Deliverable **HAZARD SCENARIOS MAPS**

test sites GANDERBERG & TRAFOI (South Tyrol, Italy)

(explanatory notes)

Date May 2012
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Legislation in South Tyrol regarding Hazard and Risk Mapping for land use planning

Legislative framework

For the territory of the Autonomous Province of Bolzano the relevant natural hazards are grouped as following:
- Mass movements
- Hydraulic hazards
- Snow avalanches

Following the national laws Decreto Legge 11 giugno 1998, n. 180 and Legge 3 agosto 1998, n.267 the Autonomous Province of Bolzano established guidelines in 2008 for the preparation, elaboration and approvation od Hazard Zone Plans (HZP) (Piano delle Zone di Pericolo, Gefahrenzonenplan) which are a part of the communal masterplan.

Decree of the President of The Province n.42, 5th august 2008 – regulation about hazard zone plans
The natural hazards are described within the following three types:
- mass movements – rock fall, slide, slump, flow, collapse
- hydraulic hazards – flood, flood with solids, debris flow canalised, erosion
- snow avalanches – avalanche dense flow, avalanche powder, gliding snow

The elaboration of the hazard zone plan (HZP) is part of the elaboration of risk zone plans (RZP) which are made in three steps:
- phase I: individualization, acquisition of available information and data and documentation of areas with hydrogeological risk
- phase II: delimitation and estimation of the hazard
- phase III: evaluation of the specific risk levels and definition of the mitigation measures

The elaboration of the hazard zone maps (HZM) is based on the so-called swiss method (BUWAL, 1998/1999 – Methods of analysis and evaluation of natural hazards).

The responsibility for the elaboration of the phases I and II is given to the Municipalities (HZM). For the phase III there has to be elaborated also the specific risk zone map (SRZ).
Evaluation of Hazard

The hazard zone plan has to be regularly revised and updated considering changing protection measure which can reduce the intensity of hazardous phenomena.

For urbanistic planning purposes the hazard zones (H4-H1) are adopted which are defined as following:

Zone H4 (red) – zone of interdiction
- Very high hazard: loss of human lifes is possible and serious damages to people, buildings, infrastructures and to the territory, destruction of socio-economic activities.
- People are endangered inside and outside of buildings
- Sudden collapse of buildings is possible

Zone H3 (blue) – zone of constraints
- High hazard: safety of people is not guaranteed, functional damages of buildings and infrastructures are possible, socio-economics activities can be interrupted and the territory can be affected by damages.
- People outside of buildings are endangered; inside of buildings they are safe.
- Possible functional damages to buildings; if they are built respecting the law they should not collapse,

Zone H2 (yellow) – zone of attention
- Middle hazard: minor damages to buildings, infrastructure, territory are possible – people are not endangered; buildings can be used and socio-economic activities can be carried out without interruptions.
- Low hazard also for people outside of buildings

H1 – residual hazard

The HZP allows an evaluation of hazard which derives from natural phenomena with a maximal return period of 300 years. Very rare events or with an “infinite” intensity (dsgsd, flood due to dam collapse) have to be considered as a residual hazard H1.
The hazard level is quantified crossing the intensity of the phenomena with the probability of occurrence which is quantified by the return period. The following figures show the matrix for mass movements and hydraulic hazards.
Matrix for the detection of the hazard level, for mass movements and hydraulic hazards (from guidelines for the elaboration of hazard zone plans, deliberation of the Council of the Province n 2741 July 28th)

Following parameters have been defined in order to calculate the hazard class from the hazard matrix (modified after BUWAL).

**Intensity (I) = SG x VEL**
SG: geometry
VEL: velocity

**Hazard (H) = Ix TR**
I: Intensity
TR: Returning Period

<table>
<thead>
<tr>
<th>Probabilità di accadimento</th>
<th>Tempo di ritorno (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>elevata</td>
<td>100% finito a 82%</td>
</tr>
<tr>
<td>media</td>
<td>82% finito a 40%</td>
</tr>
<tr>
<td>bassa</td>
<td>40% finito a 15%</td>
</tr>
<tr>
<td>molto basso</td>
<td>&lt; 15%</td>
</tr>
</tbody>
</table>

Table of the probability of occurrence, expressed with the return periods (from guidelines for the elaboration of hazard zone plans, deliberation of the Council of the Province n 2741 July 28th)

In case of landslides following geometry parameters have to be adopted:

- Scivolamenti superficiali 
  superficie di scivolamento: < 2m  SG1
- Scivolamenti medi 
  superficie di scivolamento: 2-10m  SG2
- Scivolamenti profondi 
  superficie di scivolamento: > 10m  SG3.

