An overview of natural hazard zoning with special reference to avalanches

25 years of experience and results in Austria

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ABSTRACT. Natural hazards are increasingly a limiting factor in mountainous countries in connection with the growing population and economical development. People become more and more estranged to environmental conditions and are unable to recognize and control natural hazards. On the other hand the demand for safety of life and property is increasing in society and is requested to be transfered from the individuals to the authorities. In this state elaboration and presentation of natural hazards like avalanches, floods, debris flows, rockfalls and landslides in the mountainous areas of european countries like Austria was started in the last decades. The legal base and implementation of hazard zoning in Austria with special reference to avalanches, the use of runout models, the question of return periods, safety or risk consequences and acceptance by the people, political and economical consequences and prospective goals of avalanche hazard zoning in the future are briefly presented in the paper.

INTRODUCTION

Austria covers an area of 84.000 km^2 with 8 Million inhabitants. The federal territory is divided in 9 provinces (Bundesländer) with a total number of 2 355 communities. 70 % of the country are located within the Alps, reaching up to 3.800 m above sea level. The geological formations are varying between sediments, limestone in the peripher areas and schist, granit, gneis in the central part, often covered by deposits from the ice ages.

Big floods in the last century were the reason to establish a public service for torrent and avalanche control in 1884 to protect settlements and installations against this kind of natural hazards. The main work period in this field however was started after the second world war especially as a consequence of two big avalanche disasters in 1951 and 1954 when 270 people were killed within a few days.

Increasing and uncontrolled use of land as a consequence of the economical development - especially by tourism in the valleys of Western Austria - has led to further need of protective measures in the following decades.

Therefore land use planning was necessary to prevent further extension of settlements into areas endangered by natural hazards as floods, avalanches, rockfall and landslides.

For this reason hazard zoning, which is in the responsibility of the Federal Government, was started at the beginning of the seventies and regulated by Federal Laws. Hazard maps, confirmed by different administrative decisions are now considered as one of the basic data for further land use planning within provincial laws. These federal and provincial regulations which have to be observed by the communities led to passive disaster prevention in Austria in an effective way. They are also a base for temporary safety measures and the implementation of permanent protective works against natural hazards.

LEGAL REGULATIONS

Hazard zoning was started in Austria around 1970 by the Federal Foresttechnical Service for Torrent and Avalanche Control and after some years of practical experience regulated officially in the new Forest Law 1975. The details regarding Hazard Zone Plans were settled in a decree by the Federal Minister of Agriculture and Forestry in 1976

Beyond these federal regulations executive rules concerning hazard zones are hold in provincial laws for landuse planning. In these laws it is stated generally that areas endangered by natural hazards as floods, avalanches, debris flows, rockfalls and landslides are not allowed to be defined as development areas. The

hazard zone maps have to be observed by local authorities (municipalities and rural communities) in the relevant decisions.

In addition the Ministry of Agriculture and Forestry has decided that in case of disregarding of the Hazard Zone Maps public funds for flood and avalanche control works are not available resp. money already used has to be reimbursed.

THE HAZARD ZONE PLAN

According to the decree of 1976 the Hazard Zone Plans for avalanches and torrents have to be prepared by the Federal Foresttechnical Service for Torrent and Avalanche Control and are free of charge for the communities.

A Hazard Zone Plan is worked out normally for an area of one community and consists of a cartographic and a textual part.

The cartographic part

includes a

a) Hazard Map (scale 1:10.000 - 1: 50.000) with all relevant catchments and starting zones and an overview of the whole community area.

b) Hazard Zone Map (scale 1:1000 - 1:5000 at least), showing the results of investigated and valuated data of each hazard in form of „Hazard Zones" on the base of a return period of approximately 150 years for torrential floods and avalanches and 100 years for floods of rivers. The map has to include the landregister.

The textual part

consists of a description of the

a) basic data
b) arguments of valuation and
c) arguments for the hazard zoning.

The Red Hazard Zone

includes areas which are endangered by torrential floods or avalanches to such an extent that their permanent use for settlements, infrastructures and traffic facilities is not possible. The Red Zones include also less, but frequently endangered areas.

