Consiglio Nazionale delle Ricerche
Istituto di Ricerca per la Protezione Idrogeologica

European Project DAMOCLES (EVG1-1999-00027P)

DETAILED REPORT OF ASSISTANT CONTRACTOR CNR IRPI PERUGIA FOR THIRD ANNUAL REPORT

Reporting period: March 2002 – February 2003

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Summary

We report on the results obtained by CNR-IRPI Perugia in the period March 2002 to February 2003. The research activities focused on two of the five project working packages, namely: WP2, Development of a GIS hazard assessment methodology using field data, available databases and model developments, and WP5, Dissemination of the project deliverables. Activities carried out in the framework of WP2 aimed at the further testing of the 3-dimensional rock fall simulation program STONE. The program was tested by the CNR IRPI outside the areas originally selected for the DAMOCLES project, and in particular in the Yosemite Valley, in central California, USA, and in the Nera River Valley, Umbria Region, central Italy. Tests aimed at verifying the software performance in different physiographical environments and at evaluating the possibility of using the program outputs to determine rock fall hazards and risk along the transportation network. Activities carried out in the framework of WP5 consisted in the maintenance and update of the DAMOCLES web sites, contributing to the dissemination of the project results and deliverables. The main project web site was updated whenever new information was made available by the partners. The availability of a new release of the GIS-software used to publish maps on the web allowed for the transfer of the GIS web server on a Linux-based system. The change was transparent to the end users, and made the system more robust and less prone to network attacks and consequent failures.

Section 3.1 - Objectives of the reporting period

The main objectives of the research activities conducted at CNR IRPI in the period March 2002 to February 2003 can be summarized as follows:

WP2: Test of the 3-dimensional rock fall simulation software STONE in different physiographical regions. Comparison of the modelling results against field data on rock fall occurrence. Evaluation of rock fall hazards and risk in selected test areas, with emphasis on the risk to the transportation network.

WP5: Maintenance and updating of the DAMOCELS web sites, helping disseminating the information on the project deliverables. Continuation of the experiment aimed at testing the possibility of publishing on the Internet landslide inventory, landslide hazard, and other thematic maps. Update of the GIS software tools used for publishing geographical information on the web.

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

The rock fall simulation program STONE (*Guzzetti et al*., 2002) was tested in two different areas, namely: a portion of the Yosemite Valley, in central California (USA) (*Guzzetti et al.*, 2002), and a section of the Nera River Valley, in the Umbria region of central Italy (*Guzzetti et al*., 2003). Tests were aimed at verifying the software performance in different physiographical environments, and at evaluating the possibility of using the program outputs to determine rock fall hazards and risk along the transportation network.

The Yosemite Valley is located in the previously glaciated headward segment of the Merced River canyon in central Sierra Nevada, California. The valley has very steep rock cliffs, 1000 metres high or more. Rock falls and minor rock slides occur frequently from the steep rock slopes, posing a severe treat to the more than 3 millions annual visitors (*Wieczorek and Jäger*, 1996; *Wieczorek et al.*, 1992). To ascertain the rock fall hazards and risk in the Yosemite Valley we performed a rock fall simulation using STONE. For the Yosemite Valley, a DEM with a ground resolution of 10×10 m was prepared using topographic contour lines from the U.S. Geological Survey 1:24,000-scale maps. Rock fall release points were identified as DEM cells having a slope steeper than 60 degrees, an assumption based on the location of historical rock falls. This rather simple approach allowed identifying 61,435 grid cells (10×10 m in size) as possible sources of rock falls, i.e., 6.1 km^2, in plan view; approximately 7% of the Yosemite Valley. Correcting for the steep topographic gradient, this is an area of about 19.1 km^2. Maps of the normal and tangential energy restitution coefficients and of the rolling friction coefficient were produced from a surficial geological map. Modelling parameters were calibrated at a few sites where detailed cartographic information on historical rock fall events was available. At these sites the simulation consisted in launching several hundreds rock falls from the area that was identified in the field as the detachment zone of the rock fall. The model results were then compared visually and quantitatively with the extent of the rock fall area mapped in the field (Figure 1). Model parameters were adjusted and the simulation repeated until the result was judged satisfactory, i.e., there was good agreement between the modelled and the mapped rock fall. Using the modelling parameters calibrated at the test sites, a rock fall model was then prepared for the entire Yosemite Valley. The only difference was that only 10 boulders were launched from each rock fall source cell.

