9 FLOOD PROTECTION AND INFRASTRUCTURAL DEFENSE

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Three domains of infrastructure defense against floods may be distinguished: (1) Dams and nuclear power plants, with a federal protection level, (2) Plants of water and energy supply with directions and recommendations involving authorities and private associations, and **(3)** Remaining infrastructure for which no guidelines are actually available, and for which infrastructure defense is a private concern. Currently, this state is particularly discussed though not realized.

9.1 DAMS AND NUCLEAR POWER PLANTS

For dams and nuclear power plants, the federal authorities are in. charge of security aspects. This is due to the national and even international significance of such infrastructure. Therefore, their damage is not the prime concern but the prevention of particularly long reaching consequences.

Up till today, Switzerland has not been *hit* by dam failures. The fact, *that such disasters* have occured internationally rind that roughly one third may be demonstrated to result from overtopping is noteworthy. As long as dams are operational, floods can be significantly stored or at least dampened. If full dams fail, however, the resulting flood is much larger than when there would have been no storage, and has an enormous potential of destruction. The Swiss regulations aim to exclude any dem failure, therefore. This concept is based on three bases, including (1) structural safety, (2) control and (3) emergency concept. in the following, these three items are shortly reviewed.

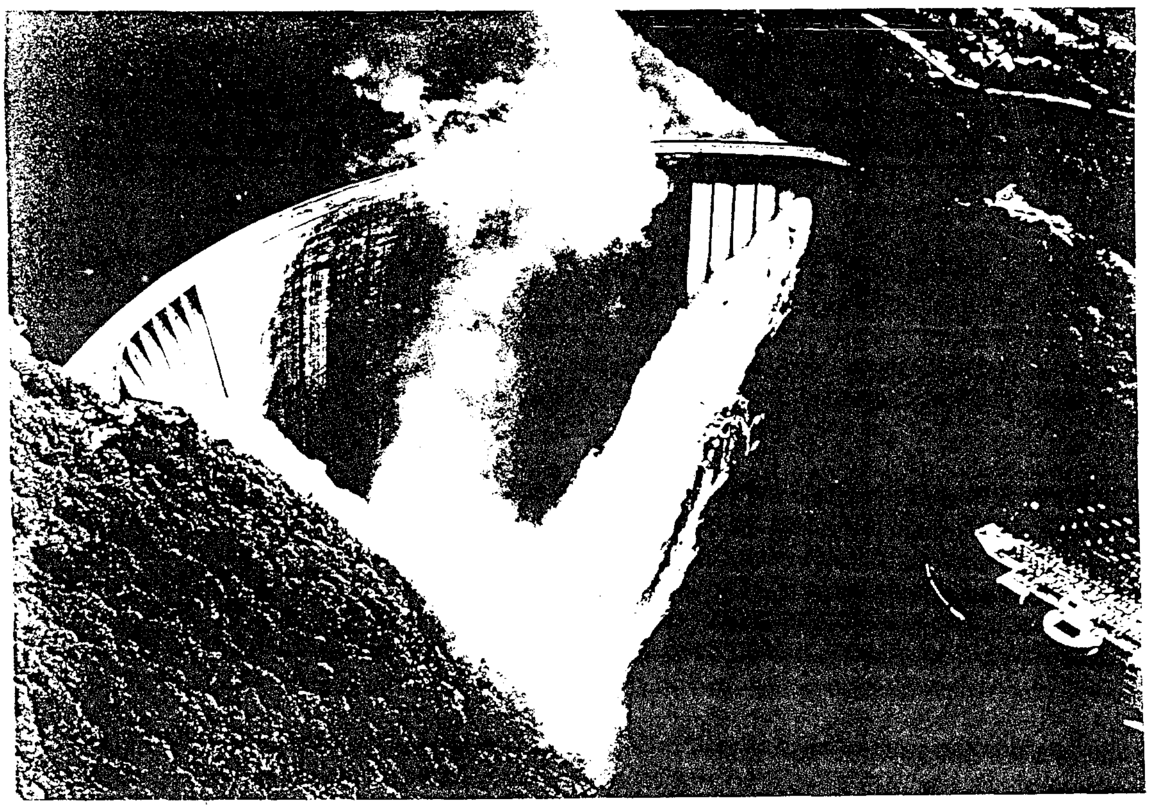

Fig.9.1 Spillway overflow at Contra arch dam close to Locarno, Switzerland, 221m height, into service since 1966.

