Projekt

Multilingual Glossary on Geomorphological Processes and Definition of Minimal Standards for Hazard Maps

Titel

Final Report

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1. Introduction

The project, which is embedded in the WP 5, “Hazard Mapping”, of the Interreg IVB project “AdaptAlp”, was awarded to *alps – Centre for Natural Hazard and Risk Management* in Innsbruck by the Bavarian Environment Agency (LfU). The project was scheduled to last 17 months, from October 2009 to February 2011 and required a close cooperation by all participating partner countries (Germany, Switzerland, Italy, France, Spain, United Kingdom and Slovenia).

Purpose and motivation for this project are the difficulties traditionally encountered when using or defining mass wasting related terms in scientific papers. This results in different methods and concepts being used by geological agencies and leads to misunderstanding and problems when cooperating on international projects. A typical example is the notion of “Sackung”, which is inconsistent across the different terminologies defining mass wasting processes. The term, used in German-speaking countries, can describe multiple concepts. It can be employed as a “kinematical term” to depict a slow, continuously decreasing creep of the bedrock within a hillside, whereas no discrete basal movement area is defined (Stini 1941, Poisel 1998). “Sackung” can as well describe a geomorphological observation of pronounced vertical motion without any hints about movement zones (Weidner, 2000). In that case, it is closely related to sliding processes. The term “Talzuschub” (Stini,1941) is also employed to prevalently characterize geomorphological phenomena instead of kinematical ones.

In order to tackle that complexity and ambiguity, found not only in the German-speaking geology, but generally throughout Europe, a multilingual glossary was created. This glossary aims at an international harmonization by providing the user with a selection of official terms used by the geological agency in a specific country and by setting relations to similar terms employed in other countries. The resulting harmonized terms and definitions are available for all partners and the general public on the internet through the AdaptAlp internet page.

As expressed in the official description of Workpackage 5, “…*AdaptAlp will evaluate, harmonise and improve different methods of hazard zone planning applied in the alpine area…”* (www.adaptalp.org). Within this sentence the motivation and the goals for the second main part of the project is described. Because of the big variety of types and approaches in creating hazard maps, “minimum requirements” to “hazard mapping” were elaborated inside joined discussions from all the involved partners.

This Final Report should summarize the main topics and project progress and also major results will be shown.

2. Multilingual glossary

Generally the work on the multilingual glossary was divided in two main parts. On the one hand the technical infrastructure for a user-friendly query and searching for terms must be developed and on the other hand the input, namely the terms and definitions to landslides in six languages have to be elaborated. Therefore the following part will first pay attention to the technical part and after that the textual element will be described.

2.1 Technical part

The first step was to design and implement the technical infrastructure required to store and query the terms. For this purpose, a relational database management system was used as a back-end.

2.1.1 Requirements

Before the actual database design work could start, it was essential to assess the exact requirements such a glossary must fulfill. This made the following conceptional work a lot easier and minimizes the risk of having to perform time-consuming adjustments and changes to the model later on.

The first step was to define a list of attributes needed for a single glossary term as well as a type for those attributes (e.g. numbers, text, keys etc.). The type of an attribute determines which relations can be saved in the database and what kind of information can be queried using them. Every attribute corresponds at least to a column in the main glossary table.

The unique language to which a term is assigned is a fundamental attribute in a multilingual glossary. Because of the pan-European character of the glossary, it was necessary to specify the languages more precisely by linking them to a specific country, resulting in a unique combination for one language and one country. It was particularly relevant for this project, as the usage of a term varies greatly within a language depending on the region where it is used, as it is the case for German (Germany, Austria, Switzerland).

If such a glossary is to be used, it is essential that the end-user can query it in an easy and intuitive way. Although the user friendliness mostly depends on the graphical user interface and is hard to control through the database design. It is important to determine what possible queries will be offered to the user (e.g. a search by synonyms, case and special character insensitive searches, etc.) and to adapt the database design accordingly.

Editing and adding glossary terms after the initial import should also be possible and requires saving metadata for each entry. For example, it would be practical to save the time and date of the creation or the last edit of a term. Using that information, it is easy to reconstruct the history of an entry at a later point in time.

Finally, the database is, to some extent, expandable if a need for extensions or special functions that were not foreseen arises in the future.

2.1.2 Relations

The classical approach followed by most glossaries is a single translation layer; a direct translation of each term into exactly one term of another language. This corresponds to a *1:n* relation between the entities (i.e. glossary terms) in an Entity-Relationship-Modell (ERM). Such a direct translation supposes an equivalence of the terms definition and meaning.

In this new glossary, the relations between the different terms should be defined solely by their technical meaning, resulting in two possible relations: same meaning or similar meaning. A direct translation is still required in order to provide the user with the exact translation of a definition in his own language.

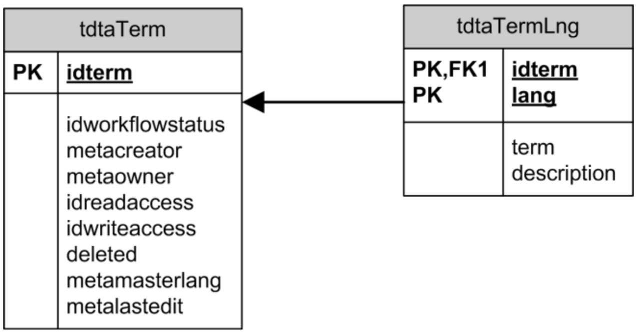


Figure 1: Example of a multilingual glossary where each term has exactly one translation in each other language. The primary key of the language table ('tdtaTermLng') is defined by its ID and language.

Following example should help clarifying the concept of “meaning” vs. “definition”: The English term “rockfall” is usually translated into “Felssturz” or “Bergsturz” in German, but that translation usually doesn't consider the effective volume transported. However, if the technical meaning is taken into account, “Bergsturz”, which corresponds to a minimum volume of 10^6 cubic meters, would have the *same* meaning as “rock avalanche”, also characterized by volume values above 10^6 cubic meters. The relation to “rockfall” (i.e. *similar* meaning) would be a looser one. The relations between “cliff falls“, “block falls“, “boulder falls“ and “Felssturz“, “Steinschlag“, “Blockschlag“ could be defined in a similar manner. (Remark: the values used above are examples and do not necessarily match any official values)

2.1.3 Database model

This chapter will describe in detail the different “sections” of the database. For the purpose of clarity, the database was divided into four “sections” or “areas” which correspond to a set of tables related to each other. Following diagram shows the relations between those “sections”.

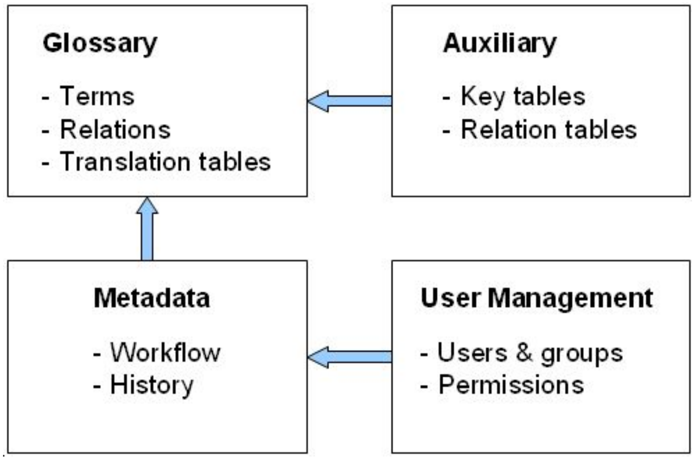


Figure 2: Overview of the database model components

The nomenclature used throughout the database follows a simple naming convention. Depending on the function or content of a particular table, its name is prefixed differently. The prefix “tdta-” stands for tables in which actual data is being stored, “tkey-” is used for key tables (key attributes can only take a value from a predefined set of keys) and “trel-” for relation tables. Unique IDs are prefixed with “id-” and meta-attributes with “meta-”. The multilingual concept, required by the direct translation, provides, for most of the tables, a second table with an identical name and the suffix “-Lng”. Those language tables hold the text values of the different glossary terms.

The first “section” is the core of the database, with its element tables “*tdtaElement”* and “*tdtaEleGlossarTerm”*. The glossary terms are stored in the latter, whereas the main element table holds additional information related to the system and not to the glossary itself (mostly through the usage of foreign keys). For each term, following field are available:

- **'term'**: the actual text value (direct translation using the *-Lng* table)
- **‘reference’:** source of information and date
- '**idlang'** and **'idcountry'**: foreign keys pointing to a unique combination of language/country
- **'idtopic'**: foreign key specifying the topic of this term
- **'searchterm'** and **'searchsynonyms'**: used for insensitive searches
- **'picture*'**: paths to pictures depicting a term

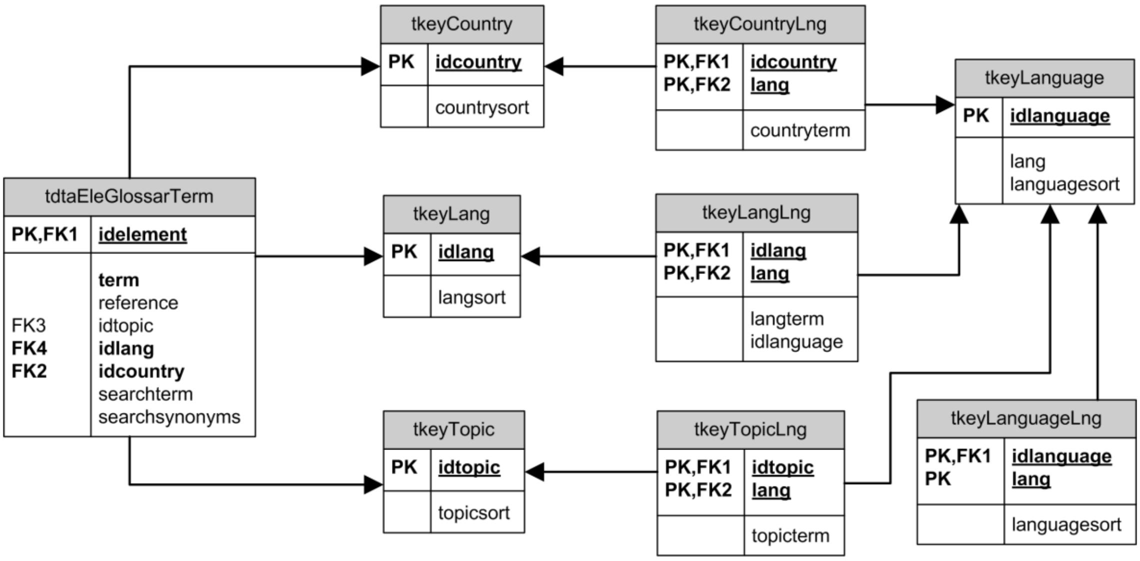


Figure 3: Auxiliary tables

The auxiliary tables are mainly key tables defining the different languages, countries and topics used in the main table. They also contain the relation table used to specify relations between terms based on a relation code ("similar" or "same").

Metadata is partly stored in the *"tdtaElement"* table using foreign keys. Those keys point to external metadata tables such as *"tkeyWorkflowstatus"* or *"tdtaUser"*, where, for example, information about the status, author or owner of an element are defined. *"tdtaHistory"* works similarly to a log by saving all actions performed on a specific element, which can be displayed as a list to an authorized user.

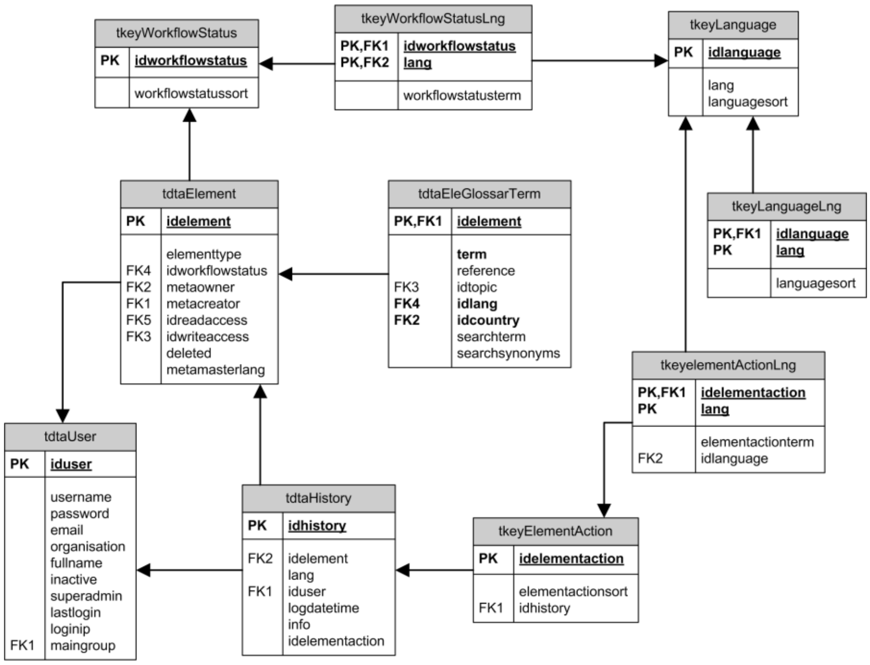


Figure 4: Metadata tables

Finally, user and group management defines the group(s) a user belongs to and which read/write rights a group or a specific user owns (through the *tdtaElement* table).

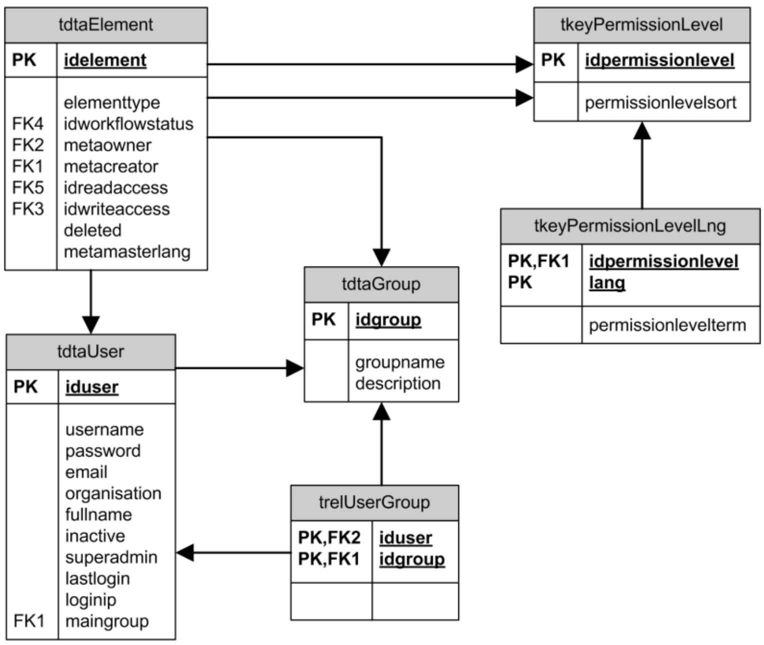


Figure 5: User and group management

2.1.4 Data capture and import

The primary data capture is done via an Excel table with a predefined format. This table is used as an interface to import data records in the database. The person responsible to fill out this table must make sure the relations between the terms are set correctly. Other errors, such as duplicate IDs, can be caught to some extent by the database itself. An extract of such a table is shown inside chapter 2.2.2.

2.2 Textual part

To fill this complex database-structure the approach in getting the topics had central importance. Unlike many other glossaries, which are rather dictionaries working with direct translation, this glossary is consisting of terms and definitions which are not necessarily have to be part of a nomenclature or literature, but really be used by the official agencies within the involved countries.

2.2.1 Languages

In general the glossary implies terms and definitions to landslides and corresponding maps, considering “danger, hazard and risk” caused by several kinds of geological hazards. Due to the “alpine – character” of the project the glossary contains all the languages spoken in the Alpine region plus English and Spanish for two further European countries dealing with geological hazards. So the glossary consists of the following six languages:

- ***German –*** Germany, Switzerland, Austria (Three different lists)
- ***Italian –*** Italy
- ***French*** – France
- ***Slovenian*** – Slovenia
- ***Spanish –*** Spain (Castellano and Catalan)
- ***English –*** United Kingdom

2.2.2 Basic Table (in German)

For the development of such a glossary it is unavoidable to create a “basic - list” in which all the desired terms and definitions are included. Therefore a table with 97 terms and definitions to geological hazards (in German) was elaborated. Based on this the other language lists were developed.

In order to facilitate this process all the terms are structured in different topics. To simplify the comparability between the languages this classification is very useful. For example it’s much easier to get the English term for “Stauchwulst” if the English expert knows that you are searching for an accumulation term. This topical limitation helps the translator to get the several experts on the right track.

The “basic – list” is structured into the following topics:

- ***Accumulation*** (Ablagerungen - z.B. Schuttkegel)
- ***General geomorphologie*** (Allgemeine Geomorphologie - z.B. Grat)
- ***General*** (Allgemeines - z.B. Primärereignis)
- ***Fracture forms*** (Anbruchformen - z.B. Bergzerreissung)
- ***Path of movement*** (Bewegungsbahnen - z.B. Sturzbahn)
- ***Flow process slow*** (Fließprozess – langsam - z.B. Solifluktion)
- ***Flow process rapid*** (Fließprozess – schnell - z.B. Blockstrom)
- ***Flow process very rapid*** (Fließprozess – sehr schnell - z.B. Murgang)
- ***Risk*** (Gefahr-Gefährdung-Risiko - z.B. Restrisiko)
- ***Maps*** (Karten - z.B. Gefahrenkarte)
- ***Classification – processes*** (Klassifikation – Prozesse - z.B. Sturzprozess)
- ***Measures*** (*Maßnahmen* - z.B. aktive Maßnahmen)
- ***Slides combined*** (Rutschprozess – Kombinierte Rutschung - z.B. Rutschung mit kombinierter Gleitfläche)
- ***Slides rotational*** (Rutschprozess – Rotationsrutschung - z.B. Rotationsrutschung)
- ***Slides translational*** (Rutschprozess – Translationsrutschung - z.B. Translationsrutschung)
- ***Landslide dynamics*** (Rutschungsdynamik - z.B. aktuelle Hangbewegung)
- ***Landslide features*** (Rutschungsmerkmale - z.B. Rutschungkopf)
- ***Falls*** (Struzprozess – Bergsturz - z.B. Bergsturz)
- ***Falls*** (Sturzprozess – Blockschlag - z.B. Blockschlag)

- ***Falls*** (Sturzprozess – Felssturz - z.B. Felssturz)
- ***Falls*** (Sturzprozess – Steinschlag - z.B. Steinschlag)
- ***Subrosion*** (Subrosionsprozess - z.B. Doline)

As mentioned above the different terms lists in a final step were integrated in the relational database. Therefore the terms are collected in a predefined excel table in which each term gets a unique ID. Over this ID the relations between the different languages are established. Figure 6 shows an extract of this predefined excel – table with the basic terms from Germany.

	DE				FR			EN		
id	term	definition	reference	topic	same	similar	direct	same	similar	direct
2080	**Hauptrutschmasse**	Gesamter Rutschkörper der primären Hangbewegung.	LfU Bayern	Rutschungsmerkmale	1080			3080		
2081	**Rutschungsfuß**	Unterster Teil des Rutschkörpers.	LfU Bayern	Rutschungsmerkmale	1081			3081		
2082	**Stirnwulst**	Wulst am Rutschungsfuß.	LfU Bayern	Rutschungsmerkmale	1082			3082		
2083	**Gleitbahn**	Bewegungsbahn von Rutschprozessen.	LfU Bayern	Rutschungsmerkmale	1083			3083		
2084	**Bergsturz**	Hangbewegung mit großem Volumen und hoher Dynamik, die oftmals dafür sorgt, dass die Massen am Gegenhang weit aufbranden. Volumen > 1.000.000m^3.	LfU Bayern	Sturzprozess	1084			3084		
2085	**Blockschlag**	Periodisches Sturzereignis von einzelnen, kleineren Festgesteinspartien mit einer Blockgröße von > 1m^3	LfU Bayern	Sturzprozess	1085				3085	
2086	**Felssturz**	Abstürzen ganzer Felspartien, Volumen 10-1.000.000m^3, die Dynamik ist deutlich geringer als beim Bergsturz. Im Gegensatz	LfU Bayern	Sturzprozess		1086			3086	
2087	**Steinschlag**	Periodisches Sturzereignis von einzelnen, kleineren Festgesteinspartien bis hin zur Blockgröße. Volumen 0-10m^3.	LfU Bayern	Sturzprozess	1087				3087	
2088	**Doline**	Relativ engräumige, mehr oder weniger runde Hohlformen an der Erdoberfläche als Folge der Auflösung von Sulfat-, Chlorid- oder Karbonatgesteinen durch über Klüfte versickernde Oberflächenwässer.	LfU Bayern	Subrosionsprozess	1088			3088		
2089	**Uvala**	\"Zusammenwachsen\" von mehrerer Dolinen zu einer größeren Senke	LfU Bayern	Subrosionsprozess	1089			3089		
2090	**Dolinenfeld**	Anhäufung mehrerer Dolinen.	LfU Bayern	Subrosionsprozess	1090			3090		
2091	**Erdfall (Vorgang)**	Erdfälle bilden sich infolge unterirdischer Lösung/Ausspülung durch den plötzlichen Einsturz der Erdoberfläche und bilden Trichter- oder Schlotformen, die bei oft nur geringer Tiefe einen Durchmesser von Dezimetern bis zu Zehnermetern aufweisen. Erdfallgebiete sind in ihrer Ausdehnung meist bekannt, doch kann der einzelne Erdfall sowohl zeitlich als auch örtlich kaum vorhergesagt werden. Man findet sie in Gruppen; mitunter sind sie auch perlschnurartig aneinander gereiht.	LfU Bayern	Subrosionsprozess	1091			3091		

Figure 6: Extract of predefined excel table

2.2.3 "Harmonization" and data acquisition

"…A glossary will facilitate transdisciplinary and translingual cooperation as well as support the harmonization of the various methods…" (www.adaptalp.org).

Striving for "Harmonization" of regional terms and methods seems to be a guiding principle not only in WP 5 of the AdaptAlp project but in multiple European cooperation projects.

In the literature a lot of definitions are used for the term harmonization. According to the business dictionary harmonization is an *"adjustment of differences and inconsistencies among different measurements, methods, procedures, schedules, specifications, or systems to make them uniform or mutually compatible"* (www.businessdictionary.com).

This definition implies some important points which are mentioned as main goals in many projects supported by the EU. The adjustment of differences and the achievement of compatibility are also playing a major role for the WP 5: *"AdaptAlp will evaluate, harmonise and improve different methods of hazard zone planning applied in the alpine area. The comparison of methods for mapping geological and water risks in the individual countries"* (www.adaptalp.org) will be brought into focus.

Concerning the development of the multilingual glossary to geological hazards the "Harmonization" is implemented by the following approach.

Unlike many other glossaries, which are rather dictionaries working with direct translations, this glossary consists of terms and definitions which are used by the official agencies from the involved countries. So the big difference too many other word lists is the way of getting the topics.

Basically the data acquisition was made within short visits in the involved countries. Building on the German "Basic-list" within these talks "term after term" is discussed with the respective person responsible. With regard to linguistic problems each "Harmonization" is carried out with the help of native speakers who also be well versed in the thematic of geological hazards. The terms are related in the following three forms:

- ***Same meaning*** (The term has the same meaning in both languages)
- ***Similar meaning*** (The term has a similar meaning in both languages)
- ***Not existing*** (No term with the same or similar meaning does exist)

To facilitate the harmonization – process in the run-up of the visits by means of several national literature lists with suggested terms were worked out from the native speakers.

These lists also contain short descriptions of the desired expressions and they are sending to the responsible persons for orientation and preparation. A picture paints a thousand words, therefore also pictures and illustrations were used within the talks.

2.2.4 Graphical user interface (AdaptAlp Homepage)

SCREENSHOTS FROM THE HOMEPAGE!!!!!!!

3. “Minimum requirements” to Hazard Mapping

In dealing with geological hazard today geotechnical (active) and spatial (passive) measures comes to implementation to minimize risk. Because of a time limitation of active measures (e.g. protective walls) and the decrease of space for permanent settlings spatial planning gets more and more important. Due to avalanche catastrophes in the 1950ies which were affecting large parts of the Alps, in 1954 in the swiss municipal Gadmen the first “Avalanche-Zone-Plan” was passed. This was the first time a natural hazard was considered in spatial planning (cf. Glade a. Felgentreff 2008, p 160f).

Nowadays almost 60 years later “hazard mapping” builds a central part in risk management. Countless types of “Danger-, Hazard- and Riskmaps” are produced to all kinds of risks. With regard to natural hazards especially geological processes a large variety of maps and methods are used in the different European countries to prevent natural disasters.

Exactly this variety, which reaches from simple danger mappings to legally binding “Hazard Zone Plans” (Gefahrenzonenplan), should be shown inside this part of the AdaptAlp project. However main goal of Workpackage 5 (WP 5) is not only the description of this variety, but a development of a “least common denominator” which includes the minimum requirements for the creation of Danger-, Hazard- and Riskmaps.

The following part focuses on the “state of the art” in “hazard mapping” in the involved countries. Therefore inside this project two “Expert Hearings” were performed in Bolzano and Munich. Main goal of these two meetings was the development of so called “minimum requirements in hazard mapping”. All the contributions and the harmonized results are shown inside the following chapters.

3.1. “State of the art” in the involved countries

Within the hearing in Bolzano representatives from each involved country were presenting their “status quo” in dealing with geological hazards. The main outputs of this hearing were also published in a joined publication within the Journal of “Torrent and avalanche control” in Austria. The “state of the art” contributions from each involved region are shown in the following part.

3.1.1 Germany (Karl Mayer)

In Germany, geogenic natural hazards, such as mass movements, karstification, large scale flooding as well as ground subsidence and uplift affecting building ground, shall in future be recorded, assessed and spatially represented using a common minimal standard. For this purpose, the “Geohazards” team of engineering geologists of the different German federal governmental departments of geology (SGD) are giving recommendations on how to create a danger map. These recommendations of minimum requirements are directed at the employees of the SGD. An important component for developing danger maps is the construction and evaluation of landslide inventories (e.g. landslide or sinkhole inventories).

The recorded data in the inventories should have a minimal nationwide standard and are divided into:

- Main data of the topic mass movements and subrosion / karst with information about the spatial positioning, about determination of coordinates, etc.
- Commonly shared technical data of the subject mass movements and subrosion / karst with information about the date of origin, about the land use and about damage, etc.
- Specific technical data of the subject mass movement and subrosion / karst
- Data concerning subsidence and uplift

Computerized modelling increasingly allows the identification of danger areas that have been verified using the landslide inventory or through evaluation of the results of field work. The current emphasis in Germany is on the hydrological modelling of flood events that are used for water management issues in flood prevention. Geotechnical modelling is used increasingly for rock fall, avalanches and shallow landslides. If necessary, in addition to the tools described above, field studies have to be used for exact clarification and assessment of given situations.

In alpine regions natural hazards are a common phenomenon. Landslides, rock falls and mudflows occur in the course of mountain degradation that reflects the natural slope instability of mountain areas. Landslides are mostly triggered by extreme rainfall that will, according to climate scientists, become more relevant especially in alpine regions (Umweltbundesamt 2008). With an increase in heavy rainfall events an increase in landslide events must be expected.

With approximately 4450 km² the Bavarian Alps are covering about 6.3 % of Bavaria. The Bavarian Alps are the most important touristic region of Bavaria and therefore of particular importance. Furthermore they have a unique ecological value that has to be protected particularly. Since it is more and more difficult to ensure this protection by structural activities, protective measures need to be involved in the planning process which also allows sustainable and cost effective strategies.

