

## Flash floods in mountain areas

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**Abstract** The main causes of flash floods in mountain areas are cloud bursts or stationary rainfall, heavy rainfall and rapid snow melt in high mountain areas, glacial lake outbursts, failure of dams built up by landslides, rock falls or debris flows, and overspill following the failure of water power reservoir dams. The sudden rise and rapid fall of water levels, as well as the high flow velocities combined with large sediment transport, demand special procedures in flood risk management. Some approaches to flood risk management in Switzerland and guiding principles with regard to flash floods, are presented here.

**Key words** flash floods; extreme precipitation; debris flows; hazard maps; flood risk management; Switzerland

### INTRODUCTION

Every year flash floods cause the loss of a great number of lives as well as tremendous damage. The main impact of flash floods is undercutting of check dams, the collapse of river banks, debris flows, debris deposits, river damming by debris, river-bank erosion, channel displacement, clogging of bridges, scour and inundations.

Most of the basins in Switzerland are prone to flash floods, landslides, and debris and mud flows. During the last few centuries, structural protection measures have substantially improved flood prevention and have helped the economic development of the country.

Experience with extreme floods during recent years has shown that structural measures alone cannot guarantee sufficient protection, however, and new approaches are needed. Major efforts in flood prevention are required in future for the following reasons:

- the damage potential has increased considerably in many areas owing to intense land use and increasing economic value in endangered zones;
- in channelized rivers runoff concentration time is affected, often resulting in higher flood peaks;
- a lack of space and retention areas to manage large-scale events;
- poor maintenance of structures and river beds;
- changes in runoff as a result of climate change and variations.

A new flood protection policy has therefore been developed which takes into account not only the safety aspects but also all other aspects of sustainable development. This policy is based on land-use planning, maintenance of the systems and structural measures. Environmental concerns and economic factors must be included in the planning process as early as possible. This comprehensive hazard assessment, with differentiated protection measures, adequate planning of measures and the limitation of the remaining risks are set out in the Federal Flood Control Act of 1993. The modern approach is based on proper risk analysis, risk assessment and risk management (Fig. 1).

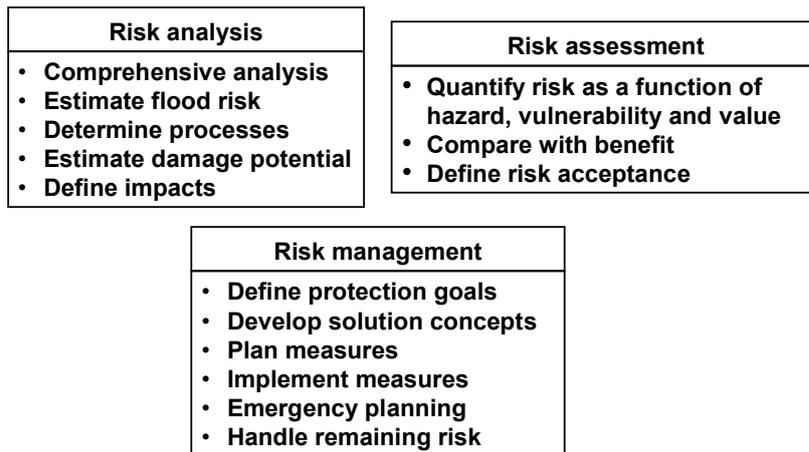
### ESTIMATING THE HYDROLOGICAL RISK DUE TO FLASH FLOODS

Comprehensive analysis includes the investigation of the hydrometeorological situation, hydraulic conditions, damage potential, the river bed and aquatic and terrestrial issues.

Estimating flood risk is a complex problem. Some selected procedures for obtaining meteorological and hydrological baseline information, as well as the advanced systems for estimating flash floods developed in Switzerland are presented here.

