

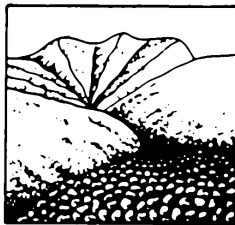


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# **DEBRIS FLOWS: Disasters, Risk, Forecast, Protection**

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Pyatigorsk, Russia, 22-29 September 2008



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S.S. Chernomorets

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## Debris flow hazard assessment in Dolomites: a simulation model approach

R. Genevois<sup>1</sup>, P.R. Tecca<sup>2</sup>

<sup>1</sup>Padova University, Dept. of Geosciences, Padova, Italy

<sup>2</sup>Research Institute for Hydrological and Geological Hazard Prevention – CNR, Padova, Italy

## Оценка селевой опасности в Доломитовых Альпах: подход через моделирование

Р. Женева<sup>1</sup>, П.Р. Текка<sup>2</sup>

<sup>1</sup>Университет Падуа, кафедра наук о Земле, Падуа, Италия

<sup>2</sup>Исследовательский институт гидрологических и геологических опасностей – CNR, Падуа, Италия

WlZklZlvy hibkuZl ijhpñjm hpgdb kehc hiZkghklb gZ ehdZevghf mjhg\_ ; LZdhc ihðh^ [ue ijbfgg ey ljo [Zkkcg\ hdheh DhjlbGZ ^ :fipph (<hk-lhqu\_ >hehflhù\_ :eviu , BlZeby). IjhpñjZ khklhbl ba ]hfhjnheh]bqkdh]h b ]heh]bqkdh]h bkkeñZgby ey hijégby ihlgpbZevguo keuo hqZ]h\ b hpgdb h[tfZ [mñsbo kec \ dZñf [Zkkcg\_ . Ijh]ZffZ ñfjgh]h fhéb - jhZgby FLO-2D [ueZ ijbfggZ ey ZgZebaZbihùo [Zkkcg\ k 5 jZaebqgufb ]heh]bqkdbfb oZjZdljbklbdZfb . HiZkgu\_ mqZklbd[ueb hqjggu dZddhf]bgZ - pby jZkohZ , ]em[bgu ihldZ b kdhjhklb . Blh]hZy dZj]Z hiZkghklb \ fZkrlZ[\_ 1:10000 yeylky kmsklgguf bgkljmfghf ey fklgh]h ieZgbjhZgby bk-ihvahZgby afev .

This article presents a procedure for evaluating the debris flow hazard on a local scale; this approach was applied to three basins near Cortina d'Ampezzo, Eastern Dolomites, Italy. The procedure consisted of a geomorphologic and geological study to determine the potential initiation zones and design volumes of future debris flows for each basin. The bi-dimensional numerical code FLO-2D was applied to analyse the sample basins with 5 different rheologies. The hazard areas have been delineated as a combination of runout, flow depth and velocity. A final hazard map, at a scale of 1:10000, provides an essential tool for local land use planning.

### 1 Introduction

Debris flow-prone areas can be easily identified through field experience and evidence of previous events. However, it is the accurate prediction of runout distances, velocities and the knowledge of flow rheology that can reduce damages, providing means to produce hazard maps and to provide parameters for the design of protective measures.

During the last decade, the bi-dimensional model FLO-2D (O'Brien et al., 1993) is being used increasingly for debris-flow simulation as a useful tool for predictive purposes and hazard map delineation, in many studies on hazard and risk assessment (Tecca et al., 2006).

The aim of this paper is to present a procedure to assess the debris flow hazard at local scale using FLO-2D to model both propagation and expansion of debris flows. The methodology has been applied to three small basins of the western slope of the Mount Pomagagnon (Cortina d'Ampezzo, Italian Eastern Alps). The results focus on the assumed approach and on its possible application to other mountainous areas.



Table 2. Calculated yield stress and viscosity for  $C_v=0.55$ .

Rheology	Viscosity $\eta$ (Pa s)	Yield stress $\tau_v$ (Pa)
R 1	2	3893
R 2	36	928
R 3	88	218
R 4	135	83
R 5	147	184

A roughness  $n$ -value of 0.18 was assumed, typical for open ground with debris; the specific weight of the mixture  $\gamma_m$  and the resistance parameter for laminar flow  $K$ , were assumed equals to  $26.5 \text{ kN/m}^3$  and 2285 respectively, as suggested values for debris flows. The hydrologic model CLEM (Cazorzi, 2002) has been used to predict the design storm rainfall-runoff hydrograph, assuming flow velocities of 2 m/s and 0.03 m/s in the flow net and over the slope respectively. The maximum annual rainfall series (1984-2004) of the nearest station have been analyzed; the design hydrograph has been obtained, considering the upper confidence limits of depth-duration-frequency curve for a return period of 200 years. The sediment concentration by volume assigned to the hydrograph, ranges between not less than 0.3 along the rising and falling limbs of the hydrograph, and a maximum of 0.55 corresponding to a mature debris flow. The peak discharge was assigned a sediment concentration slightly less than the frontal wave to account for water dilution.