The most effective and sustainable method to prevent losses arising from hazardous events is to avoid land use in the endangered areas. In areas where construction already has been established or where construction of new infrastructure or buildings is unavoidable it is essential to determine areas endangered by geological hazards.

In May 2008 the Bavarian Environment Agency launched the project Danger map for the Bavarian Alps. The aim of the project is to create a danger map for deep seated landslides, shallow landslides and rock fall areas for the whole extent of the Bavarian Alps. It will be finished within December 2011.

Definition of a Danger Map

The federal geological Surveys of Germany agreed on definitions for the terminology used for mapping of geological hazards (Personenkreis “Geogefahren” 2008) based on BUWAL (2005). A danger map gives a first overview of areas affected by landslides (potentially endangered area) and can be a basis for the detection of conflicts of interests. By defining a most probable design event and integrating it in the landslide modelling process a danger map also gives a qualitative statement about the probability of a landslide event. The potential process areas of the expected landslides are varying depending on the design event, the geological, topographical and morphological situation and the existence of forest. Modelling parameters for rock fall and shallow landslide simulations can be deduced and trivialised from comprehensive data. Generally the scale of a danger map ranges from 1:10.000 to 1:50.000. Within this project, despite the possibilities of the zoom function of a GIS, the danger map is produced for a scale of 1:25.000.

Basis maps

Essential data basis for modelling the danger map is a high resolution digital elevation model (DEM) derived from airborne laser scanning. The datasets are used in different resolutions (1 m, 5 m, 10 m) depending on the modelling approach. The vertical resolution is better +/- 0.3 m, except for very few areas where currently no laser scanning data is available.

Basis data for landslide modelling

Information about geological hazards like landslides, rock falls and earth falls, especially in the densely populated areas in the Bavarian Alps, is available in the section Georisk of the Bodeninformationssystem Bayern (BIS-BY, www.bis.bayern.de), a GIS-based inventory of Bavaria including numerous geological data. By now (October 2010), about 4500 landslide events have been detected and evaluated within the project area. Every event is described concerning its process type and dimension, the age and potential future trend of the landslide as well as annotations about the source and the degree of information. Origin and accumulation zones of landslides have been digitised and stored as well as significant photos. With all of this the BIS-BY is the most important source of information.

Also integrated in the BIS-BY are maps of active areas that have been mapped by field work, aerial photo analysis and archive data for the main settlement areas. Within these maps landslides are classified into four levels of activity to give an indirect statement about the level of danger. These maps can be used to estimate the extension of deep seated landslides for example.

Above all, results of two other projects have been used: Within the project HANG (historical analysis of alpine hazards) historical data of landslides have been evaluated and digitised. Within the project EGAR (catchment areas in alpine regions) the risk potential of alpine torrents has been estimated analysing the discharge and catchment potential.

Fall processes - Minimum requirements in Germany

In many states of Germany, only medium to long term large scale numeric modelling of rockfall hazards are possible, using high resolution terrain models and specialised software. In the first stage, a “black and white map” is created showing verified / potential rockfall areas derived from the landslide inventories and / or remote sensing (DEM). This map shows verified as well as potential rockfall escarpments i.e. slopes with an inclination > 45° (in Alpine areas). The entire process area is, however, not depicted.

In the second stage, the runout zone, i.e. the entire process area, is depicted. That means areas prone to rockfalls due to the inclination, but which are not confirmed. To define these areas estimated empiric angle methods can be used or physical deterministic models.

To determine rockfall escarpments, the shadow angle and the geometric slope angle is applied. Both the shadow angle (e.g. 27°) as well as the geometric slope angle (e.g. 32°) can be used as the estimated angle (Mayer & Poschinger 2005). An angle of deflection from the vertical slope can be used as a lateral boundary of the process area (e.g. 30°).

In Bavaria this method is used for huge rock masses. For single blocks a physical trajectory model from Zinggeler + GEOTEST is used (MAYER 2010).

Modelling rock fall of single blocks (in Bavaria used methods)

For the detection of potential starting zones of rock fall two empirical approaches can be applied. In a first step potential starting zones stored in the BIS-BY are extracted.

These starting zones are detected by field work. In areas where no information is available, an even more empiric approach must be applied: it has to be assumed that every slope steeper than 45° is a potential detachment zone (Wadge et al. 1993).

According to Meißl (1998) or Hegg & Kienholz (1995) the process model can be divided into two parts: the trajectory model calculating the paths of the blocks as vectors and the friction model calculating the energy along these paths as well as the run out length. In this project the vector based simulation model of Zinggeler & GEOTEST (Krummenacher et al. 2005) is used.

Beside the topographical information derived from the DEM, damping and friction characteristics of the slope surface and the vegetation have to be known. Furthermore it is very important to define a design event for rock fall. That means that, according to the geology, form and dimension of typical blocks have to be determined.

As the block dimension is the only variable parameter within the simulation, it plays an essential role in the calculation of the run out zone. To assess the design events, the starting zones already determined within the disposition model have been intersected with the geological map. The affected geological units have been checked by field work. As a result, a mean block size and geometry that represents the most probable event has been determined for every geological unit. This design event has been assigned to one of four volume classes. For each of these classes the mean block mass has been calculated. The block mass of a geological unit is an input parameter for the simulation.

The simulation of the block movement is carried out according to physical principles of mechanics and is separated into falling, bouncing and rolling (Fig. 7). The calculation is a succession of these processes with intermediate contacts to underground and tree trunks.

The loss of energy during tread mat is controlled by deformability and roughness of the surface. These parameters have to be deduced and trivialised from the basis data of the area to be investigated.

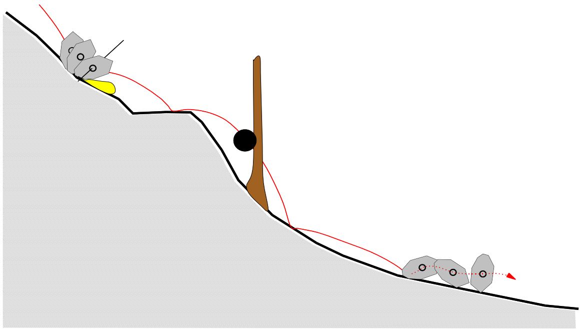


Figure 7: Basic processes during rock fall simulation (Krummenacher et al. 2005)

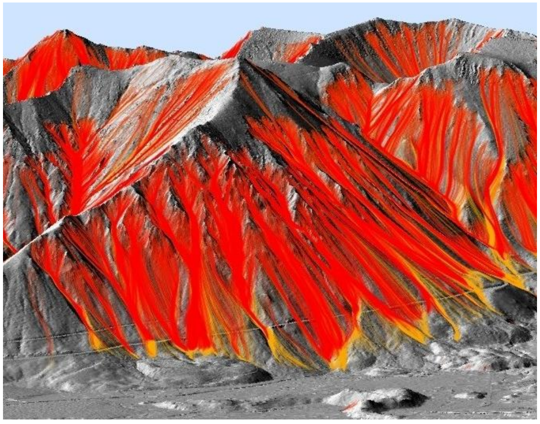


Figure 8: 3D Trajectories with (red) and without (orange) the protecting function of forest

The simulation has been executed for two different scenarios. Within the first scenario the forest with the protecting function of the trees has been considered. To simulate a worst-case scenario the forest has not been included in the second scenario.

Modelling rock fall masses (Bavarian approach)

The trajectory model for rock fall (chapter 4.2) calculates the reach of single blocks. For the run out zone of larger rock fall volumes an empirical process model with a worst case approach is used. Numerous papers (Lied 1977, Onofri & Canadian 1979, Evans & Hungr 1993, Wieczorek et al. 1999, Meißl 1998) show that a global angle method is an appropriate approach to determine the maximum run out zone of rock fall. Two different global angles have been applied. The first and more important one is the shadow angle (β in Fig. 3). It is defined as angle between the horizontal line and the connecting line from the block with maximum run out and the top of the talus. According to Evans & Hungr (1993) a shadow angle of 27° has been assumed. The other global angle is the geometrical slope angle that spans between the horizontal line and top of detachment zone (α in Fig. 9). A minimum geometrical slope angle of 30° is presumed (Meißl 1998).

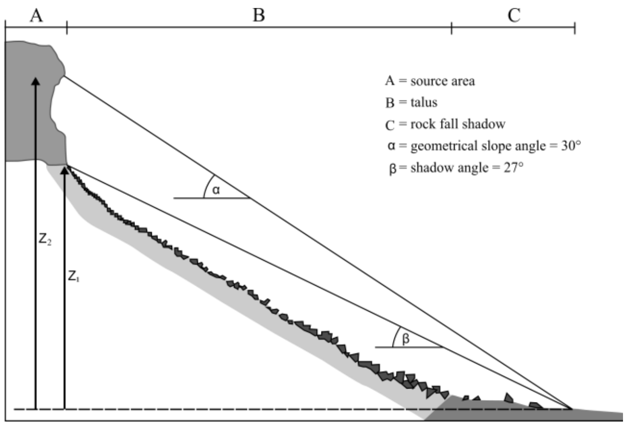


Figure 9: Global angle models: shadow angle (β) and geometrical slope angle (α) (Meißl 1998, modified)

The application of the different global angles depends on slope morphology. A proper decision for one global angle model can be reached by the quotient of shadow angle tangent and geometrical slope tangent. If the quotient is below 0.88 the shadow angle has to be used. Otherwise the geometrical slope angle is better suited to describe the maximum run out zone (Mayer & von Poschinger 2005).

Global angles can easily be modelled with implemented functionalities of standard GIS programs. Within the project, the viewshed function of Spatial Analyst in ArcGIS has been employed. This function identifies all cells on a surface (DEM) that can be seen from selected observation points. There are a number of important attributes of every starting point necessary for the modelling process: the vertical view angle which is the predefined global angle, the horizontal view angle that is defined with 30° as well as the aspect that can be calculated out of the DEM.

For identification of danger areas only important rock fall areas with evidence of activity have been processed. Due to long lasting field work there is an excellent overview about the situation within the densely populated areas in the Bavarian Alps. Beyond those areas it is assumed that all important rock fall areas are known. To start the modelling process first the global angle approach has to be chosen (shadow angle or geometrical angle). After digitizing starting points and determination of necessary attributes the viewshed modelling with ArcGIS can be executed.

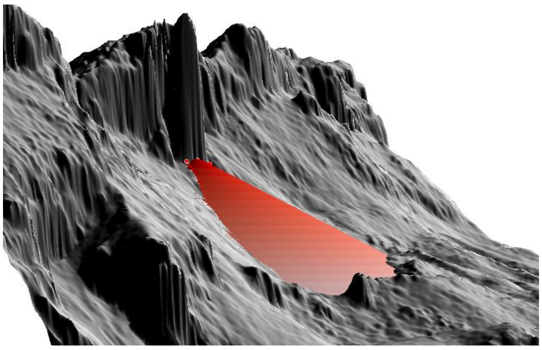


Figure 10: The viewshed function identifies all raster locations to be seen from appointed starting points with defined global angle.

Slide processes - Minimum requirements in Germany

In the first stage, landslide inventories, e.g. all registered objects and the associated near-surface processes should be visually displayed. That means affected by definite indications of active and inactive landslides and landslides that have already occurred (Reactivation or enlargement of the landslide area is possible). The areas can be found using mapping (registers) or remote sensing (DEM) methods.

In the second stage, potential landslide areas are determined in addition to the verified landslide areas. That means areas prone to landslides due to the geological and morphological situation and the land use (were landslides have not yet taken place). These areas can be found by using empirical methods due to the geological and morphological circumstances and the land usage; alternatively / additionally: Visualisation of semi-automatically derived areas (cross-over between DEM / geological entity); e.g. using an additional signature

The distinction between shallow and deep-seated slides is optional when visualising the danger map. Near-surface landslides of a small volume (shallow slides) are either separately determined using above procedure or are displayed simultaneously alongside the deep-seated slides.

Modelling deep seated landslides (in Bavaria used methods)

Deep seated landslides are mostly result of activation of predefined failure zones, i.e. by long lasting rainfall. Experience shows that they can range from about 5 m up to more than 100 m depth. To identify areas endangered by deep seated landslides, two different approaches have been applied. On the one hand areas showing evidence of former deep seated landslides, with either ongoing activity or a clear probability of reactivation, have been evaluated. On the other hand the terrain has been evaluated concerning an increased susceptibility for deep seated landslides.

The locality of the origin of danger (areas showing a higher probability for the development of a deep seated landslide) has been identified within the previously cited disposition model.

Previous experiences and analysis have demonstrated that deep seated landslides mostly occur in areas already affected by landslides in the past. For this reason they can be used as design events. To detect these areas information about known landslides, extracted from the databases listed in chapter 3.2 has to be evaluated. Permanent activity or more or less recurrent reactivation likely produces enlargement of the landslide area identified in the disposition model, both the detachment and run out zone upward and downward.

Since a numeric modelling of deep seated landslides is not available for a regional scale, the determination of the potential process area has to be worked out with empirical methods, taking into account the local geology and morphology.

Under extreme conditions the process area can reach the next ridge, terrace or depression in the greater surrounding of the landslide. In the case of small scaled scars in smooth slopes a margin of 20 – 30 m has been added to the detachment areas to assess the potential process area.

To determine the potential run out of an active or reactivable landslide the present run out length has been determined by databases, hillshades and field work in a first step. If there are indications for active movements in the landslide toe it is assumed that the run out length will proceed even further in case of a reactivation. The danger area has to be dimensioned according to geomorphologic conditions.

Flow processes - General approach

The procedure and depiction of flow processes like deep seated landslides (Talzuschub) is similar to the method used for slide processes. Flow processes rarely occur in low mountain ranges. In the German alpine area, debris flows are more related to water related hazards and for this reason not explained here in detail. The deep seated landslides are handled in the same way like the slide processes. The process occurring in the run out zone of shallow landslides is also mostly a flow process. To estimate this process as disposition model in Bavaria the physical computer model SLIDISP is used. To find the run out zones and to simulate the process the model SLIDEPOT (GEOTEST) is applied.

Modelling shallow landslides (in Bavaria used methods)

Shallow landslides are usually triggered by heavy rainfall, depending on the predisposition of the slope. Like the rock fall simulation the modelling of shallow landslides is carried out in two steps. The starting zones will be calculated in the disposition model and the run out zones will be calculated in the process model. For the disposition model the deterministic numerical model SLIDISP (Liener 2000 and GEOTEST AG) is used that assumes an above average precipitation for a certain area. Applying the Infinite-Slope-Analysis the slope stability for every raster cell will be calculated. Fundamental basic data are the slope angle, derived from the DEM from which the thickness of soil will be deduced and the geology which allows to determine friction angle and cohesion as geotechnical parameters. The factor of safety F will be calculated for every raster cell to describe the ratio of retentive and impulsive forces (Fig. 11, Selby 1993).

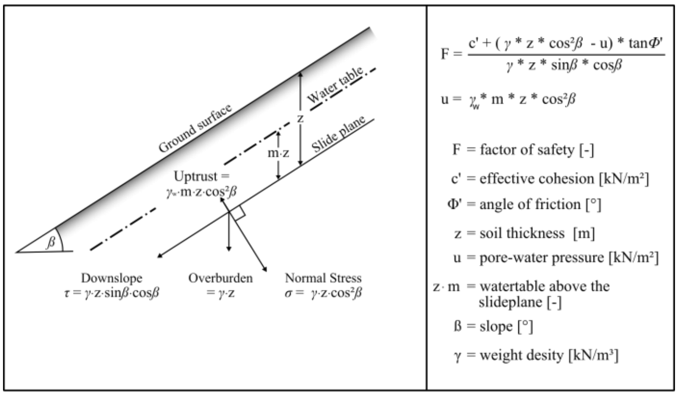


Figure 11: Principle for the calculation of the factor of safety F for every raster cell (Selby 1993)

The natural range in variation of different input parameters will be considered using a Monte-Carlo-Simulation. For every raster cell the number of instable cases will be determined. The higher the number of instabilities the higher is the probability of slope failure. Since the occurrence of forest affects the stability in an enormous way the root strength will be integrated in the calculation of the factor of safety as an additional parameter. Considering the root strength and its effect on soil stability it is possible to simulate two scenarios with different intensity of the “root effect” (high and low).

To calculate the run out zones the raster based model SLIDEPOT is used (GEOTEST AG). For every raster cell in the starting zone the accumulation will be modelled in flow direction. The model is based on neighbourhood statistics. Above a potential accumulation cell, the raster cells inside a 20° sector will be analysed (Fig. 12). Accumulation will be calculated if there is a starting zone and if the topography in the sector named above is not convex. Every step of expansion will analyse the neighbourhood up to a defined distance (4 cells; red circle in Fig. 12). With every step the hypothetical starting volume respectively the rest volume will be reduced by a degradation factor which depends foremost on the slope angle. The expansion stops if a defined number of expansion steps is achieved or if the calculated value falls below a defined threshold.

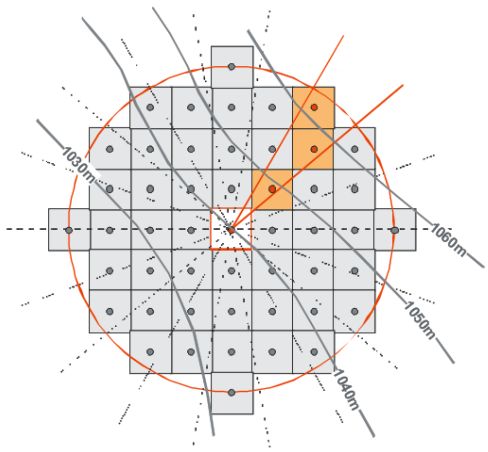


Figure 12: Calculation of accumulation: for the central cell with exposition of 210° –230° the 20° sector identifies 3 cells that are either starting zones or already show accumulation (orange cells)

The run out zones will be calculated for both scenarios. In both cases maximum 8 expansion steps have been calculated while in the forest the degradation factor has been reduced.

Because of uncertainties concerning complex edge conditions the degradation factors have been defined quite pessimistic. With this the run out zones are large enough and rather too large in the case of doubt.

Subrosion / Karstification

Superficial or near-surface subrosion features (sinkholes) and the knowledge of subrodable sediments serve as criteria for the analysis of a process area. In the first stage, the following danger areas are distinguished:

Verified karstification features from the Geological map, event register or remote sensing (e.g. DEM) methods. In the first stage, superficial or near-surface subrosion features (e.g. sinkholes, depressions, clefts) are visualised. There is no differentiation between fossil and current subrosion features. The second stage includes the visualisation of the dispersion of karstifiable sediments. Danger fields can be derived using a point or area statistical evaluation (e.g. using the feature density or a raster based density calculation), as well as using influencing factors, such as geology, tectonics and hydrogeology.

The result of the second stage determined the differentiation of danger areas. Where applicable, the danger areas can be coupled with general geotechnical recommendations as to construction work in karst landscapes. Special conditions in individual states, e.g. mining influences on karstification, can be noted in a further category. Optionally, a differentiation between carbonate, sulphate and chloride karstification can be implemented in the first or second stage of the danger map. If the information is available in individual states, the spread of the inner and outer salt slopes as well as intact salt domes should be entered into the danger map.

Discussion

The danger map has been worked out for a regional scale (1:25.000). Therefore the boundaries of the danger areas are not sharply bounded lines and a detailed view on particular areas or objects is not allowed. In addition, the modelling of the different processes can make no claim to be complete. The maps show potentially endangered areas that have been determined on the basis of available information that has been computed with modern numerical models. Anthropogenic preventive measures haven't been introduced into the models.

Improbable and extreme events haven't been considered. Instead frequently occurring events have been modelled since they are more representative and rather felt as risk. From a geological view rare and extreme events have to be accounted as an unavoidable residual and remaining risk.

The danger maps for rock fall of single blocks and rock fall masses and deep seated landslides are based on field work for the most part. In contrary the danger areas of shallow landslides are solely based on computer models and represent a typical susceptibility map. Therefore they are presented as hatched areas. In the field witnesses of former traces of shallow landslides are hard to find due to weathering. Anyway, if the predicted consequences of climate change with an increase in extreme rainfalls will come true, an increasing number of shallow landslides must be taken into account.

Climate change predictions could be implemented in the model if maps with predicted precipitation on a local scale were available. This would allow the identification of hot spots with heavy rainfall and therefore a higher susceptibility for landslides. The identification of such hot spots is one target in the Alpine Space Programme project AdaptAlp that also focuses on evaluation, harmonizing and improvement of different methods for hazard mapping.

Conclusions

A danger map is a very helpful tool for planning authorities to get an overview about land use conflicts and potentially endangered areas. It is a general map created under objective scientific criteria and indicating geological hazards that have been identified and localized but not analysed and evaluated in detail. A danger map does not contain specifications about the degree of hazard or the intensity or probability of an event.

The map will be provided to local and regional planning authorities, to water-, traffic- and forest management. It helps the planner to identify hot spots and to make decisions concerning measures of protection. On the other hand it also shows areas not endangered and free for planning.

In critical cases the danger map has to disclose the requirement for further analysis. In this cases a detailed expertise has to decide if measures are technically feasible, economically reasonable and under sustainable aspects really necessary.

To help potential users interpreting the danger map, the results are presented to all authorities. Furthermore an intensive cooperation with the Bavarian Environment Agency is offered. In addition a limited version of the danger map is published via internet (www.bis.bayern.de).

But the alpine part of Bavaria is not the only region which is affected by geological hazards. The alpine foothills and the Swabian-Franconian Jurassic-mountains are affected as well. On the midterm the goal is to develop danger maps for the whole of Bavaria.

3.1.2 Switzerland (Hugo Raetzo)

Switzerland is a country exposed to many natural hazards. These hazards include earthquakes, floods, forest fires, snow avalanches, rockfalls and debris flows. More than 6% of Switzerland is affected by hazards due to slope instability. These areas occur mainly in the Prealps and in the Alps. The Randa rock avalanches of 1991 are a good example of the potential of such hazards. Thirty million m³ of fallen debris cut off the valley for two weeks. In another case, a landslide was reactivated with historically unprecedented rates of displacement up to 6 m/day, causing the destruction of the village of Falli-Hölli in the year of 1994.

The legal and technical background conditions for the protection against landslides have undergone considerable changes since the 80’s. The flooding of 1987 promoted the federal authorities to review criteria governing natural hazard protection. The Federal Flood Protection Law and the Federal Forest Law came into force in 1991. Their purpose is to protect the environment, human lives and property from the damage caused by water, mass movements, snow avalanches and forest fires. Following the promulgation of these new regulations, greater emphasis has been placed on preventive measures. Consequently, hazard assessment, the identification of protection objectives, purposeful planning of preventive measures and the limitation of the residual risk are of central importance. The cantons are then required to establish inventories and maps denoting areas of hazards, and to take them into account in the land use planning. For the improvement of the inventories and the hazard maps, the federal government provides subsides to the cantonal authorities (50%).

In a first step the landslides are identified and classified. During this phase inventories and maps of phenomena are established. In a second step the hazard of landslides is assessed according to the methods used in the swiss strategy against all natural hazards (e.g. floods, avalanches). The hazard assessment is then integrated into land use planning and in the risk management (3. step).

First step: Hazard identification

Landslides can be classified according to the estimated depth of the sliding plane (< 2m: shallow; 2-10 m: intermediate; >10 m: deep) and the long term mean velocity of the movements (< 2 cm/year: substabilised; 2-10 cm/year: slow; > 10 cm/year: active). These depth and velocity parameters are not always sufficient to estimate the potential danger of a landslide. Differential movements must also be taken into account since they can generate buildings to topple or cracks to open.

Rockfalls are characterized by their speed (< 40 m/s), the size of their elements (Østone < 0.5 m, Øblock > 0.5 m) and the volumes involved. Rock avalanches with huge volumes (v > 1million m3) and high speed (> 40 m/s) can also happen although these are rare.

Due to heavy rainfall, debris flows and very shallow landslides are frequent in Switzerland. These are moderate volume (< 20'000 m3) and high speed features (1-10 m/s). These phenomena are very dangerous and annually cause important traffic disruptions and fatalities.

A map of landslide phenomena and an associated technical report provide signs and indications of slope instability as observed in the field. The map represents phenomena related to dangerous processes and delineates the vulnerable areas.

Field interpretation of these phenomena allows areas vulnerable to landslides to be mapped. This is based on the observation and interpretation of landforms, on structural and geomechanical properties of slope instabilities, and on historical traces. Extensive knowledge of past and current events in a catchment area is essential if zones of future instability are to be identified.

Some recommendations for the uniform classification, representation and documentation of natural processes have been established by the swiss federal administration. Consequently the definition of features on a natural hazard map are based on a uniform legend for landslides, floods and snow avalanches. The different phenomena are represented by different colours and symbols. An additional distinction is made between potential, inferred or proved events. According to the scale of mapping (e.g. 1:50,000 for the Master Plan, 1:5,000 for the Local Plan), this legend may contain a large number of symbols.

Inventories: Recommendations for the definition of a uniform Register for slope instability events has been developed, including special sheets for each phenomenon (landslides, floods, snow avalanches). Each canton is currently compiling the data for its own register. These databases (StorMe) are transferred to the FOEN to allow an overview of the different natural disasters and potential associated damage in Switzerland.

Second step: Hazard assessment of landslides

Hazard is defined as the occurrence of potentially damaging natural phenomena within a specific period of time in a given area. Hazard assessment implies the determination of the magnitude or intensity of an event over time. Mass movements often correspond to gradual (landslides) or unique (falls, debris flows) events. It is sometimes difficult to make an assessment of the return period of a massive rock avalanche, or to predict when a dormant landslide may reactivate.

Some federal recommendations have been proposed in the 90's for the management of landslides and floods. Since 1984 similar recommendations have already existed for snow avalanches. Hazard maps, according to the federal „recommendations" (guidelines), express three degrees of danger, represented by corresponding colours: red, blue and yellow (Figure 13). The various hazard zones are delineated according to the landslide phenomena maps, the register of slope instability events and additional documents. Numerical models (analysis of block trajectories, calculations of factors of safety) may be used to determine the extent of areas endangered by rockfalls, or to present quantitative data on the stability of a potentially unstable area.

RED: high hazard

- People are at risk of injury both inside and outside buildings.
- A rapid destruction of buildings is possible.

or:

- Events occuring with a lower intensity, but with a higher probability of occurrence. In this case, people are mainly at risk outside buildings, or buildings can no longer house people.

The red zone mainly designates a prohibition domain (area where development is prohibited).

BLUE: moderate hazard

- People are at risk of injury outside buildings. Risk is considerably lower inside buildings.
- Damage to buildings should be expected, but not a rapid destruction, as long as the construction type has been adapted to the present conditions.

The blue zone is mainly a regulation domain, in which severe damage can be reduced by means of appropriate protective measures (area with restrictive regulations).

YELLOW: low hazard

- People are at slow risk of injury.
- Slight damage to buildings is possible.

The yellow zone is mainly an alerting domain (area where people are notified at possible hazard).

***YELLOW-WHITE HATCHING*: residual danger**

Low probability of high intensity event occurrence can be designated by yellow-white hatching. The yellow-white hatched zone is mainly an alerting domain, highlighting a residual danger.

***WHITE: no danger** or negligible danger, according to currently available information.*

A chart of the degrees of danger has been developed in order to guarantee a homogeneous and uniform means of assessment of the different kinds of natural hazards across Switzerland (floods, snow avalanches, landslides…) – e.g. : Fig.1 for fall processes. Two major parameters are used to classify the danger: the intensity, and the probability (frequency or return period). Three degrees of danger have been defined. These are represented by the colours red, blue and yellow. The estimated degrees of danger have implications for land use. They indicate the level of danger to people and to animals, as well as to property. In the case of mass movement, people are considered safer inside the buildings than outside.