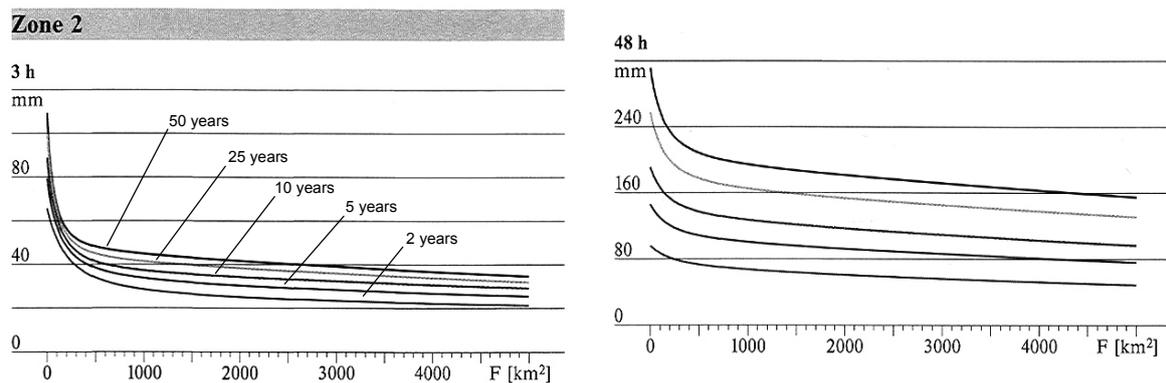
#### **Extreme regional precipitation of varying duration and return period**

Precipitation is a phenomenon defined by area and limited in extent and duration. The area covered by a precipitation event, its duration and its depth and spatial distribution are determined by the processes of precipitation generation in the atmosphere and their horizontal movement and evolution.



**Fig. 1** The pillars of flash flood protection.

A knowledge of regional precipitation is essential for estimating floods. Absolute regional precipitation depths for durations of 3, 12, 24 and 48 hours have therefore been calculated for eight different zones in Switzerland. These precipitation depths have been plotted against the surface area (Fig. 2).



**Fig. 2** Extreme regional precipitation of varying duration and return period (HADES, 2000).

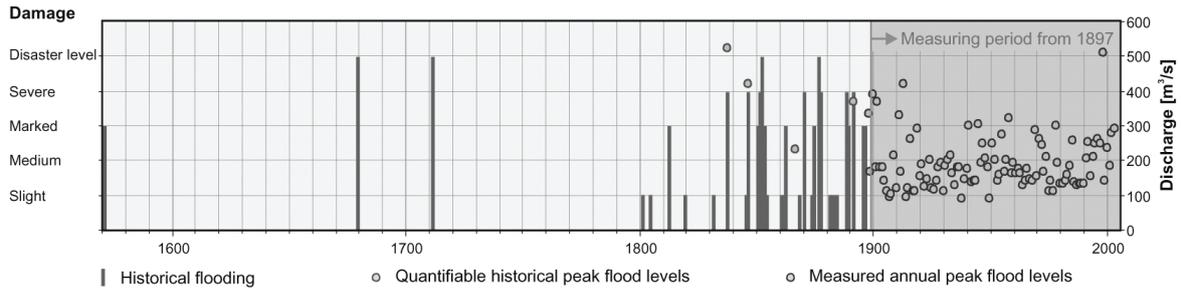
### Observation of discharge

It is very difficult to measure flood flows in mountain environments owing to high flow velocities and turbulence, floating debris and changes in the profile of the river bed. Floods in small catchments are of short duration, from a few minutes to some hours at the most. A water–solid mixture can be observed in very steep rivers; estimating the percentage of water discharge is fraught with uncertainties. For this reason it is often impractical to use conventional current meters. New technologies for measuring discharge have therefore been developed or implemented by the Swiss National Hydrological Survey (SNHS). Examples are measurement using a light-fibre fluorometer based on the principle of the dilution method or measurement of discharge using various types of acoustic Doppler current profilers.

### Documentation and analysis of extreme flood events

Extreme floods during the last three decades have been analysed with regard to meteorological conditions, hydrology, flow generation processes, social, economic and environmental indicators, comparison with historical floods, frequency, etc. This information provides a useful input for drawing up hazard maps (EVED/EDI, 1991; BWG, 2000).

Information about historical floods can be helpful, but it is quite difficult to interpret floods that occurred in previous centuries owing to artificial changes in the water systems and incomplete descriptions of the events.

