DETAILED REPORT OF CONTRACTOR
FOR FIRST ANNUAL REPORT

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Section 3.1: Objectives of the reporting period

According to the proposed work programme for DAMOCLES project the research team of the University of Padova (Mario A. Lenzi, Vincenzo D'Agostino, Carlo Gregoretti, Diego Sonda, Francesco Comiti) had the following objectives included in the Workpackage WP1 "Development of functional relationships for debris flow behaviour" and WP3 "Development of a small basin debris flow impact model":

- Organisation of the research team and scientific coordination of activities
- Acquisition of existing data on debris flow characteristics in small basins located in the Veneto Region and in the Autonomous Provinces of Trento and Bolzano
- Acquisition of the available numeric and cartaceous maps
- High-precision topographic surveying of the Rio Lenzi main channel and alluvial fan (test area C)
- Development of the DTM (Digital Terrain Model) for the Rio Lenzi entire catchment and for the alluvial fan
- Development of a 1-D submodel for debris flow routing
- Installation of ultrasonic sensors in the Rio Rudan main channel

Section 3.2: Methodology and Scientific Achievements Related to Work Packages

3.2.1 WP1 "Development of functional relationships for debris flow behaviour":

- Creation of a database concerning debris flow torrents in the Autonomous Province of Bolzano using a standard form to be used by both Research Institutes and Technical Services
- Development of a methodology for the assessment of debris flow volumes
- Development of a methodology for the assessment of magnitude-frequency relations of debris flow volumes

3.2.2 WP3 "Development of a small basin debris flow impact model":

- Implementation of GIS techniques to obtain the Digital Terrain Model (DTM) and Thematic Maps (geolithology, land use, basic hazards) for two study basins (Rio Lenzi and Rio Rudan)
- High-precision topographic survey of the Rio Lenzi fan area (test area C)
- Creation of the DTM for the Rio Lenzi alluvial fan
- Development of a 1-D submodel for debris flow routing
- Installation of ultrasonic sensors in the Rio Rudan main channel

3.2.3 Deviation from the proposed work schedule

According to the proposed activities the planned goals have been fulfilled.

3.2.1 WP1 "Development of functional relationships for debris flow behaviour":

Debris flow database

In order to make up a simple and user-friendly archive of all the debris flow-prone streams, a data collection from several sources (“Ufficio Bacini Montani, Prov. Autonoma di Bolzano”, “CARFRA project, Ufficio Geologia e Prove Materiali, Prov. Autonoma di Bolzano”, CORINE database, First Intervention Squad reports (FI), newspapers and others publications) was carried out for the Alto-Adige Region first (Bertotto, 2000).

A standard form to be used in the setting up of the database was developed, featuring administrative characteristics, morphometry, geology and geomorphology, land use, water discharges and recorded debris flow events.

30 streams have been inserted in the database so far, but the available data will allow to increase their number in the future.

The database file (in a “Word 2000” version) is attached in the CD-ROM (“debris flow database.doc” file).

Assessment of debris flow volumes

The estimation of debris flow magnitude, i.e. the volume of debris material discharged during a single event, is a basic step toward the assessment of debris flow hazard. A number of methods, including empirical and statistical formulas (e.g. Takei, 1984, Kronfellner-Kraus,1985, D’Agostino et al., 1996), geomorphological approaches (Hungr et al., 1984, Scheuringer, 1988, Thouret et al., 1995), and combined methods (Spreafico et al., 1999) have been proposed for the volumes assessment.

Although several estimation procedures are available, the assessment of debris flow magnitude poses still serious problems. The analysed area is a vast mountainous region in the eastern part of the

Italian Alps. It corresponds to the Provinces of Trento and Bolzano and to Veneto and Friuli - Venezia Giulia Regions (Fig. 1).