A description of the magnitude of potential damage caused by an event is based on the identification of threshold values for degrees of danger, according to possible damage to property. The intensity parameter is divided into three degrees:

High intensity: People and animals are at risk of injury inside buildings; heavy damage to buildings or even destruction of buildings is possible.

Medium intensity: People and animals are at risk of injury outside buildings, but are at low risk inside buildings; lighter damage to buildings should be expected.

Low intensity: People and animals are slightly threatened, even outside buildings (except in the case of stone and block avalanches, which can harm or kill people and animals); superficial damage to buildings should be expected.

Criteria for the intensity assessment:

There is generally no applicable measure to define the intensity of slope movements. However, indicative values can be used to define classes of high, mean and low intensity. Applied criteria usually refer to the zone affected by the process, or to the threatened zone.

For **rockfalls,** the significant criterion is the impact energy in the exposed zone (translation and rotation energy). The 300 kJ limit corresponds to the impact energy to which can be resisted by a reinforced concrete wall, as long as the structure is properly constructed. The 30 kJ limit corresponds to the maximum energy that oak-wood stiff barriers can resist (e.g. rail sleeper). For rock avalanches, the high intensity class (E > 300 kJ) is always reached in the impact zone. The target zones affected by block avalanches of low to medium intensity can only be roughly delineated. Therefore, it is recommended not to artificially delineate zones affected by low to medium intensities.

Most **landslides**: A low intensity movement has an annual mean speed of lower than 2 cm/y. A medium intensity has a speed ranging from one to 10 cm per year. The high intensity class is assigned to velocities higher than 10 cm per year and to shear zones or zones with clear differential movements (D). It may also be assigned if reactivated phenomena have been observed or, if horizontal displacements greater than one meter per event may occur. Finally, the high intensity class can also be assigned to very rapid shallow landslides (speed > 0.1 m/day). In the area affected by landsliding field, intensity criteria can be directly converted to danger classes. Other criteria as velocity changes or accelerations (dv), differential movements (D) and thickness of the landslide (T) can lead to increase resp. to reduce the intensity class as derived from the long term velocity.

For **earth flows and debris flows**, the intensity depends on the thickness of the potentially unstable layer. The boundaries defining the three intensity classes are set at 0.5 m and 2 m.

Phenomena	Low intensity	Medium intensity	High intensity
Rockfall	E < 30 kJ	30 < E < 300 kJ	E > 300 kJ
Rock avalanche	-	-	E > 300 kJ
Landslide	v ≤ 2 cm/y dv, D, T	v : 2-10 cm/y dv, D, T	v>10 cm/year dv, D, T v > 0.1 m/day for shallow landslides; displacement > 1 m per event
Earth flows and debris flows			
potential	e < 0.5 m	0.5 m < e < 2 m	e > 2 m
real	-	h < 1 m	h > 1 m
E: kinetic energy; e: thickness of the unstable layer; h: height of the earthflow deposit; v: long term mean velocity, dv: variation of velocity (accelerations), D: differential movements, T: thickness of the landslide.			

Probability

Probability of landsliding is defined according to three classes. The class limits are set at 30 and 300 years and are equivalent to those established for snow avalanches and floods. The 100-year limit corresponds to a value applied in the design of flood protection structures.

The results of probability calculations to determine if mass movements occur remain very uncertain. Unlike floods and snow avalanches, mass movements are usually non-recurrent processes. The return period, therefore, only has a relative meaning, except for events involving stone and block avalanches and earth flows, which can be correlated with recurrent meteorological conditions. The probability of mass movement occurrence should mainly be established for a given duration of land use. Thus, the probability of potential damage during a certain period of time, or the degree of safety of a specific area should be taken into account, rather than the frequency of dangers.

The probability of occurrence and the return period can be mathematically linked, if attributed to the same reference period:

$$\mathbf{p = 1 - (1 - 1/T)n}$$

where p is the probability of occurrence, n represents the given time period (for example 30 or 50 years), and T is the return period.

For example, considering a time period of 30 years, an event with a 30-year return period has a 64% probability of occurrence (or about 2 in 3), of 26% (or about 1 in 4) for a 100-year return period, and of 10% (or about 1 in 10) for a 300-year return period.

The calculation of the probability of occurrence clearly shows that even for a rather high return period (300 years), the residual danger remains not significant.

In principle, the probability scale does not exclude very rare events, neither does it exclude the intensity scale for high magnitude events. Hazards with a very low probability of occurrence are usually classified as residual dangers under the standard classification. In the domain of dangers related to mass movements, the limit for a residual danger has been set for an event with a 300-year return period.

The degree of hazard is defined in a hazard matrix based on intensity and probability criteria (Raetzo & Loup 2009). The resulting hazard map is mainly used for planning (land use), while the design of protection measures needs more detailed investigations. In general the methods used are related to the product, scales and the risk in order to respect economic criteria: low efforts are done for the swiss indicative map (level 1), important efforts are done when a hazard map is established or reviewed (level 2). Detailed analyses and engineering calculations are foreseen for the planning of countermeasures (level 3). Applying this concept rising efforts for geological investigations are planned when the assessment on the second or third level takes place.

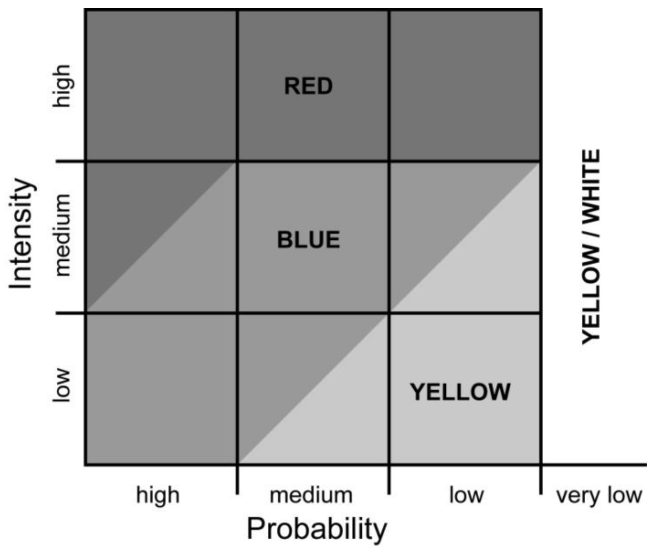


Figure 13: matrix for the assessment of hazard

Third step: land use planning and risk management

The hazard map is a basic document used in land use planning. Natural hazards should be taken into account particularly in the following situations:

- Elaboration and improvement of cantonal Master Plan and Communal Local Plans for land use.
- Planning, construction, transformation of buildings and infrastructures.
- Granting of concessions and plannings for construction and infrastructural installations.

Granting of subsidies for building and development (road and rail networks, residences), as well as for slope stabilisation and protection measures.

According to Art. 6 of the Federal Law for Land use Planning, the cantons must identify all areas that are threatened by natural hazards.

The **cantonal Master Plan** is a basic document for land use planning, infrastructural coordination and accident prevention. It consists of a map and a technical report, and is based on studies. The Master Plan allows to decide the following:

- It shows how to coordinate activities associated with different land uses.
- It identifies the goals of planning and specifies the necessary stages.
- It provides legal constraints to the authorities in charge of land use planning.

The objectives of the Master Plan with respect to natural hazards are:

- To early detect conflicts between land use, development and natural hazards.
- To refine the survey of basic documents concerning natural hazards.
- To formulate principles that can be applied by the cantons to the issue of natural hazard protection against.

To define necessary requirements and mandates to be used in subsequent planning stages.

The constraints on **Local Planning** already allow and ensure appropriate management of natural hazards with respect to land use. The objective of these constraints is to delineate danger zones by highlighting restrictions, or to establish legal frameworks leading to the same ends.

At the same time danger zones can be delineated on the local plan with areas suitable for construction as well as additional protection zones.

The degrees of danger are initially assigned according to their consequences for construction activity. They must minimise risks to the safety of people and animals, as well as minimising as possible damage to property. In agricultural zones, buildings affected by different degrees of danger are constrained by the same conditions as those in built-up areas.

Conclusions

In Switzerland legal and technical references are published to clarify which responsibibities the authorities have and how the assessment has to be done in order to apply the concept of integral risk management. The hazard map indicates which areas are unsuitable for use, according to existing natural hazard. The integration of hazard maps into land use planning (including construction conditions, building licences) and the development of protective measures to minimise damage to property are main objectives.

When the hazard map is compared with existing land use conflicts may occur. Since it is difficult or impossible to change land use, specific construction codes are required to reach the desired protection level. Hazard maps are also considered in planning protective measures as well as the installation of warning systems and emergency plans. The federal recommendations are on attempt to mitigate natural disasters by restricting development on unstable areas.

3.1.3 Austria - Carinthia (Richard Baek)

In Austria there are several public organizations (HÜBL et al. 2009) involved in the assessment of rapid gravitational mass movements such as rock-fall and landslides. Inventories of such events are maintained by the Austrian Torrent and Avalanche Control (WLV) and the Geological Survey of Austria (GBA) apart from independent assessments done by the national railway and road administrations.

On the level of the federal administrations different approaches to document and/or forecast such mass movements are being followed. These organizations deal with those hazards with different approaches (method and target).

As there are no legal instructions in Austria how to deal with the evaluation of mass movements the federal states all follow a different course of action. Also, the status of available historical data is very different in the individual states. In some of the federal states almost no data is available, others have collected a lot of data but it is not digitally available. And then there are states that can rely on a lot of digitally available data and are working on generating landslide susceptibility maps. In the following a short summary about the efforts in the federal states is given.

Mass movement-inventories in Austria

Since 1978 the Geological Survey of Austria is gathering and displaying information (e.g. documents, photos, inventory maps) about gravitational mass movements and other hazardous processes. Due to the increasing amount of data the Department of Engineering Geology of the Geological Survey of Austria developed a complex data management system called GEORIOS. It consists of a Geographical Information System (GIS) which is the basis for the digital storage and display of data and overlay of different data types. Additionally the data management system consists of a relational data base which manages additional thousands of meta-information (documents, photos etc.).

The database includes detailed information about the mass movements (geology, hydrology, geometric and geographical data, studies or tests carried out, mitigation measures) and the source of information (archives, etc.), and also information about who carried out the field work and added the data into the database.

22,000 mass movements are stored in the database already. The compilation of a part of the mass movements in Austria is publicly accessible via the internet (www.geologie.ac.at) in German and English language. However, the web application includes only events such as slides, rock falls, or more complex mass movements, which have been published already in the media or the internet and are free available for everyone (KOCIU et al 2007).

An engineering geological database, as well as a bibliographical database is also included in the GEORIOS system.

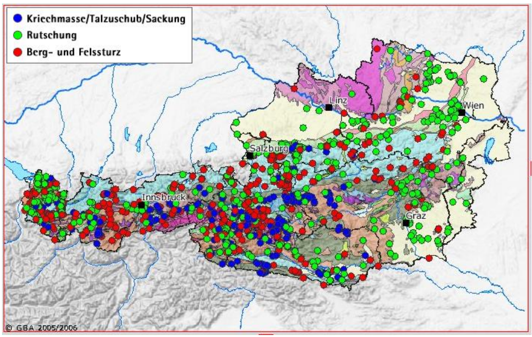


Figure 14: Inventory of mass movements in Austria (source Geol. B.-A.: www.geologie.ac.at)

In cooperation with the Geological Survey of Carinthia the Geological Survey of Austria has created not just one “inventory map”, but a “level of information”, as is explained in the following (Kociu et al 2010):

Level of information:

- Process index map, map of phenomena (“Prozesshinweiskarte”, “Karte der Phänomene”): This kind of map can have different scales (1:50,000 and bigger) and can be of varying quality, it contains information about process areas as phenomena of mass movements that have already happened.
- The event inventory (“Ereigniskataster”) records only those processes, for which an event date is known (5W- questions), it is independent of a scale and can contain processes without information of location. In Carinthia a digital landslide inventory was created with historical events of the last 50 years (Bäk et al 2005).

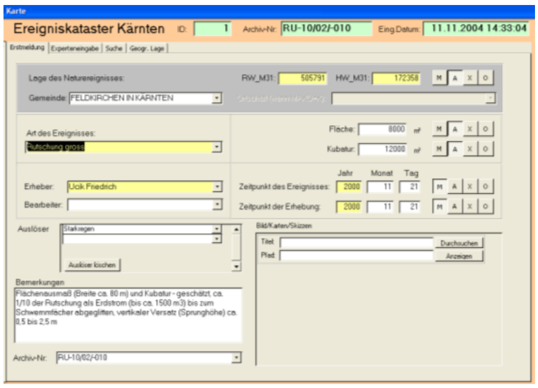


Figure 15: Event inventory of Carinthia with 5W-questions and quality remarks MAXO (M-sure;A-estimate; X-uncertain; O-unknown)

- The inventory map/ event map ("Ereigniskarte") contains only information about processes for which an event date is known (5W- questions: What, When, Where, Who, Why). The symbols are correlated to process typ and magnitude (triangle – small events, pentagon – great events).

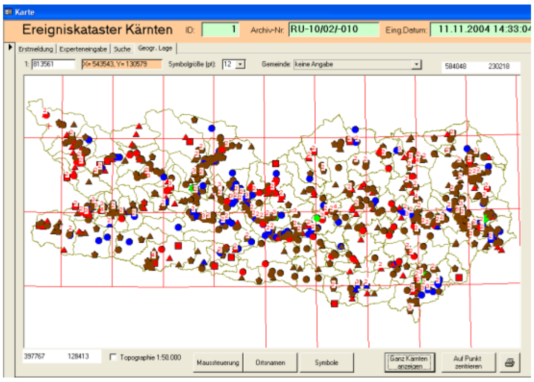


Figure 16: Event map of Carinthia (brown – landslides; blue – earth flow; red – rock fall; green – earth fall)

- The thematic inventory map contains only information related to a type of process, categorized according to the quality of the data.

The Austrian Torrent and Avalanche Control (WLV) is also maintaining an inventory covering torrential floods, avalanches, landslides and rockfalls – the so called "Wildbach- und Lawinenkataster".

ID	ART	ERSTELLT	LETZTE ÄNDERUNG	EINZUGSGEBIET bwz ORTSBEZEICHNUNG	GEMEINDE	EREIGNIS-ZEITPKT.
2982	»Massenbewegung Steinschlag/Felssturz	15.04.09	12.05.09	Brunnfelder	Außervillgraten (Tirol)	24.03.2009
3090	»Massenbewegung Steinschlag/Felssturz	12.05.09	12.05.09	Steinschlag Gstättenberg/Roith	Bad Ischl (Oberösterreich)	19.03.2004
3241	»Massenbewegung Steinschlag/Felssturz	13.07.09	13.07.09	Gruben	Matrei in Osttirol (Tirol)	14.04.2009
4770	»Massenbewegung Steinschlag/Felssturz	19.07.10	19.07.10	Mehrnstein Süd	Brixlegg (Tirol)	17.07.2010

Figure 17: WLV-Inventory of mass movements in Austria (source: www.die-wildbach.at)

<u>Standards of susceptibility/hazard assessment in Austria</u>

Because of the lack of a regulatory framework or technical norm concerning landslides and rock fall in Austria - only the course of actions concerning floods, avalanches and debris flows are regulated by law (ordinance of hazard zone mapping, Rudolf-Miklau F. & Schmidt F., 2004) - the federal states are all following a different course of action.

E. g. in Vorarlberg risk maps (susceptibility map, vulnerability map, risk map) were produced in the course of a university dissertation (RUFF, 2005). For modeling bivariate statistics (for landslides) and cost analysis (for rockfall) were used, working with a 25x25m raster. The susceptibility, meaning spatial susceptibility, is presented in 5 classes (very low, low, medium, high, very high). The inventory map is included in the susceptibility map. On the other hand the local department of the Austrian Service for Torrent and Avalanche Control (WLV) creates "hazard maps" within the "hazard zonation plan".

In Upper Austria, Lower Austria, Burgenland and Carinthia different approaches are chosen to develop susceptibility maps (different scales, processes) derived from existing data sets and maps (Posch-Trötzmüller G., 2010): Main focus of Burgenland is concentrated on shallow landslides with an annual rate of movement of 1-2cm. For the prediction of landslide susceptibility based on morphological and geological factors, the method called "Weights of Evidence" was chosen (KLINGSEISEN et al., 2006). Three (respectively 4) hazard zones were classified (["high Hazard"], "hazard", "hazard cannot be excluded", "no hazard", Klingseisen et al., 2006). In Lower Austria up until now the susceptibility maps have been created using a heuristic approach based on geological expertise, historical data and interpretation of DEM and aerial photos. Three to ten classes of susceptibility are delineated at a scale ranging from 1:50,000 to 1:25,000 (Schweigl & Hervas 2009). To offer assistance for the municipalities in land-use planning, landslide susceptibility maps were generated for the major settled areas in Upper Austria (OÖ). For each type of mass movement the priority, which is a susceptibility class, was evaluated on the basis of the intensity and the probability of an event. The priority was classified in 3 stages (high – medium – low; Kolmer, 2005). As these maps include the intensity and the frequency of mass movements, they can be called "hazard maps" by definition. Nevertheless it has to be taken into account that the method of generating these maps included neither field work nor remote sensing techniques. The method of assessment is based on geological expertise solely.

Using the digital geological map of Carinthia (1:50000), the inventory map of mass movements (landslides and rock-falls), DEM (10m x10m raster), land-use and lithological- geotechnical characteristics of bedrock and unconsolidated sediments, process related susceptibility maps for Carinthia were generated in a collaboration of the Geological Survey of Austria (GBA) and the Geological Survey of Carinthia at a scale of 1:200000 (Bäk et al., 2005). Of course these maps are still lacking information about intensity and recurrence period or probability of occurrence. Because of the imprecision of used input data the accuracy of prediction regarding the susceptibility for rapid mass-movements based on maps like the ones mentioned above is limited.

For a small study area in Styria the Geological Survey of Austria generated a susceptibility map for spontaneous landslide (soil slips and earth flows) at a scale of 1:50000 using neural network analysis (SCHWARZ et al., 2009). Any susceptibility class is not a ranking or the degree of slope stability, but a description of the relative propensity/ probability of a landslide of a given type and of a given source area to occur.).

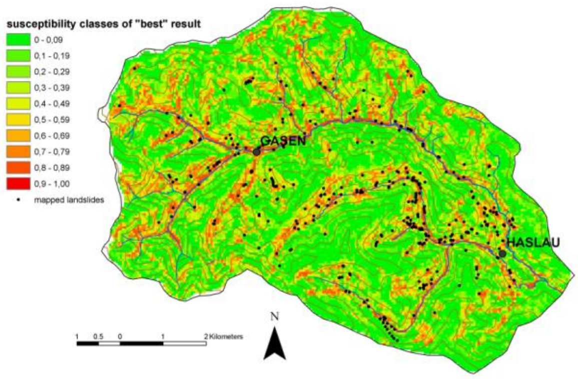


Figure 18: Susceptibility map for spontaneous shallow landslide at Gasen – Haslau (Schwarz et al 2009).

At the Geological Survey of Austria (GBA) susceptibility maps in different scales and with different methods (heuristic approach, neural network analysis) have already been generated. (KOCIU et al., 2010, MELZNER et al., 2010, TILCH et al., 2009, TILCH et al., 2010, TILCH et al., 2010, TILCH et al 2009).

Legal situation, requirements by the law, responsibility of different authorities

The key feature for susceptibility/hazard mapping is a good documentation of historic events, a thorough mapping of the phenomena involved and an accurate interpretation of the failure with the subsequent processes.

The WLV is legally obliged to do an inventory of all events regarding natural hazards such as torrential processes, avalanches, rock-falls and landslides in the so called “Wildbach- und Lawinenkataster – WLK” (Forstgesetz 1975). The GBA defines its very own tasks among others: “the assessment and evaluation of geogenically induced natural hazards". These inventories (WLV, GBA, geological surveys of provinces like Carinthia) are established to guarantee a complete documentation of processes and events that can eventually endanger infrastructure and/or people. The data collected in the inventories allow for better information and further evaluation where, when, how often and with which intensities those events took place. These inventories can form an important basis for the elaboration of hazard maps and related hazard zones, which give the authorities good evidence to optimize land-use planning and avoid areas which tend to be exposed to natural hazards. For already developed areas the assessment of the type of process, magnitude, run-out, location, frequency etc. allows for a better priority-rating and design of mitigation measures.

To elaborate hazard zone maps (Forstgesetz 1975 and BGBl. 436/1976) for potentially endangered zones caused by natural hazards (except flooding by rivers and earthquakes, which are done by other authorities) for all communities is the task of the Austrian Torrent and Avalanche Control (WLV).

The delineation of potential immission-zones of rapid mass movements such as rock-falls and landslides are not mandatory and therefore can be illustrated as “brown hazard indication areas” by the WLV.

The legal implication of these indication areas lies in the obligation of the authorities issuing building permits to consult an expert to evaluate the hazard for the planned construction site explicitly, otherwise the community can be excluded from public funding for the financing of mitigation measures in the future.

Standards, guidelines, official and legal documents

Several standards issued by the IAEG (Internat. Association of Engineering Geology – UNESCO Working Party of World Landslide Inventory exist for the documentation and classification of landslides. Furthermore for the documentation of landslide and rock-fall events (avalanches and torrential processes are covered as well) a short course of the Universität für Bodenkultur Wien, Dpt. f. Bautechnik und Naturgefahren, Inst. f. Alpine Naturgefahren exists, which certifies documentalists for those processes.

For the assessment and evaluation of rock-fall processes and the design of protection measures an Austrian Standard is currently under development (ONR 24810: Technischer Steinschlagschutz).

State of the art in the practice

The code of practice is to be adapted to the state of the art due to the absence of binding standards. The state of the art according to the "Wasserrechtsgesetz WRG 1959 §12a(1)" is defined in Austria as the following: The use of modern technological methods, equipment and modes of operation with proven functionality which represent the status of progress based on relevant scientific expertise.

Rockfall hazard assessment

The state of the art regarding the assessment and evaluation of hazard for rock-fall processes can be described by the following workflow. The methods to be applied are just roughly described, for detailed description see cited literature. Depending from the objective of the assessment the tools to be applied may vary in respect to the scale of the result, being more coarse at regional scale and detailed at slope-scale.

Standard procedure for the assessment of rock-fall hazard (best practice):

Preparation

- Definition of the boundaries of the project area in compliance with the stakeholder
- Acquisition of basic data (topografic maps, geology, land use, literature, etc.)
- Collection of historic event information (written and oral)

Fieldwork:

- Collection of properties of forest (if relevant), identification (by field work and/or according to e. g. JABOYEDOFF 1999) and
- evaluation of detachment areas
  - description of discontinuities (type, dip/direction, opening, filling …),
  - properties of rock mass,
  - relevant failure mechanisms,
  - probabilistic distribution of joint-bordered rock bodies
- Scree slopes: block-size distribution (statistics)
- Analysis of rock fall processes (MELZNER et al 2010, MELZNER et al 2010, MÖLK 2008):
  - Rough estimation of runout e. g. by shadow angle (regional scale)

- 2D or 3D modelling (probabilistic): provides runout length, energy- and bouncing-height distributions for slope-scale problems

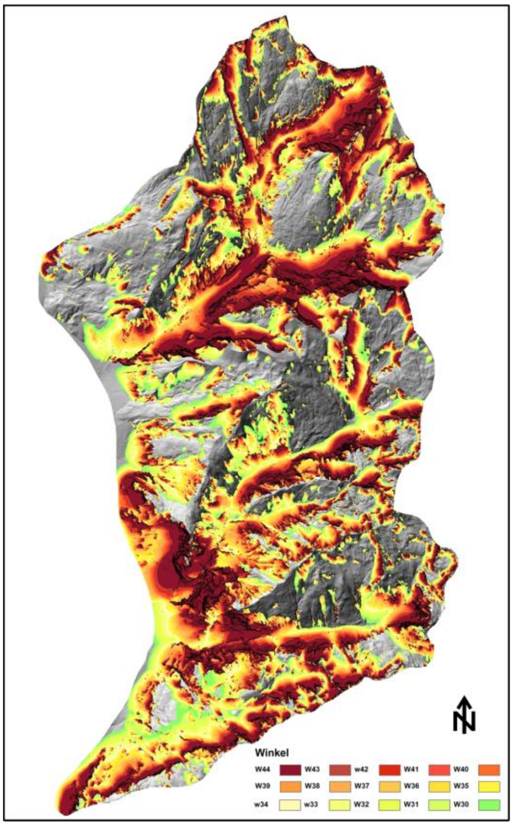


Figure 19: Delineation of potential conflict areas at regional extent using an empirical model (Melzner et al 2010)

For the design of mitigation measures a probabilistic approach is going to be defined as a standard procedure in Austria (ONR 24810) following the concept of partial factors of safety (Eurocodes) for actions/resistances and varying accepted probabilities of failure depending on the casualty- and reliability-classes of Eurocode 0.

Landslide hazard assessment

Landslides present complex natural phenomenas for both the variability of processes and the dimensions. A landslide may exhibit a translational sheet slide of some square meters involving the ground surface or a deep seated mass movement of several cubic kilometers.

Rapid landslides with reference to Cruden & Varnes (1996) feature velocities of some meters per minute to several meters per second. In Austria the main processes exhibit different slides and debris slides. Very rapid to rapid flow slides, which one can find for example in Scandinavia or in Canada have no relevance in Austria.

Slides include rotational, translational and compound slides. Rotational slides own a circular sliding surface, which results from shear failure in relatively homogenous rock or soil of low strength. Translational slides take place in rock on forgiven more or less planar features like bedding planes, joints etc. The failure results when the shear resistance on the plane is exceeded. Relatively often one can find these slides in the soil cover of the ground, called sheet slides, where the sliding surface is formed by a weak clay layer, such as a gley horizon in the range of groundwater fluctuations.

The combination of a rotational and a translational sliding mechanism is called a compound slide. These may develop in horizontally stratified soils and rocks, where the upper part of the slope shows a rotational failure which is constrained by a plane of weakness at the base (e. g. a claystone layer).

A process, which frequently can be observed in Austria are debris slides (e. g. Gasen and Haslau 2005, Vorarlberg). These failures occur in porous soils, especially after extraordinary water input resulting from precipitation and/or snow melt leading to an excess of pore water pressure. The mass movement often starts as a rotational slide, which turns into a debris flow down slope.

When assessing landslide hazard it is important to distinguish between preparatory factors and the triggers (WL/WPLI 1994). The triggering of a mass movement to occur is the last step of destabilization over a longer period of time. Concerning to Therzaghi (1950) the stability of slopes is stated by the factor of safety, which is expressed by the ratio between driving forces and resisting forces. Stable slopes feature a factor of safety over one, meaning that the resisting forces exceed the driving forces. If the driving forces are greater than the resisting forces the slope fails, i.e. the factor of safety drops under one.