Figure 2 is a three-dimensional representation of a section of the Yosemite Valley portraying the map of the rock fall count computed by STONE. The image was obtained by overlaying the map of the rock falls count on a three-dimensional scene prepared using the available DEM. Colours show the rock fall count, from few (1-2 boulders, yellow) to numerous (more than 500 boulders, blue). Figures 2 clearly shows the local concentration of rock fall trajectories along steep channels and the lateral spreading of rock fall trajectories on talus slopes and debris cones. These features would hardly be seen using a two-dimensional simulation program (*Guzzetti et al*., 2002).

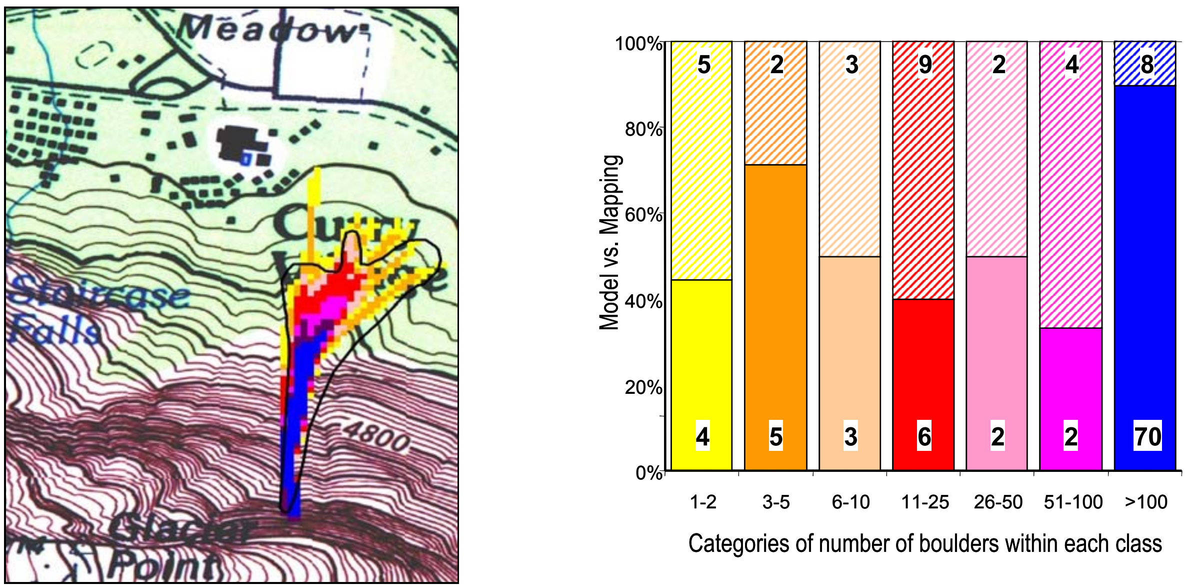

Figure 1. Comparison between the Glacier Point rock fall, of 16 November 1998 near Curry Village, Yosemite Valley, USA (thick black line), and a rock fall simulation performed by STONE (colours). Original scale 1:24,000. Histogram shows the number of cells falling inside (solid colour) and outside (oblique pattern) the mapped landslide. Figures in the coloured bars are number of cells. From *Guzzetti et al*., 2002.

The model results were compared with a map of rock fall talus (*Wieczorek and Jäger*, 1996) and with a geomorphic assessment of rock fall hazard based on potential energy referred to as a shadow angle approach, recently completed for the Yosemite Valley (*Wieczorek et al*., 1998, 1999). The STONE computer model was a better representation of the rock fall hazard than that provided by the shadow angle concept. This is mostly because the apex of the fans used for representing the shadow line is somewhat arbitrary and does not well represent all potential rock fall sources, but only those that have produced large talus fans.

