Flood corridors to handle residual risk

Markus W. Klauser, Dr. sc. ETH, Dipl.Ing.[1]; Christian Willi, Dipl. Forsting. ETH[2]; Werner Fessler, Dipl. Kult. Ing. ETH[3]; Josef L.A. Eberli, Dipl. Kult. Ing. ETH[3]

ABSTRACT

Settlements are spreading in the floodplains of rivers as a result of economic development and the rising demand for land. By means of structural and organizational measures, it is possible to reduce the integrated risk (in terms of expected loss per year, aggregated over all investigated scenarios). However, it should be noted that only spatial planning measures like the elimination of flood corridors (i.e. areas with reduced or no damage potential) as part of the urban planning measures of municipalities can guarantee a forward-looking, controlling effect.

In the «Stanser Talboden, Switzerland», structural and organizational measures have already been implemented to protect settlements. These measures were part of the flood protection project «Engelberger Aa» and have shown a positive efficiency in the past. This study focuses on additional spatial planning instruments and shows that the flood protection can be further developed by creating a flood corridor, in a cost-effective and trend-setting way.

KEYWORDS

floods, hydraulic engineering - organizational - spatial planning measures, emergency planning, flood corridors, climate change, damage potential, effect-cost analysis

INTRODUCTION

Sustainable spatial planning is a key component in the integrated risk management of natural hazards. It is implemented by taking into account the hazard zones in the land-use plans of municipalities. These measures, such as building bans or the set-up of physical protection measures help to mitigate the negative effects of flood hazards, but do not provide an adequate solution to control settlement evolution.

Flood corridors allow the reduction of settlement evolution in certain areas. In addition, the instrument is very flexible, allowing a certain worsening of the natural hazard situation due to e.g., climatic changes. The present study examines the instrument of flood corridors at the economic level using the example of the flood protection system «Engelberger Aa». We show that the implementation of such spatial instruments can be cost-effective measures complementing both existing hard (hydraulically engineered) and soft (organizational) measures.

1 Tiefbauamt Kanton Nidwalden, Stans, SWITZERLAND, markus.klauser@nw.ch
2 Ernst Basler + Partner AG
3 Tiefbauamt Kanton Nidwalden

The planning and design of the «Engelberger Aa» flood protection project started in 1987. The first four stages were completed at the end of 2007. The main elements of the project included four flood dikes to control excess load (flood dikes A-D, see Figure 1). These were created in locations where, in the case of excess load, the excess water with a low hazard potential can be discharged outside the river channel but in a controlled way. In traditional flood protection management, «excess load» would typically result in the uncontrolled breaching of structures (such as banks) and, in most cases, extensive damage as observed during flood events of the recent past.

The flow path used in our case for the discharged water is called a flood corridor. Buildings or settlements located in the flow path are protected to the level of their protection objective and through the implementation of local measures. 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 river section. As soon as the flood hydrograph returns to a level below the dimensioning-based water volume, flood water will again be discharged through the river channel. After the raising of the dikes, the maximum flow rate in the main settlement area between Dallenwil and Ennerberg has been 300m^3/s. After the construction of the fourth flood dike, a maximum flow rate of 150 m^3/s will remain in the river bed; this is the maximum discharge which can be channeled into the lake without causing any damage to the settlement of Buochs (Kanton Nidwalden, 2009)

This study focuses on the flood corridor of the «Stanser Talboden» which affects the municipalities of Dallenwil, Oberdorf, Stans, and Stansstad (Figure 1). The corresponding excess load dike D deviates excess waters of the Engelberger Aa into the «Stanser Talboden» in the case of very rare event (extreme flood, EHQ), which in turn will result in a residual flooding risk (noteworthy, parallel acting torrent processes are not covered in this study and therefore not considered further). A weir edge secures flood dike D (EHQ excess overload) from failure. In organizational terms, the functionality of the flood corridor is guaranteed by a documented and practiced emergency planning.

Settlement pressure at the «Stanser Talboden» is high and growth will likely continue in the future. Due to the current flood situation, it is therefore essential to guide settlement pressure and to align it within the flood corridors in a sustainable manner. Therefore, it is important to incorporate flood corridors in zoning plans of municipalities and to be able to control construction activity within this corridor through suitable provisions in zoning regulations.

