Consiglio Nazionale delle Ricerche
Istituto di Ricerca per la Protezione Idrogeologica

European Project DAMOCLES (EVG1-1999-00027P)

SECOND ANNUAL REPORT OF ASSISTANT CONTRACTOR CNR-IRPI PERUGIA

Reporting period: March 2001 – February 2002

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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 March 2001 – February 2002. 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 and testing of a stochastic and random approach in the simulation of rock-fall trajectories. The software was also tested in different environmental settings, including an area in the Apennines (Umbria Region, central Italy) and the Yosemite Valley, California (USA). For WP5 we have maintained and updated the DAMOCLES project web sites, contributing to the dissemination of the project results and of some of the project deliverables.

Section 3.1 - Objectives of the reporting period

As stated in the project proposal, DAMOCLES aims 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 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 the regional scale debris flow and rock-fall hazard. This includes assembling databases of thematic (geographical) information in support of model development and refinement. These objectives are addressed by WP2, led by the University of Milano-Bicocca of which CNR-IRPI 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 and debris flows applicable to mountain environments in Europe. The principal field area is currently located in the Lombardy Region, in the Southern Italian Alps. Additional test areas were identified in the Central Apennines (Valnerina area, Umbria Region) and in the Yosemite Valley, California.
- To transfer the technologies and deliverables to key end-users and to make the outcomes accessible through the public domain. These objectives are addressed by WP5 led by the University of Newcastle. Within this work package CNR-IRPI has designed, implemented and is maintaining the DAMOCLES Internet Web site, and has tested the possibility of using GIS-based Web technology to publish on the Internet thematic and landslide hazard maps. The test area selected for the experiment is the Montagna Lecchese, in the Lombardy Region of Northern Italy.

Section 3.2 – Methodology and Scientific Achievements

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

Working Package 2

Within WP2 activities carried out at CNR-IRPI were focused on testing the rock fall simulation program STONE in different geological and morphological settings, and on improving its modelling capabilities. The major improvement was obtained introducing stochastic and random components to the simulation of rock–fall trajectories, allowing for the uncertainties associated with the simulation of rock falls and for the natural variability of the input data. 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. The software was also successfully tested in two new test areas: the Valnerina area, in the Central Apennines (Umbria region, Italy) and the Yosemite Valley, California (USA).

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 was 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.

We also tested the performance of STONE with simple three-dimensional topographic surfaces. Figure 4 shows the result for a concave geometry in the source area, a channelled topography in the middle part of the slope, and a flat terrain at the bottom of the slope. In nature this setting corresponds to a steep valley head (an escarpment 400 meters high), followed by a gully on a steep talus slope and an open flat valley at the bottom of the slope; a rather common geomorphological setting for rock-falls in a mountain region. Maps showing the count of rock-falls (Figure 4A) show that trajectories concentrate along the channel due to the three-dimensional effect of topography. In Figure 4A most of the rock-falls stop before reaching the plain and only a minority gets to the lower part of the slope. This is due to the low energy restitution and high dynamic friction coefficients used in the simulation. If less conservative values are adopted (Figure 4B and 4C) the boulders travel further down slope, many of them reach the lower talus and some of them get to the flat valley bottom.

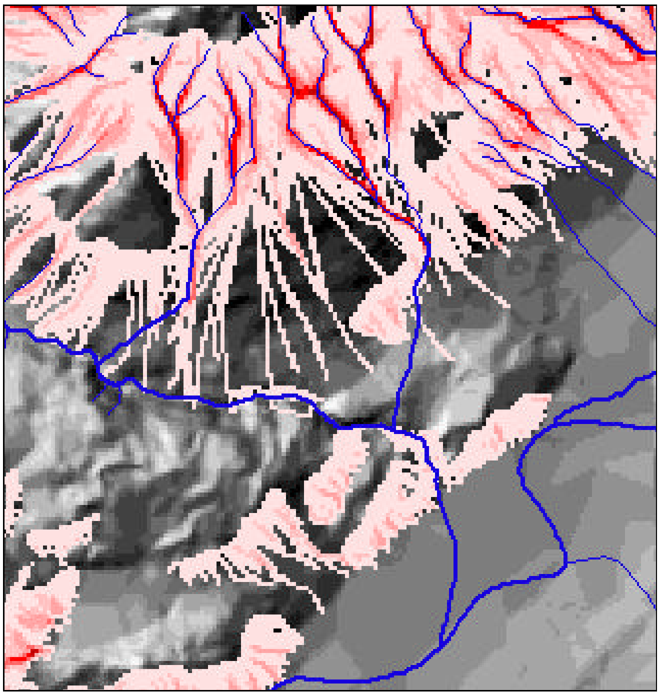


Figure 1 – Map of rock fall count. Completely deterministic model. No random component used. One boulder was launched from each source cell.