The combined analysis of a spatially distributed rock fall simulation model with the distribution of the roads and trails in the Yosemite Valley identified the sections of the roads and trails that are potentially subject to rock falls. The roads and trails were classified according to the number of expected rock fall trajectories, considered to be a proxy of the rock fall hazard. In the Yosemite Valley there are approximately 166.5 km of roads and trails, of which 31.2 percent (~52 km) intersect an area of possible occurrence of rock falls. Limiting the analysis to the roads and trails that intersect an area of possible rock fall occurrence, about 25% of the roads and trails are subject to low (1-2 boulders) hazard, 31% to moderate hazard (3-10 boulders), 30% to high hazard (11-50 boulders), and 14% to very high hazard (more than 50 boulders). If one considers all the roads and trails in the Yosemite Valley, 7.8% of the infrastructure is subject to low hazard, 9.7% to moderate hazard, 9.4% to high hazard, and only 4.3% to high rock fall hazard.

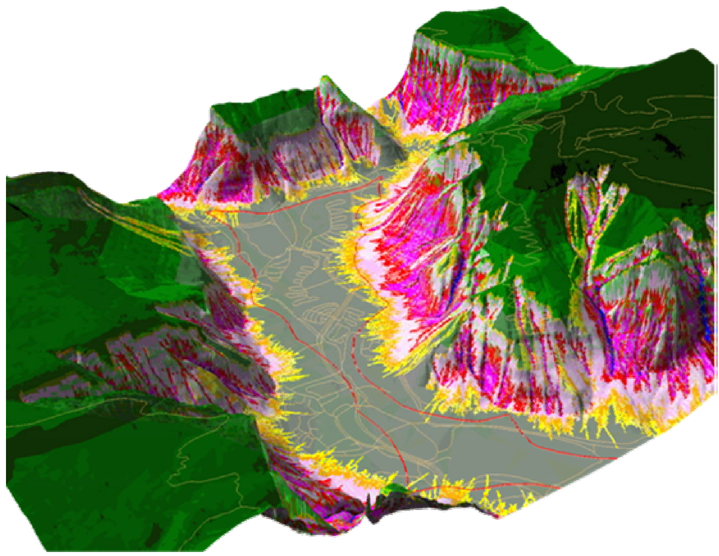

Figure 2A. Three dimensional view of the rock fall hazard in the eastern section of the Yosemite Valley. Colours show rock fall count. Yellow, 1-2 boulders; orange, 3-10; pink, 11-50; red, 51-100; light violet, 101-250; dark violet, 251-500, > 500, blue. Red line is the 22° shadow angle line of *Wieczorek et al*. (1998). Light brown lines are roads and trails.

The Nera River, a tributary of the Tiber River, flows from north to south across the Umbria-Marche Apennines in a deep and narrow valley. Two regional roads, SS 320 and SS 209, and several villages are located along the valley bottom. The villages and the roads are frequently affected by rock falls. On October 1997, aftershocks of the Umbria-Marche earthquake triggered tens of rock falls, ranging in size from few cubic decimetres to 100 cubic metres (*Antonini et al*., 2002). Rock falls caused severe and widespread damage mostly to the transportation network. The two national roads were interrupted at several locations and remained closed for weeks after the earthquakes while rock fall elastic barriers were installed and the existing artificial tunnels were repaired, reinforced or extended.