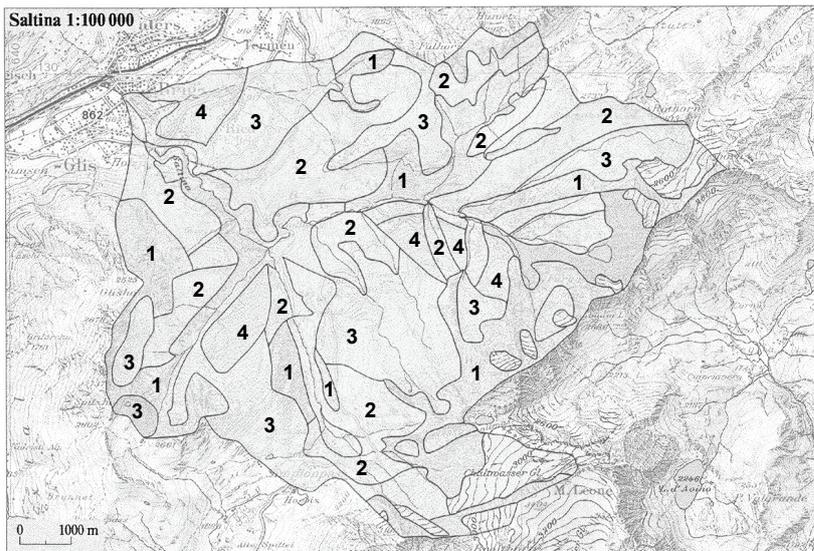


**Fig. 3** Flooding of the River Emme: historical flooding with recorded extent of damage within the catchment or known peak discharge rate and peak annual flood maxima measured at the Emmenmatt station by Gees (BWG, 2005a).

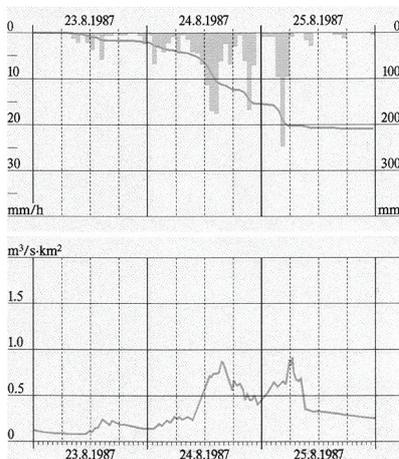
**Flood generation and concentration processes**

To determine the hydrological risk, a knowledge of runoff generation and concentration is very important. Based on experiments involving artificial rainfall on test catchments, as well as geological and pedological maps, it is now possible to define areas in a catchment where the runoff formation process and water retention capacity vary.

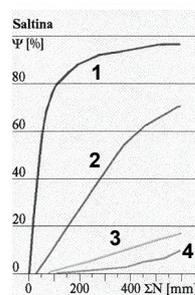
Slow and moderate reaction of the Saltina catchment



Highest observed flood



Typical flow formations



- 1 Fast reaction
- 2 Slight delayed reaction
- 3 Delayed reaction
- 4 Strong delayed reaction
- Ψ Percentage of precipitation causing flow
- ΣN Sum of precipitation

**Fig. 4** Reaction of Saltina catchment to rainfall input (HADES, 2000).

### Estimation of flood peak discharge in ungauged basins

Owing to the fact that discharge can only be monitored at selected sites, an advanced system for estimating discharge at ungauged sites has been developed in Switzerland. This practical guide is a powerful tool for developing hazard maps (BWG, 2003).

