KANTON
NIDWALDEN TIEBAUAMT

Integrated Risk Management
On the River Engelberger Aa

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Natural hazards and safety

Safety from natural hazards is a basic need of humans and society. However, the way we deal with natural hazards and the associated risks has changed over the course of time.

Since the last Ice Age, the river Engelberger Aa has created the Nidwalden valley plain from millions of cubic metres of bed load. Only during extraordinary storm events was this flood plain raised through extensive overbank sedimentation and moved a little further towards the lake. This process continues unabated.

The first inhabitants who settled on the flood plain of the valley floor were aware of the risks associated with the location and of their responsibility for their own safety. Thus, they settled on the slopes. In order to gain additional land, the water courses were gradually contained and provided with flood protection structures. These structures and the conversion of the fens into fertilised meadows gave people a sense of security and they started to build on the flood plane.

As a result of economic development and the increasing demand for land, the settlements spread extensively on the flood plane and, hence also, in the hazard areas. The risk reduction achieved by means of protective structures was quickly counteracted by the rapidly increasing hazard potential created by the new settlements.

The disproportionately high settlement growth of recent decades, which mainly took place on the flood plane, can be clearly identified in the areal statistics for Stans, the capital of the canton of Nidwalden.

The storms in the canton of Uri and other cantons in 1987 clearly highlighted the newly created hazard potential and the associated vulnerability of the built structures and previous flood-risk strategy. The realisation dawned that the risk posed by natural hazards could not be overcome through technical measures alone. Land use constitutes the central element of damage reduction. Thus, in accordance with the Swiss legislation, flood protection measures must be implemented primarily through spatial planning. This ranges from the designation of hazard zones with object protection requirements and segregation of non-development areas and river spaces to the designation of drainage and discharge corridors which must be kept free of development.

Because there is no upper limit on the scale of natural events, when it comes to natural hazards there is no such thing as absolute safety. A residual risk always remains.

The advent of global climate change also contributed to the realisation that a change of strategy is needed. This change means a shift away from a culture of safety to a more comprehensive culture of risk and is embodied in the concept of integrated risk management as practised in the canton of Nidwalden.

The following options for dealing with risk are available under integrated risk management:

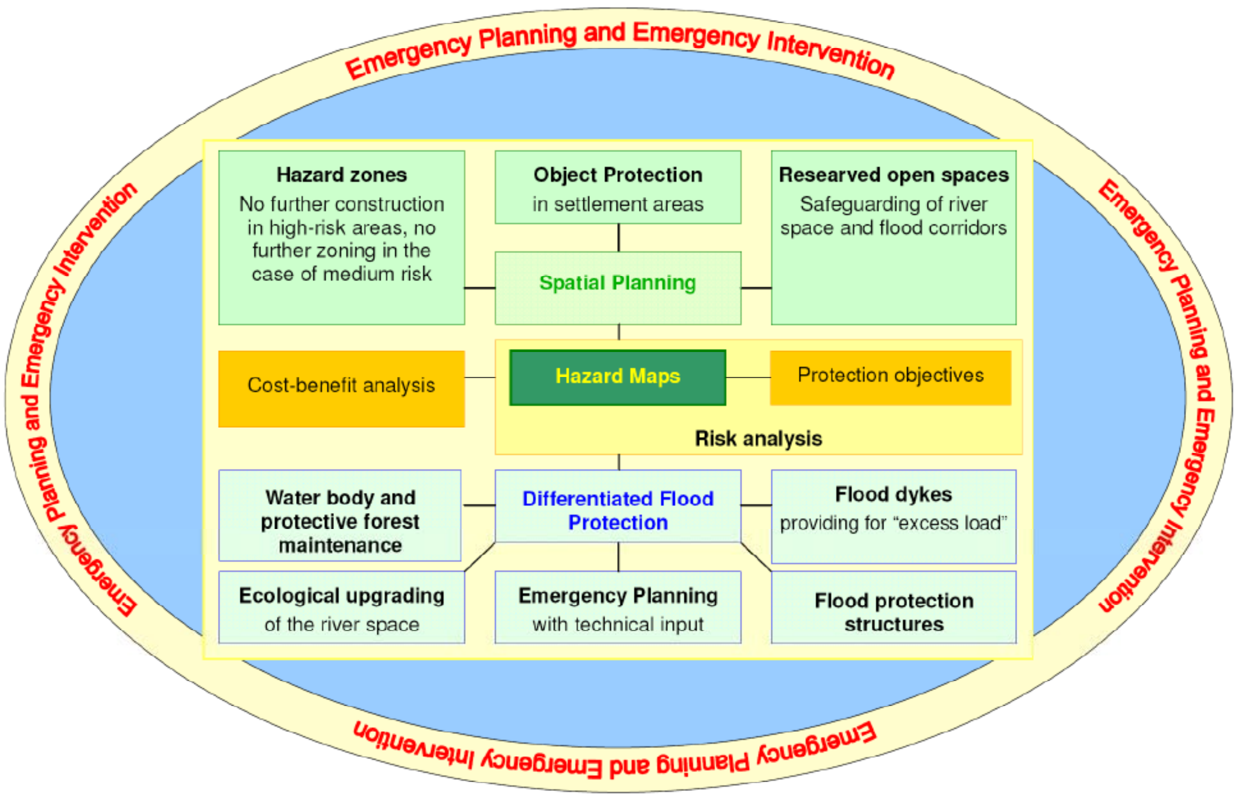
With the help of suitable measures corresponding risks can be:

- **avoided** (for example by not building in areas at risk from natural hazards)
- **alleviated** (for example by providing adequate space for water bodies, maintaining water bodies and protective forests)
- **reduced** (for example with the help of flood protection structures or object protection)
- **curtailed** (for example through effective emergency intervention based on emergency planning)
- **accepted** (for example through the flooding of discharge corridors in the context of the low-damage management of residual risk as absolute protection does not exist)
- **financially cushioned** (for example through solidarity-based natural-hazard insurance policies).

1. Integrated risk management

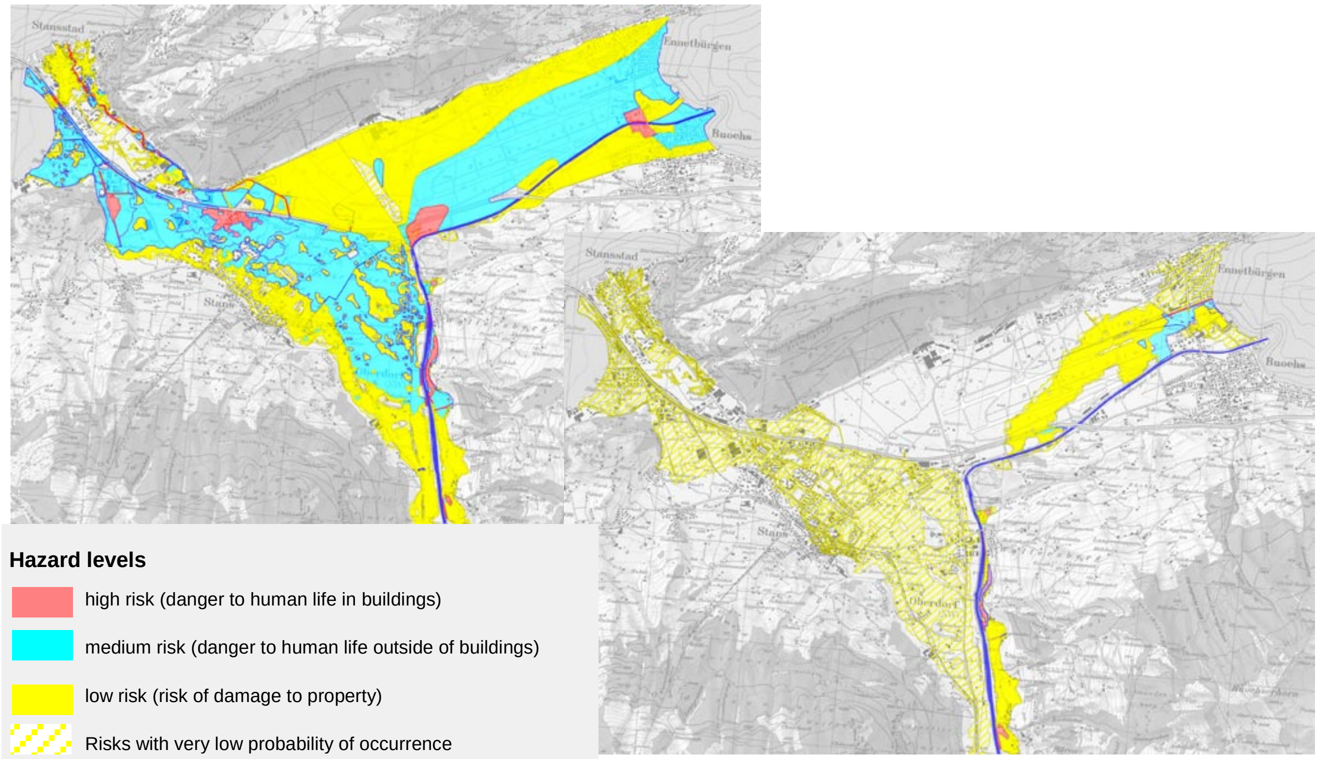
The differentiated flood protection concept on the river Engelberger Aa takes account of the fact that there is no such thing as absolute safety and protection against natural hazards. Excess load, i.e. when greater volumes of water or bed load arise than can be discharged or drained off, is incorporated into the planning. Flooding is not prevented at any cost. Instead, the water should be allowed to breach the banks in a controlled way in specified locations where the least possible damage will arise. The aim is to avoid dike breaches and uncontrolled flooding. The excess water flows into low-damage discharge corridors. Eventual damage-intensive uses in the discharge corridor, e.g. settlements, are protected by secondary flood dikes or training dikes.