We used STONE to quantitatively evaluate rock fall hazard in an area of about 48 km^2 centred on the village of Triponzo (*Guzzetti et al*., 2003). In this area seismically induced rock falls were numerous in the fall of 1997 (*Antonini et al*., 2002). The aim of the analysis was to determine rock fall hazards and risk along the transportation network, and to evaluate to what extent the new defensive measures reduced rock fall risk in the valley. For the study area, a DEM with a ground resolution of 5×5 m was prepared using topographic contour lines from the available 1:10,000 and 1:5,000 scale topographic maps (CTR Series). The source areas of rock falls were mapped from vertical aerial photographs, and checked in the field. A total of 2.05 km^2 of rock fall source areas were identified, corresponding to 4.17% of the study area. Correcting for the steep topographic gradient, we found that the rock fall detachment areas extend for approximately 3.04 km^2. Parameters controlling the loss of energy at impact points and during rolling were obtained from a surface geology map prepared updating the existing large scale geological map through the analysis of aerial photographs and filed surveys. The rock fall modelling revealed that about 7.00 km^2, 14.58% of the study area, can be affected by rock falls, including 2.05 km^2 of rock fall detachment areas. Correcting for the steep topographic gradient, the area affected by rock falls extends for about 9.51 km^2. Figure 3 is a three-dimensional representation of a section of the Nera River Valley portraying the map of the rock fall count computed by STONE.

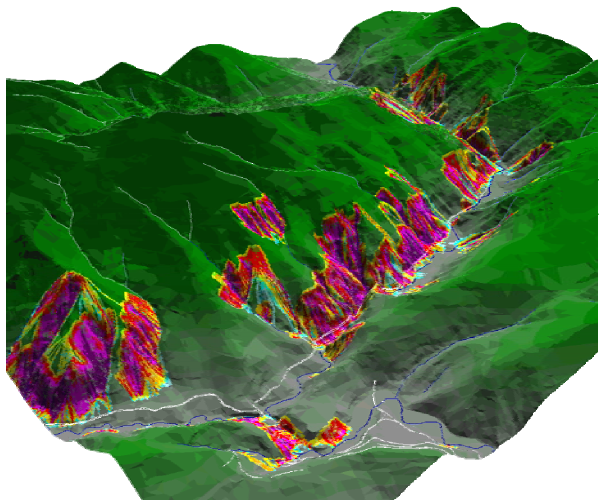

Figure 3. Three dimensional view of the rock fall hazard in the Triponzo study area. Colours show rock fall count. Light blue, 1-10; yellow, 11-100 blocks; red, 101-250 blocks; violet, 251-500 blocks; dark violet, > 500 blocks. White lines are roads. Blue lines are rivers.

To ascertain rock fall hazard in the study area, we adopted a simple heuristic approach that assumes that rock fall hazard, H_{rf}, is a simple combination of rock fall count (*c*), maximum rock fall flying height (*h*), and maximum rock fall velocity (*v*), or $H_{rf} = f\ (c, h, v)$. Levels of rock fall hazard are attributed using a three-digit positional index, similar to that proposed by *Cardinali et al.* (2002) for other landslide types. In the index, the left digit refers to the rock fall count (*c*), the central digit to the rock fall flying height (*h*), and the right digit to the rock fall velocity (*v*). The index expresses rock fall hazard by keeping the three components of the hazard distinct from one another. This facilitates hazard zoning by allowing to understand whether the rock fall hazard is due to a large number of expected rock falls (i.e., high frequency), a large intensity (i.e., high flying height or high velocity), or some combination of the three. Rock fall hazard is not distributed uniformly in the study area. About 3.39 km^2 of the study area (in plan view) are subject to low (25.49%) or very low (23.01%) rock fall hazard, 1.55 km^2 (22.19%) are subject to intermediate hazard conditions, and 2.05 km^2 are subject to high (15.34%) or very high (13.97%) hazard (Figure 4).

In the Triponzo study area, we used the hazard map to determine rock fall risk along the transportation network. A map of the transportation network was obtained in vector format from the 1:10,000 and 1:5,000 scale topographic maps (CTR Series). A constant width was assigned to each graphical element (e.g., road, bridge, tunnel, etc.), and the map of the transportation network was transformed into a raster map, of the same size and spatial resolution (5×5 m) of the hazard map. By overlying in a GIS the rock fall hazard map with the map of the transportation network we identified the sections of the roads potentially subject to rock fall risk. Of the 31.76 kilometres of paved roads in the study area, 9.05 km (28.49%) were found to be potentially affected by rock fall hazard.

