DAM/PR/0110/3

DAMOCLES

DEBRISFALL ASSESSMENT IN MOUNTAIN CATCHMENTS FOR LOCAL END-USERS

Contract No EVG1 - CT-1999-00007

DETAILED REPORT OF
CONTRACTOR FOR
THIRD PROGRESS MEETING
(1 March – 31 October 2001)

University of Newcastle upon Tyne
UK

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DETAILED REPORT OF THE CONTRACTOR

Contractor: University of Newcastle upon Tyne

Responsible Scientist: Dr J C Bathurst

Address:
Water Resource Systems Research Laboratory
Department of Civil Engineering
University of Newcastle upon Tyne
Newcastle upon Tyne
NE1 7RU
UK

Telephone: +44 191 222 6333/6319

Fax: +44 191 222 6669

Email: j.c.bathurst@newcastle.ac.uk

SUMMARY

(i) Field visits to the Valsassina and Ijuez focus areas were carried out to collect soil property data, to measure channel dimensions and sediment characteristics and to be familiarized with the areas. Soil samples were brought back to the University of Newcastle for laboratory analysis and soil property maps have been compiled.

(ii) Catchment time series and property data have been assembled for both focus areas and used to create the necessary files for running and testing the SHETRAN landslide model. The data include precipitation and evaporation records, runoff records, topographic, soil and vegetation maps and landslide inventories.

(iii) Preliminary SHETRAN simulations have been carried out for the two focus areas, meeting the Newcastle team's obligations to deliver preliminary simulation data to Workpackage 2 in Month 18 (August 2001).

(iv) Validation of the SHETRAN landslide model for the Llobregat catchment has been completed. The results demonstrate an ability to bracket the observed occurrence of debris flows with simulated distributions and to determine catchment sediment yield within the range of regional observations.

1 OBJECTIVES OF THE REPORTING PERIOD (1/3/2001 – 31/10/2001)

(i) Assembly of Valsassina and Ijuez catchment time series and property data, including field measurements and laboratory analysis of soil samples.

(ii) Creation of SHETRAN model files for the two focus areas.

(iii) Initial SHETRAN simulations for the two focus areas to meet the Newcastle team's obligations to deliver preliminary simulation data to Workpackage 2 (WP2) in Month 18 (August 2001).

2 SCIENTIFIC/TECHNICAL PROGRESS

2.1 Gantt Chart

The project Gantt Chart is attached. At this stage there is no change from the version in the project contact document.

2.2 Resources Used

The originally planned and actual use of manpower resources from the start of the project (ie over 20 months) is as follows:

	Additional personnel (person-months)	Permanent personnel (person-months)
Workpackage 4	18.5	2
Workpackage 5	0.1	0.6
Total actual use	18.6	2.6
Original planned use	26.3	2.5

The project benefitted from 4½ months of work contributed by Ms Greta Moretti, visiting the University of Newcastle as an Occasional Student as part of her PhD studies at the University of Bologna. This work (apart from fieldwork expenses) was not charged to the project.

Mr Aidan Burton (Research Associate) was funded for half a month to complete the Llobregat validation.

Mr Rob Hiley (Senior Research Associate) was funded for half a month for computer systems and SHETRAN software support.

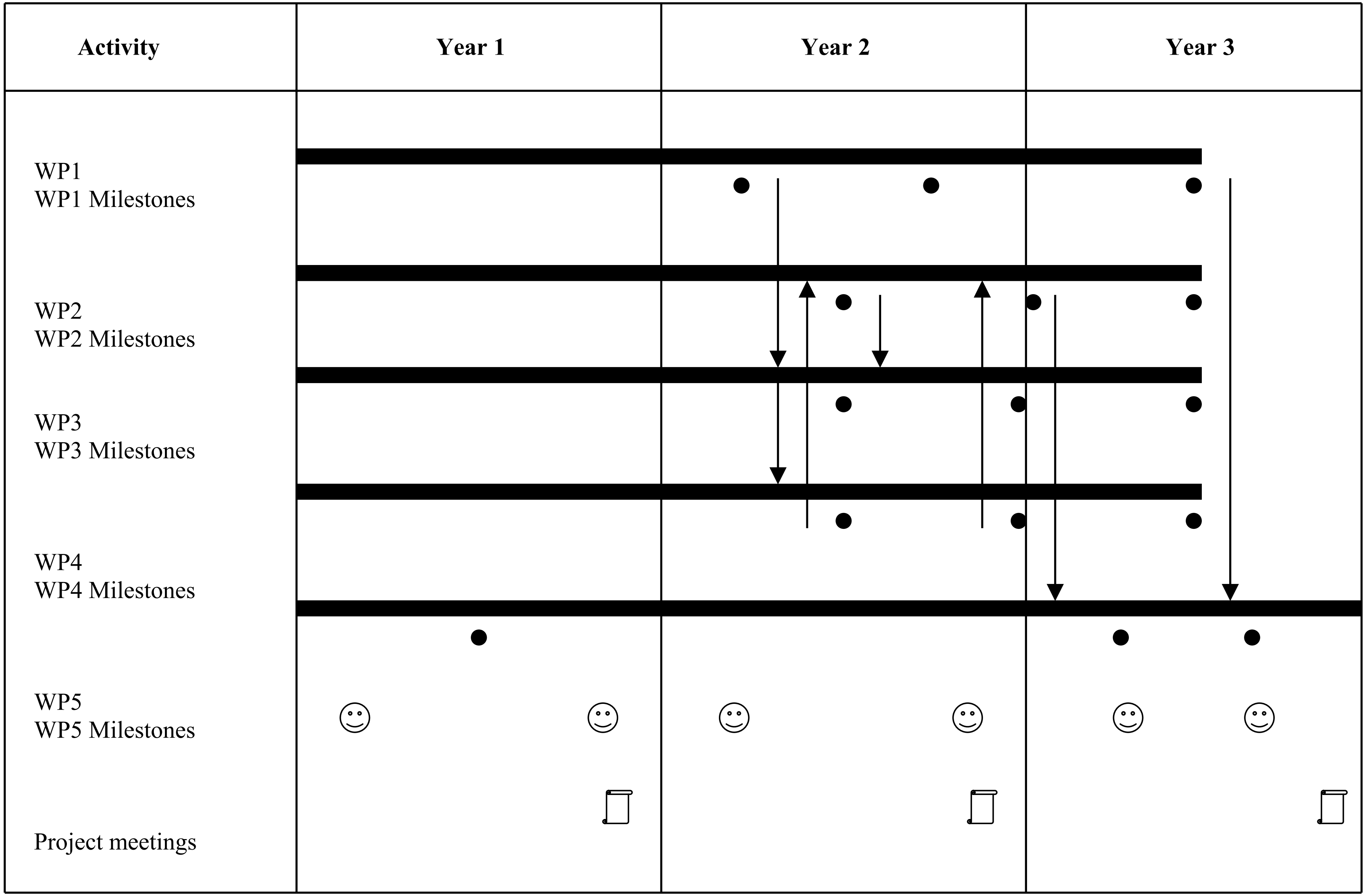
The originally planned and actual use of financial resources from the start of the project are respectively 148,460 and 106,590 euros.