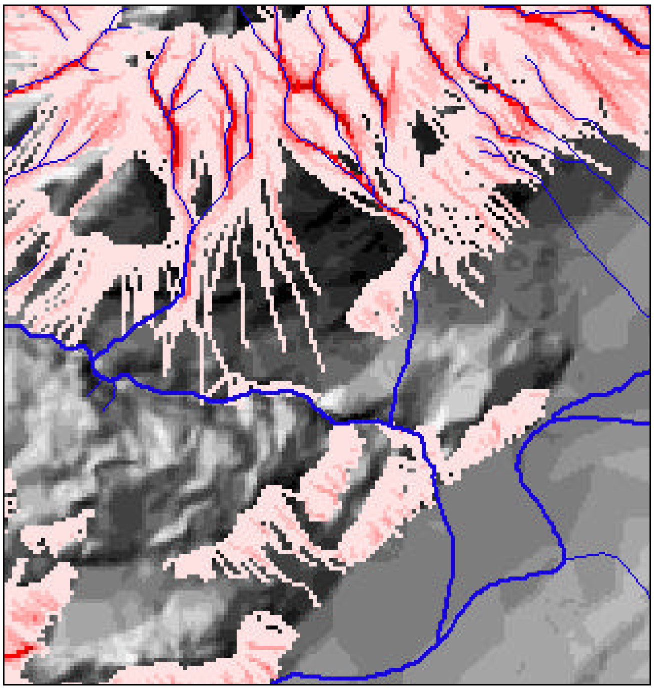


Figure 2 – Map of rock fall count. Simulation obtained by adding a random variation to the input parameters. One boulder was launched from each source cell.

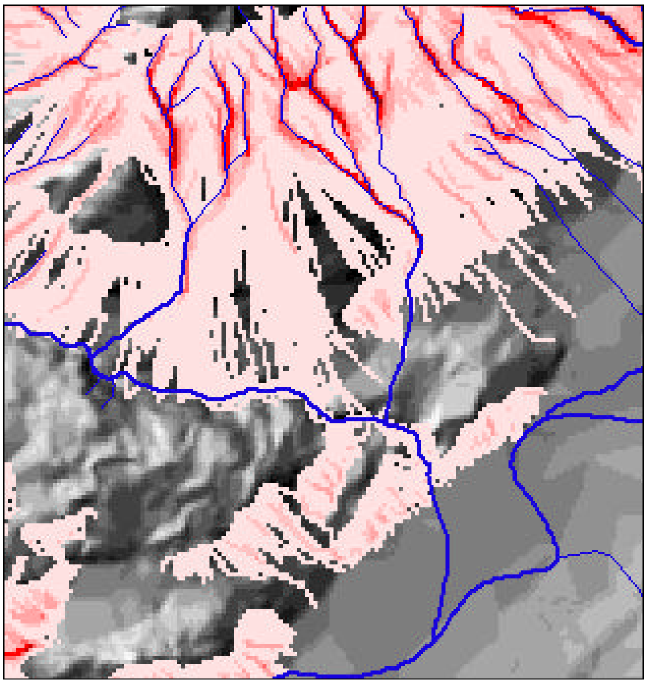


Figure 3 – Map of rock fall count. Stochastic simulation obtained varying randomly the input parameters and by launching 10 rock falls from each source cell.

