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Lessons Learnt from Landslide Disasters in Europe

Edited by
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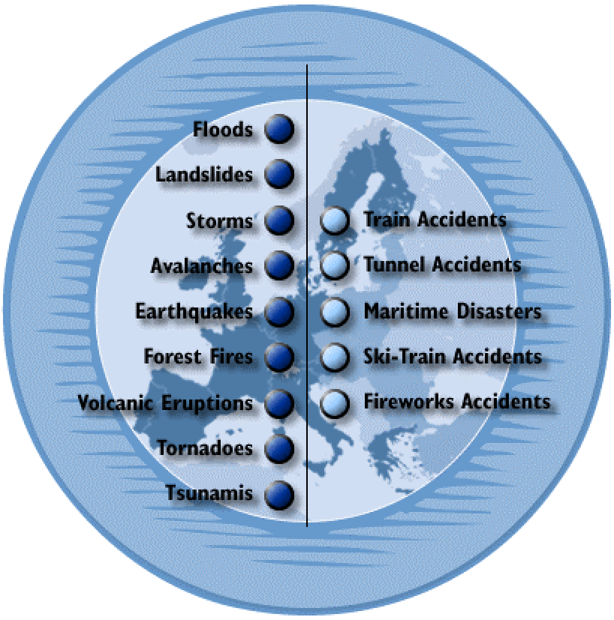

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Abstract

Landslides are a widespread hazard in many mountainous and hilly regions of Europe. They cause significant economic losses as well as human victims. The socio-economic impact of landslides is however difficult to quantify at European scale, mainly because it is usually not considered separately when landslides acompany other natural hazards such as floods or earthquakes. This fact often decreases both authorities' and people's awareness of landslide risk.

In order to get a better understanding of landslide disaster management practices in Europe, the NEDIES Project (Natural and Environmental Disaster Information Exchange System) of the European Commission's Joint Research Centre (JRC) organised a workshop on 14-15 March 2002 at Ispra, Italy. Representatives from civil protection services from various EU Member States and Accession Countries contributed to the workshop and to subsequent discussions with information on lessons learnt from a number of landslide disasters recently occurred in their countries. In some cases, an overview of the overall situation or of specific aspects of landslide management in some countries was provided.

This report thus describes some recent catastrophic landslides in Europe, their causes and consequences. It especially discusses lessons learnt from the prevention and preparedness measures adopted, the response actions carried out, the dissemination of information to the public and the socio-economic implications in connection with the portrayed disasters.

Contents

1. Introduction

Every year in Europe landslides cause disasters resulting in fatalities, injuries, destruction to houses, infrastructures and property, as well as loss of productive land. The spreading of urban settlements and transportation networks into landslide-prone hilly areas is increasing the potential impact of landslides. Destructive landslides are triggered not only by prolonged or heavy rainfall but also by other natural hazards such as earthquakes, flooding and volcanic eruptions, as well as by construction and other human activities, or by any combination of these factors.

Landslides are responsible for significantly higher economic losses and casualties than is generally recognised; when landslides are associated to other major natural disasters their effects are often overlooked by the media. This decreases authorities and people's awareness of landslide risk.

In addition to the above-mentioned effects, landslides can cause technological disasters in industrial or developed areas and hence pollution. In coastal zones and volcanic islands they can trigger other natural hazards like tsunamis. Most frequently, landslide related damage is directly caused by the mass movement itself. However, in Europe there are well documented examples of devastating flash floods caused by the collapse of natural dams created by large landslides in narrow river valleys, or by high waves in artificial reservoirs because of landslide impact or by sliding and collapse of mine waste dams.

In this report, lessons learnt from landslide disasters recently occurred in EU Member States and Accession Countries are discussed with the aim to exchange information and experiences that can help to cope with future landslides. This is done within the framework of the NEDIES project (Natural Disaster Information Exchange System), carried out at the Institute for the Protection and Security of the Citizen (IPSC) of the European Commission's Joint Research Centre (JRC). The report is primarily based on the contributions presented by representatives from national or regional civil protection services at the NEDIES expert meeting held at the JRC in Ispra, Italy, on 14 and 15 March 2002, and on subsequent discussions with them.

This report mainly presents the prevention and preparedness measures adopted, the response actions undertaken and the dissemination of the information to the public in connection with these disasters, as well as the lessons learnt derived from the various disaster management phases. It also provides an overview of the events, their causes and consequences, including in some cases their socio-economic impact. Part I of the report portrays lessons learnt from landslide disasters that occurred in recent years in Italy, Slovenia, Portugal, Sweden, Romania and Lithuania. In Part II, other experiences and policies related to landslide disaster management in France, Bulgaria and Sweden are discussed. Both are listed in the Contents section. Lastly, some conclusions are drawn. To assist the non-expert reader, an annex is provided, which contains a selected classification of landslides together with some important definitions and concepts.

It should be noted that the term landslide is used in this report in a generic sense, unless specified, to refer to gravitational mass movements ranging from slides, flows and spreads to rockfalls, topples and rock avalanches.

This report mainly addresses the European Commission Services and Civil Protection authorities and personnel of the EU Member States and Accession Countries. It also addresses scientists and engineers involved in natural and environmental disaster prevention and mitigation. The report is available on-line on the NEDIES Project website (http://nedies.jrc.it/doc/Landslides_Final.pdf).

PART I

Lessons Learnt from Specific Landslide Disasters

2. The 5-6 May 1998 mudflows in Campania, Italy

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2.1 Description of the event and consequences

On 5 and 6 May 1998 a large number of mudflows occurred in the area of Pizzo d'Alvano, in the Southern Apennines (Campania Region, Italy), to which the Sarno ridge belongs (Fig. 2.1). At the start of May 1998, intense and long-lasting rainfalls triggered about 150 mudflows in 10 hours between 14.00 and 24.00 hrs on 5 May (Fig. 2.2). These mudflows affected an area of approximately 75 km^2 (Dipartimento della Protezione Civile, 1998). Their speed reached 50 km/h at the exit of the Sarno ridge gullies. Maximum discharges were about several hundred m^3/s and the total volume of the mudflows reached several thousand cubic metres. The event caused severe damages, therefore the intervention of the National Department of Civil Protection (*Dipartimento della Protezione Civile*) was required.

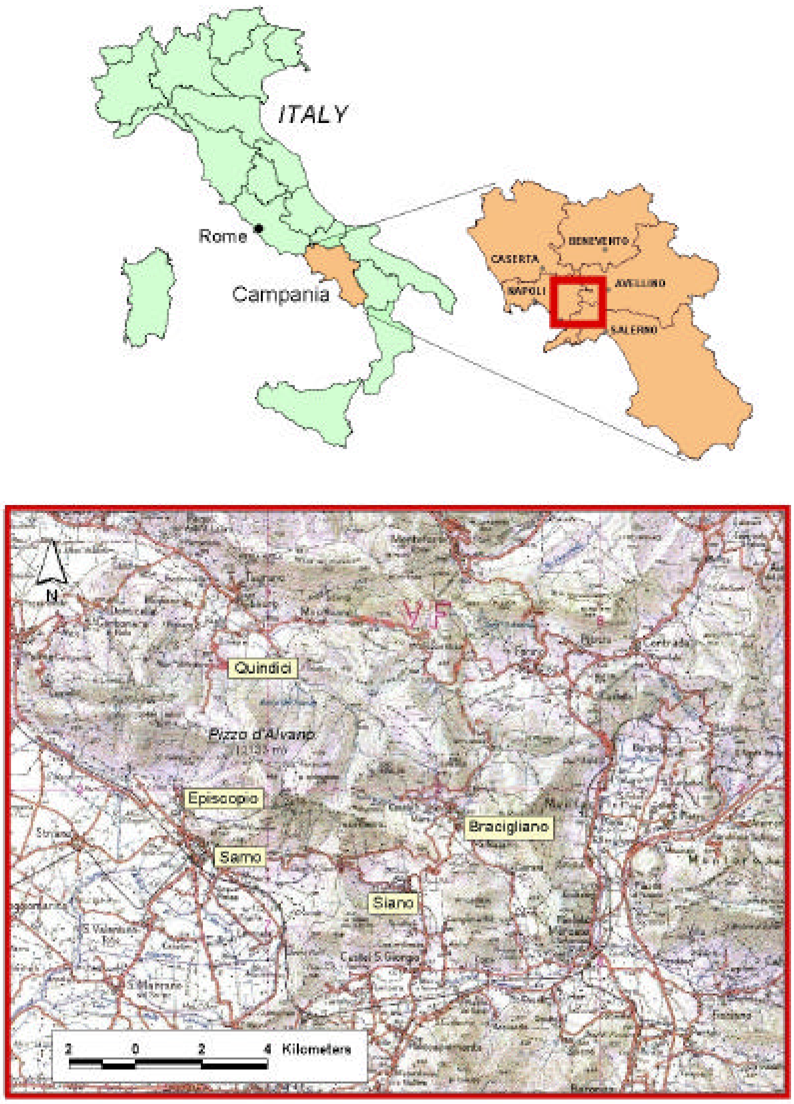

Figure 2.1 Location of the Sarno ridge area

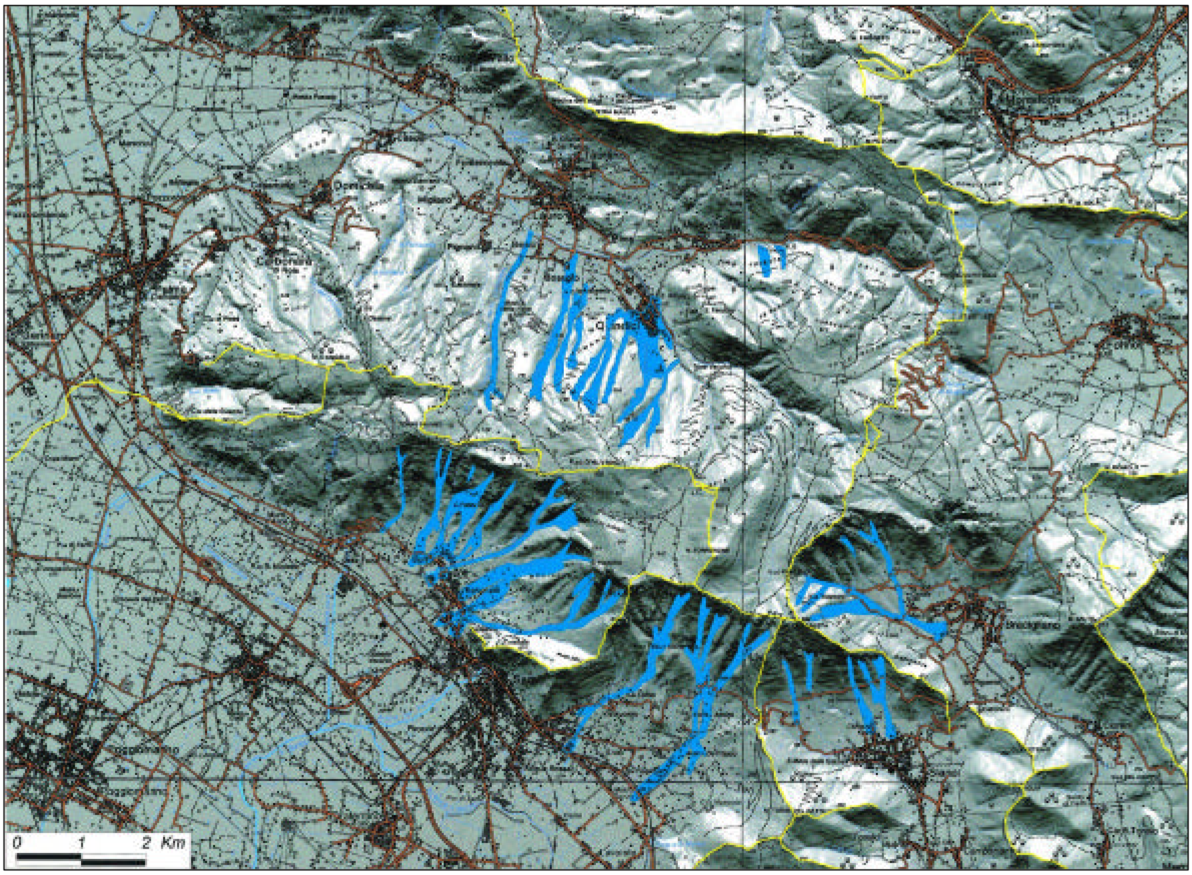

Figure 2.2 Map of volcanoclastic mudflows of Sarno – Quindici of 5 May 1998 (in blue) (Pareschi *et al.*, 2000)

In this area, mudflows were well known in the past but today they still represent a serious hazard. They originate from the detachment and fluidification of a pyroclastic layer, which was a few metres thick. This layer was deposited during the eruptions of “Phlegraean Fields” caldera (Rosi *et al.*, 1999) and Somma-Vesuvio volcanic system; thus it lays on a paleo-morphologic limestone bedrock, which is often characterised by very steep slopes. The total saturation of the pyroclastic layer due to continuous heavy rainfalls and seepage pressure, perhaps caused by the underlying carbonatic aquifer, reduced the stability of the layer, triggering mudflows.

The Sarno ridge trends NW attaining heights of 874 m a.s.l. at Torre Savaio and 1,133 m a.s.l. at Pizzo d’Alvano. The mudflows occurred on the SW, SE and NE slopes of the ridge, affecting the municipalities of Sarno e Siano, and Bracigliano e Quindici. The detachments of the highest pyroclastic-strata mudflows occurred at altitudes of 900 and 600 m a.s.l., while the flows hit urbanised areas between 250 m a.s.l. at Quindici and 30 m a.s.l. at Sarno.

The most devastating mudflows, which came down the Sarno slope, covered a distance of over 3 km. At the head of the mudflows, slopes angles varied from 35° to over 45°, while the mudflows came to rest on slopes varying from 12° to 15° on the piedmont fans. The approximate dimension of the detachment zones varied from tens to hundreds of square metres. Deep gullies, 20–30 m wide at the top, 6–10 m wide at the base and 30–40 m deep, incise the piedmont fans. The mudflows reached a thickness of 6–8 m near the buildings that obstructed the flow (Campagnoni *et al.*, 1998; Fig. 2.3).

Figure 2.3 Area impacted by the mudflow in Sarno (Centro Documentazione, VV.F. Napoli).

Human consequences

The event caused 160 fatalities; 115 people were injured and 1210 became homeless. The number of residents and fatalities for each municipality is given in Table 2.1 (Dipartimento della Protezione Civile, 2001; ISTAT, 1991).

Table 2.1 Residents and fatalities of the affected municipalities

Municipality	Residents	Fatalities
Sarno (SA)	31,509	137
Siano (SA)	9,265	5
Bracigliano (SA)	5,105	6
Quindici (AV)	3,023	11
S. Felice a Cancello (CE)	16,771	1
TOTAL	65,673	160

48 hours after the event, the Operations Centre of the Department of Civil Protection (*Centro Situazioni*, Ce.Si.) in Rome released the data in Table 2.2 (Dipartimento della Protezione Civile, 1998).

Table 2.2 Fatalities, missing and displaced people 48 hours after the event

Municipality	Fatalities	Missing	Displaced
Sarno (SA)	38	89	436
Siano (SA)	5	0	500
Bracigliano (SA)	5	1	70
Quindici (AV)	5	8	120
S. Felice a Cancello (CE)	1	0	84
TOTAL	54	98	1,210

The highest number of missing people, reported 72 hours after the event, was 208. Only on 9 May the Ce.Si. knew exactly that there were 115 injured. As a precaution, 400 persons were evacuated from the neighbouring Municipality of Lauro and other 55 from the Municipality of Taurano in the Province of Avellino.

Economic losses

The event caused heavy damages to public and private buildings (Dipartimento della Protezione Civile, 2001; Fig. 2.4), as shown in Table 2.3, and infrastructures; furthermore, they visibly changed the local landscape.

Figure 2.4 Excavators in action during the response phase in Sarno. In the lower picture, the grey bend on the white building, which marks the maximum level reached by the mudflow can be observed (Centro Documentazione, VV.F. Napoli).

Table 2.3 Assessment of damages to public and private buildings

Municipality	Destroyed buildings	Inaccessible	Partially accessible	Accessible
Bracigliano (SA)	2	7	2	2
Quindici (AV)	19	154	46	105
S. Felice a Cancello (CE)	2	7	2	2
Sarno (SA)	126	195	66	549
Siano (SA)	5	34	10	170
TOTAL	154	397	126	828

According to the data collected by the surveyors (Dipartimento della Protezione Civile, 2001), the overall assessment of the damaged houses amounted to approximately € 25.56 million, while that to the production sector amounted to approximately € 8.52 million, including damages to buildings, machinery and stocks (Table 2.4).

Table 2.4 Distribution of damages among the 5 municipalities affected

Municipality	Damage to houses (million €)	Damages to the production sector (million €)
Bracigliano (SA)	0.28	0.17
Quindici (AV)	3.41	0.41
S. Felice a Cancello (CE)	0.28	1.31
Sarno (SA)	19.32	6.40
Siano (SA)	2.27	0.23
TOTAL	25.56	8.52

2.2 Prevention measures and related lessons learnt

Neither monitoring instruments, such as rain gauges, piezometers or water-level staffs, nor a local meteorological service existed in the area; hence, no forecast for mudflows and hazard assessment had ever been made. In addition, the area is characterised by uncontrolled, rapidly increasing urbanisation as a result of the high demographic growth in the past decades.

The Veglia–Meteo Office of the Civil Protection Department issued a 72-hour-range weather forecast at synoptic scale every day. These forecasts did show only strong winds in the area, but no intense rainfall.

Mudflows were known in the area since the past 200 years. To mitigate such events, canals (the Regi Lagni) were built from the Bourbon times onward. These canals worked as flood retention barriers to divert surface waters away from urban areas. The canals lacked however maintenance; thus in the event’s day they were an insufficient barrier against mudflows.

Lessons learnt

- The hazard from mudflows was known, therefore the areas at risk could have been defined well before the event had happened.

- The lack of a hazard zoning map of the area subject to mudflows (and to other hydrogeological disastrous events) and the lack of an adequate urban planning allowed wild urbanisation without any control.
- Synoptic-scale weather forecasts were insufficient to identify the rainstorms that struck the area. Real-time critical weather conditions could have been predicted with efficient radar devices and the correct interpretation of satellite imagery.
- Rainfall data records together with the data of past mudflow events would have helped to define rainfall thresholds. These thresholds would have allowed the definition of three alert levels (attention, warning and alarm). Italy's Civil Protection refers to these very levels to face disaster intervention activities and to plan any preventive evacuation scheme (Dipartimento della Protezione Civile, 1998).

2.3 Preparedness measures and related lessons learnt

During the event, there was no emergency plan to face mudflows. This inhibited any preliminary step to carry out any proper Civil Protection intervention.

As a consequence, only few months after the event the Department of Civil Protection, the Prefectures (i.e. the Provincial Office of the Italian Government responsible for the implementation of civil protection interventions during the emergency), the National Fire Brigade and the five municipalities affected developed and implemented a common emergency plan against mudflow risk for the whole area. This plan is now regularly updated.

Lessons learnt

- Over the last few years emergency plans have substantially improved the efficiency of the Civil Protection service. Emergency planning is essential also in those places where monitoring systems lack and where no step has been taken to implement prevention measures.

2.4 Response actions and related lessons learnt

Few hours after the beginning of the event, the Prefectures of Caserta, Salerno and Avellino set up their Relief Management Centres (*Centro Coordinamento Soccorsi*, C.C.S.: operations centre for the management of the interventions at provincial level). Because of the seriousness of the event, the Ministry of the Interior immediately mobilised the Fire Brigades of the whole Campania Region and alerted the Regional Rescue Convoys of the other Italian Regions. Such convoys consist of fire brigade vehicles that carry the materials necessary for emergency assistance (e.g. tents, field kitchens, beds and food) and special equipment (e.g. bulldozers) for first relief At the same time, the Department of Civil Protection mobilised the Volunteers Associations of the Campania Region, who had already arrived in the disaster zone on the evening of 5 May together with the Italian Red Cross (*Croce Rossa Italiana*, C.R.I.) and the Italian Army.

During the nights of 5 and 6 May various helicopters, equipped for night flight, rescued many people in difficulty. Immediate actions included first aid to injured people, recovery of dead bodies and general logistic and psychological assistance to survivors.

Simultaneously, actions were taken to restore lifelines and viability, to demolish unsafe buildings, to remove rubble and mud, to provide veterinary assistance, to monitor further mudflow activity, to assess damages and to provide police patrolling of the territory.

Immediately afterwards, the Interlocal Operations Centres (*Centro Operativo Misto*, C.O.M.), of Sarno, Siano and Quindici and the Local Operations Centres (*Centro Operativo Comunale*, C.O.C.) of Bracigliano and S. Felice a Cancello were operative so to ensure better co-ordination of activities. The C.O.M. is the operations centre responsible for emergency actions carried out by different operational bodies, in a territory with several municipalities; this structure supports the activities of the mayors. The C.O.C. is the operations centre that coordinates the emergency activities in the municipal territory; it is run by the Mayor.

Each C.O.M. was organised as support functions (e.g. technical and scientific support, health assistance, volunteerism, materials and resources, transport and traffic circulation, telecommunications, life line and population logistics). Each function had a responsible, chosen among the officers of Public Authorities, expert in civil protection. The C.O.M. supported mayors to co-ordinate local relief. These centres monitored the mudflow hazard evolution in order to guarantee people safety.

48 hours after the beginning of the event, the Ce.Si. reported 2,970 men and 192 vehicles (cars, buses, water-scooping machines, excavators, dog units, ambulances, helicopters and breakdown lorries) operating in that area. The highest number was registered on 22 May: 5,043 men and 1,470 means, as listed in Table 2.5 (Dipartimento della Protezione Civile, 1998; Fig. 2.5).

Figure 2.5 Operational bodies at work in Sarno (Centro Documentazione, VV.F. Napoli)

Table 2.5 Operational bodies, men and means involved in the response action

Operational Bodies	7 May 1998 20.00 hrs		22 May 1998 8.00 hrs	
	Men	Means	Men	Means
Firemen	1,000	53	1,139	638
Volunteers	600	6	1,039	211
Army	466	60	1,611	229
Police Forces	746	39	890	309
National Forest Corps	108	20	40	13
Italian Red Cross	50	14	300	47
National Roads Department (ANAS)	0	0	24	23
TOTAL	2,970	192	5,043	1,470

Rescue activities lasted 10 days. Evacuated people generally found accommodation in relatives' houses or in elementary schools turned into reception centres. People returned to their undamaged houses a month after the event.