2.3 Workpackage 4: SHETRAN Landslide Model

2.3.1 Summary

This section summarises the work that has been carried out since the beginning of May 2001 regarding data assembly and preliminary SHETRAN simulations for the Valsassina and Ijuez focus catchments. Data assembly included climate data such as precipitation and evapotranspiration, soil and vegetation maps, and discharge records for stations in the catchments and in the surrounding areas. Disaggregation and gap-filling has been done for temporally varied data by applying simple statistical techniques, mainly correlation between stations and/or between values at the same station but at different times. Soil and vegetation properties for both catchments were derived by means of field work and laboratory analysis. Spatial distribution was defined by correlating the derived parameters with available geological and vegetation maps.

Gantt Chart for the DAMOCLES Project



Vertical arrows indicate exchanges between workpackages at the times indicated by the milestones.

Three-day field visits were made to Valsassina in May and to the Ijuez catchment in June. The Newcastle team was joined by the Milan Bicocca team for the Valsassina visit and by the Pyreneen Institute of Ecology team for the Ijuez visit.

The Valsassina focus area contains two catchments: the main Pioverna catchment and the small neighbouring Esino catchment.

2.3.2 Data acquisition and analysis

a) Valsassina Catchment, Lombardy, Italy

a.1 Precipitation records:

The purpose of the precipitation analysis is to disaggregate the available daily precipitation data into hourly precipitation as required for the landslide model. Precipitation records at daily recording stations have to be disaggregated both temporally as well as spatially using hourly precipitation records wherever available. The statistically based model "Raindist", developed by Mr Chris Kilsby at WRSRL, was selected for this purpose. Two main relationships have to be defined as input for the Raindist model. These are daily total versus hourly duration for hourly recording stations, and annual total versus elevation for all stations in the surrounding areas.

Daily precipitation records were obtained for raingauges in and around Valsassina. The Barzio hourly precipitation data were used to construct a daily total versus hourly duration relationship. A simple Thiessen Polygon method was used for spatial distribution of precipitation data. No clear correlation between rainfall and altitude was identified. Raindist was set up for Valsassina and used to disaggregate the daily rainfall in four other stations in the catchment. The resulting hourly precipitation values were prepared as an input data file for SHETRAN covering the period between 1993 and 1999 inclusive. This defines the initial Valsassina simulation period.

a.2) Evapotranspiration data

Evapotranspiration data were derived from the available daily average temperature data at Lierna station. This station has continuous record starting from 1993 to 1995 which was used by Blaney-Criddle formula to calculate the daily average evapotranspiration from which hourly mean values were derived. The produced values for this period were repeated for the following 4 missing years as there were no reliable temperature data available for the period of 1996 to 1999.

a.3) Vegetation cover:

A vegetation map for Valsassina was prepared using a 1:10000 scale topography map, a landuse map produced by the CARINA project in Italy, and most important of all a vegetation distribution map prepared by Carta Geoambientale (Regione Lombardia, 1987). In addition, notes taken during the field visit to the area and personal observations were useful for this analysis. By combining these sources four main vegetation types were identified in Valsassina. These are pasture and grass at valley bottom, pine forest at elevations up to about 1000 m, grass and meadows at elevations up to about 1500 m, and bare rock at higher elevations. Pasture and grass were lumped together and a vegetation map of three vegetation types was prepared for SHETRAN.

