Chapter 6
HAZARD ASSESSMENT AND LAND-USE PLANNING IN SWITZERLAND FOR SNOW AVALANCHES, FLOODS AND LANDSLIDES

The previous chapters describe the assessment of various natural hazards and mitigation measures that may reduce the consequences of these natural hazards. Land-use planning and the resulting zoning laws are among the most effective tools for the prevention and mitigation of disasters resulting from natural hazards. Effective planning and zoning require consideration of all the natural hazards that could affect a location in a commensurate and consistent manner. In Switzerland, new Federal legislation requires the Cantons to establish hazard maps and zoning for floods, snow avalanches and mass movements to restrict development on hazard-prone land. Areas highly exposed to natural hazards have to be mapped at regional or local scales. A coherent code of practice for landslides, snow avalanches and floods is now available, taking into account the possible threat to human life and important facilities in settled areas. The codes of practice also include some practical criteria to establish hazard maps based on intensity and return period of events. The transposition of these maps for the purposes of land-use planning is proposed for planners and policy makers. This example of combined assessment of natural hazards in Switzerland provides guidance for similar combined or composite assessments of natural hazards in other areas that are prone to multiple natural hazards.

6.1 SWITZERLAND: A HAZARD-PRONE COUNTRY

Located in the Alps, Switzerland is a small "hazard-prone" country (covering 41 300 km^2 with 6.7 million inhabitants) exposed to natural disasters, such as debris flows, earthquakes, floods, forest fires, hail storms, landslides, rockfalls, snow avalanches and wind storms.

Protection against natural disasters is incomplete and suitable protection does not exist in many places or no longer exists owing to changes in the use of the environment. Catastrophic floods took place in the summer of 1987 (damages of US $1 billion), as well as in 1990 and 1993. Floods cause damages amounting to US $150 million annually. In August 1995, a debris flow (40 000 m^3) cut the highway in Villeneuve, near Montreux, destroying some houses and vineyards (loss: US $15 million). Yearly, snow avalanches kill more than twenty-five people. In 1356, the city of Basel was destroyed by a violent earthquake (Intensity IX on MSK scale, 1 510 victims), and this highly industrial area remains under the threat of future earthquakes. More than eight per cent of the Swiss territory may be affected by landslides, mainly in the Prealps and the Alps. The Randa rock avalanche of 1991 (30 million m^3 of fallen rock debris) cut off the villages of Zermatt, Täsch and Randa from the rest of the valley for two weeks. In 1994, a prehistoric landslide experienced a strong reactivation with historically unprecedented rates of displacement up to 6 m/day, thus causing the destruction of the village of Falli-Hölli (41 houses, loss of US $15 million). Future climatic warming and unfavourable development of forests could lead to increased debris flow hazards in the periglacial belt of the Alps.

6.2 REGULATIONS

Switzerland is a Federal country where 26 Cantons are sovereign in principle: the central authorities only have jurisdiction in those domains determined by the Federal Constitution and all other state powers automatically belong to the Cantons or to the communities. Each Canton has its own government, constituting laws and regulations within the framework defined by the relevant Federal laws. The prevention and management of natural disasters follow the same rules.

The legal and technical background conditions for protection from mass movements have undergone considerable changes during the past few years. The flood of 1987 prompted the federal authorities to review the criteria governing the protection of the habitat against natural hazards.

A former regulation, the Federal Law for Land-use Planning of 1979, required each Canton to elaborate a Master Plan, including a map of scale 1:50 000, designating, among others, the hazardous territories. At the communal level, a Local Plan, including a map of scale 1:5 000, was requested for apportionment of land-use (e.g., agriculture, settlements) taking into account natural hazards. Due to the lack of Federal subsidies, the Cantonal and communal authorities didn't support such investigations, which restricted the use of their own land. Therefore, in many places in Switzerland, these maps are still lacking.

Two new regulations, the Federal Law on Flood Protection and the Federal Forest Law, came into force in 1991. Their purpose is to protect the environment, human lives and objects of value from the damaging effects caused by water, mass movements, snow avalanches and forest fires. Following these new regulations, the main emphasis is now placed on preventive measures to an increasing extent. Therefore, hazard assessment, the differentiation of protection objectives, the purposeful planning of measures and the limitation of the remaining risk are of central importance. The Cantons are required to establish registers and maps depicting endangered areas, and to take hazards into account for their guidelines and for the purposes of land-use planning. For the elaboration of the hazard

registers and hazard maps, the Federal government is providing subsidies to the Cantonal authorities up to 70 per cent of the costs. Land-use planning and the resulting zoning laws are among the most effective instruments to prevent substantial losses and casualties caused by natural hazards in sensitive areas.