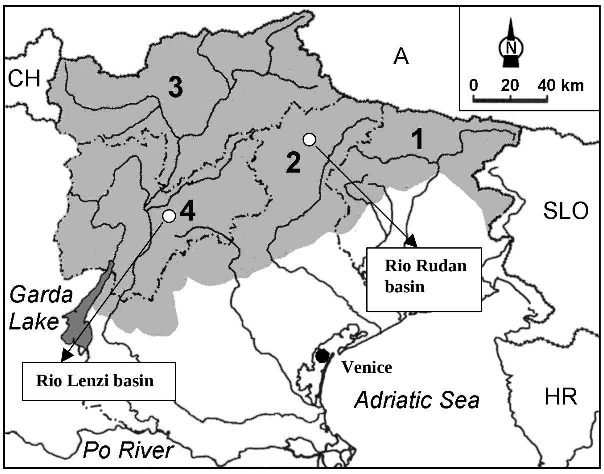

Figure 1 - Location map; the shaded area correspond to the the mountainous zone of the: 1-Friuli Venezia Giulia, 2-Veneto, 3-Autonomous Province of Bolzano, 4- Autonomous Province of trento

The central and southern parts of the area, encompassing the Dolomites, are mostly characterised by sedimentary and volcanic rocks. In the inner belt of the alpine range, outcrops of metamorphic rocks prevail, whereas massive cristalline rocks occur in the western part of the considered region.

Quaternary deposits are widespread throughout the alpine valleys. They consist of glacial and fluvio-glacial deposits, scree, landslide accumulations and alluvial fans. Complex orography influences the climatic characteristics of the Eastern Italian Alps causing high variability in the spatial distribution of precipitation and temperature. As far as the precipitation is concerned, valleys parallel to the Alpine structure are characterised by relatively dry conditions, with annual precipitation of about 500-600 mm, whereas transverse-oriented valleys have a higher precipitation rate (1500-2000 mm); annual amounts of precipitation exceed 3000 mm in some prealpine areas.

Seasonal distribution of precipitation is continental, with summer maximum, in the inner part of the alpine range, whereas spring and autumn maxima are observed in the prealpine belt. Landslides and debris flows frequently occur in the studied region, often resulting in high risk because of the heavy urbanisation in valley floors and on alluvial fans and of the presence of important transportation routes.

Earliest data begin from mid-19th century; amongst the floods that occurred in the considered period, two major events (September 1882 and November 1966) should be mentioned, which affected vast areas and caused serious damage.

The range in drainage area of basins in which quantitative data on debris flow volumes have been collected is rather wide, however small basins (< 5 km^2) prevail, corresponding to about 75 % of the total sample.

Figure 2 shows a scatterplot of debris flow magnitude versus drainage basin area; when more than one event has been recorded in the same basin, only the largest value was plotted. An upper limit can be outlined, which approximately correspond to an unit value of 70000 m^{3}km^{-2}; this value, which confirms the findings of a previous study (Marchi and Tecca, 1996), express the maxima that were attained in the considered region on the occasion of high intensity storms in basins where large amounts of sediment were available. The upper envelope does not show a clear tendency to a reduction of volumes per unit area for increasing basin size.

A particular case is represented by two basins in which the mobilisation of large landslides resulted in multiple surges debris flows which lasted for several days and discharged huge amounts of sediment (Fig. 2). Concerning the lower limit of debris flow volumes, minimum values of 1000 m^3 are often observed, only in two cases lower values being reported.

Debris flows of lower magnitude actually occur, but they are reported only for a very few basins carefully surveyed because of their dangerousness. Even taking into consideration debris flows other than the largest event in each basin, volumes in the range of 300 - 800 m^3 would be reported only for a very few streams. The increase of magnitude M (m^3) with basin area A_d (km^2) is very limited and the lower envelope can be expressed by the following equation:

$$M = 1000 \cdot A_d^{0.3} \tag{1}$$

Since also small magnitude debris flows can prove very hazardous, e.g. when they affect railways and motorways, the lower envelope drawn in figure 2 can help defining minimum values of magnitude to be considered in the design of debris flow attenuation measures. The two envelope lines drawn in Figure 2 are merely intended to outline the volume range of debris flows in Northeastern Italy and do not represent statistical relations between debris flow magnitude and basin area.