La caduta sassi è distinta dalla caduta massi e blocchi attraverso il diametro del materiale, mentre la distinzione fra aree di crollo grande e di crollo medio si fonda sui volumi coinvolti. La caduta sassi comprende materiale con diametri <0.5m (SG1), la caduta massi/blocchi diametri >0.5m (0.5-2m=SG2, >2m=SG3); il volume coinvolto rimane sempre sotto i 100 m³. I crolli in roccia media sono caratterizzati da distacamenti dall’incassato di banci interi di roccia più o meno frammentati, che comprendono volumi tra 100 e 100.000 m³. Crolli in roccia grandi coinvolgono invece volumi minimi di 1.000.000 m³.
<table>
<thead>
<tr>
<th>Parametro</th>
<th>Frase</th>
<th>Severeità geomecànica (SG) [media limiti caratteristici]</th>
<th>Velocità (VEL) [velocità media caratteristiche]</th>
<th>Intensità di SG a VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>aree crolli grandi, aree crolli masi, caduta blocchi</em></td>
<td>aree potenziali distacco crolli di blocchi</td>
<td>Ø blocchi: &gt;2m (SG2)</td>
<td>&gt; 3 m/min (VEL3)</td>
<td>alta</td>
</tr>
<tr>
<td></td>
<td>aree potenziali depositone crolli di blocchi</td>
<td>Ø blocchi: 0.5-2m (SG2)</td>
<td>&gt; 3 m/min (VEL3)</td>
<td>alta</td>
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<tr>
<td><em>caduta masi</em></td>
<td>aree potenziali distacco crolli di masi</td>
<td>Ø masi: &lt;0.5m (SG1)</td>
<td>&gt; 3 m/min (VEL3)</td>
<td>alta</td>
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<tr>
<td></td>
<td>aree potenziali depositone crolli di masi</td>
<td>Ø masi: &lt;0.5m (SG1)</td>
<td>&gt; 3 m/min (VEL3)</td>
<td>alta</td>
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<tr>
<td><em>caduta masi</em></td>
<td>aree potenziali distacco crolli di masi</td>
<td>Ø masi: &lt;0.5m (SG1)</td>
<td>&gt; 3 m/min (VEL3)</td>
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<tr>
<td></td>
<td>aree potenziali depositone crolli di masi</td>
<td>Ø masi: &lt;0.5m (SG1)</td>
<td>&gt; 3 m/min (VEL3)</td>
<td>alta</td>
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<tr>
<td></td>
<td><strong>Sediamenti in roccia (traslazi-onali, rotostrud-zionali)</strong></td>
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<tr>
<td></td>
<td>aree potenziali distacco</td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 3 m/min (VEL3)</td>
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<td></td>
<td>&gt;8m (SG3)</td>
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<tr>
<td></td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 1.5m/mese + 3m/min (VEL2)</td>
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<td></td>
<td>&gt;5m (SG2)</td>
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<td>spessore materiale mobilizzato</td>
<td>&gt; 3 m/min (VEL3)</td>
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<td>2-5m (SG2)</td>
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<td>&gt; 1.5m/mese + 3m/min (VEL2)</td>
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<tr>
<td></td>
<td>0-2m (SG2)</td>
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<td></td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 3 m/min (VEL3)</td>
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<td>&lt;2m (SG1)</td>
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<td></td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 1.5m/mese + 3m/min (VEL2)</td>
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<td></td>
<td>&gt;8m (SG3)</td>
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<td></td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 1.5m/mese + 3m/min (VEL2)</td>
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<td>&gt;5m (SG2)</td>
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<td></td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 3 m/min (VEL3)</td>
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<td></td>
<td>2-5m (SG2)</td>
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<td></td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 1.5m/mese + 3m/min (VEL2)</td>
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<td></td>
<td>0-2m (SG2)</td>
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<td></td>
<td>spessore materiale mobilizzato</td>
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<td></td>
<td>&lt;2m (SG1)</td>
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<td></td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 1.5m/mese + 3m/min (VEL2)</td>
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<td></td>
<td>aree potenziali depositione</td>
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<td>&gt;8m (SG3)</td>
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<td></td>
<td>&gt;5m (SG2)</td>
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<td></td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 3 m/min (VEL3)</td>
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<td></td>
<td>2-5m (SG2)</td>
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<tr>
<td></td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 1.5m/mese + 3m/min (VEL2)</td>
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<tr>
<td></td>
<td>spessore materiale mobilizzato</td>
<td>&gt; 1.5m/mese + 3m/min (VEL2)</td>
<td>alta</td>
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</tbody>
</table>
### Scuolemiento in sedimenti sciolti, in argilli, silti