6.3 HAZARD MANAGEMENT

The identification of natural hazards, the evaluation of their impact and the general risk assessment are decisive steps towards the selection and dimensioning of adequate protective measures. Therefore, a three step procedure has been proposed and is shown in Figure 6.1.

6.3.1 Hazard identification: What might happen and where?

Some recommendations for the uniform classification, representation and documentation of natural processes (e.g., snow avalanches, floods, debris flows, landslides and rockfalls) have been established by the Swiss Agency for the Environment, Forests and Landscape, and by the Federal Office of Water Management (Kienholz and Krummenacher, 1995). From these, the elaboration of the map of phenomenon should be based on an uniform legend. According to the scale of mapping (e.g., 1:50 000 for the Cantonal Master Plan, 1:5 000 for the Communal Local Plan), their legends offer, in a modular manner, a great number of symbols. For the 1:5 000 scale map, more symbols are available within an "extended legend". However, for a hazard assessment map to be deemed adequate, it must meet certain minimum information requirements. These requirements are contained in the "minimum legend". This "minimum legend" is a basic list of information that is included in each map used for hazard assessment. The map of phenomenon is based upon fieldwork and can be supported by other information, if available (e.g., floods records, geological maps, geodetic measurements, aerial photography).

The various phenomena (landslide, flood, debris flow and snow avalanche) are represented by different colours and symbols. Additional distinction is made between potential, inferred or observed events. Following the recommendations and the uniform legend, maps can be established exhibiting the different hazardous phenomena within an area of investigation. Owing to nation-wide consistent application of procedures, maps from different parts of the country can easily be compared.

Based on the Federal recommendations, harmonized Registers of Events are under development. Each register will include special sheets for every phenomenon (snow avalanches, landslides, rockfalls, debris flows and floods). Each Canton is responsible for its own register. Finally, these registers or databases will be transferred to the Federal Forest Agency, allowing the agency to overview the different natural disasters and damages in Switzerland, according to the standards of classification.

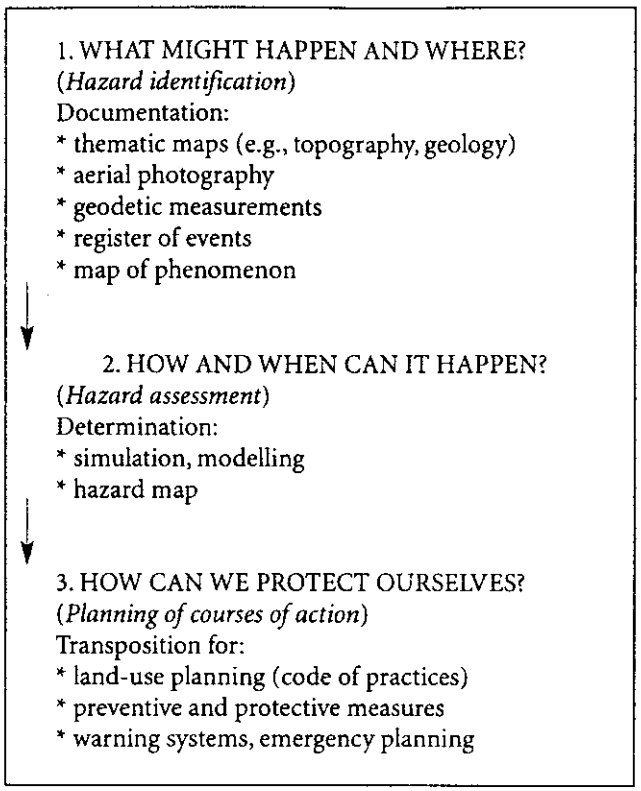

Figure 6.1 — Procedure for collecting data on natural hazards and planning courses of action

6.3.2 The hazard assessment: How and when can it happen?

Hazard means the probability of occurrence of a potentially damaging natural phenomenon within a specific period of time in a given area. Hazard assessment implies the determination of a magnitude or intensity over time. Mass movements often correspond to gradual (landslides) or unique events such as rock avalanches, which are extremely rapid flows of dry debris created by large falls and slides. It is, therefore, difficult to evaluate the return period for a massive rock avalanche or to predict the reactivation of a latent landslide. For processes like rockfalls, snow avalanches, floods or debris flows, it is much easier to evaluate their probability of occurrence. A rockfall is defined as a relatively free-falling newly detached segment of bedrock of any size from a cliff or steep slope.