a.4) Soil cover

Eighteen soil samples were collected in different locations in the catchment through field work conducted by the Newcastle and Milan-Bicocca teams. These samples were analysed in the laboratory for studying the physical and mechanical characteristics of the soil. Three major soil types were found by analysing the soil samples according to percentage of sand content. Using a geology map provided by Carta Geologica, Region Lambardia (2001), it was noticed that soil distribution (three classes) is in agreement with the major geological features in the catchment. Figure 1 shows the locations of the soil samples overlaid on geology. Thus, soil coverage was distributed according to this pattern and a map in SHETRAN format was produced and transferred as an input file. A report on the soil analysis has been produced by Ms Moretti.

a.5) Discharge record

Only 1½ years of unreliable stage data at the Bellano outlet station are available. For this reason a regionalisation analysis in the study area and a channel bank-full discharge investigation were done instead. The analysis indicates that for a catchment similar to Valsassina, a 1-year flood may reach a maximum of 200 m^3/s (Brath and Franchini, 1998). This value should be used here as a guide limit for the simulation results.

b) Ijuez Catchment, Northern Spain

b.1) Precipitation records

Daily precipitation records are available for stations in and around the catchment. Hourly precipitation data are available only at Jaca, 10 km away from the catchment. Daily records for Bescos have therefore been used and disagregated into hourly values by using the hourly precipitation data at Jaca station. Following the procedure mentioned above, a daily total precipitation versus duration relationship was constructed for Jaca. The Raindist model was then set up to incorporate the Ijuez catchment and used to disaggregate the Bescos daily rainfall. The resulting hourly precipitation were prepared as input data files for SHETRAN for the period between 1995 and 1998 inclusive. This defines the initial Ijuez simulation period.

The Ijuez catchment was therefore divided into three rainfall areas according to altitude (800-1200m, 1200-1600m, and over 1600m). Each area has different hourly rainfall values calculated from the Bescos disaggregated precipitation data and based on the annual total precipitation versus elevation linear relationship.

b.2) Evapotranspiration

Pan evaporation data are available for certain years and for the summer months only. Potential evapotranspiration values were therefore derived from the mean daily temperature record (average of maximum and minimum) at Bescos, which is vailable for 1971 to 1994, excluding 1990, and from 1998 to 1999. The conversion (with the Balney-Criddle equation) was first carried out for 1991 and 1998, as those years had pan data available. The derived daily evapotranspiration values could therefore be compared with the recorded values and the conversion equation could be calibrated. The calibrated equation was then applied to generate daily evapotranspiration (assumed constant in each day) for 1995-1998.

b.3) Vegetation cover

A vegetation map that contains seven main vegetation types was available. These vegetation types are meadows, beeches, farmed areas, oaks, pines, shrubs, and reforested pines. Treelike vegetations (including beeches, oaks and pines) were lumped together in one type. Both beeches and oaks cover a small area and including them with pines was therefore considered reasonable. Grass-like vegetations (including meadows and shrubs) were also lumped together to form the second vegetation type. Finally, reforested areas were left as an individual vegetation type. The resulting map of three major vegetation covers was transferred into SHETRAN format.

b.4) Soil cover

Twelve soil samples were collected during the field visit and brought back to Newcastle for further laboratory analysis. From field observations and laboratory analysis it was concluded that the soil does not vary significantly in the Ijuez catchment. However, two main soil types (silty clay and silty clay loam) can be derived with slight differences in the physical and mechanical characteristics. These were best correlated with vegetation cover. It was noticed that soil type one is located mainly in areas covered with natural forest while soil type 2 is located in the re-forested areas. Figure 2 shows the original vegetation cover map overlain by the soil sample locations.

b.5) Discharge record

Discharge records for the Aragon River at Jaca were used as a means to generate the discharge at the Ijuez outlet. To do that discharge records were collected from a number of stations in the area. Annual total discharge versus catchment area as well as monthly mean discharge versus area relationships were established using 34 catchments ranging in size from 40 km^2 to more that 2000 km^2. These have been used to scale the mean daily discharge records for the Aragon to the level appropriate to the Ijuez catchment.

2.3.3) Simulations

At this stage only hydrological outputs will be presented here. It is premature to show the results of sediment yield and landslide simulations although preliminary were carried out before submitting this report. The presented results should not be taken as final as more considerable refining will be undertaken during the next reporting period.

Figure 3 shows the simulated hydrographs at the Valsassina Pioverna and Esino outlets, compared with the input rainfall record. From the regionalisation studies, the results are encouraging in terms of timing and magnitude. Similarly figure 4 shows the simulated hydrograph at the Ijuez outlet compared with the input rainfall values and the “observed” hydrograph which was scaled from the Aragon catchment. The timing of the peak flows is encouraging but the magnitudes remain to be checked for plausibility.

2.3.4 Llobregat validation

Validation of the SHETRAN landslide model has been completed for the November 1982 landsliding event in the 500-km^2 Llobregat catchment in the eastern Spanish Pyrenees. Details of the validation approach have been given in previous progress reports but are summarized here with details of the results.

Because of uncertainty in evaluating the model parameters and other inputs, the aim is not to reproduce the observed occurrence of debris flows as exactly as possible with one simulation but to bracket the observed pattern with several simulations. Between them, these simulations should represent the uncertainty in the key input conditions, considering not only the landslide component of the model but the hydrological and sediment transport components also.

