JAG • Volume 2 - Issue 1 - 2000

Collecting data to define future hazard scenarios of the Tessina landslide

Franco Mantovani[1], Alessandro Pasuto[2], S. Silvano[2] and A. Zannoni[2]

[1] Dipartimento di Scienze Geologiche e Paleontologiche, Università di Ferrara, Italy (fax: +39-049-8295827; e-mail: mnt@dns.unife.it)
[2] CNR-IRPI, Padova, Italy (e-mail: alessandro.pasuto@irpi.pd.cnr)

KEYWORDS: Running head: Defining future hazard scenarios, Tessina landslide

ABSTRACT

Research has been carried out within the framework of the RUNOUT project to define future hazard scenarios of the Tessina Landslide and to determine whether the slide can be related to hydrogeological factors or deep tectonic structures/discontinuities. The work consisted mainly of mapping the geology and geomorphology, collecting meteorological, hydrological and kinematic data, and data modelling. We describe the monitoring system installed on the Tessina landslide and the analyses of data acquired since the start of RUNOUT, a project funded by the EC. Our main goal was to support the group doing the modelling by providing measurements of the principal parameters, such as displacements, groundwater level variations, rainfall, etc., for improving the models used to simulate the behaviour of the landslide and forecast the risk scenarios for the villages. We discuss the critical phase of September-October 1998 and propose a possible future geomorphological evolution of the landslide based on analysis of this data. The second goal was to focus the monitoring on maintaining an alarm system for the safety of the population threatened by the landslide.

INTRODUCTION

In April 1992 the Tessina landslide caused a high risk situation for the villages of Funes and Lamosano in the Province of Belluno (Northeastern Italy). Adequate measures to safeguard the people exposed to the risk had to be considered, as well as the need to monitor and check the evolution of the landslide [Pasuto *et al*, 1992; Angeli *et al*, 1994].

During the past few years the monitoring and alarm system has produced hydrological and kinematic data which allow us to develop forecasting models and future evolution scenarios to assess the landslide hazard. In particular, during 1998 some critical situations for the stability of the whole slope were recorded; they later contributed to a better definition of the triggering and development conditions for the slope movement.

Data was acquired within the framework of RUNOUT, a project funded by the EC, and this allowed us to calibrate models to identify areas potentially prone to landsliding. The modelling shows particularly interesting potential, especially for civil defence purposes.

TESSINA LANDSLIDE HISTORY

The Tessina landslide is located on the south slope of Mt. Teverone, in the eastern part of the Alpago valley in the Province of Belluno (Northeastern Italy, Figure 1). It was triggered on 30 October 1960 by a rotational slide involving some 1 million $m^3$of material following intense rainfall (398.7 mm in the month of October alone). In the following four years, three reactivations took place, always after considerable precipitation and affecting the same volume of material; they led to the formation of a flow which eventually came to a standstill at 600 m from the village of Lamosano (Figure 2). In 1966, although all the Belluno region was struck by disastrous flooding, the landslide did not show any significant reactivation and up to 1987 its activity was extremely low.

In August 1990 there was an important reactivation of the upper part of the landslide's eastern sector. Following this event, a flow which maintained its motion

FIGURE 1 Location of the Tessina landslide.