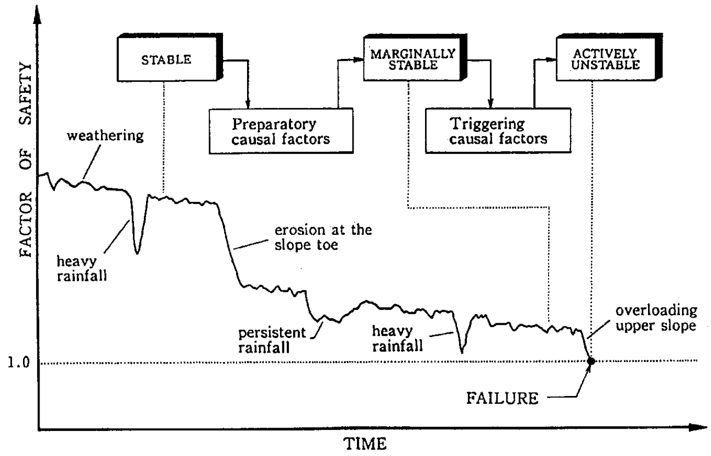


Figure 20: An Example of changes of the factor of safety with time after WL/WPLI (1994)

Figure 20 (WL/WPLI 1994) shows the development of a stable slope to one that fails. Since the slope is exposed to weathering, erosional processes etc. the factor of safety of the slope decreases to the point where it is close to failure (marginally stable). At this point the slope is susceptible to many triggers.

When assessing landslide hazard the following information is needed regarding the ground conditions:

- geology and structures
- hydrogeology,
- type of process
- velocity of the process
- geotechnical properties of materials involved
- potential role of human activities (triggers?).

State of the practice in landslide assessment

Conventional methods are based on observations of potentially unstable slopes. Aerial photos, both stereographic and orthophotos, are used since decades to detect these slopes by characteristic geomorphological phenomena in combination with available geological maps (BUNZA 1996, Kienholz 1995). This first analysis is completed by mapping in the field. The data are commonly presented in landslide hazard maps, which show the spatial distribution of different hazard classes. Additionally chronicles, which occasionally exist at the town halls, turned out to be very useful.

State of the art in landslide assessment

Since several years high resolution Lidar data are available for most regions in Austria bearing landslide activity. They are a powerful tool to recognize geomorphological structures of landslides (Zangerl et al., 2008). A main advantage of Lidar data in comparison to conventional photos is the information on shaded areas and of areas covered with wood. Additionally remote sensing systems (e.g. airborne and satellite-based multispectral and radar images) provide information on unstable, slowly creeping slopes, which may fail and transfer into a rapid moving masses (Prager et al., 2009).

Until recently susceptibility/hazard maps in Austria were often made on demand. Since some years authorities (LReg Kärnten, WLV Oberösterreich und Vorarlberg) are going to make comprehensive hazard maps giving a basis on decision-making for land use and development. Landslide inventories (databases of WLV, GBA, several federal states) in combination with GIS applications are used to get rapid information to areas prone to landslides.

Collected surface data in combination with subsurface data gained from trenches and boreholes or seismic refraction, ground-penetrating radar and electrical resistivity profiles allow for the drawing of a underground-model and deduce the type of failure mechanism which is most likely to occur.

Geotechnical data are also required to assess the factor of safety and the probability of failure by means of analytical calculations or numerical modeling (e.g. Poisel et al. 2006). Additional information on the process can be provided by a monitoring system. This serves as a check for the taken assumptions and an evaluation of the mechanical model. Furthermore a monitoring allows the prediction of failure time under certain circumstances (e.g. Fukuzono 1985, Krähenbühl 2006, Rose & Hungr 2007)

Future development

The development of forecast-models for the prognosis of the location and/or time of rapid gravitational mass movements to take place or even the meteorological settings which will trigger such events is at an early stage. Due to the fact that the authorities are strongly asking for such tools, many practitioners and scientists are focusing on that topic.

The multitude of parameters influencing the development of the erosional processes in question will keep the stake high and will not allow to provide the authorities with the accurate models they ask for within a considerable time. Given the necessary detailed parameters such as geology, hydrogeology, geotechnical parameters etc. triggering, influencing or allowing for the processes in question are at hand, and all the necessary models are developed, it is highly likely, that they will work in certain regions with similar or corresponding geological, morphological and meteorological conditions only.

The accuracy of these models will necessarily depend highly on a thorough calibration with well documented events. This emphasizes the necessity of a consistent documentation of events, to provide the model-developers with calibration data.

This means that the expertise of experts applied at defined locations with all the necessary field work and assessment of natural parameters, fed in apt models will not become obsolete in the near and very probably not even in the far future. Models showing the disposition of a given environment to tend to mass-movements and also forecasting the location, time and run-out of such processes will be a precious tool for the experts although a replacement of a thorough evaluation of the conditions on site is not to be expected anytime.

3.1.4 Italy - Emilia Romania (Giovanni Bertolini)

The Emilia-Romagna Regional Geological Survey has identified over 70,000 landslide bodies that cover one fifth of the hilly and mountainous territory. As regards dimensions, it may be estimated that at least 1300 of them have a volume exceeding one million cubic metres. The great majority (~ 90%) of these large landslide bodies originated as earth flows.

The majority of them (52%) reaches a depth ranging from 10 to 30 meters and about 12% of them exceeds 40 m. Their lithology is extremely variable, with a prevalence of clay matrix produced by the softening of shaly units. The 90 % of the historical landslide events (by archive records) are situated on pre-existing and already mapped earth flows. The majority of them alternate periods of activity and dormancy which can be lasting from a year to a century. A recurring behaviour can be seen in the majority of reactivations of ancient earth flows.

The sequence of events was observed in many recent cases and is described in Figure Seldom, the clay matrix reaches the limit of moderate-high plasticity, thus contributing to the appearance of a general flowing movement, as occurred in the “Cà Lita case” in 2003-2004.

From the moment it is triggered, the time required for a full reactivation of a landslide can vary between a few days (e.g. Morano) to a few years (e.g. Corniglio). In the great majority of cases, the movement comes to a stop in a few months.

Present tools for hazard management

The Emilia-Romagna Landslide Inventory Map (LIM) reports over 70,000 landslides, while the historical data base contains about 6600 landslide events. LIM may be considered as an elementary form of hazard map and, based on this, enforce rules and obligations addressing landslide hazard reduction: only existing hamlets and villages can extend on dormant landslides; on active ones, all new construction is forbidden. Otherwise, the use of a purely descriptive terminology (active, dormant), restricts the usability of this map, being often obsolete, and is therefore a frequent bone of contention.

Final remarks

In order to minimise the effect of the above cited uncertainties this assessment should be reached by a site-specific, multiple and partially heuristic approach, pooling together all the above mentioned elements of evaluation.

Most importantly, using detailed field observation and all other available means, the hazard estimate must consider possible indicators of present and recent movement, or situations that could lead to future reactivation, with special attention to present or historical local instability in the source area.

3.1.5 Italy - Piemonte (Stefano Campus)

Facing a natural hazard, the risk management can be divided in several stages:

- *Danger characterization, hazard assessment and vulnerability analysis*
- *Risk evaluation and assessment*

- *Risk prevention (protective works, land use regulation, monitoring, etc.)*
- *Crisis and post-crisis management*
- *Feedback from experience*

It is essential to well distinguish the three aspects of landslides studies:

- **DANGER** - Threat characterization (typology, morphology even quantitative, inventory…)
- **HAZARD** - Spatial and temporal probability, intensity and forecasting of evolution (scenarios) are needed
- **RISK** - Interaction between a threat having particular hazard and human activities. We need vulnerability and damage analysis

These differences are theoretically well known by all technicians but often there are some problems when they have to be applied in a legal framework. So, it is not so unusual to find *inventory maps* used as *hazard maps* or *damage maps* called *risk maps*.

Then, we have to distinguish two situations:

1) **Landslides studies with no influence from legal point of view**, like land planning. Typical cases are the studies carried out by Universities about some relevant landslides. The aim is, for example, to understand the mechanical features of instability or to study different ways of evolution of the phenomenon (scenarios) in order to assess residual risk. Any method to assess landslide hazard and risk can be used. They include statistical, deterministic, numerical etc. methods for hazard and qualitative or matrix calculus for risk. Landslide inventory can be made by means of historical, morphological, etc., approach.

2) **Landslides studies that have direct consequences to land planning laws**, at local scale or higher. GIS methods allow to perform analyses over wide areas useful to include in Basin Plans or Master Plans. National or local laws can require standard ways to present the results (common graphical signs on the maps, for example).

Legal framework in Italy and Piemonte

The national Law (high level) n. 445/1908 (*Transfer and consolidation of unstable towns*) and Royal Decree R.D. n. 3267/1923 (*Establishment of areas subject to hydrogeological constrains*) were the first public regulations on land use planning. At the beginning of ‘70s the land use management was transferred to regions.

The national Law n. 183/1989 introduced land use planning at a basin scale: the Government sets the standards and general aims without fixing a methodology to analyse and evaluate the dangers, hazards and risks related to natural phenomena. The same law designated the *Autorità di Bacino* (Basin Authority) whose main goal is to draw up the Basin Plan, a tool for planning actions and rules for conservation and protection of the territory.

About Po basin, the last plan adopted in 2001 is called PAI (*Piano per l'Assetto Idrogeologico* or Hydrogeological System Plan of River Po Basin). It tries to verify the geological instability of the whole territory as regards the land use planning through a process of upgrading and feedback with the local urban management plans. Moreover all the municipalities are classified according different risk levels, mainly from a qualitative point of view. For landslides existing two atlas (1:25.000 scale):

1) **Atlas of Hydrogeological Risks** (landslide, flood, alluvial fans, avalanches)

This atlas is worked out at municipal level. Every municipality is valued on the basis of the hazard, vulnerability and expected damage. Landslide hazard is function of ratio between area of landslides within municipal boundaries and whole area of municipality.

This atlas has 4 qualitative classes:

- *R1-moderate risk:* Social damages and few economic losses are possible.
- *R2-medium risk:* Few damages to buildings and infrastructures without loss of functionality.
- *R3-high risk:* Problems to human safety. Many damages and economic losses.
- *R4-very high risk:* Deaths and severe injuries are possible.

2) **Atlas of Landslides**

It is an inventory, in which polygons and points are divided in 3 classes:

- ***Fa*** - area with *Active Landslides* ("very high hazard"). No new buildings or infrastructures are allowed. Only measures of protection and reduction of vulnerability

- ***Fq*** - area with *Quiescent Landslides* ("high hazard"). Some enlargements are allowed. New buildings are allowed according to city development plan.
- ***Fs*** - area with *Stabilized Landslides* ("medium-moderate hazard"). The development of these areas is indicated in the city development plan.

The catastrophic event of May 1998, which caused heavy damages and victims in municipalities of Sarno and Quindici (Campania), urged the Government to give answers for development regulation (to reduce or eliminate landslides losses). According to the national Law n. 267/1998, the Government enforced legislative measures at national level, including the procedure to define landslide risk areas.

Another important aspect of the Law n. 267/1998 regards the development of "Extraordinary Plans" to manage the situations of higher risk (R.M.E.-*Aree a Rischio Molto Elevato)*, where safety problems or functional damages are possible. Local and regional authorities are obliged to define, design and apply proper measures to risk mitigation, with national funding. In Piemont these actions have been applied in some significant cases such as in Ceppo Morelli (Valle Anzasca in northern part of Piemonte), classified as a very high-risky area.

Low Level Legislation (Local Urban Development Plan)

The classification of areas made of Po Basin Authority is a binding act. The Municipality must adopt a new town development plan taking into account that classification. If the Municipality wants to change PAI classification, a deep analysis of the areas has to be done to justify new land use destination.

Regione Piemonte Law for Urban Development L.R. n. 56/1977, which is the main legal instrument of land use management at a local scale, as well as the Regional Law L.R. n. 45/1989 which regulates land use modification and transformation in areas subject to environmental protection, divides areas in more detailed classes having (almost) same meaning of PAI classification.

In Piemonte, the local management plan (required by the Regional Law L.R. n. 56/1977) includes the danger/hazard zoning in order to identify landslide prone areas on the basis of geological and morphological features and historical analysis.

In state of emergency (as established by the Regional Law n. 38/1978, which regulate and organise interventions related to severe instability phenomena) a specific article of the regional law 56/1977 (art. 9/bis) allows to inhibit or to suspend development in the involved areas. Consequently a new land use planning must be realised (upgrade/revision of the local management plan).

The last integrations to this law (*Circolare del Presidente della Giunta Regionale*, n. 7/LAP/1996 and *Nota Tecnica Esplicativa*, 12/1999) introduced the concept of *hazard* and *risk zoning*, classifying the whole territory in different classes where land uses are precisely regulated and defined, where building is forbidden, where preventive measures have to be taken, etc.

It is important to clarify that Regione Piemonte does not have an official regional Geological Survey. Some geological functions are executed by Arpa Piemonte (Agency for Environmental Protection) having two “geological” departments: one dedicated to Geological Informative System, research and applied projects, the other one deals with geological aspects of municipality urban plans. So we produce landslide danger, hazard and risk analyses that have not any legal consequences.

Within many regional, national and European Projects, we carried out many experiences in fields of assessing methodology for landslides hazard assessment (for instance, Interreg PROVIALP Project for Rock Fall or national Project of Geological Cartography for shallow and planar landslides in Langhe region).

So we have complete coverages of basic information (lithology, geothecnical geo-database, landslides inventory, etc…) but only a few applications of hazard & risk assessment.

One of the available tools produced by ARPA Piemonte is the Italian Landslides Inventory (IFFI). It is a national program of landslides inventory, sponsored by national authorities and made locally by the Regions. It is the first try of an inventory based on common graphical legend and glossary.

In Piemonte, almost 35’000 landslides were recognized by interpretation of aerial photos and field survey and Informative System of Landslides is constantly updated with inclusion of new landslides or corrections and deeping of existing landslides.

Every Region decided by itself if the results of IFFI Project (danger maps) have or not a legal value. IFFI represents a very important tool for the planners who finally have the first homogeneous, shared, detailed and most complete knowledge of the landslide occurrence on the whole territory. As a general remark for Italy it has to be observed that public legislation defines general principles and lines of conduct, functions, activities and authorities involved, while the regional administrations apply restrictions on land use through different regional laws.

Final remarks

- *Laws or rules that indicate how a landslide analysis (danger, hazard, risk) has to be done, do not exist*
- *There is often some confusion among danger, hazard and risk. An inventory map can be used as hazard map (i.e. susceptibility map), without any prevision of scenarios*
- *There is some lack of trust in quantitative methods. Qualitative approach seems to be preferred*

The technicians who make the maps have to think firstly:

- *Who will be the end users?*
- *What will be the use of maps?*
- *Is the scale of work suitable for this?*
- *Are the complexity of methods (time, resources, needed input data…) and results appropriate and understandable for decision makers?*

3.1.6 Italy - South Tyrol (Volkmar Mair)

Since many years in South Tyrol Hazard and Risk planning is strictly required by spatial and provincial legislation. Some important laws for South Tyrol are:

- *DL 180 of 8. June 1998 converted in law Nr. 267 of 3. August 1998*
- *DPCM 29. September 1998: atto di indirizzo e coordinamento per l´individuazione dei criteri relativi agli adempimenti di cui all´art. 1, commi 1 e2, del decreto-legge 11 guigno 1998, n. 180*

- *Durchführungsverordnung zum Landesraumordnungsgesetz – DLH vom 23.02.1998 Nr. 5*
- *Landesgesetz vom 11. August 1997, Nr. 13 Landesraumordnungsgesetz art 22/ bis (Gefahrenzonenpläne)*
- *Guidelines for hazard planning have been approved by the „Beschluss der Landesregierung vom 28. Juli 2008, Nr. 2741"*
- *The implementing order has been approved by the "Beschluss der Landesregierung vom 28. Juli 2008, Nr. 2740"*

In the federal state law from august 11th 1997 the base for the approval to guidelines to the creation of hazard plans (Gefahrenzonenpläne) was laid. Also the role of municipalities, to carry out the planning within three years was defined. Finally the approval of plans and the role of coinvolved partners are also part of this law (see figure 21).The following figure shows the development of a "Hazard Plan" (Gefahrenzonenplan) in South Tyrol from the preparation to the approval.

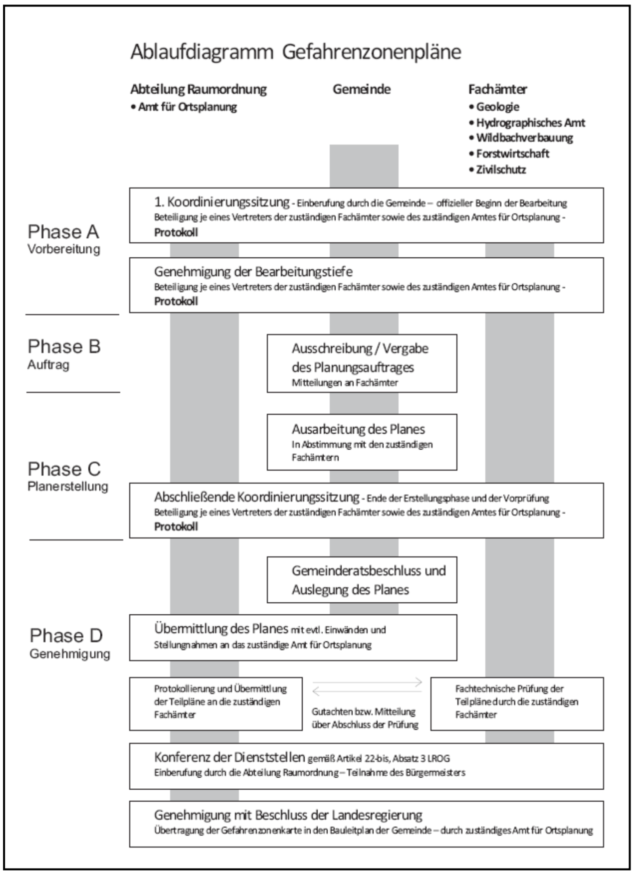


Figure 21: Workflow from the creation of hazard plans (Gefahrenzonenpläne) in South Tyrol

- **Phase A: Preparation**

The first action of the process is a coordination meeting, the assembly of which is called for by the respective municipals and within this session all the responsible partners have to define the working details.

- **Phase B: Application**

In this phase the official call for tenders and the placing of the application is made.

- **Phase C: Creation of the plans**

Main part is the elaboration of plans and documents from private engineers in collaboration with the official agencies, which are approving the elaborated plans and documents within the last coordination meeting.

- **Phase D: Approval**

Most difficult and longest part is D in which the approval by district council and the possibility of inspection and appealing by citizens are very important steps. The last step is the final approvement by partners and provincial government.

Analyzed processes

The following table shows the three main natural hazard types (Landslides, Hydrological Hazards, Avalanches) which are analyzed within the hazard plan of South Tyrol. Each type includes divers processes, which are indicated with different colours and signatures in the map. In addition to the three main types also areas with permafrost are mapped in the plan.

Naturgefahrentypen	Prozesse	Farben	Kurzform
Massenbewegungen: LX	Sturz	rosa	LF…landslide+fall
	Rutschung	hellbraun	LG…landslide+gravity
	Einbruch	hellbraun	LC…landslide+collapse
	Hangmure	hellbraun	LD…landslide+debris flow
Wassergefahren: IX	Überschwemmung	dunkelblau	IN… inundation
	Übersarung	orange	IS… inundation+solid
	Vermurung	orange	DF…debris flow
	Erosion s.l.	hellrot	E… (L,D,A)…s. unten NB.
Lawinen: AX	Fließlawine	hellblau	AD…avalanche - dense
	Staublawine	hellblau	AP… avalanche - powder
	Gleitschnee	hellblau	GS… gliding snow
Permafrost: PF	versch. Ereignisse mög-	hellbraun (schräg schraf-	PF… permafrost

Figure 22: Basic legend of the processes with colours and letter combination

Hazard Matrix

Within a combination from intensity and return period the hazard is structured into three classes (high, medium, low).

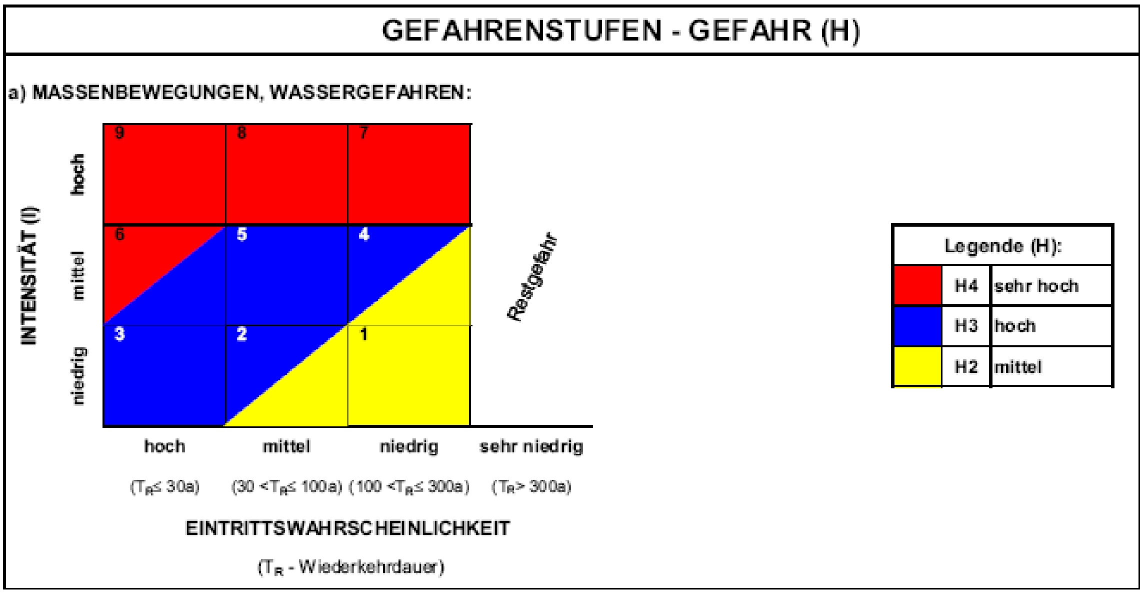


Figure 23: Hazard - Matrix for landslides and hydrological hazards

Additional to the matrix special intensity and probability tables are used, in which velocity and dimension of the mass movement and the return period is structured into several classes (see figure 24).

Eintrittswahrscheinlichkeit		Wiederkehrzeit (Tr)	
	bezogen auf 50 Jahre:	in Jahren:	
hoch	100% bis 82%	$T_R \leq 30$	sehr häufig
mittel	82% bis 40%	$30 < T_R \leq 100$	häufig
niedrig	40% bis 15%	$100 < T_R \leq 300$	selten
sehr niedrig	< 15%	$T_R > 300$	sehr selten

Figure 24: Probability of occurrence and return period

The scale of the hazard plan (“Gefahrenzonenplan”) in South Tyrol tends to the working level of detail for the analyzed area. In settlements a 1:5000 scale and in other regions a 1:10000 scale is used.

3.1.7 Spain (Oller Perre, Gonzalez Marta)

The Parliament of Catalonia approved, by Law 19/2005, the creation of the Geological Institute of Catalonia (IGC), assigned to the Ministry of Land Planning and Public Infrastructures (DPTOP) of the Catalonian Government.

One of the functions of the IGC is to "study and assess geological hazards, including avalanches, to propose measures to develop hazard forecast, prevention and mitigation and to give support to other agencies competent in land and urban planning, and in emergency management". Therefore, the IGC is in charge of making official hazard maps for such a finality. These maps comply with the Catalan Urban Law (1/2005) which indicates that in those places where a risk exists, building is not allowed.

The high density of urban development and infrastructures in Catalonia requires geo-thematic information for planning. As a component of the Geoworks of the IGC, the strategic program aimed at acquiring, elaborating, integrating and disseminating the basic geological, pedological and geothematic information concerning the whole of the territory in the suitable scales for the land and urban planning. Geo-hazard mapping is an essential part of this information. Despite some tests having been carried out with wide land recovery (Mountain Regions Hazard Map 1:50000 [DGPAT, 1985], Risk Prevention Map of Catalonia 1:50000 [ICC, 2003]), at present the work is done mainly on two scales: land planning scale (1:25.000), and urban planning scale (1:5.000 or more detailed). These scales imply different approaches and methods to obtain hazard parameters used for such purpose. The maps are generated in the framework of a mapping plan or as the final product of a specific hazard report. These different types of hazard mapping products are explained below.

<u>Geological Hazard Prevention Map of Catalonia 1:25.000 (MPRGC25M)</u>

The most important mapping plan is the Geological Hazard Prevention Map of Catalonia 1:25.000 (MPRGC25M). This project started in 2007. The MPRGC includes the representation of evidence, phenomena, susceptibility and natural hazards of geological processes. These are the processes generated by external geodynamics (such as slope, torrent, snow, coastal and flood dynamics) and internal (seismic) geodynamics. The information is displayed by different maps on each published sheet.

The main map is presented on a scale of 1:25000, and includes landslide, avalanche and flood hazard. Hazard level is qualitatively classified as high (red), medium (orange) and low (yellow). The methods used to analyze hazards basically consist of geomorphological, spatial and statistical analysis. Several complementary maps on a 1:100000 scale show hazard caused individually by different phenomena in order to facilitate the reading of the sheet and understanding of the mapped phenomena. Two additional maps for flooding and seismic hazards, represented on a 1:50000 scale, are added to the sheet. The map is intended to enable government and individuals to have an overview of the territory, with respect to geological hazards, identifying areas where it is advisable to carry out detailed studies in case of action planning. At the same time a database is being implemented. It will incorporate all the information obtained from these maps. In the future it will become the Geological Hazard Information System of Catalonia (SIRGC).

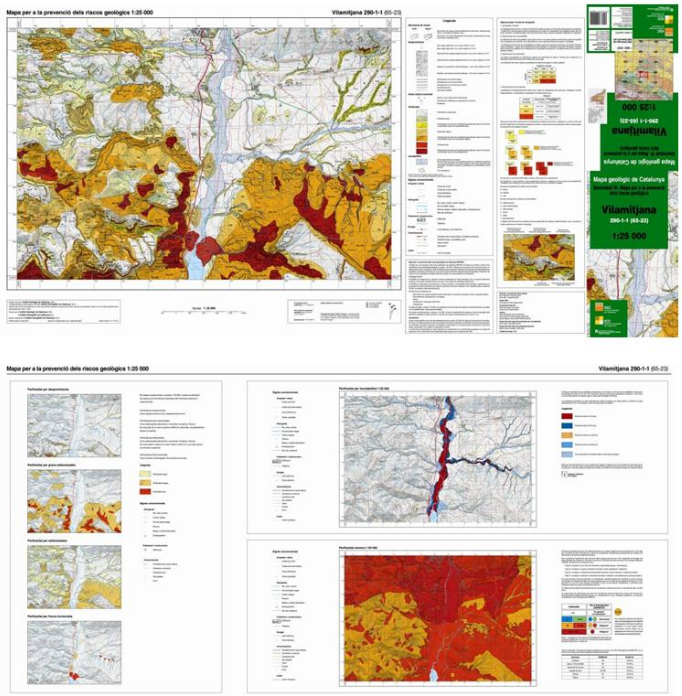


Figure 25: First published sheet, Vilamitjana (65-23), in 2010.

The procedure followed in the main map consists of three steps:

1.Catalogue of phenomena and evidences

2.Susceptibility determination

3.Hazard determination

The catalogue of phenomena and evidence is the base of the further susceptibility and hazard analysis. It consists of a geomorphologic approach and it comprises the following phases:

1. Bibliographic and cartographic search: the information available in archives and databases is collected.

2. Photo interpretation: carried out on vertical aerial photos of flights from different years (1957, 1977, 1985, 2003, etc.). The observation of the topography and the vegetation allows the identification of areas with signs of instability coming from the identification and characterization of events that occurred recently or in the past, and from activity indicators.

3. Field survey: checking and contrasting on the field, the elements identified in the previous phases. Field analysis allows a better approach and understanding, and therefore identifying signs and phenomena not observable through the photointerpretation.