METHODS

As part of the efforts to improve flood protection on the Engelberger Aa, various measures have been implemented in recent years or are currently under investigation. Based on the reference condition of the Engelberger Aa (before 2003), the following three measures have been realized or are planned:

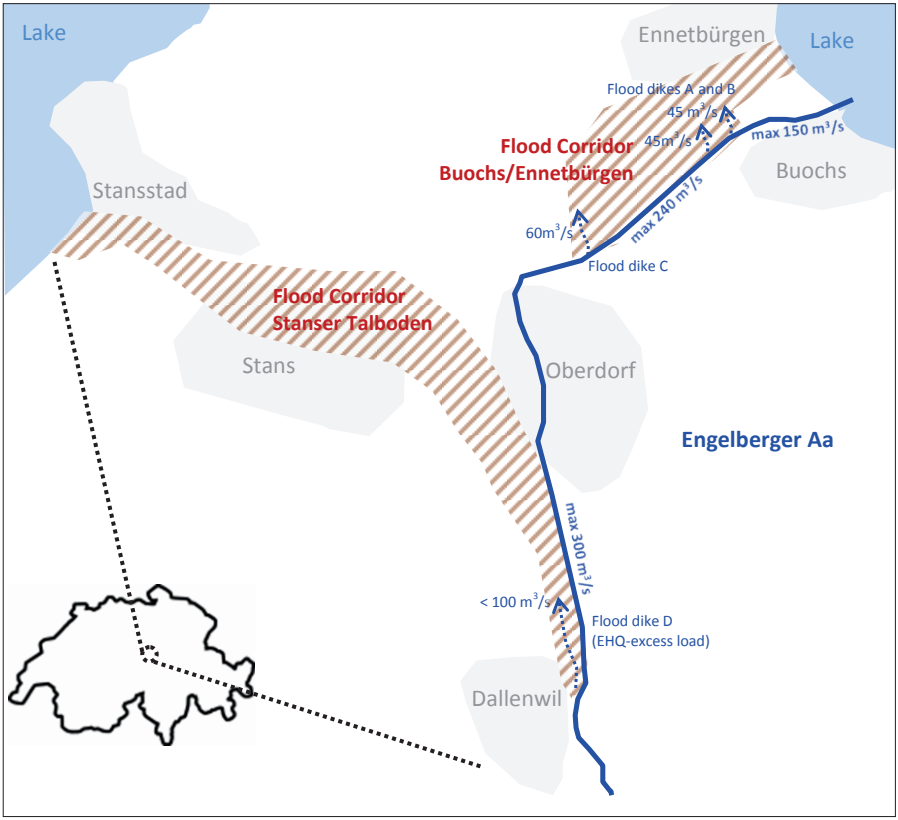

Figure 1: Schematic layout of the flood corridor within the „Stanser Talboden"

– Hydraulic Engineering: all hydraulic engineering measures within the flood protection project of the Engelberger Aa, such as spillways, dam remediation, bank protection, or flood proofing have been realized between 2003 and 2008. The associated calculations describe the risk-reduction achieved by hydraulic engineering measures.
– Organization: the existing emergency planning complements the hydraulic engineering measures and is used by the emergency services to reduce flood impacts. The associated calculations describe the risk reduction achieved by organizational measures.
– Spatial Planning: it is assumed on a notional basis that the flood corridor in the «Stanser Talboden» is spatially established in 2015 and able to control settlement evolution over the coming 70 years. It is important to mention that the flood corridor (which was built as part of the hydraulic engineering measures for very rare events) is already operational and functional. However, future settlement evolution is not yet guided by a forward-looking management like a flood corridor, which is simulated in this study.

During the investigation, we started by defining the study area within the «Stanser Talboden». The actual risk situation was then determined based on existing risk assessments (Kanton Nidwalden, 2012). As a result, settlement evolution in the municipalities of the «Stanser Talboden» was then estimated based on data from the Canton's agglomeration program (Kanton Nidwalden, 2011) for the next 70 years (i.e. until 2085). This was done as follows:

– Assumption of an average increase in population by 0.55% per year over the next 70 years.
– Definition and spatial localization of the necessary building zones.
– Combination of the investigated settlement situation in 2085 with the flood hazard situation (i.e. intensity map). Determination of process intensities.
– Conversion of potentially constructed areas into property categories.

The assumed growth scenario results in a total settlement area requirement of about 200 ha within the four municipalities. Two-thirds of this land would be required as residential land; whereas one third was defined as land for public, commercial, or industrial buildings. Within the flood corridor about 70 ha of land are defined as construction land. Noteworthy, only one-third of this surface will not be flooded by the extreme flood of the Engelberger Aa. Residential development can be controlled through the introduction of a flood corridor zone. By refining the flood corridor zone through a definition of different sectors, the guiding effect of land-use development can be optimized as follows:

– Sector A: Absolute construction ban.
– Sector B: Designation and development of building zones is not possible – especially not yet constructed areas between buildings have to be removed. No possibility to add new buildings (except for replacement).
– Sector C: Consolidation and realignment of existing building zones is possible (non-constructed areas between buildings, etc.). Existing building zones remain intact.