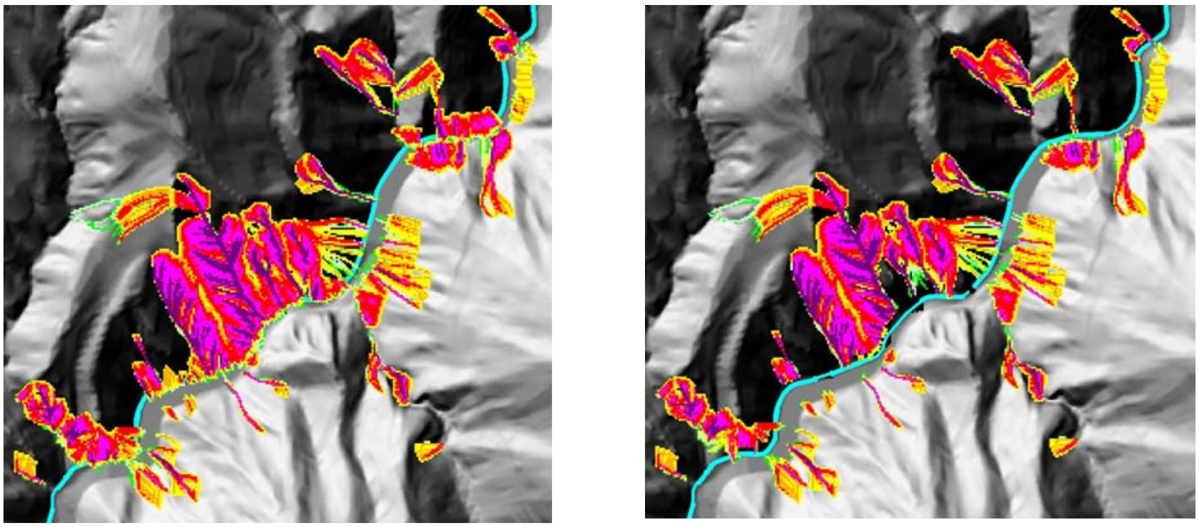

Figure 4. Portion of the Nera River Valley. Comparison of rock fall hazard models. Left: the model does not consider the presence of rock fall defensive barriers. Right: the model takes into consideration the presence and the location of the rock fall elastic barriers. For display purposes rock fall hazard is ranked into six classes, shown by different colours, from green (very low hazard) to dark violet (very high hazard).

This estimate does not consider the numerous rock fall defensive structures (including rock fall revetment nets, elastic barriers, concrete walls and artificial tunnels) present in the study area. We performed an inventory of these structures, and we used this information to evaluate the effectiveness of the existing defensive measures in mitigating rock fall risk (Figure 4). This was accomplished in three steps. We first considered the presence of the passive revetment nets. A total of 0.32 km^2 of revetment nets were mapped, mostly along or in the vicinity of the roads. We assumed that the revetment nets were fully capable of preventing rock falls and, based on this assumption, we prepared a new rock fall hazard model that differs from the previous model only for the reduced extent of the rock fall source areas. In the new model the area potentially affected by rock falls decreases to 6.49 km^2 (13.51%) and the length of roads subject to rock fall hazard decreases to 6.53 km (20.54%). The presence of the passive revetment nets reduces by 7.4% the extent of the area potentially subject to rock falls, and by about 27.9% the total length of roads subject to rock fall hazard. We then considered the presence of the other defensive structures. A new rock fall hazard model was prepared considering the presence of the revetment nets, the location of the elastic rock fall fences and concrete barriers, and the presence of the artificial tunnels. The new model reveals that the extent of the area subject to rock fall hazard reduces to 6.27 km^2 (13.07%). Correspondingly, the total length of roads subject to rock fall hazard reduces to 2.92 km, 9.21% of the road network. The analysis indicated that the combined effect of all the existing defensive structures reduces by about 10.37% the extent of the area subject to rock falls, and by about 67.75% the total length of roads subject to rock fall hazard.