Sarno emergency management

As reported by Golizia (1998), after evaluating the seriousness of the event the C.C.S. of Salerno established a C.O.M. in the Municipality of Sarno to manage local relief interventions. The immediate measures adopted by the head of the C.O.M. were:

- The decision to place C.O.M. in a strategic position for viability (the premises of Sarno market).
- The identification of a 6.5-ha area near the C.O.M. to organise a base camp to gather rescuers and resources, and the provision of an area for helicopters landing.
- The installation of emergency telephone lines.
- The activation of all bodies participating in civil protection activities.

In addition to the relief management, the C.O.M. carried out the following activities:

- The census of disable and needy people.
- The organisation of an "Advanced Centre of Operations" in Episcopio, the most damaged and densely populated quarter of Sarno. The centre was run by civil protection operational bodies (Firemen, Red Cross, Army, Police Forces and Volunteers Organisations), who used their resources.
- The implementation of the project "Surveillance Service – organisation of Mobile Technical Units" (*Unità Tecniche Mobili*, U.T.M.) for the direct control of the areas at risk during heavy storms. This project aimed to organise the U.T.M., the drafting of a detailed 1:2,000 scale map of the areas at risk (Geri and Ciancio, 1999) and to define the U.T.M. operative procedures within the alert levels as described in the evacuation plan.
- The development of a rapid emergency evacuation plan for people living in high-risk areas.
- Organisation of a "family twinning" program, called "*Accoglinfamiglia*", between families living in the areas at risk and those living outside.
- The establishment of a "civic committee", with a head, to better know, in real time, people's needs.

Identification of the areas at risk

According to the Operational Unit (*Unità Operativa*) of the University of Salerno (1998), on 6 May 1998 the Department of Civil Protection set up an "Operational Unit 2.38" (a component of the *Gruppo Nazionale per la Difesa dalle Catastrofi Idrogeologiche*, G.N.D.C.I: National Group for the Prevention of Hydrogeological Catastrophes) at the Italian National Research Council (*Consiglio Nazionale delle Ricerche*, C.N.R.), which in ten days from the event drafted a "Preliminary Map of the Areas at Residual Risk", at 1:5,000 scale. This map was necessary to highlight high-risk areas so as to implement prevention and emergency plans. National survey offices and some university departments were directly involved in this activity.

The number of people and families that still live today in the area at risk, as reported in the Municipal Emergency Plans, is shown in Table 2.6.

Table 2.6 People and families in the area at risk

Municipality	People	Families
Sarno (SA)	4,303	1,312
Siano (SA)	2,208	650
Bracigliano (SA)	2,769	862
Quindici (AV)	2,400	600
S. Felice a Cancello (CE)	1,503	371
TOTAL	13,183	3,795

Meteorological and pluviometric monitoring

During the emergency phase, the Veglia–Meteo Office of the Department of Civil Protection issued weather forecasts. Because of the lack of rain gauges, the Department of Civil Protection immediately installed five telemetered rain gauges run by the Naples Division of the National Hydrographic Survey (*Servizio Idrografico e Mareografico Nazionale – Compartimento di Napoli*). With the help of real-time data forwarded by the rain gauges, it was possible to quantitatively define a rainfall alert system gauged on the three alert levels: attention, warning, and alarm. The alert level of “attention” corresponds to the “Notice of Adverse Meteorological Conditions” issued by the Veglia-Meteo Office or the reaching of a minimum rainfall threshold. The warning and alarm levels are determined by the reaching of the rainfall thresholds.

Evacuation plans

Each of the five municipalities struck by mudflows enforced their evacuation plan, while the activities to guarantee safety in the area at risk were underway. These evacuation plans were divided into three operational phases, each one being implemented according to the relative alert level (attention, warning and alarm). The intervention of operational bodies of civil protection is scheduled during the warning phase, whereas people evacuation is scheduled only during the alarm phase.

Evacuation plans provide three different possibilities of accommodation for evacuated people (Table 2.7):

a) Autonomous accommodations in relatives’ houses or in holiday houses.

b) Accommodation in reception centres arranged by the municipality.

c) Accommodation in families living in the surrounding safe areas, according to the twinning project “*Accoglinfamiglia*”.

Table 2.7 Typology of accommodation for evacuated people

Municipality	People to be evacuated (Total)		Autonomous accommodation		Accommodation according to the project "*Accoglinfamiglia*"		Accommodation in Reception Centre	
	People	Families	People	Families	People	Families	People	Families
Sarno (SA)	4,303	1,312	732	230	2,403	722	1,168	360
Siano (SA)	2,208	650	-	-	1,655	514	553	136
Bracigliano (SA)	2,769	862	-	-	987	311	1,782	551
Quindici (AV)	2,400	600	-	-	360	90	2040	510
San Felice a Cancello (CE)	1,503	371	-	-	453	112	1,050	259

Urgent measures plan to overcome emergency

After the "Declaration of the State of Emergency" by the President of the Council of Ministers, the Minister of the Interior, responsible for civil protection, issued on 21 May 1998 the Ordinance no. 2787 to draft a plan to face emergency infrastructural interventions (restoration of bridges, roads, sewerages, waterworks, etc) and to provide immediate hydrogeological recovery to the disaster area (e.g. cleaning the draining system).

Lessons learnt

- For a prompt intervention it is necessary to identify in advance the allocation of emergency control activities centres (C.O.M.) and the areas arranged to gather rescuers and resources. This would improve co-ordination between central and local civil protection bodies and, as a consequence, reduce the time of intervention.
- It was crucial to know in real time the number of persons and means involved during the emergency phase. This enabled the correct management of both national and local available resources.
- Organising the C.O.M. in support functions, and knowing the person who controls them, allowed an efficient management of different emergency activities. Such an organisation is compulsory during the planning phase of an emergency.
- During a hydrogeological emergency, as opposed to a seismic event, people's accommodation in premises turned into reception centres, rather than in camps with tents and caravans, proved to be the right choice. The "*Accoglinfamiglia*" project was particularly useful and it was adopted as a model for other plans.
- During the emergency, it is necessary to organise teams composed of local experts who know the area so that they can help in monitoring the situation, highlighting the most critical problems.

2.5 Dissemination of information to the public and related lessons learnt

Prior to the event

People had no information on the hydrological hazard of the area. Furthermore, they did not know any directive to follow in case of a disastrous event.

During the event

No procedure was adopted to inform people about the hazard. However, the Mayor of Quindici was aware of the seriousness of the event and alerted people through local operational bodies urging their evacuation.

Following the event

The information was guaranteed at national and local level by the spread of news among the various operational centres and mass media.

People living in the area at risk received specific information on the hazard of the mudflows and they were informed about the behaviour to follow during the two phases of alert (i.e. warning and alarm) provided by the evacuation plan.

These information systems are still used to evacuate people in case an event occurs; they are listed below:

- Handing out of a leaflet with the rules to follow during warning and alarm phases.
- Broadcast of brief messages by local radio and TV.
- Use of loudspeakers to disseminate standard messages.
- Intermittent siren wailing to let everybody know that they are in the warning phase and continuous siren wailing for the alarm phase.
- Door to door warning of the beginning of the alarm phase by local bodies involved in civil protection activities.

The above-mentioned system is still in use today to alert people living in hazard areas before the event occurs.

Lessons learnt

- ➢ Dissemination of information about the possible risk prior to a disaster is necessary to raise public awareness on the phenomena and related risks.
- ➢ The knowledge of this phenomenon allows the definition of the right behaviour to follow to tackle its consequences.
- ➢ The involvement of people through the organisation of the "civic committees" allows knowing in real time people needs and their priorities.

2.6 Socio-economic implications

Important local socio–economic impacts related to the event were (De Vivo *et al.*, 2000):

- Difficulties for the loss of relatives or friends.
- Problems caused by body injuries.
- Loss and/or damage to houses.
- Problems due to loss of work.

A survey conducted on a sample of 272 people in Sarno 15 months after the event reported the following results: 48% of persons interviewed reported economic difficulties, 29% reported problems at work (temporary or definitive loss of work) and 32% reported family difficulties (quarrels, and relationship difficulties).

After the "Declaration of the State of Emergency" numerous ordinances were issued to ask for the first allocation of funds necessary to overcome the emergency.

In order to carry out the emergency plan, some funds were allocated by the EU and national and regional authorities.

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3. The Stoze landslide and the Predelica Torrent debris flow of November 2000 in Slovenia

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3.1 Description of the event and consequences

The Stoze landslide and the Predelica torrent debris flow, which occurred between 15 and 18 November 2000, could be denoted as the worst natural disaster in Slovenia in the last years. This study will focus only on this event, which caused 7 deaths in the village of Log pod Mangartom, in the Bovec community, western Slovenia, as well as great devastation (Fig. 3.1).

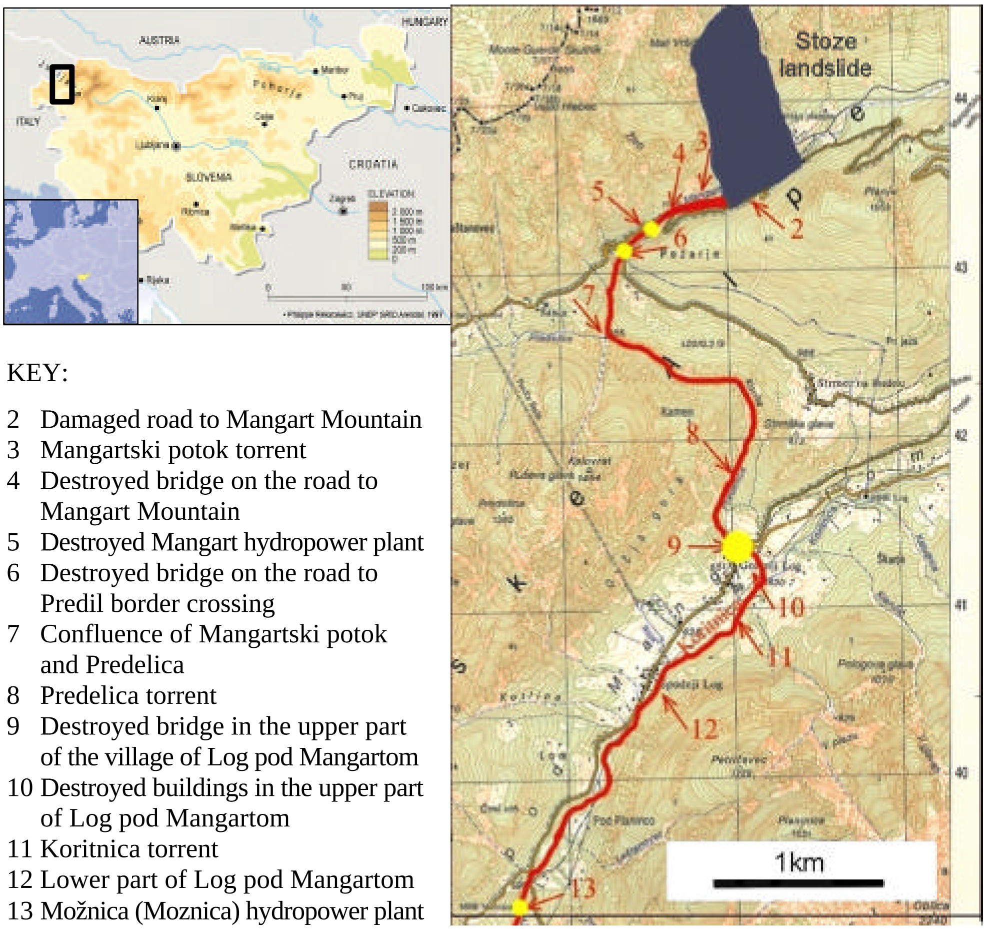


Figure 3.1 Location map of the Stoze landslide and the major damages along the Predelica torrent

According to the data of the Hydrologic Forecasting Service at the Hydro-meteorological Institute of the Republic of Slovenia (*Hidometeorološki zavod Republike Slovenije,* HMZ)[1]

[1] The Hydro-meteorological Institute of the Republic of Slovenia ceased to exist when the Law on changes and complements of the law on organisation and working area of ministries entered into force. Its activities are today carried out by the Agency for Environment of the Republic of Slovenia. In this study, the old name will be used.

and the Notification Centre of the Republic of Slovenia (*Center za obvešcanje Republike Slovenije*, CORS) for the year 2000, the rivers and torrents overtopped the banks as bigger floods in the autumn (October and November) took place in almost all the characteristic flood areas.

Autumn 2000 was extremely wet in Slovenia. In September and October there was very high precipitation, which significantly increased in November. Western Slovenian hills and mountains were exposed to rainfall amounts of 250 to 500 mm in October, and 600 to 1,400 mm in November. Rainfall in November was up to 400% above the average (Komac, 2001).

Heavy precipitation began on 6 and 8 November 2000 in Western and Northern Slovenia and then spread to other parts of the country, causing flooding on many rivers, streams and torrents. The rivers and torrents in Western and Central Slovenia started to flood first and then many others followed, particularly in the Eastern and Southern part of the country.

A number of severe disasters occurred in November 2000. The event that caused the most significant damage was the Stoze landslide, which provoked a debris flow at the Predelica torrent. The landslide occurred in the Stože area at 1,340- 1,580 m a.s.l., close to the 2,679 m high Mangart Mountain, in the Julian Alps. The landslide source area was mostly covered with mixed mountain forest.

The endangered settlements were situated around the Koritnica valley. This is an alpine valley lying with the SW- NE direction, which was transformed by glaciation. In November 2000, 140 inhabitants lived in the village of Log pod Mangartom and 11 in the village of Strmec. Log pod Mangartom was famous for its sheep products prepared in the traditional way. The development of tourism was also important.

The first landslide occurred on 15 November 2000 at around 1 p.m. in the bed of the Mangartski potok torrent. The maximum inclination of the torrent was 15%; the length of the slide was 1 km, its average width was approximately 100 m and its volume was estimated to be 600,000 m^3. The speed of the landslide was less than 1 m/s.

The bed of the Mangartski potok torrent rests on moraine and torrent deposits. Such material, even if it is totally wet, cannot slide if the inclination is only 15%. The most likely triggering factor of the landslide was the tremor provoked by the earthquake that occurred also on 15 November. The tremor caused the liquefaction of the waterlogged material.

The landslide destroyed the Mangart hydropower plant (Fig. 3.2), located some 800 m downstream of the landslide head, and the bridge on the road to the Predil border crossing, about 200 m further downstream (Fig. 3.3). In the Mangartski potok torrent gorge the slide changed into a debris flow due to the very steep bed inclination. The debris flow stopped at the deposition area in the gorge of the Predelica torrent near the confluence with the Mangartski potok torrent. The debris consolidated and the flow regime turned back to a free flow of sediment (Horvat *et al.*, 2001).

On 17 November a second landslide was released in the Stože area, about 130 to 150 m above the bed of the Mangartski potok torrent. The detachment involved an area of 200,000 m^2 and a volume of 1,000,000 m^3 (Fig. 3.4a). The triggering of this second landslide was not in direct connection with that of the first landslide. As the source area was very steep, the landslide immediately changed into a debris flow with an estimated speed of 8 to 10 m/s. (Majes *et al.*, 2001). After about 500 m the debris flow reached the bed of the Mangartski potok torrent (Fig. 3.4b). As the first landslide caused the complete devastation of the middle and lower stretch of the Mangarstki potok torrent bed, as well as the middle stretch of the Predelica torrent, there was practically no more room for the dissipation of energy or

Figure 3.2 Mangart hydropower plant before and after its destruction by the landslide of 15 November 2000 (photograph: archives of the PGD Log pod Mangartom)

Figure 3.3 New bridge over the Mangartski potok torrent on the road to Predil (Photograph by M. Slokar)

the deposition of debris. Mainly because of its high energy, the debris flow destroyed the Mangartski potok and Predelica torrent beds, as well as part of the village of Log pod Mangartom (Fig. 3.5). It also caused huge devastation in the bed of the Koritnica torrent, where another small hydropower plant was damaged (Horvat *et al*., 2001).

In the same period, in two other parts of Slovenia, two other large landslides had been very active, namely the Macesnik landslide in the Upper Savinja Valley and the Slano blato landslide above the village of Lokavec, in the Vipava Valley (Usenicnik, 2001).

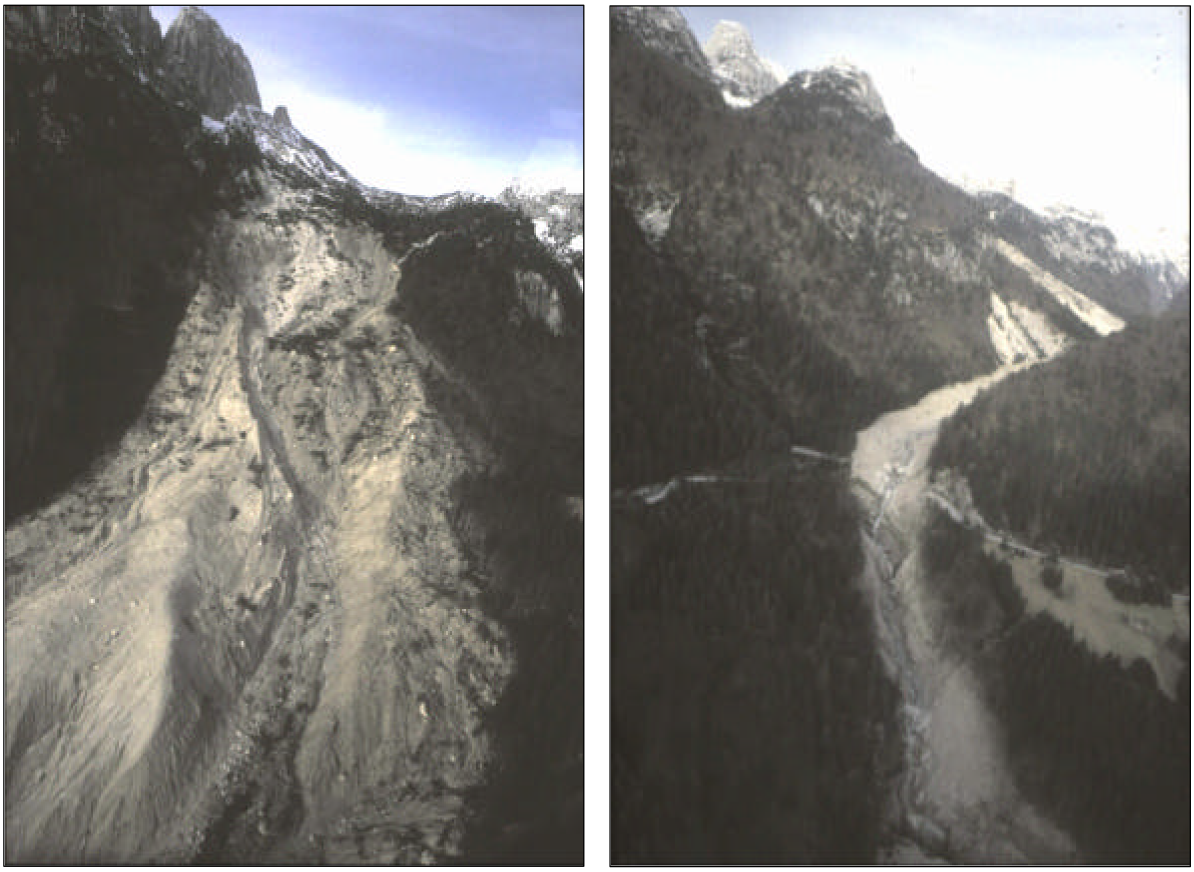
Human consequences

There were 7 deaths during this event. The inhabitants of the village were evacuated to a hotel in Bovec, or in private residences and relatives' houses until spring (cf. Usenicnik, 2001).

Economic losses

6 houses and 7 farm buildings were destroyed. Another 11 houses and 1 farm building in the village were damaged.

The beds of Mangartski potok, Predelica and Koritnica torrents were destroyed along most of their length.



(a) (b)

Figure 3.4 a) The Stoze slide of 17 November.2000. b) The Mangart potok torrent after the debris flow. The Stoze slide can be seen in the background (Photographs by B. Ušenicnik)

Figure 3.5 The village of Log pod Mangartom before and after the debris flow (photographs by Ž. Mlekuž and A. Horvat)

Two bridges on the state road to Italy (Bovec-Predel Pass-Tarvisio) were destroyed and the important road connection to Predel was cut off.

The important tourist road to Mangart Col was cut off and destroyed over a 1 km long stretch.

Two small hydropower plants were damaged. There were great damages to electricity supplies and telephone connections.

The local economy, such as tourism and farming, suffered great losses (Komac, 2001).

The damage caused by the landslide, as calculated by the National Commission on Damage Assessment (*Državna komisija za ocena škode zaradi naravnih nesrec*) in 2000, amounted to € 36 million.

3.2 Prevention measures and related lessons learnt

Prevention measures before and after the first landslide

The precipitation and floods in November 2000 were predicted. The Hydro-meteorological Institute of the Republic of Slovenia (HMZ) sent several warnings every day to the Notification Centre of the Republic (CORS). The Administration for Civil Protection and Disaster Relief of the Republic of Slovenia (*Uprava Republike Slovenije za zašcito in reševanje*, URSZR) announced warnings of hazards to the competent authorities, rescue services and the public, but did not specifically mention debris flows. Most of the warnings were forwarded down to all 13 regional notification centres. On 3 November this Administration sent a special letter of warning against flooding of rivers, streams and sea, including landslides and advisory measures, to all the regional defence agencies and communities, especially those in the western, southern and central parts of Slovenia. The warnings were repeated on 6, 14, 15, 16 and 17 November. The mayors of communities were advised to monitor the situation and to ensure the appropriate preparedness of the community headquarters of civil protection and other rescue services, including timely warning the endangered population. They were also reminded to inform their regional notification centres both verbally and in written form.

