PROTECT – A Swiss Approach to the Assessment of the Effectiveness of Mitigation Measures

Stefan Margreth [1,*] Hans Romang [2]
[1] WSL-Institute for snow and Avalanche Research SLF, Davos, Switzerland
[2] Federal Office of Meteorology and Climatology MeteoSwiss, Zurich, Switzerland

ABSTRACT: PROTECT describes a general procedure to assess the effectiveness of mitigation measures and includes detailed instructions for avalanches, rockfall, landslides, debris flows and floods. The results of the project have recently been published and will be broadly evaluated via practical application in 2009. The first part of PROTECT involved the definition of basic principles necessary for consideration of mitigation measures related to hazard maps. These principles make sure that a minimal level of quality, safety and sustainability is met and that mitigation measures are tested not only with respect to regular design events but also to extreme events. Once the basic standards are met, the effectiveness of the mitigation measures is analyzed in more detail. This approach is subdivided into three main steps. In the first step it is investigated whether the effect of the countermeasures may be relevant in any way to the hazard assessment or not. In the second step the mitigation measures are assessed technically by determining their reliability. Reliability is defined in terms of structural safety, serviceability and durability of the mitigation measures. The third step involves the quantification of the effectiveness, taking into account the mitigation measures with respect to their reliability. Finally, the adaptation of hazard zones can be elaborated based on this information.

KEYWORDS: mitigation measure, hazard map, avalanche defence, risk management

1 INTRODUCTION

In Switzerland hazard maps are of great importance. They are decisive for land use planning and are important for the organization of temporary safety measures. Hazard maps are further used to document the demand for protection measures and to illustrate their effect. For example since 1951 about CHF 1.5 billion have been spent for structural avalanche mitigation measures. Since the space untouched by natural hazards is small in the Alps, structural countermeasures are essential in order to allow extension of settlement areas. In the last years pressure on the authorities was increased to reclassify hazard zones after mitigation measures were built. Therefore the question of how to consider their effect became important for practical implementation. In Switzerland a unified strategy covering all natural hazards was missing. In 2002 the “Specialists natural hazards – Switzerland (FAN)” group organized a workshop where experts from Switzerland and neighbouring countries had the chance to discuss and develop this topic. One outcome of the workshop was the launching of the project PROTECT to develop a general procedure applicable to all natural hazards. PROTECT started in 2006 and in 2009 the results in form of a general procedure (Fig. 1) as well as practical guidelines for selected countermeasures against snow avalanches, rockfall, landslides, debris flows and floods were introduced to the natural hazards practitioners in Switzerland.

2 BASIC PRINCIPLES

Countermeasures that are to be considered in hazard maps should fit some basic principles (Tab. 1). These principles guarantee that a minimal level of quality, safety and sustainability is fulfilled. The main focus of PROTECT is the adaptation of hazard maps for settlements. Due to the high safety requirements the basic principles are rather strict. Therefore for example temporary measures such as artificial release of avalanches cannot be considered although they can be very effective. According to the principles the effect of the countermeasure has to be analysed for the 30, 100 and 300 years scenario as well as for an extreme scenario that exceeds the design scenario of the measure. With regard to avalanches the following countermeasures are suited for a consideration in hazard maps:

- Permanent snow supporting structures: steel bridges and snow nets.
- Avalanche dams: catching dams, deflecting berms
- Protection forest

Corresponding author address:
Stefan Margreth, WSL-Institute for snow and Avalanche Research SLF, Flueelastrasse 11, CH 7260 Davos, Switzerland;
tel: +41 81 417 0254; fax: +41 81 417 0110;
email: margreth(at)slf.ch

Table 1: Basic principles for the consideration of countermeasures in hazard maps

No.	Principle	Rule
1.	Quantification of hazard reduction	The effectiveness of countermeasures is estimated by the effect on the risk parameters, e.g. the intensity and probability of hazardous processes. This effect therfore has to be quantifiable.
2.	Effect exceeds uncertainties	The effect of the countermeasures has to be higher than the uncertainties relied to the hazard and risk management are.
3.	Assessment of scenarios	The effect of the countermeasures has to be analysed for different scenarios such as the relevant scenarios for hazard maps (e.g. in Switzerland with a theoretic return period of 30, 100 and 300 years) as well as for extreme scenarios representing a remarkable overload of the system.
4.	Delineation of the system	The countermeasures have to be assessed focusing on the single element / structure as well as with respect to the whole system (e.g. a catchment area with several interacting elements).
5.	Permanent availability	Countermeasures considered in hazard maps have to be present at the time of the assessment and have to be permanently available over the next 50 years, at least with a common maintenance.
6.	Inspection and maintenance	Inspection, maintenance and, if necessary, renovation and renewal work have to be guaranteed for every countermeasure.
7.	Temporary countermeasures	Temporary countermeasures such as artificial release of snow avalanches or mobile flood protection generally are not considered in hazard maps.
8.	New countermeasures	When planning new countermeasures their effect can be assessed in the same way as for existing countermeasures. However, their consideration in land-use planning implies that they must first be constructed.
9.	Time effects	Countermeasures as well as processes are changing over time. Thus, the consideration of countermeasures implies on the one hand an adequate maintenance of the countermeasures and of the whole system and on the other hand a periodic verification of the risk situation.