Structural safety is considered the most important feature of dams including their design and execution. Dams have to resist of course the enormous water pressure, particularly during floods. In addition they include a spillway to exclude overtopping (Fig.9.1). The hydraulic design of spillways includes thus two design discharges, namely the one thousand year flood, and the catastrophic discharge.

The *one thousand year flood* should be diverted without any damage to the dam. The following assumptions are thereby considered: (1) This flood enters a full reservoir, with ail intakes closed (particularly important for Switzerland with an general use of water power), (2) The reservoir freeboard relative to wave action and other imponderables are guaranteed. For dams equipped with gates, the (n-1) condition has also to be satisfied, invoking that the gate with the largest discharge capacity is closed during the flood event.

The *catastrophic discharge* is defined as being equal to the one thousand years discharge times a factor of 1.5 applied to both flood peak and basis, and corresponds roughly to the ten thousand years discharge. This flood should pass the spillway without initiating dam failure but causing some minor damages. The freeboard can partly be used and the (n–1) condition applies only to embankment dams.

Control as the second basis of the security concept guarantees that a dam with itsconsiderable longevity does not temporally change. This may mean that gated spillways remain always fully operational, or that temporal changes in hydrology are accounted for by a corresponding design flood. The latter may cause an increase of the spillway facilities.

The *emergency concept* as the third basis includes emergency drawdown of the reservoir level to inhibit dam failure or warning of' downstream zones if this is impossible. In regions where the flood would arrive within 1.5 hours after a dam break, the warning is made with specially installed water emergency sirens.

For nuclear power plants, flood protection is basically required though not detailed up till today. There are currently no standards available as for dams, and a local procedure is accounted for. Switzerland with only four nuclear power plants has no real need as compared to about 200 dams under federal authority. Such dams are characterized by a height larger than 10 m, a reseroir volume larger than 50.000 m^3 or a specific potential of damage. Cantonal authorities are in duty for the lots of smaller dams.

9.2 PIPELINE-BOUND SUPPLY AND DISPOSAL PLANTS, TRANSPORTATION SCHEMES

The pipeline systems include the water and gas supply, the electricity supply and the sewage disposal schemes. Given their locally fixed installation, their damage by natural disasters is particularly large.

Drinking and industrial *water supply* as used in Switzerland originate by 80% from the groundwater reservoirs and by 20% from lakes. There is a federal law dating from 1991 and relating to the securing of drinking water in emergency situations. It contains minimum criteria regarding quantity and quality of supply waters and also regulates the responsibilities. Details are left over to owners and operators which are members of the Swiss Gas and Water Association SGWA. Accordingly, a SGWA-regulation indicates the design and operation of drinking water emergency supplies, with only a general account to floodings, however.

Spring and lake water intakes arc flood-proof in general, whereas groundwater fountains are often not if they are located in flood plains and thus suffer from floodings. Contaminant flood water can enter a fountain and thiis contaminate a complete supply system. Groundwater fountains are thus elevated to above the flood level, typically on a small artificial hill to inhibit damages.

Earthborne water supply systems are not really in danger during floods, except damages due to scour or erosion. During the Brig disaster in 1993, the supply pipelines were damaged and filled with solid matter, which eventually reached the filters upstream of the buildings and caused clogging. The drinking water supply was practically out of operation and the reoperation was significantly retarded. The current guidelines thus recommend to place filters sufficiently high that sedimentation is impossible and cleaning remains simple.