The basis and, therefore, central element of flood protection is the risk analysis, which incorporates all possible processes and must reflect the widest possible range of scenarios. Different protection objectives are defined for the land-use categories based on the corresponding levels of vulnerability. Thus, for example, agriculturally used areas are protected up to the level of a 20-year flood and settlements to the level of a 100-year flood.
The insights from risk analysis are implemented in the context of spatial planning, flood protection and emergency planning. The main components of the associated measures are presented in the following diagram.



Integrated risk management in the area of flood protection

Risk analysis involves the examination of all relevant hazard processes, the presentation of the various possible scenarios and assessment of the associated risks. The consequences of climate change and the inconceivable ("worst-case" scenario) are incorporated into the considerations. The risks are presented in hazard maps.



Hazard map prior to (left) and after (right) the implementation of the flood protection measures

2. Spatial planning

The hazard maps are integrated into zoning maps in the form of hazard zones and the corresponding provisions in the construction and zoning regulations. A ban is usually imposed on development in high-risk areas. Object protection requirements are applied in medium-risk areas and for risks of up to medium frequency. In addition, no new zoning is allowed in the medium-risk areas. The regulations apply to all new and replacement buildings and to major conversion projects.

The discharge corridor provided for the case of excess load is safeguarded in the cantonal spatial master plan and municipal land-use planning and underpinned by additional provisions.

To ensure that the water courses can guarantee their function in terms of flood protection and ecology, the necessary space is safeguarded through the designation of river space zones and areas. These extend over several generations on the basis of a long-term perspective.

3. Differentiated flood protection

The planning and design of the "Engelberger Aa" flood protection project began in 1987 and is being implemented in six stages. The first four stages in the heavily populated lower valley floor were completed at the end of 2007. The main elements of the project include flood dikes for the case of excess load, channel widening, dike reinforcement, river bank rehabilitation, near-natural design, adaptation of bridges, protection measures in the flood area and the improvement of the bed load regime. The river area was upgraded both agriculturally and ecologically with the help of these measures. This means that the requirement of the Federal Act on Hydraulic Engineering "for the re-establishment of a natural river course" is largely fulfilled. The provision of a local recreational amenity was also incorporated into the project as an important ancillary element.

Secondary flood dikes or training dikes in front of the settlement areas also reduce the risk of flooding. These display a very good cost-benefit ratio. In addition, the owners of buildings are informed about the object protection measures they can avail of to shield themselves against residual risk and the measures they must undertake to ensure that their properties do not pose any increased risk to their neighbours or environment (e.g. heating oil tanks).