Some Federal recommendations for land-use planning in landslide-prone areas (Lateltin, 1997) and in flood-prone areas (Petrascheck and Loat, 1997) have been proposed to the Cantonal authorities and to planners for the establishment of hazard maps using an intensity-probability diagram. Similar recommendations have existed since 1984 for snow (OFF and IFENA, 1984).

Hazards maps established for the Master Plan (e.g., scale 1:50 000) display all hazard-prone zones at the Cantonal level. The classification is made in a simple way: endangered or not endangered areas. Based on a diagram combining intensity and probability, hazard mapping for the Local Plan (e.g., scale 1:5 000) represents four classes or grades of hazard: high danger (dark grey), moderate danger (grey), low danger (light

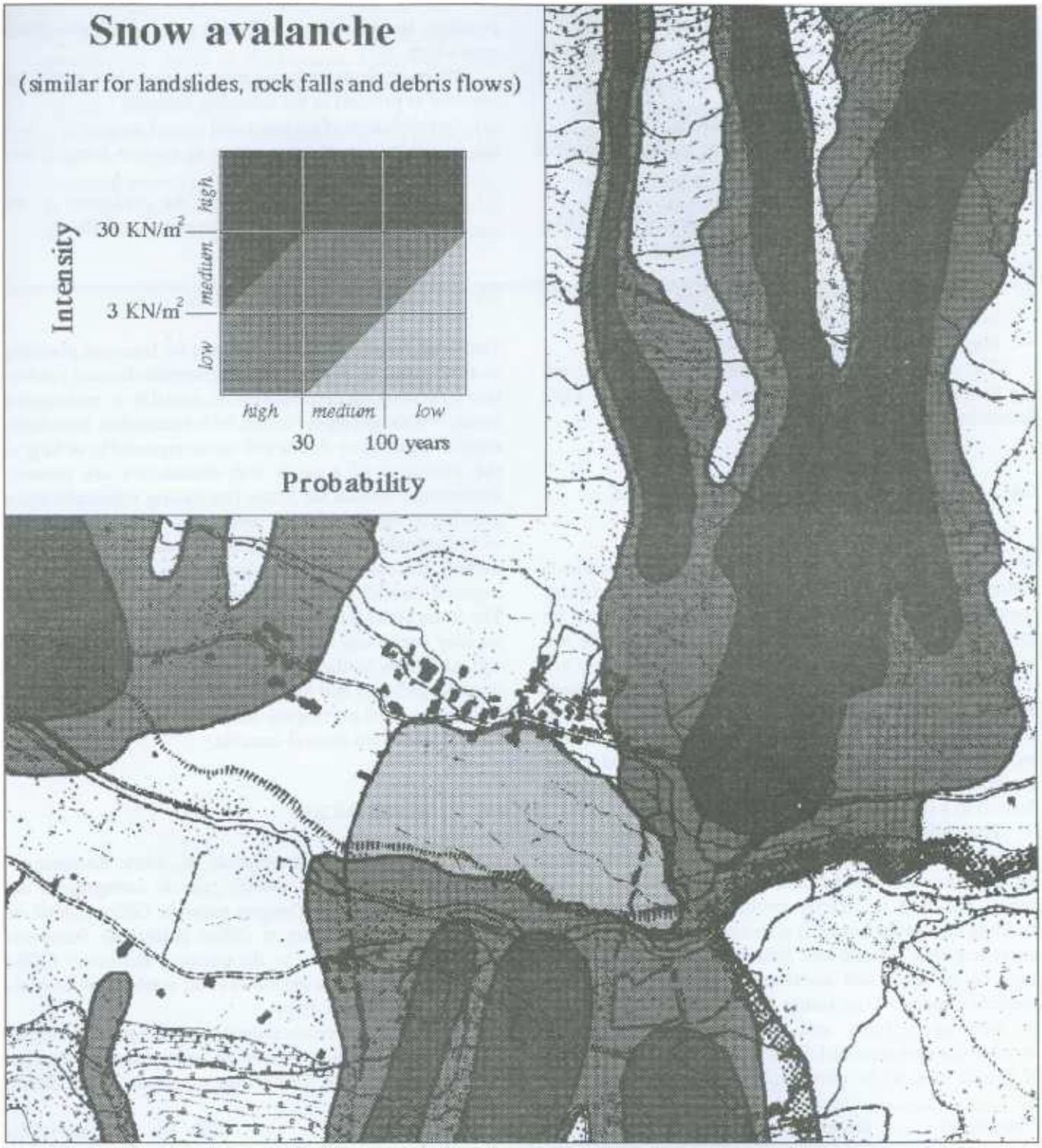

Figure 6.2 — Intensity-probability diagram and an example of hazard zoning for snow avalanches

grey) and no danger (white). An example of such a hazard map for snow avalanches in the form of an intensity-probability diagram is shown in Figure 6.2.