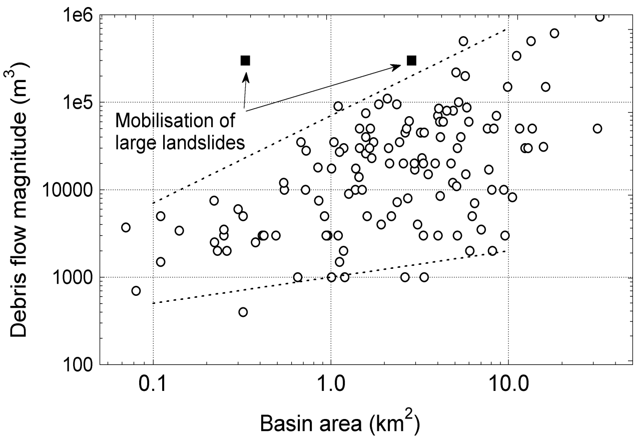

Figure 2 - Scatterplot of debris flow volumes (magnitude) versus drainage basin area

An analysis aimed at assessing the relationships between debris flow magnitude and morphometric and geolithologic characteristics of the basins was carried out for a sample of basins lying in the Provinces of Trento and Bolzano (Fig.1). The analysis of historical records in the archives of the Forest Offices of these provinces made it possible to extract the largest debris flows occurred over a long time period (about 100 years). On these basis, debris flow volumes may be deemed representative of high intensity, centennial frequency events. A previous analysis conducted by D'Agostino et. al. (1996) on the debris events occurred in the eastern part of the Province of Trento, proposed a relation to asses the magnitude of the total sediment volume yielded.

The relation assumes, as independent variables, the catchment area A (km^2), the mean gradient of the stream S (%) and a dimensionless geological index (GI):

$$M = 45 \cdot A^{0.9} \cdot S^{1.5} \cdot GI \tag{2}$$

Eq. (2) was obtained by means of a multiple regression, imposing to minimise the mean square error.

Following an analogous procedure, a largest set of data including also the most notable events occurred in the upper part of the Adige basin (Province of Bolzano), was processed. The determination of the independent variables was conducted using standard topographic and geologic maps. No GI values less than 0.5 occurred in the sample; in case they should be set to 0.5. The relation obtained is the following:

$$M = 70 \cdot A \cdot S^{1.28} \cdot GI \tag{3}$$

Eq. (3) gives a level of accuracy lower than eq. (2): this fact can be ascribed to the wider region under study that involves less homogenous geologic and climatic conditions.

The loss function selected (eq. 3) induces a tendency to an overestimation in the forecast equation. In fact, the data included in the sample differ even of three order of magnitude, passing from the lowest (700 m^3) to the highest (950000 m^3), and the most severe events have more influence on the determination of the parameters that produce the minimum error. Considering the heterogeneity of the sample and the "biased" nature of the phenomenon, the use of the three parameter *A, S* and *GI* confirms its robustness for assessing empirical equations on a regional context where historical data are available.

Assessment of magnitude-frequency relations of debris flow volumes

Most empirical and statistical equations for the estimation of debris flow magnitude compute "maximum" or "extreme" possible volumes. Less information is usually given about the magnitude - frequency relations, which can usefully contribute to the planning of attenuation measures. Van Steijn (1996) plotted patterns of debris-flow magnitude versus return period (computed as the inverse of the frequency of occurrence) for several mountainous regions of Central and Northwest Europe and observed that debris-flow frequency is strongly related to triggering conditions. Van Steijn (1996) suggested that debris availability is a limiting factor for the Northwestern Europe, but much less for the Alps. Brochot (1999) identified groups of homogeneous basins in the Arc River basin (French Alps) by means of the principal component analysis and assessed magnitude - frequency relationships within homogeneous groups. This approach made it possible to overcome the limited sample size of records on sediment volumes available in single basins. In the Italian Alps, historic data on debris flow volumes are reported for many basins, but only in a few cases time series including a sufficient number of non-null cases are available: this causes serious limitations to the probabilistic analysis of magnitude - frequency relations. A preliminary analysis has been carried out in three basins: the Moscardo Torrent (4.1 km^2, 9 years of records), the Rio Bianco (0.88 km^2, 20 years of records) and the Rio Inferno (0.69 km^2, 46 years of records). The extreme value distribution-EVI was used to interpret the complete duration series of annual maximum values of debris flows magnitude. For the Rio Bianco and Rio Inferno many annual maximum values correspond to a null volume (i.e. no debris flows have occurred in many years). In the Moscardo Torrent (Arattano et al., 1999) more than one data was available in some years: the maximum annual value was then selected for the analysis.