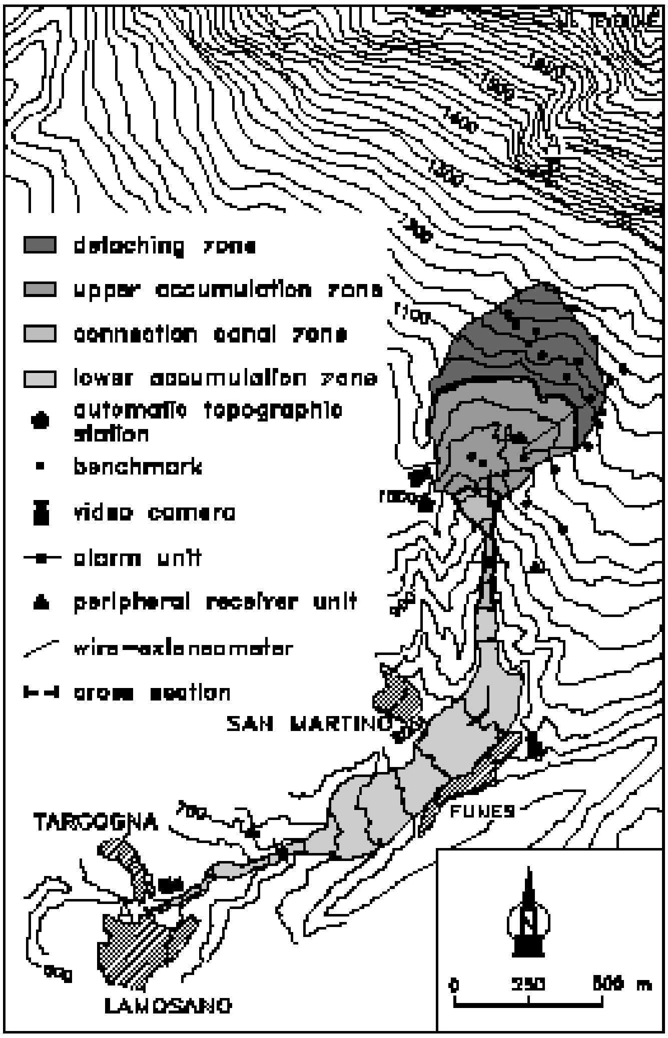

FIGURE 2 Morphodynamic units of the Tessina landslide and the monitoring system installed after the reactivation of April 1992. The track of the geological section is also shown (see Figure 3)

for another 200 m, was formed in the lower accumulation area; this episode stopped after ten days.

Until 1991 the resumed activity of the Tessina landslide had always been by means of progressive movements that had never caused a particular risk situation for the villages of Funes and Lamosano. In December 1991, perhaps at the same time as a light seismic shock, significant movements occurred in the eastern sector of the flow area, and in the following April, an area of 40,000 m^2 suddenly collapsed, giving rise to a flow which crossed the Funes-San Martino road at the end of the month (Figure 2). In May a new reactivation affected the same sector and the flow reached an embankment built near the hamlet of Tarcogna (Figure 2). The maximum landslide advancement, which was followed by a decrease in movement, was recorded on 15 June 1992. In July and August 1993 new reactivations took place, which mobilised some 20,000 m^3 of material. After these events, the landslide showed an overall longitudinal extension of more than 2.5 km and a maximum width of some 500 m.

In 1995 the displaced material reached the village of Lamosano for the first time, causing a serious risk. This reactivation started on 21 May with the onset of a flow which moved downstream for 300 m within 10 days. Once again, the flow arose from the eastern sector.

Finally, in September 1998, without any apparent triggering cause, the whole upper accumulation resumed its movement, displacing all the main scarp and giving rise to a landflow which reached the village of Funes in a few days.

GEOLOGICAL SETTING AND MORPHOLOGICAL EVOLUTION

From the geological viewpoint, the slope area affected by the landslide belongs to the northern flank of the asymmetrical brachy-syncline of the Alpago catchment basin; this structure, which developed in Tertiary formations, has an axis showing a slightly curved trend [Mantovani *et al*, 1976]. In its northernmost part, this syncline is also affected by some important NNW-SSE orientated tectonic alignments. In the Alpago valley there are outcrops of formations of a chronostratigraphic sequence spanning the Jurassic to the Quaternary. Only the Mesozoic and pre-Oligocene Cainozoic formations are important as far as the Tessina landslide is concerned, whereas subsequent formations (*ie,* from Oligocene and Miocene) are only marginally affected by the flow's lowermost portion. The calcareous, marly-calcareous and cherty-calcareous formations (Upper Cretaceous-Palaeocene), are mainly organised in layers of variable thickness and are permeable due to fissuring.

The material involved in the slope movement belongs to the Flysch dell'Alpago (Lower Eocene). It is made up of a rhythmic alternation of marlstones, clay shales and calcarenitic layers up to 1 m thick. The overall thickness of the formation ranges between 1000 and 1200 m; it makes up the substratum of the whole landslide area. This formation is particularly permeable due to a high degree of fissuring mainly resulting from tectonic stresses. It dips generally upstream, with overturned strata corresponding to the main scarp and the upper part of the landslide. Further downhill, it dips south, downstream at a low angle (Figure 3). The Quaternary deposits are Pleistocene and Holocene in age and from the foot of the Mt. Teverone slopes there are regular outcrops of variable thicknesses covering the underlying formations. Apart from vast, detritic covers found at the foot of Mt. Teverone, moraines from the Piave glacier and local glaciers are also present. The latter, in the form of glacis, are seen on both sides of the valley.