For each rheology, a debris flow hazard map has been obtained: different areas are classified into different hazard levels defined in terms of a combination of flow depth ( $h$ ) and the product depth times velocity ( $hv$ ), based on literature data and on our own experience on Dolomites debris flows (Table 2).

Table 3. Hazard degrees range.

Definition of mud or debris flow intensity			
	Maximum depth $h$ (m)		maximum depth $h$ times maximum velocity $v$ ( $\text{m}^2/\text{s}$ )
High	$h \geq 1.0$ m	OR	$v h \geq 1.0 \text{ m}^2/\text{s}$
Medium	$h \geq 0.4$ m	AND	$v h \geq 0.4 \text{ m}^2/\text{s}$
Low	$h \geq 0.2$ m		$v h \geq 0.2 \text{ m}^2/\text{s}$

#### 4 Results

The following values of design debris volumes, for Gere, Fiames and no. 154 basins, were estimated for numerical simulations: 30000, 30000 and 15000  $\text{m}^3$ . Five runs with the different combinations of rheologies were calculated for each basin. As an example, Figure 2 shows the hazard zonation at n. 154 basin, for the lowest, medium and higher viscosity (rheologies 1, 3 and 5 respectively).

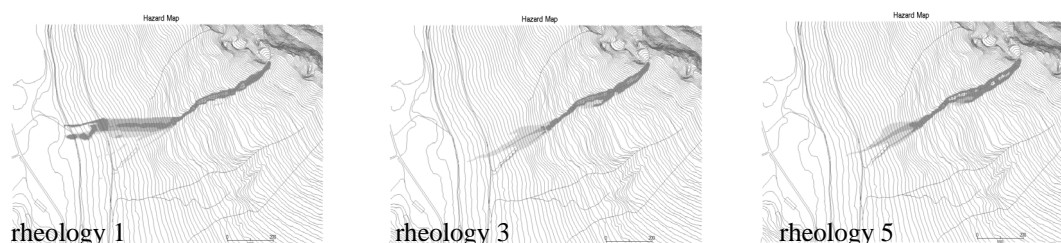


Figure 2. Hazard maps at no. 154 debris flow site for the rheologies 1, 3 and 5.

In case of low viscosity, the velocity and flow depth show high intensity values ( $v > 1 \text{ m/s}$  and  $h > 1 \text{ m}$ ) until the flows reaches the road; medium or low intensity are indicated in the middle slope. Different flow behaviour is displayed with the rheologies 3 and 5 where high hazard is exclusively related to the flow path and to the upper part of the slope, whereas the middle part is located within the moderate hazard zone. The lower part of the slope was con-

sidered a low hazard zone because indirect impact by slurry flows or afterflows seem to be here possible. Very low hazard was only defined at the marginal parts of the slope.

The final hazard map (1:5000) for the n. 154 debris flow is obtained by superposition of the hazard maps obtained for each rheology, combining the different hazard classes, and delineating comprehensive low, medium and high hazard areas. This map is not presented here as it cannot be well displayed for space reasons. However, the runs showed the most critical channel section is located just where the slope decreases its gradient and the debris flow, depending on the rheology, would break out of the channel and mainly move downslope on the southern sector of the slope.

### 5 Discussion and conclusions

The results obtained show the need of a comprehensive debris flow hazard assessment and the usefulness of such studies for adequate urban planning. The fast growth of urbanisation and the limited space in the valley floors have created a need to construct buildings and transportation links on the debris fans.

The study establishes a procedure to evaluate the debris flow hazard at a local scale applied to three debris flow catchments of the Cortina d'Ampezzo area. The final hazard maps showed that all three basins had a moderate or even high hazard degree in the areas already urbanized or selected for future urbanisation. The multi-step approach established for hazard assessment combines the results obtained from a geomorphologic– geologic study and numerical simulations. Taking into account the different steps of the assessment, volume estimates of the design debris flows were a rather problematic and delicate task because of the lack of historic data. This problem can be overcome by the use of a two-dimensional numerical model that simulates the debris flow spreading on the fan. Such two-dimensional modelling, however, strongly depends on the accuracy of the digital elevation model and never replaces the critical examination in the field of the simulation results focusing on morphologic and hydraulic aspects. Because of its simplicity and the very low cost– benefit rate, the present approach can be applied to debris flow catchments in other mountainous areas.

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