After the first landslide on 15 November a local disaster management system was activated in Log pod Mangartom. The system informed the mayor of Bovec about the situation, as well as the Enterprise for Torrent and Erosion Control (*Podjetje za urejanje hudournikov*, PUH), the geologists of the Enterprise for Road Maintenance (*Cestno podjetje Nova Gorica*, CP Nova Gorica) and the North Primorska Regional Headquarters of the Administration of Civil Protection. On 15 November an "ad-hoc co-ordination body" was appointed. It consisted of the mayor of Bovec, the representatives from the Civil Protection Local Headquarters from Bovec, the Civil Protection Regional Headquarters from North Primorska, the Police department of Bovec and the local fire brigade from Log pod Mangartom. They concluded that the inhabitants of five houses had to be temporary evacuated.

The next day (16 November) the experts and the "ad-hoc co-ordination body" thoroughly examined the landslide area and prolonged the previous day's preventive orders that the inhabitants from the most endangered houses should stay further on safe. Due to the very bad weather and safety conditions in the area the landslide was closely monitored in all possible zones (cf. Usenicnik, 2001).

Prevention measures after the second debris flow

The second debris flow occurred few minutes after midnight on 17 November 2000, approximately 130 to 150 m higher up on the right side slopes of Stoze, in the same torrent catchment as the first one. Unfortunately 7 people lost their lives because they returned to their homes in Log pod Mangartom not considering the warnings. The following morning the local disaster management and the "ad-hoc co-ordination body" system took the decisions about rescuing and organising the life in the village. The whole village was evacuated and its population was settled at Bovec in hotels and private apartments or at relatives' houses. The road to the village was opened only for authorised persons. The local rescue services from Bovec took all the precautions and actions for rescuing and protection in the area. The Civil Protection Headquarters of the Republic of Slovenia and the Civil Protection Headquarters of North Primorska provided professional logistics and other help to the local disaster management system.

Because of the complex situation a team of experts from various fields was formed on 18 November. The team was split in two groups: one with the experts in engineering geology (Majes *et al*., 2000) and the other in hydrotechnics and torrent control (Horvat *et al*., 2000). On 25 November 2000 they examined the situation and proposed temporary measures for the affected area. The evacuated inhabitants should stay out of the village of Log pod Mangartom until the following spring. The Municipal protection unit, the local fire brigade and some inhabitants from the village also took care of the animals and the property in the village (Fig. 3.6 and 3.7).

Figure 3.6 First intervention measures (Photograph: archives of the PGD Bovec)

Figure 3.7 Care of the animals after the landslides (Photo: archives of the PGD Log pod Mangartom)

The day after the debris flow, the Administration for Civil Protection and Disaster Relief of the Republic of Slovenia raised another repeater at the Kluže fortress to improve radio connections. Monitoring of the area of the landslide continued 24 hours a day until 23 December, when a special mobile public alerting system was set up in Log pod Mangartom. The Slovenian Air Force also helped with helicopters of the 15th brigade. According to the needs and conditions in the affected areas, exceptional human solidarity was provided all over Slovenia by humanitarian organisations (e.g. Red Cross, Caritas, etc.).

The final experts' report was concluded on 19 January 2001 with implemented intervention measures and recommendations for further actions with approximate cost evaluation (cf. Usenicnik, 2001).

Lessons Learnt

- Consecutive flooding and strong precipitation increases the probability of another flooding.
- Flooding also causes other problems in form of slides, which can change into debris flows on steep slopes or torrent beds.
- Realistic and accurate natural hazard assessments are the basis for further planning and actions. It is however very difficult to assess the areas with debris flow hazard zones due to both the state of knowledge and the available data, especially when they are connected with earthquakes.
- The failures and missed opportunities in the prevention phase, insufficient allocation of financial resources for torrent control and inadequate interventions in the environment (e.g. building settlements and roads in areas endangered by erosion) have increased the probability of landslides and torrential damages with possible human losses, and contributed to the serious consequences of the November floods in Slovenia.
- The municipal authorities should take more into account the professional opinion of torrent control experts. Torrent control should also receive more financial resources.

3.3 Preparedness measures: related lessons learnt

The lessons learnt during the preparedness phase are shown below.

Lessons learnt

- Any intervention in the zones endangered by any type of erosion must be carried out according to the conditions under which the land use in these areas is possible.
- Hazard zoning is the best prevention measure.
- An effective organisation of the local authorities for disaster management results in a very positive impact on the endangered population.

3.4 Response actions and related lessons learnt

On 25 November the Civil Protection Headquarters of the Republic of Slovenia, according to the proposals of the experts' teams, adopted the following measures and actions:

- Improving observation and information services in the affected area.
- Taking precautions while working in the area, taking under consideration another possible debris flow.
- Drainage of the landslide area.
- Removal of debris from torrent beds and deposition areas.
- Rebuilding new bridges on the regional road (cf. Fig. 3.3).
- Restoring life in the valley (domestic animals, pasture and tourism).

- Ensuring temporary residence for the evacuated inhabitants during the winter in Bovec.
- Ensuring permanent care for animals and property.
- Ensuring the necessary changes in land use plans.
- Controlling access to the affected area.

The key national decision-making bodies agreed on these measures and secured the funds for the intervention measures for protection, rescuing and help with approximately € 670,000.

On 21 December the Slovenian Government discussed the disaster and adopted the proposition of a law to ensure the resources for further activities as follows:

- Observation of the whole area affected by the landslide and the debris flow.
- Urgent landslide consolidation measures.
- Urgent control measures on Predelica, Koritnica and Mangartski potok torrents.
- Reestablishment of the road connections (bridges).
- Ensuring the primary conditions for life and economy in the affected area.
- Necessary corrections in land use planning.

The President of the Republic of Slovenia, together with the Civil Protection Commander and the Director of the Administration for Civil Protection and Disaster Relief of the Republic, visited the affected area several times.

The key rescue services and measures against this natural disaster were carried out by the local fire brigade, the Enterprise for Road Maintenance and the Enterprise for Torrent and Erosion Control. The latter started with necessary monitoring and torrent control measures (e.g. redirecting the Predelica torrent flow in the area of Log pod Mangartom, drainage of the landslide, etc), in cooperation with Slovenian Air Force's helicopters (Fig. 3.8). Fire-fighting units from the region were fully activated. Their activities could be grouped into four key areas:

- Rescuing and transportation, and supplying of the necessary resources to the affected people.
- Monitoring of the torrents and landslide.
- Care for the property and animals left in the village.
- Informing the evacuated inhabitants about the situation in the village.

Figure 3.8 Transportation of torrent drainage equipment by Slovenian Air Force's helicopters after the landslides (Photograph: B. Ušenicnik)

All of the rescue and protection activities were carried out using mostly municipal resources; only a small part was done with inter-municipal or regional resources. The municipalities are obliged, according to the principle of gradual use of forces and means, to use up their own forces and means first, before requesting outside intervention. Only in case they are insufficient, the help from other municipalities or state may be requested (cf. Usenicnik, 2001). The latter was requested only in this exceptional case where the local forces lacked equipment or personnel (horizontal inter-municipal co-operation).

Lessons learnt

- Understaffed, technically inadequately equipped and not sufficiently trained institutions or companies could not suitably perform during the increased labour pressure in the crisis.
- The rescue and protection services that became victims during the disaster could not perform as supposed by the protection and rescue plans.
- The need for participation of armed forces in protection and rescue activities is relative and dependent on the needs of municipal authorities.
- Limited (human and technical) resources at rescue services and other institutions force them to prioritise their activities.
- Hazard assessments should be continually updated, especially erosion hazard.

3.5. Dissemination of information to the public and related lessons learnt

The disaster caused by the Stoze landslide and the Predelica torrent debris flow in November 2000, which affected the village of Log pod Mangartom, triggered a great response by the media. This focused on the process of rescuing and solving the situation. The analysed documentation shows that the public was regularly and timely informed during the November events at local, regional and national level. The Administration for Civil Protection and Disaster Relief of the Republic of Slovenia set an experienced representative for public relations, who provided all the information and the sources of information. The journalists also reported correctly and objectively from the affected area with the aim to support the crisis headquarters (cf. Usenicnik, 2001).

After the natural disasters of November 2000, the Slovenian media transmitted information predominantly focused on damage assessment and reimbursement. The media became significantly more critical towards floods, landslides, debris flows and crisis management in the months following the disaster. The dissemination of information to the neighbouring countries (Italy and Austria) was immediate.

Lessons learnt

- Conditions soon after the disasters are very tense. All the information about the disaster and further measures is very sensitive and should be entirely and appropriately transmitted.
- The media, as transmitters of information to the public, could also be vulnerable to the effects of landslides and debris flows. In such a case, the notification centres must redirect their public messages to other relevant media, covering approximately the same area.

- An understaffed and technically inadequately equipped notification centre could not inform the public in an appropriate way.

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4. The October 1997 landslides in San Miguel Island, Azores, Portugal

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4.1 Description of the event and consequences

On 31 October 1997 near 1000 landslides occurred at S. Miguel Island, in the Azores archipelago, a few of them killing 29 people living in the village of Ribeira Quente (Fig. 4.1). In addition, 7 people were injured and 69 remained homeless. The Povoação and Nordeste counties were particularly affected during this event (Gaspar *et al.*, 1997; Gaspar and Guest, 1998). Several houses and bridges were partially or totally destroyed; communications, transportation and the energy supply system were disrupted and areas of fertile land were covered by mud (Fig. 4.2, 4.3, 4.4 and 4.5). Ribeira Quente remained isolated for more than 12 hours. In total, the material losses amounted to € 21 million.

The main cause of this extensive phenomenon was a local and catastrophic rainstorm. In the nearby town of Furnas the total rainfall registered until November was about 1,800 mm. On 29 and 30 October the levels were, respectively, 57.3 mm and 23.5 mm, while 153.1 mm were measured in the morning of 31 October.

The strong SE winds that accompanied the heavy rain and the vulnerability of the volcanic soils, already saturated as a result of long periods of continuous precipitation, certainly contributed to the magnitude of the event (cf. Gaspar and Guest, 1998).

The village of Ribeira Quente lies at the base of Furnas Volcano (cf. Fig. 1), which is the easternmost of the three active central volcanoes (Furnas, Fogo and Sete Cidades) on the island of S. Miguel. Furnas does not have a well developed edifice, but consists of a steep

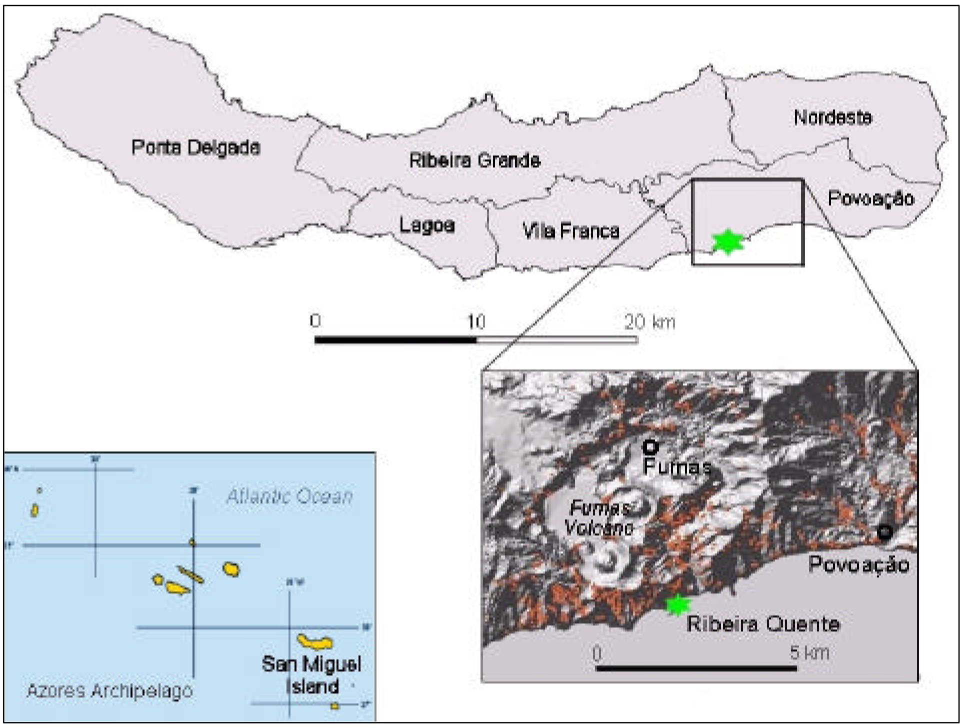

Figure 4.1 Density map of landslides occurred in the Povoação county on 31st October 97

Figure 4.2 Village of Ribeira Quente after the landslides

Figure 4.3 Houses destroyed in Ribeira Quente, and mud and debris covering the village

Figure 4.4 House and property destroyed by mudflows in Ribeira Quente

sided caldera complex 7 km × 4.5 km across. It is built on the outer flanks of the Povoação/ Nordeste lava complex to the east and north and is relatively low lying. Constructive flanks to the volcano exist on the southern side, where they form the coastal cliffs, and to the west. Most of its southern flank has been removed by marine erosion and faulting leaving high cliffs. To the east and north-east the Furnas volcano abuts against the old eroded volcanoes

Figure 4.5 Road cut off by the collapse of the edge of a streamline at Furnas Volcano, during the 1997 event

Figure 4.6 Head of debris flows and mudflows caused by the intense precipitation occurred in the dawn of 31 October 97, on a hillslope in the Povoação district

of Povoação and Nordeste; to the east it merges with the lavas formed from vents in the region between Furnas and Fogo volcano.

Most of the landslides were essentially very fluid debris flows, consisting of a mixture of water, pumice and ash. Trees with their root systems, trunks and branches were included in most deposits (Valadão, 2002; Valadão *et al*., 2002). Depending on the source, some debris flows transported large blocks of lava, normally less than 1 m across. The predominance of water conferred the debris flows low viscosity, enabling them to gain high speed.

Although there were some exceptions, the majority of the landslides were originated on very steep slopes, usually greater than 45º. Also, for most of the slides excavation of the slope was relatively shallow (Fig. 4.6). This high fluidity of the events produced some deposits that covered areas near 4,000 m^2.

4.2 Prevention measures and related lessons learnt

No risk assessment, land use planning or building codes related do landslide hazard existed prior to the event. The meteorological network in the island was well equipped and the number of stations was adequate. To complement the meteorological information, the Azores' Civil Protection and Firefighters Regional Service (*Serviço Regional de Protecção*

Civil e Bombeiros dos Açores, SRPCBA) mounted various meteorological stations in different places. Currently, there is a station in Povoação.

Lessons learnt

- Living in an active seismic-volcanic region obviously implies a certain amount of risk. Such reality implies that the community must be ready to face also any kind of associated natural disaster, namely landslides.
- Landslide hazard assessment is naturally one of the most important steps in order to diminish this very frequent risk. All stakeholders involved in Civil Protection Plans have to adopt strategies aiming to reduce the effects of these phenomena in society.
- Strategies for risk reduction should be developed in direct collaboration with the scientific and civil protection structures, where the former should provide all the specific information needed for land use management and elaboration of emergency plans.
- The production of hazard and risk maps is absolutely crucial, since it enables authorities to implement eventual prevention measures.

4.3 Preparedness measures and related lessons learnt

No preparedness measures were taken prior to the event.

Lessons learnt

- The most important lesson learnt was the need for a specific emergency plan for this kind of event and an in-depth scientific study, namely a geological, geotechnical and natural hazards study, regarding the particular case of Ribeira Quente and the general situation of Povoação County, that can serve as a work base to any emergency planning.

4.4 Response actions and related lessons learnt

After the event a technical and scientific report was jointly produced by the Centre of Volcanology and Geological Hazards Assessment (*Centro de Vulcanologia e Avaliação de Riscos Geológicos*, CVARG), the Civil Engineering Regional Laboratory (*Laboratório Regional de Engenharia Civil*, LREC), University College London and the Nordic Volcanological Institute (cf. Gaspar *et al*., 1997). This report includes:

- Geological setting of the affected area.
- Climatic conditions at the time.
- Characterisation of the detritic flows.
- The study of the genetic mechanisms of the landslides.
- Hazard assessment.
- Risk assessment.
- Perspectives of new occurrences.
- Recommendations for the future.

In 2001, CVARG drafted the Povoação County Emergency Plan including the following topics:

- Civil Protection structure at the county level.
- Definition of the geological hazards in the county, such as earthquakes, volcanic eruptions, landslides and tsunamis.
- Human response mechanisms such as evacuation planning.

Lessons learnt

- Before the Ribeira Quente event, the Autonomous Region of the Azores did not have any County Emergency Plan, the operational structure of the Civil Protection and Firefighters Regional Service (SRPCBA) was not the most suitable and the telecommunications network was not appropriate for the Azores geographic discontinuity, which was highlighted by this disaster.
- From this moment on the Regional Government decided to implement a new emergency communications network and started promoting the development of all Counties Emergency Plans (*Planos Municipais de Emergência*, PME), through direct collaboration with the Civil Protection Service and the City Counties.
- It was necessary to articulate the Civil Protection Service with the Firefighters in order to avoid the failures that occurred at operational level. This resulted in the establishment of the current structure of the Civil Protection and Firefighters Regional Service (SRPCBA), already tested in several occasions with positive results.

4.5 Dissemination of information to the public and related lessons learnt

Prior to the event

No information was supplied at that time.

During the event

During the event, the Civil Protection Service set up an improvised pressroom both at its headquarters and at the disaster area to disseminate through the Media all the information gathered locally.

Following the event

The failures existing in the civil protection system were brought to light, specially by the Media, which originated an inquiry from the Justice Department about the acting of the Civil Protection Service in Ribeira Quente's disaster.

As a result of this enquiry, the whole civil protection system was restructured as follows:

- Creation of the current Civil Protection and Firefighters Service of the Azores (SRPCBA).
- Implementation of a new emergency communications network.
- SRPCBA's technical and human support to all counties for the elaboration of Emergency Plans.
- Establishment of a technical and scientific collaboration protocol with the University of the Azores (*Universidade dos Açores,* UA) in the areas of seismology, volcanology and geology.

4.6 Socio-economic implications of the disaster

The main socio-economic implications of this disaster were:

- Several families had to be moved to other places, but most people preferred to stay at Ribeira Quente because of their secular attachment to this place, in spite of the Regional Government's purpose to move all population to a safer place.
- Interdiction of new constructions in this area.
- Tourism in Ribeira Quente was affected because its beautiful and natural beach was partly destroyed by this disaster.
- Construction of a new fishing harbour, which was very encouraging to this fishing community that lost their boats and resources.
- Construction of a heliport to avoid that the village of Ribeira Quente become isolated again, because the only existing road is particularly vulnerable to future landslides and it is impossible to build another road.

These socio-economic implications incurred costs in the order of € 21 million, as broken down in Table 4.1.

Table 4.1 Socio-economic costs incurred by the landslide disaster

Concept	Cost (€)
Improvements in the transportation system	14 million
Damages to housing	2.5 million
Damages to the environment and water management system	1.8 million
Damages to interior roads leading to agriculture exploitations	1.5 million
Damages to agriculture	800,000
Damages in the fishing sector	450,000
Losses of local commerce	150,000
Losses of education sector	100,000

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5. The May 1997 landslide in soft clay at Vagnhärad, Sweden

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5.1 Description of the event and consequences

During the night between 22 and 23 May 1997, a landslide occurred in the community of Vagnhärad, in the Södermanland province, about 70 km south-west of Stockholm (Fig. 5.1). It was the largest landslide that occurred in a populated area of Sweden since the mid 70s. It took place in a clay slope and covered a 200 m stretch along the Trosa river, reaching a height of 60 m upbank. It displaced the course of the river by 15 m, raised the ground surface at the original position of the river by 2 m and lowered the surface along the upper edge of the slide by 5 m. This landslide was preceded by a smaller slope failure along the river on 15 May 1997 (Fig. 5.2).

There were no fatalities, although 5 people were taken to hospital for minor injuries and nearly 100 people were evacuated after the slide. Three houses were destroyed and several others damaged or undermined (Fig. 5.3 and 5.4). A total of 33 properties were judged to be in the risk zone for further slides and the railway on the other side of the Trosa river was temporarily closed.

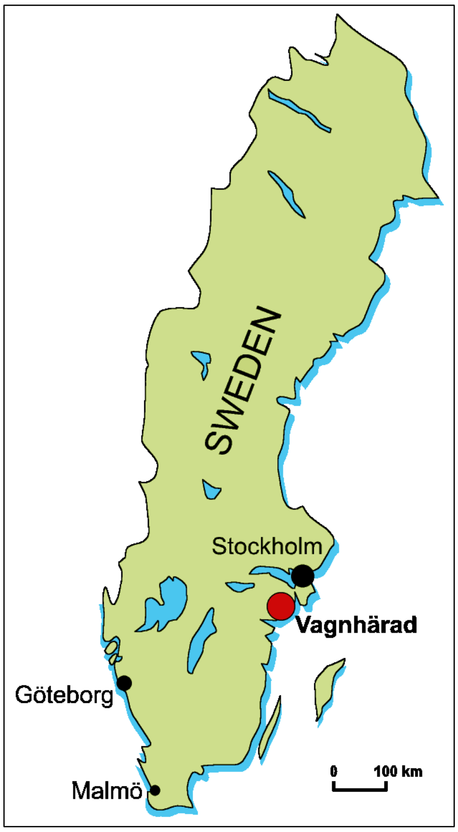

Figure 5.1 Location of the community of Vagnhärad.

The slide area consisted of a long slope on soft clay leading down to the river. The altitude difference between the top of the slope and the ground surface at its toe was approximately 15 m. The depth of the river increased the difference by a further 2 m. Within the populated part of the area, the natural ground surface prior to development had had an inclination of 1:12. On the steepest sections between the houses on the road closest to the river and the river the inclination was however 1:5. The thickness of the clay layer varied from about 1 m in the upper part of the slope to 10–14 m on the lowest parts. The clay lays on top of a layer of friction soil (Fig. 5.5). Areas of rock and sandy gravel at a higher altitude in the surroundings act as infiltration zones, i.e. areas where rainwater can penetrate beneath the clay. In the slide area and adjacent areas, the clay formed an impervious lid over the friction soil.

