Comparison of Scenarios After Ten Years: The Influence of Input Parameters in Val Canale Valley (Friuli Venezia Giulia, Italy)

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Abstract

On August 29th 2003 many debris flows were activated along different streams of the Fella river basin (North–East Italy). After that huge event a program of debris flow risk analysis was started and through the use of FLO-2D software, a new outline of the hazardous areas was obtained. In the last years, part of a PhD research project was addressed to define a quick field and laboratory survey methodology suitable to obtain reliable rheological parameters and to reproduce debris flow scenarios in the absence of back analysis. An example of the methodology is presented, including grain-size and rheological analysis on samples of a watershed located in left side of the Fella river, the reconstruction of its DTM starting from detailed laser scanner data (Civil Defense of Friuli Venezia Giulia Region) and the updating of the morphometric parameters in virtue of the more detailed data. For the present research, a comparison between previous simulated scenarios and those obtained through the introduction of new basic data was provided. In particular, the simulations based on the parameters collected after the 2003 event on the DTM of 2003 were used as back analysis, whereas new simulations were performed using the rheological parameters derived from samplings and laboratory analyses realized during 2013 on the DTMs of 2008, in order to create future possible flooding scenarios on the actual morphology and to test the effectiveness of the mitigation measures, built up after the 2003 event.

Keywords

Debris flow • Val Canale • Rheological analysis • FLO-2D

87.1 Introduction

The area of the Val Canale, Canal del Ferro and Val Aupa, with the whole northeastern part of the Friuli Venezia Giulia Region as well, on 29th August 2003, was invested by a high intensity rainfall (Calligaris et al. 2012). In that occasion, the main part of the tributaries of the Fella River gave rise to debris flow phenomena, in right and left side, causing also the obstruction of the main roads present in the valley.

One of the left tributaries of the Fella River, called "Fella SX", during the 29th August event overflowed and a large amount of debris reached the highway A23. This small but dangerous stream has been chosen as test site for the present research in order to compare, 10 years later, the simulation

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results obtained at that time (Calligaris et al. 2010) with the one obtainable now using more detailed input parameters. Moreover after the alluvial occurrence, Fella SX watershed suffered a complete transformation in order to mitigate the risk on the area. On the torrent path in fact, are present a check dam and a debris basin. Further downstream, two debris barriers were placed, one just upstream the highway.

A way to understand if the realized mitigation works are effective is the use of a simulation software that permits to recreate scenarios of event on different morphologies. An available and commercial one is the FLO-2D software, born for simulating alluvial river events, but well fitting also for the mud-debris phenomena.

87.2 Geological Framework and Morphometric Characterization

From a geological point of view, the substrate lithostratigraphic units outcropping in the studied area are essentially represented by formations chronologically included between post-hercynian Palaeozoic and Mesozoic sequences comprehending the geological formations of Serla Dolostone (middle Triassic), Werfen (Early Triassic) and Bellerophon (Late Permian) (Carulli 2006).

The coarse deposit present in the riverbed reflects the lithology of the area with eterometric clasts of sandstone and carbonatic nature. The debris is the product of the superficial outcropping rocks' degradation mixed to the Quaternary till and alluvial deposits wide present in the area especially in the valleys' bottoms. From a grain-size point of view, it consists of coarse gravel mixed with fluvial gravelly sand immersed in a finer silt and clay matrix.

At the time of writing, a huge amount of mobilizable material is still present in the riverbed and in the neighboring areas.

During the alluvial event of 2003, the channel was eroded and deepened giving rise to the actual morphology (Fig. 87.1b). For the Fella SX event was estimated a total volume of about 6,000 m^3, with a corresponding flooded area of approximately 14,000 m^2, having an average thickness of 0.25 m.

87.3 Grain-Size and Rheological Analysis

To perform grain-size and rheological analysis field sampling surveys were realized in the study area. Researchers collected several meaningful samples in different points of the interested stream (Fig. 87.1c). The maximum diameter detected along the course was about 0.04 m, moreover on the sides are still present bigger boulders (Boniello et al. 2010). First of all a grain-size analysis was performed on all samples: dry sieving was carried out for the gravel screening, wet sieving was necessary to separate sand and silt from the gravel. A representative sample of the fraction