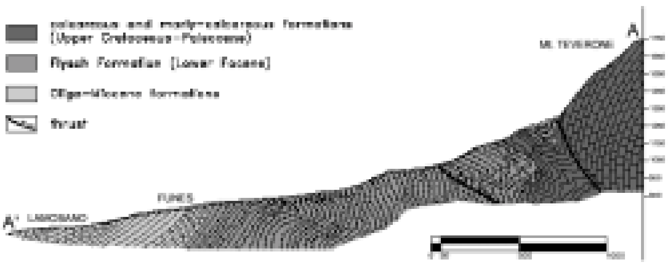

FIGURE 3 Geological cross section of the Tessina landslide (see Figure 2).

The Tessina landslide extends from 1200 m down to 640 m above sea level. It is classified as a complex movement, including a rotational slide and translational slides in its upper part and a flow in its mid-lower part.

Before 1960 the Tessina valley was deeply cut by erosion and flanked by steep slopes. During the 1960s several reactivations occurred, involving about 5 million m^3 of material and filling the Tessina valley with displaced material from 30 m to 50 m thick. These movements seriously endangered the village of Funes, which is situated on a steep ridge, originally quite high above the river bed, but now at nearly the same level as the mud flow (Figure 4). The collapsed sector of the April 1992 event occupies an area of 40,000 m^2, on the eastern side of the Tessina stream, and has an approximate volume of 1 million m^3. The movement corresponds to a rotational slide with a 20 m to 30 m deep failure surface, which also affects the flysch bedrock. Initially it caused the formation of a 15 m high scarp and a 100 m displacement downstream with consequent disarrangement of all the unstable mass and destruction of the drainage systems set up some years earlier. The movement continued, with a velocity of some several tens of centimetres per day, up to June, causing the mobilisation of another 30,000 m^2, with a total volume of about 2 million m^3 of displaced material.

The intensely fractured and dismembered material from this area was channelled along the river bed where, owing to the continuous remoulding and increasing water content, it became more and more fluidised, thus giving rise to small earth flows converging into the main flow body. After these events the villages of Funes and Lamosano were evacuated. The landslide is still in progress and this has led to a constant widening of the source area: from the original 300,000 m^2 it is now about 500,000 m^2. The total displaced volume has been assessed at about 7 million m^3.

FIGURE 4 The mud flow in the Lower Accumulation Zone just north of the village of Funes.

The velocity of the movement varies considerably according to the episodes and sections considered. The maximum velocities attained were recorded uphill of Lamosano in May 1992, with displacements of 70 to 100 m/day along the main flow. In the same period, in the proximity of Funes, velocities of about 25 to 30 m/day were recorded.

INSTRUMENTATION

The particular evolution and typological features of the slide, the expansion of the area involved, the extent of the flow movement, and the intense dislocation of the slide made it necessary to plan a series of innovative solutions for the installation of an automatic alarm and monitoring system that could guarantee a sufficient level of safety for the population.

The system (Figure 2) consists of an arrangement of sensors and measuring instruments which transmit their signals to a central station from peripheral receiver units. The station is installed in a building in Lamosano and it receives information concerning changes and movements of the mud flow and of the upper section of the slide. It processes the data, gives a visual layout of the situation on a peripheral unit installed at the Belluno Fire Station and transmits an alarm signal to suitably located stations if a dangerous situation should develop.

Two multiple-base wire extensometer units, measuring 280 m and 390 m, were installed in the upper section of the landslide in order to maintain a constant check on the movement at the surface. These units are fitted with an appropriate scaling system, and consist of a series of 12 purpose-built meters, capable of detecting movements as small as one millimetre.

On the upper landslide section, an electronic distance measurement system (EDM) with an automatic landmark detector for measuring surface movements was also installed. Every 6 hours it monitors a network of more than 20 bench marks, assessing their displacements with respect to previous readings. The data are recorded and sent to the control centre in the town hall of Chies d'Alpago in Lamosano. Two alarm units, one comprising three directional bars and an ultrasonic echometer, the other with two directional bars and an echometer, were installed on the body of the mud flow, upstream of the villages of Funes and Lamosano. Three video cameras were also installed to record and monitor the slide movement in the areas considered as the most critical, *ie,* the upper accumulation zone and the two areas uphill of Funes and Lamosano.