<table>
<thead>
<tr>
<th>area potenziale disacco</th>
<th>spessore materiale mobilizzato: &gt;10m (SG3)</th>
<th>&gt; 3m/min (VRL3)</th>
<th>alta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>spessore materiale mobilizzato: &gt;5m (SG3)</td>
<td>12m/min + 2m/min (VRL2)</td>
<td>alta</td>
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<tr>
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<td>spessore materiale mobilizzato: &gt;3m (SG3)</td>
<td>&lt; 12m/min (VRL1)</td>
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<td>spessore materiale mobilizzato: &lt; 3m (SG3)</td>
<td>&lt; 3m/min (VRL1)</td>
<td>bassa</td>
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</table>

<table>
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<tr>
<th>area potenziale trasporto</th>
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<th>&gt; 3m/min (VRL3)</th>
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<tbody>
<tr>
<td></td>
<td>spessore materiale mobilizzato: &gt;5m (SG3)</td>
<td>12m/min + 2m/min (VRL2)</td>
<td>alta</td>
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<tr>
<td></td>
<td>spessore materiale mobilizzato: &gt;3m (SG3)</td>
<td>&lt; 12m/min (VRL1)</td>
<td>media</td>
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<td>spessore materiale mobilizzato: &lt; 3m (SG3)</td>
<td>&lt; 3m/min (VRL1)</td>
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<tr>
<td></td>
<td>spessore materiale mobilizzato: &gt;5m (SG3)</td>
<td>12m/min + 2m/min (VRL2)</td>
<td>alta</td>
</tr>
<tr>
<td></td>
<td>spessore materiale mobilizzato: &gt;3m (SG3)</td>
<td>&lt; 12m/min (VRL1)</td>
<td>media</td>
</tr>
<tr>
<td></td>
<td>spessore materiale mobilizzato: &lt; 3m (SG3)</td>
<td>&lt; 3m/min (VRL1)</td>
<td>bassa</td>
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### Colata di fango; Colata di versante

<table>
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<th>area potenziale disacco</th>
<th>spessore materiale mobilizzato: &gt;10m (SG3)</th>
<th>&gt; 3m/min (VRL3)</th>
<th>alta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>spessore materiale mobilizzato: &gt;5m (SG3)</td>
<td>12m/min + 2m/min (VRL2)</td>
<td>alta</td>
</tr>
<tr>
<td></td>
<td>spessore materiale mobilizzato: &gt;3m (SG3)</td>
<td>&lt; 12m/min (VRL1)</td>
<td>media</td>
</tr>
<tr>
<td></td>
<td>spessore materiale mobilizzato: &lt; 3m (SG3)</td>
<td>&lt; 3m/min (VRL1)</td>
<td>bassa</td>
</tr>
</tbody>
</table>
Evaluation of Risk

For the evaluation of the specific risk (Rs) the territory has to be analyzed and risk elements have to be detected:

- urbanizations
- industrial/productive activities
- infrastructures
- territory and cultural heritage
- areas of public services (sport, culture,...)

The classification of the areas of different vulnerability is made from the masterplan and from the land use map and the different categories from the masterplan have the following vulnerability classes (supplement of the guidelines, fig. 5):

- V4 (red): very high
- V3 (blue): high
- V2 (yellow): medium
- V1 (green): low
The safety of persons and the number of persons are the two main criteria for the definition of vulnerability.
Vulnerability Classification of masterplan and land-use categories (from guidelines for the elaboration of hazard zone plans, deliberation of the Council of the Province n 2741 July 28th)

Following risk classes are defined:

- **very high risk**: losses of human lives and serious damages to people, buildings, infrastructures and to the territory, destruction of socio-economic activities.
- **high risk**: safety of people is not guaranteed, functional damages of buildings and infrastructures are possible, socio-economics activities can be interrupted and the territory can be affected by damages.
- **medium risk**: minor damages to buildings, infrastructure, territory are possible – people are not endangered; buildings can be used and socio-economic activities can be carried out without interruptions.
- **low risk**: damages to the territory and socio-economic activities are marginal
Specific risk matrix (from guidelines for the elaboration of hazard zone plans, deliberation of the Council of the Province n 2741 July 28th)
Adaptation to South Tyrol case studies of Monitor 2 concept for Hazard Scenarios Mapping

Rationale

The existing South Tyrol’s framework for hazard mapping oriented to land-use planning, needs to be integrated and tailored for emergency management.

Hence, the Monitor 2 concept for Hazard Scenarios Mapping, thoroughly described in WP3 brochure was adapted to 2 specific case studies in South Tyrol: the Ganderberg and the Trafoi landslide complexes.

Both test sites are characterized by complex slope dynamics related to the presence of deep seated gravitational deformations in association with more superficial rock and earth sliding phenomena. Moreover, part of these slope instability phenomena can evolve in the future by associating large scale rock slide failures that can evolve into destructive rock avalanches.