Sewers are typically based on the combined sewer system practice, with stormwater and sewage in the same pipeline. Separation into the treatment facilities and the receiving waters occurs at so-called stormwater overflow structures. The most important guidelines are included in the 1991 federal law on water protection, with details dealt with by the Swiss Water Pollution Association VSA.

A sewer with stormwater floods can cause additional floodings, an effect not further elaborated here. The impact of natural floods on sewer systems is of relevance, however. *Stormwater overflows* normally discharging sewage into the receiving waters can become intake structures to a sewer system during high flood levels. Such undesirable events can be countered by clieck valves with some risk for clogging in both flow directions. They are therefore not generally accepted. The flood level can even reach lower building iniakes which must be located at a certain minimum elevation, according to VSA-regulations.

Out-of-the-river floodings may cause damage to sewers via submergence and intake by manholes. Examples such as those of Poschiavo in 1987, and Brig in 1993 have led to highly undesirable conditions with a complete *clogging* by mainly sand and gravel. Only after a fortnight, the sewers of Brig for example were flushed with high-pressure systems. It seems that this potential o fdamage cannot really be countered by infrastructural protection.

Outlets of sewage treatment facilities into a receiving water car? also be influenced by floodings, arid the outlet elevation is normally located at the 100 years flood level. Therefore, the sewage is often elevated with screw *pumps* to a sufficiently high level. These pumps are located either at the facility inlet, or between various basins of the plant, or even at the facility outlet. If the treatment facility is still subject to floods, the control installations are at least located at flood-pioof elevation.

The Swiss *gas supply* is based on imported gas. Therefore, this country has a distribution network but no gas production plants. The distribution network is not really sensitive to floods, although there might be a damage potential for pipelines located close to rivers and brooks. An example is the pipeline running along Rhone river which might be scoured by out-of-the-river floods. Then, explosions can occur. At the time of design, it was necessary to demonstrate that the Rhorie river is actually stable in terms of thalweg geometry, and river migration could be excluded. An additional scour arid erosion protection was only exceptionally applied. The control of such pipelines is under the Swiss Federal pipeline inspectorate and details are regulated by SGWA.

The Swiss *electric supply* involves roughly 60% hydropower and 40% nuclear power. The flood-proofing of its infrastructure was already discussed. One may add that practically all dams are related to hydropower and only few are used for flood storage. Flood security of river powerplants with a large potential of damage follow similar regulations as dams. The overground powerhouses are usually in the flood regions and must be made floodproof, therefore. The access road and the powerhouse entrance must be elevated at least above the 100 years flood level. For underground powerhouses, flooding danger is low and safety may easily be obtained by a sufficiently high entrance elevation. There are actually no guidelines available. The coordinator of such questions is the Swiss Electricity Supply Association.

The gross distribution of electricity involves high tension networks, whose poles are normally flood-proof. Breakdowns are thus seldom and are not really known for the Swiss electric supply network. The large switchyards are normally erected sufficiently above flood elevation, whereas smaller works may be located in flood risk zones. As was demonstrated by recent incidents the corresponding subworks, transformation stations and distribution cabins are often not sufficiently safe against floods. Cable lines may enhance flooding of electricity stations. Due to an old and unfortunate tradition, the measuring, dismbution, regulation and safety installations of the buildings are generally installed at the basement where they. may immediately break down.