In stage 1, the event hydrological response was simulated, so as to obtain the soil saturation and water flow data which form the input to the landslide simulation. The observed outlet hydrograph was successfully contained in a simulation uncertainty envelope, derived as a function of uncertainty in the overland flow resistance coefficient and the timing of the measured rainfall.

In stage 2, uncertainty in the soil erosion and sediment transport calculations was determined as a function of uncertainty in the soil erodibility coefficients. However, no measurements of sediment yield were available for comparison.

In stage 3, uncertainty in the debris flow simulations was determined as a function of vegetation root cohesion. The cohesion was decreased by 50% and increased by 25% relative to a baseline value (based on literature data), so yielding an overestimate and an underestimate respectively of the observed debris flow occurrence. In each case a preceding simulation was carried out for a rainfall event scaled at 30% of the November 1982 event, so as to eliminate from the main simulation those debris flows which could have occurred as a result of storm events in previous decades. The resulting patterns are shown in Figures 5 and 6. The upper bound (Figure 5) is a considerable overestimate of the observed pattern (around 17,000 compared with an observation of around 700). However, it reproduces several of the principal clusters in the observed pattern, notably the half-ring of debris flows along an escarpment just to the west of the main north-south valley and clusters in the north-western and north-eastern sectors of the catchment. It is important that such clusters should be reproduced in the overestimate as this provides confidence in the model’s ability to represent at least the general features of physical reality. The lower bound (Figure 6) contains rather fewer debris flows than were observed (around 500).

The results demonstrate the desired ability to bracket the observed occurrence of debris flows, based on realistic uncertainty bounds in the model parameters. By indicating those parameters to which the debris flow simulations are most sensitive (and which therefore provide the basis of the uncertainty estimates) the validation also provides important experience which will benefit the Valsassina and Ijuez simulations.

The final stage in the Llobregat simulation is calculation of the uncertainty bounds on the event sediment yield. Simulations were carried out for each combination of the hydrological, sediment transport and debris flow uncertainty runs. In addition the yields were determined without the debris flow contribution. As examples:

(i) For the combination of the maximum flow and maximum soil erodibility estimates, sediment yield is 2.54 x 10^6 t without the debris flow contribution and 7.52 x 10^6 t with the yield from the upper bound on debris flow occurrence (respectively 5080 and 15,040 t km^{-2}).

(ii) For the combination of the minimum flow and minimum soil erodibility estimates, sediment yield is 1.97 x 10^6 t without the debris flow contribution and 2.47 x 10^6 t with the yield from the lower bound on debris flow occurrence (respectively 3940 and 4940 t km^{-2}).

Between them, these two sets of simulations effectively provide maximum and minimum estimates of the event sediment yield. There are no measured data from the Llobregat catchment with which to test the estimates. However, data for a reservoir in the central Pyrenees (catchment area 1250 km^2) indicate that intense floods can increase the annual sediment yield from a long term average of 350 t km^{-2} yr^{-1} to around 2000 – 3000 t km^{-2} yr^{-1} (Valero-Garces et al., 1998). A yield of around 6800 t km^{-2} is estimated for the 1996 Biescas event in the central Pyrenees (although this is for a rather smaller catchment of 18.8 km^2) (White et al., 1997). The lower estimates for the Llobregat event sediment yield are therefore not unreasonable. However, the upper estimates seem high, perhaps not surprising given the overestimate of debris flow occurrence in Figure 5.

For the upper sediment yield estimate, 66% of the total yield is attributed to debris flow supply. For the lower estimate, 20% of the total yield is supplied by debris flows.

2.4 Workpackage 5 : Dissemination

The Valsassina simulations were reported at a conference on hydrogeological risks organized by the Land and Urban Office of the Lombardy Region government during 26 – 27 September 2001.

3 MILESTONES AND DELIVERABLES

The Newcastle team was contracted to delivery preliminary simulation results for the focus areas to WP2 in Month 18 of the project (August 2001). Results were produced by the end of August and, for the Valsassina focus area, were reported in September as noted in Section 2.4. However, these results are very preliminary and the simulations will undergo considerable refinement. The results should therefore be considered as no more than demonstrations of capability.

4 DEVIATIONS FROM THE WORK PLAN AND/OR TIME SCHEDULE

Work has unfolded as planned. However, the project research associate, Dr Ahmed El-Hames, is leaving the University of Newcastle in November 2001 for a permanent position at the King Abdulazziz University in Saudi Arabia. The process of replacing him has begun but (as an unforeseen event) his departure will inevitably cause a delay in the Newcastle project.

5 COORDINATION BETWEEN PARTNERS AND COMMUNICATION ACTIVITIES

The Newcastle team’s Valsassina and Ijuez applications have benefitted greatly from the collaboration of the Milan-Bicocca and Pyreneen Institute of Ecology teams, both in provision of existing datasets and in data collection during the field visits.

The preliminary Valsassina simulations have been reported as described in Section 2.4.

Dr Bathurst (Newcastle) and Dr Crosta (Milan-Bicocca) are joint convenors of a session on Rainfall Triggered Landslides and Debris Flows at the 27th European Geophysical Society General Assembly during 21 – 26 April 2002 in Nice.

