2.7. Floods

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Floods arise through the interaction of precipitation, temperature and the physical condition of the catchment area. During extreme floods, the long-range flood peaks are substantially exceeded. The flood peaks in Switzerland show no uniform increase or decrease in the course of the 20th century. Climate change can, however, influence the occurrence of floods through increases in temperature, changes in precipitation and changes in the catchment area. In those areas of the Central Lowlands in which floods already occur in winter, an increase in the risk of floods is probable. For catchment areas in the high Alps, factors that increase or decrease runoff must be considered, so that changes in the risk of floods are very difficult to predict.

Introduction and definition

The term flood denotes a runoff rate significantly above the average. In hydrological science, peak runoff values are assigned various probabilities (return periods), reference being made to a 10 or 100-year flood (HQ10 or HQ100). Although a HQ100 is a rare event, it only results in damage where the runoff rate is significantly larger than the majority of peak values observed up to that point. Thus a comparison of the high-water peaks in the River Albula in Tiefencastel and of the Rhine in Domat-Ems (Fig. 39) shows that the natural variation must be taken into account. For the Rhine, the runoff is 40% higher for a 100-year event than for a 10-year event, and the water level is 1.5 m higher. Contrary to this, for the River Albula, the runoff is only 20% larger for a 100-year event than for a 10-year event, and the water level rises by only 25 cm more.

Although probability values are essential for many purposes, they contain no information on the extent of runoff and its significance to humans and the environment. From the standpoint of the natural environment, the runoff quantities of interest are those that initiate bed load transport, flood alluvial forests or alter the course of a river. Events of this sort are usually relatively frequent, with return periods of less than 2 to 10 years. Also, they generally do not lead to damage, and little notice is taken of them since humans and the ecosystem have adapted to them. From the human standpoint, runoff rates are of interest for which the river leaves its bed and penetrates into exploited areas.

As a rule, extreme events considerably exceed all floods recorded in the recent past. Thus, for example, the runoff of the River Reuss in the Canton of Uri was 50% larger in 1987 than over the previous 90 years. Flooding of the River Langeten in Lotzwil (Canton of Bern) in November 1975 (Fig. 40) was even more extreme, exceeding all previously recorded flood peaks since 1924 by a factor of several times. Events of this kind reshape the hydrological system, and areas well beyond the normal river bed are flooded. Where nature is concerned, such events are part and parcel of normal landscape dynamics. For humans, they signify high losses and/or natural catastrophes.

Floods are recognised as events that cause damage: whether or not they lead to losses is