In the Figure 3 the unit values of magnitude for the three cases are plotted versus the reduced variate *y*. The probability value assigned to each magnitude was computed using the Weibull formula. The control of sediment supply on magnitude and frequency of debris flows, whose importance has been stressed by Bovis and Jakob (1999) for basins of the British Columbia, arises also from this analysis. In fact, a very active basin like the Moscardo Torrent (4.1 km^2), where the availability of loose debris can be deemed unlimited, debris flows occur very frequently and the magnitude corresponding to return periods of 5 - 10 years can reach about 10000-15000 $m^3\ km^{-2}$. Similar conditions, even if with a lower frequency of events, occur in the Rio Bianco basin (0.88 km^2).

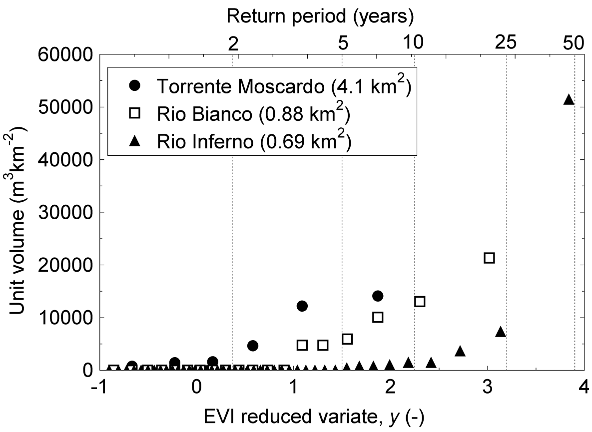

Figure 3 - Plot of unit debris flow volumes versus frequency: EV1 distribution

Although rather active, the Rio Inferno (0.69 km^2) displays a markedly lower frequency of debris flows; moreover, most of recorded events are of small or moderate magnitude, whilst one (51000 $m^3\ km^{-2}$) exceeds by far all the others. Small events could be referred to the removal and transport of an amounts of debris easily mobilisable even by minor floods, while the largest events express both the massive release of more consolidated debris along the stream, and the collapse of the potential unstable slopes and sediment sources areas.

3.2.2 WP3 "Development of a small basin debris flow impact model":

Study basins

Two basins are involved in this research: Rio Lenzi (test area C), located within the Autonomous Province of Trento, and Rio Rudan, in the Province of Belluno (Veneto Region) Their main morphometric characteristics are summarised in Table 1 and their location is shown in Fig. 1. For a detailed description of basin's characteristics see the First Six Months Report and the Figures attached in the CD-ROM (files "Rio Lenzi Figures.doc" and "Rio Rudan Maps.doc").

Table 1 – Main morphometric characteristics of the two study basins

	Rio Lenzi	Rio Rudan
Catchment area (km^2)	2.43	3.003
Length of the main channel (km)	2.29	4.02
Main channel mean gradient (%)	26	34

Both the basins are prone to generate debris flows as it results from many historical records.

In the 1882 an extraordinary precipitation event occurred all around Trento, triggering a massive debris flows in the Rio Lenzi basin. Several deep erosion (still active) were incised in the upper part, delivering huge amounts of sediment to the main channel which built many lateral deposits downstream. The urbanised fan was flooded with severe damages. In 1917 and 1951 other smaller debris flow events affected the catchment fan. In the 1966 other extraordinary rainfalls produced a debris flow which flooded on the lower part of the fan leaving boulder up to 0.5 m large.

Dem implementation

The GIS WODITEM (Watershed Oriented Digital Terrain Model) (Cazorzi, 1996), a raster-type geographical information system especially devised for hydrological investigations in mountain basins, was used in order to create the Digital Elevation Model (DEM) for the two basins, from which the slope and aspect raster maps were produced. A grid base of 10×10 m was used, apart from the Rio Lenzi fan where a 5×5 m grid was adopted. Pits were identified and removed in the raster elevation map; a synthetic channel network was then extracted from the basin DEM. Digital Terrain Model (elevation, slope and aspect) and thematic maps were created and edited using Arcview 3.1 software (see "Rio Lenzi Figures.doc" and "Rio Rudan Maps.doc" attached in the CD-ROM).

Rio Lenzi main channel and fan survey

In order to develop a physical based, user-friendly 1-D (channel routing) and 2-D (propagation on the fan) models for the debris flow, a high-detailed elevation map is much needed if the topography is assumed to be the determining factor upon the movement downstream of the flow, assumption which is taken to simplify the numerous variables affecting the phenomenon.