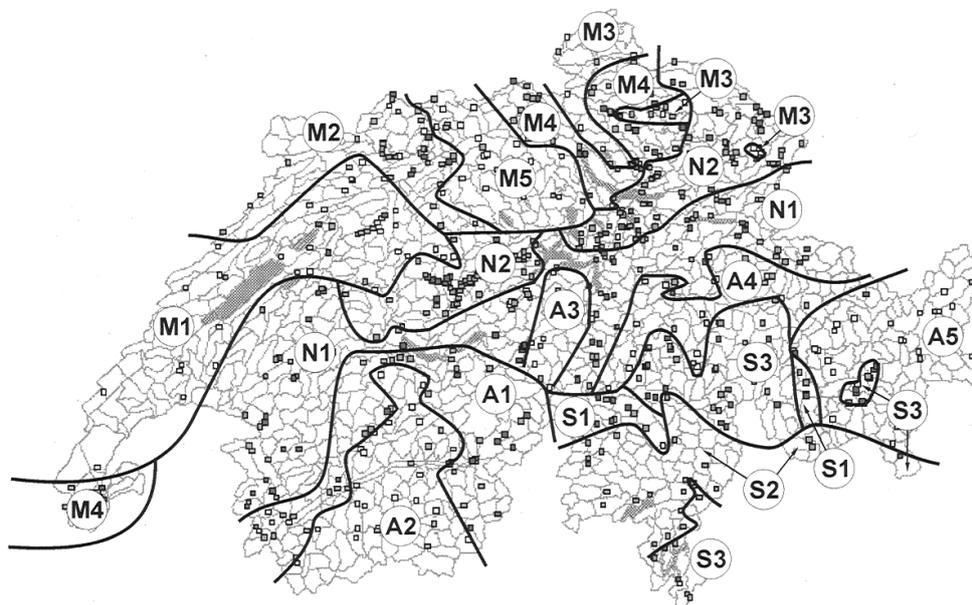


Fig. 5 Different flood flow regions in Switzerland after Kan (BWG, 2003).

### Impact of climate change on runoff

This impact was investigated by using different individual climate change scenarios for several basins. Fig. 6 shows the increase of winter peak flows of the Thur catchment. The frequency and height of peak flow vary much less during the summer half year than the winter half year.

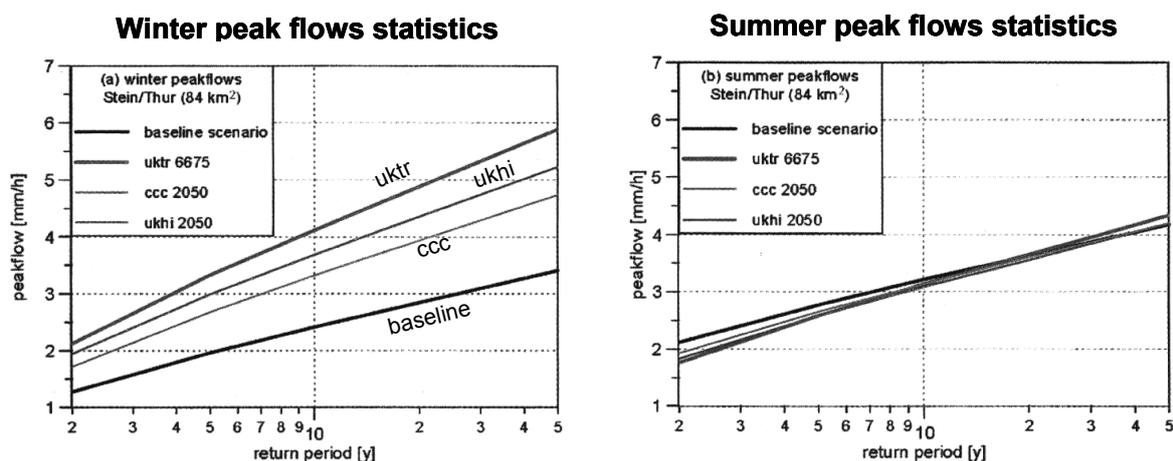


Fig. 6 Changes in winter and summer peak flows in the River Thur with respect to different climate change scenarios (CHR, 1997).

### SEDIMENT TRANSPORT

Debris flows cause a huge amount of damage in Switzerland. To gain a better knowledge of the processes involved, research stations with hydrophones are used. The operation of a network of sediment retention basins provides estimates of sediment yield all over Switzerland (Fig. 5). The recommendations for the estimation of sediment potential and sediment transport in catchments are an important aid in drawing up hazard maps (GHO, 1999).