The week before the slide, there was unusually heavy rain for the season. During the month of May 77 mm of rain fell, compared to normally 34 mm. During the period 4–9 May there was heavy rainfall amounting to 60 mm, of which 34 mm fell during one day (Andersson *et al*., 2000). Measurements indicate that the water pressure in the lower parts of the slope was

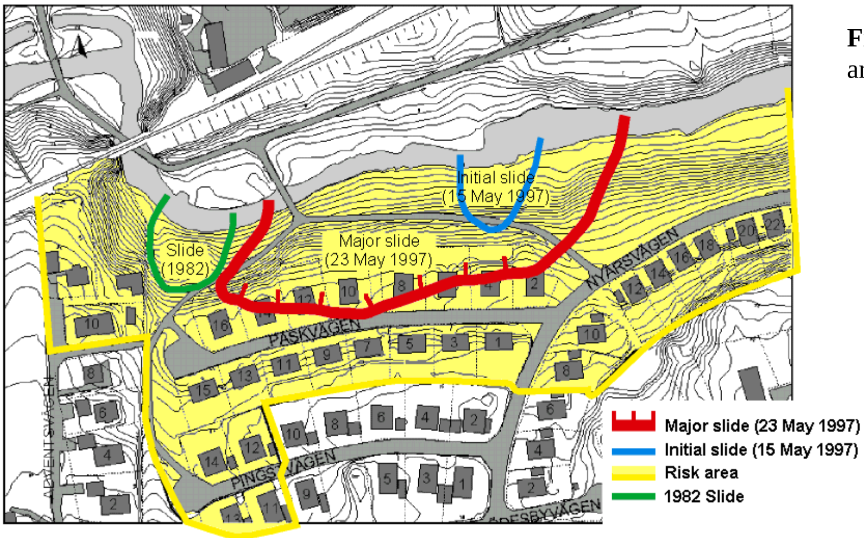

Figure 5.2 Map of the slide area (Andersson *et. al*., 1998)

Figure 5.3 Partial view of the head of the 23 May 1997 landslide. A tilted house can be seen near the upper left corner

Figure 5.4 House destroyed by the 23 May 1997 landslide

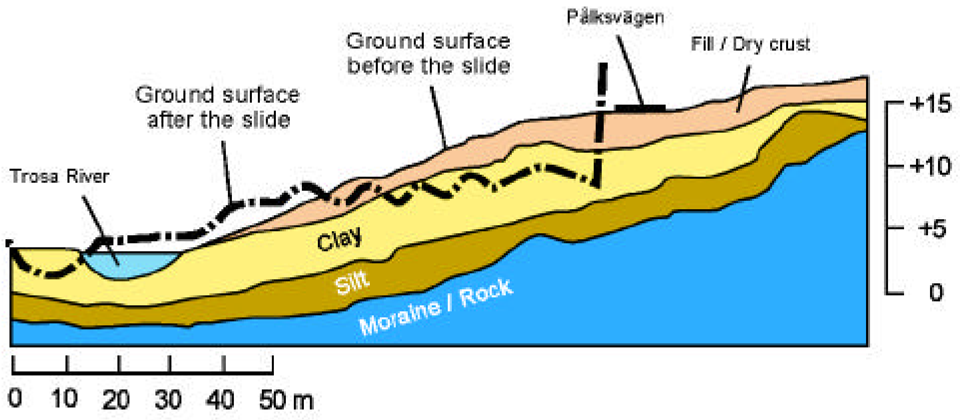

Figure 5.5 Section of the landslide area

artesian. The groundwater levels were also higher than normal for that period. The pressure level in the friction soil was about 2 me above the ground surface by the river.

A thorough study together with mapping of the geotechnical characteristics of the area has been carried out. It included the determination of the soil layer sequence, strengths, groundwater pressures and pore pressure (Andersson *et al.*, 1998). Considerable effort has been put into understanding the formation of the valley and the loading history of the clay. Stability calculations have been performed according to Swedish national directives (IVA Skredkommission, 1995).

These calculations for a short, circular failure surface in the area of the initial slide show that if an artesian water-pressure at the river of about 2 m was assumed slide safety was very low. Even for a long, mainly flat failure surface from the river to the rear edge of the main slide, slide safety was low. The calculations show that the water pressure in the soil down at the river was decisive for the stability of the slope.

The study concluded that the main cause of the slide was that the slope was so stressed that even very small changes in the conditions could result in a slide. The factors that triggered the slide at just that point in time may have been:

- Heavy rainfall for the season, which increased pore pressures.
- Erosion and small, local slides along the river.
- Large and repeated ground movements, which reduced strength.
- Low water level in the river over a period of time.
- Increased pore pressures due to heavy rainfall in combination with water leakage.

The most probable cause is a combination of two or more of these factors.

5.2 Prevention phase prior to development of the area

The residential area of Vagnhärad known as Ödesby was developed in the mid 70s. The plan for building Ödesby recommended that the area should be built with "one-family" houses. In the building plan it was suggested that 45 "one-family" houses should be built in the area and that these should only be one-storey houses. There were also restrictions about the height of the houses, the living area of each house and the number of main buildings and outbuildings.

Geotechnical investigations prior to planning and development of the area were carried out in the early 70s. In these investigations, restrictions for development of the area and general recommendations for foundation of buildings were given. It was stated that the soil was sensitive to settlement for increased loads and that there was a risk for landslides even with small load increases. Concerning the planning of houses in the area, a more detailed geotechnical investigation was carried out, which included detailed recommendations for foundations of buildings and restrictions on the height of fillings in the area.

Lessons Learnt

- It is of great importance that general stability surveys are carried out before the development of areas where conditions of low stability can be found. The landslide at Vagnhärad has revealed that the priority for these stability surveys had to be looked over. Earlier, areas where nothing had been done had the highest priority. Thereafter, old landslide risk surveys were checked. Today areas with the highest risk are given the highest priority.

5.3 Preparedness phase after the first small landslide of 15 May 1997

On Monday 12 May, local residents noticed minor cracks in the path and cycle way. These were reported to the municipality. After the cracks became larger, the municipality called in geotechnical engineers who found, on Thursday 15 May, that a minor landslide was taking place. Movements of about 2 cm/h were registered.

After the small landslide of 15 May, a "rescue service phase" was applied in accordance with § 2 of the Rescue Services Act (*Räddningstjänstlagen*). An initial risk zone was cordoned off and three houses evacuated with the support of § 45 of the same Act. Two families were allowed to remain in their houses during the day while landslide warning devices were fitted to the external walls (Swedish Rescue Services Agency, 1998). The three immediately affected homeowners were informed of the estimated risk of a landslide and given an order for evacuation. At the same time, others living in the area were invited to an information meeting on the course of events and the assessed situation. A maximum speed of 40 km/h was imposed on the railway on the opposite side of the river.

At the same time, an inventory and plans were made for organising rescue work if a larger landslide would occur. A checklist with priority actions and telephone numbers was drawn up for the rescue leader. This also included an alarm list to be used by the SOS Alarm Centre (*SOS Alarm*) in case of a landslide. Initial measures and contact persons were also specified. A meeting point for gathering rescue forces was chosen and a command centre specified. The distribution of responsibilities within the rescue service was determined. A rescue leader, information manager and site organiser were then appointed. These were able to think over their roles and make suitable preparations. The preparations included close contact with social and technical personnel from the municipality, who in turn made their own preparations. When evacuating the three houses, continuous monitoring of the area was arranged during night-time. The purpose of this was to observe a possible increase in movements in the area, to warn residents and the alarm centre, and to provide assistance in an initial rescue or evacuation.

Throughout this time, regular information was provided daily or every two days to evacuated families and to others in the area. The local press showed great interest and reported frequently on the situation. Local politicians were kept informed and made visits to the area in order to follow events. By far the most difficult part of preparation was to imagine what would happen if the worst case became a reality.

Lessons learnt

- As the large slide was preceded by a small slide, the rescue service was prepared for what could happen. Although few actions can be so well planned, it is valuable if organisations are prepared in case of a large accident.

Other important lessons from the preparations were the following:

- Evacuation and enlargement of the risk zone proved very effective.
- Priority was given to geotechnical surveys in the area in order to obtain further information for making decisions.
- The rescue service and the municipality were prepared for a worst case scenario.
- Information on events and implemented measures was provided regularly and openly to those directly affected, as well as to nearby residents and the authorities.

5.4 Response phase, after the main landslide of 22–23 May

The time was about 00.40 hrs on 23 May. The person in charge of monitoring the area was sitting in his car when he suddenly heard a crash. The lighting poles in front of him began to sway and the lights then went out. Further along the road, he saw several houses beginning to slide towards the river. He then tried to warn the SOS Alarm service at the same time as he ran towards the edge of the landslide. He was met by residents who came up from the houses still in place on the other side of the road. Together, they were able to use a ladder to help 6 people up the scarp that had suddenly appeared. At the same time, one of the residents in the area managed to contact SOS Alarm.

The alarm was received by the rescue service at 00.59 hrs and the brigade that arrived first was the part-time fire brigade, consisting of 5 people, from the closest municipality. Soon thereafter, the fire and rescue services arrived, and 17 people in total were in place during the first hours. According to the earlier decision, the rescue leader and information manager had already been appointed.

The first need was to help the residents away from the area. The day care centre for the area was used as a collection centre. There, evacuees were kept warm, given coffee and provided with a personal counsellor. It was also verified that no one was missing. Only 5 injured people were taken to hospital. The psychological strain of suddenly losing house and home naturally affected everyone involved to a varying degree. Crisis personnel from the municipality and County Council were called to the site to look after the families. Two hours after the landslide, the rescue leader was able to inform the evacuees about the situation in the slide area, to decide on setting up a special crisis centre and to arrange bus transport. Several of the important decisions for looking after the victims were made directly in consultation with municipal personnel.

The most important immediate measures were:

- Evacuating a new risk zone.

- Establishing an indoor collection centre for almost 100 persons.
- Deciding on a crisis centre for looking after victims.
- Deciding on a command centre for the municipality's management group.
- Deciding on premises for press conferences and the time for the first press conference.

After the emergency handling of 33 homeless families during the first day, the rescue leader began to plan evacuation of all personal belongings in 29 of the houses. The strategy for this work was that the rescue workers, reinforced with military personnel, should work in groups within the risk zone. The Defence Forces provided about 200 personnel for this purpose. The houses were emptied successively, each being visited on four occasions before everything was removed. Geotechnical experts were allocated as safety lookouts outside the houses were work was in progress. Emergency exits were arranged from the houses if a new landslide were to occur. In certain specially exposed houses that were situated exactly on the edge of the landslide, landslide-warning devices were also fitted to the outside before personnel were allowed to enter. All smaller possessions were packed in boxes that were then removed together with furniture and other goods on trailers drawn by four-wheeled motorcycles. Larger and heavier vehicles were avoided within the area. Roads were built up to the three houses that had been carried away by the landslide. Outside the area, the house owners and insurance companies took over responsibility for handling the goods and storing them. Throughout the work of emptying the 29 houses, the affected families were informed at regular meetings in the crisis centre together with others taking part in the rescue operation.

Lessons learnt

- Geotechnical expertise is essential for evaluating risks to personnel working within a landslide area.
- Recovery of personal possessions is important for starting a new life after surviving a landslide that has destroyed house and home.
- Where large numbers of people are needed, the military is a large and important resource.
- Regular communication with the victims makes it possible to explain and create understanding for rescue work. It also creates confidence and can influence decisions on recovery work in a positive direction.
- The memoranda written during the whole rescue phase proved very valuable for keeping in mind what happened which day, as well as in the request for subsidies according to the Rescue Services Act.

5.5 Dissemination of information to the public

Inhabitants

Even before the landslide of 23 May an information manager had been appointed in the rescue service. The municipality also appointed an information manager after the slide occurred. Both of these proved to be very valuable.

Dissemination of information to the victims was given very high priority. Before the main landslide, bulletins were distributed every day or every second day within the area. At the same time, people were invited to attend information meetings. The bulletins contained information on the current situation, present and planned measures, and results of measurements. They were also given to other persons requesting information. The information was divided according to the following target groups: those directly affected, those indirectly affected (nearby residents), other members of the public, the media, internal personnel and other authorities.

After the landslide of 23 May, the atmosphere at the meetings with the victims was at times openly bitter. Some of the residents criticised the rescue service and geotechnical engineers, since they considered it their fault that the landslide had occurred. Later, the criticisms subsided and after a few days the relationship between the victims and the rescue service became very good as more and more people were able to collect possessions from their homes. It was as though many regained part of their identity after they were able to recover valuable photographs or memorabilia. The priority work of regularly informing and supporting the families led to increase confidence in the rescue service. Close personal contact developed between rescue workers and families during the recovery of possessions from the houses.

Mass media

The local radio station was called up by the rescue leader during the night after the main landslide. The intention was to inform the local inhabitants about the catastrophe as soon as they awoke. The first press conference was an improvised arrangement when the area was cordoned off at 04.00 hrs on 23 May. Afterwards, the press was able to take pictures inside the landslide area. The area was then closed off completely. A press centre was established close to the crisis centre. In this, further press conferences were held when interesting and important information became available. The rescue leader also took part in individual interviews upon request from various media. Contact with the media was characterised by a positive climate. The municipality provided press releases and updated its website at regular intervals.

Lessons learnt

- Information to victims must be given priority in a catastrophe of this type.
- Information should be characterised by an attitude of openness and understanding towards those affected.
- Information that is considered honest and reliable is very highly valued by the victims.
- Information managers were appointed very early, which proved necessary. The need for information was very high from both the media and the residents.

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6. The 12 July 1999 mudflow at the hydroelectric workers village of Tomeasa, Hunedoara county, Romania

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6.1 Description of the event and consequences

Heavy rainfall on the night of 11-12 July 1999, totalling 136 mm in 2 hours, led to torrential flows on the slopes of the Raul Mare river valley, triggering a landslide (a mudflow) at 04:45 hrs, approximately 5 km downstream of the Gura Apelor dam, in the Retezat Mountains, Hunedoara county, Romania (Fig. 6.1). The mudflow destroyed one of the buildings owned by the commercial company Hidroconstructia S.A., where their employees lived with their families, and caused 13 fatalities, 21 injured and 30 homeless. Economic losses were estimated at € 9,000, while the cost of the response actions amounted to € 300,000.

The workers village of Tomeasa, where the workers that finished the Gura Apelor dam lived, is located on the right bank of the Raul Mare river, at the base of an alluvial fan. The bedrock in the area consists of Precambrian metamorphic rocks of the Rausor formation, which is made of biotite phyllites and quartz schists with chlorite-sericite interlayers. In the Tomeasa area, the Rausor formation at the base was covered with alluvial and colluvial

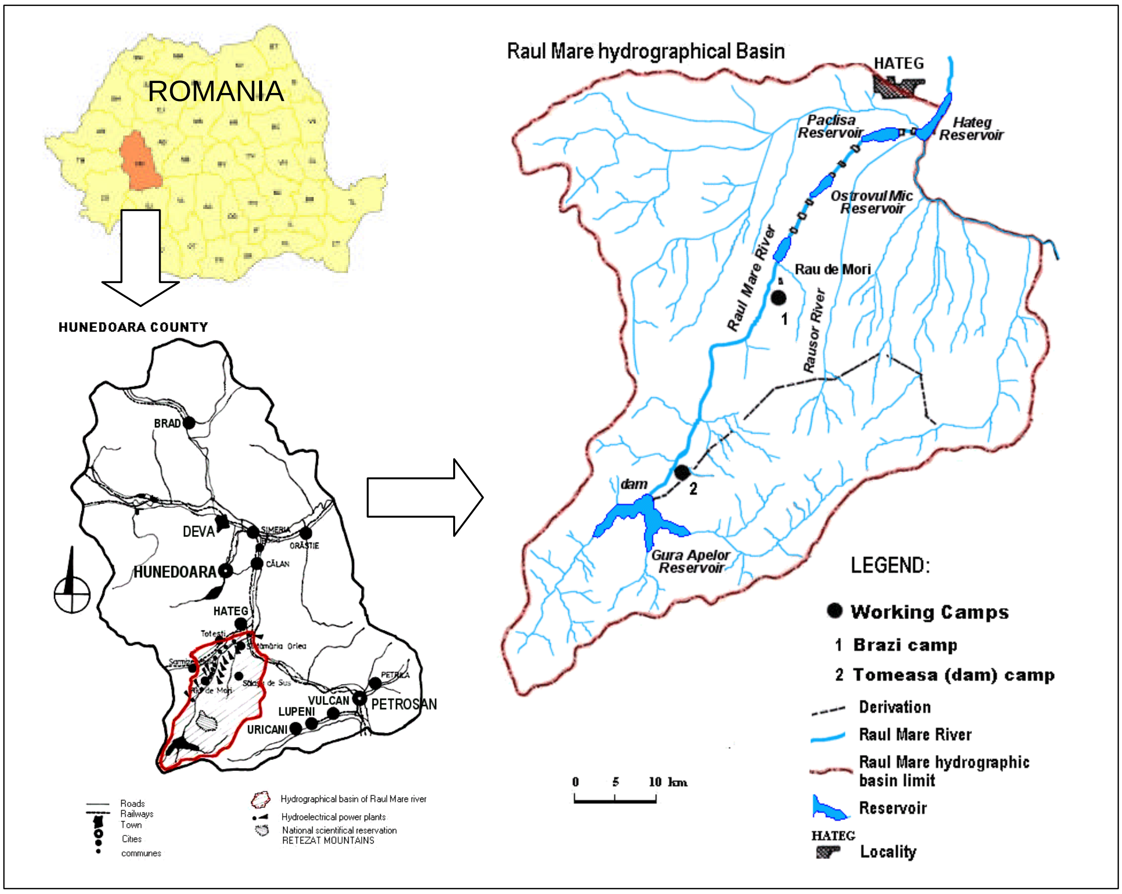

Figure 6.1 Location map of the Raul Mare river and the Tomeasa workers village

deposits, which represented the source for the mudflow (Fig. 6.2).

The triggering factor of the landslide at the workers village of Tomeasa was the substantial increase of the water discharge (usually 5 l/s) of the spring located at the base of the alluvial fan, on the right side of the Raul Mare river defile, combined with the above-mentioned very high precipitation. This led to a mudflow, which carried a large amount of eluvial, colluvial and woody debris into the village (Fig. 6.3).

The precipitation fallen in the area also produced affluent discharges in the Gura Apelor reservoir of about 800-1000 m^3/s, which correspond to an exceeding probability of $1^0/_{00}$. Supplementary water in the reservoir was then discharged through the dam bottom spillway (about 80 m^3/s), thus protecting the downstream localities from high floods.

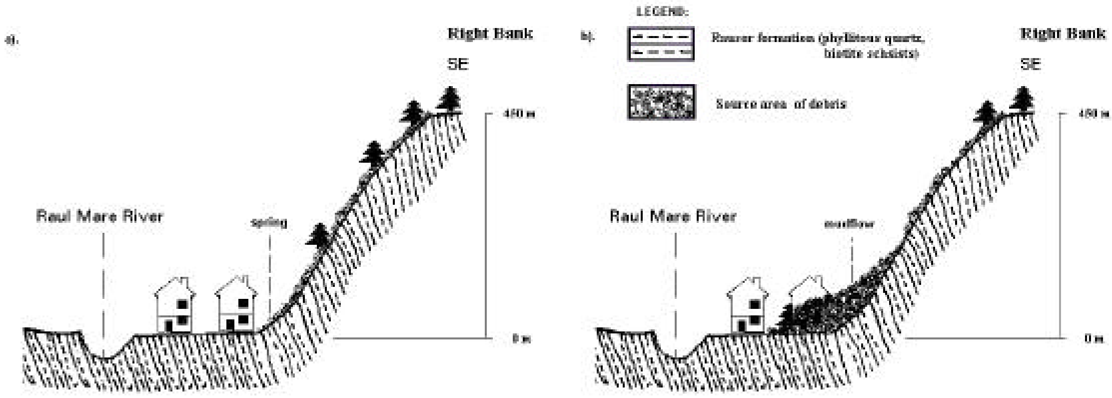

Figure 6.2 Geological section of the Tomeasa village mudflow site

Figure 6.3 Left: spring contributing to the mudflow triggering. Right**:** debris carried by the mudflow at Tomeasa

6.2. Prevention measures and related lessons learnt

According to the Romanian Regulation of defence against the floods, dangerous meteorological phenomena and accidents at the hydrotechnical works, the dam owners have the obligation to establish warning-alerting plans for the downstream localities and infrastructure in case of accidents.

Such a plan was set up by the commercial company Hidroelectrica SA, Deva branch, for the Gura Apelor dam and approved by the Central Commission for Defence Against Floods, Dangerous Hydrometeorological Phenomena and Accidents at the Hydrotechnical Works (*Comisia Centrala de Aparare Impotriva Inundatiilor, Fenomenelor Meteorologice Periculoase si Accidentelor la Constructiile Hidrotehnice* - CCAI). The provisions of this plan were not applicable in this situation because the disaster was not caused by a dam accident but because of a mudflow, which did not affect the respective hydrotechnical works.

Due the activity of the Civil Protection County Inspectorates plans exist also for operative interventions in case of disasters, made at county level and also at the level of each locality. It has to be mentioned that the area affected by the disaster is an isolated zone, far away from the localities.

A cause of the disaster was that in the past 20 years, in the area of the workers village of Tomeasa, works such as those for cleaning up the woods debris deposited along the past, soil erosion protection works and torrential regulation and protection works were not undertaken because of lack of funds.

Also the alpine pastures, forests and other categories of land, are usually owned by a group of 4-5 administrators/owners, who, due to lack of funds or interest, did not undertake defence works against soil erosion.

For the delimitation of the areas exposed to natural hazards, the Romanian legislation in force stipulates that the documentation of urbanism and territorial planning include the chapter “zones exposed to natural risks”, including floods, landslides and earthquakes. In the local General Urban Planning (PUG’s), which is managed by local authorities, the areas exposed to natural hazards, such as floods, landslides and earthquakes, where building is forbidden, excepting mitigation works for potential natural disasters are indicated. In addition, in the PUG's land use planning and building codes are provided for the whole commune area.

The Permanent Technical Secretariat of CCAI from the Ministry of Waters and Environmental Protection (*Ministerul Apelor si Protectiei Mediului* - MAPM) organised in the May-June 1999 period, training of the personnel in the actions of defence against the floods (majors, leading staff of the units which own works for flood protection, members of the Permanent Technical Secretariats of the County Commissions for Defence Against the Disasters (*Secretariatele Tehnice Permanente ale Comisiilor Judetene de Aparare Impotriva Dezastrelor* - STP-uri ale CJAID-uri) regarding the problems of the information flow and their competences for the flood defence activities at a distinctly section in the plans for protection and intervention in case of disasters.