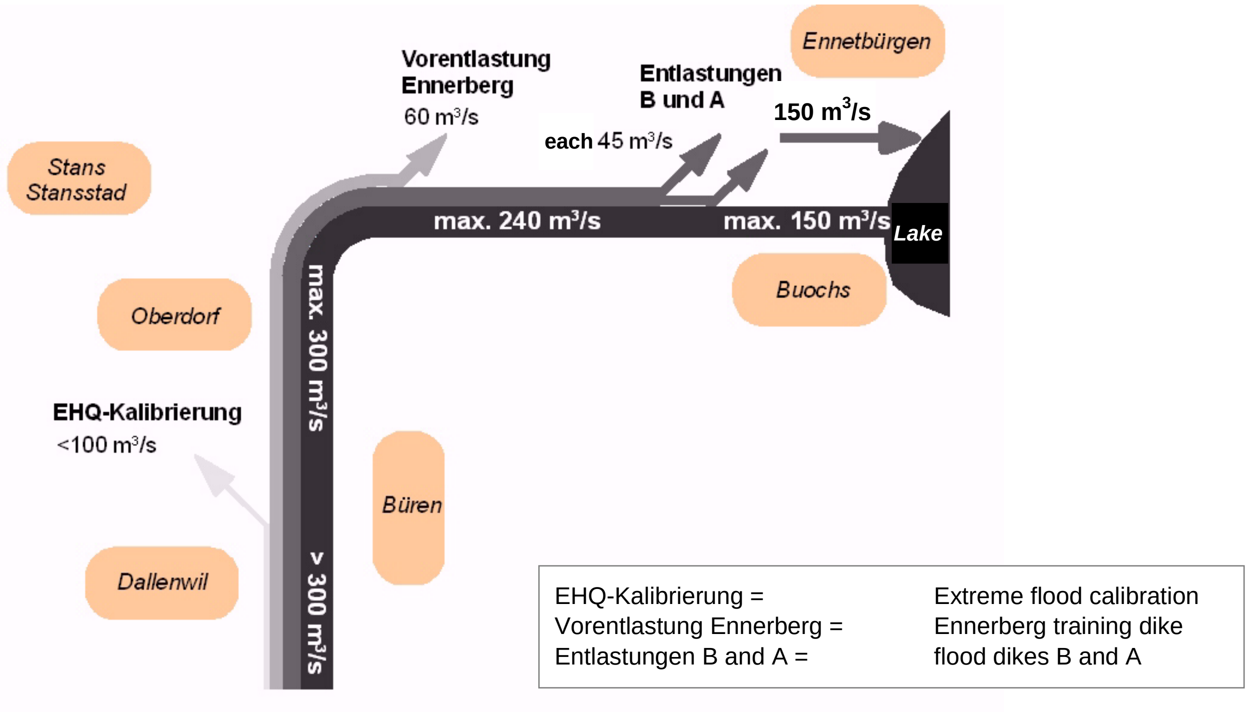


Diagram of flood discharge measures on the river Engelberger Aa

The four flood dikes constitute a central component of the flood protection structures. These were created in locations where, in the case of excess load, the excess water with a low hazard potential can be discharged to the side in controlled way. The flow path used for the discharged water is called a discharge corridor. Buildings or settlements located in this flow path are protected to the level of their protection objective through local measures.