The Yellow Hazard Zone

covers areas with reduced danger between the Red Zone and the boundaries, where the damaging effects of the design event with a return period of approx. 150 or 100 years come to an end (criteria see below). Buildings and infrastructures are allowed to be built in the Yellow Zone but they must be protected by reinforcements and special architectural designing. People within new buildings should be safe, but outside they are endangered nevertheless. In areas which are already settled, an expert opinion has to be observed by public authorities for the permission of buildings and infrastructural installations. Limiting terms are: reinforced walls and windows, no doors and windows towards the avalanche or flood site, anchoring of the roof construction and so on.

In non settled areas natural dangers normally have to be eliminated by technical defence works before their dedication as developing areas, but public funds are not available for this purpose.

As a special regulation in Austria it has been decided by the Ministry for Traffic in the so called "Avalanche Decree for Cable Railways" that in ski areas at least one appropriate skirun per skilift must be "permanent safe from avalanche danger". That means the lift and one adequate run must be situated outside of avalanche hazard zones resp. protected by permanent defence measures. This strict regulation is beyond international practice and rules.

CRITERIAS FOR HAZARD ZONES

The criteria for the hazard zones of avalanches, torrents and rivers are regulated in Guidelines of the Ministry of Agriculture and Forestry as shown in table 1 and table 2 and figure 1.

Criteria	Returnperiod	
	150 years	1 - 10 years
Avalanche pressure: Red Zone Yellow Zone	 25 kN/m^2 1 - 25 kN/m^2	 3 kN/m^2 1 - 2 kN/m^2

Table 1. Criterias for Avalanche Hazard Zones

Criteria	hazard zone	150 year frequency	10 year frequency
stagnant water	red yellow	water depth > 1,5 m water depth < 1,5 m	boarder line > 50 cm boarder line < 50 cm
flowing water	 red yellow	height of energy line > 1,5 m -"- < 1,5 m	height of energy line > 0,25 m -"- < 0,25 m
erosion	red yellow	depth > 1,5 m depth < 1,5 m	possible runoff with out erosion
deposition of bedload or sediments	red yellow	height > 0,7 m height < 0,7 m	deposition possible no deposition

Table 2. Criteria for Torrential Hazard Zones in catchments up to approx. 150 km²

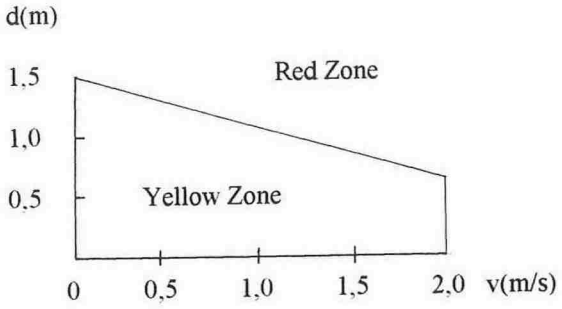


Fig. 1. Criteria for River Hazard Zones (for catchments bigger than approx. 150 km²): Combination of water depth (d) and flowing velocity (v)

Further criteria for River Hazard Zones:

Relation between flowing velocity (v) and tractive tension t (N/m^2): Exceeding of the limiting values for the existing soil and terrain conditions.

Water runoff: Areas with potential and essential effects on runoff of floods.

Water retention: Areas for water retention of a large scale influence.

FURTHER DELIMITATIONS IN THE HAZARD MAPS

Brown Areas

These areas are not endangered by floods or avalanches but obviously by rockfall or landslides. In this case experts for geology, soilmechanics, hydrogeology e.g. must be consulted by the competent authorities.

Blue Areas

These areas are needed and have to be reserved for protective measures in the future and also forests needing a special management to obtain their protective function.

Violet Areas

These areas have special morphological protective effects, for example a natural earth dam among a settlement, therefore such an area has to be kept free from every kind of development or alteration.