The control centre receives data from the peripheral stations and also defines possible hazard situations. It sends the data and signals via modem to an alarm station located at the Belluno Fire Station. This station has an integrated image acquisition and recording system that allows direct visual observation of the upper landslide section.

The peripheral units receive the data from the various instruments (*ie,* echometer, directional bars, extensometer), perform preliminary processing and verify their effectiveness. In the event of a critical development, various alarm levels can be determined (Pre-alarm, Normal Alarm, Serious Alarm), with an indication of the peripheral units and sensors directly involved. It is also possible to have access to the data in real time mode by connecting each peripheral device and checking the instrumentation. Daily, weekly or monthly trends in the data of each sensor are provided by means of special programs.

DATA COLLECTION

The monitoring system installed on the Tessina landslide provides the data necessary to prepare a suitable Civil Defence programme, which would include evacuation from the residential areas in case of danger. The stored data may further be used to analyse long-term trends in the behaviour of the landslide as a whole and, in particular, provide basic data for testing model simulations of its development [Avolio *et al*, 2000].

DISPLACEMENT DATA

At present, the most reliable deformation data are provided by the EDM network in the upper accumulation zone. During 1998 the displacements of 25 bench marks were monitored; most were located in the eastern sector of the detachment area. Measurements were taken at intervals of 2 to 6 hours, depending on the state of landslide activity.

From the kinematic viewpoint, the area was subdivided into three sectors with different rates of movement. Figure 5 summarises the annual displacements obtained at the head of the landslide in 1998. Near the detachment zone and southeastern scarp, the rates of movement have ranged between centimetres and decimetres. Within the basin of the upper accumulation zone, however, total displacements have exceeded tens of metres. Much of this displacement occurred in September 1998

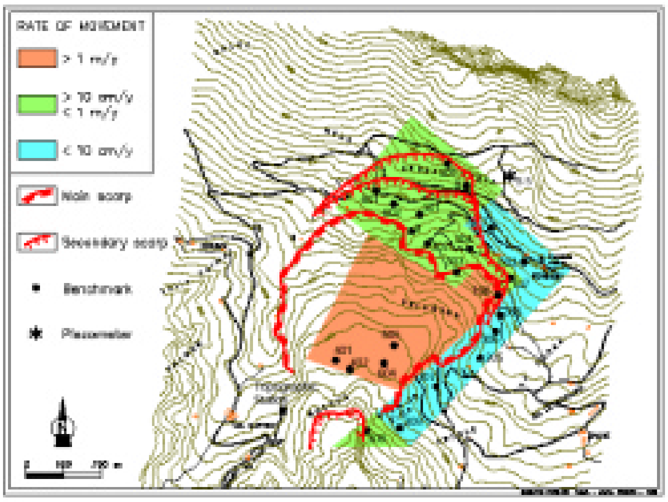

FIGURE 5 Zoning of the source area by means of benchmarks displacement occurred in 1998. The different colours represent areas of comparable rates of movement. The main morphological features are shown.

and intensive monitoring is now continuing in case a new episode of major reactivation should be imminent.

For each of the three sectors identified, the trends of the recorded cumulative displacements for the most representative bench marks, are shown in Figure 6; colours refer to the subdivision based on the different rates of movement shown in Figure 5. The EDM network was reinforced by integration into a new satellite-based (GPS) information network. The present aims are to extend the integrated network and assess the reliability of the real time GPS monitoring capability.

PIEZOMETRIC DATA

Observations carried out since 1960 suggest that sustained periods of intense rainfall and/or melting snow may be an important trigger for major reactivations of the Tessina landslide. Reactivation normally begins in the upper accumulation zone, following renewed collapse in the detachment zone, and propagates down the slope. In

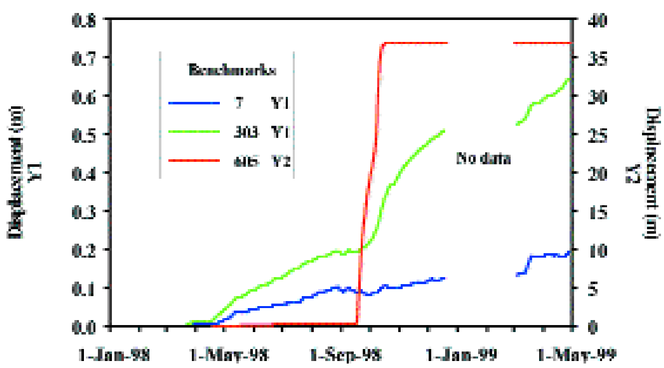

FIGURE 6 Trend of displacements recorded in the source area. The three benchmarks represent the different coloured areas shown in Figure 5. The period with no data is due to yearly maintenance of the EDM (electronic distance measurement) system.