It has to be noted that according to the Regulation of organisation and functioning of the “Central Commission for Defence Against the Landslides and Seismic Effects” (*Comisia Centrala de Aparare Impotriva Alunecarilor de Teren si Efectelor Cutremurelor*), constituted through the former Ministry of Public Works and Territorial Planning -the current Ministry of Public Works, Transport and Housing- (adopted through the Governmental Decision HG no. 438/1995), the following measures were taken during 1999 (before the Tomeasa disaster) in order to prevent landslides:

- Ensuring the information to the public through the media regarding the potential risk areas, the imminence of landslides, their effects and the measures undertaken.
- Development of regulations for prevention and mitigation of the effects of potential natural disasters such as landslides and earthquakes. Indirect measures were also

undertaken, mainly for developing areas at risk from landslides, including performing specific studies (e.g. topographic, geotechnical, geophysical and hydrogeological) for implementing the works for risk reduction.

- Validating the regulations of the county commissions for defence against the disasters regarding the way of organisation, constitution, the specific duties and their way of operation regarding the prevention and defence against landslides.
- Validating the defence plans against disasters at the level of the county and the local commission for defence against the disasters, revised upon the experience from previous landslide phenomena.
- Collaborating with the Civil Protection Commandment, which planed and organised general simulation exercises in order to train the population and the public administration bodies to cope with the disaster situations due to landslides.
- Ensuring the material means necessary for prevention, intervention and mitigation of the landslide effects, within the limit of the allocated funds.

Lessons learnt

- Intense rainfall is one of the major landslide triggering and reactivation factors (Balteanu, 1979, 1999), and as such it must be duly forecast.
- The lack of field studies, the absence of laboratory research, the lack of knowledge of the real situation from the point of view of stability and the characteristics of the usual ground parameters in the areas where it is intended to design and execute any type of works, can lead to landslides producing countless material damages and sometimes human losses.
- The necessity of issuing the Law regarding the “Plan of the national territory development, the Fifth section – Areas of natural hazards”, which includes risk maps of Romania for the areas prone to natural hazards (floods, landslides and earthquakes), as well as the exact geographical and administrative localisation of these areas, including the indication of the risk level of producing the specific hazards (Department for Local Public Administration and Ministry of Waters and Environmental Protection of Romania, 1998).

6.3 Preparedness measures and related lessons learnt

Since 9 July 1999, the National Institute of Meteorology and Hydrology (*Institutul National de Meteorologie si Hidrologie* - INMH-SA) issued warnings to the competent authorities and the population regarding the large volume of precipitation forecast for the following days in the western and central parts of the country. However, they did not specify the exact location and volumes. Also on 9 July 1999 at 12:40, the Mures Water Branch of the “Romanian Waters” National Agency (*Directia Apelor Mures a Agentiei Nationale "Apele Romane"*) transmitted a hydrological warning for the period between 9 and 14 July 1999 to the Civil Protection Inspectorate of the Hunedoara county. In this warning they informed about the increase of water discharges, being thus possible for the rivers in the area to reach or exceed the danger levels.

This warning was forwarded to the county Prefecture, the Regional Forestry Administration (*Regia Nationala a Padurilor* - "Romsilva") and also to the National Company of Electricity

(*Compania Nationala de Electricitate* - C.O.N.E.L. S.A.). The personnel of the company Hidroconstructia S.A. at the workers village of Tomeasa was not warned in order to be able to organise properly the defence against the effects of the intense rainfall. They were therefore taken by surprise, as it was revealed in the later “Report regarding the dangerous meteorological phenomena recorded in the area of Retezat Mountains and the way in which were applied the provisions of the Ordinance No. 47/1994 regarding the defence against the disasters, approved through the Law No. 124/1995”, issued on 26 July 1999 by the Control Department of the Government.

During heavy rainfall periods, when the major watercourses can produce floods by over-spilling, affecting extensive areas of the country, the Central Commission for Defence Against Floods, Dangerous Hydrometeorological Phenomena and Accidents at the Hydrotechnical Works (CCAI) can be called in extraordinary meetings and establish the set of measures for reducing the effects of the floods. In such a situation as that in the summer of 1999, when the flood event was produced during just few hours and on small areas, the technical duties of this Commission included the supervision of the transmission of the forecasting and hydrological warnings to the county commissions for defence against floods, the operation of the hydrotechnical works regarding flood protection measures and the information to the media both about the events occurred and the measures undertaken by the county commissions for defence against the disasters (CJAID-uri).

Lessons learnt

- Weather forecasts for small areas are difficult to carry out with the inadequate and insufficient meteorological network currently available in the country.
- The covering of the national territory with Doppler type meteorological radar is being now undertaken. This is considered the best technology for detecting, identifying and monitoring severe meteorological phenomena, and also to anticipate and precisely locate both the place and time of a storm with risk of destruction and human losses. Their use is very important for early warning and alerting in order to increase the safety of the population.

6.4 Response actions and related lessons learnt

On 12 July 1999 at 08:00 hrs, the Director of the company Hidroconstructia S.A. Raul Mare informed the prefect of the county of Hunedoara by telephone that in the area of the Gura Apelor–Retezat dam, a great catastrophe took place because of high floods, destroying one of the buildings where the company's employees lived and blocking the road connecting the Gura Apelor dam with the locality of Rau de Mori (the first locality situated some 25 km downstream) in several locations.

Immediately afterwards, the Permanent Technical Secretariat of the Hunedoara county commission of defence against the disaster was gathered. The Secretariat decided to send leading staff of the institutions dealing with disaster management to the disaster area in order to get information and take urgent measures. Also the Directorate of Public Health was requested to send medical assistance with ambulances to the affected area, including also the workers village of Brazi, at the entrance in the defile of the Raul Mare river. The Government's Department for Local Public Administration (*Departamentul Administratiei Publice a Guvernului*) was informed by telephone about the disaster.

The company Hidroelectrica SA took action with bulldozers, excavators, and trucks in order to clear the access road to the dam.

The real situation in the disaster area was not realised until 14:00, when the last blockage of the access road, located at 5-km distance from the dam, was reached. Until then, no connection with the isolated workers village of Tomeasa could be established either by telephone or radio. In the afternoon of 12 July 1999 the disaster area was visited, among other authorities, by the Prefect of the Hunedoara county and the Director of the Romanian Waters National Company, which requested urgent measures for food and water supply, as well as the mobilisation of Army troops and personnel from the Ministry of Interior to clear up rubble and debris and search for missing persons.

At 15:00 hrs 4 helicopters and 10 ambulances evacuated 22 people, including one injured and one deceased. Over 30 homeless people were sheltered into a forest hut and the National Forests Administration and the “Romanian Waters” National Company ensured them the necessary food supply. This company also offered 5 tones of diesel for the clearance equipment working in the affected area.

During the flood event prior to the Tomeasa mudflow, the defence commandment of CONEL- Hydropower plant, Hateg branch, acted according to their own warning and alarm Plan in case of accident at the dam, taking the following actions:

- Dumping of the high flood in the Gura Apelor reservoir in order to protect the downstream area of the dam.
- The transition of the water flow through the downstream reservoirs of Ostrovul Mic, Paclisa and Hateg in safety conditions until the discharge in the main watercourse, the Strei river.
- Limitation of flooding of the unprotected watercourse of the Raul Mare river, downstream of the Gura Raului dam.
- Maintenance of the continue radio connection with the Civil Protection Commandment of the Hunedoara county, the County Commission for Defence Against Disasters (CJAID) Hunedoara and the local commissions for defence against the disaster from the downstream villages of the area. The localities of Hateg and Rau de Mori were thus warned of the effects of the possible high floods downstream of the Gura Raului dam.

As a result of the above measures in order to limit the effects of the flooding of the Raul Mare river, there was no flooding downstream of the Gura Apelor reservoir. Therefore villages in that area did not need to be evacuated. Just in the outskirts of Hateg 90 ha of agricultural land were flooded.

Since the disaster was caused by a landslide, the Ministry of Public Works and Territorial Planning (*Minsterul Lucrarilor Publice si Amenajarii Teritorului* - MLPAT) issued the Order No. 43/12 July 1999, by which an operative group was formed at the level of the Ministry, which was co-ordinated by the State Secretary.

Because of the dimension of the disaster the Permanent Technical Secretariat of the CCAI took the decision to propose the President of this commission to call an extraordinary meeting.

After the disaster the workers village of Tomeasa received donations for the affected persons. In addition, on 15 July 1999 the Ambassador of the Netherlands to Romania put at the disposal of the Hunedoara prefecture the sum of US$ 250,000.

Also the Public Health Directorate of the Hunedoara County (*Directia de Sanatate Publica a Judetului Hunedoara*) launched a vaccination campaign against tetanus, type A viral hepatitis and typhoid fever for the homeless from the affected workers village.

Lessons learnt

- It is necessary to establish agreements with specialised transport units (especially by air), for rapid and efficient intervention in case of disasters. These units have to take actions according to some pre-established programmes and scenarios, in order to be sent immediately to the requested locations by the county commissions for defence against disasters.
- It is necessary to complete the current installation of the warning - alert systems for the population located in the areas at high risk from disasters. The system should be capable to be activated only by qualified personnel.

6.5 Dissemination of information to the public and related lessons learnt

No information was provided prior to the disaster. Because of the lack of telephones and radio stations, Tomeasa area remained isolated after the disaster from 04:45 to 14:00, when the rescue teams arrived.

There was no malfunctioning of the information flow with the local commissions of the downstream localities near the entrance of the defile of the Raul Mare river.

The presidents of the local commissions informed the County Commission of Defence Against Disasters, including the Water Management System (*Sistemul de Gospodarire a Apelor Deva* - SGA) appropriately and in due time, as well as all competent bodies (the Central Commission from Bucharest, County Commission of disasters, the Civil Protection Inspectorates, the media, etc.).

During this event the local commissions assured the permanent activity for the afternoon and evening, including Saturday and Sunday.

The County Commission for Defence Against Floods Hunedoara, through the information centre of the Water Management System (SGA Deva), assured the connection with the local commissions. The transmission from the County Commission to the Central Commission for Defence Against Disasters at Bucharest was done by fax and telephone.

The day of the disaster, the first information received at the Permanent Technical Secretariat of the Central Commission for Defence Against Floods, Dangerous Hydrometeorological Phenomena and Accidents at the Hydrotechnical Works (CCAI) from the County Commission for Defence Against Disasters of the Hunedoara County, was received just at 10:54. It announced that a small landslide (a different one) had blocked the road between the workers village of Brazi (located at the entrance of the Raul Mare river defile) and the Gura Apelor dam. At 15:00 the same commission transmitted a more precise report, informing about the decease of 15 persons and the real dimension of the landslide disaster.

Lessons learnt

- It is necessary to implement a permanent telephone and radio connection system between the public from different isolated facilities or offices of the same commercial company and their own commission for defence against disasters, as well as any connection with the other commissions of the local or county administrations.

It must be taken into account that in the rural areas telephone connections are maintained just by the communal telephone switchboard, which ends up its activities at 16:00 and does not work during the weekends.

6.6 Socio-economic implications of the disaster

In order to prevent and attenuate the effects of natural disasters, as in the case of landslides and floods, it is necessary to take some measures to limit the socio-economic impact, which have to include:

- Delimitation of all the areas where building is prohibited in the documentation of urbanism and planning (cf. PUG above).
- Obligation to carry out geological surveys, including laboratory and in situ geotechnical tests, in order to know the properties of the soil and bedrock of the populated areas and areas with a socio-economic activity.
- Implementation of special building rules, which have to take into account the existence of natural hazards in the area (Ministry of Waters and Environmental Protection and Ministry of Public Works, Transport and Housing, 2001).
- Measures for prevention and reduction of natural risks have also to be implemented. These have to include:
  - Maintenance of the equipment and works for protection from and mitigation of natural disasters.
  - Control of the degree of land occupation and the completion of the specific land use and building plans.
  - Information to the population regarding the potential risks specific to their respective area.

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7. The 11 August 2000 landslide disaster in the "Dvarcionys" plant site, Vilnius, Lithuania

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7.1 Description of the event and consequences

Lithuania is a country of plains; its highest altitude is only 292 m above sea level. This is reached at the Juozapines hill, near Medininkai, in the Vilnius region, in the Eastern part of the country, while the Medvegalis hill, whose height is 230 m, is situated in the Western part of the country. Therefore, events such as landslides are not very common and they do not result in major losses (e.g. death of people or destruction of houses or villages, etc.). However, during the Ice Age, when ice cover was crossing the territory of Lithuania, big ravines and gullies were formed in some regions. Thus, in some areas riversides are high, and steep slopes can be found there. During this time, some hills and hilly areas have formed and people started to settle in these areas, where farming and other human activities began to influence the disasters.

If a landslide occurs in uninhabited areas, it might not be recorded and only a few scientists may know about it. Therefore such an event does not have influence on people's lives and property. However, landslides are recorded and investigations are carried out if they affect towns or other built-up areas, or if they cause big material losses. In hilly areas, if there are some construction or similar activities, some geological surveys are made, but not everywhere. These investigations are very costly; they are not ordered before constructing on in order to save money.

After the Second World War, about 100 landslides causing some losses were investigated in Lithuania. The investigations were carried out trying to get knowledge about the causes of a landslide, in order to gain experience for the future so that such disasters would not cause large losses. After 1990, 22 landslides were recorded in the country. Some of them were not large: one occurred in 1998 in the city of Kaunas; it involved some 45 m^3 of soil and slightly damaged only one economy house. Some of them were bigger, like the one on the Kaunas – Marijampole road in 1994, when 20,000 m^3 of soil slid down on the road. The costs incurred in rebuilding the slope and road were over € 145,000. The last and biggest landslide disaster in Lithuania occurred on 11 August 2000 in the capital city of Vilnius.

The August 2000 landslide disaster

On 11 August 2000 at 22.25 hrs, the guard of the Joint Stock plant "Dvarcioniu keramika", which produces wall and floor ceramic tiles, noticed that two storehouses for keeping the production of the company had crashed and fell down the precipice, together with about 80,000 m^3 of soil, to the valley of Dvarcios creek. The landslide affected an area of 7,200 m^2, 2,150 m^2 of which belonged to the plant site, covered with asphalt and including the rain sewerage. The landslide destroyed two storehouses: an underground oil collection system (738 m^2 and 432 m^2), a 132 m long section of the rain sewerage system, a 135 m long technical water underground system, a 220 m long underground heating route with a concrete chute, the plant fence and an artificial slope. It also blocked the Dvarcios creek and valley by a dam of debris and mud 3-4 m high. Also, this landslide destroyed 110,874 m^2 of the tiles produced by the company (Fig. 7.1 and 7.2).

Figure 7.1 Landslide head scarp and destroyed storehouses

Figure 7.2 Partial view of the landslide head scarp

This landslide took place in Ašmenos, a hilly area in Vilnius, which is characterised by ravines and gullies. In this area, some hills are over 20 m high, while the absolute height of the area ranges from 143 to 166 m. The exposition of the landslide slope was to the northeast. The landslide was 285 m long and 10 to 15 m high; the slope angle was 30-32^0. This artificial slope was built 20 years ago in order to enlarge the plant site.

The company was established in this site 115 years ago. Ever since ground works were carried out. It is worth mentioning that until 1960 the clay for the production of bricks was taken from this region.

In an aerial photograph of 1952 it could be seen that there was an untouched natural slope at the site where the landslide occurred. In this site, a 10 m deep natural hillside ravine was seen. Later, this ravine was filled with all kinds of soil and production waste, like crushed bricks and tiles, clay whose condition was not good enough for production, gravel, sand and so on. This job was started with a view to enlarging the plant site and finished in 1980. At that time a decision was made to prepare the project and to build a slope, which would be the foundation for storehouses and communication infrastructure of the plant. This was done by the Institute for Design and Industrial Construction, Vilnius branch, in 1981, and was adopted by the Ministry of Building Materials on 30 June 1981 (Order No. 151). The work started in 1981 and finished in 1985. During this period, all communications needed for the plant and one storehouse were built on this artificial slope, and the whole surface was covered with asphalt. The newly built artificial slope was 2.5 m thick. On 18 January 1985, the State Commission for Adoption of Buildings for Use approved the work completed and gave a permit for usage. The Commission had not found any problem.

7.2 Prevention measures and related lessons learnt

Geological and geotechnical surveys were carried out in 1981 and 1985. At that time the ground condition was still good, the groundwater level was 143.2–150.8 m (according to the absolute height scale), but when measures were made after the disaster, groundwater levels were 149,5 - 151,8 m, meaning that the level had raised 1.0–6.3 m. One of the reasons why the groundwater level at the moment of disaster was very high, is that the summer was very rainy: in July the monthly rainfall was 209 mm, 2.6 times more than average.

The landslide caused big material losses because the company had tried to save some money on the expenses of a timely geological survey. The administration and the owners of the company, in turn, have called this event a natural calamity and an ecological catastrophe.

Lessons learnt

- Geological specialists did not agree with the assertion that the disaster was a natural calamity. According to the Director of the Lithuanian Geological Survey, if all geological and geotechnical conditions had been ascertained and a geological survey had been done at a proper time, the disaster could have been prevented. There was an artificial slope at the site where the storehouses and the underground communications were built, and the soil condition was not as good as natural.
- A lot of landslide disasters could be prevented if owners of buildings and companies showed geological specialists the real purposes.

7.3 Preparedness measures

An emergency plan was prepared and adopted for the “Dvarcioniu keramika” plant site according to the Civil Protection Law, which was approved by the competent authorities. This document was prepared taking into account all emergency situations and the methods and processes of production, whereby very high temperatures are reached and dangerous materials are used. Other emergencies which can take place during production were also considered and an action plan for such emergency situations was prepared, so everybody would know what to do if such situations occurred.

But in this case nobody was thinking about a landslide disaster. The ravine had already been started to be filled with various soil and building waste long time ago. The artificial slope, which was built 20 years ago, was overgrown with bushes and trees, and looked like a natural slope. Young people born in this place did not know that this slope was artificial, and the older people said that if somebody earlier said that this slope would go down they would merely laugh.

7.4 Response actions and related lessons learnt

All responsible services received the information about the landslide disaster in the Dvarcionys company very soon after the disaster, but it was decided not to do any works during the night because it was dangerous. One of the production lines was stopped immediately, and all workers were evacuated. The landslide area was delimited by fences and it started to be guarded.

The morning after, all needed actions for saving other buildings, the production and the environment were taken. First, oil products from the underground oil storage near the landslide were pumped to the road tankers and moved away to a safe distance. Production from the site of the disaster was also moved to other storage houses of the plant. The landslide dammed the Dvarcios creek and the water level rose in the valley dangerously. After consultations with the specialists, a temporary channel was built to drain the creek.

The same day, a commission was formed through an order of the County Governor to identify the causes of the landslide. This Commission started working immediately. After an investigation, the Commission came to the conclusion that the cause of the disaster was the very high ground water concentrated in the artificial slope Another conclusion was that there were no violations of exploitation orders.

Geological specialists, after investigations, came to the conclusion that the ravine was filled with soil without a project design and was not in accordance with the construction norms. There was no drainage bed, soil layers were not thickened and the slope was covered with waterproof clay, but this had not been done taking into account stability issues. Although the slope had been built 20 years ago, geological surveys were not done until the landslide disaster. There is a reason to believe that the groundwater in the slope came to a critical level and the effect was the landslide. Specialists have recommended to investigate all the sites in the area where there is landslide danger and to rebuild the slope according to all geological and building norms. This includes constructing a drainage bed under the slope, stabilising the soil by means of a concrete wall with anchors and piles, reinforcing the soil using a geo-textile net and arranging the installation for groundwater level observation. The same recommendations were distributed to all state-owned companies.

Lessons learnt

- The landslide disaster showed that all responsible people of the company, all competent authorities and services were informed very quickly. The line of production, which was operating near the site of the disaster, was stopped immediately and the workers were evacuated from the dangerous area. The site was fenced, guards started to preserve the plant site and police forces guarded the landslide area.

7.5 Dissemination of information to the public

The day after the disaster, all press, radio and television stations informed about the greatest landslide disaster in the history of the country. Everybody was talking about big material losses, but they abstained from comments and suppositions about the cause of the landslide.

7.6 Socio-economic implications

This landslide disaster has brought the company very big material losses: only the production losses were estimated to be over € 1 million. The costs of the response actions were also very high. To recover the area affected by the landslide, the company had to build a road to the valley where the landslide occurred, to make a new creek bed, to rebuild the slope and to perform many other expensive works.

Such big material losses were incurred because a long time ago the company tried to save some money on the expenses of a geological survey. In addition, the company was not insured against geological hazards.

The administration and the owners of the company have called this phenomenon a disaster, a natural calamity and an ecological catastrophe, and started to make steps towards receiving some funds from the government, because the company was not insured against geological hazards.

Lessons learnt

- Saving money by not conducting geological-geotechnical surveys and by violations of geological, building, environmental and other orders can result in very big material losses. It was a sheer luck that no people were killed or injured in this disaster, and that the landslide had occurred during the night, so the destroyed storehouses were empty.

7.7 Concluding remarks

The natural slope was not involved in the landslide, only the artificial slope was destroyed.

The Lithuanian Geological Survey provided an independent evaluation of this disaster. The conclusion was that the disaster was not a natural calamity, but an accident which took place because of violation of norms during designing and building.

After this disaster, some proposals by competent authorities were issued regarding the need to carry out geological and hydrogeological surveys during the design and building phases.

PART II

Other Experiences in Landslide Disaster Management

8. The case study of Les Ruines de Séchilienne landslide, France: Crisis management

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8.1 Introduction

Because of both the large extent and the incurred risks, the lessons learnt so far from the management of the crisis and the public information policy related to the "Les Ruines de Séchilienne" slope instability constitute a characteristic element to be taken into account in the comparison with other experiments in Europe.

Landslides constitute a violent gravitational adaptation of a natural environment subjected to various factors (edaphic, climatic and paleo-climatic, geological, tectonic, morphological and vegetational).