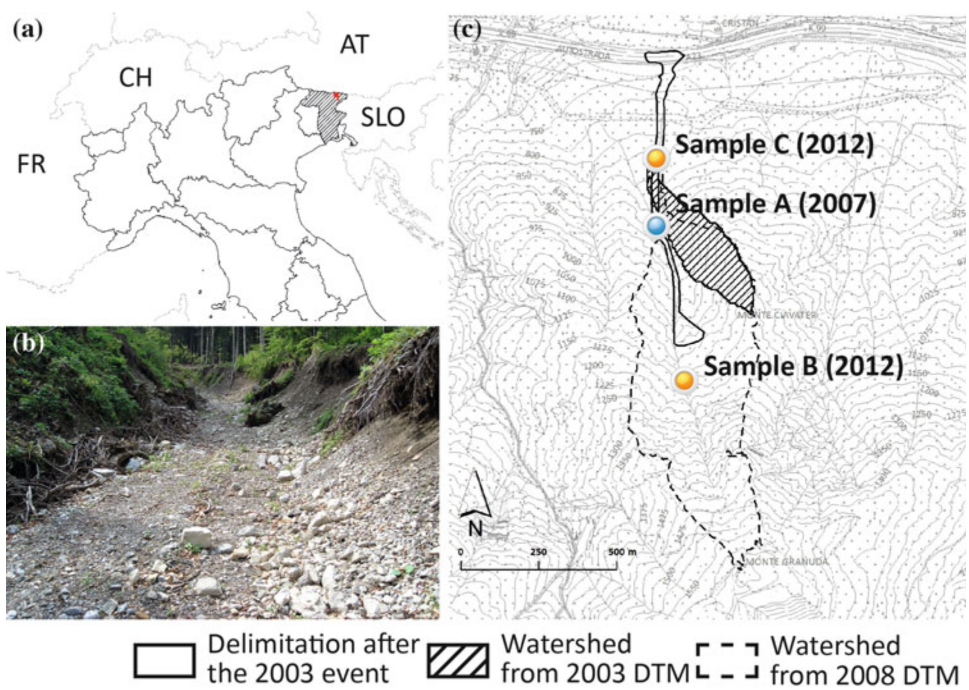

Fig. 87.1 Study area: **a** Location, **b** Fella SX transport area after the alluvial event of August 2003, **c** Fella SX watershed and sample points

Table 87.1 The fitting coefficients α, β, γ, δ of the samples collected along the stream in different years

Sample	η_P		σ_B	
	α	β	γ	δ
Sample A—2007	2 E-07	42.23	5 E-05	42.01
Sample B—2013	2 E-05	31.52	8 E-05	40.86

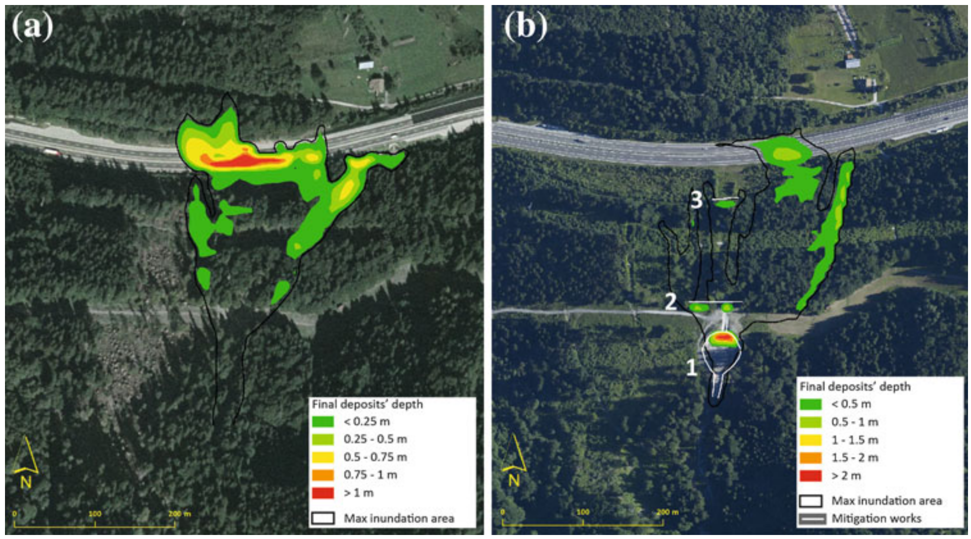

Fig. 87.2 Back analysis scenarios on 2003 DTM (**a**) and on 2008 DTM (**b**) with the rheological parameters of Aspen watershed model; in B are indicated also the mitigation works: *1* debris basin; *2* and *3* barriers

passing the 1 mm sieve was used for the laser diffraction analysis.

The samples collected in the different years diverge much in percentage terms: the sample A (2007) contains 64.8 % of gravel, 14.8 % of sand and 20.4 % of silt and clay, while the samples of 2012 have more than 85 % of gravel and less than 3 % of silt and clay.

The rheological study concerned only the fine fraction passing the 0.063 mm sieve. Suspensions at different water content were prepared from this fraction.

The experimental tests were performed using a controller stress rheometer (Rheostress Haake RS150, Haake GmbH, Germany) equipped with a parallel plate geometry with rough surface (35 mm diameter, 2 mm gap).

Through viscoplastic models, it has been possible to extrapolate basic parameters able to characterize the flow behavior as the yield stress and the viscosity. Bingham model permitted to correlate the collected data with an acceptable approximation. The Bingham yield stress σ_B and the plastic viscosity η_P are usually correlated with the solids volume concentration C_v with the empirical expressions proposed by O'Brien and Julien (1988), depending on fitting coefficients α, β, γ, δ, that for the samples of Fella basin are reported in Table 87.1. Since the sample C was collected in the accumulation area, on it rheological analysis were not performed.

