

## AN INTEGRATED METHOD FOR DEBRIS FLOW HAZARD MAPPING USING 2D RUNOUT MODELS

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Settlements and communities in mountain regions are threatened by natural hazard processes including debris flows. In last decades important efforts have been made in order to develop efficient and objective procedures for hazard mapping and management. These efforts produced number of empirical relations, analytical, one and two-dimensional numerical models. However, the results are often different, and the problem is especially critical in basins with poorly documented event history, and in the presence of structural mitigation measures.

Differences in hazard mapping results the use of subjective and deterministic instead of objective numerical methods, may endangered persons and settlements and generate confusion among the stakeholders. For this reason, the uncertainty of hazard mapping is a key factor for the safety and the effectiveness of future develop of involved settlement.

We describe an analysis of two case studies debris flow hazard mapping where both empirical and physically-based methods are evaluated with respect to previous hazard phenomena, protection measure dimensioning and presence of different scale mitigation measures.

The study case is located in Zinal (Valais, CH) and involves two mountain basins of the mount Les Diablons, Bondes and Tracuit. Permanent settlements were established in 60's related to the development of a new ski area. The existing mitigation measures were constructed at the end of the 1800's to protect seasonal barns from avalanches and debris flows. Further larger measures were built to increase the safety following damaging events. Presently, three retention basins are situated on the Bondes catchment for a total storage volume of about  $2 \times 10^5 \text{ m}^3$ . In the Tracuit basin, a retention basin with a storage volume of about  $2 \times 10^4 \text{ m}^3$ , was enlarged in response to a new hazard analysis.

Thorough and integrative field studies were designed to assess the expected magnitude (volume) of debris flow. Both geomorphic and volumetric analyses were carried out in all the basins, and rheological analysis was performed in laboratory on a physical model to obtain a more realistic two-dimensional numeric simulation. Finally, an integrated approach as suggested by Hurlimann et al. (2006) was performed to obtain an objective estimation of all the variables required by the different hazard map methodologies to be used.

Several empirical relations for debris flow (Rickenmann, 1999, D'Agostino et al., 2010) and two commercial two-dimensional models (FLO-2D and RAMMS) have been used to assess hazard maps, although it must be emphasized that the federally-mandated hazard maps in Switzerland are constructed after a thorough synthetic hazard analysis, also considering e.g., the event history and the anticipated influence of likely channel obstruction, and not based solely on run out model results. We emphasize the apparent precision of hazard map produced by the O'Brien quadratic rheology based model and by the Voellmy fluid based one. At the same time we stressed the differences between the model result, and we compare also these findings with run out distance from the empirical relations. The differences in the study cases showed a difficult in the determination of unique and objective hazard maps using these tools.

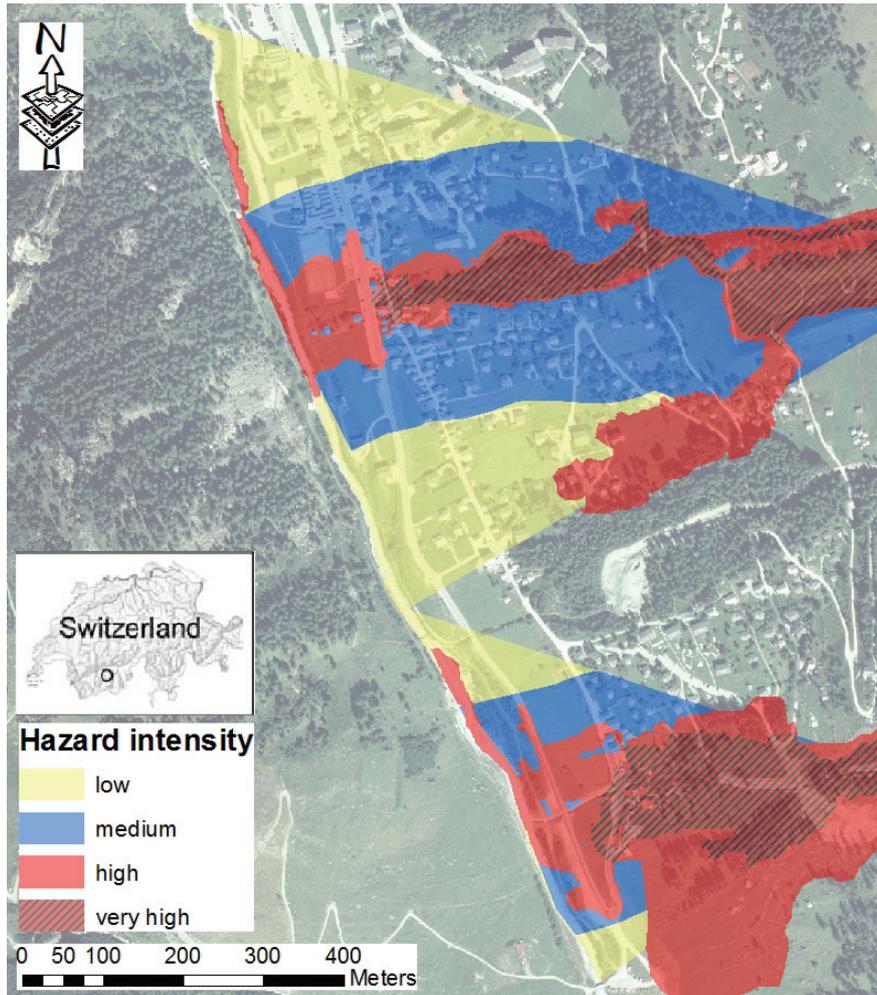
Finally, we propose a procedure which integrates the topographic precision of 2D-numerical models with 1D-empirical predictions. For the production of hazard maps, the models should be combined with scenarios for expected channel obstruction and the other changes in the flow paths. Such procedure produces a four classes hazard classification forming a modelling approach to its probable uncertainty, that should increase the degree of safety of mountain settlements.

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**Fig. 1** Example of the resulting hazard map obtained using our procedure.

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