Consiglio Nazionale delle Ricerche
Istituto di Ricerca per la Protezione Idrogeologica nell'Italia centrale, Perugia

European Project DAMOCLES (EVG1-1999-00027P)

DETAILED REPORT OF ASSISTANT CONTRACTOR CNR-IRPI PERUGIA

Reporting period: April 2001 – September 2001

Fausto Guzzetti
(F.Guzzetti@irpi.pg.cnr.it)

Assistant Contractor: CNR-IRPI Perugia
Responsible Scientist: Fausto Guzzetti

Address: via della Madonna Alta, 126
06128 Perugia, Italy
Telephone: +39 075.5014.413
Fax: +39 075.5014.420
Email: F.Guzzetti@irpi.pg.cnr.it

Summary

We report on the results obtained by CNR-IRPI Perugia as an Assistant Contractor (AC) of the University of Milano Bicocca, for the period April 2001 – September 2001. The activities followed what was originally established in the project work plan, and focused on two working packages: WP2 and WP5. For WP2, in cooperation with the University of Milano Bicocca, we continued the development and testing of a 3-D rock-fall simulation program (STONE); the main achievement consisted in the introduction of a stochastic and random approach in the simulation of rock-fall trajectories. For WP5 we have maintained and updated the DAMOCLES project web sites, contributing to the dissemination of the project results and deliverables.

Section 1 - Objectives of the Reporting Period

The DAMOCLES project is aimed at developing technologies for assessing the distribution of rapid slope failures (including debris flows and rock-falls) and their hazard, for determining the physical impact of debris flows and rock-falls, for assessing the mitigating effects of control and defensive works and land management. Emphasis is given to the transfer of the

project deliverables to relevant end-users. Among the project objectives, those pursued by CNR-IRPI Perugia can be summarised as follows:

- To develop and apply advanced models for hazard assessment, impact prediction and mitigation studies, relevant at a range of scales, using Geographical Information System (GIS) technology for assessing rock-fall hazard at the regional scale. This includes assembling databases of thematic (geographical) information in support of model development and refinement. These objectives are addressed by WP2, lead by the University of Milano-Bicocca of which CNR-IRPI Perugia is an Assistant Contractor (AC). WP2 is intended to develop a GIS-based hazard and risk assessment methodology using field data, available data and model developments. This involves statistical and physically based modelling and benefits from the data and model developments of other work packages. The result will be a quantitative hazard and risk modelling technology for rock-falls applicable to mountain environments in Europe. The test area selected for the experiment is the Montagna Lecchese, in the Lombardy pre-Alps (Italy).

- To transfer the technologies and deliverables to key end-users and to make the outcomes accessible through the public domain using the Internet and Web-base technology. These objectives are addressed by WP5 led by the University of Newcastle. Within this work package CNR-IRPI Perugia has designed, implemented and is maintaining the DAMOCLES Internet Web site, and is testing the possibility of using GIS-based Web technology to publish on the Internet thematic and landslide hazard maps. The Web site currently contains thematic maps for the Pioverna Basin, in the Lombardy pre-Alps (Italy), but the system is ready to host geographical (thematic) data for the other study areas.

For the reporting period (April 2001 – September 2001) the objects of the work, as originally planned, were:

- To test and improve the 3-d rock-fall modelling software STONE (WP2); and

- To maintain and update the project web sites, disseminating information on the DAMOCLES deliverables, and experimenting the publication on the Internet of thematic and landslide hazard maps (WP5).

Section 2 - Scientific/Technical Progress Made

During the reporting period progress made in the two working packages can be summarised as follows:

Working Package 2

WP2 focuses on the production and testing of rock falls hazard and risk assessment procedures using GIS technology. Within the WP the main improvement consisted in the introduction of a stochastic and random component to the simulation of rock–fall trajectories. Experiments were also made to test the sensitivity of the model results to the resolution of the input data, and in particular of the DTM.

Parameters such as the rock-fall starting velocity and direction, the dynamic friction coefficient and the normal and tangential energy restitution coefficients vary largely in nature and are difficult to define precisely, particularly over large areas. STONE now provides a way to cope with the natural variability and local uncertainty associated with such information by adding to these values a random component. The user can select a range of variation (in percentage) around the given (default or central) values. During the computation, where needed (i.e., at the beginning of a new rock fall trajectory for the starting angle, at each impact point for the normal and tangential energy restitution coefficients, and where the boulders rolls for the dynamic friction coefficient), STONE draws randomly a value from the selected range around the given (default) values. As an example, if a user selects the ranges ± 3% and ± 2% for the normal and tangential energy restitution coefficients respectively, and the values in the input grids for any given cell are 50 and 65, respectively, STONE will select randomly a value for the normal coefficient in the range 47-53 and a value for the tangential coefficient in the range 63-67. Values for the range of variation are kept separated for the various input parameters. Thus, the normal and/or tangential energy restitution coefficients can be varied separately keeping the dynamic friction coefficient and the starting angle constant. Similarly the starting angle can be selected randomly keeping the parameters controlling the loss of energy constant. This allows for flexible and complex simulations, and for sensitivity analyses. If one or more of the selected ranges is set to zero, STONE will use the given (default) value.