87.4 Numerical Simulation Model

The numerical simulations were performed using the FLO-2D software (Version 2007.06). The main input features needed from this flood-routing model are a DTM, an hydrograph and couples of rheological parameters, expressed by the fitting coefficients α, β, γ, δ. For the simulations of 2003 was used a DTM with a grid 5 × 5 m obtained from the CTRN Map provided by FVG region. For the simulations, performed during the present study, was available a new generation of DTM, derived from a laser scanner survey, carried out between 2008 and 2009 from the Civil Defense of FVG Region. To be able to compare the results obtained 10 years after the event, the computational domain was maintained with a kernel of 5 m. For the hydrograph, the hydrologic model CLEM was used (Borga et al. 2002). For the simulated phenomenon, witnesses reported of an event developed in subsequent waves with a parossistic phase occurred between 17h10 and 18h50. In order to calculate the solid hydrograph

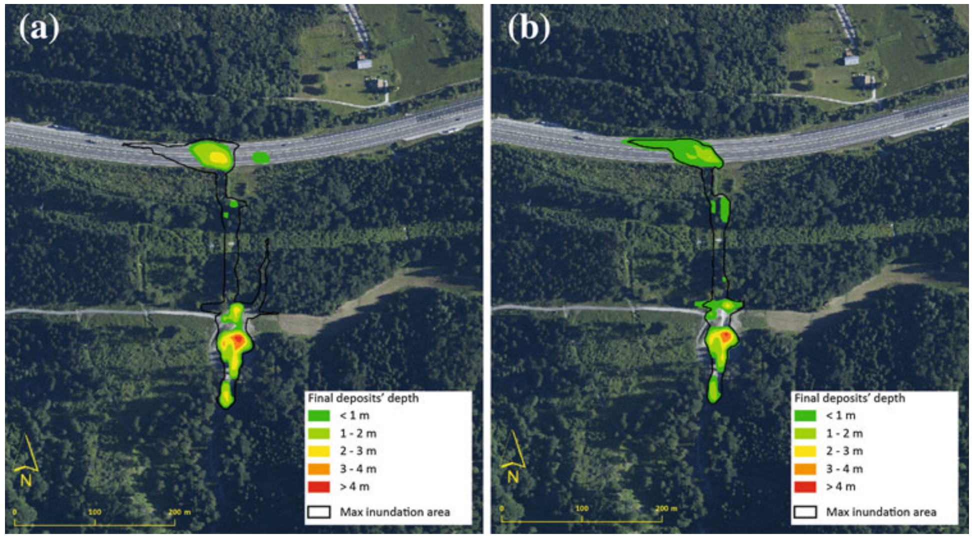

Fig. 87.3 Scenarios on 2008 DTM using the experimental rheological parameters of the sample collected in 2007 (**a**) and the one in 2012 (**b**)

the maximum concentration by volume (C_v), setted in the software, has been 0.55 for all the simulations.

For the present study, a back analysis was performed on DTM of 2003 using 12 couples of different rheological parameters, chosen from the ones available on literature, trying to reconstruct the real scenario, outlined during the field survey just after the alluvial event of 2003. Among all the available models, Aspen Watershed (O'Brien and Julien 1988) was selected (Fig. 87.2a). The simulated debris volume was equal to 4,972.62 m^3, with a final inundated area of 23,000 m^2.

Figure 87.2b represents the scenario obtainable on the DTM of 2008 using the same rheological parameters. The only difference with the simulation of Fig. 87.2a is the DTM; this last one contains also the mitigation measures realized after 2003. For this simulation, the volume was calculated to be 4,732.43 m^3, with a final inundated area of 11,000 m^2.

Figure 87.3a represents instead a possible scenario of event on 2008 DTM using rheological experimental parameters obtained by the sample collected during 2007 survey. In this case, the volume calculated was 4,738.64 m^3, with a final inundated area of 14,600 m^2. Finally, Fig. 87.3b represents a flooded scenario over the 2008 DTM, using rheological parameters obtained from the sample collected during 2012 survey (Table 87.1). In this case, volume was 4,787.10 m^3, while the final inundated area was 15,800 m^2.

87.5 Conclusions

On Fella SX basin a back analysis simulation was realized using firstly the 2003 DTM and secondly the 2008 DTM including also the mitigation measures. The obtained results show that the mitigation works are not completely efficient: the debris basin is not able to contain all the material and the barriers were simulated as impermeable walls, condition that creates a flow deviation to NE. Seen that also the back analysis realized with rheological parameters coming from the literature do not completely fit the real event, new simulations were realized with rheological parameters collected on the field.

From the results of the grain-size analysis emerged that the textural characteristics of the debris flow deposits are not homogeneous and it was decided to use a range of parameters. In the last two simulations the coefficients γ and δ take to high yield stress values and to an overestimation of debris depths. The results can be influenced by the type of rheometric device used, that analyzes only grain-size less than 0.063 mm.

The obtained results underline the importance of the rheology in this kind of elaborations and will be improved using other rheological devices, able to analyze coarser materials.

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