Commercial and industrial as well as public areas will be planned and realized outside the flood corridor – but not inside. New residential buildings will be restricted to sector C. These measures result in a reduction of the damage potential in the flood corridor, but also in a reduction of land surface suitable for construction from 70ha to about 2ha which corresponds to roughly 90 housing units which can still be realized within sector C.

We also considered property protection measures within the flood corridor, to be undertaken in the context of building renovations.

The costs for the implementation of the flood corridor can be categorized as follows:

– Compensation: costs related to the removal of building zones from the flood corridor were estimated at ca. 1,500,000.— CHF.
– Property protection measures: a contribution of 5,000.— CHF was taken into account per building which needs to be renovated.
– Procedural and administrative costs: it was assumed that administrative costs will be in the order of CHF 75'000.— CHF.

– The costs for flood dikes, protection gates, terrain adjustments or excess load protection have been attributed to the hydraulic engineering measures for the flood protection project «Engelberger Aa».

RESULTS

The hydraulic engineering, organizational and planning measures can be evaluated based on two parameters, namely effect and efficiency.
The effect can be investigated by comparing the integrated risk before and after the implementation of measures. Previous studies (Kanton Nidwalden, 2012) provide the results of the hydraulic engineering and organizational measures (Table 1). They show an overall reduction in integrated risk from ca. 4,261,000. to 1,292,000.— CHF/yr (-77%) as a result of the structural measures (Figure 1). Through the addition of organizational measures the integrated risk was reduced by an additional 400,000.— CHF/yr (or -16%).

Table 1: Effect-cost ratios of the structural and organizational measures (Kanton Nidwalden, 2012).

		Measure		
		none	Hydraulic Engineering	Hydraulic Engineering + Organisation
Risk Integrated risk	[CHF/yr]	5,553,000.--	1,292,000.--	400,000.--
Effect: Reduction of integrated risk	[CHF/yr]	--	4,261,000.--	5'153,000.--
Cost Costs of measures	[CHF/yr]	--	332,000.--	438,000.--
Efficiency Effect/Costs	[-]		13	12

Efficiency is achieved by comparing the effects of measures with their annual cost. The annual costs include investment costs as well as operation and maintenance costs. It can be shown that the hydraulic engineering measures account for ca. 332,000— CHF/yr. Additional cost for the organizational measures (ca. 106,000.— CHF/yr) increase the total coast to ca. 438,000.– CHF/yr.

Table 2 shows the effect of the spatial planning measures studied in this paper (Kanton Nidwalden, in preparation). First it can be seen that settlement activity in the following years will increase risk significantly – followed by an increase in integrated risk from ca. 400,000.– CHF/yr today to ca. 478,000.– CHF/yr in 2085. The implementation of the flood corridor can not only compensate this increase, but also reduce it to ca. 366,000.– CHF/yr, which means a reduction of 23% by 2085.

The above effect and efficiency calculations for the spatial measures were derived with EconoMe (Bundesamt für Umwel BAFU, 2015), a tool especially designed for risk calcula-

tions, and show that the implementation of a flood corridor will result in a effect-cost ratio of approximately 3 by 2085 (Table 2). Noteworthy, annual cost of 40,000.– CHF/yr for spatial planning measures have been divided into compensation of land being removed from building zones (and thus reclassified, also in monetary terms), property protection as well as administrative costs. By far the largest proportion of costs (ca. 90%) is attributed to the compensation for land being removed from the building zone. Ignoring these costs leads to a effect-cost ratio of about 26. The efficiency (effect-cost) ratio is also shown in Figure 2.

Table 2: Effect-cost ratios of the structural-organizational and structural-organizational+spatial planning measures (Kanton Nidwalden, in preparation) for the reference year 2085.