We then attempted to evaluate the efficacy of the rock fall retaining structures. This was accomplished in two steps. First, the maximum height of the computed rock fall trajectories was compared to the height of the retaining structures, then the possibility that a boulder could have enough kinetic energy to brake through an elastic fence or a concrete wall was considered. The analysis revealed that about 20.66% of the retaining structures can be “jumped” by high flying rocks, and that 10.19% of the existing retaining structures can be destroyed or damaged by falling blocks. The analysis showed that 20.96% of the rock fall elastic fences or concrete walls could be either bypassed by high flying rock falls, or could be damaged or destroyed by fast moving boulders. To estimate the residual rock fall risk along the roads in the Triponzo study area we prepared a final hazard model not considering the presence of the ineffective defensive structures. The model revealed that 4.06 km of roads in the study area (12.78%) are potentially subject to rock fall hazard, indicating that despite the considerable reduction in the risk of rock falls due to the presence of numerous defensive structures, residual risk still exists along the roads of the Nera River valley.

Two scientists were involved in the activities of WP2, for a total of about 179 working hours. An additional scientist and a student completing her Thesis at the Earth Sciences Dept. of the Perugia University were involved in the field and in the laboratory activities in the Triponzo study area, for a total of about 260 hours. Work in the Yosemite valley was conducted in cooperation with Gearld F. Wiecorek, U.S. Geological Survey, Reston, USA. Most of the work carried out in this working package was not originally planned, and should be considered an addition to the project results and deliverables.

Working Package 5

Three main activities were carried out in WP5:

- Due to changes imposed by a new policy of internet naming at the Italian National Research Council (CNR), the URL address of the DAMOCLES project web site was changed from http://damocles.irpi.pg.cnr.it to http://damocles.irpi.cnr.it. The old internet address still exists, providing continuity to the new addresses.
- Implementation of the GIS-web server on a new computer, courtesy of CNR IRPI. The availability of a new release (release 4.0) of the ESRI Arc-IMS software used to publish maps and other geographical information on the web, made it possible to transfer the GIS-based web site from a Windows-based system to a Linux-based system. The change was transparent to the end user, and made the system more robust and less prone to network attacks, and subsequent degraded services or failures typical of Windows systems.
- Update of the content of the project web site with information and data provided by the DAMCLES partners. In details: a) the project coordinator (Prof. James C. Bathurst) contributed the minutes of the Saragoza and Milan meetings, b) the University of Padua (Prof. Mario A. Lenzi) provided an updated description of the Rio Lenzi Study area (Veneto Region, Italy) and the teaching material used at the DAMOCLES training course held at the University of Padova, on September 2002, on the application of the debris flow models developed by the Padua team; and c) the University of Milano Bicocca (Prof. Giovanni B. Crosta) provided updated information on the Pioverna study area (Lombardy Region, Italy).

Additional activities included: a) updating the web software “apache” whenever new stable releases, security fixes or patches were made available, b) updating the web site whenever a new deliverable or new information was made available by the partners, and c) correcting errors and inconsistencies in the several web pages in the DAMOCLES web site.

It should be noted here that not all the information, data and maps produced within the project or available to the partners, were made available for publication on the DAMOCLES web site. No description was provided for the SHETRAN model. The GIS-based web site contains a limited amount of thematic and landslide hazard maps, and only for the Pioverna study area, in the Lombardy Region of northern Italy. Geographical and thematic data for the other study areas in Spain and in northern Italy were not made available. The lack of geographical information and thematic maps has limited the usefulness of the GIS-based web site, and has not allowed for an exhaustive, fully comprehensive test of the advantages and limitations of the available web-technology to publish digital landslide hazard maps on the Internet.

A team member was involved in the activities of WP5 for about 92 hours. A software and GIS expert was involved in the activities of WP5, for a total of about 92 hours. The cost of the latter consultancy was not charged to the DAMOCLES project, but was paid by CNR IRPI grants. The work was completed on schedule.

Section 3.3 – Socio-Economic Relevance and Policy Implementation

Among the goals of the DAMOCLES project the dissemination of the results obtained and of the deliverables to local end users was particularly important. Throughout the project efforts were made to present to actual and potential end-users the results obtained, and to evaluate their potential socio-economic relevance.