- Morphological: a slope has to exist for a landslide to occur. On flat areas, this natural phenomenon does not exist.
- Geological: the nature of the ground materials determines the occurrence of the phenomenon: a marly formation reacts differently from an ice-weathered sandstone or a massive and unfractured granite.
- Climatic: the climatic elements, in particular the rainy sequences, often constitute the landslide triggering factor (in a permafrost soil there is no sliding, in the same way as in an arid climate). The historical knowledge of the evolution of the climate over a long period also provides data of interest to the current behaviour of a slope.
- Vegetation: the nature and the areal extent of the vegetation cover of a slope often determine its stability. For example, an excessive deforestation has often resulted in a landslide.
- Edaphic: the climate-morphology-geology association induces the growth of vegetation, which in turns leads to a pedogenesis that is not neutral with respect to mass movements (e.g. a brown forest soil behaves differently from a rendzina or a gley). Acid soils (with PH < 6) are particularly unstable.

Landslides can also be triggered by an earthquake, but this is not our case here. Other more or less man-made factors can intervene in the release of these phenomena (e.g. reactivation of river course erosion, river channelling, road and railroad cuttings, mine works, extraction of aggregates, terracing of agricultural land, etc.), but they are generally marginal and localised.

Finally, if the causes and the mechanisms are recurrent, the consideration of the scale of the phenomenon often determines the difference between a natural disaster and a ground micro accident (e.g. solifluction in grazed land does not have obviously the same consequences as a landslide affecting an entire slope).

If the slope movements are frequent, their size can give them a particularly destructive character. France, as all the countries with periglacial climate, is familiar with this kind of phenomenon.

The example of the possibility of a collapse of Les Ruines de Séchilienne (Isère Department, France) is of such a relevance that it will be discussed in the following sections.

8.2 Description of the event

The size of the moving mass involved at Les Ruines de Séchilienne site (between 3 and 40 million m^3), which presages a foreseen, inevitable disaster in a few days, a few months or a few years, deserves a detailed description as follows.

8.2.1 Site location

The area known as Les Ruines de Séchilienne is located approximately 20 km south of Grenoble, between the communes of Vizille and Séchilienne (Fig. 8.1). It is limited to the south by the generally west-east oriented national road (*route national*, RN) 91 at the bottom of the valley of the Romanche River. This axis, which connects Grenoble to Briançon and enables to access Italy by the Col de Montgenèvre, has a particular importance:

- It is the only access road to the Oisans Massif from the north. Its obstruction would oblige the vehicles to carry out a detour of nearly 200 km, while passing over the Col de Lautaret at more than 2000 m of altitude.
- In addition, this road provides access to a number of ski resorts (e.g. L'Alpe d'Huez, Les Deux Alps, etc) and the Vénéon Valley, having thus an obvious economic importance (8,500 vehicles/day annually, much more in winter, as it is in permanent growth).

Lastly, two communes, Séchilienne and Saint Barthélémy de Séchilienne, as well as the hamlet of l'lle Falcon, are directly threatened by both the impounded area upstream of the possible natural dam and the air blast effect in the event of a catastrophic rock mass collapse. In addition, the eventual wash out of this dam would seriously endanger the nearest towns downstream as well as the chemical industries between Vizille and Pont-de-Claix (Antoine *et al*., 1994).

8.2.2 Geological setting

The geology of the area is mainly represented by a series of micaschists of Westphalian (Carboniferous) age, locally overlain by Keuper (Triassic) limestone. On the surface, glacial deposits of the Würm I and Würm II periods (from less than 90,000 to less than 10,000 years of age) locally appear.

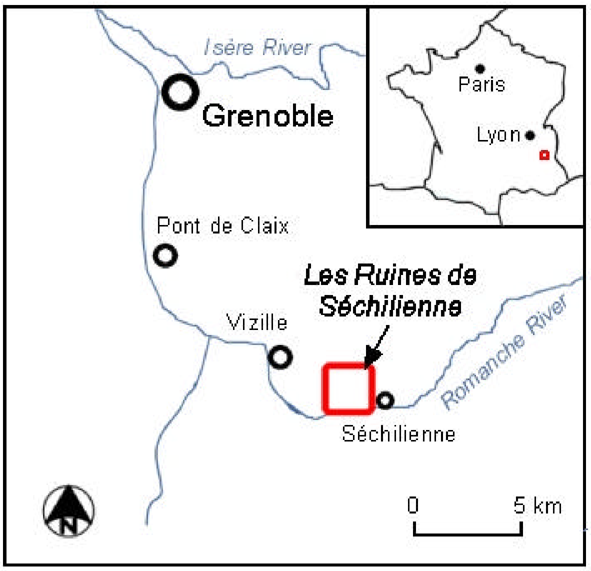

Figure 8.1 Location of Les Ruines de Séchilienne landslide

The unstable slope has an elevation difference of 800 m and an inclination of 45º (Fig. 8.2). In this area the rock formations are split up by major fractures, provoking numerous internal displacements evidenced by very marked depressions in the morphology of the slope (Fig. 8.3). If an image had to be given, we could say that there are many rock blocks of some tons to some hundred tons floating in a kind of detritic moraine generated by the grinding of the rocks due to tectonic faulting. The consistency of this "gangue" is thus directly related to the water content of the ground. There is a very significant water flow and a rise of the pore water pressures. Therefore gravitational movements slowly develop.

Figure 8.2 View of the central and lower part of the unstable slope at Les Ruines de Séchilienne. The lighter area corresponds to shallow movements (topples and rockfalls). The Romanche River and the diverted road are apparent at the bottom

Figure 8.3 Closer view of the shallow movements shown in the previous figure. The irregular morphology of the slope reflects however deeper deformation in the rock massif

8.2.3 Paleo-climatic and climatic geomorphological evolution

Taking into account the historical evolution of this slope, this should have already reached equilibrium. It is the reactivation of the erosion caused by the existence of glaciers during the Riss period, and especially during the Würm, that made it possible for the slope to regain all its dynamics. In fact, the existence of glaciers during several thousands of years has caused a deepening of the valley and a considerable pressure on its sides.

In spite of the disappearance of the glaciers approximately 10,000 years ago, side decompression still continues nowadays. Also, the equilibrium limit of the unstable mass, which directly threatens the two above-mentioned communes, seems reached today.

The volumes involved in the landslide would exceed several million m^3. Uncertainties however remain, as the zone of rupture is badly known. The evaluation of this crucial data would require very precise surveys with the aid of deep boreholes.

8.2.4 Landslide case histories in the Alps

Regarding recent history, numerous rock mass movements have marked the past of the valley of the Romanche River as follows:

- At the exit of the village of Riouperoux, huge blocks border the RN 91 road, witnessing the extraordinary rock mass originating from the rockfall of the summit of Aiguille.
- The site of Petite Vaudaine, classified for a long time as a risk area that was subject to many rockfalls. The most important, in 1191, dammed the Romanche River producing a water flow retention that eventually flooded the plain of Bourgh-d'Oisans downstream.
- Other rockfalls and rock avalanches were noted in 1415, 1465, 1617, 1666, etc. In 1219 at Vaudaine, the natural dam collapsed producing the drawdown of the lake, causing approximately 30,000 fatalities.
- A similar case can be found in the 28 July 1987 Val Pola landslide, in the valley of the Adda River, in Valtellina, Italy (Azzoni *et al.*, 1992).

8.2.5 Monitoring of the Séchilienne landslide activity

The phenomenon is latent since the glacial age. The old aerial photographs of 1937, and 1943, amongst others, show a narrow and little active talus cone. Since 1984-1985, an increase of the rockfalls has been noticed during the winter following a long rainy period. The first studies launched at that time highlight the development of a failure mechanism.

Since then, some large fractures opened several metres, whilst others opened a few tens of centimetres. The whole slope is fractured and gradually the landscape changes and becomes chaotic. This phenomenon is little noticeable from the bottom of the valley, which leaves the inhabitants and people in general sceptical and badly informed. Three sensors show fractures which opened 2.7 m, 1.2 m and 60 cm respectively, between 1985 and 1993.

In 1992 an extensometer measured an opening of 25.4 cm between mid-November and mid-December. In 1995, following heavy rainfall, openings of 5 to 6.5 cm/month were measured. For the entire 1998, following both heavy rainfall and snowmelt, a total displacement of 40 to 50 cm was recorded. These two factors produced a new acceleration in 1999. Ever since the speed has stabilised to a few centimetres per year.

Nevertheless, the disintegration of the accumulation zone of the landslide tends to accelerate and the slope thus becomes more vulnerable to bad weather conditions or to an earthquake of medium intensity.

For the internal reconnaissance of the massif there exists 3 galleries: a 240 m long and a 90 m long mine gallery at 585 m and 900 m of altitude respectively, and a 240 m long reconnaissance gallery at an altitude of 710 m.

8.3 The French management approach to the case of Séchilienne

This story of an announced disaster follows three essential aspects: Monitoring the evolution of the phenomenon, the prevention policy and the communication strategy.

8.3.1 Landslide monitoring

The monitoring network, set up since 1985, has been completed in several phases according to the increase of awareness of the importance of the phenomenon and the introduction of more and more sophisticated equipment. This network entails:

a) A topometric survey:

- A topometric survey using 39 benchmarks. The control of the different points is carried out once annually.
- Monitoring of targets located in the active zone using GPS (13 targets measured once per year).
- Surface manual extensometric measurements, enabling to monitor the opening of the fractures with a precision of about ± 0.2 mm. 49 extensometric baselines cover the sector; they are measured every 3 months.

b) A survey by periodic monitoring of reconnaissance and mine galleries

60 extensometric and topometric benchmarks have been placed in several galleries. It is thus possible to monitor the evolution of the fractures and to determine the movements in the core of the massif.

c) Two remote monitoring systems

- Automated extensometric devices with a controlled pulley: this system returns information to the people in charge at the Centre for Equipment Technical Studies (*Centre d'Etude Technique de l'Equipement,* CETE) of Lyon using the terminal at the village of Thiébauds, near the unstable zone. Measurements are carried out every hour, but this time can be reduced to 15 minutes during periods of crisis.
- An automatic geodetic station, which enables to monitor since mid-July 1996 31 benchmarks, in particular in the inaccessible sectors.
- The installation of a radar, operational since 2001, designed by ONERA (National Office for Aerospace Studies and Research - *Office National d'Etude et de Recherche Aérospatial*) of Toulouse. This system allows all-time (night, fog) continuous monitoring of the entire unstable slope (100 ha).

This system is completed by a meteorological station installed at the top of the 1,125 m high Mont Sec (above the landslide). This makes it possible to determine the amount of water infiltrated in the ground. The whole system enables an alert notice of 72 hours to several days.

Some have thus stated that this is considered to be the most monitored mountain in France.

8.3.2 Prevention policy

The prevention policy is based on the various possible failure scenarios. Such scenarios are defined, based on the numerous studies carried out, including geological, hydrological and hydrogeological and geodetic studies.

The conclusions of experts have evolved according to the advancement of knowledge. The "Panet" report (Panet *et al*., 2000) is currently regarded as description of the most likely scenarios in the near future and beyond.

Possible scenarios of slope failure

The data provided for 15 years by the various studies and the monitoring of the unstable slope makes it possible in general to consider the following scenarios:

a) Very short and short term foreseen scenarios

- The most obvious scenario for the very short and short term is the continuation of what was observed along centuries on the site of Les Ruines de Séchilienne, namely rock mass failures by toppling, not exceeding a volume of a few hundred to a few thousand m^3. The blocks would follow the corridor of the "ruins", reaching the old national road in the valley. The current movements show that such rockfalls are likely in the very short term.
- The collapse of the whole active zone, including its possible extension to the southwest, while the extension to the southeast is also a foreseeable short-term scenario (Fig. 8.4). There are no elements that enable to clearly identify a surface of rupture, but the continuation of the flexion and compression movements can lead to a massive rock avalanche. Its volume could then be estimated to be between 2.2 and 2.6 million m^3.

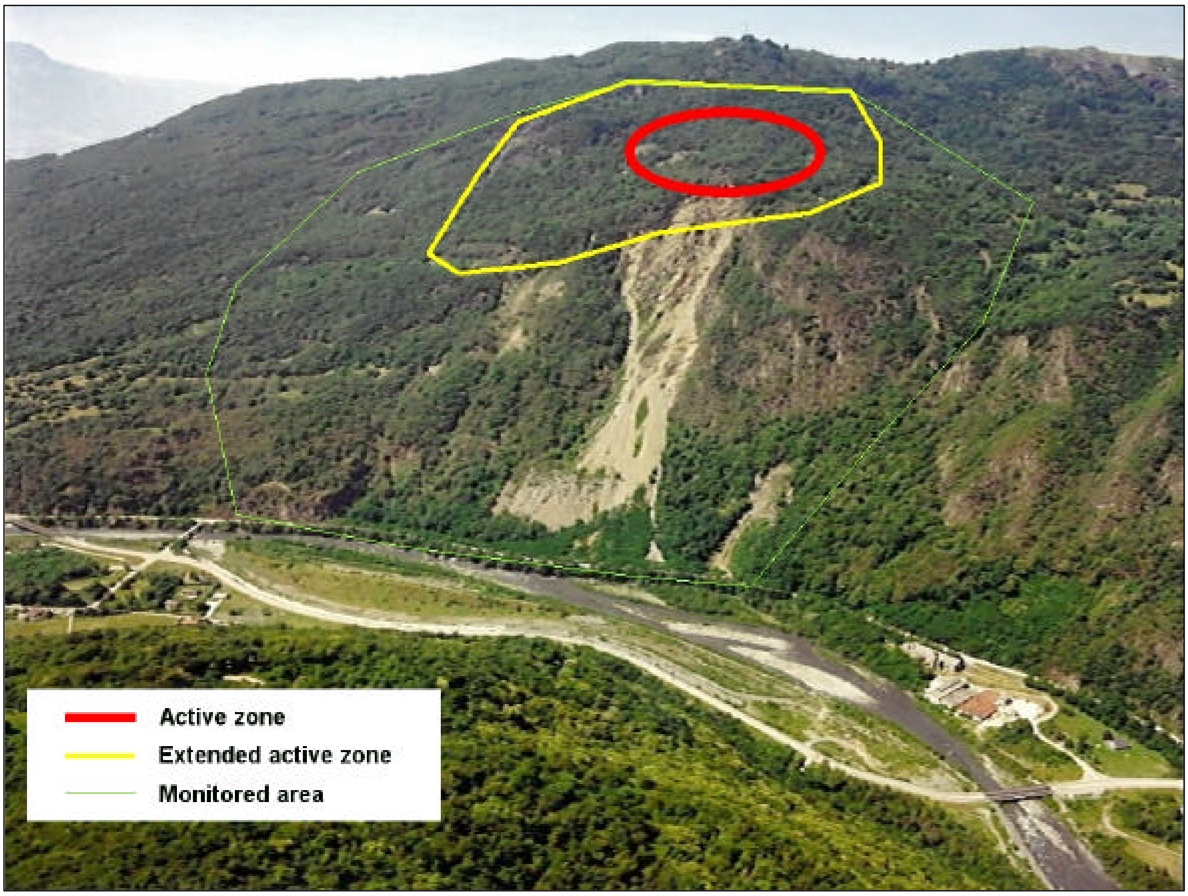

Figure 8.4 Zones considered in future catastrophic mass failure scenarios at Les Ruines de Séchilienne

b) Mid and long term possible scenarios

From the analysis of all the data available over the site the occurrence of other envisaged scenarios leading to rockfall or avalanche volumes of 20 to 50 million m^3 is considered very unlikely. This estimation is based on the following:

- It has not been possible to identify the start of a generalised failure surface.
- The displacements measured outside the active zone can at best be interpreted as settlements and deep deformation movements.
- The amplitude of the displacements measured during 15 years is for some experts too low for a large collapse to occur.

Lastly, it should be noted that the site is classified within seismic zone Ib. This means that:

- The return period of an earthquake of intensity VI is 50 to 100 years.
- The return period of an earthquake of intensity VII is 100 to 250 years.
- The return period of an earthquake of intensity VIII is 250 to 700 years

Prevention measures considered and not selected

- Controlled demolition of the mountain: At the rate of 20,000 tons/day, it would be necessary 10 years to complete it. In addition, factors such as providing areas for storage, transportation problems, use of explosives, cost, evacuation of the population during works, etc, should also be taken into account.
- Covering the Romanche River: Regardless of the thickness of the cover, nothing would resist an avalanche of 20 million m^3. In addition, the potential flood flow of the Romanche River can exceed 800 m^3/second.
- Pumping of water upstream: The capacity of pumping on floating raft is 10 m^3/second and the power needed is 6000 to 8000 KVA. This would be completely useless in the event of a flood caused by Romanche River.

Prevention measures selected and carried out so far

- Move of the RN 91 to the other side of the valley along a 1,500 m stretch.
- Building of a 200 m long continuous structure at the toe of the slope, including a retention basin, a 5 m high wall to stop fallen blocks, and a system for detection of rockfalls on the top of the wall connected to automatic traffic lights and barriers on the national road (low assumption).
- Creation of a diversion channel for the Romanche River also protected by an earth wall.
- Expropriation of 90 houses exposed to major risks.
- Construction of a gallery for diversion of the Romanche River, allowing a flow of approximately 50 m^3/second.
- Carrying out the emergency plans (*plan de securité et secours*, PSS) of Séchilienne and Saint Barthélémy, which is currently being adapted to the scenarios in the “Panet” report. The principle of these plans is described in detail in a widely distributed special issue of the “Prisme” journal (Préfecture de l'Isère, 2001)

The principle of the emergency planning has been addressed since the beginning of the "crisis" with the continuous evolution of the risk assessment.

Measures recommended by the experts' report

- Maintenance of the monitoring of the slope in order to follow the evolution of the deformations and to detect as soon as possible the possible changes of behaviour which could produce deformations leading to a dangerous situation.
- In the same line, extending the monitoring to certain zones of possible enlargement of the subsidence phenomena.
- Continuing the excavation of the reconnaissance gallery so as to get a better understanding of the internal fracture zones.
- Completing the knowledge of the geomechanical properties of the whole massif.
- Approaching Italian specialists who have a good knowledge of microseismic monitoring of slope deformations.
- Comparing the "Séchilienne" experience with others in the whole Alpine chain.

The alert plan

This plan is based on four situations as follows:

- The normal situation.
- The situation of vigilance.
- The situation of reinforced vigilance.
- The alert.

When the surface displacement recorded on the site reaches 3 mm/day, the CETE of Lyon is put in a state of alert, i.e. the behaviour of the massif is particularly monitored (state of vigilance). The displacement is connected with the climatic conditions that define a situation as "normal" or not. If it reaches 10 mm/day, the authorities (prefecture, DDE**,** etc) are informed. The authorities are responsible for activating the alert based on the evolution of the situation. The alert is here defined as lead time of 3 days, which enables to organise the evacuation of the zones at risk.

8.3.3 Communication strategy

The elected authorities require all the truth on the incurred risks, which is legitimate, but at the same time request that the population does not panic.

It is also important to maintain a "culture of risk" in the medium and long term within the framework of an "announced" disaster, but whose reality vanishes between two more or less long periods of paroxysm.

The extent of the threat and the considerable potential consequences (e.g. loss of human lives, economic disaster, risk of pollution, etc) raise the question of the scale of the management of such a crisis.

Communication difficulties

- The time factor represents one of the main difficulties: in 18 years most of the crisis stakeholders have changed (e.g. elected authorities, various services, population, etc).

- The difficulty of a simple explanation for a complex phenomenon leads to a feeling of lack of information.
- The evolving notion of the risk for the population concerned as well as for the elected officials.

Dangers

- Underestimation: The danger must always be taken into account.
- Overestimation: Fear of the persons in charge to be caught unprepared.

Concertation bodies

The role of The Local Commission of Analysis and Information of Les Ruines de Séchilienne (*Commission Locale D'analyse et D'information des Ruines de Séchilienne,* CLAIRS), which meets at least twice per year or upon request.

Information channels

- In normal periods the information role corresponds to the technicians (monthly report by the CETE, in particular to the local authorities).
- In the event of a crisis, the technicians hand over the information tasks to the institutional authorities (prefect and elected officials).
- A background document: "Prism".
- The role of the Media, including local newspapers, regional television, local radio stations, publications, etc.
- Briefings of the local authorities.

There is a need to ensure a homogeneous message at the level of the Prefect, cabinet director, DDE, SIDPC, etc.

8.4 Main lessons learnt

Based on the long-term management of the Les Ruines de Séchilienne landslide threat several major lessons can be drawn as follows:

- ➢ The management of a risk that exceeds the scale of the normal human capabilities because of both its amplitude (several million m^3) and the time (5, 10, 20 years and more) constitutes a novelty in France when taking into account major risks. It is therefore not easy to establish a general methodology from such an example. These problems are also found in volcanic and seismic risks.
- ➢ Nevertheless, it has been possible to test several approaches (maximalist or minimalist), which have enabled to refine a more general method regarding:
    - → The understanding of the phenomenon.
    - → The monitoring of the zone concerned.
    - → The slow awareness of the real danger to the human environment as well as to the economy.
    - → The need for adapting emergency plans especially for the companies at risk downstream.

Are we therefore today better prepared to manage a major crisis?

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9. Landslide disaster management in the Republic of Bulgaria

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9.1 Description of landslide problems in Bulgaria

The occurrence of landslides in Bulgaria is greatly favoured by widespread rugged relief and high level of seismicity. Landslides are very different in their type and size. There are 960 landslide areas catalogued within the territory of the country, 350 of which are situated in built-up areas and health resorts, and they are spread on a territory of 20,000 ha. (Fig. 9.1).

As a result of landslide processes many engineering structures have been destroyed and considerable damages have been caused to transport, tourism, farming and forestry, as well as to houses and residential buildings.

The most serious landslides in Bulgaria are located on the northern part of the country's seacoast. A “General Plan for the Black Sea coast protection” was projected and developed back from 1984 to1988. According to this plan, the cost of all kinds of structures and other measures and actions were estimated to be approximately € 310 million. Up to 1990 only 25% of this programme was carried out. The following year, Bulgaria started a period of transition in connection with the new political and economic situation. From 1990 to 1993 there were no investments in anti-landslide (i.e. prevention and mitigation) activities at all.