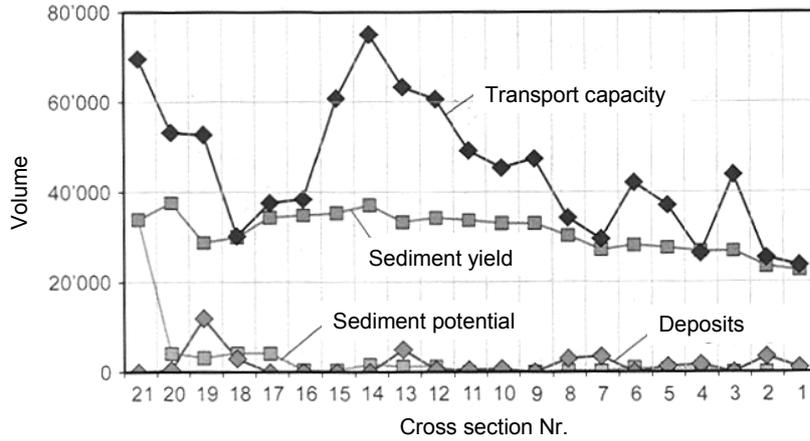


Fig. 7 Sediment transport in the Guppenruns (BWG, 2005b).

**HAZARD MAPS**

Risk cannot be properly managed without a sound knowledge of what that risk entails. Risk is dependent on the hazard and the potential damage. Since potential damage is a highly dynamic parameter, depending on constantly changing land-use, it was decided that hazard mapping was more important than risk mapping. The risk can be evaluated by each user if the hazard is known. Since different players need different information concerning the hazard, it was decided that hazard maps should be generalized, indicating the type and the degree of the hazard. The types of danger distinguished in the flood risks maps are: inundation (dynamic, static), bank erosion and debris flow (BWG, 2001).

**DIFFERENTIATED SAFETY CONCEPT**

Different protection levels are used, depending on the damage potential (BWG, 2001). Expensive infrastructure requires more advanced flood protection than cheap infrastructure. Based on this principle, agricultural land and isolated buildings need less protection than dense residential and industrial areas, but detailed investigations are still necessary for decision making.

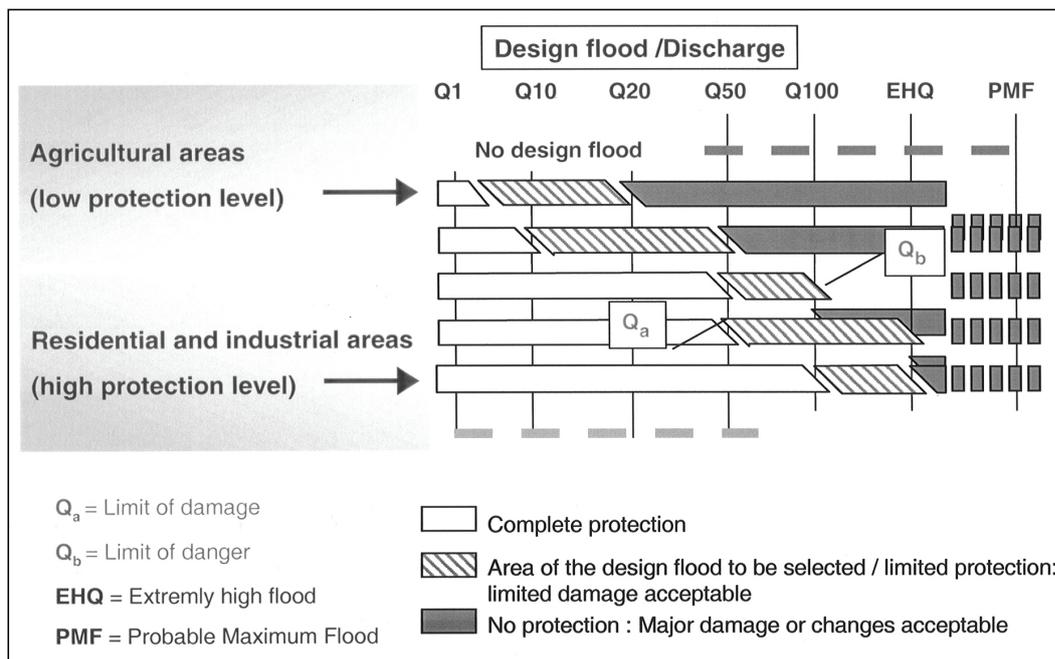


Fig. 8 Differentiated safety concept.

## ALTERNATIVE FLOOD PROTECTION MEASURES

### Maintenance of the water courses

Means:

- removal of vegetation in the river,
- excavation of sediment retention structures,
- repair of damage to protective structures,
- maintenance of river beds and banks.