ADMINISTRATIVE PROCEDURE

The draft of the Hazard Zone Map has to be submitted to the mayor of the concerning community and to be published there for public inspection during four weeks. Everybody affected by hazard zones is entitled to express his written opinion on the Hazard Zone Plan.

After this public announcement the draft of the hazard map has to be checked by a commission of four persons: two competent experts and two representatives of the political level as follows:

a) Ministry of Agriculture and Forestry,
b) Federal Service for Torrent and Avalanche Control resp. Hydraulic Engineering Administration
c) Provincial governement and
d) Concerning community (municipality).

This commission has also to consider the comments delivered by the people during the public announcement.

The commission makes its decision by simple majority of votes, in case of parity the vote of the representative of the ministry is deciding. Finally the reviewed Hazard Zone Plan has to be approved

Fig. 2. Overview of the Wolfsgruben Avalanche as a typical alpine type of avalanche, Community of St.Anton, Austria: The right part of the starting area is already covered with supporting structures

officially by the Minister of Agriculture and Forestry and handed over to the relevant authorities (municipality and district administration). The original of the approved Hazard Zone Plan remains at the competent technical office for public inspection.

If basic elements of the hazard zones have changed, the plan has to be adapted to the new conditions.

Finally the Hazard Zone Map can be considered as a general planned expert opinion covering a defined area with a maximal administrative and political confirmation but needs further interpretation by competent experts in case of detailed application.

APPLIED METHODS

With reference to the main goal of the conference in Voss the criteria of hazard zoning for torrents and rivers will not be described in detail in this paper and therefore are limited to avalanches.

First of all it is important to collect all data and informations available of the concerned avalanche area, which have to be taken into account for the assessment and delimitation of hazards. Such parameters are climatic and snow conditions, terrain conditions in the starting zone, avalanche track and run out zone , description and valuation of historical disasters and hazard indicators or „silent witnesses" such as pattern of vegetation, former damages etc.. Additionally the results of theoretical calculations and models have to be taken into account and compared with the above mentioned observations in well known and defined avalanche pathes.

The applied methods result in an optimal delimitation of hazard zones in avalanches with well known parameters and enable some kind of calibration with "nearest neighbours". Of course, this proceeding is easier in areas with long settlement history and with vegetation as trees and shrubs where avalanche events are visible for a long time. In avalanche areas with less known data the use of models for calculating the runout distance becomes more important than in cases as described above.

Used runout models

In Austria the „Swiss Model" (Salm, Burkard, Gubler) for calculating the runout distance of avalanches is mainly used, but recently also the "PCM-Model" (Perla, Cheng, Mc Clung) and the "Norwegian Topographic Model" - adapted to Austrian conditions - are taken into consideration in avalanche hazard zoning. Recently the simulation of powder snow avalanches - developed in cooperation between the Austrian Federal Service for Avalanche Control and the Avalanche Research Institute in Innsbruck - is a valuable support in the assessment of the runout distances of avalanches.

CRITICAL REMARKS AND OPEN QUESTIONS

Can we rely on the used models?.

This question can not be replied in one sentence. There are avalanches as above mentioned which are most suitable for calculation because of their clear determination of the starting area, avalanche mass and track conditions. In such cases the models are a crucial completion and support for the accuracy of the determination of the Hazard Zone. They also enable to compare results with neighbouring avalanches under similar conditions. In this way the used models can be regarded as transfer methods to support the expert opinion in a quantitative way. On the one hand the models deliver a frame of possible events (statistical models) and on the other hand a deeper understandig and knowledge about avalanche dynamics.