6 DIFFICULTIES IN MANAGEMENT AND COORDINATION

There have been no difficulties during the reporting period.

7 PLAN AND OBJECTIVES FOR THE NEXT PERIOD

The following activities in WP4 are required to meet the Newcastle team's contractual obligations to deliver final simulation data to WP2 in Month 24 (February 2002).

(i) Enhancement of SHETRAN landslide model with relationships from WP1. Final relationships are due in Month 21 (November 2001).

(ii) Validation of SHETRAN for the focus catchments.

(iii) Development of scenarios for future land use and climate.

(iv) Scenario applications for Valsassina to provide a basis for a revised regional hazard assessment model, as input to WP2.

(v) Initial SHETRAN applications to develop guidelines for land management to mitigate debris flow occurrence and impact, for the Valsassina and Ijuez focus catchments.

However, the departure of Dr El-Hames and the need to train a new research associate to run SHETRAN is likely to cause a delay to the Newcastle project.

8 PUBLICATIONS

Bathurst, J.C., El-Hames, A.S., Moretti, G., Crosta, G. and Frattini, P. 2001. Application of a basin scale, landslide sediment yield model, River Pioverna, Valsassina (Lake Como). Proceedings of Conference on La Prevenzione del Rischio Idrogeologico Attraverso la Conoscenza del Territorio. Regione Lombardia, Territorio e Urbanistica, Milan, 26-27 September.

9 REFERENCES

Brath, A. and Franchini, M. 1998. La valuatzione regionale del rischio di piena con il metodo della portato indice. In: La Difesa Idraulica dei territori Fortmente Antropizzati, U. Maione and A. Brath (eds.), BIOS, Cosenza, Italy, pp31-60.

Valero-Garcés, B.L., Navas, A., Machín, J. and Walling, D. 1999. Sediment sources and siltation in mountain reservoirs : a case study from the Central Spanish Pyrenees. Geomorphology, 28, 23-41.

White, S., Garcia-Ruiz, J.M., Martí, C., Valero, B., Paz Errea, M. and Gómez-Villar, A. 1997. The 1996 Biescas campsite disaster in the central Spanish Pyrenees, and its temporal and spatial context. Hydrological Processes, 11, 1797 – 1812.