order to quantify any link between rainfall intensity and duration, variation in groundwater level, and rates of landslide reactivation, a meteorological station was installed in 1992 and piezometer S5 has been equipped for the continuous measuring of the water table since 1997. This piezometer, considering its position within the source area, is believed to be the most significant for investigating these correlations.
As a result, since 1998, it has been possible to compare piezometric and meteorological data with variations in rates of movement across the EDM network in the upper accumulation zone. To mediate the triggering effect of rainfall, a drainage tunnel was dug through the Cretaceous calcareous units in 1995-96.

Figure 7 shows the relations between pluviometric inflows (A), changes of the water table recorded by piezometer S5 (B) and the rate of discharge in the drainage tunnel (C).

DISCUSSION

Analyses on the displacement data have pinpointed that, between April and September 1998, rates of displacement around the detachment zone and upper accumulation zone remained almost constant on a weekly timescale, at about 7 x 10^{-3} m per week and at half that rate around the southeastern scarp (Figure 6). In mid-September, however, the movement of all the basin material rapidly accelerated up to 10 m per week in the upper accumulation zone and remained constant for about ten days. This rapid movement declined in early October, and afterwards it continued with a constant velocity until March 1999.

Firstly, the analysis of the displacement data has allowed a different deformational style to be pinpointed in the 1992-98 period, as well as during the displacements which have occurred since the second half of 1998. In fact, since mid-1998, a slow but continuous movement of the whole unstable area has taken place (detachment zone, southeastern scarp and upper accumulation zone), whereas in the preceding years the movement mainly affected the eastern sector of the detachment zone. The upper accumulation zone partially resumed its movement due to the overload resulting from the flows coming from the main scarp.

In September 1998 the whole unstable area resumed movement, including the upper accumulation zone; this was confirmed not only by topographic measurements but also by the appearance of a continuous fracture at the foot of the main scarp (see Figure 5). These movements, which at some points exceeded 10 m per week, caused the collapse of the frontal part of the accumulation zone and the retreat of the crown by some tens of