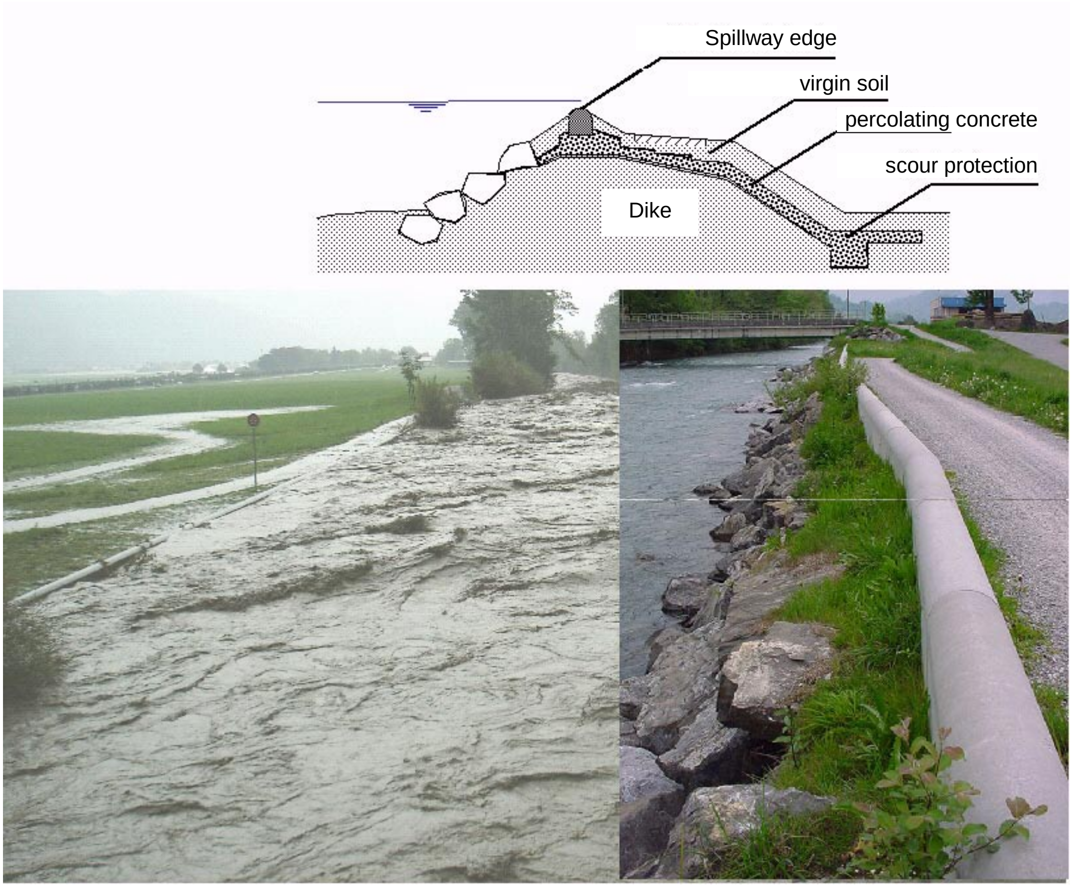
The discharge structures are designed in such a way that they can be subject to overflowing without the dikes being breached. In the case of excess load,[1] the excess water is channelled laterally over the dike into the discharge corridor. Thus it is guaranteed that the maximum volume of water that remains in the channel at each discharge point corresponds to the capacity of the next section. As soon as the flood hydograph returns to a level below the dimensioning-based water volume all of the water discharges in the river channel.

The Engelberger Aa as the flood of 2005 subsided. The "excess" water leaves the river channel at the intended locations and flows through the discharge corridor between Ennetbürgen and Buochs towards Lake Lucerne. A maximum discharge of 150 m3/s remains in the river channel.

Due to the extensive settlement development, the previous dimensioning-based water volume of the Engelberger Aa of 120 m^3/s was increased. After the raising of the dikes, the maximum flow rate in the main settlement area between Dallenwil and the Ennerberg training dike is 300m^3/s. After the fourth flood dike, a maximum flow rate of 150 m^3/s remains in the river bed which can be channelled into the lake without causing any damage in Buochs.

1 Excess load" is referred to when a river carries more water than the dimensioning-based flood level (volume of water dimensioned on the basis of a flood protection structure). With traditional flood protection structures, "excess load" results in the uncontrolled breaching of banks and, in most cases, the extensive damage familiar from the flood events of the recent past.

The profile narrows in the vicinity of the flood dikes. As a result, the further transport of the bed load is guaranteed due to the greater shear stress, on the one hand, and it is possible to keep the dikes short in length, on the other. The dike crest is formed in each case as a spillway edge. Moreover, the flood dikes are arranged above a longitudinal offset to separate aggradations in the flow-off area from flood dikes.



Ennerberg training dike: only the “excess” water flows over the spillway edge during flooding (205 m^3/s) (photo left); training dike during normal flow (photo right)

4. Emergency planning

The cantonal and municipal emergency organizations are coordinated in the “Engelberger Aa” emergency planning. Elements of the emergency planning include a uniform system for alerting and providing information to the public, the joint organization of dike monitoring and road block management. The use of construction machinery is coordinated throughout the canton. A committee of experts in the forecasting and assessment of critical situations was also established.

Thanks to the integration of the case of excess load into the planning, there is clear information available as to when and where flooding arises and the volumes of water involved. This gives the municipal management bodies and emergency services the possibility of using their resources and powers in situations where action is necessary and makes most sense. The level at which punctual evacuations and temporary measures must be implemented is defined. The planning of interventions makes it possible to use the very limited resources of the relief units to the maximum possible effect and to keep the necessary reserves available for the rising flood waters. The residual risk can be further reduced through the rapid and targeted intervention of the emergency organisations.