Figure 1 shows an example of a "fully deterministic" simulation prepared by STONE. The map of rock fall count was obtained without using the new random option, and by launching a single boulder from each source cell. The result can be compared with the map shown on Figure 2 that was prepared by adding a random variation to the input parameters, and always launching a single boulder from each source cell. It can be seen that the two maps showing the count of rock falls are different. The difference is due to the small (± 3%) random variation in the input (thematic) data. Adding the random component to the simulation of rock fall trajectories proved very useful to test the program outputs for errors or inconsistencies due to local conditions.

Another improvement added to STONE is the possibility of launching a variable number of boulders form each source cell (up to 1000). This feature can be used to simulate the variable frequency of occurrence of rock falls from different source areas. When combined with the possibility of varying (within user selected ranges) the values of the input data (i.e., simulating the spatial variability of the input themes), the option provides a way of coping with the natural variability and the intrinsic uncertainty associated with rock falls. As a drawback the time required to complete a single simulation increases. Figure 3 shows a map of rock fall count prepared by applying the random variation to the input parameters and launching 10 rock falls from each source cell. In the central part of the map, representing a talus slope, the difference with the previous simulations (Figures 1 and 2) is clear.

Two researchers were involved in the activities of WP2 for about 15 days each. The work is on schedule with what originally planned.

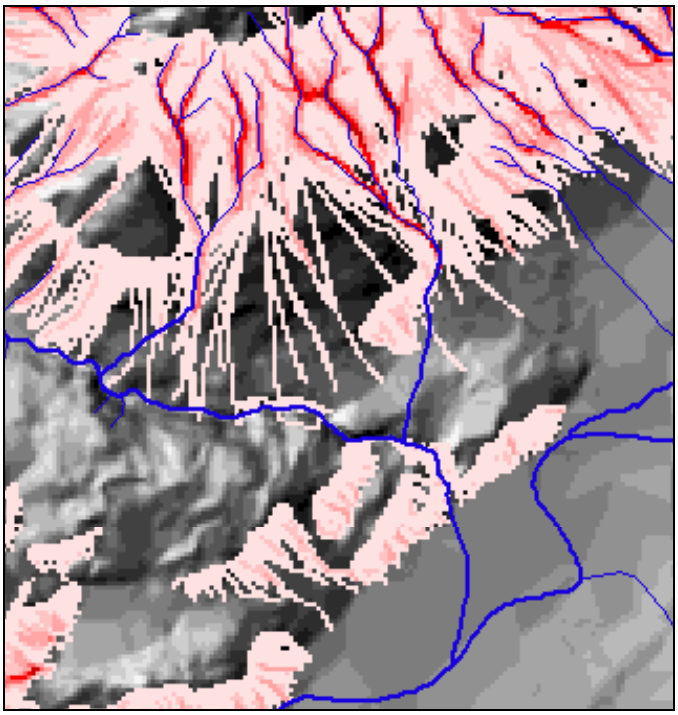

Figure 1 – Map of rock fall count. Completely deterministic model. No random component used. One boulder was launched from each source cell.

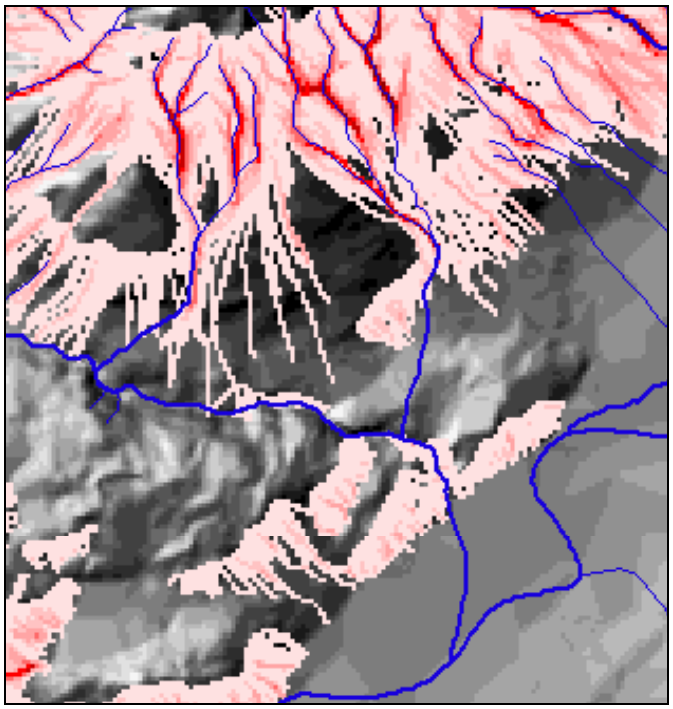

Figure 2 – Map of rock fall count. Simulation obtained by adding a random variation to the input parameters. One boulder was launched from each source cell.