The complex and composite nature of mass movements affecting the study areas results in multiple possible hazard and risk scenarios. This type of hazard and risk situation is hardly summarized by static hazard and risk map, such for instance those adopted for land use planning in South Tyrol. This is because the same spatial location can be affected by different phenomena with different probability of occurrence, an information that can be partially hidden in a static hazard map.

In order to integrate hazard maps with a more explicit indication of multiple evolution, simplified scenario models were developed for the Ganderberg and Trafoi areas by merging a “processes routing” approach that is generally used for analysing watershed processes and the “hot spots” concept of Monitor 2 brochure. Hot spots are intended indicators for information linking hazard process and the contingency fields. They should provide key information on process, by assess information points (a general standardized description of the event), critical points (an indication of where the process is triggered or is modified by complex evolution), observation points (that can be either points where monitoring is required or where it is possible to observe directly the course of events) and intervention points (that is where countermeasures should be taken).

The following figure shows a schematic version of scenario maps produced for Trafoi case study with the purpose of increasing awareness on risk processes in the frame of hazard mapping.
It actually makes reference to temporal probability classes that are in use in South Tyrol for hazard mapping (Provincia Autonoma di Bolzano 2005), and it is meant to summarize the processes and the consequences that are related to the ongoing and the potential evolution of the Trafoi landslide.

Schematization of hazard and risk scenarios in TRAFOI produced to increase awareness on hazard processes and related risks.
Hazard Scenario Maps and Spatial Databases

Hazard Scenario Maps and GIS spatial databases were actually produced for the Ganderberg and the Trafoi landslide complexes.

In both sites, 4 Hazard Scenarios according to the different return periods (1-30 yrs / 30-100 yrs / 100-300 yrs / > 300 yrs) have been compiled for each type of mass movement occurring along the Ganderberg and Trafoi slope.

Rock avalanche run out modelling allowed determining run out deposits and dimensions in case of the failure of the rock slides in given return period scenarios.

Hazard levels for each return period (i.e probability level) have been assessed by adopting the South Tyrol legislative framework by the combination of Intensity and Return Period attributes.

Moreover, a Maximum Hazard map has been derived by representing the maximum hazard level obtained in a specific area by stacking of all scenarios.

The table of attributes for each scenarios included the following additional fields:

<table>
<thead>
<tr>
<th>FIELD</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC1 DESCR</td>
<td>description of the ongoing scenario, e.g. “rockslide evolving in rock avalanche”</td>
</tr>
<tr>
<td>SC1 ONSET</td>
<td>“Sudden” or “Stepwise”</td>
</tr>
<tr>
<td>SC1 CT</td>
<td>Causes and triggers</td>
</tr>
<tr>
<td>SC1 RP</td>
<td>relevant parameters</td>
</tr>
<tr>
<td>SC1 FMO</td>
<td>forecasting monitoring option</td>
</tr>
<tr>
<td>SC1 ETI</td>
<td>expected time of impact</td>
</tr>
<tr>
<td>SC1 PROBAB</td>
<td>probability / return period</td>
</tr>
<tr>
<td>SC1 VEL</td>
<td>velocity (where applicable measured data)</td>
</tr>
<tr>
<td>SC1 VOL</td>
<td>Volume</td>
</tr>
<tr>
<td>SC1 THICK</td>
<td>Thickness</td>
</tr>
<tr>
<td>SC1 VEL_CL</td>
<td>velocity class: classes from hazard mapping</td>
</tr>
<tr>
<td>SC1 SG_CL</td>
<td>geometry class: classes from hazard mapping</td>
</tr>
<tr>
<td>SC1 INT_CL</td>
<td>intensity class: I = SGxVEL; classes from hazard mapping</td>
</tr>
<tr>
<td>SC1 H_CL</td>
<td>hazard class: H = IxTR, classes from hazard mapping</td>
</tr>
<tr>
<td>SCA TR_CL</td>
<td>Return Period; 1-30 yrs, 30-100 yrs, 100-300 yrs, &gt;300 yrs, classes from hazard mapping</td>
</tr>
</tbody>
</table>

The following figures are meant to explain, with reference to Ganderberg, the scenario mapping procedure, while Hazard Scenario Maps for Ganderberg and the Trafoi landslides are presented in ANNEX 1 and ANNEX 2.
Ganderberg: Types of mass movements

TR1 – 1-30 Yrs
For all mass movements hazard class H3
TR 30-100 Yrs
Reactivation of rotational landslide (H4)

TR 100-300 yrs
Reactivation of rotational landslide, block slide and collapse of rock slide
TR >300 yrs. Collapse of the rock slide and rock avalanche run out (green deposits)

a) national road will be interrupted
b) provincial road will be interrupted
c) Passer stream will be dammed
d) formation of a temporary lake (light blue)
Hazard Scenario Maps for Ganderberg (see ANNEX 1 for full scale)

Hazard Scenario Maps for Trafoi (see ANNEX 2 for full scale)