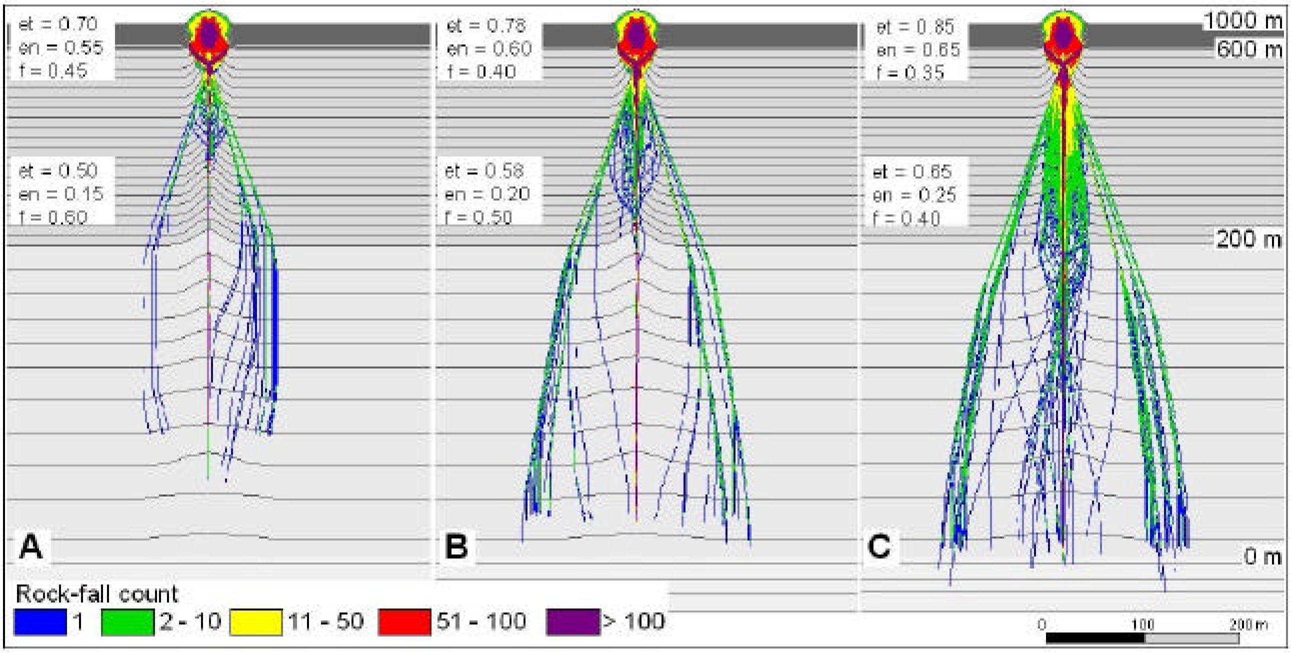


Figure 4 – Example of the behaviour of the program STONE on a simple (synthetic) three-dimensional topographic setting.

Figure 4 proves the importance of simulating rock-falls in three-dimensions. The concentration of rock-fall trajectories along the main channel and the lateral spread of rock-fall trajectories on the upper part of the talus slope would hardly be seen using a two-dimensional simulation program working on a pre-defined slope profile. The figure also shows that limited (minor) changes in the input parameters affect (locally substantially) the result, in particular with respect to the spatial distribution of rock fall trajectories. This supports the need for considering in the simulation of rock-falls the local variability of the terrain and of its mechanical properties. The former can be taken into consideration using high quality, detailed DTMs; the latter can be simulated by adding a random component to the input modelling conditions

Two researchers were involved in the activities of WP2 for about 12 days each. Additional work was carried out by two master students, one of which in the framework of the Erasmus exchange program. The work is on schedule with what originally planned.

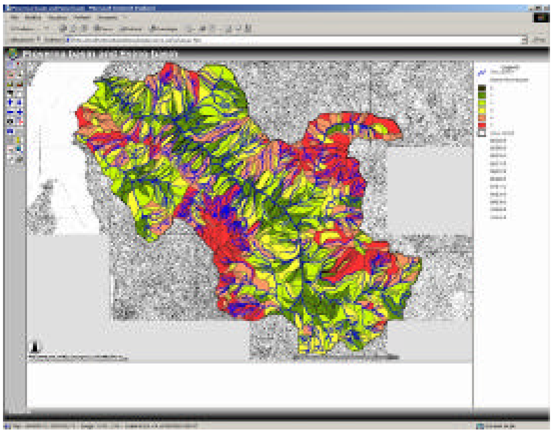
Working Package 5

WP5 deals with the dissemination of the project results and some of the project deliverables. Activities within the WP are co-ordinated by the project leader, Prof. James Bathurst (Newcastle). As for the previous year, the activities at CNR-IRPI Perugia focused on maintaining and upgrading the DAMOCLES web site, and on updating and improving the GIS-based Web site for the publication on the Internet of thematic maps, including debrlis flows and rock fall hazard maps.

