DAM/PR/0010/1

# DAMOCLES

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**DEBRISFALL ASSESSMENT IN MOUNTAIN CATCHMENTS FOR LOCAL END-USERS**

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**Contract No EVG1 - CT-1999-00007**

**DETAILED REPORT OF CONTRACTOR FOR FIRST PROGRESS MEETING (1 March – 23 October 2000)**

**University of Newcastle upon Tyne**
**UK**

**October 2000**

## DETAILED REPORT OF THE CONTRACTOR


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## 1 MAIN WORK CARRIED OUT DURING THE REPORTING PERIOD

(i) This report covers the period 1 March – 23 October 2000.

(ii) A research associate has been appointed to the project from 16 October 2000.

(iii) A specification has been prepared for the focus catchments for application of the SHETRAN landslide erosion and sediment yield component in Workpackage WP4.

(iv) The first field validation of the SHETRAN landslide component has been completed, providing experience and a basis on which to carry out the DAMOCLES applications.

## 2 MAIN RESULTS OBTAINED

### 2.1 Project Staff

A research associate, Dr Ahmed El-Hames, has been appointed to the project from 16 October 2000. Dr El-Hames has a strong modelling background and a wide range of experience from different hydrological projects in a variety of climatic and topographic environments.

The time taken to make an appointment represents a delay in the Newcastle programme, which was originally due to start in Month 1 of the project. However, the delay is not considered to be serious, not least because the available funding does not anyway support a full time appointment for the full length of the project.

To allow some progress to be made in the project before Dr El-Hames's arrival, the SHETRAN landslide model was validated for the Llobregat catchment in the eastern Pyrenees. This work built on a preliminary model application carried out during the EC MEDALUS III (Mediterranean Desertification and Land Use) project. The validation was performed by Mr Aidan Burton, research associate, and funded by DAMOCLES for half a month. The work is reported in Section 2 and provides an excellent basis of experience for the DAMOCLES applications.

## 2.2 Workpackage 4 : SHETRAN Landslide Model

### 2.2.1 *Focus catchment specification*

The SHETRAN erosion and sediment yield model will be applied to two focus catchments, one in the Pyrenees, the other in the Italian Alps. These catchments should be selected according to the following specification.

Location. The Italian catchment should be within the test area for the hazard assessment GIS model of WP2, to provide the maximum opportunity for integration of WP4 and WP2. This means that the catchment will be in the experimental area of the team from the University of Milan-Bicocca. The Pyreneen catchment should be convenient for access from Zaragoza and could be one from which basic data have been collected for debris flow characterization in WP1.

Area. 100 – 500 $km^2$.

End-user interest. Ideally the catchment should have some point of relevance to the end-users, eg a significant debris flow hazard, concern about the impacts of proposed land use change or a changing climatic regime. The output from the SHETRAN landslide model will be most relevant to downstream sediment impacts, such as reservoir siltation or channel instability.

SHETRAN core model. To run the core hydrology and sediment transport model, the following data are needed: time series of rainfall and potential evaporation (or the meteorological data which can be used to calculate evaporation); soil, vegetation and topographic properties and distributions for the catchment; response variables such as river flow discharge, river sediment discharge and well levels. Ideally the time varying data should be available at hourly intervals.

SHETRAN landslide model. To validate the landslide component the following data are needed: a high resolution (eg 50 m) Digital Elevation Model; records of landslide events at the catchment scale, for which the determining precipitation conditions are known, for which there is a record of the spatial occurrence of shallow landslides and for which there is a measured hydrological response and sediment yield (eg reservoir siltation patterns).

This is a demanding specification which is unlikely to be met in full. One consequence of an inability to satisfy all the data requirements will be a need to incorporate uncertainty in the presentation of simulation outputs.

Selection of the focus catchments is being pursued jointly with the University of Milan-Bicocca and the Pyreneen Institute of Ecology teams and is expected to be completed by the end of 2000.