5. Test case 2005

The storm of August 2005 was an extraordinary event. Extensive areas of the canton of Nidwalden were affected by landslides, floods and groundwater rise (for key data, see page 10). The peak discharge of the Engelberger Aa on 22 August 2005 was 230 m^3/s. Considerable damage arose subsequently in the sections of the river from Grafenort to Dallenwil where flood protection measures had not yet been carried out.

Flooding in the section of the river in the upper valley plane betweem Grafenort and Dallenwil where flood protection measures had not yet been carried out. The photo shows a section of the river in Wolfenschiessen with uncontrolled bank erosion, local aggradations of the channel, overbank sedimentation and flooding. Due to the fact that settlement is still largely limited to the traditional location at the foot of the slope, the damage caused was not too extensive.

The capacity of the Engelberger Aa in these areas was far smaller than the discharge.

The water widened the partly straightened and secured channel and extended it in part by a factor of three. The result was dike breaches, extensive flooding and bed load deposits; new stream courses arose as a result of the enormous energies released by the dike breaches. Extensive erosion occurred just below the aggradations. A total of 250,000 m^3 of bed load was mobilised.

In order to minimise the damage, as an immediate measure the channel was excavated at sensitive points or its aggradation prevented through the excavation of bed load. When the flooding abated, the bank was stabilised in critical locations.

Thanks to the flood protection project, large-scale damage was prevented in the controlled section of the Engelberger Aa in the lowest part of the valley floor. The flood protection structures functioned technically as planned.

The discharge of 230 m3/s was automatically reduced to the existing discharge capacity of 150 m3/s in Buochs. Without the flood protection measures, it would not have been possible to avoid a dike breach in Buochs.

The monitoring of the situation revealed that the desired volume of water was discharged with precision. The newly developed uncontrolled tilting elements of flood dike A functioned steadily and completely. When the flood wave waned, small bed load aggradations started to accumulate but did not, however, interfere with the discharge function. Intervention was not required despite the large volume of driftwood present.

The A2 Gotthard motorway had to be closed for around three hours due to the presence of the laterally discharged water. It could be reopened to traffic when the upstream discharge had decreased to the level of a 100-year event.

As a result of the deliberately low level of shear stress in the discharge corridor, the turf remains undamaged. In contrast, the uncontrolled floods in the upper valley floor caused considerable erosion at the same slope ratios.

Effects of the intensive processes resultig from a dike breach in the section of the river where flood protection measures had not been carried out

Regulated forces in the discharge corridor prevent erosion (Buochs-Ennetbürgen discharge corridor)

Due to objections, training dikes planned for the protection of the settlements in Ennetbürgen had not yet been built and CHF 30 million worth of damage was caused.

The re-modelling of the flood of 2005 in a scenario minus the flood protection measures reveals that the first dike breach would have occurred upstream of Buochs at a good 120 m^3/s and the village of Buochs would have been flooded. With a further increase in discharge to 180 m^3/s, the Engelberger Aa dike in the Ennerberg curve would have been breached. A new river channel would have formed which would have interrupted traffic on the A2 for several days and would have flowed through the village of Ennetbürgen and parts of Buochs. The upstream dikes would have been breached from a discharge rate of around 200 m^3/s. At this stage the water would have severely devastated the settlements of Oberdorf, Stans and Stansstad.

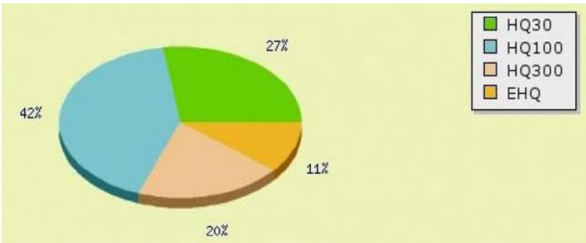
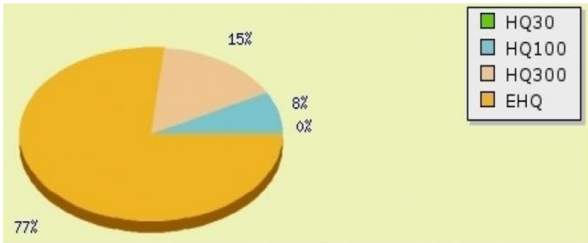
6. Integrated risk management pays off

The concept of integrated risk management and the measures undertaken as part of the differentiated flood protection project in the lower reaches of the Engelberger Aa proved successful. The design of the flood dikes its practical test with flying colours. The protection objectives defined by the cantonal parliament (*Landrat*) were fulfilled. Dike breaches and the resulting damage were avoided (the estimated cost of the flood of 2005 is in excess of CHF 160 million). Thus, the investment of CHF 30 million more than paid off in the first test case.