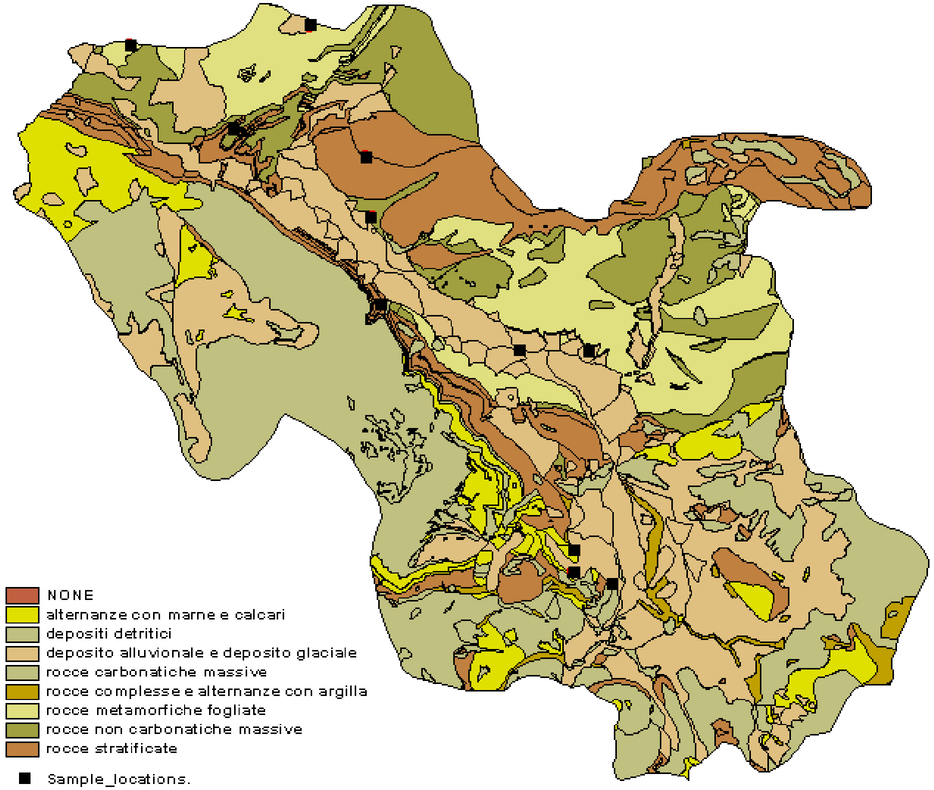


Figure 1 Valsassina geology and soil sample locations

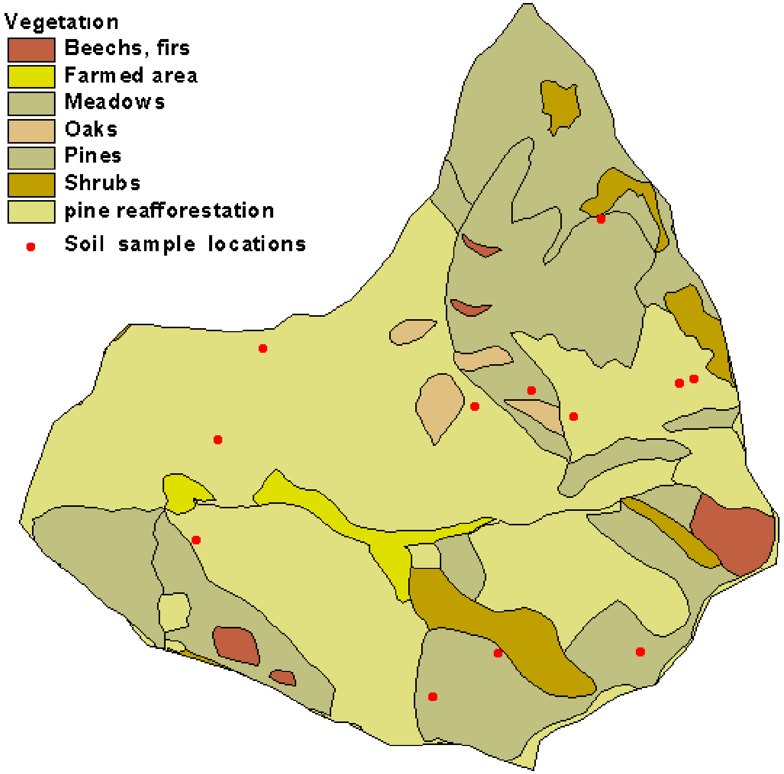


Figure 2 Ijuez vegetation distribution and soil sample locations