The rock fall hazard assessment produced using STONE for the Yosemite valley was presented to the U.S. National Park Service (NPS), the organization responsible for the safety of people, structures and infrastructure in the Yosemite National Park. Results of the hazard assessment, and in particular the map of the rock fall count produced by STONE, were received with interest. Whether the NPS will adopt the computer model as an alternative or as integration to the 22° shadow angle line or the talus line (*Wieczorek et al.*, 1988, 1999) currently used to identify rock-fall hazardous areas is unknown. The empirical approach is simpler than the STONE computer model, and some effort will be needed to transfer the new technology to the NPS (*Guzzetti et al.*, 2002). The U.S. Geological Survey is considering the possibility of publishing the map showing rock fall hazard in the Yosemite Valley.

Preliminary estimates of rock fall hazard and of the associated risk to the infrastructure in the Triponzo study area were presented to geologists working for the Perugia Province, the organization responsible for the maintenance and safety of most of the roads in the Nera River valley. The Province is considering the possibility of using the results of the 3-dimensional rock fall simulation to determine the areas where rock fall defensive measures are not adequate in mitigating landslide risk.

The outcomes of the project meetings, the morphological and geological descriptions of the study areas, the material distributed during the DAMOCLES training activities, and the information on the other project deliverables (publications, reports, etc.) were made available on the DAMOCLES web site (http://damocles.irpi.cnr.it). The Web proved to be a very efficient and economic technology to disseminate many of the project results and deliverables. As previously noticed, the lack of geographical information and of landslide and landslide hazard maps for some of the study areas has limited the usefulness of the GIS-based web site, and has not allowed a fully comprehensive test of the advantages and limitation of the technology to publish digital maps on the Internet.

Section 3.4 – Discussion and Conclusion

We have reported on the activities conducted by CNR IRPI in WP2 and WP5 during the third and final year of the DAMOCLES project. Most of the scientific, technical and socio-economic goals outlined in the original project proposal were successfully achieved. Some of the results that were obtained (e.g., testing of the rock-fall simulation program in the Yosemite Valley and in the Nera River valley) were not foreseen and are additions to the original project plan. With this respect the results are satisfactory and the project can be considered successfully completed.

During the last year of the project, the most important result obtained by CNR IRPI was the testing of the three-dimensional rock fall simulation software STONE, and its application in two different study areas ranging in extent from few to several tens of square kilometres, in different physiographical and geographical regions. Outputs of the rock fall simulation program were used to ascertain rock fall hazards and to start determining quantitatively rock fall risk to the infrastructure.

The DAMOLCES web site was successfully used to deliver to the public domain most of the results and deliverables obtained by the DAMOCLES partners. The potentialities of the GIS-based web technology used to implement the DAMOCLES web site were (at least partially) exploited. Results suggest that the technology may be suitable to effectively distribute thematic and geographical information on landslide and landslide hazards available in digital format to a very large audience.

Section 3.5 – Recommendations Arising from the Project

Most of the scientific, technical and socio-economic goals outlined in the original project proposal of CNR IRPI were achieved. Some of the results that were obtained (e.g., testing of the rock-fall simulation program in the Yosemite Valley and in the Nera River valley) are additions to the original project plan. With this respect the project was completed beyond expectations.

The 3-dimensional rock-fall simulation program STONE proved capable of simulating rock fall trajectories at the local and the regional scales. Output of the simulation software were used to determine rock fall hazard and risk at different scales. Developments to the program STONE are certainly possible. Improvements may include: a) a more efficient way of handling the two-dimensional and three-dimensional vector files, b) a better description of the loss of velocity during rolling and at the impact points, c) modelling of rock-fall sliding at starting, impact and stopping points, d) the implementation of a hybrid or a fully dynamic model to simulate rock falls, e) improved statistics associated with the program raster output files, and f) a better framework for combining the existing and the foreseeable program outputs for the assessment of rock fall hazard and the associated risk.