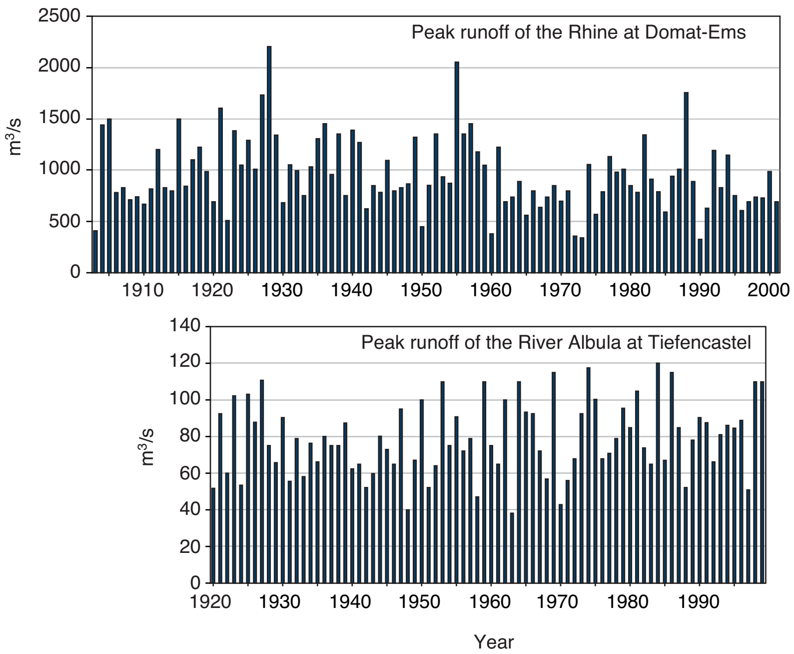

Fig. 39 Flood peaks of the Rhine at Domat-Ems display considerable variability. In the period 1899-1962, a 10-year flood corresponded to runoff of 1550 m^3/s and a high-water mark of 10.1 m. For a 100-year flood, the runoff was 43% higher (2200 m^3/s) and the high-water mark 1.5 m higher (12.6 m). In distinction, the flood peaks of the River Albula at Tiefencastel are more evenly distributed, a 100-year flood hardly being experienced as extreme. A 10-yearly flood corresponds to runoff of 105 m^3/s and a high-water mark of 8.2 m. For a 100-yearly flood, runoff is 130 m^3/s and the high-water mark 8.45 m.

influenced by the presence of protective structures. Thus in September 1993, a runoff of 90 m^3/s in the River Saltina in Brigue resulted in losses of approximately 500 million CHF. In October 2000, although the runoff was higher at 125 m^3/s, the safety structures erected in the meantime prevented more extensive damage. For Brigue, of course, 1993 remains the critical year for floods.

Conditions leading to floods

Floods arise through the interaction of precipitation, temperature and the physical condition of the catchment area.

In rivers with large catchment areas (>300 km^2), extreme flood events are associated with frontal weather systems leading to long-enduring precipitation over the entire catchment area (cf. Chapter 2.5). The extensive flood events of 1910 and 1999 are attributable to large-scale weather systems centred over the northern Alps, and those of 1987, 1993 and 2000 to humid air flows from the south. Where small catchment areas (<100 km^2) are concerned, thunderstorms in summer represent the greatest danger (examples: Sachseln 1997 and Gantrisch 1990).

There is no direct connection between precipitation quantity (or intensity), and peak runoff, since the quantity of water stored in the catchment area varies according to the weather history. Thus the extreme runoff in the River Langeten (Fig. 40) resulted not from exceptionally high precipitation alone, but also because its capacity for water storage had already been exhausted. Previously – but under different conditions – comparable precipitation had been heavily damped by the river overflowing its banks.

In Alpine regions, temperature plays an important role. With a low zero degree line, part of the precipitation falls as snow and does not run off immediately. Thus in October 2000, Valais was spared more serious consequences by a fall in the zero degree line from 3000 m to 2600 m in the final precipitation phase. Temporary storage of precipitation in the form of snow reduces peak runoff. In contrast, melting snow increases runoff, whereby the latter is more likely to take the form of a moderate increase over one to two weeks than of an extreme peak. Thus in spring 1999, thawing of snow in combination with heavy, but not exceptional, precipitation led to record water levels in the Central Lowland lakes and to high water in the Rhine, the Thur and the Aare.

Trends in the 20th century

No consistent trends are identifiable in peak runoff in Swiss rivers during floods. This is also related to the heavy influence humans have on them. Thus between 1955 and 1970, the exploitation of the Rhine at Domat-Ems for hydropower (Fig. 39) resulted in a reduction of annual peak runoff. Other factors such as the increasing areas of forest and extended flood protection affect runoff. In a systematic study of the Bavarian Landesamt für Wasserwirtschaft[2], no trend at all was identified at 73 stations, whilst 2 others displayed a positive and a negative trend, respectively.

The identification of trends in these very rare extreme events is almost impossible on a statistical basis (cf. Chapter 1.4). Recent times have seen a conspicuous concentration in floodscausing heavy losses (1987, 1993, 1999, 2000 and 2002). Note, however, that a comparable concentration also occurred in the 19th century (1834, 1838, 1852 and 1868). Moreover, a glance at the long-range data and the chronicles shows periods without any significant floods, for example between 1940 and 1950. Thus till now, it has only been possible to speculate on – but not to explain – this episodic behaviour.