4. Population inquiries: the goal of this stage is to complement the information obtained in the earlier stages, especially in aspects such as the intensity and frequency. It is done through a survey to witnesses who live and/or work in the study areas.

In a second step, areas susceptible to be affected by the phenomena are identified from the starting zone to the maximum extent determinable at the scale of work. Their limits are drawn taking into account the catalogue of phenomena, geomorphological indicators of activity, and from the identification of favourable lithologies and morphologies of the terrain. This phase includes the completion of GIS and statistical analysis to support the determination of the starting and run-out zone. It can be extensively applied with satisfactory results with regard to the scale and purpose of the work.

Finally hazard is estimated on the basis of the analysis of the magnitude and frequency (or activity) of the observed or potential phenomena. Susceptibility areas are classified according to hazard matrix represented in Figure 26. Hazard zones are represented as follows: areas where no hazard was detected (white), zones with low hazard (yellow), medium hazard zones (orange), and areas with high hazard (red).

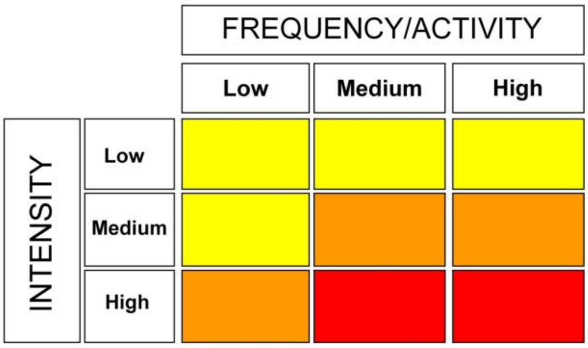


Figure 26: Hazard matrix (based on Altimir et al, 2001).

In order to obtain an equivalent hazard for each phenomena, an effort was made to equate the parameters that define them. The same frequency/activity values were used for all phenomena, but magnitude values were adapted to each of them.

Each hazard level contains some considerations for prevention (Figure 27). These considerations inform about the need for further detailed studies and advise about the use of corrective measures.

	PREVENTION	
HAZARD	DETAILED STUDIES	HAZARD MANAGEMENT
Not observed	-----	-----
Low	Recomendable	Necessary in certain cases
Medium	Indispensable	Necessary in many cases
High	Indispensable	Necessary in most of the cases

Figure 27: Prevention recommendations.

Hazard from each phenomena is analyzed individually. The main challenge of the map is to easily present the overlapping hazard of different phenomena. A methodology identifying that this overlap exists has been established with this objective in mind. It indicates what the maximum overlapped hazard is (Figure 28), but in any case, without obtaining new hazard values.

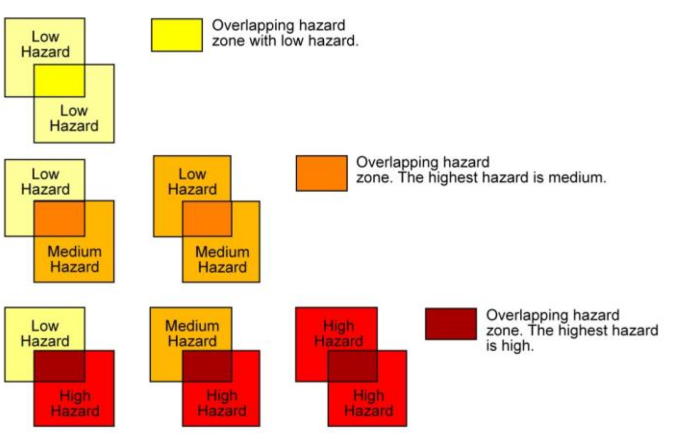


Figure 28: Multi-hazard representation.

To identify what is the hazard level and the phenomena that causes it, especially in overlapping areas, an epigraph is assigned (Figure 29). This epigraph consists of two characters, the first in capital letters, indicates the value of hazard (A for high hazard, M for medium hazard and B for low hazard), and the second, in lower-case, indicates the type of phenomena (e for large landslides, s for landslides, d for rockfalls, x for flows, a for avalanches and f for subsidence and collapses). The higher the overlapping is, the longer the epigraph will be.

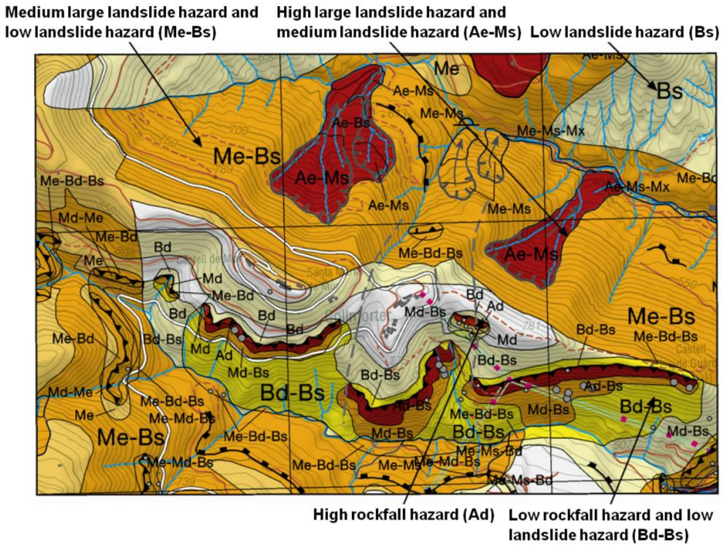


Figure 29: Example of multi-hazard representation.

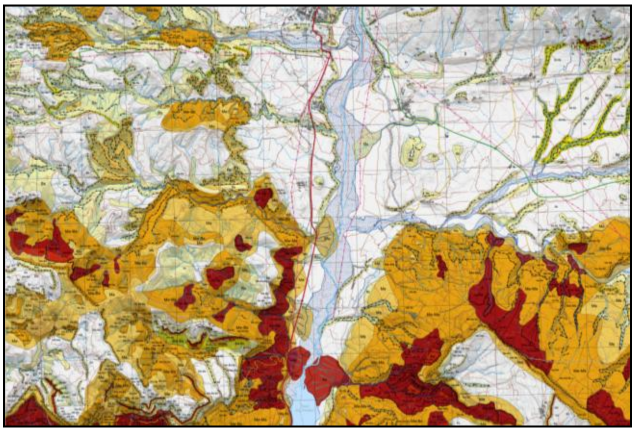


Figure 30: Main map 1:25000, which includes landslides, avalanches, sinking and flooding according to geomorphologic criteria.

<u>Complementary maps</u>

Complementary maps represent the hazard established for each individual phenomena at 1:100000 scale. The purpose of these maps is to facilitate the interpretation of the main map. Depending on the type of phenomena identified in the main map, the number of complementary maps can vary from 1 to 6.

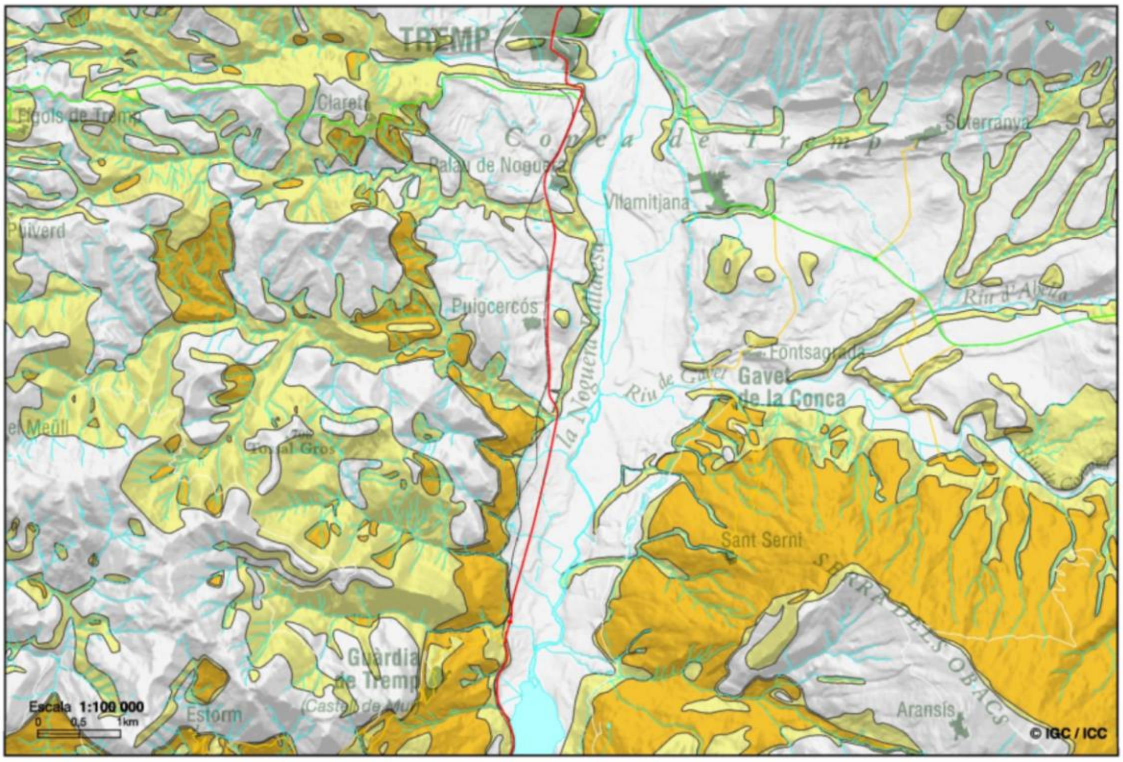


Figure 31: Complementary map of surface landslide hazard.

Seismic Hazard Map

This map was obtained from the map of seismic areas for a return period of 500 years, for a middle ground, and considering the effects of soil amplification.

To take into account the amplification of the seismic motion due to soft ground, a geotechnical classification of lithologies from the Geological Map of Catalonia 1:25000 into 4 types was carried out: R (hard rock), A (compact rocks), B (semi-compacted material) and C (non cohesive material). This classification is based on the speed of the S-wave through them (Fleta et al., 1998). The proposed amplifications were assigned to each group of lithologies. For types R and A no additions of any degree of intensity were made, but for types B and C, there was an addition of 0.5 degrees of intensity.

The final map (Figure 32) also represents the values of the basic seismic acceleration of the compulsory "Norma de Construcción Sismorresistente Española" (NCSE-02) for a placement in rock, and the intensity of the seismic emergency plan (SISMICAT).

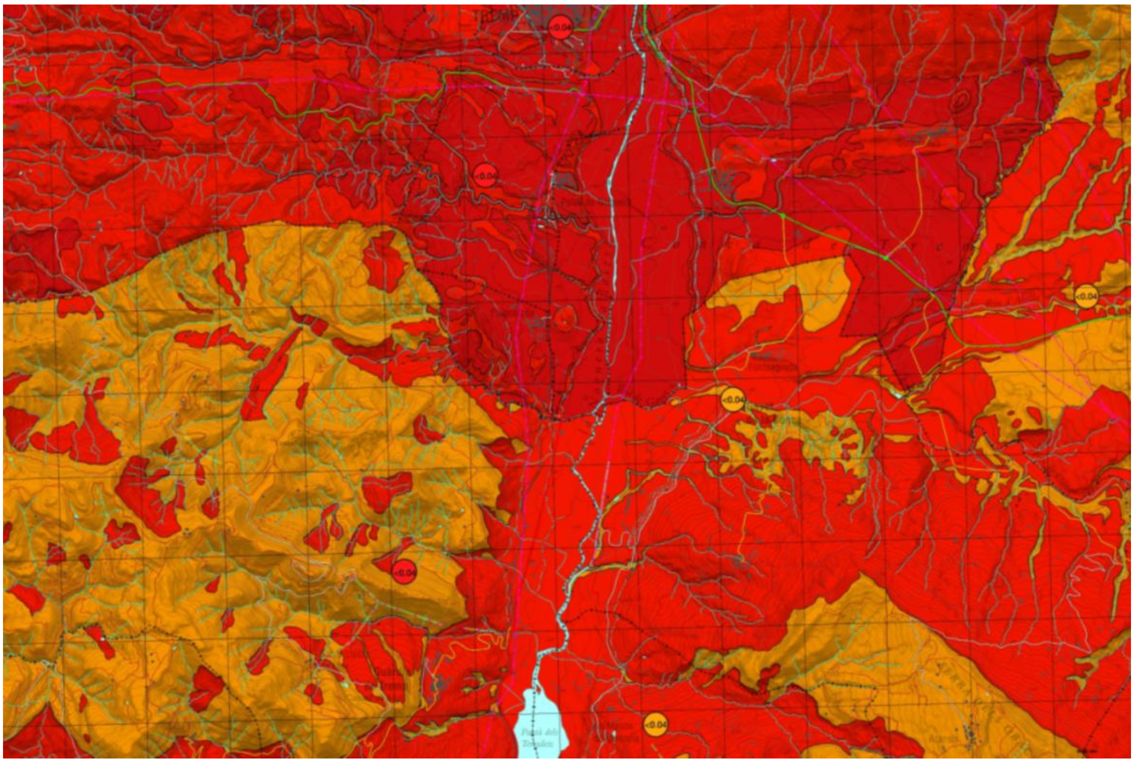


Figure 32: : Seismic hazard map 1:100000.

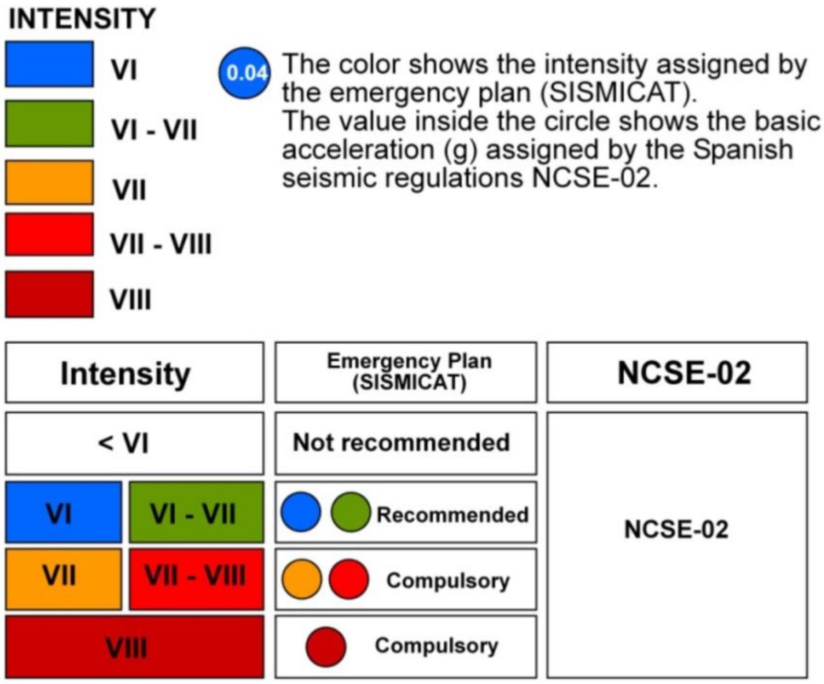


Figure 33: Seismic hazard map symbology.

Flooding hazard map

The flooding hazard map 1:50000 scales shows the limits of the hydraulic modeling for periods of 50, 100 and 500 years provided by the Catalan Water Agency (ACA). A flooding map according to geomorphologic criteria was done in those streams were hydraulic modeling was not performed.

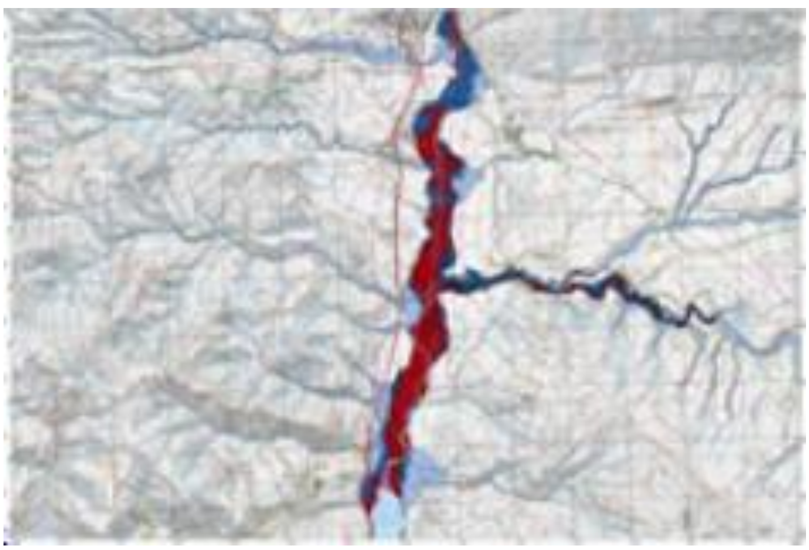


Figure 34: Flooding hazard map 1:100000 based on hydraulic modeling.

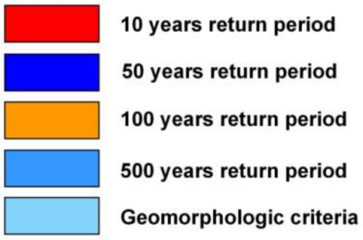


Figure 35: Flooding hazard map symbology.

Avalanche Paths Map (MZA)

A second mapping plan, already finished, is the Avalanche Paths Map (MZA). It was begun in 1996 and finished in 2006. An extent of 5092 km2 was surveyed. During this process 17,518 avalanche paths were mapped. This is a susceptibility map on a scale of 1:25.000, useful for land planning in the Pyrenean areas. The methodology is based on the French “Carte de Localisation des Phénomènes d’Avalanches” (Pietri, 1993). On this map, the avalanche paths, mapped from terrain analysis (photointerpretation and field work), are represented in orange, and the inventory information (witness surveys, historical documents, field surveys and dendrochronology) is represented in violet.

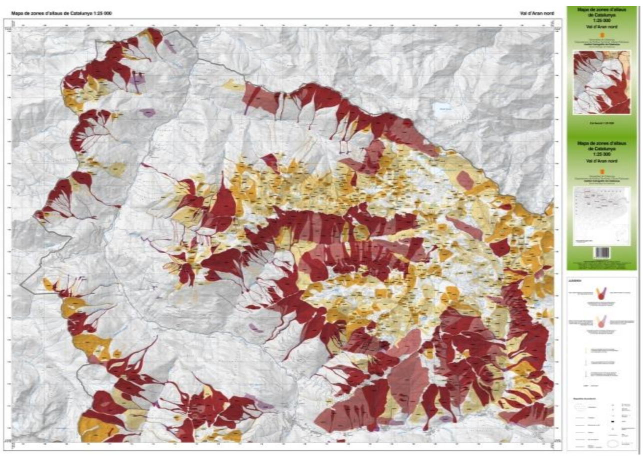


Figure 36: First published Avalanche Paths Map, “Val d’Aran Nord”, in 1996.

The termination of the MZA allows a first global vision of the avalanche hazard distribution in this region. The area potentially affected by avalanches covers 1,257 km2. That is at 3.91% of the Catalan country, and considering the Pyrenean territory, it affects a 36%.

At present, all the avalanche information is stored in the Avalanche Data-base of Catalonia (BDAC). New events, coming from avalanche observation, are added to this database. The information is available via the Internet at: http://www.icc.cat/msbdac/.

Figure 37: Interface of the avalanche data server

Hazard maps for urban planning

At present, for all the municipalities that want to increase their building limits, the procedure is, first of all, to make a preliminary hazard map on a 1:5.000 scale. This element is, in fact, just a map of “yes or not”, which states if hazard exists or not. If the municipality decides not to develop in hazardous areas, the process finishes. In the case that the municipality wants to build in the hazard-zone areas, more detailed studies have to be completed. These studies include complex data collection, usually via drilling specific boreholes, other geotechnical work, and advanced modeling. The phenomena taken into account are landslides, rock falls, sinking and snow avalanches. In these maps, the hazard mapping is obtained from frequency/intensity analysis. Advanced modeling analysis is performed in order to obtain the most accurate results, and to support the observational data and expert criteria. Up to the present day, there is no standard methodology. The current challenge for the IGC is to prepare guidelines for such a goal in order to guarantee the standards of quality and homogeneity.

There are preliminary studies of a hazard mapping plan 1:5000 for snow avalanches. In this map terrain is classified into high hazard (red), medium hazard (blue) and low hazard (yellow). Urban planning implications regarding hazard have not been defined yet. An analysis of the MZA, supported by the statistical α-β model, resulted in the identification of 24 urban areas to be mapped. The mapping methodology includes terrain analysis, avalanche inventory, nivometeorological analysis and numerical modeling to complete the information.

3.1.8 Slovenia (Mateja Jemec, Marko Komac)

Slovenian territory occupies the Eastern flank of the Alpine chain. As in other areas of the Alpine region Slovenia is exposed to different slope mass movements (SMM) above the average in comparison to the rest of the Europe. SMM that represent substantial problems can be generally divided into three groups, 1) landslides, 2) debris-flows, and 3) rockfalls. Majority of SMM events cannot be prevented, but they can be mitigated or avoided applying adequate legislation measures supported by corresponding expert argumentation. Although Slovenian legislation (and hence also measures) mainly focuses into the remediation phase and mitigation of consequences of already occurred SMM events, it's biggest deficiency lays in the area of prevention measures. While in the case of rare SMM events the current approach of exclusively post-event-measures approach is conditionally sustainable, in the case of frequent events becomes unsustainable and brings huge burden to local, regional and state budget. The only reasonable approach would hence be minimising interaction between SMM events and elements at risk. Graphically this interaction would be presented as a cross-section between natural hazard on one side and vulnerability of elements at risk on other side (Fig. 38).

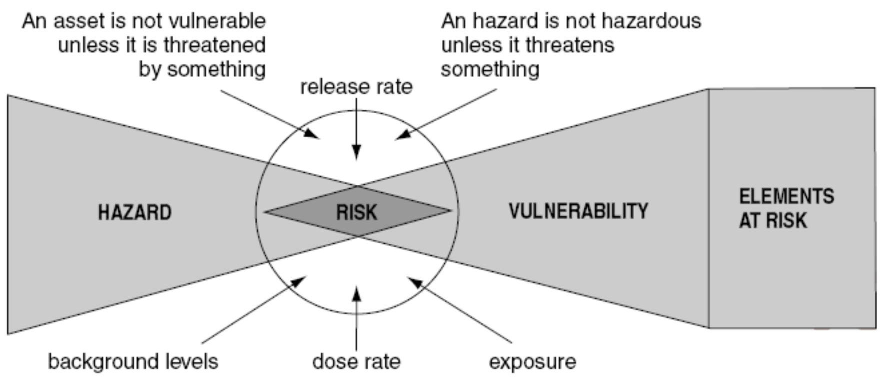


Figure 38: Relation between hazard on one side and elements at risk on the other, and the risk in between (after Alexander, 2002).

Legislation in the field of slope mass movement domain

In the area of systematic prevention measures regarding SMM Slovenia lacks behind other Alpine countries or regions. One of the basic approaches to solve the problem is to establish potentially hazardous areas due to natural phenomena and inclusion of this information in spatial plans. Information on geology upon which the slope mass movement occurrence heavily depends, it is not yet an integral part of spatial plans. Legislative acts deal mostly with remediation issues instead with the prevention measures.

The protection strategy against landslides (within legislation the term landslide also other types of slope mass movements are included) varies substantially and is tailored according to different terrain conditions. They are mainly divided into prevention, emergency protective measures and permanent measures adopted in the process for remediation. In the frame of preventive actions, the emphasis is on creating a national database of active landslides (and other SMM) and intentions of government to include hazards doe to landslides into spatial planning. In the planning and implementation of emergency protective measures, the emphasis is on protecting human lives and property.

Law on protection against natural and other disasters (Official Gazette of RS, no. 64/94)

The Act governs the protection against natural and other disasters and includes protection of people, animals, property, cultural heritage and environment against any hazard or accidents (risk) that can threaten their safety. The main goal of the protection against natural and other disasters system is to reduce the number of disasters, and to forestall or reduce the number of victims and other consequences of disaster. The basic tasks of the system are: prevention, preparedness, and protection against threats, rescue and help, providing of basic conditions for life, and recovery.

National program of protection against natural and other disasters (Official Gazette of RS, no. 44/02)

On the basis of the Resolution, the National Programme of Protection against Natural and Other Disasters for the period 2002 – 2007. The National Programme is oriented towards the prevention and its basic aim is to reduce the number of accidents and to prevent or minimise its consequences.

Law on the Remediation of consequences of natural disasters (Official Gazette of RS, no. 114/05)

The Act defines a landslide as a natural disaster. According to the article 11, with some restriction and at some level of damage state budget funds may be used to ease the effects of natural disasters. Damage assessment is made in accordance with the Regulation on the methodology for damage assessment (Official Gazette of RS, no. 67/03, 79/04), after which the landslide is considered a landslide, which threats a property or infrastructure.

Water Act (Official Gazette RS, no. 67/02, 4/09)

Protection against the harmful effects of water that is among other issues dealt with this act also refers to protection against landslides. Threaten area is defined by Government, which is responsible to protect population, property and land in dangerous exposed areas. In order to protect against the harmful effects of water, is land on the threaten area categorized into classes based on the risk.

Act on measures to eliminate the consequences of certain large-scale landslides in 2000 and 2001 (Official Gazette RS, no. 21/02, 92/03, 98/05)

Act defines the format and the method of financing and form of allocating state aid for the implementation of remedial measures, to prevent the spread of landslide and stabilization of landslides on the specific area of influence. It covers several major landslides in Slovenia.

Spatial Development Strategy of Slovenia (Official Gazette of RS, no. 76/04)

Spatial Development Strategy of Slovenia is a public document guiding development in the field of landslide problematic. It provides a framework for a spatial development throughout the country and sets guidelines for development in European space. It provides the creation of spatial planning, its use and conservation. The spatial strategy takes into account social, economic and environmental factors of spatial development.

Slovenia's Development Strategy

Slovenia's Development Strategy sets out the vision and objectives of Slovenia and five development priorities with action plans. The chapter on protection against natural disasters is included in the fifth development priority, which is designed to achieve sustainable development.

Regulation of the spatial order of Slovenia (Official Gazette of RS, no. 122/04)

Regulation of spatial order in Slovenia provides the rules for managing the field of landslide problematic. One of the important articles is Article 67, in which is mentioned how to plan according to the limitations which are caused by natural disasters and water protection.

Resolution of the National Environmental Act (Official Gazette of RS, no. 2/06)
National Environmental Action Programme (NEAP) is the basic strategic document in the field of environmental protection, aimed at improving the overall environment and quality of life and protection of natural resources. NEAP was prepared under the Environmental Protection Act and complies with the European Community Environment Programme, which addresses the key environmental objectives and priorities that require leadership from the community. The objectives and measures are defined in the four areas, namely: climate change, nature and biodiversity, quality of life, and waste and industrial pollution.

Methodology

Due to specifics of different slope mass movement processes a single approach would be hampered in its results / prognosis. In the following chapter an overview of approaches to slope mass movements (1 – landslides; 2 – debris-flows; 3 – rock falls) hazard assessment is presented. Also the presented approaches are similar to a certain level they also differ according to the scale of the assessment. The final results (but not the only ones) of approaches presented in the following text were presented in a form of warning maps that are still the main product used by end users. All the analyses were conducted in GIS, which enables the end users to implement results also in a form of databases or a digital format.

According to Skaberne (2001) the terminology of slope mass movements in Slovenia are as follows: landslides are processes of translational or rotational movement of rock or soil as a consequence of gravity at discontinuity plane(s). Rock falls are processes of falling or tumbling of a part of rock or soil along a steep slope. Debris-flows are processes of transportation of material composed of soil, water and air.