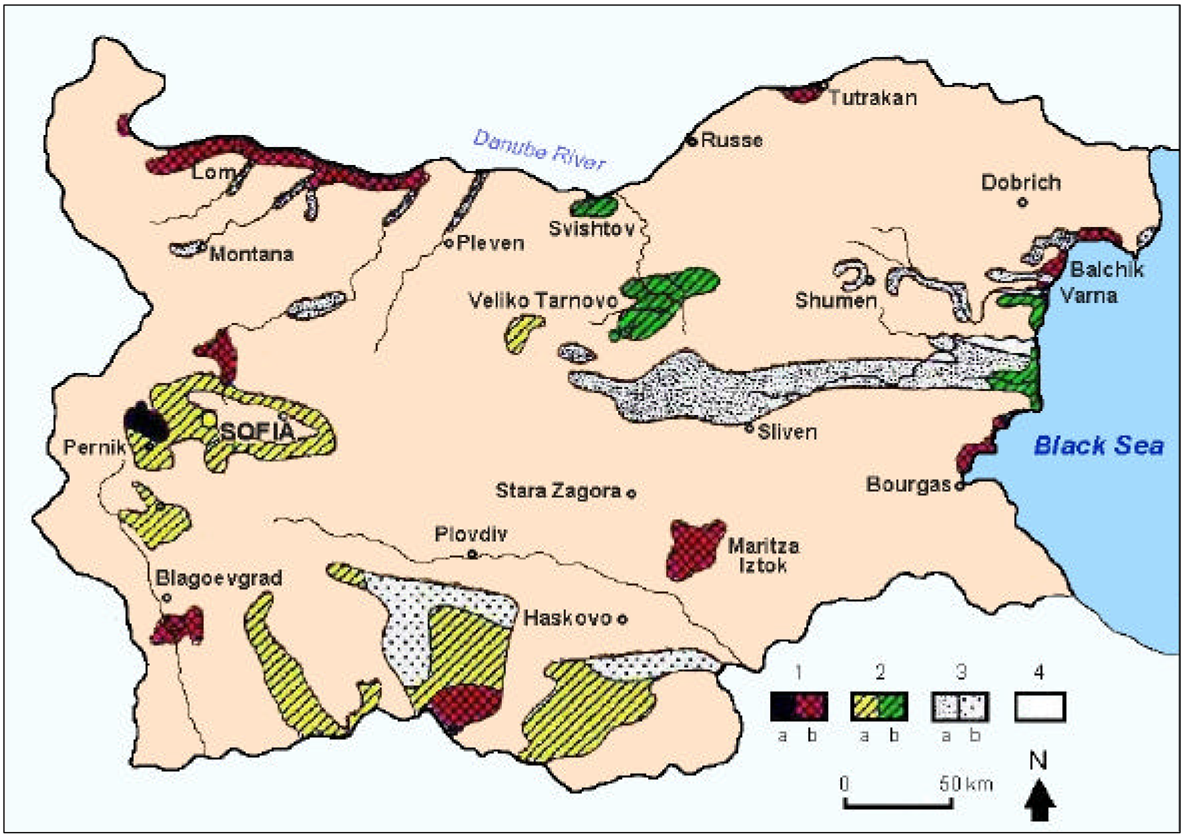

Figure 9.1 Landslide hazard map of the Republic of Bulgaria. Hazard level: 1- High; 2 - Medium; 3 - Low; 4 - Nil. "a" denotes higher level; "b", lower level.

Between May 1993 and February 1997 only some negligible funds from the State budget were allocated for solving landslide problems. They consisted of investments for implementing the most urgent strengthening works and other actions that had the highest priority.

According to the regulations and laws in force in the country, the Bulgarian Ministry of Regional Development and Public Works (*Ministrerstvo na regionalnoto razvitie i blagoustroistvoto*) conducts the State policy in different actions against landslides. These actions are coordinated with other Departments and Regional Governments.

There are three companies managed by the Bulgarian Ministry of Regional Development and Public Works that are concerned with landslide prevention and mitigation activities. These companies, named “Geoprotection”, are administrated in the regional centres of the towns of Varna, Pleven and Pernik. They carry out all activities concerning landslide inventorying and observations, prospecting, planning and implementation of strengthening structures.

Many landslides were triggered in Bulgaria as a result of the unsolved problems concerning landslide prevention activities coupled with late activation of mitigation activities and the March-April 1997 rainfall events. The ratio of the monthly rainfalls to their average amount for this season in some regions was as follows: Varna – 306%; Shabla – 419%; Dobrich – 280%; and for the whole country it was about 180%. The most affected regions were these along the Black Sea coast (Fig. 9.2, 9.3 and 9.4).

Back in 1995 it was ascertained a sudden rise of the groundwater level of 2 to 3 m (and in some places up to 5 m) higher than the normal level in the whole country, but mainly in the Black Sea coast regions. The causes were as follows:

- Intensive urbanisation.
- Construction of many illegal houses and buildings without any drainage system.
- Construction of water supply systems to these buildings, but without planing in advance sewerage for waste waters.
- The old water mains with finished lifetime (more than 25 years), almost 95% of which were made from asbestos-cement pipes, and the existing leaks and other damages to the whole water system.

The above-mentioned causes led to a disaster concerning the stability of the potentially threatened areas.

The landslides started in the spring of 1997. Only in this year the damages caused in built-up areas and resort complexes were estimated at approximately € 6 million. The cost estimate of damages by landslides in three municipalities (Varna, Aksakovo and Balchik) was about € 4 million (cf. Fig. 9.4).

Between 1997 and 1998 funds of approximately € 6.4 million from the “Elemental calamities” section of the State budget were invested in stabilisation of areas affected by landslides. Roughly € 4.8 million of this amount was spent on strengthening works and other important anti-landslide measures, including the most urgent actions (e.g. implementation of some strengthening structures in the shortest period of time after the landslide occurrences and others depending on the case).

In response to this disastrous situation a “National Strategy on landslide problems” was created and developed. The strategy selected the main issues to be solved in the period between 1998 and 2001. The prevention phase was the top priority in this strategy (Chachev, 1998).

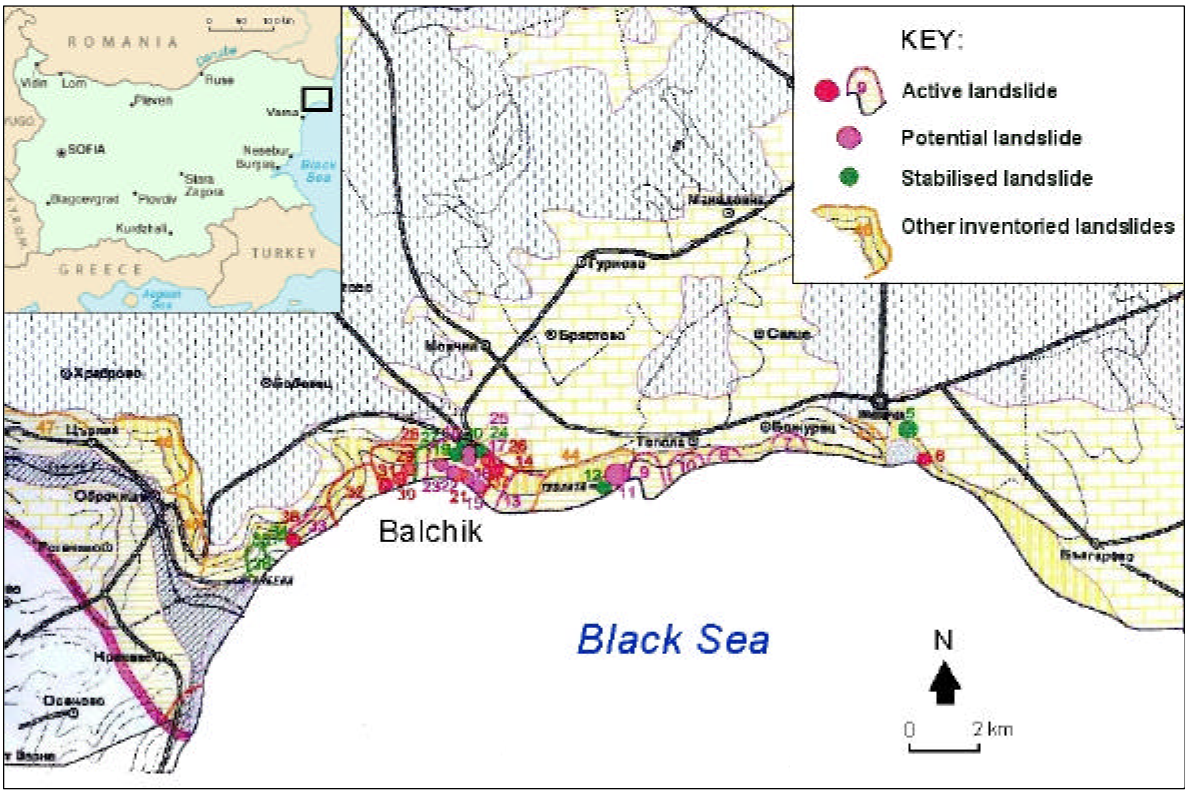

Figure 9.2 Areas most severely affected by landslides along Bulgaria's Black Sea coast

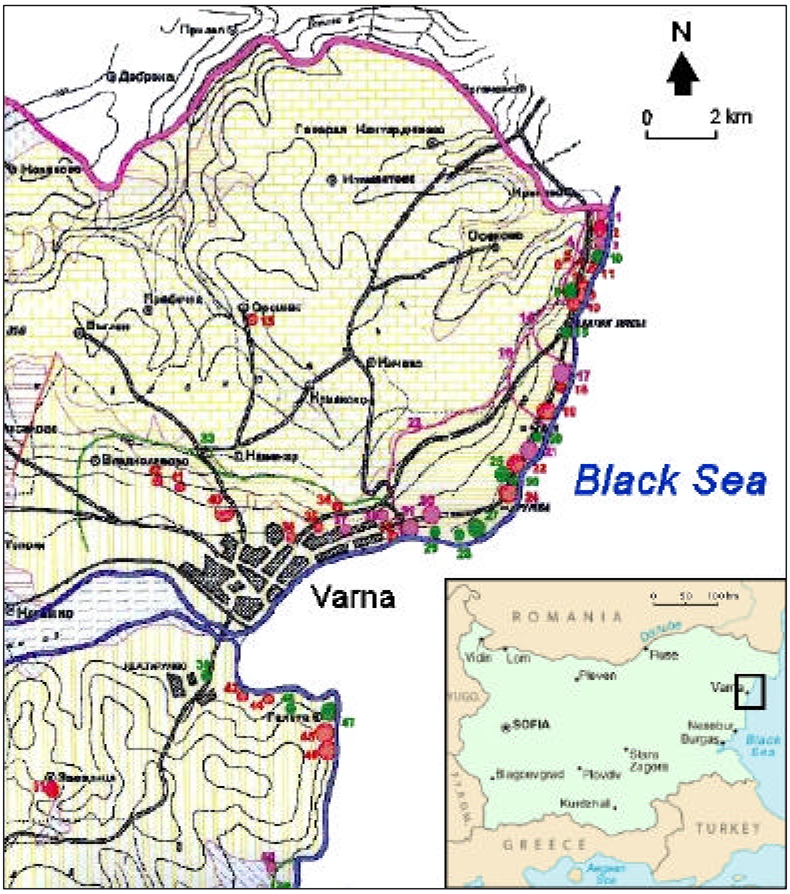

Figure 9.3 Areas most severly affected by landslides along Bulgaria's Black Sea coast (2). Key as in Figure 9.2.

Figure 9.4. Effects of the the February - April 1997 landslides in the Gold Sands health resort area, near Valna. Most of these landslides consisted of lateral spreadings.

9.2 Prevention measures and related lessons learnt

9.2.1 Main prevention measures to be considered

- Providing financial resources for national and regional programs for landslide stabilisation in Bulgaria.
- Improvement of laws in force and other regulations concerning all anti-landslide initiatives.
- Developing a strategy for landslide forecasting.
- Increasing research work in the design and project management of the most important sites.
- Increasing the amount and improving significantly the geological surveys.
- A total improvement of the whole investment process for landslide prevention and mitigation activities. This includes setting up a special management staff whose role is to

invest funds received from loans and other international programs. Also, creation of new regulations for prevention and mitigation activities should be implemented in a standardised manner.

9.2.2 Other prevention measures

- Present regulations in the normative system, strictly following the processes of each building activity. Current regulations are as follows:
  - The Territorial planning Law.
  - Regulation No. 1/20.I.1994 concerning landslide prevention and mitigation activities.
  - Regulation for landslide monitoring on the territory of the Republic of Bulgaria (1997-1998).
  - Regulation for licences concerning the juridical and physical persons dealing with survey design and implementation of anti-landslide strengthening structures (1997-1998).
  - Quotas and rules for the design of anti-landslide strengthening structures (1997-1998).
  - Other norms for designing structures.

  One of the most used standards at the moment is the Regulation No.12/03.07.2001 for anti-landslide strengthening structures and design of building structures and installations in landslide inventoried areas.

  Regarding the fact that more than 90% of the territory of Bulgaria is seismically threatened, new specific norms are in the process of being established. These concern the design of building structures and installation norms in landslide inventoried areas, taking into consideration the seismic effect on their stability (Frangov *et al*., 1988; Toshkov, 1998).

- Intensification of the regulated observations, landslide surveys and research works in the areas with pipelines, dams, channels, sewerage systems, underground diggings, open-pit mines, etc.

  The observations carried out for more than 20 years give us very useful information about the landslide processes occurring in Bulgaria. This information offers us an opportunity for drawing some conclusions on a sufficiently good level to be a base for the assessment of the dynamics, intensity and the possible damages which may derive from the landslide activation.

  This information helps to draw some of the main activities to be done as follows:
  - Assessment of the risk level for a particular object concerned.
  - Localisation of the main factors having influence on landslide activity.
  - Determination of the main priorities concerning the strengthening measures and works needed.
  - Commissioning some general or specific preventive measures.

  Usually the preventive measures and surveys ordered on each site can be “purely preventive”, “effectively preventive” and “operationally preventive”.

– ***"Purely preventive" measures:***
  - Water sanitation, which consists of improving, controlling, cleaning up and restoring the natural drainage system. Its purpose is to allow runoff of surface water without any retention.
  - Hydrotechnical sanitation, which includes all additional hydrotechnical equipment (e.g. open drainage systems, ditches, gully regulations, drainpipes, etc.) that reduces the possibility of feeding groundwater into the surface water regime.

– ***"Effectively preventive" measures:***
  - Activities in the area of the landslide, such as design and implementation of interventions and engineering structures for the improvement of the area stability factor.

– ***"Operationally preventive" measures:***
  - Activities that are to guarantee a normal functioning of the built up structures and equipment and which do not allow the worsening of strength quality of the ground foundations.

· Making of a geotechnical map of the landslide-prone areas on the territory of Bulgaria at 1:100,000 scale is under development. So far, approximately a quarter of the country has been covered. The information is stored in digital form on CD-ROM, so it can be used in conjunction with the cadastre information (Kamenov *et al*., 1973, 1977; Frangov *et al*., 1996).

Lessons learnt

➢ An established fact from the analyses of the landslides occurred between 1995 and 2001 shows that the highest landslide activity has taken place in the most urbanised areas with the highest density of buildings and country houses.

  → The main reason for this is human technical activity. The most striking examples are buildings with no underground utilities built in advance (e.g. water supply networks and sewage systems). Other case is building up in such areas in spite of the heavily damaged underground communications existing in them.

  → Total reconstruction of the whole water supply and sewage systems in both actual and potential landslide areas needs to be done with the aim to make them watertight.

  → Building in areas affected by exclusion or restriction regulations must by no means be permitted. Regulations on building restrictions in these areas should not be changed without the previous implementation of additional underground utility systems.

➢ Stability analysis and risk assessment of steep slopes should be done prior to building up any structure on them. Both the density and the height of the existing building structures on these areas should be taken into consideration, along with the capacity of the particular massif of the slope in accordance to non-admission a change for the worse, concerning the area stability. The stability of the whole zone should be examined as a result of the construction plans. The latter includes all kinds of building structures already existing in the zone, together with those which are to be implemented. An assessment of the latest stability factor for the buildings-slope system should be done.

➢ It would be necessary to:

  - → Create a cadastre of the populated areas, residential districts, underground and open-pit mine sites, railways, highways and other areas that are affected by landslides.
  - → Produce large-scale maps of the landslides affecting populated areas and main communications.
  - → Produce geotechnical maps of the populated areas and sites of economical importance. They should be made at the scale of the town-planning maps.
- For all surveys, examinations and design works concerning the implementation of built up structures in landslide areas or near them, binding rules should be established to coordinate authorities dealing with landslide prevention and mitigation.
- Determination and localisation of the most dangerous landslide areas in the country where landslide would produce the highest economical and social impacts. Some implementation of damage reduction projects must be done.
- Ecological ensuring of the anti-landslide structures and equipment. Their rehabilitation problems must be solved concerning their property, management and maintenance.
- The protection functions of the anti-landslide measures must be coordinated with other architectural landscape functions so that they can be integrated into the environment.
- As a final result, the investments on prevention and mitigation activities must be assessed according to the effectiveness of these activities.
- The insurance schemes relative to damages caused by landslides must be improved.

9.3 Preparedness measures and related lessons learnt

Landslide and erosion processes predetermine the requirement of commitment from the Civil Protection State Agency (*Durjavna Agencia – Grajdanska Zashtita* – DAGZ), as well as from local administrations and other competent authorities to address this problem. Commitment is practically relevant in solving landslide problems and in preparing and organising the response actions in the event of a landslide disaster. The organisational and practical activities done by the Civil Protection State Agency are the following:

- Creating regional committees and organisations specialised in surveying and monitoring the landslide-prone areas. These committees work in full collaboration with the anti-landslide authorities in the country.
- Analysing landslide processes by the regional organisations and carrying out emergency plans for risk prevention or reduction.
- Making the most vulnerable areas and roads safe from landslides.
- Organising and carrying out anti-landslide actions as follows:
  - Maintenance of the communal services and electric supply systems, keeping them in a good functioning mode.
  - Drainage and afforestation of the threatened areas.
  - Suspension of building and blasting works.
  - Reducing some weight on slopes and applying some strengthening measures.

The Civil Protection State Agency works on response action plans. These plans outline and ensure the completion of the following protection activities:

- Determining the tasks of the State Agency regarding organising and carrying out actions for protection of the population and national economy, according to the expectation (results forecasting) in each case.
- Creating an alarm system and a local radio net system in the most dangerous landslide areas.
- Providing an amount of forces (non-military, military, municipal and regional) and equipment for rescue operations and for setting up emergency restoration works.
- Keeping preparedness at a good level for carrying out rescue operations, emergency restoration works and evacuation, if necessary.
- Population training and acquainting with the landslide consequences and landslide prevention or mitigation activities that are already done or are to be done.

The planning and carrying out of the above-mentioned activities is made both at municipal and regional level. The planning of activities is a detached section of the regional plans for response actions in the event of a disaster (Broutchev and Frangov, 1998).

Lessons learnt:

- It is necessary to increase the importance and the role of the Government Standing Commission for population protection in cases of disasters, emergencies and accidents.
- Planning and implementation of the preventive actions at the site should be a priority when carrying out the landslide prevention and mitigation activities.
- An effective and ready-to-apply emergency plan is needed (for response actions) in landslide threatened areas.
- It is necessary to improve the legislation basis concerning some preventive actions for the population and reduce economic losses in threatened areas.

9.4 Response actions and related lessons learnt

As a whole, the response actions in case of landslides are neither so varied nor so effective as the prevention measures. The prevention measures should be applied before the landslide occurs, when they will be most effective and helpful.

Nevertheless, when the landslide has already been triggered, response actions should be carried out right away in the shortest possible time. These actions differ according to the place where the landslide has occurred and its level of activity. It may be a starting phase of movement or a full activation phase. Response actions can be classified in two groups according to their priority level as follows:

a) First priority actions

- Marking the danger area with warning signs.
- Prohibition of circulation of motor cars and other vehicles on the roads and streets near active landslides. Detours to other accessible roads should be identified to channel traffic through them.
- Banning entry to the area at risk by establishing effective and close protection measures.
- Disconnecting all the electric power and water supply systems in the threatened areas, because leaks from these systems could increase the landslide movement and therefore the danger level.

· Urgently carrying out the assessment of the stability of the building structures and the state of the other engineering systems. As a result of this assessment it should be determined if there is a risk for people's lives and if it is necessary to proceed with their evacuation.

· Very precise checking of the underground engineering systems concerning last human activities done in the area. This could enable to identify a possible landslide triggering or reactivating factor (e.g. a damaged water main, a large excavation, explosion works, flooding and other factors).

· If there is still an active triggering factor for the landslide, it should be eliminated as soon as possible, for example by:

  – Removal of the damaged water line.

  – Urgently filling up a large excavation ditch.

  – Immediately stopping all activities creating ground vibrations.

  – Directing in some cases the river waters into another riverbed or channel if necessary.

b) Second priority actions

· Organising the permanent monitoring of the landslide area and submitting all collected information to the regional standing committees, to the local authorities and to the departments of the "Geoprotection" company, which carry out the whole anti-landslide activity in the country (cf. section 9.1).

· Developing some instructions regarding the urgent anti-landslide activities and organising their carrying out. The Civil Protection State Agency does this in collaboration with the anti-landslide authorities, local authorities on land planning, Roads State Executive Agency (*Izpulnitelna Agencia Putishta*), and other authorities of the local government (cf. section 9.1). These instructions and the respective activities are as follows:

  – Channelling the surface water flow and other slope waters from the landslide areas without any retention. This may be done by:

    a) Digging channels and ditches.

    b) Urgently repairing the damaged parts of the existing sewerage systems and channels.

    c) Cleaning the existing ditches and drainage pipes, making some new if necessary or implementing setting up works (repairs).

    d) Checking the whole water supply system.

    e) Draining all the water from the water retention basins that are in the landslide and nearby areas.

  – Making terrain levelling and shaping slopes and angles of repose.

  – Carrying out some of the most urgent strengthening measures, such as repairing supporting walls or assembling some rock gabions.

  – Setting up some power lines or shifting communication lines to other permanent ways or to other aerial ways in the affected regions.