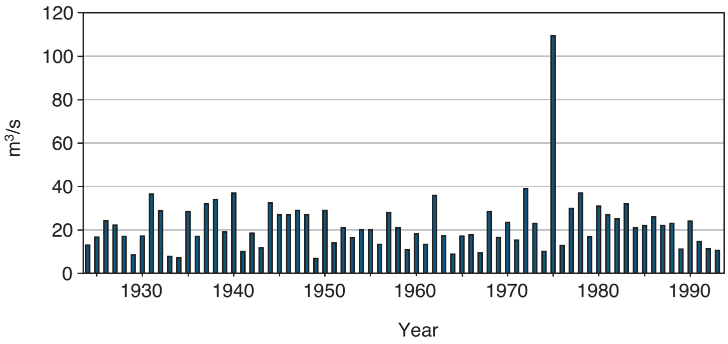

Fig. 40 Maximum summer and winter flood peaks of the River Langeten during the observation period 1924-1993.[1]

Influence of climate change on flood processes

Climate change can influence the occurrence of floods via various processes:

Influence of temperature increase

In Switzerland, the risk of floods cannot be discussed independently of where the zero degree line lies. In the Alpine catchment areas with their extremely varied altitude, snow has an important function, firstly in retarding runoff and secondly as a supplier of water in the thawing season. As a result of climate change, the zero degree line will rise, and rain will fall over wider parts of catchment areas. The likelihood that heavy precipitation will coincide with a high zero degree line, leading to extremely high runoff, is increasing. In addition, should the precipitation quantity per event increase with the change in climate, the peak runoff and the probability of floods will rise. If the effects of safety measures are for the moment ignored, the danger of floods, and thus of more frequent and more extensive losses, would be expected to increase.

Changes in precipitation

The latest simulations show that in winter, precipitation in the Alps will probably increase as a result of climate change. At low and central altitudes of the Central Lowlands, there will be more rain and less snow, so that the frequency of floods in winter will increase. This will particularly affect the Rhine downstream of Basel. Also, certain areas in the Cantons of Aargau, Thurgau, Basel Land, Jura and Zurich will be put at risk. Whether or not the increase will affect both frequent and extreme events will depend on changes in the frequency and intensity of the frontal weather systems.

In spring, floods occurs when thawing coincides with heavy precipitation. The 'heat input' in spring will probably change little as a result of climate change. Therefore the change in precipitation will have a larger influence on floods than the melting of snow. Although the increase in average winter precipitation will lead to larger quantities of snow in the high Alps, snow cover at lower altitudes will decrease owing to the higher winter temperatures. Which of these effects will have a greater influence on the occurrence of floods depends on the altitude profile in the catchment area, the increase in the quantity of winter precipitation and the frequency with which snowfall and melting snow alternate. Altogether, the 'flood-free' periods resulting from low winter temperatures will become shorter.

Floods in the smaller catchment areas are mostly associated with summer thunderstorms. Local thermal updrifts are responsible for the intensity and quantity of precipitation. Any predictions of an increase or decrease are purely speculative. Frequency changes resulting from thundrous weather conditions tend to have a greater effect on losses due to hail (cf. Chapter 2.6) than on those due to floods.

Changes in the catchment area

Glaciers and permafrost at high altitudes in the Alps are on the retreat as a result of climate change. For this reason, more debris can be mobilised. Furthermore, soil generation is influenced by changes in vegetation, indicated, for example, by the rising tree line. These processes can alter the course of rivers, thereby altering the risk of floods. Such processes take place very slowly – changes in permafrost requiring decades or centuries, and those in soil generation centuries to millennia.

More immediate effects will result from higher transpiration of plants at higher temperatures, causing more rapid depletion of the water reserves in the ground, and having a damping effect on flood generation. This effect will be mainly noticeable in areas with frequent floods, but also in Alpine and sub-Alpine regions subject to summer floods, and where no significant changes in summer precipitation are to be expected.

In conclusion, it may be said that the risk of floods will increase in those parts of the Central Lowlands in which the influence of floods in winter is dominant. This follows from the predicted increase in winter precipitation and the reduced snow fraction at altitudes between 1000 and 1500 m. At high-Alpine altitudes subject to typical summer floods, the rising zero degree line could lead to an extension of the period in which snow-free precipitation occurs and there is a risk of floods. To what extent this effect may be compensated at lower altitudes by plant transpiration is difficult to predict.

1 Spreafico M. und K. Stadler, Hochwasserabflüsse in schweizerischen Gewässern: Abflussmessreihen mit mehr als 30 Jahren in den Einzugsgebieten des Rheins und der Aare. Band I, Mitteilung der Landeshydrologie und -geologie Nr. 7, Bern, 1986.

2 Bayerisches Landesamt für Wasserwirtschaft [Hrsg.], Hochwasser, Spektrum Wasser 1, München, 80 S., 1998.