Development of landslide susceptibility model for Slovenia at scale 1:250,000 was developed at Geological Survey of Slovenia in 2006 (Komac & Ribičič, 2006). The final result of this approach was presented in a form of a warning map (Fig. 2). Based on the extensive landslide database that was compiled and standardised at the national level, and analyses of landslide spatial occurrence, a Landslide susceptibility map of Slovenia at scale 1 : 250,000 was completed. Altogether more than 6,600 landslides were included in the national database, of which roughly half are on known locations. Of 3,257 landslides with known location, random but representative 65 % were selected and used for the univariate statistical analyses (χ2) to analyse the landslide occurrence in relation to the spatio-temporal precondition factors (lithology, slope inclination, slope curvature, slope aspect, distance to geological boundaries, distance to structural elements, distance to surface waters, flow length, and land cover type) and in relation to the triggering factors (maximum 24-h rainfall, average annual rainfall intensity, and peak ground acceleration). The analyses were conducted using GIS in raster format with the 25 × 25 m pixel size. Five groups of lithological units were defined, ranging from small to high landslide susceptibility. Also critical slopes for the landslide occurrence, other terrain properties and land cover types that are more susceptible to landsliding were defined. Among triggering factors critical rainfall and peak ground acceleration quantities were defined. These results were later used as a basis for the development of the weighted linear susceptibility model where several models with various factor weights variations based on previous research were developed. The rest of the landslide population (35 %) was used for the model validation. The results showed that relevant precondition spatio-temporal factors for landslide occurrence are (with their weight in linear model): lithology (0.3), slope inclination (0.25), land cover type (0.25), slope curvature (0.1), distance to structural elements (0.05), and slope aspect (0.05).

Beside landslide susceptibility assessment a rainfall influence on landslide occurrence was analysed as rainfall plays an important role in the landslide triggering processes.

Analyses of landslide occurrence in the area of Slovenia have shown that areas where intensive rainstorms occur (maximal daily rainfall for the 100 years period), and where the geo-logical settings are favourable, abundance of landslide can be expected. This clearly indicates the spatial and temporal dependence of landslide occurrence upon the intensive rainfall. Regarding the landslide occurrence, the intensity of maximal daily and average annual rainfall for the 30 years period was analysed. Results have shown that daily rainfall intensity, which significantly influences the triggering of landslides, ranges from100 to 150 mm, most probably above 130 mm. Despite the vague influence, if any at all, of the average annual rainfall, the threshold above which significant number of landslides occurs is 1000 mm.

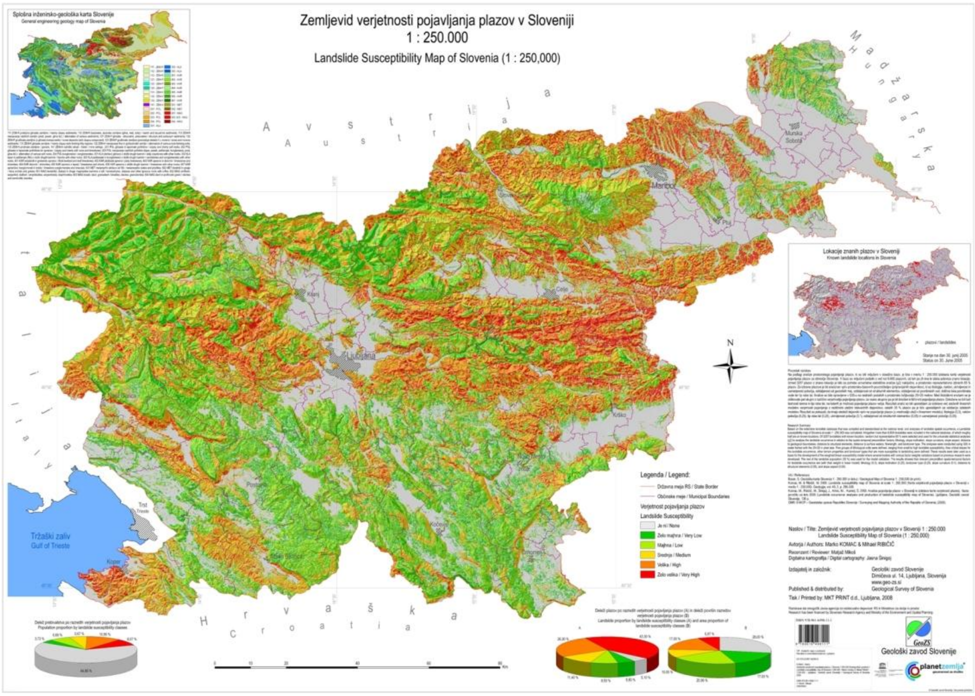


Figure 39: Landslide susceptibility warning map of Slovenia at scale 1:250,000 (Komac & Ribičič, 2006, 2008).

Development of debris-flow susceptibility model for Slovenia at scale 1:250,000 was also developed at Geological Survey of Slovenia in 2009 (Komac et al., 2009). The final result of this approach was presented in a form of a warning map (Fig. 40). For the area of Slovenia (20.000 sqr. km) a debris-flow susceptibility model at scale 1:250,000 was produced. To calculate the susceptibility to debris-flow occurrence using GIS several information layers were used such as geology (lithology and distance from structural elements), intensive rainfall (48-hour rainfall intensity), derivates of digital elevation model (slope, curvature, energy potential related to elevation), hydraulic network (distance to surface waters, energy potential of streams), and locations of sixteen known debris flows, which were used for the debris-flow susceptibility models' evaluation. A linear model weighted sum approach was selected on the basis of easily acquired spatio-temporal factors to simplify the approach and to make the approach easily transferable to other regions. Based on the calculations of 672 linear models with different weight combinations for used spatio-temporal factors and based on results of their success to predict debris-flow susceptible areas, the best factors' weight combination was selected. To avoid over-fitting of the prediction model, an average of weights from the first hundred models was chosen as an ideal combination of factor weights. For this model also error interval was calculated. A debris-flow susceptibility model at scale 1:250,000 represent a basis for spatial prediction of the debris-flow triggering and transport areas. It also gives a general overview of susceptible areas in Slovenia and gives guidance for more detailed research areas and further spatial and numerical analyses. The results showed that approximately 4 % of Slovenia's area is extremely high susceptible and approximately 11 % of Slovenia's area of susceptibility to debris-flowsishigh. As expected these areas are related to mountainous terrain in the NW and N of Slovenia.

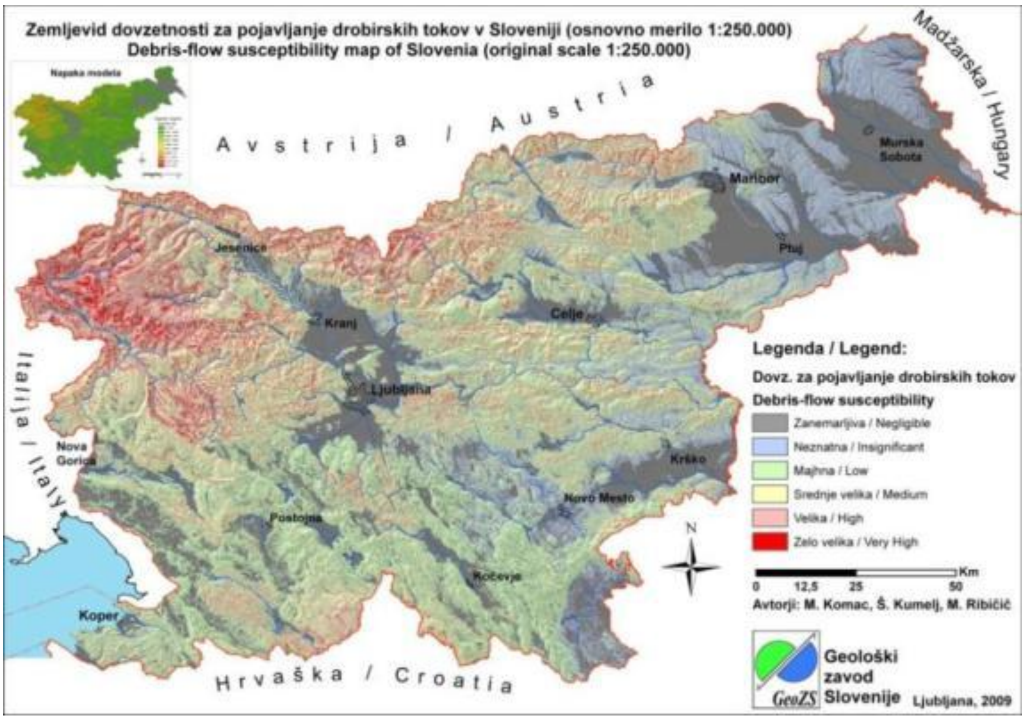


Figure 40: Debris-flow susceptibility warning map of Slovenia at scale 1:250,000 (Komac et al., 2009).

In the frame of a research project Slope mass movement geohazard estimation – The Bovec municipality case study an approach to assess the landslide and rock-fall susceptibility at the municipal scale (1:25.000) (Bavec et al, 2005; Komac, 2005). The production of susceptibility map that should represents (officially it's not included among the documentation yet) one of basic layers in the spatial planning process is shown in the Fig. 41. Methodology was developed for estimation of geohazard induced by mass movement processes, taking the Bovec municipality as the case study area. The geohazard map at the scale 1:25.000 as the final product is aimed to be directly applicable in spatial planning of local communities (municipalities). The requirements that were followed to achieve this aim were: expert correctness, reasonable time of elaboration, and easy to read product. Elaboration of the final product comprises four consecutive phases, of which the first three are done in the office: 1) synthesis of archive data, 2) probabilistic model of geohazard induced by mass movement processes, 3) compilation of phases 1 and 2 into the final map at scale 1:25.000. As the last phase, field reconnaissance of most hazardous areas is foreseen. The susceptibility model development was based on the upgrading of the expert geohazard map at scale 1:25,000 with a probabilistic model development that included relevant influence factors. For analytical purposes 10816 models were developed, 3142 for landslide susceptibility and 7674 for rock-fall susceptibility. In both cases geology / lithology and slope angle showed to be the most important influence factors. Regarding landslides, additional important factors were land use and synchronism of strata bedding and slope aspect, and in the case of rock-falls additional important factor was synchronism of strata bedding and slope aspect.

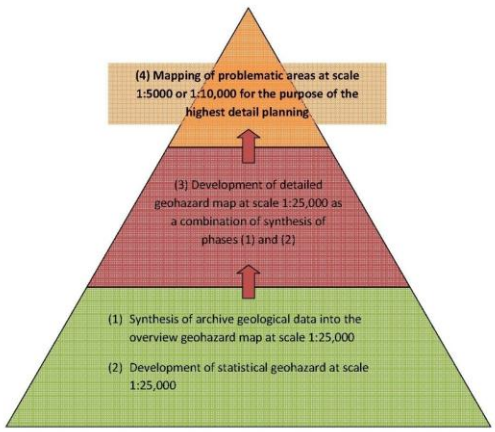


Figure 41: Schematic diagram of the process of production of landslide and rock-fall susceptibility at the municipal scale (1:25.000) (Bavec et al., 2005).

Methodology is focused towards the direct use of the final product in the process of spatial planning at the municipal level and is divided into four phases as show in Fig. 4:

- (1) Synthesis of archive geological data into the overview geohazard map at scale 1:25,000 (Budkovič, 2002).
- (2) Development of statistical geohazard at scale 1:25,000 (Komac, 2005).
- (3) Development of detailed geohazard map at scale 1:25,000 as a combination of synthesis geological map (1) and statistical geological model (2) and delineating the most problematic areas.
- (4) Mapping of problematic areas at scale 1:5000 or 1:10,000 for the purpose of the highest detail planning.

All presented approaches are based on probability statistical model that is a part of conceptual model of development of general or detailed slope mass susceptibility maps represented in Fig 42.

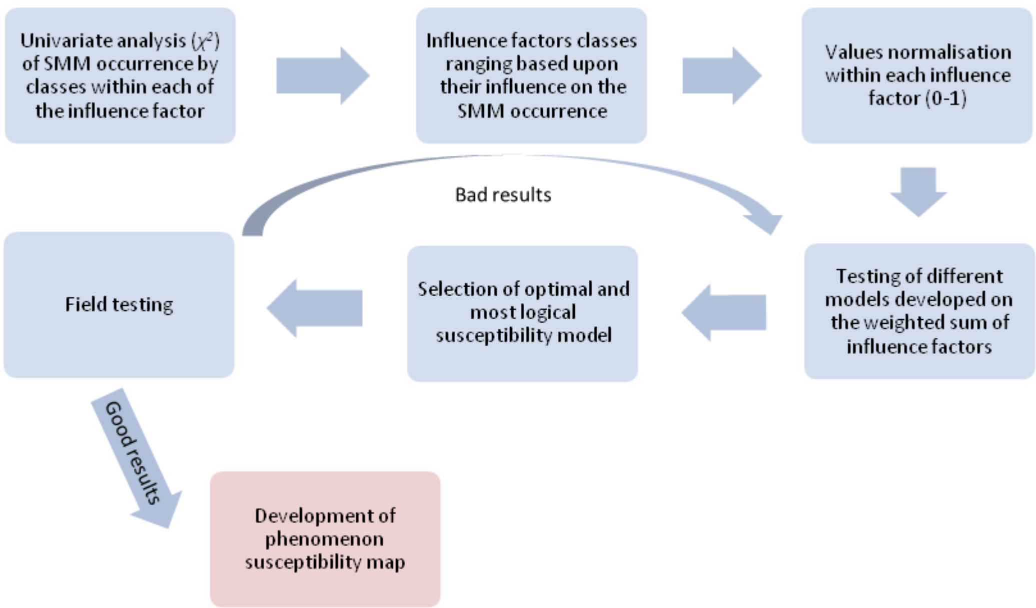


Figure 42: Conceptual model of development of general or detailed slope mass susceptibility maps.

For all influence factors that were included into the weighted sum model calculation, original values were transformed into the same scale, which ranged from 0 – 1 to assure the equality of the input data. In other words, within each factor original values were normalised with the eq. 1.

$$NVR = \frac{(RV - Min)}{Max - Min},$$

Where NVR represents new and normalised value, and RV the old (nominal) value. Min and Max represent the minimum and maximum original value within the factor, respectfully. For the purpose of the development of the best and at the same time the most logical susceptibility model a weighted sum approach (Voogd, 1983) was used (eq. 2).

$$H = \sum_{j=1}^{n} w_j \times f_{ij}$$

.

Where H represents standardized relative phenomenon susceptibility (0 – 1), wj represents the factor weight, and, f_{ij} represents a continuous or discreet variable value. Final slope mass movements susceptibility values (the range is between 0 and 1) were classified into 6 susceptibility classes: 0 – Negligible (or None); 1 – Insignificant (or Very Low); 2 – Low; 3 – Medium (or Moderate); 4 – High; 5 – Very High.

Conclusion

Slope mass movement processes are specific in their nature, hence separate analyses had to be performed and different model development had to be developed. In Slovenia slope mass movement susceptibility maps on national and on local level have been developed. In the case of latter, which has actual application value maps were developed only for some test areas. Thus several questions remain open and these are when will the geohazard layer be included as a compulsory part of the spatial planning document, to what extent quality geological data will be used for the assessment, and how the lack of detailed geological data would be tackled.

3.1.9 England (Helen Reeves, Claire Foster)

Prior to the 1966 Aberfan disaster, which led to the deaths of 144 people, landsliding was not widely considered to be particularly extensive or problematic in Great Britain (GB). In the years following the disaster a limited amount of research into landslide distribution and mechanisms was undertaken but failed to lead to a structured regulatory framework for managing landslide risk. The Aberfan landslide and costly disruptions to infrastructure projects in the 1960/70's (Skempton & Weeks 1976 and

Early & Skempton 1972) strengthened the view that the extent of ground instability was neither well understood nor managed by developers or planners. This view led to national assessments of landslides being carried out in the 1980's and 1990's on which the current national policy is largely based. These assessments provided the basis for planning policies and guidance that to some degree continue to control development on or around unstable ground. However, limited resources since this initial push to understand the problem meant that these initiatives have failed to develop into an effective, integrated, national response to deal with landslides in GB. The current systems, which are neither centralized nor legally binding, comprises a system of planning regulations (Town and Country Panning Act 1990), guidance notes, operational regulations and building codes (Building Regulations, 2006). With the exception of the Building Regulations, none of these legal statutes specifically mention landslides. The majority of the legislation can be interpreted as placing responsibility with the developer, utility operator or landowner to ensure landslides are not an issue.

The main source of regulatory information regarding slope instability issues is contained within Planning Policy Guidance Note 14 (PPG14) and its associated Annex (Anon 1990, 1994). The Annex sets out the procedure for landslide recognition and hazard assessment and emphasises the need to consider ground instability throughout the whole development process from land-use planning, through design to construction. These documents provide recommendations that slope instability is considered in any planning decision. If landsliding is a known issue 'a developer' must provide evidence that any development activity will not exacerbate landslide activity and that any building will be safe. However, PPG14 is not legally compulsory and only recommends that the local planning authorities should endeavour to make use of any relevant expertise when assessing whether a planning application may be affected by ground instability. The guidance notes do not specifically refer to geological or geotechnical expertise but details of some information sources of are provided, including BGS data. Despite this, there is no legal compulsion for a planning authority to understand the extent or nature of landslide hazards within their area of concern and, thus, include them in planning decisions. Building regulations put further emphasis on the role of the developer to control the impact of instability requiring that "The building shall be constructed so that ground movement caused by…. land-slip or subsidence (other than subsidence arising from shrinkage), in so far as the risk can be reasonably foreseen, will not impair the stability of any part of the building." (Anon. 2004).

The current PPG14 predates the era of GIS and advises that citizens consult geological maps and the now defunct Department of the Environment Landslide Database. These sources of information have been superseded by the BGS's 'GeoSure' and continually updated National Landslide Database. Despite the availability of these resources national guidance has never been updated to take this into account. Despite the advances in landslide mapping and hazard mapping there is still no legal compulsion to use or consider it within a planning application in GB.

Development of landslide susceptibility maps and databases in GB

BGS began to map geological hazards digitally in the mid 1990's, these early steps have paved the way for the development of much more detailed hazard maps that cover the whole of Great Britain and are complimented by detailed landslide mapping and an extensive National Landslide Database (NLD).

The first systematic assessment of hazards was triggered by the insurance industry after it identified a need to better understand geological hazards. Insurance losses caused by ground movements (including subsidence) between 1989 and 1991 reached around £1-2bn following a particularly dry period and as a result, a digital geohazard information system (GHASP – GeoHAzard Susceptibility Package) was developed by the BGS. This first decision support system (DSS) gave a weighted averaged result for each of the 10000 postcode sectors in GB and came to be used by around 35% of the Industry (Culshaw & Kelk, 1994). Since the development of GHASP, improvements in GIS technology and the availability of digital topographical and geological mapping for 98% of GB have led to advances in the methods used to map geohazard potential.

The BGS has since developed a Geographical Information System (GIS)-based system (GeoSure) to assess the principal geological hazards across the country (Foster et al. 2008, Walsby 2007, 2008). One output is a GIS layer that provides ratings of the susceptibility of the country to landsliding on a rating scale of A (low or nil) to E (significant), which has been simplified for Figure 1. Importantly, a high susceptibility score does not necessarily mean that a landslide has happened in the past or will do so in the future, but where a landslide hazard is most likely to occur if the slope conditions are adversely altered by a change in one or more of the factors controlling slope instability (Figure 1). GeoSure is produced at 1:50 000 scale and can be integrated to show the spatial distribution of landslide susceptibility in relation to buildings and infrastructure. According to the dataset, 350 000 households in the UK, representing 1% of all housing stock, are in areas considered to have a 'significant' landslide susceptibility (Rated E).

GeoSure works by modelling the causative factors of landsliding: lithology, slope angle and discontinuities being of prime importance. This has been made possible through the use of GIS due to its ability to spatially display and manipulate data (Soeters & Van Westen, 1996). The GeoSure methodology uses a heuristic approach to assess and classify the propensity of a geological formation to fail as well as to score the relevant causative factors. The BGS holds large amounts of information about the lithological nature of the rocks and soils within Great Britain. The National Geotechnical Physical Properties database contains information on the geographical distribution of physical properties (such as strength) of a wide range of rocks and soils present in GB. This information is vitally important in determining the propensity of a material to fail. The scores assigned to each lithology are based on material strength, permeability and known susceptibility to instability. Discontinuities were assessed as an important causative factor as they reflect the mass strength of a material, its susceptibility to failure and its ability to allow water to penetrate a rock mass. Scores were defined in line with those used in the British Standard 5930: Field Description of Rocks and Soils (British Standards Institute 1990) and by Bieniawski (1989). Analysis of known landslides showed that slope angle is one of the major controlling factors and this was derived from the NEXTMap digital terrain model of Britain at a 5m resolution. The scores for all the causative factors at each grid cell are combined in an algorithm to give an overall score based on the relative susceptibility to landsliding. The method is flexible enough to allow alteration (nationally or locally) of the algorithm in the future and include other factors such as the presence and nature of superficial deposits.

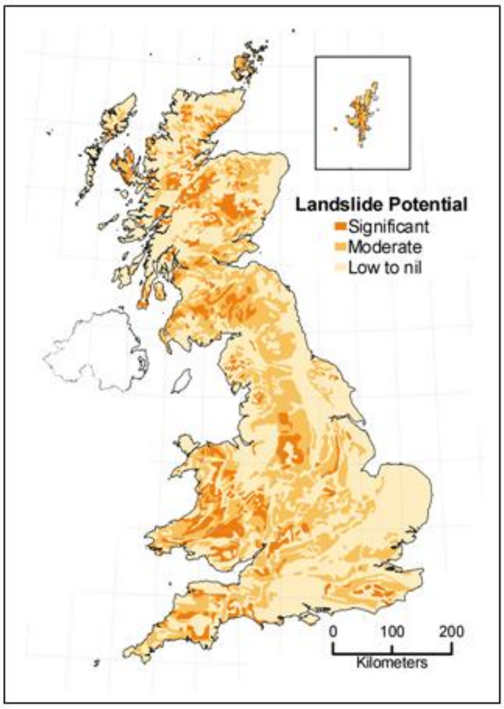


Figure 43: GeoSure layer showing the potential for landslide hazard.

Another important tool to both inform and assess landslide susceptibility in GB is the National Landslide Database (NLD). Landslide databases are commonplace in Europe but there is variability in their complexity and amount of further work carried out to further enhance or update the datasets. Assessing an area's susceptibility to landsliding requires knowledge of the distribution of existing failures and also an understanding of the causative factors and their spatial distribution. This type of information is only available from a detailed database of past events from which one can draw out relevant information which may inform the user of where landslides may occur in the future. The National Landslide Database is the most comprehensive source of information on recorded landslides in GB and currently holds records of over 15 000 landslide events (Figure 44). Each of the 15 000+ landslide records can hold information on over 35 attributes including location, dimensions, landslide type, trigger mechanism, damage caused, slope angle, slope aspect, material, movement date, vegetation, hydrogeology, age, development and a full bibliographic reference. A fully digital workflow has been developed at BGS to enable capture of landslide information. The first stage of the process involves using digital aerial photograph interpretation software (SocetSet) to capture digital landslide polygons which can then be altered through field checking using BGS·SIGMA mobile technology (Jordan 2009; Jordan et al. 2005). BGS·SIGMAmobile is the BGS digital field data capture system running on rugged tablet PCs with integrated GPS units, and is used extensively for all geological mapping activities within the British Geological Survey (Jordan et al., 2008).

Figure 44: Distribution of landslide database points from the National Landslide GIS database. OS topography © Crown Copyright. All rights reserved.

When collecting landslide information, either for the NLD or for digital maps, internationally recognised standards have been followed where appropriate. The database dictionaries have been produced using internationally recognised terminology. For landslide type, the dictionary definitions follow the conventions set out by Varnes (1978), the EPOCH project (Flageollet, J.C., 1993) and the WP/WLI (1990). Age and activity of a landslide are important factors to record within a landslide inventory. Temporal landslide data is as important to understanding the geomorphic evolution of an area as the spatial distribution of slides. However, it is extremely difficult to date ancient landslide events with any degree of accuracy and, as such, the ages assigned to landslides only provide an arbitrary indication of age. The WP/WLI

(1990) regrouped the Varnes (1978) definitions on age and activity under the following headings: 'state of activity,' 'distribution of activity' and 'style of activity.' Whilst the NLD follows the style of activity definitions, it has simplified the state of activity terms defined by Varnes (1978) into active, inactive and stabilised whilst also adding descriptions on the state of development (Advanced, degraded, incipient). Whilst activity state and style have been described in the WP/WLI definitions (WP/WLI, 1993), age has been somewhat neglected. Data for modern landslides observed either at the time of the event or through comparison of aerial photographs and geological mapping, is included in the NLD. To record cause, the NLD has incorporated both triggering and preparatory factors, limited to those most likely to be identifiable and relevant in GB. The definitions are based upon the WP/WLI (1990).

Further adaptations of landslide susceptibility maps in Great Britain

Following the creation of the Geosure methodology BGS has worked within a consortium including the Transport Research Laboratory (TRL) and the Scottish Executive to create a digital hazard layer specifically for debris flows. This work was triggered in August 2004 following a period of intense rainfall which led to two debris flows trapping 57 motorists on the A85 trunk road in Scotland. As a consequence of this event, and others, during the same period, the Scottish Executive commissioned a study to assess the potential impact of further debris flows on the transport network of Scotland (Winter et al., 2005). BGS was involved in the provision of a GIS layer highlighting slopes susceptible to debris flows. Debris flows, one of the five main types of landslide, have a specific set of preparatory criteria which differs from translational and rotational slides. This modified assessment sought to digitally capture this set of criteria and create a layer showing areas where debris flows are most likely to occur in the future. An initial study determined five main components which should be considered when determining the hazard potential of debris flows affecting the road network:

1. Availability of debris material
2. Hydrogeological conditions
3. Land Use
4. Proximity of Stream Channels
5. Slope Angle

It was considered that information regarding each of these could be extracted from existing digital datasets. The resulting interpreted data were combined to produce a working model of debris flow hazard that could be validated by comparing with known events. The 2004 A85 debris flow event is shown alongside the modelled susceptibility layer, existing drainage channels are shown as particularly susceptible to failure through debris flows. Whilst the assessment of debris flows highlights areas where they may occur in the future it does not attempt to model the run-out of such failures.