The existing topographic maps do not offer the proper accuracy (1:1000 - 1:500 scale), therefore a high-precision topographic survey was needed for the fan area.

A classical survey methodology was adopted by using a total station system, with 124 stations and 7453 measured points at a spatial density varying according to the local morphology and to the proximity to the channel. In fact the survey methodology has to consider all the natural (large boulders, sediment heaps) and artificial (riprap, roads, buildings, check-dams, bridges) structures that might affect the debris flow trajectory. As to the main channel, 36 cross-sections have been surveyed.

The Aulitzky methodology for debris flow hazard mapping was also applied to the fan. The high precision of the elevation model obtained in this way will allow comparison with quicker and cheaper survey techniques (GPS, photointerpretation, laser scanning) which are more likely to be adopted for operative purposes, given the high cost of a topographic survey so detailed as that it is being carried out.

Development of 1-D sub-model for debris flow routing

The use of mathematical models in the simulation of diverse hydraulic phenomena has become essential as a predictive tool in the evaluation of proposed engineering works or the degree of safety of undisturbed fluvial systems. The researchers were forced to revert physical modelling in order to simulate the effects of floods events on hydraulic works and their environmental context. Dealing with the triggering, routing and spreading of debris flows the modelling necessity is even higher, because only a large number of scenarios may be helpful for the mud/debris flow hazard assessment (Laigle e Marchi, 2000), i.e. considering the simultaneous occurrence of certain rheological parameters and peak discharge values for a given total sediment volume (magnitude).

The first step for developing a mathematical model for mapping hazard areas which can be flooded by a debris flow is the simulation of the routing along the stream reach that flows through the fan. This channel can be: an undisturbed alluvial stream; a torrent interested locally or continuously by longitudinal or cross-stream works for controlling the phenomenon; a completely artificial fixed bottom channel designed for convey downstream the debris flow; a combination of the previous considered situations.

The length of the channel into consideration starts from the apex of the hydraulic fan and ends at the confluence of the stream with the higher order stream. The hydraulic apex of a fan differs from the geological one in the sense that often stream reaches located just upstream of the geological fan apex are prone to be congested and/or overflowed during debris flow events. This circumstance is thus decisive for the fan evolution and for the assessment and mapping of hazard areas.

The main goal of the 1-D simulation is the location of critical cross-sections along the channel, where the debris flow spreading on the fan begin for a given scenario of event.

In alpine areas fan slope of catchments where debris flow may occur (basin area < 10 km^2) are rarely lower than 3%. Considering the unsteady flow for a gradually varied open channel, the inertial terms are negligible in the momentum equation in comparison with the bed slope (Henderson, 1966). In this case the Saint-Venant equations reduce to (Weinmann and Lauerson, 1979):

$$\frac{\partial Q}{\partial t} + c\frac{\partial Q}{\partial x} = D\frac{\partial^2 Q}{\partial x^2} \tag{4}$$

where: t is the time; x the spatial coordinate; Q is the flow rate; $c=dQ/dA=(1/B)\, dQ/dh$= kinematic wave speed (B= channel top width; h= flow depth; A=flow area); $D=Q/(2BS)$=diffusion coefficient (S=channel bed slope).

Cunge (1969) proved that the conventional Muskingum equations are assimilable to a convective-diffusive equation like (4), if the numerical diffusion is equated to the physical diffusion (D, eq.4). Developing this hypothesis in a computational space-time grid, it follows:

$$Q_{j+1}^{n+1} = g_1 Q_j^n + g_2 Q_j^{n+1} + g_3 Q_{j+1}^n \tag{5}$$

where the variable parameters g_i are expressed by the relations:

$$g_1 = \frac{1+N-P}{1+N+P}; \quad g_2 = \frac{-1+N+P}{1+N+P}; \quad g_3 = \frac{1-N+P}{1+N+P}; \tag{6}$$

with $P=2D/(c\,\Delta x)$ and $N=c\,\Delta t/\Delta x$..P and N parameters are computed by averaging the three respective values coming from point 1, 2 and 3.