The project web site proved a valuable tool for distributing the project deliverables, and in particular the annual, interim, and thematic project reports. Development of the GIS-based part of the DAMOCLES web site proved that a significant amount of geographical information showing landslides and landslide hazards can be delivered to interested parties, including concerned citizens, using innovative web-based technologies. However, further tests on a larger number of datasets are necessary to determine the extent to which web technology can be used to disseminate thematic and geographical information on landslides and landslide hazards. Due to the increasing complexity of the software systems, and the increasing expectations of the end-users, we recommend that a specialized team of landslide hazards experts and computer experts on GIS and Web technology should be established whenever such systems have to be implemented.

Section 3.6 – References

Antonini, G., Ardizzone, F., Cardinali, M., Galli, M., Guzzetti, F. and Reichenbach, P.: Surface deposits and landslide inventory map of the area affected by the 1997 Umbria-Marche earthquakes. *Boll. Soc. Geol. It.*, Special Volume 1, Part 2, 843-853, 2002.

Cardinali, M., Reichenbach, P., Guzzetti, F., Ardizzone, F., Antonini, G., Galli, M., Cacciano, M., Castellani, M., and Salvati, P.: A geomorphological approach to estimate landslide hazard and risk in urban and rural areas in Umbria, central Italy. *Natural Hazards and Earth System Sciences*, Vol. 2:1-2, 57-72, 2002.

Wieczorek, G.F. and Jäger, S.: Triggering mechanisms and depositional rates of in the Yosemite Valley, California: *Geomorphology*, 15, 17-31, 1996.

Guzzetti, F., Crosta, G., Detti, R. and Agliardi, F.: STONE: a computer program for the three-dimensional simulation of rock-falls. *Computers & Geosciences*, Vol. 28: 9, 1079-1093, 2002.

Wieczorek, G.F., Morrissey, M.M., Iovine, G. and Godt, J.: Rock-fall Hazards in the Yosemite Valley: *U.S. Geological Survey Open-file report 98-467*, scale 1:12,000, 7 p., 1998.

Wieczorek, G.F., Morrissey, M.M., Iovine, G. and Godt, J.: Rock-fall potential in the Yosemite Valley, California: U*.S. Geological Survey Open File Report 99-578*, 1 plate, scale 1:12.000, 7 p. http://greenwood.cr.usgs.gov/pub/open-file-reports/ofr-99-0578/, 1999.

Wieczorek, G.F., Snyder, J.B., Alger, C.S. and Isaacson, K.A.: Rock falls in Yosemite Valley, California: *U.S. Geological Survey Open-File Report 92-387*, 38 p., 2 appendixes, 4 plates, 1992.

Section 3.6.1 List of publications in 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	Vol. 28: 9, 1079-1093
Guzzetti F., Reichenbach P. & Wieczorek G.F.	2002	Rockfall hazard and risk assessment in the Yosemite Valley, California, USA	Natural Hazards and Earth System Sciences	Accepted for publication
Guzzetti F., Reichenbach P. & Ghigi S.	2003	Rockfall hazard and risk assessment in the Nera River Valley, Umbria Region, central Italy	Environmental Management	Submitted

Non refereed literature:

Authors / Editors	Date	Title	Event	Reference	Type[1]
Guzzetti F.	2003	Spatial rock fall hazards and risk assessment: applications of the computer program STONE	Geography Depart., University of Bonn, November 2003.	-	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.	EGS02-A-00925, Geophysical Research Abstracts, Vol. 4, ISSN 1029-7006	Abstract and 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.	EGS02-A-01191, Geophysical Research Abstracts, Vol. 4, ISSN 1029-7006	Abstract and 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.	EGS02-A-04594, Geophysical Research Abstracts, Vol. 4, 2002, ISSN 1029-7006	Abstract and Oral presentation
Guzzetti F., Reichenbach P. Crosta G.B., Agliardi F. & Detti R.	2002	Spatial assessment of rock fall hazard and risk	Sediment Disaster Prevention Technology Conference, Tokyo and Hiroshima, 7-14 April 2002.	5p.	Extended Abstract and Oral presentation
Ghigi S.	2002	Un approccio sperimentale in Valnerina (Umbria sud-orientale)	University of Perugia	Unpublished Thesis	Thesis

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