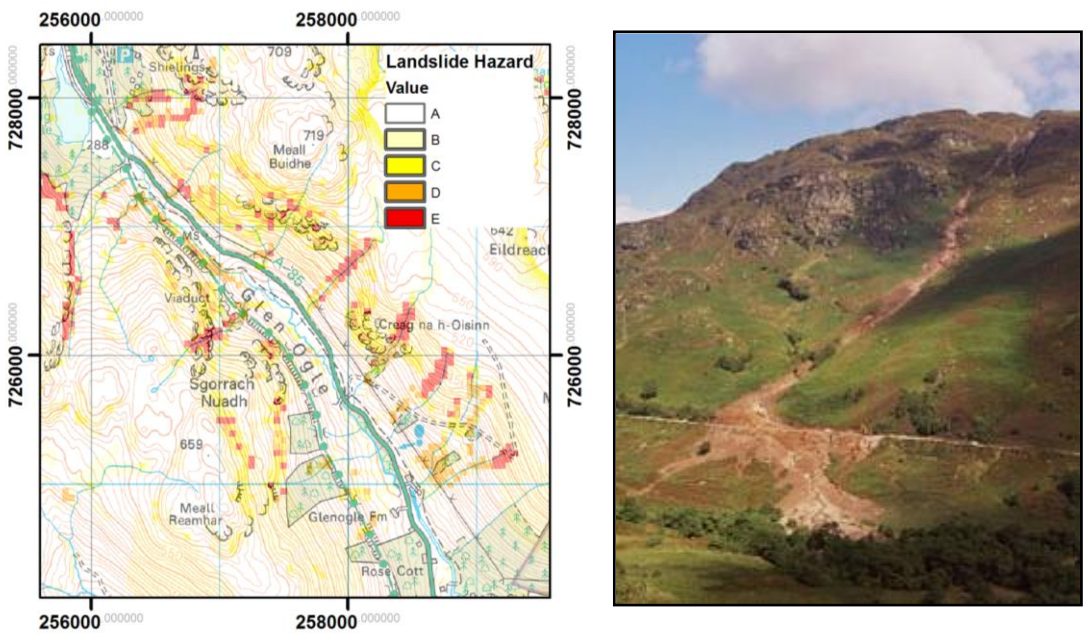


Figure 45: Extract from the Debris Flow Susceptibility Layer along with b) the Glen Ogle debris flow of 2004

Future Developments

Currently work is ongoing to validate the current methodology against statistical methods such as bivariate statistical analysis and probabilistic methods. The GeoSure method is based upon expert knowledge and a heuristic approach which is being tested against more statistically based approaches to assess its validity. Naranjo et al., (1994) consider statistical methods to be the most appropriate method for mapping regional landslide susceptibility because the technique is objective, reproducible and easily updateable. Bivariate analysis for instance relies upon the availability of landslide occurrence and causal parameter maps, which are compared against each other to create a weighted value for each parameter determined by calculating the landslide density (Aleotti and Chowdhury, 1999 and Süzen and Doyuran, 2004). Results from an initial pilot study suggest that, in small areas, where detailed landslide mapping exists bivariate (conditional probability) and probabilistic approaches are able to more accurately predict landslide susceptibility than GeoSure. However, this approach only works where landslides have been mapped. This technique cannot be used where no landslide mapping has been undertaken. Another issue with the conditional probability technique is that it relies on the assumption that all the parameters are mutually exclusive. The value of the heuristic approach is its ability to highlight areas where there are no known landslides but where there is existing knowledge on the underlying causative factors. The heuristic approach is able to produce national scale assessments which could be refined in the future by numerical methods for smaller, regional studies.

Further adaptations to the GeoSure methodology, similar to those used to assess debris flows, are planned for the future. Rock fall hazard could be another type of mass movement that is investigated using the heuristic GeoSure approach applying different causal factors and scoring algorithms.

Conclusion

In Great Britain landsliding does not have a structured regulatory framework, but historical events, such as the Aberfan disaster and Scottish debris flow events (Winter et al, 2005), have highlighted the importance of understanding the distribution and mechanisms that cause landslide mass movement events in Great Britain. The BGS GeoSure methodology, using spatially distributed data and causal factor information contained in the National Landslide Database of Great Britain, and assesses the landslide susceptibility in Great Britain. It uses a heuristic approach to model the causative factors that cause these events. It assesses and classifies the propensity of a geological formation to fail as well as to score the relevant causative factors (e.g. slope angle). By using these methodologies and datasets a national assessment of the potential hazard to landsliding mass movement events in Great Britain can therefore be undertaken.

3.2.10 France (Didier Richard)

Hazard assessment of rapid mass movements is required for different purposes, as for other natural phenomena, and depending on the objectives must be carried out at different scales. Hazard assessment can also take different forms, but most often its final outcome is a hazard map. Different types of expertise from various experts and approaches contribute to hazard assessment. Establishing standardized approaches, methods and tools is therefore demanding. The field of land-use planning, however, has integrated standardized hazard assessment and mapping methods.

Hazards mapping and land-use planning

Natural hazards must be taken into account in land-use planning documents. These are mainly schemes of territorial coherence at an inter-urban scale and local urban planning at the community scale. Typically, urban planning procedures and decisions, under the jurisdiction of national or local authorities must integrate natural hazards. The plan for prevention of natural hazards (plan de prévention des risques naturels prévisibles - PPR) established by the law of February 2, 1995, is now one of the national authority's main instruments for preventing natural hazards. The PPR is a specific procedure designed to take into account natural hazards in land-use development. The PPR is elaborated under the authority of the department's prefect, which approves it after formal consultation of municipalities and a public inquiry. The PPR involves the local and regional authorities concerned from the very first steps of its preparation (Fig. 46). It can cover one or several types of hazard and one or several municipalities.

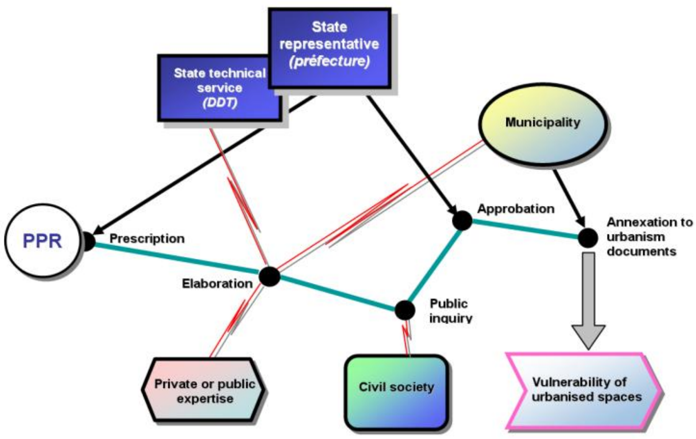


Figure 46: PPR elaboration scheme (Source: V. Boudières; 2008)

For areas exposed to greater hazard, the PPR is a document which informs the public on zones that expose populations and property to hazards. It regulates land use taking into account natural hazards identified in this zone and goals of nonaggravation of risks. This regulation extends from authorising construction under certain conditions to prohibiting construction in cases where the foreseeable intensity of hazard or the nonaggravation of existing risks warrants such action. This guides the development choices on less exposed land in order to reduce harm and damage to persons and property.

The PPR is designed for urban planning and is incumbent on everybody: individuals, companies, communities and government authorities, especially when delivering building permits. It must therefore be annexed to the local urban planning plan when such a document exists.

The basis for the regulation of projects in the perimeter of a PPR is to discontinue development in areas with the greatest hazard and therefore to prohibit land development and construction. This principle must be strictly applied when safety of persons is involved.

In other cases, this principle remains particularly warranted by the cost of preventive measures to reduce the vulnerability of future constructions and the cost of compensation in cases of disaster, financed by society. However, since the prevention objectives are then based on economic considerations, it is possible to discuss the limits of prohibitions and requirements with local actors, elected officials and economic and consumer representatives without departing from this principle. Adjustments can be accepted when the situation does not allow alternatives, for example in urban centres, where requirements to reduce the vulnerability of projects and preventive, protection and safety measures allowing the organization of emergency services will be set up.

The PPR may operate in zones that are directly at risk, but also in other zones that are not, in order to avoid aggravating existing risks or causing new ones. It regulates projects for new installations. It may prohibit or impose requirements on any type of construction, structure, development or any farming, forestry, craft, commercial or industrial activity, for their completion, use or exploitation and requirements of any kind can be used, up to total prohibition.

The PPR may also define general preventive, protection and safety measures that must be taken into account by communities as well as individuals. This option particularly concerns measures relating to the safety of persons and the organization of rescue operations as well as all general measures that are not specifically related to a particular project.

Finally, the PPR may take an interest in existing structures as well as new projects. However, for property construction that has been allowed in the past, only limited improvements whose cost is less than 10% of the market or estimated value of the property can be required.

As a complement to the PPR – the central tool of the French national authorities' natural hazards prevention action – other procedures and tools are designed to provide preventive information that must be provided to inhabitants possibly exposed to hazards (information tools: DDRM, DCS, DICRIM, IAL, etc.) as well as measures relating to the safety of persons and the organization of rescue operations that must be taken into account by communities and private individuals (safety measures plan: PCS). These procedures are mandatory for the municipalities with an existing PPR. Danger studies are also mandatory for certain classes of hydraulic works (new regulations for dams and dikes). Adequate hazard assessment (and mapping) is of course also necessary for all these prevention tools.

Rapid mass movements

Approximately 7000 French municipalities are threatened by mass movements, one-third of which can be highly dangerous for the population. Most of these towns, located in mountain regions, are exposed to various phenomena stemming from the instability of slopes and cliffs (collapses, rock falls, landslides).

Mass movements are demonstrations of the gravitational movement of ground masses destabilized under the influence of natural solicitations (snow melting, abnormally heavy rainfall, an earthquake, etc.) or human activities (excavation, vibration, deforestation, exploitation of materials or groundwater, etc.). They vary greatly in form, resulting from the multiplicity of triggering mechanisms (erosion, dissolution, deformation and collapse under static or dynamic load), themselves related to the complexity of the geotechnical behaviour of the materials (geologic structure, geometry of the fracture networks, groundwater characteristics, etc.)

According to the velocity of movement, two groups can be distinguished:

- *Slow movements, for which the deformation is progressive and can be accompanied by collapse but in principle without sudden acceleration*
  - Ground subsidence consecutive to changes in natural or artificial subterranean cavities (quarries or mines);
  - Compaction by shrinkage of clayey grounds and by consolidation of certain compressible grounds (muck, peat);
  - Creep of plastic materials on low slopes;
  - Landslides, i.e. a mass movement along a flat, curved or complex discontinuity surface of cohesive grounds (marls and clays);
  - Shrinkage or swelling of certain clayey materials depending on their moisture content.

- *Rapid movements which can be split into two groups, according to the propagation mode of materials*

The first group includes:

- Subsidence resulting from the sudden collapse of the top of natural or artificial subterranean cavities, without damping by the surface layers;
- Rock falls resulting from the mechanical alteration of fractured cliffs or rocky scarps (volumes ranging from 1 dm^3 to 10^4 or 10^5 m^3);
- Some rock slides.

The second group includes:

- Debris flows, which result from the transport of materials or viscous or fluid mixtures in the bed of mountain streams;
- Mud flows, which generally result from the evolution of landslide fronts. Their propagation mode is intermediate between mass movement and fluid or viscous transport.

<u>Standards and methods</u>

In France's administrative and institutional organization, certain activities and policies remain the jurisdiction of centralised authorities, such as the policy for natural risk prevention, overseen by the Ministry of the Environment. This is probably one of the most significant differences compared with other alpine countries. One consequence is the willingness to maintain a minimum homogeneity and coherence at the national level and in the way different types of natural hazards are treated.

Within the framework of this common procedure, a general methodological guidelines document has been published, followed by others specific to the different types of hazards: floods, forest fires, earthquakes, snow avalanches (to be approved), torrential floods (to be approved)… One of these guidelines documents is dedicated to geological hazards, including subsidence, sinking, collapse, rock falls, landslides, and associated mud flows, but it excludes debris flows in general.

The general guide, published in August 1997, presents the PPR, specifies how it should be drawn up and tries to answer the numerous questions that may arise for their implementation. The other guidelines, such as the one dedicated to mass movements, clarify the method and approach proposed for the various types of risks.

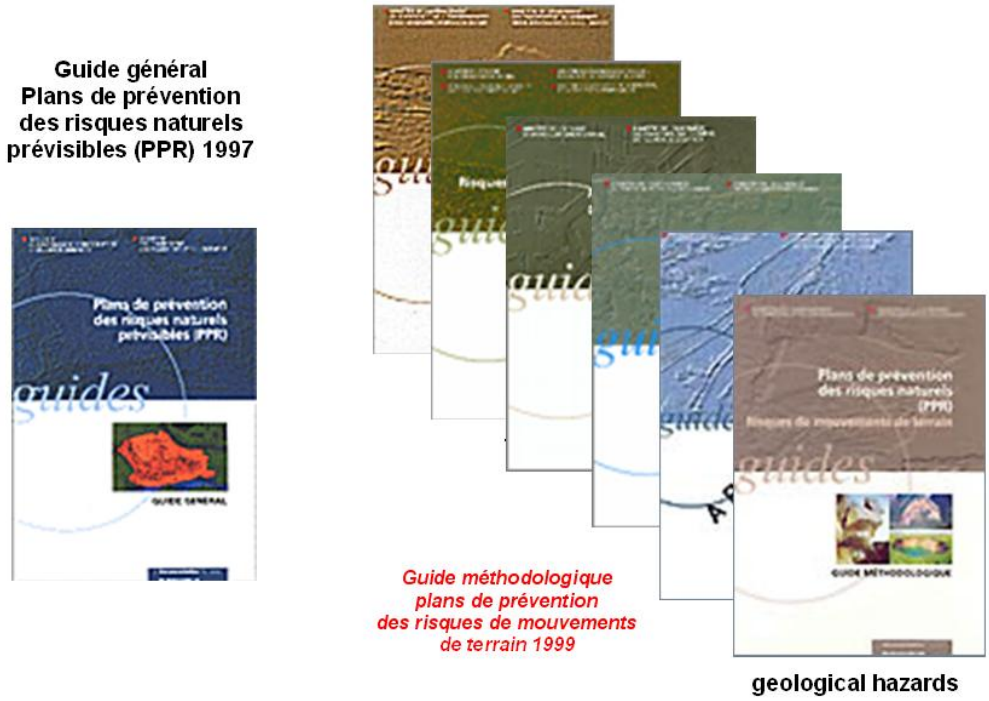


Figure 47: The PPR methodological guidelines collection

The general methodology establishes that the PPR is composed of:

- a presentation report explaining the analysis of the phenomena considered and the study of their impacts on people and existing or future property. This report explains the choices made for prevention, stating the principles the PPR is based on and commenting the regulations adopted.
- a regulatory map at a scale generally between 1:10 000 and 1:5000, which delineates areas controlled by the PPR. These are risk-prone areas but also areas where development could aggravate the risks or produce new sources of risk.
- regulations applied to each of these areas. The regulations define the conditions required for carrying out projects, prevention, protection and safety

measures that must be taken by individuals or communities, but also measures applicable to existing property and activities.

The regulatory zoning of the PPR is based on risk assessment, which depends on the analysis of the natural phenomena that may occur and of their possible consequences in terms of land use and public safety. This analysis includes four preliminary stages:

- Determination of the risk basin and the study perimeter;
- Knowledge of the historic and active natural phenomena: inventory and description;
- Hazard qualification: characterization of natural phenomena which can arise within the study perimeter;
- Evaluation of the socioeconomic and human stakes subjected to these hazards.

The elaboration of the PPR generally begins with the historical analysis of the main natural phenomena that have affected the studied territory. This analysis, possibly supplemented by expert advice on potential hazards, results in a hazard map that evaluates the scope of predictable phenomena. This map, including an analysis of the territory outcomes, carried out in consultation with the various local partners, is the basis for reflection during the elaboration of the PPR. Combining the levels of hazard and outcomes allows defining risk zones. Therefore, in this procedure, the hazard map is an intermediate step, necessary to elaborate the risk map, i.e. the real regulatory outcome of the PPR (together with the associated regulations). The study of phenomena by risk basin produces the hazard map, which is combined with the identification of elements at risk in drawing up the risk map.

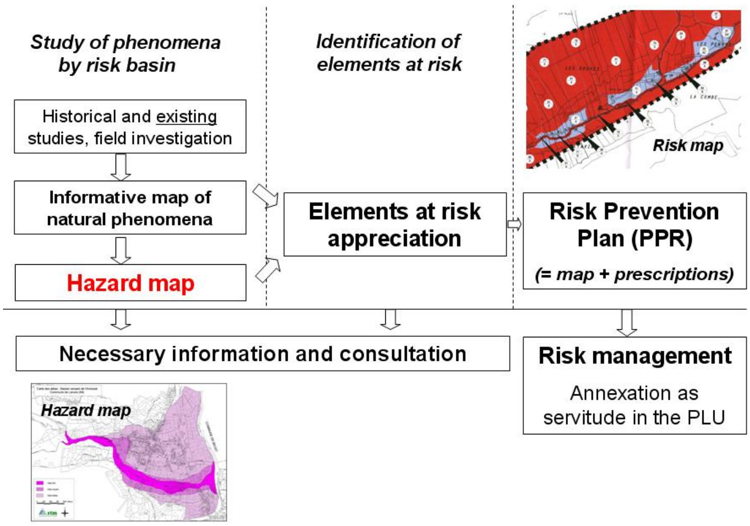


Figure 48: Positioning of the hazard map within the general procedure of PPR elaboration

Data and information

The first step in elaborating hazard maps consists of collecting all available data and information that can be exploited for hazard assessment. Priority is given to the qualitative general studies and to the back-analysis of past events. The general studies are conducted based on existing data, the back-analysis of past or current events and field surveys. Priority must be given to these elements, as stipulated by article 3 of the decree of October 5th, 1995, which specifies that the elaboration of PPR takes into account the current state of knowledge.

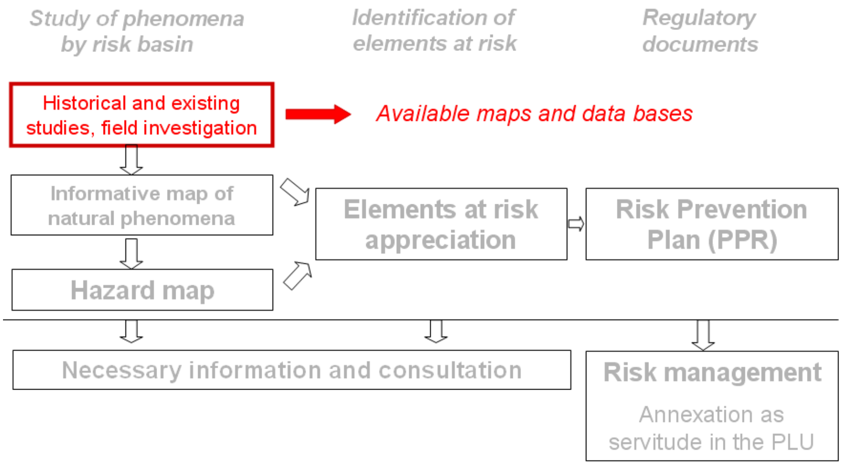


Figure 49: The first step of hazard mapping

The main information sources are:

- Municipal archives (technical documents, deliberations, miscellaneous documents, petitions, general reports or accident reports, etc.);
- Parochial archives;
- Departmental sources (archive and quarry services, miscellaneous diagnoses, etc.);
- Engineering consulting firm documents (geotechnical and geological reports, civil engineering studies and reports, field visit reports, etc.);
- General and research documents (scientific papers, geological guides, monographs, PhD theses, etc.);
- Field surveys and eye witness accounts;
- Existing databases and maps, aerial photographs.

Historical and existing studies as well as field investigations are collected for the study of the phenomena step. Maps and databases are available for this work: geological maps at a 1:50 000 scale, covering France (Fig. 50 - www.brgm.fr); a few Zermos maps (Fig. 6) of zones exposed to soil movement hazards, a combination of susceptibility levels and geomorphologic features, which are quite old and not exhaustive; a French database of mass movements (Fig. 52 - www.bdmvt.net); and an events database of the RTM services that will soon be on line.

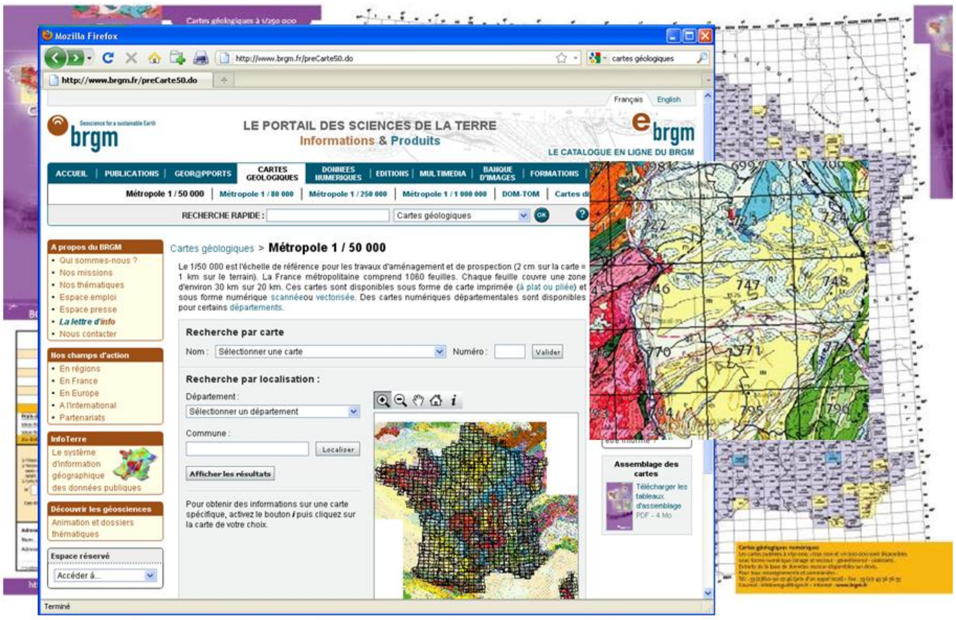


Figure 50: Geological maps and databases (www.brgm.fr)

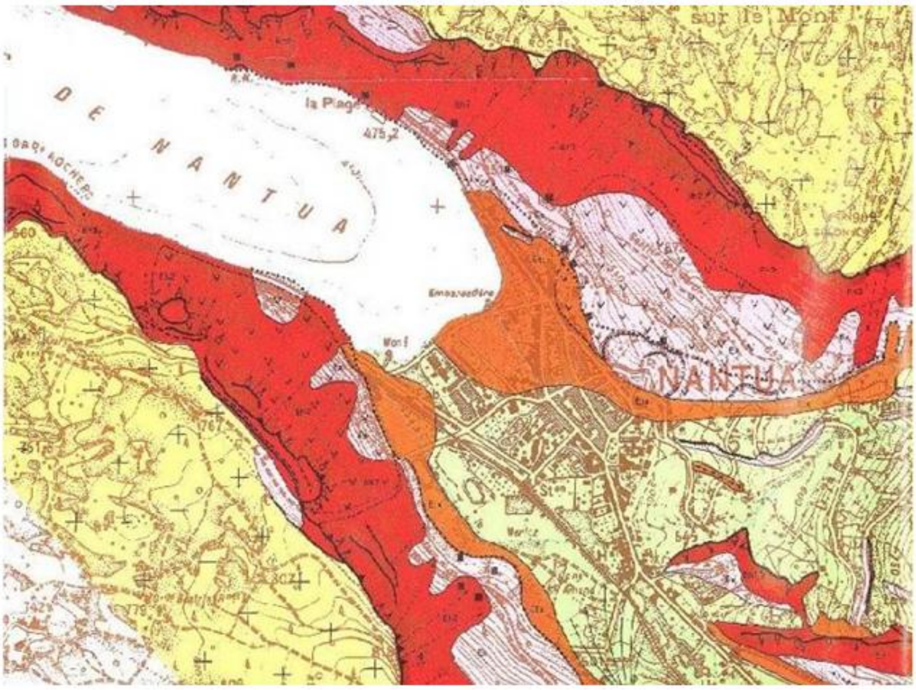


Figure 51: Example of a ZERMOS map

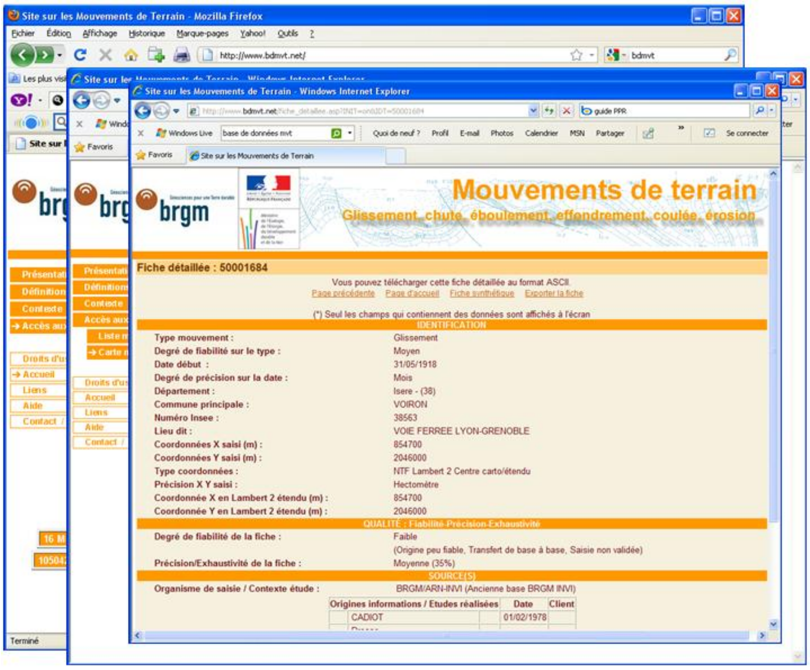


Figure 52: The BDMVT, French database of mass movements (www.bdmvt.net)

Hazard assessment

Hazard evaluation includes three components: the intensity of mass movements, the time of occurrence and the spatial extension. Once translated into regulatory zoning, the information contained in this map will be used to manage and plan land development and construction works. Hazards are thus qualified in terms of intensity.

Considering the variety of mass movements, it is difficult to directly translate their physical characteristics in terms of intensity, except by defining as many hazards as movement types, which would make the hazard zoning document difficult to read. It is therefore necessary to refer to more global criteria so they can be compared and their use for regulatory zoning facilitated.

Different methods are possible to assess a representative intensity level for all phenomena:

- As for earthquakes, intensity can be translated in terms of potential for damage, using parameters such as the volume of soil or rock involved, the depth of the failure surface, the final displacement, the kinetic energy, etc. However, damage potential depends not only on the physical phenomenon, but also on the vulnerability of buildings, which introduces a bias.
- Intensity can be assessed according to the importance and the cost of protection measures that would be necessary to implement. Different classes of

intensity can be identified if these measures remain within the domain of an individual owner or a group of owners or if they require community intervention and investment (Fig. 53).

Geological hazard qualification is based on qualitative criteria, such as the observed or expected damage or impacts or the cost range of possible countermeasures for the intensity evaluation.

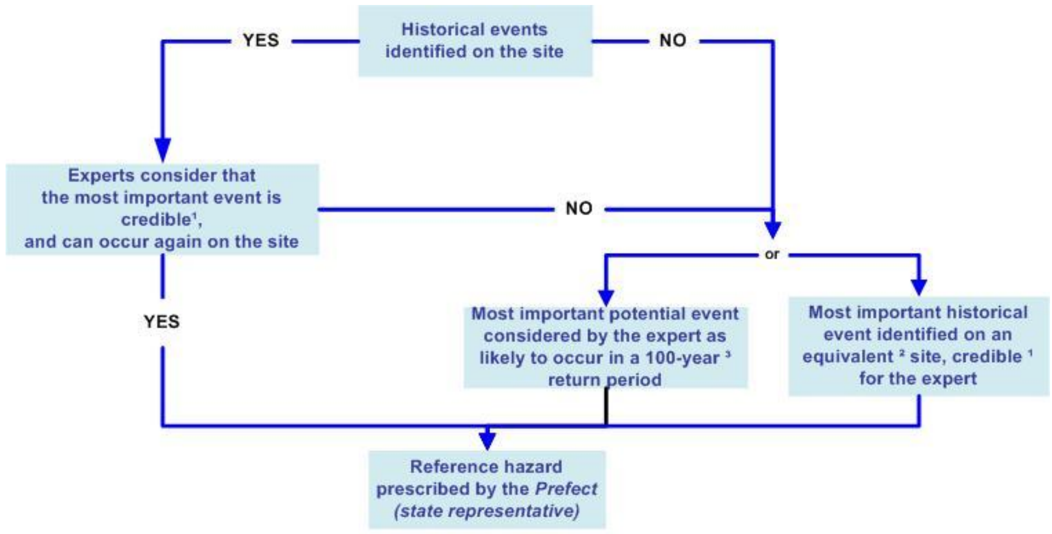
Intensity level	Coutermeasures importance level
Low	Can be financed by an individual owner
Medium	Can be financed by a limited group of owners
High	Concerns a spatial area larger than the individual ownership scale and/or very high cost and/or technically difficult
Major	No possible technical countermeasure *Only a few cases in France (Séchilienne, la Clapière…)*

Figure 53: Example of relationships proposed between the importance of countermeasures and intensity level

The frequency of events is estimated on the basis of the historical events identified on the site. The reference hazard is the most severe potential events considered by the expert as likely to occur in a 100-year period (or more frequently if human lives are concerned), or the most severe historical event identified on an equivalent site.

