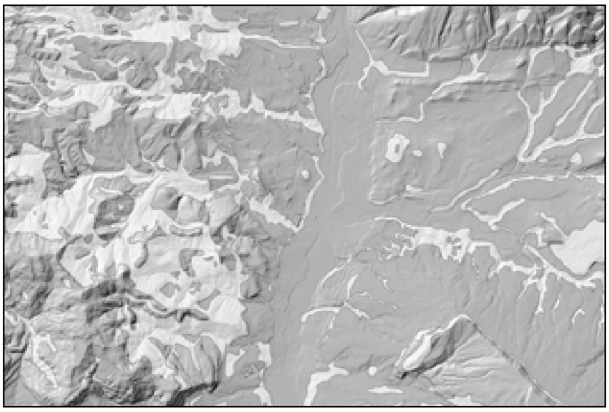

*Figure 12 – Surface landslide hazard complementary map.*

**SEISMIC HAZARD MAP**

This map was obtained from the map of seismic areas (for a return period of 500 years) for a middle ground, and considering the effects of soil amplification.

To take into account the amplification of the seismic motion due to soft ground, a geotechnical classification of lithologies from the Geological Map of Catalonia 1:25000 into 4 types were carried out: R, A, B and C, based on the speed of the S-wave through them (Fleta et al., 1998):

Type R: corresponds to hard rock (example: Paleozoic and Mesozoic).
Type A: corresponds to compact rocks (example: Paleogene or Neogen).
Type B: corresponds to semi-compacted material (example: evaporitic rocks or old Quaternary deposits).
Type C: corresponds to non cohesive material (example: non consolidated deposits with organic content).

To each group of lithologies the proposed amplifications were assigned as follows:
Type R and A: No addition of any degree of intensity.
Type B and C: Addition of 0.5 degrees of intensity.

On the final map (figure 8) the values of the basic seismic acceleration of the compulsory "*Norma de Construcción Sismoresistente Española*" (NCSE-02) for a placement in rock, and the intensity of the seismic emergency plan (NCSE-02, 2002) are represented.

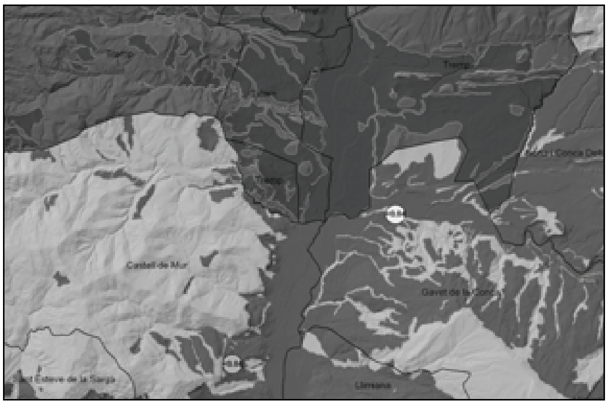

*Figure 8 – Seismic hazard map 1:100000.*

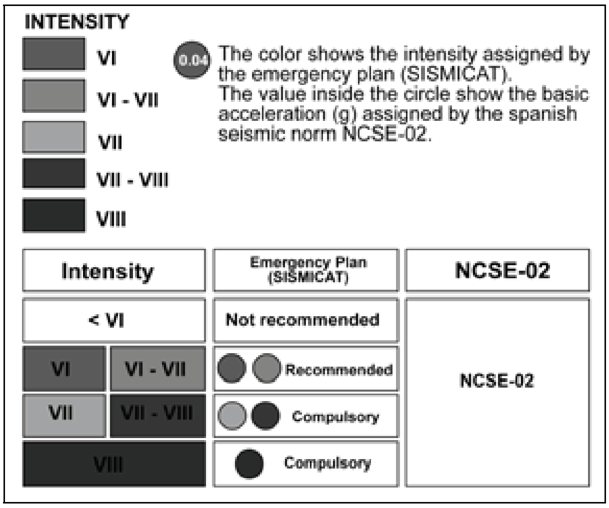


*Figure 9 – Seismic hazard map simbology.*

## FLOODING HAZARD MAP

On the flooding hazard map at scale of 1:50000, the limits of the hydraulic modeling for periods of 50, 100 and 500 years provided by the Catalan Water Agency (ACA) are represented.

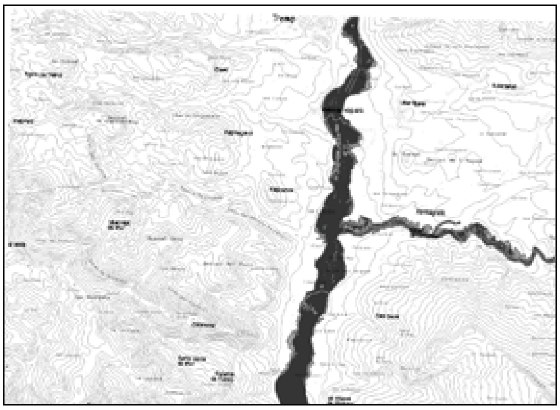

*Figure 10 – Flooding hazard map based on hydraulic modeling.*

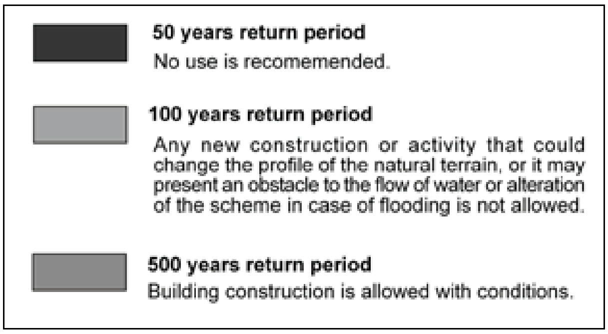


*Figure 11 – Flooding hazard map simbology.*

## CONCLUSIONS

The MPRGC will replace the shortage of hazard mapping in Catalonia.

It permits the consultation of the integrated geological hazard information at medium scale in a single document, to facilitate its understanding.

This work is the beginning of the geological hazard database, currently under construction. It will become the principal reference of geological hazards in Catalonia.

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