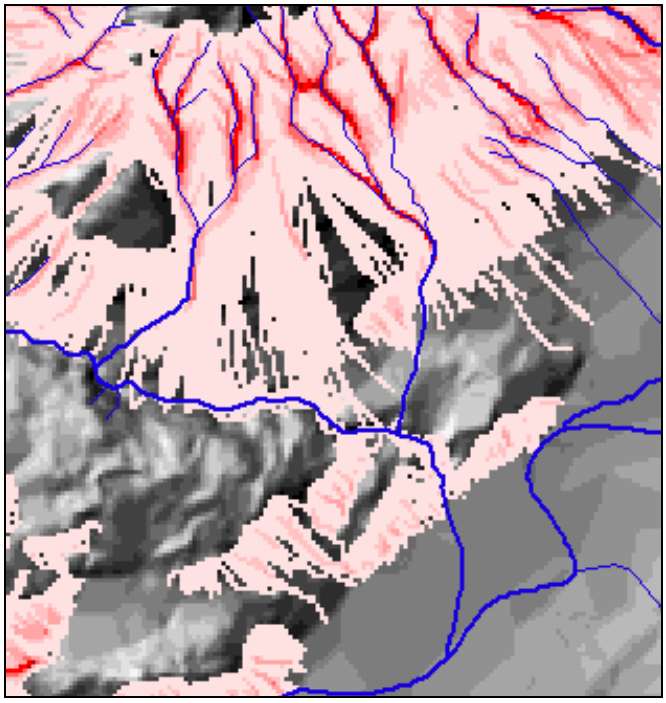

Figure 3 – Map of rock fall count. Stochastic simulation obtained varying randomly the input parameters and by launching 10 rock falls from each source cell.

Working Package 5

WP5 deals with the dissemination of the most relevant project results and deliverables. Activities within the WP are co-ordinated by the project leader, Prof. James Bathurst (Newcastle). The activities at CNR-IRPI Perugia focused on the maintenance and upgrade of the DAMOCLES web site, and on the update and improvement of the GIS-based Web site for the publication on the Internet of thematic and landslide hazard maps.

To improve the readability of the project Web site (http://damocles.irpi.pg.cnr.it) and to facilitate the access to the available information, we designed and implemented a new layout for the Web pages (Figure 4). The new layout avoids the use of frames, making the site more compatible and of faster access. An improved, more modern graphics was also used. New pages showing a list of the published papers and reports, and describing the main project deliverables were added. Additional information on the Benasque, Upper Aragon and Gallego valleys (Central Pyrenees, Spain), and the Pioverna Basin (Lombardy Region, Italy) and the Rio Lenzi (Veneto Region, Italy) study areas was also added.

Figure 4 - The new home page of the DAMOCLES web site.

A team member was involved in the activities of WP5 for about 15 days. A computer expert paid by the DAMOCLES project has worked for about 15 days to maintain and update the GIS-based web pages. The work is on schedule with what originally planned.

Section 3 - Milestones and Deliverables Obtained

Working Package 2

No specific milestone had to be met and no specific deliverable had to be prepared during the reporting period. Despite, a few new products were prepared. These include a new, regional simulation of the rock fall hazard for the Montagna Lecchese study area, a preliminary map of rock fall hazard for the same area, and preliminary maps of rock fall hazard for subsets of the study area (namely: the San Martino area, north of Lecco, and the Varenna area). Sample maps showing the rock fall count, the rock fall velocity and flying height, and of the estimated rock fall hazard are available on the Web site.

Scientists at CNR-IRPI Perugia worked closely with researchers at the University of Milano Bicocca, with whom they have prepared prototypes of rock falls hazard maps for the Montagna Lecchese study area, and for selected subsets of it. Particularly important were the results obtained using the new functionalities of the program STONE to simulate the natural variability of the input data, and to launch a variable number of boulders from each source cell. An attempt was made to systematize the use of the raster outputs prepared by STONE for regional rock fall hazard assessments.