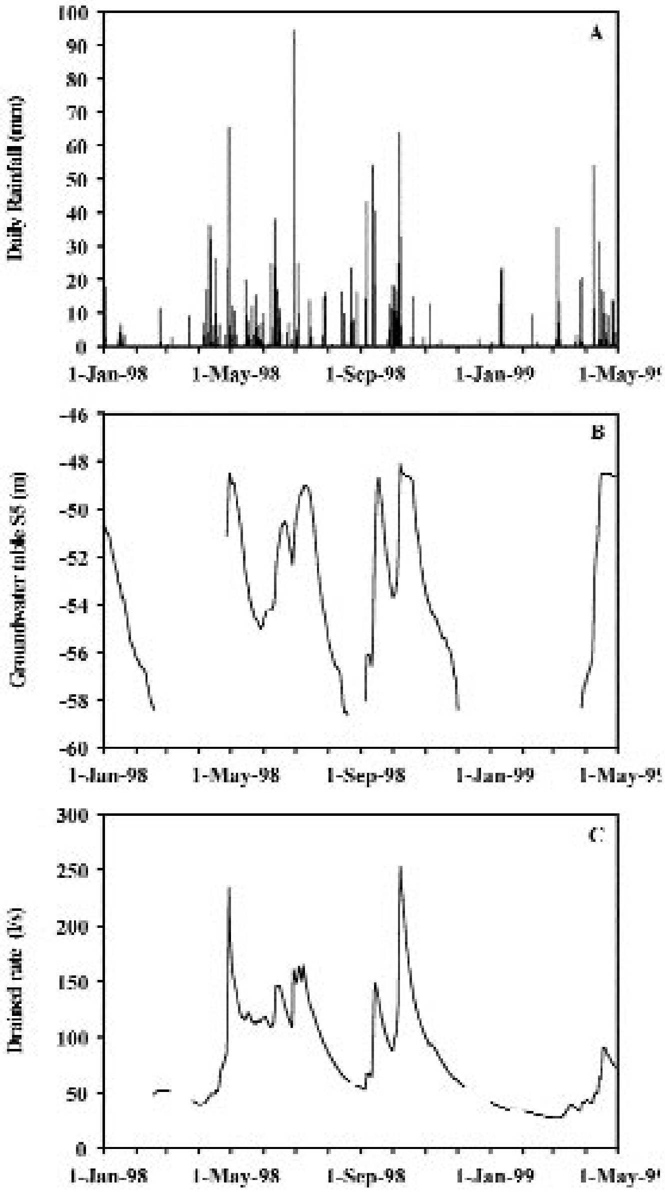

FIGURE 7 Daily rainfall, groundwater level variations at the S5 piezometer, and rate of discharge from the drainage tunnel. During the winter, precipitation corresponds to the water equivalent of snow.

metres, with a consequent worsening of the stability conditions over the whole area. It is therefore interesting to analyse in more detail the trend of the maximum displacements recorded at the points on the upper accumulation which eventually led to the collapse of the frontal portion. Figure 8 shows the displacements recorded at point 605 and the peaks relative to the beginning and cessation of major movements. In particular, the records show a velocity increase about two days before the main event; if this is also confirmed by subsequent reactivations, this fact would allow further critical situations to be forecast and adequate measures to be taken to safeguard Funes and Lamosano.

The overall trends suggest that, during the first half of 1998, the background state in the detachment zone, upper accumulation zone and side scarp was a near-steady, but very slow deformation. At least until the end of August 1998, this was quite independent of changes in rainfall and groundwater level, whereas in September, a massive increase of the deformation rate began corresponding with a piezometric peak. It therefore seems that there is a constant decline of the shear strength inside the unstable slope; this trend might also be subject to sudden accelerations corresponding with piezometric peaks even if they are not particularly high. The difference in behaviour may be ascribed to an inward migration of the groundwater effect.

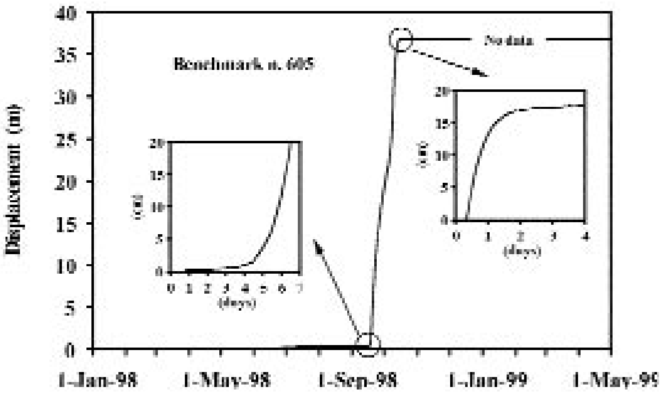

FIGURE 8 Displacements of benchmark no. 605. Separated graphs show rapid acceleration and decrease of movement.

An alternative view is that the detachment and upper accumulation zones should be considered as a single unit undergoing a constant average rate of displacement, but focusing deformation at different locations in time. If this is the case, the implication is that the whole scarp area is moving at a rate controlled by a larger-scale, underlying process, such as a movement along a deep-seated failure plane, as confirmed by morphological evidence and by the rupture of several piezometric wells at a depth of –30 m to -60 m.

If we consider the period from April 1998 to May 1999, it is possible to identify a certain correlation between rainfall and groundwater table changes, although piezometric peaks have not always triggered significant accelerations of movement even with continuous displacement. On the other hand, the critical event of September 1998 may also be correlated with a sudden increase of the water table, even though the extent of the rise was not among the highest recorded during the observation period. Finally, there is a correlation between rainfall and water table changes, although these fluctuations do not always give rise to significant reactivations. At present, it is not possible to define critical pluviometric thresholds for the triggering of movement.

As Figure 7 shows, daily rates of rainfall or peak intensities are not always directly correlated to the onset of major movements. In particular, the rapid September 1998 movement occurring in this basin was triggered at least 10 days before the intense rainfall of late September and early October. Therefore, if precipitation was involved, it can only have been an additional factor, with the material in the landslide already in a critical state. One possibility is that the amount of accumulated groundwater must exceed some threshold value to induce a major movement. In this case, rainfall might have established near-critical conditions that were superseded only after the rains of early September. As an initial test of this hypothesis, a variation in groundwater level recorded at S5 can be studied. It shows an increase to a maximum groundwater level several days before reactivation occurred in September. An obvious inference is that the reactivation may have been triggered by water saturation and associated increases in pore pressure. If so, then station S5 may yield a quantitative groundwater level above which reactivation is imminent, thereby providing a reliable warning days before a major movement begins. However, the reactivation of March 1999 does not seem to be related to particular rainfall or water table conditions.