### 2.2.2 *Llobregat validation*

The SHETRAN landslide component is being validated for a major landsliding event which occurred during a three-day rainfall event in the Llobregat catchment about 100 km north of Barcelona in the Spanish Pyrenees in November 1982. The catchment is about 500 $km^2$ in area and drains into La Baells reservoir. The validation is being carried out in collaboration with a team from the Institute of Earth Sciences (Consejo Superior de Investigaciones Cientificas, CSIC), Barcelona, which recorded the main features on the event shortly after the event occurred. The principal data for validating the model are the inlet hydrograph for the reservoir (constructed form reservoir water balance data) and an inventory and map of landslide occurrence.

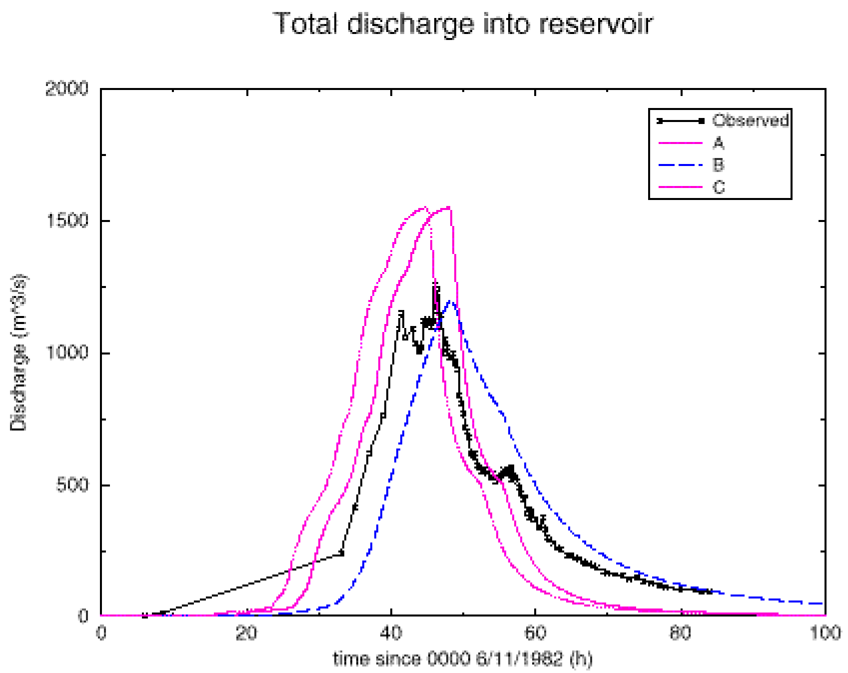
A preliminary validation was completed in the EC MEDALUS III (Mediterranean Desertification and Land Use) project but at this stage the simulation was not an adequate representation of the observed landslide pattern. The opportunity has therefore been taken in DAMOCLES to build on this work by exploring the sensitivity of the simulation results to changes in a number of inputs. It is generally accepted that evaluation of model parameters and other inputs for complex physically based systems like SHETRAN involves uncertainty. For example, it is not clear if soil parameter values based on typically point scale measurements are representative at the scale of the SHETRAN grid square. Uncertainty in the inputs translates into uncertainty in the output and SHETRAN results are therefore increasingly presented in the form of an uncertainty envelope rather than a single “best-fit” simulation. The sensitivity tests help to define the uncertainty envelope.

For the Llobregat application the aim is not to reproduce the observed occurrence of landslides 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. Defining the principal sources of uncertainty will indicate where attention most needs to be devoted in parameter evaluation for the DAMOCLES applications.