Avalanche No.	Total horizontal length (m)				
	Observed	Calculated			
		Topographic model	PCM model	NIS model	VSG model
19	1767	1810	1813	1706	1716
21	1740	1889	1982	1827	1895
28	1519	1643	1780	1625	1816
30	3256	3097	2734	2734	3120
33	2138	2293	2345	2278	2380
Mean	2084	2146	2131	2034	2185
Mean diff. to observed	0	62	47	-50	101

Table 3 Runout distances for 5 austrian avalanches calculated by different models

To apply the Norwegian Topographic Model to alpine conditions a statistical investigation of 80 avalanches in Austria has been made within a joint project in 1994/95 between the Norwegian Geotechnical Institut and the Austrian Federal Avalanche Control Service. The result was a modified equation for alpine conditions. All these avalanches were tested with the PCM and NIS model (Norem,Irgens,Schieldrop) and five of them also with the Swiss model (VSG model) as shown in table 3. The result shows that the mean difference to the observed runout distances is low but the application to several models is a better basis for the evaluation of runout distances than only the use of one.The authors of the concerning report were convinced....."that the use of a topographical - statistical model in combination with a dynamic model probably will be the best way of handling the runout calculation problem of snow avalanches".

Summarizing it can be stated from the Austrian point of view, that the delimitation of avalanche hazard zones should be the result of the experience of experts, historical records, statements of local inhabitants, statistical investigations and the use of confined runout calculations on the base of the mentioned models. This comprehensive method takes into account that avalanches as natural phenomenas can change their character and spreading in a way that cannot be forecasted and calculated only by formulas and theoretical approaches.

Can we calculate return periods?

It is not possible to calculate return periods in such long recurrence intervals because lack of adequate observation periods. In alpine countries like Austria the estimation of return periods might be easier than in other countries because of the long settlement history with corresponding chronicles about avalanche disasters like 1689, 1793, 1916, 1951, 1954 und 1984. Therefore the 150 year return period as required in the Austrian regulations is rather a theoretical approach. In practice one delimitates the biggest expected avalanche based on experience and available data.

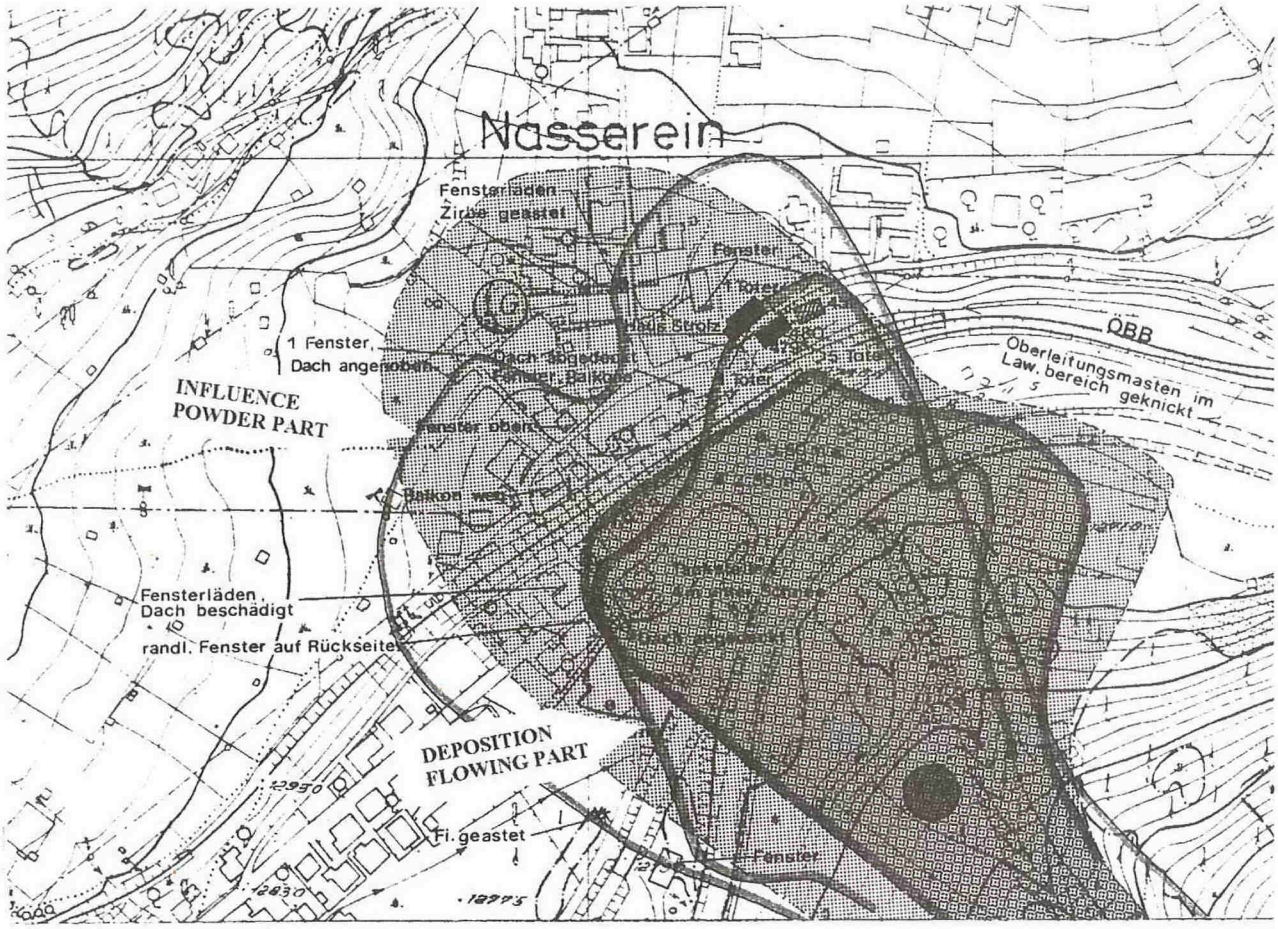
Gives the accepted return periods the population sufficient safety?