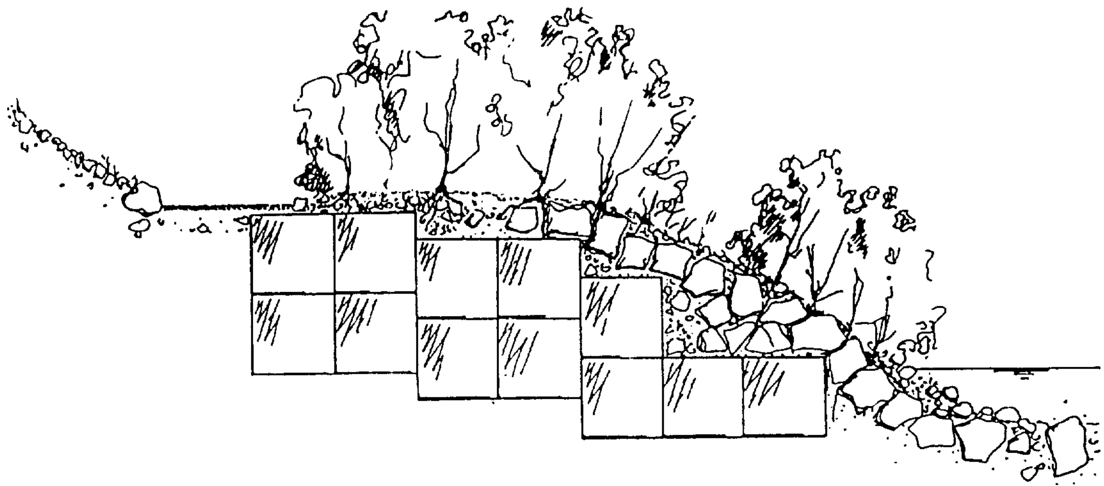

Fig.9.2 Shore protection at Reuss river close to Gotthard highway tunnel, with concrete groins of 66 t weight.

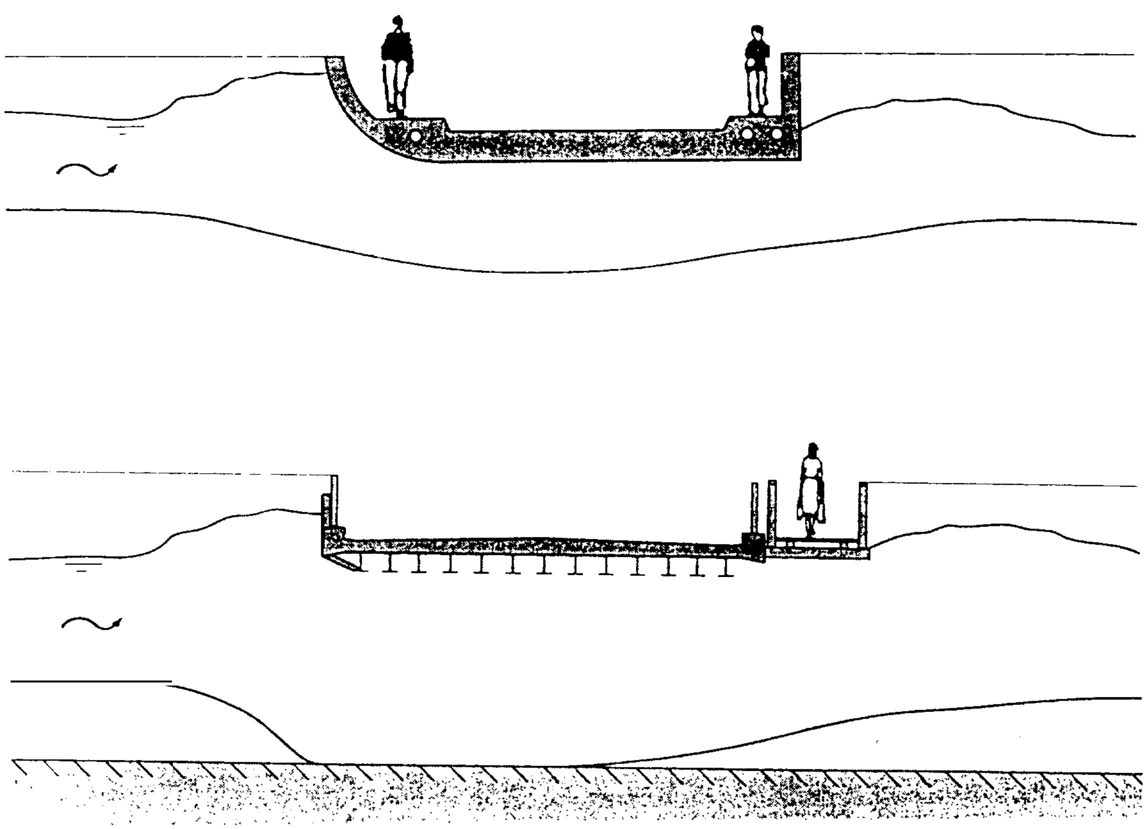

Fig.9.3 Shield backup bridge, schematic streamwise section, design example of Cimavilla bridge at Poschiavo, Switzerland.

