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Debris-flow hazard assessment at local scale. The multiple step approach applied in Andorra.

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The Principality of Andorra is located in the Eastern Pyrenees and has an extension of 420 km2. It is a densely populated area and the construction of buildings and traffic lines has strongly increased during the last decades. Although debris flows do not occur so frequently as in other mountain ranges, they are a significant hazard. Especially the lack of urban planning and regional hazard maps generated a high amount of elements that may be affected by future debris-flow events. We propose a multidisciplinary procedure to evaluate the debris-flow hazard at a local scale. Our four step approach was successfully applied to five torrent catchments in Andorra. The first step consisted of a comprehensive geomorphologic and geologic analysis providing both a magnitude-frequency relationship and an inventory map of the past debris flows and also general geomorphologic-geologic maps. These data are necessary to determine the potential initiation zones and volumes of future debris flows. A susceptibility map and different scenarios are the principal outcome of the first step and are essential for the second step, the runout analysis. The mobility of debris flows can be simulated by different types of models. We applied a 1-dimensional numerical code to analyse the scenarios previously defined and evaluated firstly the critical channel sections in the fan area. Then, we studied the maximum runout of the debris flows on the fan and finally established simplified intensity maps for each defined scenario. The third step is called the hazard zonation and summarised all the results from the two previous steps in a final hazard map. The base of this hazard map is the hazard matrix, which combines the intensity of the debris flow with its probability of occurrence (frequency). The forth step refers to the hazard mitigation and included some recommendations for the hazard reduction. This four step hazard assessment was successfully carried

out at and the final hazard maps at 1:2000 scale provide an obligatory tools for the local land-use planning. The results indicate that debris-flow frequency is rather low in the principality, but catastrophic events can occur in the future and cause significant damage. This study shows the need of a well-defined debris-flow hazard assessment in Andorra and we propose that our approach may be applied to other mountainous areas.