Considering the above mentioned aspects the population feels sufficient safety because in reality it can be assumed that the biggest expected avalanche is considered to be delimitated. Also the relying on the decisions of a public institution and the possibility of everyones participation in the decision making process is important for the acceptance. However, a special question is the safety of settled areas in the Yellow Hazard Zones: Permanent safety inside of new houses is normally given by reinforcements and architectural designing, but does not exist outside and between the houses. Therefore special temporary safety measures (evacuations) have to take place in these areas in case of relevant avalanche danger.

Enough participation of the affected people?

As already mentioned, the participation of the affected population is given by two kinds of activities:

Local people has to be asked about avalanche events in the past during the field work and everybody affected by hazard zones is entitled to give his written opinion to the draft of the Hazard Zone Map during the public inspection. Nevertheless the decision of the



Legend:

LR - Red Avalanche Hazard Zone

LG - Yellow Avalanche Hazard Zone

damaged houses

Fig. 3. Avalanche Hazard Zones 1975 of the Wolfsgruben Avalanche in comparison with the disastrous avalanche of the 13.3.1988 with seven victims. The estimated frequency of this avalanche is considered with more than hundred years (Scale 1:5 000)
Community of St. Anton, Austria

checking commission is definitely and no appeal is possible against it. From the author's point of view this should be changed and improved. According to principles of basic rights an appeal with well founded arguments should be possible. This would result in a better acceptance and confidence of land owners specially in developement sites.

Hazard zoning free of charge ?

The hazard zoning in Austria normally is implemented by public institutions and according to the existing Federal Law for the promotion of protective measures against natural hazards free of charge for the communities. This regulation guarantees a high level of independency and objectivity in the performance of hazard maps and allows their implementation according to objective priorities. It represents the political convinction that the protection against natural hazards is a public duty in a mountainous country like Austria and that corresponding restrictions for life and property have to be clearly stated and executed by public authorities. For this reason the author agrees to this regulations, although principal aspects may plead against it.

POLITICAL AND ECONOMICAL CONSEQUENCES OF THE ZONING

Land use planing

The limited living space for permanent use in the mountainous areas of Austria (e.g. in the Province of the Tyrol only 13 % of the whole territory with one third of the austrian tourism) has led to the political decision that the border between yellow and red hazard zone of avalanches is fixed with the 25 kPa pressure line.