For the evaluation of the kinematic speed (c) of a debris flow it is necessary an assumption on the joint between the surge depth (h) and its velocity (v). This assumption may be supported by the analysis of the observed maximum velocity field data in monitored stream. Even if different rheologic models may interpret the debris flow movement (O'Brien and Julien, 1984), the analysis of precise measurements of several granular surges moving on a mobile bed shows the capability of the Newtonian flow to give acceptable results. Gregoretti (2000) and Rickenmann and Weber (2000) estimated the flow resistance in terms of the dimensionless Chezy coefficient (C^*). Both authors obtained that most data are included in the region:

$$\frac{v}{\sqrt{g\ h\ S}} = C^* = 1.0 \div 3 \qquad (7)$$

where S represents the channel slope (m m^{-1}) - Gregoretti (2000) considers S =sin θ; with θ=inclination angle of the channel - and h is the surge depth (m).

Nevertheless higher value of C^* are reported by Gregoretti (2000) for surges on mobile bed subsequent to the first surge and by Rickenmann and Weber (2000) for indirect velocity estimates in the Swiss Alps, eq.(7) seems acceptable for debris flow motion on an alluvial bed. Higher C^* values (ranging from 5 to 7.5) are instead recommended for fixed bottom and/or ratios between surge depth and boulder diameters making up the front greater than 7 (Gregoretti, 2000).

The adoption of eq.(7) linked with the hypothesis to equate the energy slope to the bed slope, allows both the computation of the kinematic speed ($c=1.5\ v$) in eq.s (6) and the surge depth associated to the flow rate Q_{j+1}^{n+1} in eq.(5).

Following the above-described procedure the Muskingum model has been developed for a channel geometry described by eight points (1-8 of figure 5). Each of these contains three absolute coordinate (X and Z in the cross-section plan and X and Y for a plan view). In addition 3 additional points are automatically generated by the program: point 9 represents the channel axis, points 10 and 11 are fictitious points, located vertically 50 m above point 7 and 8 respectively. Points 10 and 11 are necessary if the bank overflow has been prevented by the user (the setting of this option may be useful in a design perspective) or if the overflow occur (above point 7 and/or 8) and temporary cross-section parameters have to be evaluated for a given depth (h).

The described computational approach has been developed using the Borland Delphi 5.0 language. Further improvements of the program are in progress dealing with the estimation of surface super elevations in bends, the presence of bridges, the diversion of the flow due right and/or left bank overflowing.

In figures 6-7 the results of an application are shown considering a channel having a rectangular cross-section and a constant slope equal to 19% (the same of the Rio Lenzi, Trento – Italy, along the fan). The channel is 5 m wide for the firsts 210 m, it follows an abrupt narrowing to 3 m for a 30 m long reach, after which the channel enlarged again to 5 m for the remaining 210 m. The input debris-flow hydrograph is triangular shaped with a peak value equal to 100 m^3 s^{-1} and the assumed roughness C^* is 3 for the whole channel.

The computation has been conducted choosing a Δx value ranging from 20 m - in the narrowing - to 50 m - in the remaining reach - and a Δt value of 5 s.

The model responds satisfactorily to the sharp input hydrograph and to the narrowing. The pattern of flow rates with time (fig.6) at different locations shows a certain lamination of the peak discharge and a progressive smoothing of the initial triangular input hydrograph. The depth pattern for the cross-sections inside the narrowing increases markedly (fig. 7) and returns downstream of the contraction to values comparable with those upstream of the narrowing. The volume conservation is still acceptable for a debris flow wave, because the entering sediment volume of 33000 m^3 of the initial cross-section becomes equal to 33650 m^3 in the terminal one, with a volume increase equal to 2%