Analysis of the data relating to precipitation, flow rate of the draining tunnels, and water table levels has allowed confirmation of some specific hydrogeological aspects of the area collected from the geomorphological study and during the excavation of the tunnel. Indeed, the delays between the beginning of precipitation and the increase of the tunnel flow rates and the water table, which have been assessed at about 3 and 6 hours, respectively, are typical of rock masses whose permeability is due to fracturing. The water circulating within Mt. Teverone is thus quickly connected with the aquifer in the unstable area through the important tectonic discontinuities found at the base of this calcareous massif. It therefore seems that the numerous springs found along the main scarp and the upper accumulation zone are fed by deep-water circuits resulting from significant tectonic discontinuities.

FINAL REMARKS

The instrumentation installed since 1992 and the geological and geomorphological studies carried out in the area have allowed the evolution of the Tessina landslide to be constantly monitored in the past few years. Forecasting models have been developed and future scenarios hypothesised in order to better define the possible risk conditions for the population, the villages and the transportation infrastructure.

A comparison between the data recorded in 1998 and those obtained from measurements carried out earlier shows a marked and worrying change in the evolution of the slope movement. In fact, up to the 1992-98 period, the movements had affected only the easternmost part of the detachment zone, giving rise to mud flows which overloaded the upper accumulation zone, causing its collapse. Since September 1998, there has been a complete and simultaneous remobilisation of the whole unstable area (detachment zone, upper accumulation zone, south-eastern scarp). From April to September 1998, all the topographic bench marks were moving with more or less the same velocity. This caused the frontal part of the upper accumulation zone to collapse and the consequent sudden activation of all the unstable area, with displacement velocities exceeding 10 m a month.

In 1998 there was also a widening of the unstable area, which increased from about 350,000 m^2 to over 500,000 m^2 (Table 1) within a few months, representing an estimated volume of over 7 million m^3 of unstable material. In this regard, based on recorded displacements, geomorphological investigations, and interpretation of aerial photographs, it has been possible to determine potential enlargements of the source area (Figure 9).

Lately, an increasingly rapid withdrawal of the boundary of the upper accumulation zone has taken place; this will probably imply, in the near future, a worrying increase of slope angles in the source area (detachment zone) and therefore a more paroxistic evolution (in a negative sense) of the landslide, both in terms of velocity and the rock masses mobilised.

The widening and simultaneous mobilisation of the whole unstable area and the continuous withdrawal of the scarp are therefore causing ever increasing risk conditions for the villages, particularly for Funes. Since the valley has been filled by the series of flows since 1960, Funes could now easily be flooded by new flow material. A mathematical model for this purpose was calibrated on the 1992 event [Avolio *et al*, 2000], and has shown that if just 1 million m^3 of material were mobilised, the flow would stretch as far as the villages of Funes and Lamosano, affecting several houses.

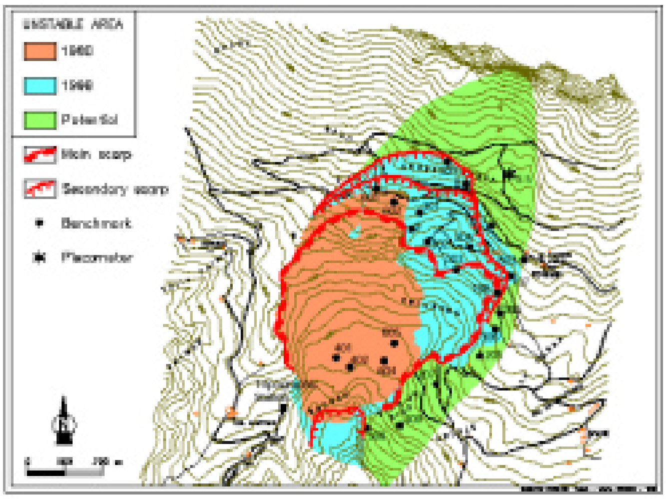

FIGURE 9 The progressive enlargement of the area involved in the landslide and its possible future development (see Table 1). rease of movement.