RiskPlan

The IT based instrument RiskPlan was developped by Ernst Basler + Partners; Zollikon (CH) and GRSoft GmbH; Büsingen in close cooperation with the federal office for environment (FOEN) and the federal office for civil protection (FOCP). It allows the evaluation of different risks in a region and the assessment of risk management measures on the basis of their cost-effectivness. (www.riskplan.admin.ch; languages german, french, english, chinese)

Risk reduction using the implemented measures was analysed using the RiskPlan method. The efficiency of the measures undertaken emerged clearly from this analysis. The annual damage expectation value was reduced from CHF 10.45 million to CHF 0.46 million, i.e. to 4%. The cost-benefit ratio is 1:17. Other results from RiskPlan are shown in the diagrams below.

<table>
<tr><th>Status prior to structural measures</th><th>Status after to structural measures</th></tr>
<tr><td colspan="2">Scenarios</td></tr>
<tr><td>
</td><td>
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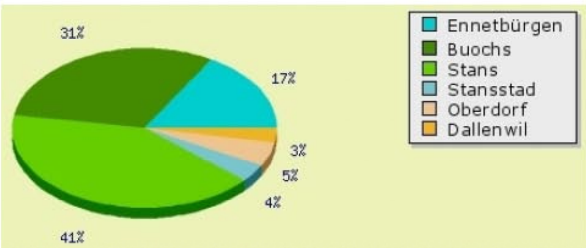
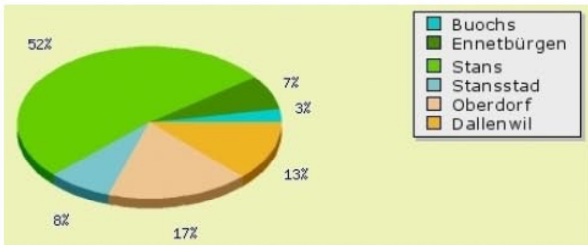
<tr><td>
</td><td>
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7. Key data Engelberger Aa

Catchment area

Area	A=227 km2;
Estuary Lake Lucerne	434 asl;
Highest point:	3238 asl (Titlis)
Land cover:	1% settlement, 41% agricultural land, 24% forest, 29% rock/wasteland, 5% glaciers
River type:	Mountain river, valley gradient 5 - 0.5%

Project Development Stages 1 to 4

Planning and design	since 1989
Construction work	1998-2007

Discharge capacity

before development	120 – 140 m^3/s
after development in the critical area of Stanserboden	300 m^3/s
after development near Buochs	150 m^3/s

Hydrological measures

Four flood dikes: enlargement of the river space, dike elevation, dike reinforcement and consolidation; erosion protection through widening and block ramps; bank protection by spur dikes, riprap and planting; protection of nearby settlements, object protection

Other measures:

Ecological upgrading (including restoration of free fish migration); recreational use

Planning measures

Safeguarding of discharge corridor and river space; definition of hazard zones with corresponding development regulations and information for landowners

Emergency planning

Coordinated cantonal and municipal emergency planning

Total cost

River engineering measures over a distance of 7.4 km	CHF 26 million
Passive and planning measures	CHF 4 million
Damage prevented as a result	over CHF 160 million

Flood event of 21 - 23 August 2005

Precipitation:

There were four main precipitation phases in August 2005. The first three were characterised by the usual August precipitation volume. For this reason, the partly saturated soils were unable to absorb the heavy rains of the 100-year event. The cause of the heavy precipitation was a Vb situation or “Genoa depression”. The recurrence period of the measured precipitation volumes is over 100 years (Stans: 193mm/m^2 in 48h, 256 mm/72h, of which discharge 171 mm/72h)).

Engelberger Aa:

Peak discharge (recurrence period approx 250 years):	230 m^3/s
Recorded bed load:	approximately 250'000 m^3
Bed load transported into the lake:	approximately 6'000 m^3
Volume of driftwood:	4'400 m^3
Number of landslides	ca. 800
Total cost of damage in Nidwalden	CHF 110 million