Figure 3 Simulated Hydrographs at the Pioverna and Esino outlets, compared with rainfall, 93-99

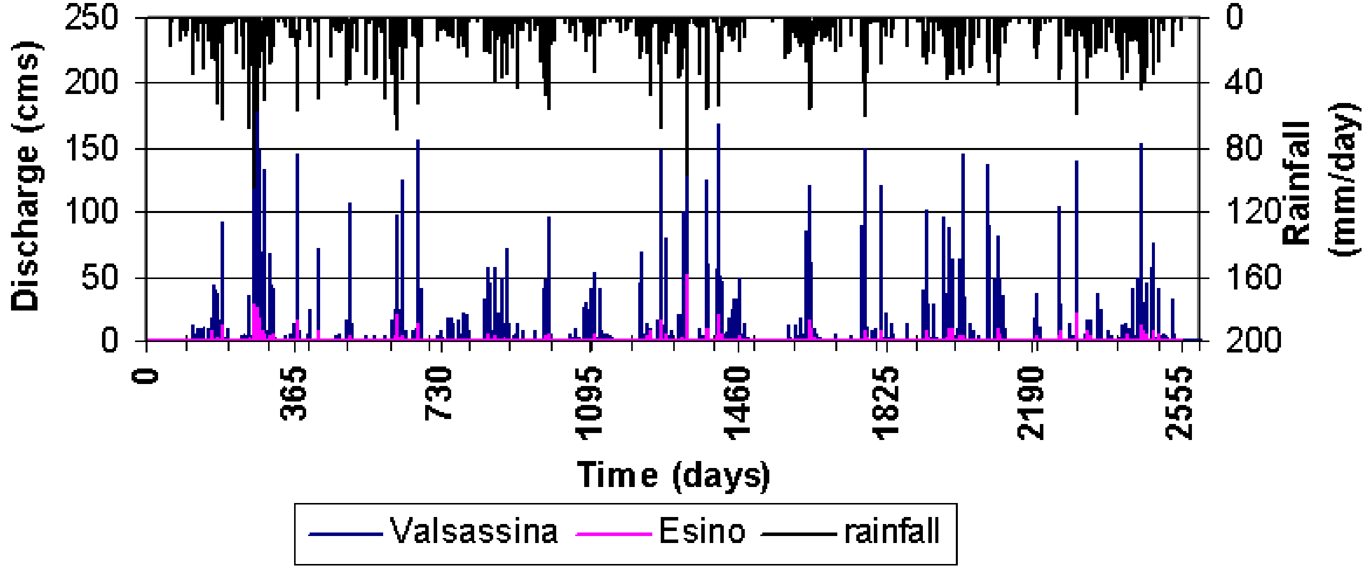
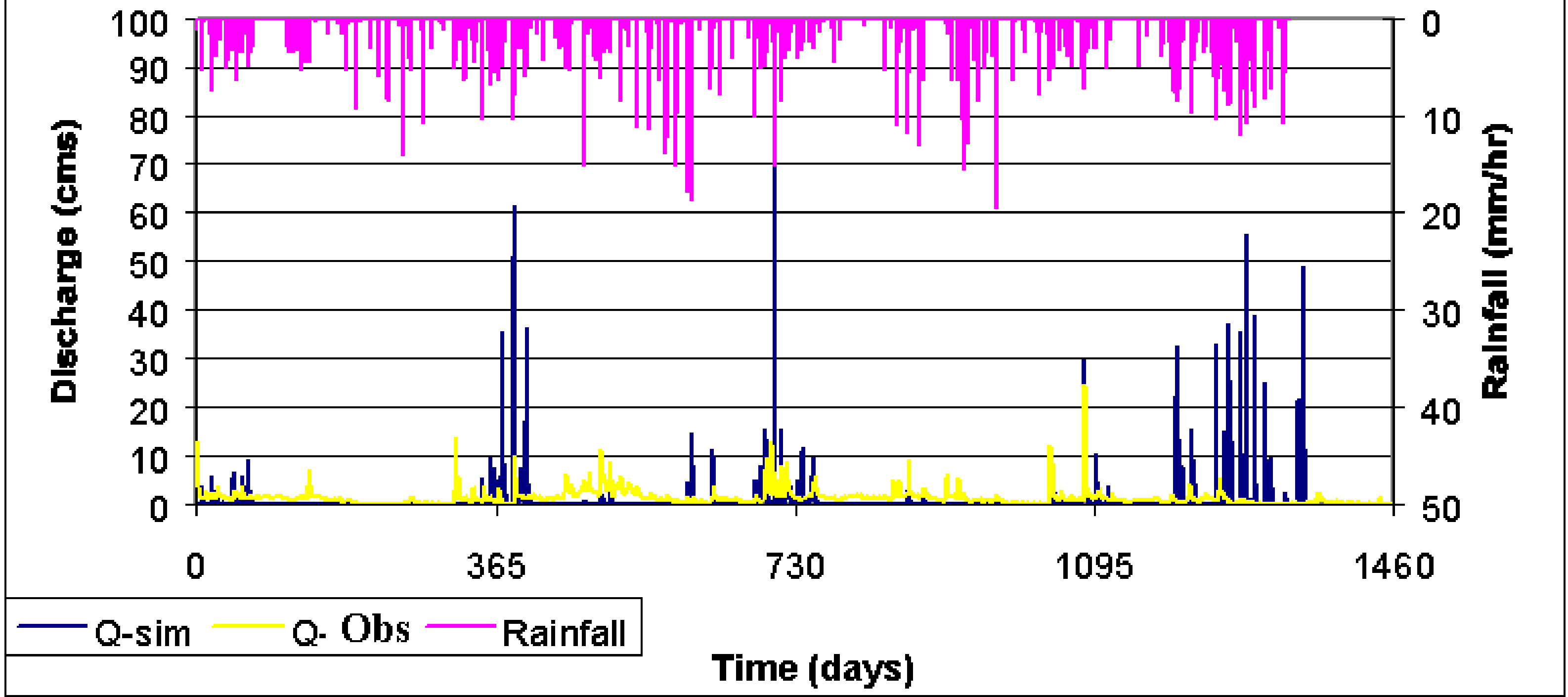