The criteria for probability of occurrence or return period are defined below:

Probability of occurrence (in 50 years)		*Return period (in years)*
high	100 to 82 %	1 to 30
medium	82 to 40 %	30 to 100
low	40 to 15 %	100 to 300

In the above table, the probability of occurrence in 50 successive years is related to the return period by the binomial distribution assuming one or more independent occurrences in n (= 50) years. The relation can be expressed as:

$$Pn = 1 - (1 - 1/Tr)^n \qquad (6.1)$$

where Pn is the probability of at least one occurrence in n successive years, and Tr is the return period in years for an event of a particular magnitude.

The criteria for intensity can be summarized in the following manner (OFF and IFENA, 1984; Lateltin, 1997; Petrascheck and Loat, 1997):

High intensity

— People endangered inside the building.
— Substantial damage to the building leading to possible destruction.

Medium intensity

— People endangered in the field, but not inside the building.
— Slight to medium damage to the building.

Low intensity

— People not endangered, neither in the field nor in the building.
— Slight damage to the building.

The detailed criteria for intensity were chosen according to Table 6.1 (OFF and IFENA, 1984, Lateltin, 1997; Petrascheck and Loat, 1997).

6.4 CODES OF PRACTICE FOR LAND-USE PLANNING

Absolute safety is impossible to achieve. In the different Federal recommendations for natural hazards of landslides, floods and snow avalanches, acceptable risks are given for the different grades of hazard. A generally acceptable risk has been fixed *a priori*, which considers only events up to a return period of approximately 300 years. That is, the possibility of damages resulting from events with return periods greater than 300 years is considered acceptable. The Federal recommendations are principally valid for cities and towns. For other forms of land use, a corresponding scheme can be derived in a similar way.

The codes of practice for land-use planning in areas prone to natural hazards (mass movements, flooding and snow avalanches) can be summarized as follows. In red zones, building is strictly prohibited. In blue zones, building is possible but with restrictions, provided certain safety requirements are met. Buildings exposed to hazards have to be designed corresponding to the hazard's possible impacts. To minimize fatalities, the establishment of warning systems and evacuation plans by the communities are required. Events involving large numbers of people have to be avoided, in blue zones as much as possible. In yellow zones, building is possible without restriction.

When implementing risk management, the Cantons are required to proceed in the following manner:

(*a*) Establishment of registers and hazard maps;
(*b*) Incorporation of areas prone to various hazards into the Cantonal Master Plan; and
(*c*) Controlling the application of the guidelines in the communal construction regulations (Local Plan).

6.5 CONCLUDING REMARKS

The Swiss Federal recommendations for land-use planning in areas prone to natural hazards promote disaster prevention by restricting development on unstable or endangered zones. Within the alpine realm, rock avalanches, landslides, snow avalanches or floods will occur repeatedly, as long as the processes of erosion and denudation are present. Increasing potential for losses (increasing vulnerability), a growing recognition for the need to increase the protection of individuals, and a decreasing acceptance of peril from natural processes, has led to a situation where action was required. In such cases, land-use regulations were enacted. The Swiss Federal recommendations outlined in this chapter may contribute to the prevention of substantial losses and casualties in the future. However, much information must be gathered and analysed, and the different Cantonal authorities must participate actively to successfully reduce future losses from natural-hazards.

6.6 REFERENCES

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Lateltin, O., 1997. *Recommandations pour la prise en compte du danger de mouvements de terrain dans l'aménagement du territoire*, Série Dangers naturels, Office fédéral

Table 6.1 — Criteria for intensity

Phenomenon	*Low intensity*	*Medium*	*High*
Rockfall	E < 30 kJ	30 kJ < E < 300 kJ	E > 300 kJ
Landslide	V < 2 cm/year	V: dm/year (V > 2 cm/year)	V > dm/day or H > 1 m/event
Debris flow	—	D < 1 m and V_w < 1m/s	D > 1 m and V_w > 1 m/s
Flood	T < 0.5 m or V_w T < 0.5 m²/s	0.5 m < T < 2 m or 0.5 m²/s < V_w T < 2 m²/s	T > 2 m or V_w T > 2 m²/s
Snow avalanche	P < 3 kN/m²	3 kN/m² < P < 30 kN/m²	P > 30 kN/m²

E. kinetic energy
V mean annual velocity of landslide
P avalanche pressure exerted on an obstacle
H. horizontal displacement
V_w: flow velocity
D thickness of debris front
T: water depth

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