The probabilistic approach based on a frequency analysis is possible only for some phenomena such as rock falls. This assumes that sufficient data are available, which is actually rare. As most mass movements are not repetitive processes, contrary to earthquakes or floods, it is necessary to consider a probability of occurrence of an event qualitatively over a given period (e.g. 50 or 100 years), without reference to numerical values. For instance, three levels or probabilities may be used: low, medium and high.

In most cases, the occurrence probability is not a true probability, but is simply a scale of relative susceptibility, relying on elements such as slope angle, lithology, fracturing of the rock mass, presence of water, etc.



[1] 100-year return period event at least, or more in case of human danger, excluding exceptional geological events
[2] Caracterised by similar configuration and geodynamic evolution
[3] or more in case of human danger

Figure 54: Decision process for assessing the reference hazard

The hazard is graded by combining the time occurrence and the intensity, typically in a 2D table (Fig. 55). There is no general specification for this stage of the hazard evaluation, but presenting the key of the hazard evaluation is strongly recommended.

6. 7. Intensity level	8. Probability of occurrence		
	9. Low 10. Determining factors identified on the site are diffuse, poorly determined.	11. Medium 12. Many determining factors are identified on the site. Some factors non repertoried can appear with time.	13. High 14. Some nonidentified determining factors on the site. The intensity of the factors is high.
15. Low 16. Rock Falls < 1 dm^3	17. Very low to low hazard	18. Very low to low hazard	19. /

20. Medium 21. Rock Falls < 100 m^3	22. Very low to low hazard	23. Medium hazard	24. High hazard
25. High 26. Collapses > 100 m^3	27. /	28. High hazard	29. High hazard

Figure 55: Example of hazard table determination for rock fall hazard (from CETE du sud-ouest)

In presence of substantial human and socioeconomic danger, methods and tools specifying the spatial extension of the phenomena, thus reducing uncertainty, can be used: run-out modelling for rock falls, geophysics surveys delineating underground mines, etc. In case of rock falls and related phenomena, hazard evaluation includes both the stability analysis of rock masses and runout distance evaluation. Numerical tools are increasingly used to estimate the maximal run-out distance, but the reliability of the results is highly dependent on the experience of the engineering geologist.

Generally, the topographic basis used is the IGN (National Geographic Institute) 1:25 000 map, enlarged to 1:10 000. In presence of substantial damage potential or if the precision of the study and the amount of available data allow it, it is possible to map the hazards on a 1:5000-scale map.As far as very large mass movements are concerned, such as La Clapière (Alpes-Maritimes) or Séchilienne (Isère), involving more than 10 million m³ of material, ad hoc methods of hazard assessment have been set up, including the monitoring of movement and various computer simulations.

Conclusion

Methods assessing hazard for rapid mass movements are still mostly empirical and rely on the experience of the engineering geologist. The PPR guidelines give a general framework and general principles for hazard assessment and mapping. Precise rules are not yet available at the national level. The geological analysis remains the basis of hazard evaluation, but numerical tools as GIS and computer simulation are also used. The main requirement is that the method used should be explained.

3.3 Harmonized Outputs

Based on the state of the arts presented above, within the second Expert hearing in Munich, “new” minimum requirements to hazard mapping were elaborated in joined discussions. The main outputs of this session are shown inside the following chapter.

3.3.1 Harmonized Definitions for “Hazard Maps”

In the history of dealing with geological hazards a big variety of different maps were produced from the experts in several countries. Because of the inconsistent usage of terms and definitions the comparability of these maps was very difficult. Inside international projects this fact could cause understanding problems. Therefore three common definitions for three main types of maps were elaborated inside the workshop in Munich.

Landslide Susceptibility Map Level 1

A Landslide Susceptibility Map (Level 1) is used for the first identification of areas showing conflicts of interests or areas under suspicion to be hazardous. It is a map created on objective, scientific criteria with information on hazard susceptibility, which are not analysed, identified and localised in detail. With empirical, statistical or deterministic methods these maps show the basic disposition for the development of landslides. In general only the potential detachment zone of the landslides is shown and no classification of different hazard levels (probability and intensity) is done.

Landslide Susceptibility Map Level 2

A Landslide Susceptibility Map (Level 2) is used for the first identification of areas showing conflicts of interests or areas under suspicion to be hazardous. It is a map created on objective, scientific criteria with information on hazard susceptibility, which are analysed, identified and localised. With empirical, statistical or deterministic methods these maps show the basic disposition for the development of landslides. In general the whole process areas of the landslides and the propagation areas are shown (potential detachment and runout zone) and no classification of different hazard levels (probability and intensity) is done.

Hazard Map

A Landslide Hazard Map builds the base for urban land use planning and the development and the costing of protective measures. It is a map created on objective, scientific criteria with information to hazard, which are analysed, identified and localised in detail. With empirical, statistical or deterministic methods in general the whole process areas of the different types of landslides, including the propagation areas are considered (potential detachment and runout zone) and a classification of different hazard levels based on probability and intensity is done.

3.3.2 Overview and fitting in of the current maps

The following table shows an overview how the current used maps are fitting in the new given definitions. The table is structured into the "new" types of maps which were elaborated and into the three main processes (slide, fall, shallow landslides). An indication for the non standardized usage and definition of current maps are the fact, that most of them are mixed-types inside this table.

Country	Process	Landslide Suscep. Map (L1)	Landslide Suscep. Map (L2)	Hazard Map
Germany (Bavaria)	slide		Susc Map (1:25.000)	
	fall		Susc Map (1:25.000)	
	shallow landslides		Susc Map (1:25.000)	
Austria (WLV)	slide			Hazard Zone Map (1:2.000)
	fall			Hazard Zone Map (1:2.000)
	shallow landslides			Hazard Zone Map (1:2.000)
Austria (GBA and Carinthia)	slide	Susc Map (1:25.000-50.000)		Hazard Zone Map (1:1.000-1:10.000)
	fall	Susc Map (1:25.000-50.000)		Hazard Zone Map (1:1.000-1:10.000)
	shallow landslides	Susc Map (1:25.000-50.000)		Hazard Zone Map (1:1.000-1:10.000)
Switzerland	slide		Susc Map (1:10.000-1:50.000)	Hazard Map (1:2.000-1:10.000)
	fall		Susc Map (1:10.000-1:50.000)	Hazard Map (1:2.000-1:10.000)
	shallow landslides		Susc Map (1:10.000-1:50.000)	Hazard Map (1:2.000-1:10.000)
Great Britain (BGS)	slide	Susc Map (1:10.000-1:50.000)		
	fall			
	shallow landslides	Susc Map (1:10.000-1:50.000)		
Italy (Arpa Piemonte)	slide		Atlas of Hydrogeological Risk (1:10.000)	
	fall		Atlas of Hydrogeological Risk (1:10.000)	
	shallow landslides		Atlas of Hydrogeological Risk (1:10.000)	
Italy (South Tyrol)	slide			Hazard Plan (1:5.000-1:10.000)
	fall			Hazard Plan (1:5.000-1:10.000)
	shallow landslides			Hazard Plan (1:5.000-1:10.000)
Italy (Emilia Romagna)	slide		Susc Map (1:10.000)	
	fall			
	shallow landslides	Susc Map (1:10.000)		
Spain (Catalonia)	slide		Geological Risk Prevention Map (1:25.000)	
	fall		Geological Risk Prevention Map (1:25.000)	
	shallow landslides		Geological Risk Prevention Map (1:25.000)	
Slovenia	slide	Susc Map (1:250.000)	Hazard Map (1:25.000) in progress	
	fall	Susc Map (1:250.000)	Hazard Map (1:25.000) in progress	
	shallow landslides	Susc Map (1:250.000)	Hazard Map (1:25.000) in progress	
France	slide	Plan for Prevention of Natural Hazard (1:25.000)	Plan for Prevention of Natural Hazard (1:10.000)	
	fall	Plan for Prevention of Natural Hazard (1:25.000)	Plan for Prevention of Natural Hazard (1:10.000)	
	shallow landslides	Plan for Prevention of Natural Hazard (1:25.000)	Plan for Prevention of Natural Hazard (1:10.000)	

Figure 56: Overview of the current maps fitting in the new definitions

3.3.3 Basic data and methods used in the involved countries

The next step in creating minimum requirements to hazard mapping was the summary of all the basic data and methods, which are used currently in the involved countries. Therefore a matrix with all the important characteristics to create hazard maps was elaborated. The criteria inside this table reach from the used scale to modeling methods. The matrix is also structured into three main process types (slides, falls, shallow landslides) and to simplify the filling two classes of maps are used: *Susceptibility map (all maps without intensity and probability)* and *Hazard map (all maps which are including intensity and probability).*

The red markings show all the basic data and methods which are mandatory and the yellow fields show the recommended. In the following part the matrices for all the involved regions are shown.

Land/Region: Bavaria			Slide processes		Fall prozesses				Shallow landslides	
					single block	rock masses	single block	rock masses		
			Suscept. Map	Haz. map	Susceptibility Map		Hazard map		Suscept. Map	Haz. map
Basic data and methods	Scale	1:25.000 - 1:50.000								
		1: 10.000 - 1: 25.000	red		red	red			red	
		1: 1.000 - 1: 10.000								
	Geoscience	Geological map	red		red	yellow			red	
		Engineering geological map	yellow		yellow	yellow			yellow	
		Geotechnical map	yellow		yellow	yellow			red	
		Soil map								
	Hydrology	Hydrological map								
		Hydrogeology								
		Hydrochemical analyses								
	Inventory and field work	Landslide inventory (e.g. Database)	red		yellow	red			yellow	
		Map of phenomena / Inventory map	red		yellow	red			yellow	
		Additional field work	red			red				
		Dating (Dendro, C 14)								
	Elevation models (remote sensing/topogr. maps)	Optical, aerial photos (Orthophotos)	red		yellow	yellow			yellow	
		Optical, Satellite imagery								
		Radar - terrestrial								
		Radar - satellite								
		LIDAR (terrestrial) (Raster resolution ?)								
		LIDAR (airborne) (Raster resolution ?)	red		red	red			red	
		Elevation model from topogr. Maps								
	Surveying	Photogrammetry								
		Geodesy (GPS)	yellow							
		Point measurements (Extensometer etc.)	yellow			yellow				
	Probing	Geophysics (Seismology usw.)								
		Probing / bore holes								
		Bore - Inclinometers	yellow							
		Bore - Piezometer								
		Laboratory tests								
	Modeling	Processmodeling - empirical (e.g. global angle methods, silent witnesses, field work)	red			red				
		Processmodeling - deterministical			red				red	
		Processmodeling statistical								
		Stability calculations								
	Probability	Spatial probability in the process area								
		Temporal probability								
	Intensity	Empirical determination								
		Nummerical determination								

Figure 57: Minimum requirements for Bavaria

Land/Region: Germany			Slide processes		Fall prozesses				Shallow landslides	
					single block	rock masses	single block	rock masses		
			Suscept. Map	Haz. map	Susceptibility Map		Hazard map		Suscept. Map	Haz. map
Basic data and methods	Scale	1:25.000 - 1:50.000								
		1: 10.000 - 1: 25.000								
		1: 1.000 - 1: 10.000								
	Geoscience	Geological map								
		Engineering geological map								
		Geotechnical map								
		Soil map								
	Hydrology	Hydrological map								
		Hydrogeology								
		Hydrochemical analyses								
	Inventory and field work	Landslide inventory (e.g. Database)								
		Map of phenomena / Inventory map								
		Additional field work								
		Dating (Dendro, C 14)								
	Elevation models (remote sensing/topogr. maps)	Optical, aerial photos (Orthophotos)								
		Optical, Satellite imagery								
		Radar - terrestrial								
		Radar - satellite								
		LIDAR (terrestrial) (Raster resolution ?)								
		LIDAR (airborne) (Raster resolution ?)								
		Elevation model from topogr. Maps (Raster resolution ?)								
	Surveying	Photogrammetry								
		Geodesy (GPS)								
		Point measurements (Extensometer etc.)								
	Probing	Geophysics (Seismology usw.)								
		Probing / bore holes								
		Bore - Inclinometers								
		Bore - Piezometer								
		Laboratory tests								
	Modeling	Processmodeling - empirical (e.g. global angle methods, silent witnesses, field work)								
		Processmodeling - deterministical								
		Processmodeling statistical								
		Stability calculations								
	Probability	Spatial probability in the process area								
		Temporal probability								
	Intensity	Empirical determination								
		Nummerical determination								

Figure 58: Minimum requirements for Germany

Land/Region: Kärnten			Slide processes		Fall prozesses				Shallow landslides	
					single block	rock masses	single block	rock masses		
			Suscept. Map	Haz. map	Susceptibility Map		Hazard map		Suscept. Map	Haz. map
Basic data and methods	Scale	1:25.000 - 1:50.000								
		1: 10.000 - 1: 25.000								
		1: 1.000 - 1: 10.000								
	Geoscience	Geological map								
		Engineering geological map								
		Geotechnical map								
		Soil map								
	Hydrology	Hydrological map								
		Hydrogeology								
		Hydrochemical analyses								
	Inventory and field work	Landslide inventory (e.g. Database)								
		Map of phenomena / Inventory map								
		Additional field work								
		Dating (Dendro, C 14)								
	Elevation models / areal photos	Optical, aerial photos (Orthophotos)								
		Optical, Satellite imagery								
		Radar - terrestrial								
		Radar - satellite								
		LIDAR (terrestrial) (Raster resolution ?)								
		LIDAR (airborne) (Raster resolution ?)								
		Elevation model from topogr. Maps (Raster resolution ?)								
	Surveying	Photogrammetry								
		Geodesy (GPS)								
		Point measurements (Extensometer etc.)								
	Probing	Geophysics (Seismology usw.)								
		Probing / bore holes								
		Bore - Inclinometers								
		Bore - Piezometer								
		Laboratory tests								
	Modeling	Modeling - empirical (silent witnesses)								
		Modeling - deterministical								
		Modeling statistical								
		Stability calculations								
	Probability	Spatial probability in the process area								
		Temporal probability								
	Intensity	Empirical determination								
		Nummerical determination (statistic)								

Figure 59: Minimum requirements for Carinthia (Austria)

Land/Region: Austria (Vorarlberg)			Slide processes		Fall prozesses				Shallow landslides	
					single block	rock masses	single block	rock masses		
			Suscept. Map	Haz. map	Susceptibility Map		Hazard map		Suscept. Map	Haz. map
Basic data and methods	Scale	1:25.000 - 1:50.000								
		1: 10.000 - 1: 25.000								
		1: 1.000 - 1: 10.000								
	Geoscience	Geological map								
		Engineering geological map								
		Geotechnical map								
		Soil map								
	Hydrology	Hydrological map								
		Hydrogeology								
		Hydrochemical analyses								
	Inventory and field work	Landslide inventory (e.g. Database)								
		Map of phenomena / Inventory map								
		Additional field work								
		Dating (Dendro, C 14)								
	Elevation models (remote sensing/topogr. maps)	Optical, aerial photos (Orthophotos)								
		Optical, Satellite imagery								
		Radar - terrestrial								
		Radar - satellite								
		LIDAR (terrestrial) (Raster resolution ?)								
		LIDAR (airborne) (Raster resolution ?)								
		Elevation model from topogr. Maps (Raster resolution ?)								
	Surveying	Photogrammetry								
		Geodesy (GPS)								
		Point measurements (Extensometer etc.)								
	Probing	Geophysics (Seismology usw.)								
		Probing / bore holes								
		Bore - Inclinometers								
		Bore - Piezometer								
		Laboratory tests								
	Modeling	Processmodeling - empirical (e.g. global angle methods, silent witnesses, field work)								
		Processmodeling - deterministical								
		Processmodeling statistical								
		Stability calculations								
	Probability	Spatial probability in the process area								
		Temporal probability								
	Intensity	Empirical determination								
		Nummerical determination								

Figure 60: Minimum requirements for Vorarlberg (Austria)

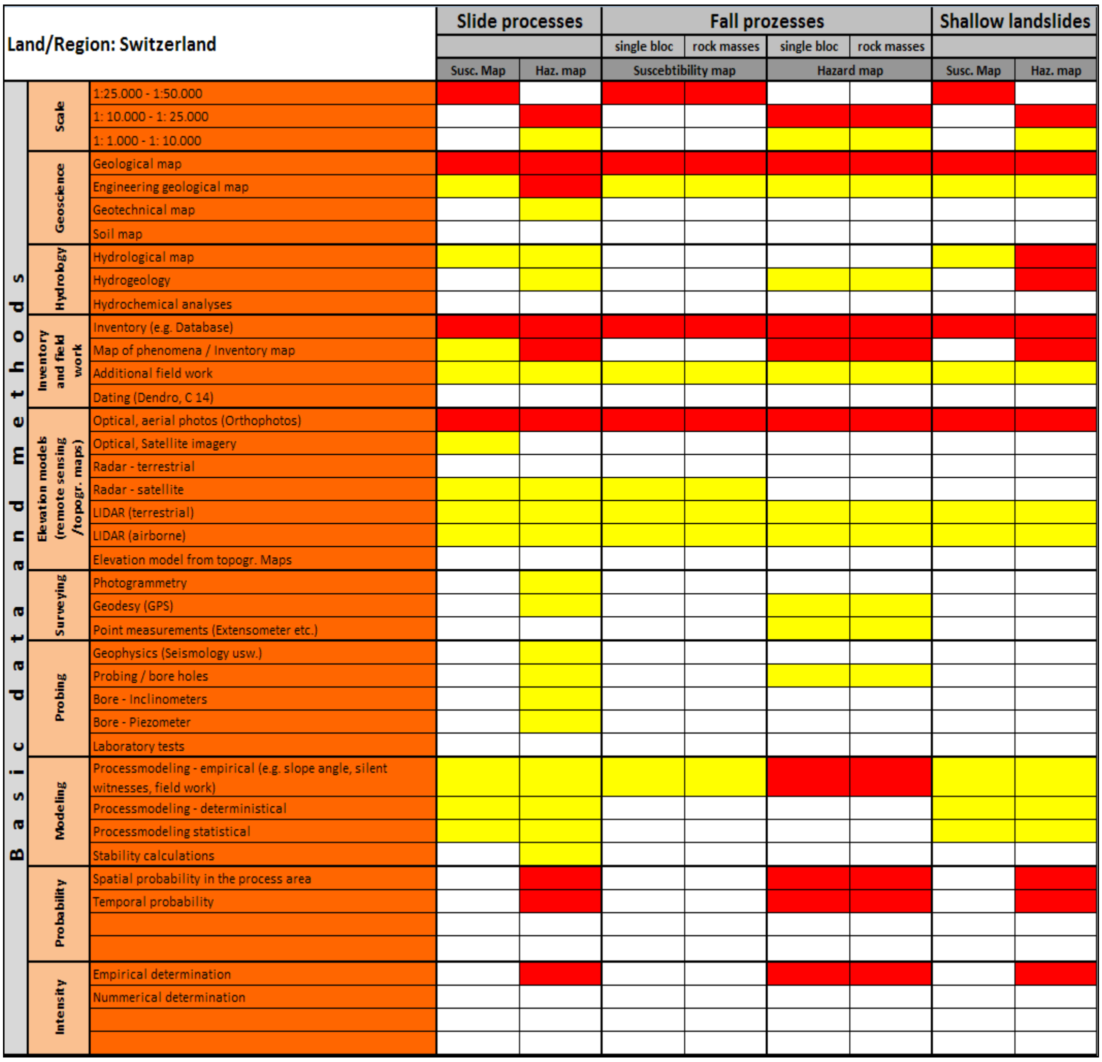


Figure 61: Minimum requirements for Switzerland

Land/Region: Great Britain			Slide processes		Fall prozesses				Shallow landslides	
					single block	rock masses	single block	rock masses		
			Suscept. Map	Haz. map	Susceptibility Map		Hazard map		Suscept. Map	Haz. map
Basic data and methods	Scale	1:25.000 - 1:50.000								
		1: 10.000 - 1: 25.000								
		1: 1.000 - 1: 10.000								
	Geoscience	Geological map								
		Engineering geological map								
		Geotechnical map								
		Soil map								
	Hydrology	Hydrological map								
		Hydrogeology								
		Hydrochemical analyses								
	Inventory and field work	Landslide inventory (e.g. Database)								
		Map of phenomena / Inventory map								
		Additional field work								
		Dating (Dendro, C 14)								
	Elevation models (remote sensing/topogr. maps)	Optical, aerial photos (Orthophotos)								
		Optical, Satellite imagery								
		Radar - terrestrial								
		Radar - satellite								
		LIDAR (terrestrial) (Raster resolution ?)								
		LIDAR (airborne) (Raster resolution ?)								
		Elevation model from topogr. Maps (Raster resolution ?)								
	Surveying	Photogrammetry								
		Geodesy (GPS)								
		Point measurements (Extensometer etc.)								
	Probing	Geophysics (Seismology usw.)								
		Probing / bore holes								
		Bore - Inclinometers								
		Bore - Piezometer								
		Laboratory tests								
	Modeling	Processmodeling - empirical (e.g. global angle methods, silent witnesses, field work)								
		Processmodeling - deterministical								
		Processmodeling statistical								
		Stability calculations								
	Probability	Spatial probability in the process area								
		Temporal probability								
	Intensity	Empirical determination								
		Nummerical determination								

Figure 62: Minimum requirements for Great Britain

Land/Region: EMILIA-ROMAGNA (ITALY)			Slide processes		Fall prozesses				Shallow landslides	
					single block	rock masses	single block	rock masses		
			Suscept. Map	Haz. map	Susceptibility Map		Hazard map		Suscept. Map	Haz. map
Basic data and methods	Scale	1:25.000 - 1:50.000								
		1: 10.000 - 1: 25.000								
		1: 1.000 - 1: 10.000								
	Geoscience	Geological map								
		Engineering geological map								
		Geotechnical map								
		Soil map								
	Hydrology	Hydrological map								
		Hydrogeology								
		Hydrochemical analyses								
	Inventory and field work	Landslide inventory (e.g. Database)								
		Map of phenomena / Inventory map								
		Additional field work								
		Dating (Dendro, C 14)								
	Elevation models (remote sensing/topogr. maps)	Optical, aerial photos (Orthophotos)								
		Optical, Satellite imagery								
		Radar - terrestrial								
		Radar - satellite								
		LIDAR (terrestrial) (Raster resolution ?)								
		LIDAR (airborne) (Raster resolution ?)								
		Elevation model from topogr. Maps (Raster resolution ?)								
	Surveying	Photogrammetry								
		Geodesy (GPS)								
		Point measurements (Extensometer etc.)								
	Probing	Geophysics (Seismology usw.)								
		Probing / bore holes								
		Bore - Inclinometers								
		Bore - Piezometer								
		Laboratory tests								
	Modeling	Processmodeling - empirical (e.g. global angle methods, silent witnesses, field work)								
		Processmodeling - deterministical								
		Processmodeling statistical								
		Stability calculations								
	Probability	Spatial probability in the process area								
		Temporal probability								
	Intensity	Empirical determination								
		Nummerical determination								

Figure 63: Minimum requirements for Emilia Romagna (Italy)

Figure 64: Minimum requirements for France

Figure 65: Minimum requirements for Slovenia

3.3.4 Harmonized basic data and methods

On basic of all the different matrices are shown above inside the meeting in Munich a harmonized table was elaborated. This matrix represents the minimum requirements to create hazard maps. In contrast to the country tables above the harmonized table only shows the basic data and methods which are really used and it is structured into the new defined three types of maps (Landslide susceptibility map Level 1 and 2, Hazard map). Concerning to modeling methods the harmonized matrix also distinguishes into disposition model (detachment zone) and process model (runout zone).

		Slide processes			Fall prozesses						Shallow landslides			Details
		Landslide Susceptibility Map		Hazard Map	Landslide Susceptibility Map				Hazard map		Landslide Susceptibility Map		Hazard Map	
					single block		rock masses		single block	rock masses				
		Level 1	Level 2	Haz. map	Level 1	Level 2	Level 1	Level 2	Hazard map		Level 1	Level 2	Haz. map	
Geologycal maps and derivated	Geological map													use of geological maps and all deviated products
Landslide inventory in the broadest sense	Landslide inventory (e.g. Database/ Inventory Map)													landslide inventory in the broadest sence
	Field work (Investigation/Validation)													including field investigation and validation
Elevation models /areal photos	Elevation model													
	Optical, aerial photos (Orthophotos)													
	LIDAR (terrestrial)													
	LIDAR (airborne)													
	Elevation model from topogr. Maps													
Modeling in the broadest sense (slides can be found by field investigaton)	Modeling				D	D+P	D	D+P	D+P	D+P	D	D+P	D+P	modeling in the broadest sence. Slide process areas can be found by field investigation
	Modeling - deterministical				D	P			P	P	D	D+P	D+P	
	Modeling - statistical				D						D	D+P	D+P	
	Modeling - empirical				D	D	D	D+P	D	D+P				
Probabilpty (spatial and temporal probability must be unified in a matrix.	Spatial probability in the process area													spatial and temporal probability must be unified in a matrix. Information can be qualitative
	Temporal probability													
Intesity (Information can be qualitative)	Empirical determination													Information can be qualitative

D = Disposition Model (Detachment Zone)

P = Process Model (Runout Zone)

Basic data or method is mantatory (red)

One out of several methods must be used (green)

Figure 66: Harmonized minimum requirements for hazard mapping

4. Conclusion

Altogether the two main targets which were set at the beginning of the project were achieved. The development of a multilingual glossary to landslide terms and definitions in six languages leads to an online glossary which can be used by the geological experts and all other interested people under www.adaptalp.org. A total of 97 terms to landslide and hazard mapping were harmonized in six languages and were registered for nine European regions. Concerning to the communication problems and misunderstandings inside international projects which were mentioned in the introduction of this report, this glossary should be an instrument to facilitate the collaboration and should help to improve the results of international projects in the future.

With regard to the harmonization efforts from the EU the second main goal can be seen as a milestone inside this project. The creation and elaboration of minimum requirements to hazard mapping was implemented inside presentations and joined discussions within the two Expert Hearings in Bolzano and Munich. Based on the state of the art presentations from all the involved experts in Bolzano differences and commonalities in hazard mapping were discussed and a least common denominator should be found and defined. As a result of this work package in a first step the body of experts inside the Hearing in Munich agreed new common definitions and naming for the three main types of hazard maps. In a second step a guideline with all the basic data and methods needed for the creation of the “new” types of hazard maps was elaborated. This table should help to unify the hazard mapping methods and also should improve the comparability of future products will be made to illustrate natural hazards.

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6. List of figures