Figure 4 Simulated hydrographs at the Ijuez outlet, compared with the "observed" hydrograph and rainfall



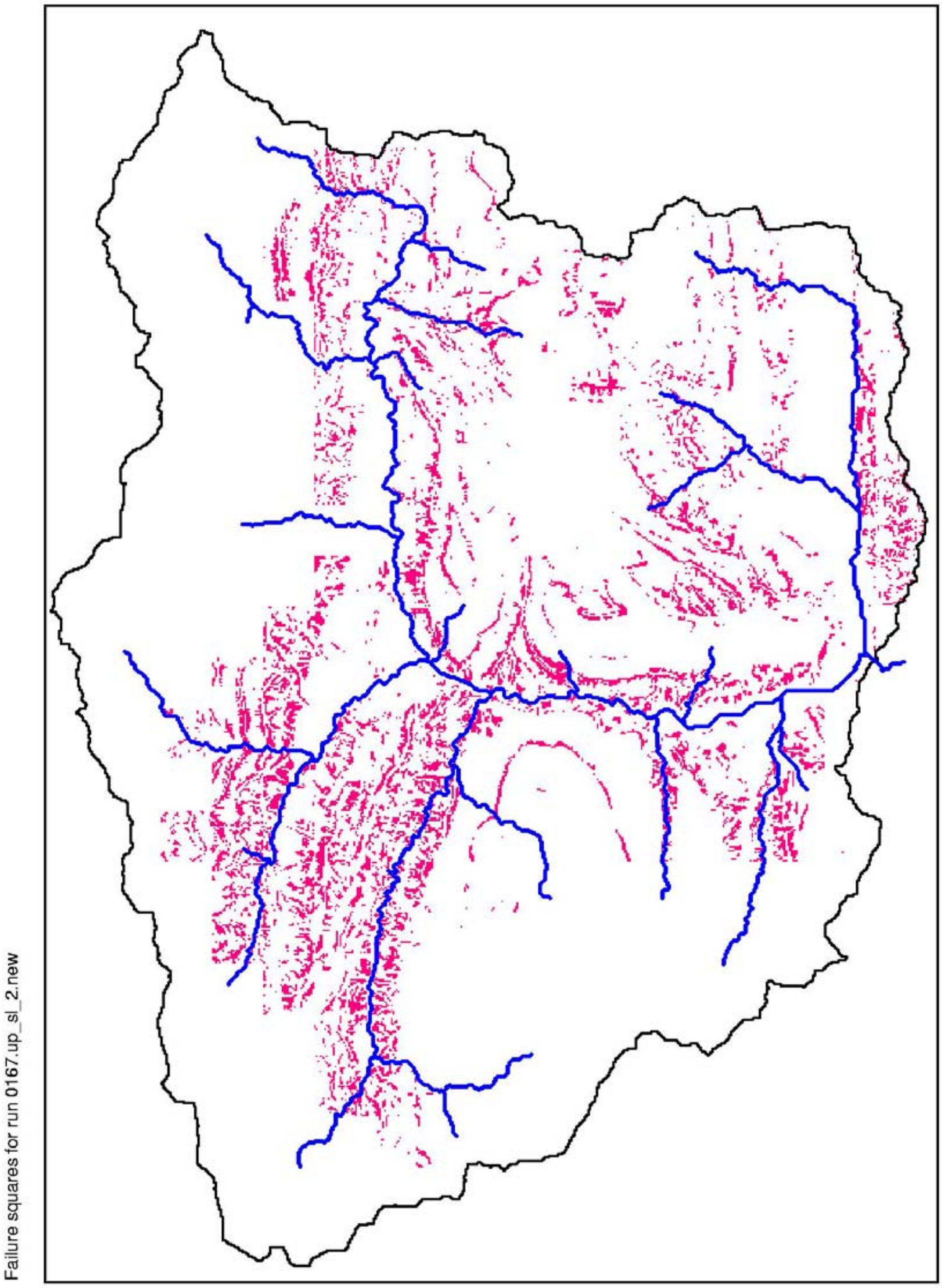


Figure 5 Landslide simulation for the Llobregat with upper bound values

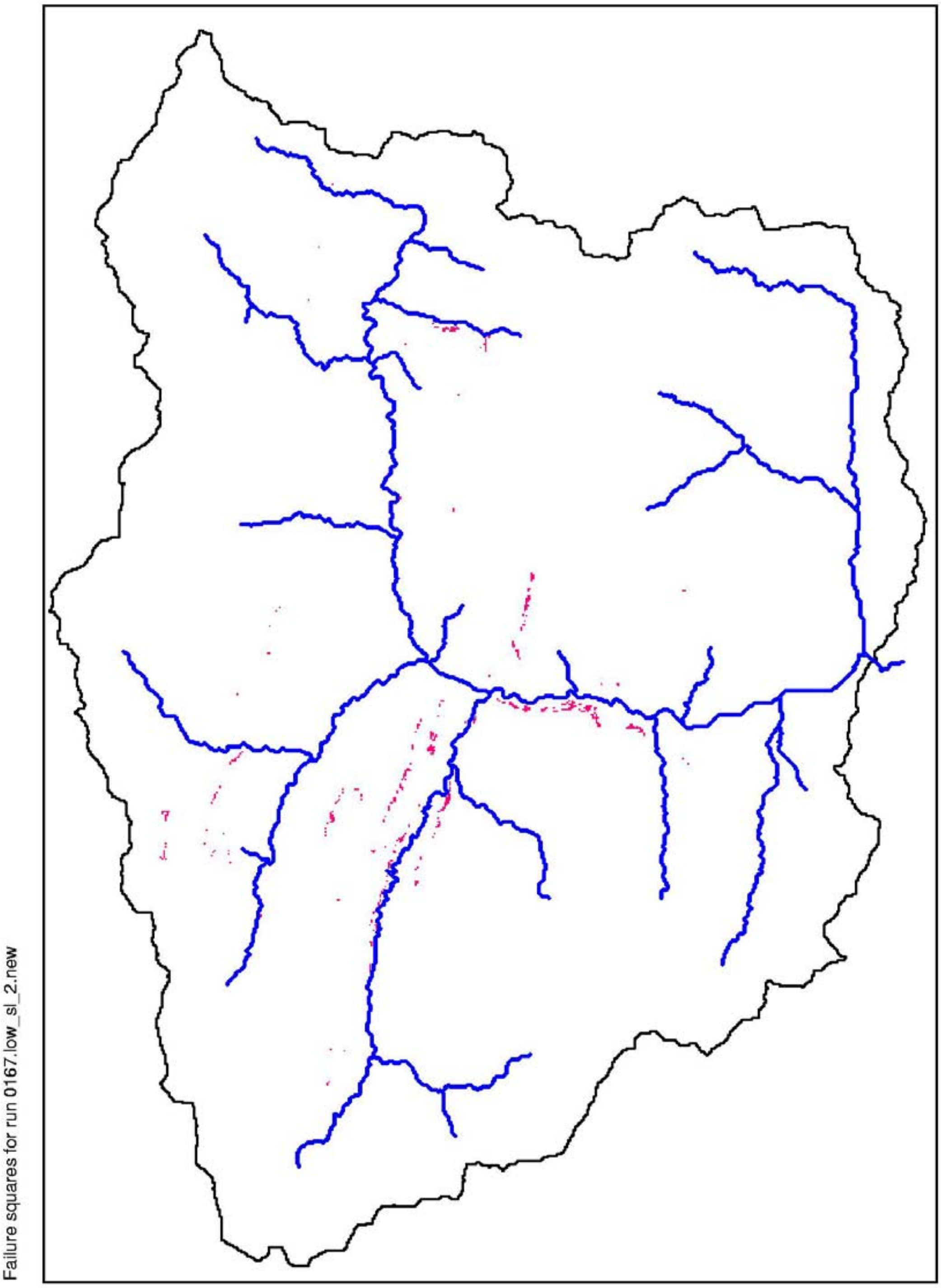


Figure 6 Landslide simulation for the Llobregat with lower bound values