3 GENERAL APPROACH

When the basic principles are fulfilled, the effectiveness of the countermeasures has to be analyzed in more detail. The need for such a study may arise either with regard to already existing measures that have to be assessed e.g. for possible effects on hazard zones or when new countermeasures are planned and their effectiveness has to be assessed in advance. Although there may be some differences (e.g. concerning the available data or the design criteria of the countermeasures), the same general approach can be used for both tasks (Fig. 1). This approach is subdivided in three main steps called general assessment, assessment of countermeasures and assessment of effectiveness. These three steps are followed by the pre-discussion of the implementation e.g. in zoning maps.

STEP 1: GENERAL ASSESSMENT

The main goal of the first step is to decide whether the effect of the countermeasures may be relevant for the hazard assessment or not. To answer this question, basic information on the processes as well as on the countermeasures is needed. To assess an area controlled with snow supporting structures the following information are mandatory:

- Extent of potential avalanche starting zone
- Extreme snow height
- Extent of area controlled with structures
- Structure type (height, design values)
- Arrangement of structures
- Actual state and maintenance plan

The situation is evaluated based on the information on processes and measures generally: are the measures arranged with respect to the whole system (e.g. avalanche dam below multi-release zones respecting the different avalanche paths) and does a hazard reduction seem probable (e.g. is the type of measure adapted to the hazard)? If yes, a relevant reduction effect is assumed. If not, the countermeasures will still be analysed in detail when negative effects (e.g. higher intensity of hazard processes) might occur. The practical instructions gives typical rules for each measure when a relevant hazard reduction can be expected, e.g.:

- More than 20% of the potential starting zone should be protected with supporting structures.
- The structure height should be bigger than the extreme snowheight minus 2 m.