		Measure	
		Hydraulic Engineering + Organization (2085)	Hydraulic Engineering + Organization + Spatial planning (2085)
Risk Integrated risk	[CHF/yr]	478,000.--	366,000.--
Effect: Reduction in integrated risk	[CHF/yr]	--	112,000.--
Cost Cost of measures	[CHF/yr]	--	40,000.--
Efficiency Effect/Costs	[--]	--	3

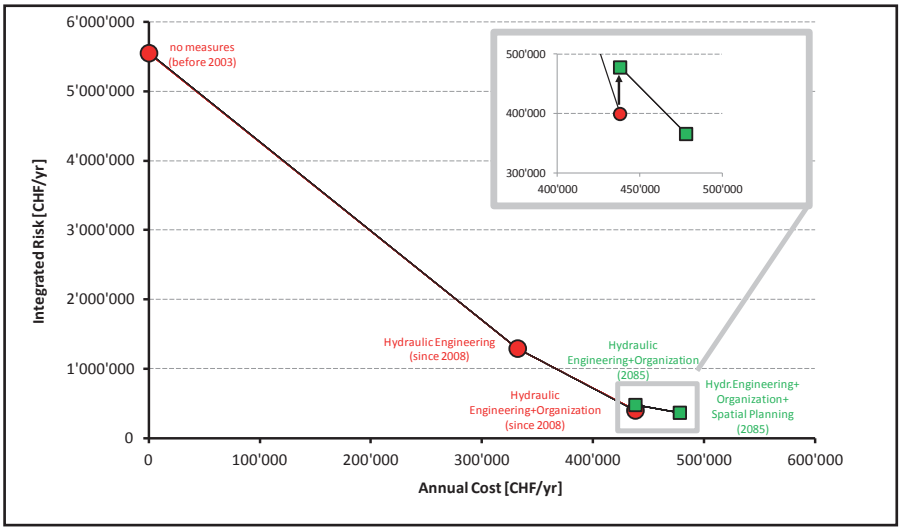

Figure 2: Effect-cost diagram.

CONCLUSIONS

The results of the structural and organizational risk analysis show a clearly positive effect-cost ratio of 13 for the hydraulic engineering and 12 for hydraulic engineering + organizational measures, respectively. The calculations are based on existing databases and are considered to be reliable.

To determine the efficiency with the spatial planning measures, we used data that we predicted for the year 2085. However, such a long-term prediction must be interpreted with caution. Furthermore, different methodological approaches of risk analysis in studies (Kanton Nidwalden, 2012 on one hand side and study Kanton Nidwalden, in preparation on the other hand side) may have led to certain inaccuracies.

Sensitivity considerations made clear that the effect-cost ratio of the definition of a flood corridor is significantly influenced by the expected construction activity and the compensation that potentially needs to be paid for land being removed from building zones. The quality of the calculated effect-cost ratio of 3 can therefore be classified as «indicative» under the above criteria.

As a conclusion, the following principles can be described:

– The designation of flood corridors form a meaningful and cost-effective complement to hydraulic engineering and organizational measures.
– The effectiveness of structural measures is continually reduced, due to the progressive housing development, thereby leading to a continuous increase in damage potential. The designation of flood corridors counteracts this effect in an economic way.
– A flood corridor is a very flexible tool which can be used to deal with future problems including climate change.

REFERENCES

- Bundesamt für Umwelt BAFU, Bundesamt für Bevölkerungsschutz BABS (2009). Adapt Alp – Case Study Nidwalden. Kurzdokumentation, erarbeitet durch die Ernst Basler+Partner AG. 13. Januar 2009
- Bundesamt für Umwelt BAFU, Bundesamt für Bevölkerungsschutz BABS (2011). RiskPlan – IT Tool fürs Risikomanagement. http://www.riskplan.admin.ch. Zugriff Mai 2012.
- Bundesamt für Umwelt BAFU (2015). EconoMe 3.0. Wirtschaftlichkeit von Schutzmassnahmen gegen Naturgefahren. www.econome.admin.ch. Zugriff 9.6.2015.
- Bundesamt für Wasser und Geologie BWG (2002). Excel Tool für die Abschätzung des Schadenpotentials Überschwemmung und Übermurung, SchaPo 2.1.
- Kanton Nidwalden (2009): Integrales Risikomanagement am Beispiel der Engelberger Aa. http//www. nw.ch. Zugriff August 2015.
- Kanton Nidwalden (2011). Agglomerationsprogramm Nidwalden 2011. Bericht. www. nw.ch.

- Kanton Nidwalden (2012). Wirksamkeit der Notfallplanung als Beitrag zum integralen Risikomanagement. Schlussbericht, erarbeitet durch die Ernst Basler+Partner AG. 18.Oktober 2012
- Kanton Nidwalden (2012). Gefahrenbeurteilung Überflutung durch Engelberger Aa. Gemeinden Dallenwil, Oberdorf, Stans, Stansstad. Technischer Bericht und Karten, erarbeitet durch die Niederer und Pozzi AG, 1. September 2012.
- Kanton Nidwalden (in Erarbeitung). Risikoanalyse. Prozess Engelberger Aa im Perimeter Stanser Talboden. Technischer Bericht.