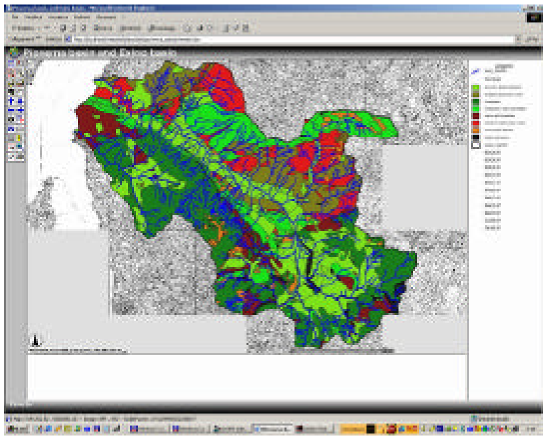
To improve the readability of the project Web site (http://damocles.irpi.pg.cnr.it) and to facilitate the access to the available information, we designed and implemented a new layout for the Web pages (Figure 5). The new layout avoids the use of frames, making the site faster to access. An improved, 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 5 - The new home page of the DAMOCLES web site.

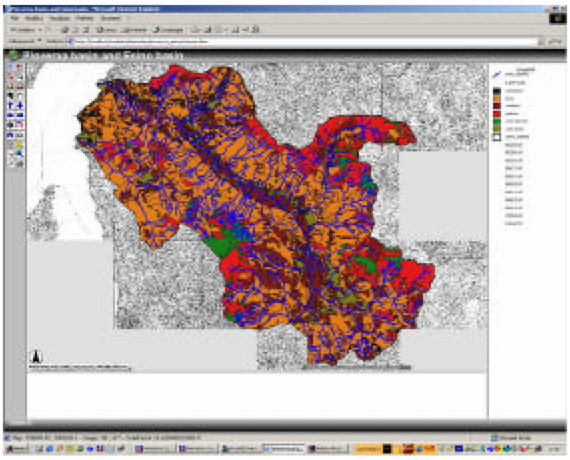
In the last months of the reporting period we have installed a new version of the ARC-IMS software (release 3.1) for the dissemination of geographical information (i.e. digital maps) through the web. Despite this was supposed to be a minor upgrade to the system (going from release 3.0 to 3.1) the structure of the software, some of the additional software needed to interface ARC-IMS to the public domain web server apache (e.g., the servlet software) changed consistently. The format and content of the XML files used to display the geographical information also changed substantially, forcing us to re-design and re-prepare the GIS-based site almost from scratch. This work was largely unforeseen. Figure 6 shows some of the new maps available for the Pioverna basin, Lombardy Region.



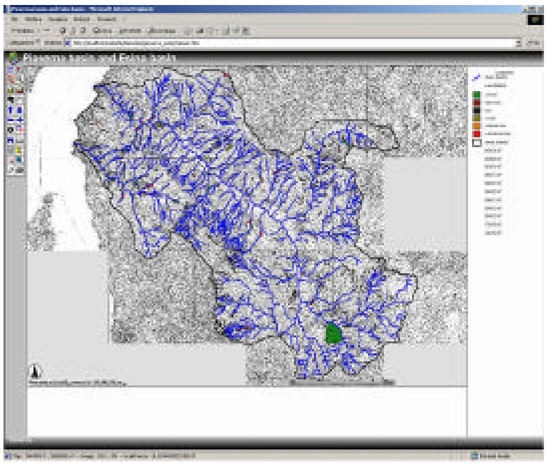
Debris Flow Hazard Map



Geological Map



Land Use Map



Debris Flow Inventory Map

Figure 6. Maps available on the GIS-based Damocles web site.

A team member was involved in the activities of WP5 for about 12 days. A computer expert paid by the DAMOCLES project has worked for about 16 days to maintain and update the GIS-based web pages. The work was completed on schedule.