<u>Hydrological response</u>. The first stage in applying the landslide model is to simulate the event hydrological response, so as to obtain the soil saturation and water flow data which form the input to the landslide simulation. A series of sensitivity tests was therefore carried out, investigating the sensitivity of the simulated catchment hydrograph to key parameters including soil hydraulic conductivity, soil depth and overland flow Strickler resistance coefficient. Three runs were selected which enabled the observed hydrograph (ie the reservoir inflow hydrograph) to be bracketed (Figure 1):

(i) Soil depth = 0.8 m, Strickler coefficient = 5
(ii) Soil depth = 0.8 m, Strickler coefficient = 0.5
(iii) As (i) but with the rainfall brought forward 3 hours to allow for uncertainty in the timing of the rainfall input (which is available only as 6-hour totals).

The range of Strickler coefficients is physically reasonable and is similar to values used in other simulations.




**Comparison of observed catchment hydrograph with simulations based on (A) Strickler coefficient = 5, (B) Strickler coefficient = 0.5 and (C) Strickler coefficient = 5 with rainfall brought forward 3 hours.**

The bracketing runs will be used in the final landslide simulations, to incorporate the effect of parameter uncertainty in the simulated hydrological response.

<u>Sediment transport</u>. The second stage in the application is to run the core sediment model. This simulates soil erosion by raindrop impact and overland flow, transports eroded sediment along the channel network and determines catchment sediment yield. The yields calculated for erosion by raindrop impact and overland flow provide a datum against which the effect of the additional yields arising from landslide erosion can be measured. They can also be used in an approximate validation of the sediment model: there are no direct measurements of sediment transport in the Llobregat catchment but the simulation results can be judged on their plausibility in the context of measurements in other similar catchments.

The core sediment component uses two erodibility coefficients to describe the ease with which the soil can be eroded by raindrop impact and by overland flow. Sensitivity of the catchment sediment yield simulations to the coefficients was tested by halving and doubling their values relative to their proposed baseline or best estimate values. Runs were made with these values for the range of conditions from the hydrological sensitivity tests, including the upper and lower values of the Strickler coefficient for overland flow. Calculating sediment yield up to hour 84 in the simulation, a range from $1 \times 10^9$ to $5 \times 10^9$ kg was obtained. This indicates a moderate sensitivity to the erodibility coefficients for the event. Translated into yields per unit area these values are 20 - 100 t $ha^{-1}$. These are high compared with long term yields of 2 - 11 t $ha^{-1}$ $yr^{-1}$ measured for thirteen catchments of area 150 - 2400 $km^2$ in a high erosion area of southeast Spain. It is not impossible for a single event to deliver more than the long term annual yield but the comparison suggests that the flow and sediment models should be parameterized to produce yields at the lower end of the range.

Landslide erosion. In the hydrological simulation of the event, the entire catchment becomes fully saturated. As a result the landslide model could potentially simulate all the possible shallow slope failures in the catchment which are triggered by hydrological conditions, a total of several tens of thousands. In reality, though, fewer than a thousand slope failures were recorded in the landslide inventory. To avoid a massive overestimate, the following points were considered:

(i) Computational constraints limit the SHETRAN grid resolution to 1350 m while the subgrid scale at which slope failures are simulated is limited to the 45-m resolution of the topographic database. Soil and vegetation properties are represented with generalized parameter values, uniform in each grid square. Consequently the failure conditions are similar for neighbouring landslide sites, enabling large numbers of failures to be simulated in a given event. In reality, though, small scale variations in soil, vegetation and topography would tend to prevent the entire catchment from becoming saturated at every point and would ensure that the conditions which favoured a slope failure at one site were not replicated at apparently similar looking neighbouring sites. This scale issue is an important source of uncertainty and is one of the reasons why the aim of the simulations is to bracket the observed pattern of slope failures rather than to simulate it exactly.