The Swiss *telephone network* is laid practically always underground and seems to be less prone to flood damages as coinpared to the electrical network. Handies increase of course the communication safety during flood flows.

Traffic infrastructure related to flood safety has a widely varying degree of protection. Railroads are particularly safe in this country and critical locations are often crossed with embankments. When running along rivers, the railroads have a special protection against bank erosion. Bridges are so high as to inhibit any overtopping or side flows. Along steep slopes, notorious brooks are often bypassed over galleries. The same methods are also used with highways and other strategic roads (Fig.9.2). In contrast, few works have been erected for normal highways, and damages are particularly numerous with road culverts and **small** bridge openings. These latter may cause significant backwater with corresponding floodings upstream or result in bridge clogging by sediment and float.

Some disasterous river overtoppings were initiated by bridges substructures too close to the water level. Two recent designs were introduced for bridges where their elevation cannot be increased, namely a so-called culvert bridge and the lift bridge. The ***culvert bridge*** (Fig.9.3) inhibits the bridge flooding by forcing water and sediment through the opening, whereas the ***lift bridge*** (Fig.9.4) just releases the water flow. Two lift bridges have been built in **Brig,** one for a public road, the other for the railroad.

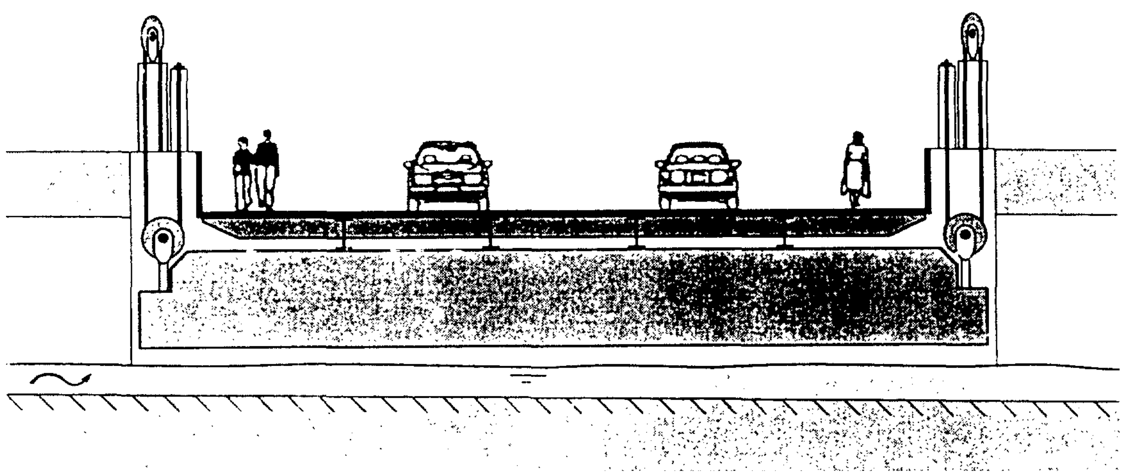

Fig.9.4 Elevation bridge at Brig, Switzerland. The roadway rests on two abutments that may be elevated by 2.8 m.

Few probleiiis arise with the many suspension railways because their poles can easily be designed flood-proof.