Section 3.3 – Socio-Economic Relevance and Policy Implementation

Maps of rock-fall hazard produced using STONE were made available to the Servizio Geologico della Regione Lombardia. Discussion with the end user proved that the map are reliable and that can be helful for regional planning. Sample maps for the Pioverna area (Lecco Province, Lombardy Region) were published on the project website. We regard this as a good step toward the dissemination of the project results to the end-users, other scientists and the general public. Results of the rock fall simulation program STONE were presented to the students of the EU ECO-GEOWATER course.

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.

Section 3.4 – Discussion and Conclusion

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 directly by the partners. Considerable interaction was necessary in particular between CNR-IRPI and the University of Milano Bicocca for the publication of the thematic maps on the Pioverna Basin.

For the assessment of rock-fall hazard at the regional scale (WP2) we performed further test of the performance of the computer program STONE that proved to be consistent with the results of other rock-fall simulation programs, to be reliable for modelling rock-falls in 3-dimensional geomorphologic settings, and to effectively aid in the assessment of rock-fall hazard over large areas. The addition of random and stochastic modelling components allowed coping with the natural variability and the uncertainty associated with the rock fall process. New maps of rockfall hazards were shown to the Geological Survey of the Lombardy Region, of the project End Users.

The project web site (WP5) was updated regularly. A new and improved dataset for the Pioverna basin (Lecco Province, Lombardy Region) provided by the Milano Bicocca team was added. The project coordinator (Prof. James C. Bathurst) contributed the agenda and the minutes of the Padua and Newcastle meetings, 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), an explanation of the MODSS (Muskingum One-Dimensional Debris flow Simulation) model, and a database of debris flow torrents in the Autonomous province of Bolzano (Northern Italy). The Instituto Geológico y Minero de España (Prof. Santiago Rios) contributed information on the Benasque study area (Central Pyrenees, Spain). The Pyrenees 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) and a report on granular flows. All this information is available on the web.

Section 3.5 – Plan and Objectives fo the Next Reporting Period

The next reporting period will coincide with the last year of the DAMOCELS project. CNR-IRPI Perugia will continue its activities on WP5 and to a lesser extent on WP2. Within WP2 activities will focus on the further testing of the rock fall modelling software in different geological and morphological environments. We plan to test the program performance and reliability at different scales, and to 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 3.6 – 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 and 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 paper was accepted for publications with minor revisions on February 2002.

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 model rock fall hazard. European Union ECO-GEOWATER project meeting, Genoa, 8 February, 2002.

In addition, three oral and poster presentations regarding STONE have been accepted for presentation to the XXVII European Geophysical Society General Assembly, to be held in Nice, 21-26 April, 2002

The following table lists all the publications for the reporting period.

Peer Reviewed Articles:

Authors	Date	Title	Journal	Reference
Guzzetti F., Crosta G., Detti R. & Agliardi F.	2002	STONE: a computer program for the three-dimensional simulation of rock-falls.	Computers & Geosciences	Accepted with minor revisions

Non refereed literature:

Authors / Editors	Date	Title	Event	Reference	Type[1]
Guzzetti F., Detti R. Crosta G. & Agliardi F.	2001	A computer program to evaluate rockfall hazard and risk at the regional scale. Examples from the Lombardy region.	XXVI EGS General Assembly, March 29, 2001.		Oral Presentation
Ghigi S., Guzzetti F., Reichenbach P. & Detti R.	2002	Preliminary assessment of rock fall hazard and risk in the central part of the Nera Valley, Umbria Region, Central Italy	XXVII EGS General Assembly, Nice, 21-26 April 2002.		Poster presentation
Guzzetti F., Reichenbach P. & Wieczorek G.F.	2002	Rock-fall hazard in the Yosemite Valley, California	XXVII EGS General Assembly, Nice, 21-26 April 2002.		Poster presentation
Agliardi F., Crosta G.B., Guzzetti F. & Marian M.	2002	Methodologies for a physically based rockfall hazard assessment	XXVII EGS General Assembly, Nice, 21-26 April 2002.		Oral presentation

[1] Type: Abstract, Newsletter, Oral Presentation, Paper, Poster, Proceedings, Report, Thesis