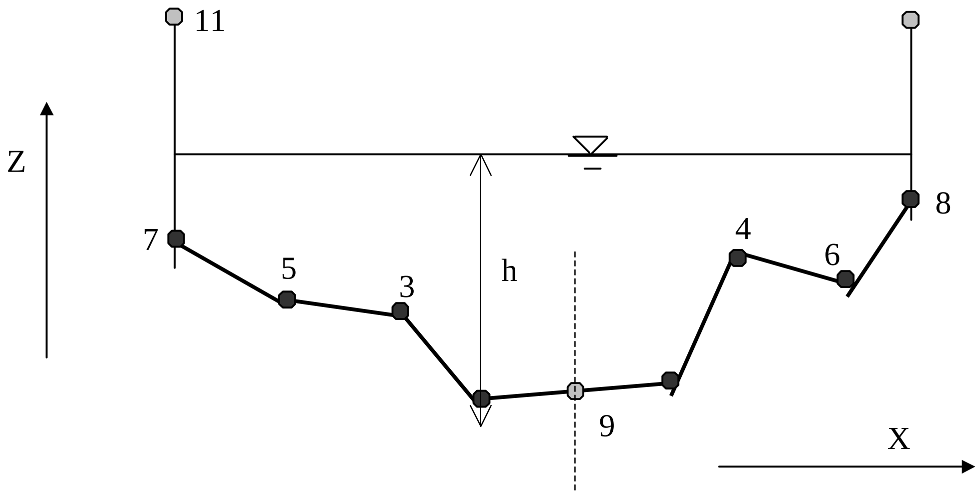

Figure 5 – Sketch of the cross-section implemented in the 1-D model

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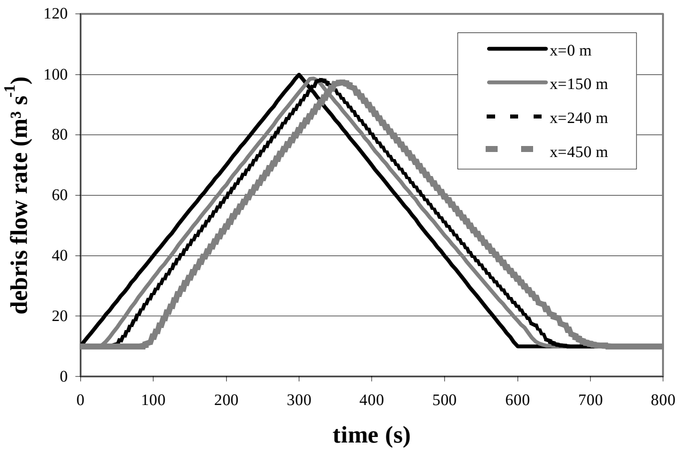

Figure 6 – Debris flow routing trough a rectangular channel 450 m long (C^* =3; S=19%; width B=5 m; abrupt narrowing to B=3 m from x=210 m to x=240 m): *flow rates hydrographs*

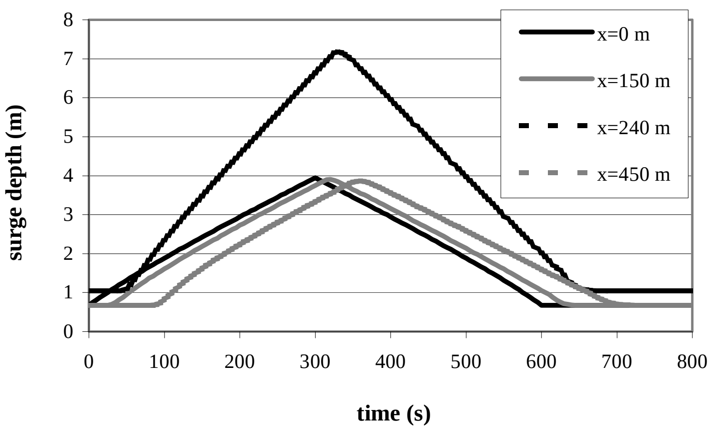

Fig. 7 – Debris flow routing trough a rectangular channel (same conditions of figure 6):

surge depths hydrographs

Installation of ultrasonic sensors in the Rio Rudan channel *(see also image files attached in the CD-ROM)*