The main political consequences for land use planing are already stated in chapter „Legal Regulations". In this way after more than twenty years of hazard zoning the Hazard Zone Maps (or at least drafts of them) are considered in the land use plans of the most of the endangered communities in Austria and the knowledge about natural hazards is widespread in the population. The restrictions concerning land use in the Red and Yellow Hazard Zones are normally accepted by the people, especially as everybody can express his opinion within the administrative procedure of hazard zoning but improvement should be made as mentioned before. Compensations for areas dedicated as hazard zones cannot be claimed by the people resp. never have been paid in Austria. On the other hand, the people became aware of the existing natural hazards and at the same time the demands for protective measures have increased as never before.

Hazard Zoning and protective measures

The implementation of permanent protective measures is one of the consequences of hazard zoning. Therefore governmental institutions for natural hazard control are claimed very often by the communities for these works and public funds of the federal and provincial governments are requested on a large scale. In Austria approx. 270 million ATS for avalanche protective works and more than one billoin ATS for erosion and torrent control measures are spent at present per year.

These technical works have to be adapted to the same parameters as used in the zoning. In Austria public money is only available for projects to protect existing settlements and installations and not to enable new developements. The reducing of hazard zones as a consequence of protective works therefore is limited to these areas and depends on type, function, maintainance and lifespan of these constructions. Especially supporting structures in the starting zone of avalanches have to be considered carefully and the reduction of hazard zones is very restrictive in this case. Generally it can be stated that the reduction of avalanche hazard zones after the implementation of protective measures seems more difficult than the first assessment of them because of the economical, social and political consequences.

Temporary safety measures

The Hazard Zone Maps are also a very important basis for temporary safety measures, especially for the evacuation of settlements and closing of roads and railways in case of avalanche danger in connection with a public warning system. For this decision the local authorities are responsible. They are supported by the so called „Avalanche Commissions".

FUTURE GOALS

According to the described methods, legal conditions and administrative regulations hazard zoning seems to have reached a relative high level of performance and acceptance by society in Austria. Nevertheless this situation is only representing knowledge and experience at the moment and the subject needs further treatment in a dynamic process in the furture such as:

- Continuous adaption resp. verification of the hazard maps in case of the occurence of extraordinary natural disasters, if basic elements in the nature have changed and after the implementation of defence works.
- Elaboration of "Evacuation Plans" by the coummunities on the base of the Avalanche Hazard Maps to ensure, that people are not endangered outside the houses in case of high avalanche danger.
- Long term management of mounainous forests to ensure their protective effects and to prevent the development of new hazard sources.
- Research on scale 1:1 under defined snow and weather conditions, using artificial released avalanches (like in Switzerland and Norway).
- Simulation of avalanches as already started in Austria with the powder snow model with extension to flowing avalanches.
- Improvement of the international cooperation and exchange of knowledge and experience in consideration of global climatic tendencies
- Intensification of research on active temporary defence measures and their use for the protection of timewise needed facilities and installations.
- Adaption of national legislative and administrative regulations (e.g. "Avalanche Decree" for cable railways) to an international standard at least within the European Union.

REFERENCES

Lied, K., Weiler Ch., Bakkehoi St. and Hopf J. 1995. Calculation methods for avalanche run-out distance for the Austrian Alps *Avalanche Symposium Chamonix 1995, Cemagref (63-68)*

Norem, H., Irgens, F. and Schieldrop 1987. A continuum model for calculating snow avalanche velocities. *Proceedings of Avalanche Formation, Movement and Effects Davos 1986, IAHS Publ. 162*

Perla, R., Cheng, T. and McClung D.M. 1980. A two- parameter model of snow avalanche motion. *Journal of Glaciologie, 26.*

Salm, B., Burkhard,A. and Gubler, H.U. 1990. Berechnung von Fließlawinen, eine Anleitung für Praktiker mit Beispielen, *Mitteilung des EISLF, 47, Juli 1990*

Austrian Federal Law regulating forestry - dated 3.July 1975;

Decree of the Austrian Federal Ministry of Agriculture and Forestry regarding hazard zone plans - dated 3. July 1976

Austrian Guidlines for the delimitation of hazard zones, 1994