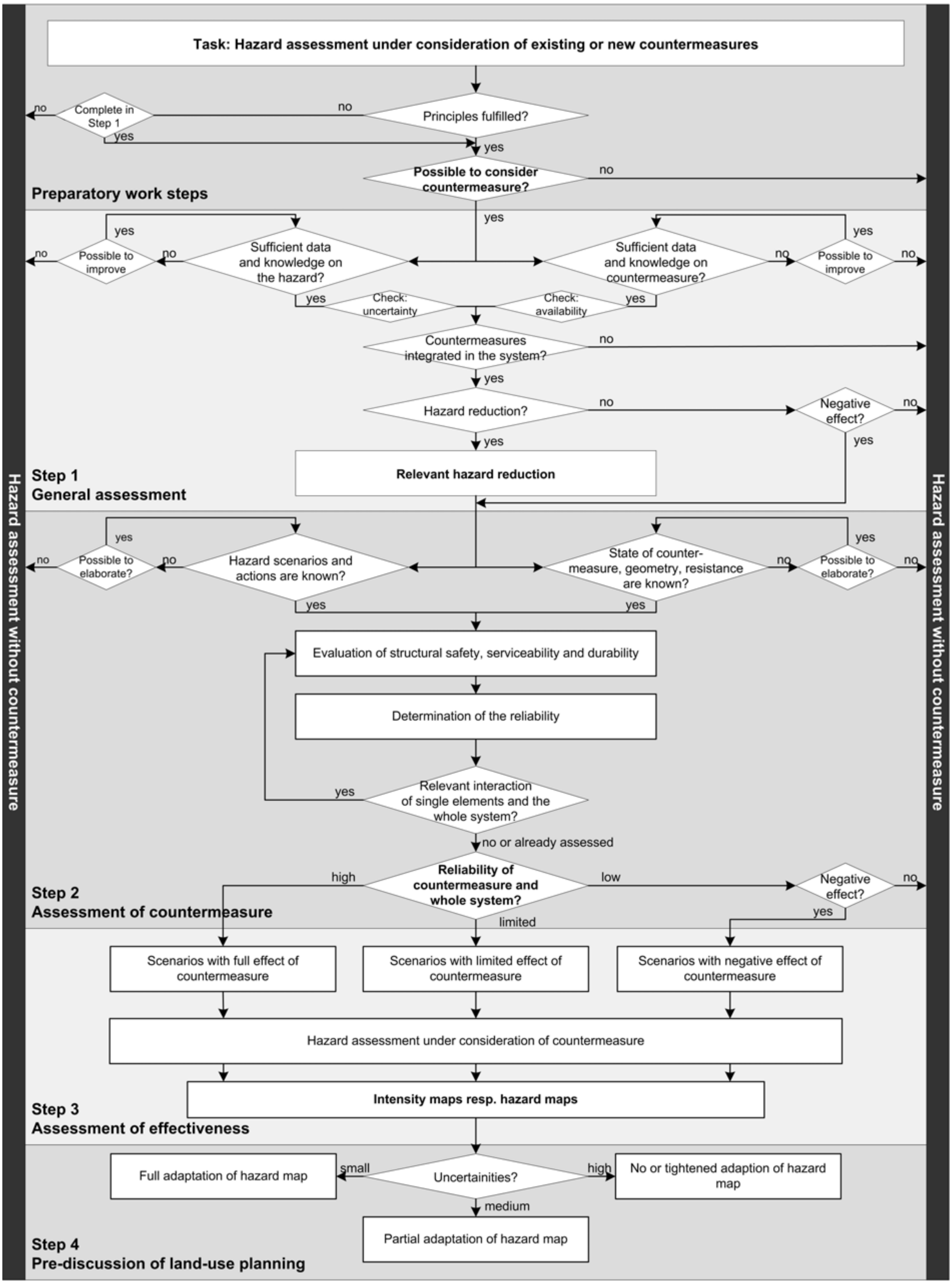

Fig. 1 Procedure for the assessment of the effect of countermeasures on hazard processes according PROTECT.

STEP 2: ASSESSMENT OF COUNTER-MEASURES

The goal of the second step is to evaluate the structure technically by determining their reliability. This step goes into much more into detail than the first one. Thus, the information on processes as well as on countermeasures has to be enhanced. The hazard should be described by different hazard scenarios and by their actions on the structure (Fig. 2).

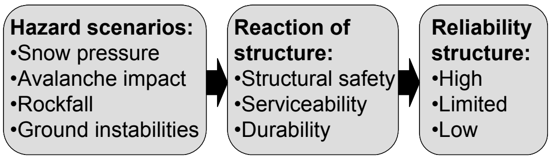

Fig. 2: Evaluation of the reliability of snow supporting structures.

Existing structures should be assessed in the field, with a particular focus on the documentation and the evaluation of the current state of the construction. Then the reliability is defined by analysing structural safety, serviceability and durability of the countermeasures for each hazard scenario. These concepts from engineering practice (Eurocode 2002) are well suited to characterise countermeasures against natural hazards, too.

- Generally, structural safety guarantees the stability of the structure. The structural safety always has to be fulfilled or the structure is not reliable (Fig. 3). If homologated snow supporting structures which fulfil the technical guidelines (Margreth 2007) have to be assessed for example, the structural safety can be regarded as fulfilled if there are no other hazards, such as rockfall.
- The serviceability ensures the functionality of the measure. For example the serviceability of a catching dam can be critical if the effective height is reduced because the storage volume is prefilled with mudflow deposits.
- Finally, durability provides for a long lasting quality of the structure. The durability is weighted less than the other two factors. This is mainly due to the fact that deficits are not immediately critical and can be solved in the near future. However, this assumption calls for a well-organised and regular maintenance service. In situations where different countermeasures interact (e.g. supporting structures above protection forest) not only the single measure but also the whole system of countermeasures has to be assessed.
- Finally, the reliability is defined as being high, limited or low. If the reliability is low and no additional negative effects are expected, the procedure will finish here.

Fig. 3: Snow supporting structures destroyed by an avalanche, which was released high above the controlled area. The structural safety is not fulfilled for impacts of large avalanches. The reliability is low.

STEP 3: ASSESSMENT OF EFFECTIVE-NESS

The third step, one of the key-points in the procedure of PROTECT, includes the hazard assessment taking into consideration the countermeasures with respect to their reliability. The effect of the measure is assessed for different scenarios in relation to their intensity and probability. The most important scenarios for supporting structures are for example (Fig. 4):

- Case 1: "Avalanche release outside of the controlled area". The areas, which are not controlled by structures, are decisive.
- Case 2: "Avalanche release in the controlled area" is decisive if the structure height is fine and if most of the starting zone is controlled by structures.
- Case 3: "Avalanche release over the filled up structures". This risk depends on the chosen structure height and the expected extreme snow height.