- Evacuation of valuables and properties from the area and suspending access to the area.
- Setting up drainage systems for the reduction of the groundwater level in the landslide area and ensuring surface water runoff on the slope.
- In some cases it may be necessary to remove some soil layers so as to reduce weight.
- In some particular cases only, lowering the groundwater level by pumping water out of some existing or newly made test wells.
- In some cases, local, time-controlled pulling down of rock masses should be provoked in order to avoid uncontrolled rockfalls. Uncontrolled rockfalls, rock avalanches or rockslides may cause significant damage to people, transportation and valuable property (Dinev and Donkov, 1998).

Lessons learnt:

- ➢ In many cases the landslide activation is a "notified" process (i.e. there are enough signs for its movement), so there is enough time to initiate response actions immediately.
- ➢ When a large area is affected by a large or many small landslides, the damages already caused and the hazard of possible subsequent damages must be quickly estimated. As a result, some additional actions outside the affected area have to be taken.

  This may happen when there are some damages or if there is a risk of damage to some infrastructure projects of great importance to the region and to the whole country. These projects include water treatment plants for public consumption or for purifying waste waters, motorways, main roads or railways, main gas pipelines, etc.
- ➢ In order to effectively carry out response actions, it is very important to:
  - → Identify and eliminate the landslide triggering factors.
  - → Make an urgent assessment of the stability of the buildings' structures and the underground engineering communication systems.

9.5 Socio-economic implications of landslides

Up to now a complete assessment of direct and indirect damages caused by landslides and erosion processes in Bulgaria has not been made.

Nowadays there are many examples of destroyed and damaged buildings and even whole residential districts, roads, water mains and channel disruptions. In addition to the main direct damages, there are also indirect damages caused by disruption of the production processes, health resort activities, transport communications and water and power supply systems. Some catastrophic situations also demand evacuation of people from the threatened area.

Except for the material damages, landslides cause a socio-economic stress in the society; they disturb people, totally disorganise the work carried out by the local authorities and put serious obstacles to their activities.

Landslides have negative effects in nature and its environment. Agricultural and forest areas are completely annihilated, the environments are heavily or totally damaged, the flow regime of the surface and ground water totally changes, ground and soils become polluted by disrupted sewage and destroyed polluting sources.

In the event of such disasters, the Civil Protection State Agency of Bulgaria plays a certain role in timely informing population and media assessing the consequences, overcoming the psychological shock of population and carrying out the most urgent restoration activities in the affected areas.

9.6 International cooperation

A large project to cope with landslides has recently started in Bulgaria. It is entitled “Bulgaria's rivers banks and seashores protection from water abrasion and erosion and from the landslide processes resulted from them”. The project cost is estimated at € 60 million, from which € 27.5 million were loaned by the European Investment Bank. € 16.5 million are from the Development Bank of the Council of Europe and € 16 million are the Bulgarian part of the joint project funding of the joint project.

The first stage of the project is 2000-2003, and the second is 2004-2005. The advisor of the whole project is the British company “Atkins”. The main designer of the seashore strengthenings is the Bulgarian company “Geoprotection” from the town of Varna.

An essential improvement of the anti-landslide activities can be planned and set up as a result of international cooperation. That would bring an opportunity to adopt some new effective and comparatively inexpensive methods and surveys for prevention and mitigation activities.

Some methods for landslide prevention and control have been worked out and tested by one of the world leading d companies in the field, Maccaferri of Bologne, Italy, and by many others.

9.7 Main lessons learnt

- Many landslides triggered by natural factors are easily observed by experts. Preventive measures can often make these landslides avoidable by keeping them stable. The nature of these measures and their level of implementation differ according to each particular case. However, preventive measures may not be so effective for debris flows, mudflows, rockfalls, rock avalanches, abrasion and erosion effects.
- Most landslides are hazards that are permanent in time and that often have some dormancy periods and some activity periods. They are classified as “dangerous” processes. The fact that many areas on the territory of Bulgaria are affected by landslides points that a full setting of activities against the landslide danger is an ideal purpose, and that it is entirely impossible now. It also shows that some strategies should be designed and developed with the purpose of reducing this danger. It would be better to carry out prevention measures before the landslide is triggered or reactivated.
- So far a large amount of funds is used for some emergency surveys and strengthening works. While this is necessary, if enough funds would be invested in setting up and building anti-landslide structures in advance, as well as in their maintenance, the emergency situations would be eliminated and the economic effect for the country would improve. Regardless of the resulting damages, once the landslides have occurred the necessary funds for anti-landslide activities are rather more inefficient.

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10. Government assistance for municipalities affected by landslides in Sweden

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10.1 Introduction

The Swedish Rescue Services Agency (*Räddningsverket,* SRV) is the government authority responsible for safety against accidents in society. Among other tasks, the agency deals with risk assessment and risk management in several different sectors, e.g. natural disasters.

10.2 General stability survey

Municipalities in Sweden are responsible for carrying out risk inventories within their own borders, taking preventive measures, establishing emergency plans, and taking measures in the event of accidents. This applies to all kinds of accidents, including also natural disasters. However, a large proportion of buildings has been constructed before the careful consideration of natural risks became commonplace.

When dealing with risks like landslides and floods the Swedish Government feels that dealing with them requires special competence, which is not always available in the municipalities. Therefore the government provides general assistance in urban areas to identify zones that are susceptible to landslides and floods. This is being achieved via a general stability survey. The Swedish Rescue Services Agency who has the responsibility to make these maps. One municipality is being mapped at a time. The priority of the municipalities to be mapped is decided according to the level of risk within the municipality.

By studying soil types and topographical conditions, conducting new geotechnical surveys and evaluating old surveys ground stability assessments can be made. The maps thus produced display different zones, which indicate the areas that are susceptible to landslides. The maps also show which areas require further study. The results of the survey are then submitted to the relevant municipalities and used as a guide to locate areas that have conditions for landslides. The survey is presented partly in a report with printed maps and partly in digital form so that the municipalities can carry out analyses with a GIS.

The maps should also form part of the basic information for everyday risk management (Naturolyckor, 2002).

The survey covers the whole country, but is carried out at a municipal level and only in built-up areas. The survey began in 1978 in the most vulnerable municipalities. Currently, the municipalities that were surveyed first are being re-surveyed mainly because of changes in surveying guidelines regarding ground stability over the years. In this context, after the Swedish Commission on Slope Stability (*Skredkommissionen*) issued its instructions new guidelines were issued.

In the municipality of Trosa, Södermanland province, a new survey was carried out after the landslide occurred in May 1997 (Löfroth, 2003, cf. Chapter 5). The resulting maps showed that several areas needed to be studied in greater detail in order to ascertain ground stability.

10.3 Government grants for prevention measures regarding natural disasters in urban areas

Natural disasters that occur in urban areas involve major costs for the affected municipality. In 1986 the government introduced an appropriation of € 2.5 million per year for preventive measures regarding landslides and floods. Municipalities with areas that have been built up without conducting sufficient surveys on ground and water conditions can apply for a grant from this appropriation to take preventive measures (cf. Naturolyckor, 2002).

The Swedish Rescue Services Agency (SRV), in cooperation with other authorities, deals with the grant applications. In recent years the total sum applied for has been € 9 million. About 30 municipalities have applied for grants for approximately 40 sites. Due to the limitations of grant funds the SRV has been forced to make an assessment of sites which most urgently need to implement preventive measures, and then give grants priority to them.

Since the new general stability survey was conducted in the municipality of Trosa further work, including also a detailed geotechnical study, has been carried out in those areas that could not be classified as stable. In those areas where the implementation of strengthening/preventive measures was necessary the municipality has worked extremely conscientiously and taken the risks very seriously. They have applied for grants for a number of measures, and since 1998 have received a total of € 2.5 million.

10.4 Dissemination of information to the municipalities and county administrative boards regarding landslide issues

The investigation of the 1997 landslide in Vagnhärad, Trosa, by the Swedish National Board of Accident Investigation (*Boverket*) showed that if the instructions issued by the Swedish Commission on Slope Stability (see below) had existed and had been followed when building in the area was being planned, then the clay hillside would have never been built on without first implementing strengthening measures.

To increase the level of knowledge concerning landslide issues, both during planning work and when measures such as, for example, slope unloading, drainage of water and protection against erosion are being implemented in existing settlements, the Swedish Geotechnical Institute (*Statens geotekniska institut*, SGI), the National Board of Housing, Building and Planning, the National Board of Accident Investigation and the Rescue Services Agency (SRV) are now running a joint campaign in which, within three years, every county and municipality in the country will have been visited in order to increase knowledge of the issues about landslides. The target groups for this information are mainly the personnel dealing with planning, the fire and rescue service, and politicians.

10.5 The Swedish Commission on Slope Stability

The Swedish Commission on Slope Stability (*Skredkommissionen*) was active from 1988 to 1996. Its task was to initiate research on the subject and disseminate knowledge about slope stability, landslides and methods of preventive measures.

Members of the Commission included personnel from municipalities, authorities, geotechnical advisers, contractors and technical universities.

The Commission has produced several papers, reports and videos. Its work has certainly increased the knowledge and understanding about how questions regarding slope stability should be treated (IVA Skredkommissionen, 1995a,b).

10.6 Lessons learnt

- The effort that is being done to prevent landslide disasters in urban areas is cost effective. The general mapping of landslide risk is a good help to the municipalities to locate where the risk of landslides is located.
- The government grant for prevention measures against landslides in urban areas is a good economic help to municipalities affected by landslides.

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11. Conclusions and key lessons learnt

Landslides are often complex phenomena, whose causes and mechanisms may in many instances not be well understood. This poses problems when coping with landslides, especially when establishing prevention and preparedness measures and actions.

The socio-economic impact of landslides is commonly underestimated. Although landslide-derived economic losses and human victims has been provided in earlier chapters for some major disasters recently occurred in Europe, in general it is very difficult to provide a reliable estimation of the direct and indirect costs incurred by landslides in Europe. A major reason for this is that the impact of landslides that accompany other natural events such as rainstorms, floods and earthquakes is usually not considered separately. In addition, frequent small landslides, mainly affecting transportation networks, which are generally acknowledged to incur high total costs, are very difficult to account for. It is thus recognised that government agencies and policy makers need to develop a better understanding of the socio-economic significance of landslides.

The NEDIES project meeting on lessons learnt from landslide disasters has provided a valuable platform for dialogue among civil protection experts in different EU Member States and Accession Countries, thus facilitating the exchange of experiences on landslide risk and disaster management. The outcome of the meeting, together with the written contributions and subsequent discussions with participants, have led to the issue of this report.

A major lesson learnt from the management of the disasters reported in this volume, was the need to restructure civil protection services and other operational intervention bodies in some countries or regions concerned, in order to cope more efficiently with future major landslide episodes.

Many of the lessons learnt derived from the management of other natural disasters can also be applied to landslides (see, for instance, NEDIES reports on page iii). However, summarised below are lessons learnt more specific to landslides.

11.1 Prevention and mitigation measures

As for other natural hazards, prevention (and mitigation) measures are considered the most important. They have to be designed and implemented based not only on the characteristics of the area at risk, including geology, geomorphology, hydrogeology and land use and development, but also on the type and location of potential landslide occurrence and the timing of landslide triggering factors. In landslides triggered by heavy rainfall, synoptic-scale weather forecasts have proved insufficient to identify the dangerous rainstorms. In many instances, critical weather conditions could have been timely predicted by having a more dense and better equipped meteorological network including also ground-based meteorological radar stations. Qualified personnel are also required to suitably interpret the data collected by these stations as well as the imagery acquired by meteorological satellites.

In the above case, it is particularly important to identify precipitation thresholds that enable the definition of three alert levels (attention, warning and alarm). In order to establish these thresholds it is necessary to collect rainfall data together with data on past landslide events and to properly model future occurrence. While this may sometimes be possible for shallow landslides such as debris flows and some mudflows, in most cases it is still an open issue.

It has been shown that, when landslides are accompanied by flooding, originally slow slides can turn into fast, and therefore very dangerous, debris flows on steep hillslopes and along torrents.

Landslides are often recurrent, hence knowledge of past landslide occurrence in an area can be effectively integrated with other relevant information to derive hazard maps, and therefore to identify the most dangerous zones. The production of landslide hazard maps (and preferably risk assessment maps in residential and industrial areas, thus accounting also for vulnerability) is considered absolutely crucial, since it enables authorities to implement eventual prevention (and preparedness) measures. This is most effective if these maps are made at a scale in accordance with local land use maps, and if different types of landslides are differentiated. Risk assessment is also needed to set up sound insurance schemes for property owners to spread the losses over a larger base.

It is also very important that specific legislation regarding the elaboration of natural hazard/risk maps, including those for landslides, be issued such that it binds land use plans according to the hazard or risk level. New constructions could thus be prohibited in disaster areas or in areas of high hazard. Where landslide-related land use and control laws exist, authorities should always ensure their compliance.

Such legislation should, in addition, entail provision of funds to endangered communes for hazard or risk mapping, particularly in urban areas, as it has proved to be effective in some European countries. Provision of expertise to carry out these maps by competent state agencies (e.g. Geological Surveys, Rescue Services Agencies or other) should also be included when needed. National government or EU funding for research to get a better understanding of landslide triggering and movement mechanisms is also acknowledged to be essential for designing some disaster prevention and mitigation measures.

It is necessary to carry out accurate geological and geotechnical surveys in landslide-prone areas, as well as keeping them updated, especially in high-risk areas. It has been demonstrated that insufficient allocation of financial resources for geotechnical surveys and torrent control, as well as inadequate actions in the natural environment (e.g. slope deforestation, inadequate river damming, developing endangered slopes, making large cuts and fills in construction, etc), increase the probability of catastrophic landslides. It is also very important that regulations regarding construction activities include the obligation to carry out geotechnical investigations on the site, accounting also for slope instability in hazard areas, prior to these activities. In this respect, specialists carrying out these investigations should be fully aware of the construction objectives.

Reforestation of hillslopes can help to reduce the occurrence of shallow but still dangerous landslides (mainly mudflows and debris flows).

Competent authorities should develop strategies for landslide risk reduction in collaboration with scientists/engineers and civil protection organisations.

Regarding major active landslides that represent a danger to population, it is stressed the significance of setting up a permanent monitoring network equipped with the latest technology. Slope movement monitoring using field instrumentation (e.g. inclinometers, extensometers, electronic distance measurement systems, ordinary surveying, lasers, tiltmeters, etc) can be effectively complemented by satellite-supported techniques (e.g. GPS and remote sensing including SAR interferometric techniques and analysis of multitemporal satellite optical imagery with high spatial resolution and frequent area coverage). Setting up automatic warning and alarm systems connected to headquarters of emergency intervention bodies, so that they can timely evacuate the area and restrict access to, should also be considered. When active landslides affect transportation lines, such systems should also be able to automatically trigger some signal to prevent the use of the line.

The evaluation of landslide mitigation activities including slope stabilisation and other engineering works is beyond the scope of this report, and has been extensively dealt with in the geotechnical literature.

11.2 Preparedness measures

The great importance of an effective organisation of the local authorities with respect to disaster management is recognised. The need for specific emergency plans to cope with landslide disasters according to the type of potential landslides and their risk in the area is underlined. Availability of landslide risk maps is thus a requirement for future emergency planning. This planning is, nevertheless, essential also in those areas where monitoring systems are lacking and where prevention measures have not been implemented.

In areas where landslides are a recurrent phenomenon, or in case of active landslides, rescue services must be prepared for prompt intervention. In the latter case, evacuation and enlargement of the risk area when substantial slope movement has been ascertained, even before it has caused significant damage, has often proved effective. Also, diversion routes should be pre-identified for key roads subject to landslides for use by emergency services.

Also, residents of affected areas must be promptly and openly informed about the possible or imminent risk of landslides and the implemented measures to deal with this risk.

Since in Europe landslides are most often related to intense rainfall, the need for real-time weather information at a local scale has also shown essential for early warning, thus increasing population safety.

11.3 Response actions

It has been ascertained that identifying and organising the emergency control centres of the civil protection, the responsibles for the centres and the various functions involved, the collection areas for evacuees and the number of persons and means involved during the emergency phase greatly helps to reduce the direct effects of the disaster upon the population. When landslides are linked to rainstorms or floods, it is also important to put up evacuees in houses or permanent structures used as reception centres, rather than in camps with tents and caravans.

It is also essential to ensure that rescue and protection services are staffed with sufficiently trained and adequately equipped personnel, and that they do not become victims themselves of the disaster.

The participation of military forces in rescue operations can be of high relevance in major disasters when large number of personnel and means are needed.

During disaster situations, it is necessary to continuously assess the hazard from landslides or other natural phenomena with the help from geological and geotechnical experts.

In rainfall-triggered landslides or when they are caused by water seepage from man-made structures, fast landslide mitigation actions are often needed so as to reduce pore pressures in the ground by draining the landslide area or, irrespective of the triggering factor, to remove landslide debris from watercourses to prevent damming, etc.

As a result of the disaster, in some areas it was considered necessary to modify the existing emergency plans, or to establish them when they did not exist.

11.4 Dissemination of information to the public

Residents of landslide hazard areas must be aware of the dangers, so that they can be more prepared to face them, including the need for evacuation. It is therefore important to provide residents with regular and open information so that they acquire confidence in the rescue services and collaborate with them. In this respect, distribution of a leaflet to residents of landslide-prone areas explaining the hazard from landslides and providing basic guidance on how to behave in the event of landslides is considered beneficial, as is informing the local population of landslide hazards in the event of heavy and prolonged rainfall, as outlined earlier. The involvement of people through the organisation of civic committees has also proved effective during emergencies.

As for other immediate severe meteorological events, issue of general warnings through TV and radio or, in areas of specific risk, directly warning people by telephone using an automatic voice messaging system, can reduce the impact of landslides.

The need to establish a notification centre and to appoint an information manager to inform both the people and the media became apparent in the management of the disasters. In remote disaster areas, this must be complemented with the improvement of telephone and radio communication systems.

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ANNEX

Classification of landslides

A landslide can be defined as the gravitational movement of a mass of rock, earth or debris down a slope (Cruden, 1991). Numerous classifications of landslides exist in the literature (e.g. Varnes, 1978; Brunsden, 1985; Hutchinson, 1988; EPOCH, 1993 in Dikau *et al*., 1996). They are based on different landslide factors and author's objectives. These can be mainly movement morphology (accounting also for the shape of the shear surface), mechanism, type of material involved and rate of movement.

The classification derived from the EU project EPOCH (1993) for European conditions is shown in the table below, as included in Dikau *et al*. (1996).

Type	Rock	Debris	Soil
Fall	Rockfall	Debris fall	Soil fall
Topple	Rock topple	Debris topple	Soil topple
Slide (rotational)	Single (slump) Multiple Successive	Single Multiple Successive	Single Multiple Successive
Slide (translational) Non-rotational	Block slide	Block slide	Block slide
Planar	Rockslide	Debris slide	Mudslide
Lateral spreading	Rock spreading	Debris spread	Soil (debris) spreading
Flow	Rock flow (sackung)	Debris flow	Soil flow (mudflow)
Complex (with runout or change of behaviour downslope, note that nearly all forms develop complex behaviour)	e.g. Rock avalanche	Flow slide	Slump-earthflow

Note: A compound landslide is the one that consists of more than one type, e.g. rotational-translational slide. This should be distinguished from a complex slide where one form of failure develops into a second form of movement, i.e. a change of behaviour downslope by the same material.

Basic definition of landslide types (after Varnes, 1978; Brunsden, 1985; Dikau *et al*., 1996)

Fall: Free movement of material away from steep slopes such as cliffs.

Topple: Forward rotation of a mass of rock, debris or soil about a pivot or hinge on a hillslope.

Slide: Movement of material along a recognisable shear surface. The shear surface type and the number of shear surfaces are used to divide the slide group.

- **Rotational slide**: Slide that occurs as a rotational movement on a circular spoon-shaped shear surface.
  - **Single slide**: As above, when only one sliding unit or body develops.

  - **Multiple slide**: Failure developing with two or more sliding units, each with a sliding surface intersecting a common basal shear surface.
  - **Successive slide:** Occurrence of a series of individual rotational slides one above the other on a slope.
- **Translational slide**: A non-circular failure which involves translational motion on a near-planar slip surface.
- **Planar slide**
  - **Rockslide**: Translational movement of rock which occurs along a more or less planar or gently undulating surface.
  - **Debris slide**: Failure of unconsolidated material that breaks up into smaller and smaller parts as the slide advances downslope.
  - **Mudslide**: Movement in which a mass of softened argillaceous, silty or very fine sandy debris advance chiefly by sliding on a discrete boundary shear surface in relatively slow moving, lobate or elongate forms.

Lateral spreading: Lateral extension of a cohesive rock or soil mass over a deforming mass of softer underlying material in which the controlling basal shear surface is often not well-defined.

Flow: Landslide in which the individual particles travel separately within a moving mass.

- **Rock flow**: Creeping, flow-type, deep-seated gravitational deformation affecting densely jointed or stratified hard rock masses which can be considered homogeneous.
- **Debris flow**: Mixture of fine material (sand, silt, clay) and coarse material (gravel and boulders), with a variable quantity of water, that forms a muddy slurry which moves downslope.
- **Soil flow (mudflow)**: Slow to very rapid, wet flow of relatively cohesive earth material that contains at least 50% sand, silt and clay sized particles.

Complex landslide: Landslide where the initial failure type changes into another as it moves downslope.

- **Rock avalanche**: Large bulk of mostly dry rock debris deriving from the collapse of a slope or cliff and moving at a high velocity and for a long distance, even on a gentle slope.
- **Flow slide**: Very rapid movement of debris or granular material with long runout.

Damage as a function of landslide type and parameters

Damage caused by landslides to structures, buildings and people is dependent on a number of parameters, mainly size (volume) and movement velocity. Small but fast landslides may, however, cause severe damage. Also, large landslides of moderate velocity may cause much less damage because buildings can be evacuated if the movement has been detected previously or the structures affected can be repaired or protected by engineering control works (IUGS, 1995). The internal deformation of the displaced mass is also an important damage-determining parameter, since structures and buildings may be damaged in proportion to the differential velocity of the sliding mass affecting their foundations. As a damaging parameter, landslide internal deformation is, however, usually less important than velocity. Therefore, damage also depends on the type of the landslide. In general, rock avalanches, flow slides, rockfalls, mudflows, debris flows and rockslides are the most potentially damaging landslides. Soil spreading can also be very harmful because of its high speed, even if it typically occurs in low angled areas. In Europe, its occurrence is however usually confined to soil conditions characteristic of local areas in Scandinavian countries.

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