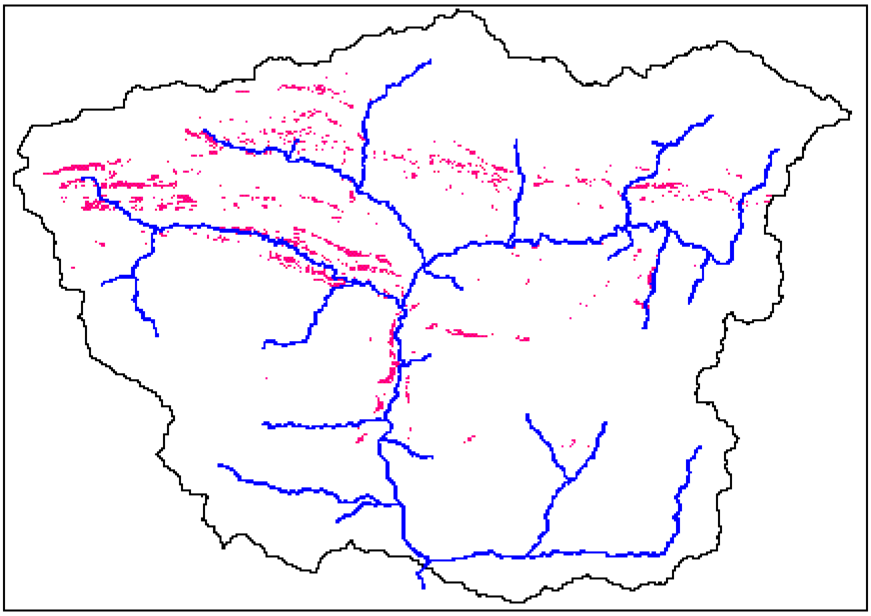
(ii) Some of the slope failures which could potentially be simulated are in effect inventions of the model, occurring where in reality there are cliffs, rock ground or slopes below the threshold for shallow landslides to occur. Simulated landslides were therefore eliminated at elevations above 1600 m and at slopes below 25º and above 50º.

(iii) Model parameterization assumes an initially complete soil cover across the catchment. In reality, though, some of the cover would have been removed by debris flows in earlier years. In the simulation the November 1982 rainfall event was therefore preceded by a rainfall event with the same temporal distribution but a reduced volume. The reduction scale was based on limited rainfall records for the region for the period from the 1940s to 1970. A reduction to 30 - 40% of the November 1982 total was considered appropriate. The slope failures triggered by the first event were removed from the map of failures triggered by the principal event.

(iv) Several of the landslide model parameters are estimated from limited field measurements or data in the literature and may provide inaccurate descriptions of some parts of the catchment. Sensitivity tests were therefore carried out to investigate the effect of parameter uncertainty. In particular, the vegetation root cohesion was halved and doubled relative to its baseline values and the soil angle of friction was increased and decreased by 5º.

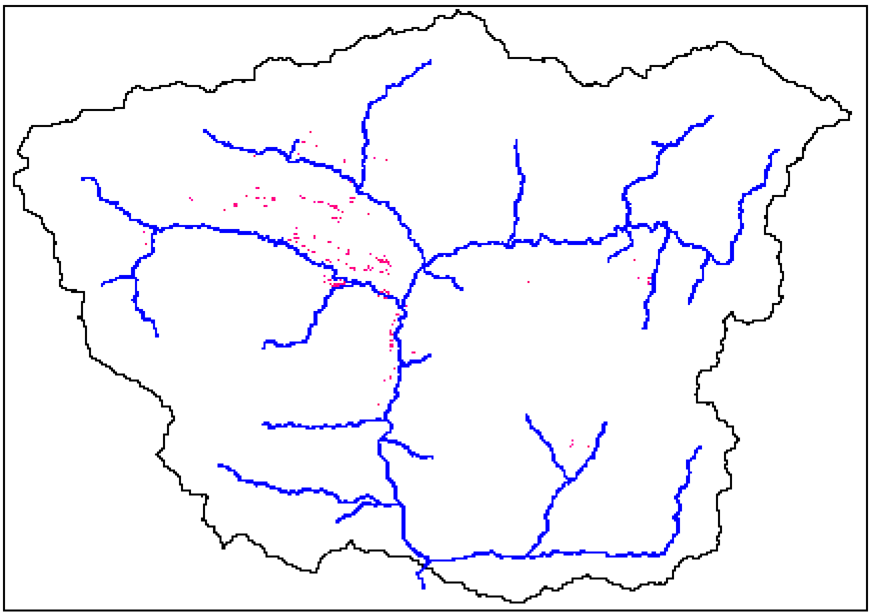
At the time of writing, the full range of simulations had not been completed. However, the general effect of the above modifications can be seen from the following:

(i) Figure 2 shows the simulated debris flow pattern based on the bounds introduced in point (ii) above and the baseline parameter values. In this case the hydrological simulation uses a Strickler coefficient of 1. The number of debris flows is still much greater than observed.



**Simulated debris flow pattern with no debris flows at elevations above 1600m or at slopes below 25º and above 50º.**

(ii) Figure 3 shows the effect of preceding this simulation with a rainfall event equal to 40% of the principal event and removing the debris flows triggered by the preceding event. The number of debris flows triggered by the principal event is then considerably reduced.



**The simulation of Figure 2, removing debris flows triggered by a preceding rainfall event equal to 40% of the principal event**.

(iii) Doubling the root cohesion completely eliminates the slope failures. Increasing the soil angle of friction by 5º also significantly reduces the occurrence of failures.

These results are very encouraging as they clearly demonstrate an ability to bracket the observed landslide pattern. The remaining simulations will refine the bracketing runs, including allowing for the uncertainty in the hydrological simulation. Finally the sediment yields from the landslide erosion will be calculated and compared with the yields derived from raindrop impact and overland flow erosion.

### 2.3 Workpackage 5 : Dissemination

The Newcastle Contractor has supplied basin information for the website which has been established by CNR-IRPI, Perugia.

### 2.4 Resources Employed

Staff have been employed on the project as follows:

Mr Aidan Burton (Research Associate, funded by project) : ½ month
Dr James Bathurst (Principal Investigator, not funded by project) : ¾ month

## 3 ACTIVITIES FOR NEXT REPORTING PERIOD

The following activities in WP4 are required to meet the Newcastle team's obligations to deliver preliminary simulation data to WP2 in Month 18 (August 2001). A timetable is attached.

(i) Selection of focus catchments in the Alps and Pyrenees.
(ii) Assembly of catchment time series and property data, including field measurements.
(iii) Creation of SHETRAN files.
(iv) Enhancement of SHETRAN landslide model with relationships from WP1.
(v) Preliminary validation of SHETRAN for the focus catchments.
(vi) Development of scenarios for future land use and climate.
(vii) Demonstration of application of SHETRAN for scenario conditions.

It is not expected that the preliminary validation and scenario simulation results will be more than demonstrations of capability showing the type of output that will be available to WP2. Refinement of the simulations, including feedback from WP2, will take place over the following six months.

Allowance is made in the timetable for the time which Dr El-Hames will need to learn how to use the SHETRAN landslide model.

## 4 REFERENCES

None

## 5 PUBLICATIONS

None

## 6 KEYWORDS

Debris flow map; Focus catchment; Landslide model; Llobregat; SHETRAN; Uncertainty.

**Timetable for Newcastle WP4 activities, October 2000 - August 2001**

| ACTIVITY | 2000 | | | 2001 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **O** | **N** | **D** | **J** | **F** | **M** | **A** | **M** | **J** | **J** | **A** |
| Learning SHETRAN | — | — | — | — | — | | | | | | |
| Catchment selection | — | — | — | | | | | | | | |
| Data assembly | | | — | — | — | | | | | | |
| Field measurements | | | | | | | | — | | | |
| SHETRAN files | | | | | | — | — | — | | | |
| Enhance SHETRAN | | | | | | — | — | — | | | |
| Preliminary validation | | | | | | | | | — | — | — |
| Scenario development | | | | | | | | — | — | — | |
| Scenario application | | | | | | | | | | | — |

**LIST OF FIGURES**