On the basis of the 3 scenarios the reduced runout distances of the avalanches can be calculated with avalanche dynamics models. Due to the effect of the structures the avalanche volume will be smaller and consequently the runout distance of the avalanche will be shorter. In scenarios with a limited effect the countermeasures will be only partly effective. For example a partial backfill of an avalanche dam reduces its serviceability and thus the effective dam height is reduced.

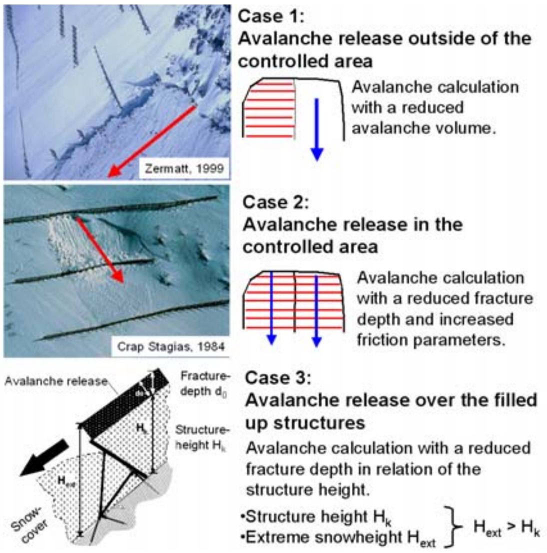

Fig. 4: The effectiveness of snow supporting structures is evaluated with three cases.

The results of step 3 are intensity respectively hazard maps for each scenario (depending on return period of the process and reliability of the countermeasures).

STEP 4: PRE-DISCUSSION OF LAND-USE PLANNING

Finally recommendations are prepared for the implementation of the adapted hazard map in land use planning. The uncertainties in the whole assessment should be evaluated particularly carefully. If the uncertainties are high (e.g. because of a very complex hazard situation or if the process is very sensitive to climate change) land-use planning should not be intensified. Because the procedure of PROTECT foresees to assess also extreme scenarios zones which represent areas with a residual risk (yellow-white striped areas) will become more important. It should always be kept in mind that natural hazards are only one relevant point for land-use planning and that the consultants responsible for are neither hazard nor risk specialists. Hence the information provided by the hazard assessment should be simple and clear.

4 CONCLUDING REMARKS AND OUTLOOK

The methodology of PROTECT allows to evaluate the effect of countermeasures in hazard maps on a common basis with a well defined terminology. The practical applicability is guaranteed by the compiled detailed instructions. The future elaboration or adaptation of hazard maps will show pros and cons of the methodology.

One of the crucial points is the assessment of effectiveness. Countermeasures can only be compared and optimally selected when their effectiveness is known. For structural measures the knowledge is continuously improving. In contrast, the situation with regard to non-structural measures is worse. Only little information is available (e.g. empirical values for the artificial release of snow avalanches) although their effectiveness in general seems to be unquestioned. The assessment of old countermeasures is difficult. If e.g. the structural safety of a measure is unknown however decisive for the effectiveness it should be evaluated in detail.

A challenge will be the implementation of adapted hazard maps in land use planning. Especially the question how to deal with residual risks resulting from extreme scenarios is not finally answered.

The main focus of PROTECT are hazard maps and land use planning. Generally the methodology could be expanded to other scopes such as traffic safety or intervention plans.

5 REFERENCES

Eurocode 2002: EN 1990 – Eurocode - Basis of Structural Design.

Margreth, S., 2007. Defence structures in avalanche starting zones. Technical guideline as an aid to enforcement. FOEN Federal Office fort he Environment, Bern, WSL Swiss Federal Institute for Snow and Avalanche Research SLF, Davos.

Margreth, S.; Romang, H., 2008: Berücksichtigung der Wirkung von Schutzmassnahmen in Gefahrenkarten: Vorgehen in der Schweiz. In: Mikos, M.; Huebl, J.; Koboltschnig, G. (eds) Schutz des Lebensraumes vor Hochwasser, Muren, Massenbewegungen und Lawinen. Interpraevent 26-30 May 2008, Dornbirn, Vorarlberg, Austria. Conference Proceedings, Vol. 2: 539-550.

Romang H. (Ed.) 2008: Wirkung von Schutzmassnahmen. Nationale Plattform für Naturgefahren PLANAT, Bern. 289 S.

Romang, H. (Ed.), 2008: Best Practice of Integral Risk Management of Snow Avalanches, Rock Avalanches and Debris Flows in Europe. In: D5.4 FP6 IRASMOS, 138 S.