It is therefore obvious that any intervention programmes for risk mitigation will have to the possible landslide evolution take into account, and not be limited to stabilising the movement and containing its effects. Such interventions can hardly guarantee a sufficient degree of safety and constraints on the use of the region will therefore have to be introduced, including the planning of evacuation and transfer measures for the villages.

ACKNOWLEDGEMENTS

This research is partially funded by the European Commission (DG Research, Environment and Climate Programme, Natural Risks: A. Ghazi, Head of Unit, Maria Yeroyanni, Scientific Officer). The authors are indebted to Regione Veneto for the hydrological data.

REFERENCES

Avolio, M.V., S. Di Gregorio, F. Mantovani, A Pasuto, R. Rongo, S. Silvano, & W. Spataro, 2000. Simulation of the 1992 Tessina landslide by a cellular atomata model and future hazard scenarios. JAG 2: {DTP, INCLUDE PAGE NUMBERS HERE}.

Angeli, M-G., P. Gasparetto, R.M. Menotti, A. Pasuto, & S. Silvano, 1994. A system of monitoring and warning in a complex landslide in Northeastern Italy. Landslide News 8: 12-15.

Mantovani, F., M. Panizza, E. Semenza, & S. Piacente, 1976. L'Alpago (Prealpi Bellunesi). Geologia, geomorfologia e nivopluviometria. Boll. Soc. Geol. It. 95: 1589-1656.

Pasuto, A., S. Silvano, & G.P. Bozzo, 1992. The Tessina landslide (Belluno, Italy). In: M. Panizza, M. Soldati & D. Barani (eds.), Proceedings of First European Intensive Course on Applied Geomorphology. Istituto di Geologia, Università degli Studi di Modena, Italy.

RÉSUMÉ

Des recherches ont été effectuées dans le cadre du projet RUNOUT pour définir des scénarios de risques futurs du glissement de terrain de Tessina et de déterminer si le glissement peut être attribué à des facteurs hydrogéologiques ou à des structures/discontinuités tectoniques profondes. Le travail consiste principalement à cartographier la géologie et la géomorphologie, en saisissant des données météorologiques, hydrologiques et cinématiques et modéliser ces données. Nous décrivons le système de contrôle installé sur le glissement de terrain de Tessina et les analyses des données acquises depuis le lancement de RUNOUT, un projet financé par la CE. Notre principal objectif était de soutenir le groupe effectuant la modélisation en fournissant des observations des principaux paramètres, tels que déplacements, variations du niveau de la nappe phréatique, précipitations, etc., pour améliorer les modèles utilisés pour simuler la tenue du glissement de terrain et prédire les scénarios de risques pour les villages. Nous discutons la phase critique de septembre-octobre 1998 et proposons une évolution géomorphologique possible du glissement de terrain dans le futur basée sur l'analyse de ces données. Le deuxième objectif était de concentrer le contrôle sur un système d'alarme pour la sécurité de la population menacée par le glissement de terrain.

RESUMEN

Se han hecho investigaciones dentro del marco del proyecto RUNOUT para definir futuros escenarios de riesgo del corrimiento de tierras de Tessina y para determinar si el corrimiento puede estar relacionado con factores hidrogeológicos o con estructuras o discontinuidades tectónicas profundas. El trabajo consistió fundamentalmente en el trazado de mapas geológicos y geomorfólogicos, recogida de datos meteorológicos, hidrológicos y cinemáticos y modelización de datos. Describimos el sistema de monitorización instalado en el corrimiento de tierras de Tessina y los análisis de los datos adquiridos desde el inicio de RUNOUT, un proyecto financiado por la CE. Nuestro principal objetivo era apoyar al grupo que realizaba la modelización proporcionando medidas de los parámetros principales, tales como desplazamientos, variaciones de nivel de las aguas subterráneas, precipitaciones, etc., para mejorar los modelos utilizados para simular el comportamiento del corrimiento de tierras y pronosticar los escenarios de riesgo para los pueblos. Estudiamos la fase crítica de septiembre a octubre de 1998 y proponemos una posible evolución geomorfológica en el futuro del corrimiento de tierras basándonos en el análisis de estos datos. El segundo objetivo fue centrar la vigilancia en el mantenimiento de un sistema de alarma para la seguridad de la población amenazada por el corrimiento de tierras.