Preliminary results of the simulation of rock fall trajectories in the Montagna Lecchese study areas, as well as in other Alpine areas (Val Camonica, Val Seriana) were presented to the Geological Survey of the Lombardy Region, one of the local end-users participating to the project. After checking the maps, the Geological Survey has expressed interest on the results, and is considering the possibility of extending the simulations to other alpine valleys in the Lombardy Region. In addition, other Regional Geological Surveys participating to the European Union Interreg IIC Project are considering with interest the results obtained by STONE. Lastly, in cooperation with the U.S. Geological Survey the program STONE is currently being used to simulate rock fall trajectories in the Yosemite National park, California.

Working Package 5

The outcomes of the project meetings, details on the morphological and geological settings of the various study areas, descriptions of the models that were developed or applied by the partners, and information on the other project deliverables (publications, reports, etc.), were made available to the public domain on the DAMOCLES Web site.

The project coordinator (Prof. James C. Bathurst) contributed the minutes of the Padua meeting, the agenda for the Newcastle meeting, and a list of the publication produced by the various partners. The University of Padua (Prof. Mario A. Lenzi) contributed a description of the Rio Lenzi Study area (Veneto Region, Italy) and an explanation of the MODSS (Muskingum One-Dimensional Debris flow Simulation) model. The Instituto Geológico y

Minero de España (Prof. Santiago Rios) contributed information on the Benasque study area (Central Pyrenees, Spain). The Pyrenee Institute of Echology (Prof. Jose M. Garcia Ruiz) provided information on the type and abundance of debris flows in the Upper Aragon and Gallego valleys. The University of Milano Bicocca (Prof. Giovanni Crosta) and the CNR-IRPI Perugia (Dr. Fausto Guzzetti) provided information on the rock fall simulations prepared for the Lecco Mountains study area (Lombardy Region, Italy). The University of Milano Bicocca (Prof. Giovanni Crosta) also provided data and information on the Pioverna study area (Lombardy Region, Italy).

As a minor progress, a new look for the DAMOCLES Web site was designed, tested and implemented, improving the readability and the access to the information and the project deliverables.

Section 4 - Deviations from the Work Plan and/or Time Schedule and Their Impact on the Project

No significant deviation from the original work plan was necessary for the activities of CNR-IRPI Perugia within WP2 and WP5.

Section 5 - Coordination of Information Between Partners and Communication Activities

Most of the research and technical activities carried by the CNR-IRPI Perugia were coordinated with, or were a consequence of, activities carried out by other partners. In particular:

- The activities within WP2 were carried out in cooperation with the University of Milano Bicocca;

- The maintenance and update of the project web site (WP5) was carried out whenever new information on the study areas, on the models, or on the project deliverables was made available by the project coordinator, or by one of the partners.

Section 6 - Difficulties Encountered at Management and Coordination Level and Proposed/Applied Solutions

Information for the project Web site was made available generally on time by the project coordinator and by the partners. The geographical (thematic) information for the Pioverna basin study area was made available a few days before the end of the reporting period. Thus, the content of the GIS-based web site should be regarded as preliminary. No other difficulty or unexpected problem was encountered in the communication with the local end users (i.e., the Geological Survey of the Lombardy Region).

The CNR headquarter in Rome made funds for the CNR-IRPI Perugia available only at the beginning of September 2001. Despite the delay, research and technical activities did not suffer, and were conducted on schedule.

Section 7 - Plan and Objectives for the next period

For the next reporting period (from October 2001 to February 2002) the CNR-IRPI Perugia will continue its activities on WP2 and WP5, as originally planned. For WP2, activities will focus on the development of the rock fall modelling software. We plan to test the program performance and reliability at different scales, and to further test the stochastic and random capabilities to take into account the spatial variability intrinsic into the input data sets. Within WP5, we will continue to update the project web sites, publishing the project reports, and the information on the other study areas when they will become available. We also plan to work on better-defined examples of the capabilities of the web-based GIS software.

Section 8 - Publications

During the reporting period the CNR-IRPI Perugia, together with the University of Milano Bicocca has submitted a paper to an international, peer-reviewed journal. The paper, submitted to Computer & Geosciences, discusses in details the algorithms implemented in the software STONE, the input data required by the software, and the different raster and vector outputs. The Montagna Lecchese is used as an example of the results obtained.

The program STONE was also presented at national and international meetings, and workshops. The following is a list of talks given during the reporting period:

- *Prospettive della ricerca sulla pericolosità e sul rischio da frana.* La prevenzione del rischio idrogeologico attraverso la conoscenza del territorio, Milano, 27 September 2001, (in Italian).
- *STONE, a computer program to evaluate rockfall hazard at the regional scale.* U.S. Geological Survey, Reston, 12 July 2001.
- *STONE, a 3-d computer software to evaluate rockfall hazard at the regional scale.* University of Vancouver, Vancouver, 25 June 2001.
- *STONE, a computer program to evaluate rock fall hazard and risk at the regional scale. Examples from the Lombardy region.* XXVI EGS General Assembly, Nice, 29 March 2001.