9.3 BUILDINGS

Buildings in the Alps are normally not flood-proof, as was already mentioned. Given that all the buildings are insured, and insurances do not apply different risk classes, no particular stimulus is created for building protection. Therefore, even new buildings can be found in out-of-the-river floodplains with garages and other installations in the basement. **A** 1993 federal law is in order that demands a *mapping* of natural hazard zones. Thus, rules and orders are supposed to follow in terms of building protection. The corresponding guidelines are still missing, but may include:

- Hood-proof design of buildings typically on small earth pourings (Fig.9.5), on piers or behind local embankments.
- Omission of basements or addition of seals for entrances, light and air supplies.
- Structural means against erosion and water pressure, including buoyancy.
- Improvement of flood resistance of water anti power supply to the buildings considered.

The realization of structural means seems rather simple, given the general stability of Alpine buildings.

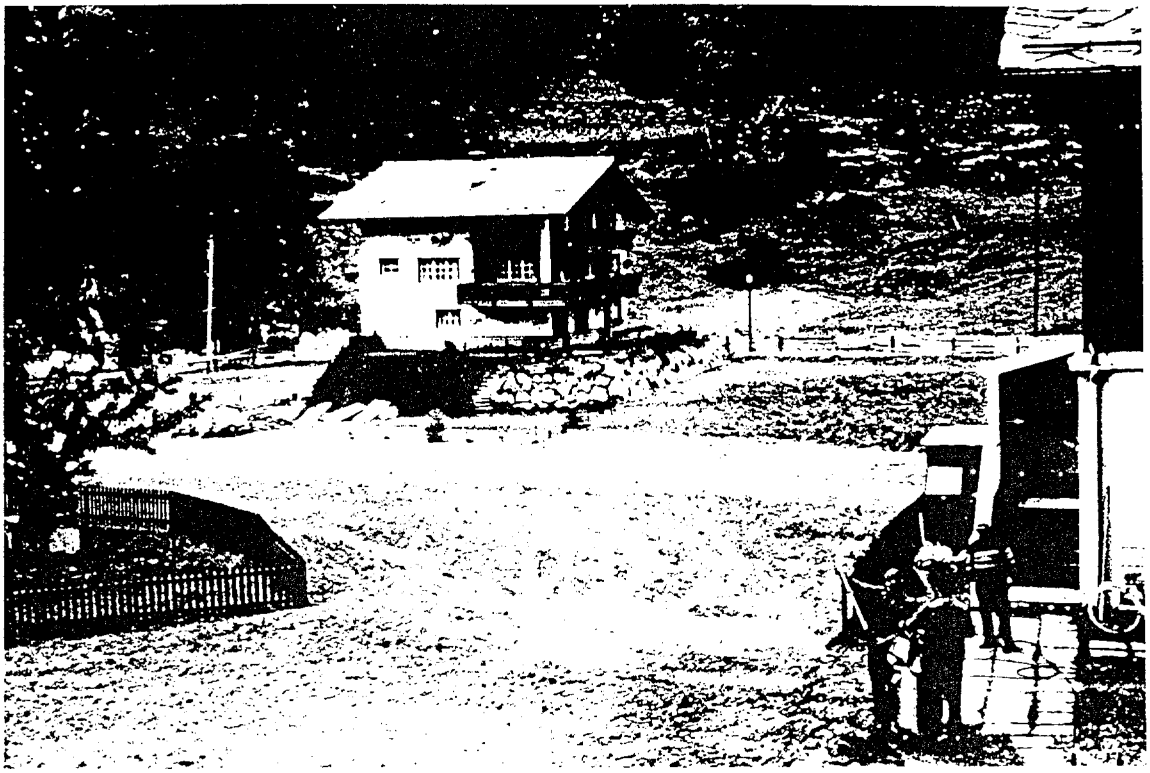

Fig.9.5 Building at Saas Balen, Switzerland, in the flood reach of Saaser Vispa. The earth fill renders it practically floodproof.

It can also be mentioned that Alpine buildings are generally heated with oil, and an oil tank is normally located close to the cellar that may be damaged by floods. It can thus buckle or even swim up. The latter case is particularly dangerous because it leads to a failure of the connecting pipes, and the leaking of oil contaminates the groundwater. Therefore, water authorities require also safety measures against those incidents.