A periodic check of the functioning and effectiveness of protective structures serves to identify weak points and to prevent total collapse during a flood event.

### Land-use planning

Hazard maps have to be incorporated into regional and local development plans. Within a hazard zone an increase in vulnerability can be limited or even prevented if a few planning principles are respected:

- avoid hazard zones (construction ban),
- reinforce existing structures,
- establish appropriate building codes.

### Structural protection measures

Structural protection measures include check dams, block ramps, dam construction, opening of river beds, spurs, debris flow breakers, etc. Structural measures should be kept as close to nature as possible and should avoid interfering with the landscape.

## EMERGENCY PLANNING

Even if all measures have been properly carried out there is still a “residual risk”. Emergency planning and its implementation therefore becomes an integral component of every flood policy. Flood forecasting, the operation of warning systems, the preparation of evacuation schemes as well as setting up and training rescue units are important parts of the emergency planning in Switzerland.

## CONCLUSIONS

After centuries of “fighting floods” the new philosophy of flood risk management is based on “living with floods”. The purely engineering approach has changed into a more integrated flood management one. This approach demands integrated problem analysis, sophisticated planning, assessment of measures and decision making and implementation on a river basin level. Hazard maps must be taken into account by development planning, warning and action planning as well as by creating awareness among the people affected.

It is possible that the magnitude and frequency of flash floods in mountain areas will increase in the future as a result of projected climate variability and change.

There is a need to improve our understanding of flash floods, their causes, development and impact.

There is also a great need for better forecasting and warning and communication systems for flash floods in mountain regions.

Dialogue between different sectors and different governance levels regarding management of flash floods and other disasters must be improved.

The general public’s lack of awareness and knowledge of the nature of flash floods and the threat they pose to communities needs to be addressed.

The main guiding principles of flash flood management are:

- divert water and sediment to locations where it will cause least harm. Differentiated safety concept!
- distribute the water over larger areas to attenuate the high energy impact;

- maintain enough space on both sides of a torrent, because the destructive forces are too strong to be managed;
- construct houses with strong foundations and entrances sufficiently high above the ground;
- provide or design safe places to which the population can escape.

Preventive measures are a MUST!

## REFERENCES

- BWW (1995) Procedure for the planning of flood protection measures. Flyer, Bundesamt für Wasserwirtschaft. Biel, Switzerland.
- BWG (2000) Hochwasser 1999, Analyse der Ereignisse. *Studienbericht nr. 10, Bundesamt für Wasser und Geologie*. Biel, Switzerland.
- BWG (2001) Hochwasserschutz an Fliessgewässern. *Wegleitung des BWG, Bundesamt für Wasser und Geologie*. Biel, Switzerland.
- BWG (2003) Hochwasserabschätzung in schweizerischen Einzugsgebieten, Praxishilfe. *Berichte des BWG, Serie Wasser, no. 4*. Bern, Switzerland.
- BWG (2004) Sachseln: Drei Bäche neu gebettet. Flyer, Bundesamt für Wasser und Geologie. Biel, Switzerland.
- BWG (2005a) The hydrology of Switzerland. *Berichte des BWG, Serie Wasser, no.7*. Bern, Switzerland.
- BWG (2005b) Feststoffbeobachtung in der Schweiz. *Berichte des BWG, Serie Wasser, no 8*. Bern, Switzerland.
- CHR (1997) Impact of climate change on hydrological regimes and water resources management in the Rhine basin. *CHR-Report no. 1-16*. Lelystad, The Netherlands.
- GHO (1999) Recommandations concernant l'estimation de la charge sédimentaire dans les torrents. Groupe de travail pour l'hydrologie opérationnelle. *Communication nr. 4a, BWG*. Bern - Ittigen, Switzerland.
- EVED/EDI (1991) Ursachenanalyse der Hochwasser 1987. *Ergebnisse der Untersuchungen, Mitteilung der Landeshydrologie und -geologie no. 14*. Bern – Ittigen, Switzerland.
- HADES (2000) *Hydrologischer Atlas der Schweiz*. Karte, Bundesamt für Wasser und Geologie. Bern – Ittigen, Switzerland.