The Rio Rudan torrent (Fig. 1) origins at 1900 m.s.m. at the foot of a cascade, 15 m high, downstream a scree placed under the southern rock faces of Monte Antelao (3264 m.s.l). The torrent pass under the bridge of the National Road n. 51 and laps against the village of Peaio (860 m.s.l) before flowing into the Torrent Boite at 800 m.s.l. . The Rio Rudan flows over a deep alluvial bed with very high and sloping banks which are continuously eroded by mass transport phenomena except that in the middle part where the torrent flows over a surficial rock layer. The average slope of the Rio Rudan between the cascade and the National Road is 24% (13.5° sloping angle). The torrent is canalised 50 m upstream the National Road n. 51. The banks of the canalised part are built by concrete quasi-vertical walls and the across section is quasi rectangular. The average width of the across section is about 10 m and downstream the bridge are located some transversal drop jumps which were built to avoid the erosion and the consequent localized scour of the bed.
The Rio Rudan, downstream the bridge, is straight with a length enough to place ultrasonic level sensors to measure directly the flow depth and indirectly the velocity of a bore. The velocity of the debris flow front is computed dividing the distance between the sensors by the time required by the debris flow front to cover this distance. This time is obtained comparing the recorded signals of the sensors. The signal recorded by the ultrasonic level sensor is not easy to read because is affected by a strong oscillation. The ultrasonic level sensors should be placed at least 30 m apart to distinguish a same peak or a same wave shape in the recorded signals.
The ultrasonic level sensors are hanged, by a steel structure fixed by flanges to the concrete banks, next to the middle of the across section. Their positioning downstream the bridge is showed in figures 7 and 8 of the attached file mentioned above.
The used ultrasonic level sensors have a range up to 10 m, a measuring frequency of 0.5 Hertz, a sensitivity of 0.001 m and an accuracy of 0.1%. The instruments are provided by a serial interface RS232 that transmits the recorded data to a data logger apparatus placed at the top of a stake 2.5 m high. A pluviometer is also placed on the bank and connected to data acquisition apparatus. The electrical power needed to supply the whole system of measuring and data acquisition instruments is furnished by a floating/buffer battery (12 Volt) charged by a solar panel. The records are acquired every 60 minutes. When the debris flow is coming, it breaks a wire, which closes a circuit, placed along the across section, 50 m upstream the upper ultrasonic level sensors. At the opening of the circuit, a continue acquisition of all recorded data starts (0.5 Hertz). All the sensors will be operated and managed by the ARPAV – Avalanche Center of Arabba.

Section 3.3: Socio-economic Relevance and Policy Implication

In order to clarify with an actual example the socio-economic relevance of the project advances, consider that the annual budget of the Autunomous Province of Trento for torrent control works and debris flow management is around 20 millions euros, whereas damages caused by debris flow events can reach tens of millions euros, with hundreds of deaths, since many towns are present on the alluvial fans. Another concern are the road closures, for example recently the important motorway connecting Verona with Innsbruck has remained blocked for two days because of a debris flow.
At this moment the end-users (i.e. the Protection Agencies) are using the Aulitzky methodology both to evaluate whether debris flows can occur along a stream and to produce maps with three different levels of hazards on the alluvial fan. This qualitative approach does not allow to assess how critical structures along the channel (i.e. bridges, check-dams, ripraps) affect the debris flow route along the channel, particularly where flooding is likely to occur and the volume of the overflowed material. The developed 1-D submodel permits to simulate such dynamics and, once the 2-D fan propagation submodel will be completed, to produce detailed hazard mapping with valuable information about deposition patterns, which can lead to an efficient land-use planning.

Section 3.4: Conclusion

A database of debris flow-prone streams within the Autonomous Province of Bolzano containing 30 records has been carried out, nevertheless available data will allow to increase their number in the future. A simple methodology for the assessment of debris flow volumes has been developed, along with an approach for evaluating of the magnitude-frequency relationship.

A one-dimensional model for debris flow routing along the channel has been developed and calibrated. It will be tested and validated in the Test Area C (Rio Lenzi channel) and in the Rio Rudan channel, which has been equipped with ultrasonic level sensors. Finally, the high-precision DTM of the Rio Lenzi alluvial fan has been obtained, enabling the application of the under-construction 2-D propagation model which will be linked to the 1-D routing model.

Section 3.5: Plan and Objectives for the Next Period

- **Task 1:** Calibration and validation of the 1-D submodel to the Rio Lenzi main channel. The detailed topographic survey of the channel will be herein used. Two different sedimentographs will be simulated.

- **Task 2:** Organisation of the Padova meeting (9-11 May 2001)

- **Task 3:** Development of the 2-D submodel for the debris flow propagation on the fan area.

- **Task 4:** Calibration of the instruments installed on the Rio Rudan channel. Acquisition and validation of debris flow data. If data will be available the 1-D submodel will be also applied to the Rio Rudan.

- **Task 5:** Calibration, validation and application of the 2-D submodel integrated with the 1-D submodel for the Rio Lenzi alluvial fan.

- **Task 6:** Preparation of the Second Year Final Report

Table 2 - Next project activities

	M	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**G**	**F**
T1	------	------	------									
T2		------	------									
T3		------	------	------	------	------						
T4						------	------	------	------			
T5								------	------	------	------	
T6												------

Section 3.6: References

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