

INTEGRATED FLOOD PROTECTION - APPROACH OF THE FEDERAL STATE OF BADEN-WURTTENBERG/ GERMANY

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Abstract: Baden-Wurttemberg, federal state of the Federal Republic of Germany (capital: Stuttgart), is striving for an improvement of flood protection. The procedure of this approach is shown here.- Pilot studies took place to prepare a standardisation of this process. For the part of the Danube belonging to Baden-Wurttemberg (length = 200 km) a **flood – risk - analysis** has been elaborated for HQ 20, 50, 100 and HQ 1000 to show the flooded areas and the occurring damages. On the basis of this a **flood protection conception** has been elaborated regarding cost-benefit-relation. The results and general conclusions are shown here. (In the meantime some flood protection systems including a flood reservoir are being planned or under construction).

All relevant organizations agreed on “**Guidelines to flood protection**“. Flood protection in principle is based on 3 columns

- precaution of surfaces and preservation of natural retention
- technical flood protection
- precaution against floods

The accompanying **Flood-Operation- Plan** says what is to do by whom to reduce the flood damages efficiently and permanently.

To identify areas, which are endangered by floods and in this way make possible the precaution of surfaces, **flood-risk-maps** should be elaborated of all catchment areas > 10 km². For this reason a digital terrain model (DTM) for Baden-Wurttemberg is being elaborated. The maps should show the flooding by HQ 10, 50, 100 and e.g. HQ 500. They are co-financed by city - and community - confederacies and other institutions. The experience of the Danube study and other pilot studies has to be taken into consideration.

Additional elements of the Integrated Flood Protection are the following:

- A **guideline** has been established, according to which flood protection systems have to have a certain cost – benefit - relation. According to this for example a HQ 200-protection should be allowed to receive funds.
- Among the communities along bigger rivers “**Flood-Partnerships**“ are in foundation to improve the preparedness for floods and helping each other during the floods.
- **Flood forecasts** are established for rivers like the Danube, and are accessible in the internet to inform and warn people. Advanced radar based prediction is in development for smaller catchment areas.
- Locations where flood protection should be improved have been identified and also the corresponding costs. This should allow to decide on priorities for the realization of such systems.
- Baden-Wurttemberg, Bavaria and the German Weather Forecasting Service are investigating the long term tendencies of **climate change** on runoff . Some results are already available.

To improve the flood- protection the state of Baden- Wurttemberg has taken several measures and prepared by pilot- studies. They shall be presented in the following.

INTEGRIERTER HOCHWASSERSCHUTZ -VORGEHENSWEISE DES BUNDESLANDES BADEN-WÜRTTEMBERG (BRD)-

Zusammenfassung: Das Land Baden-Württemberg unternimmt erhebliche Anstrengungen zur Verbesserung des Hochwasserschutzes. Das Vorgehen wird im folgenden vorgestellt. – Es wurden Pilotstudien durchgeführt, um das Vorgehen zu standardisieren.

Für die Donau in Baden-Württemberg, d.h. über eine Länge von ca. 200 km, wurde eine **Hochwasser – Risikoanalyse** durchgeführt für das HQ20, 50, 100 und 1000, um die Überfluteten Flächen und die damit verbundenen Hochwasserschäden zu ermitteln. Darauf aufbauend wurde ein Hochwasserschutzkonzept erarbeitet und zwar unter Beachtung des Kosten-Nutzen-Verhältnisses. Die Ergebnisse und allgemeinen Schlussfolgerungen werden vorgestellt. (Mittlerweile wurden einige Schutzmaßnahmen inkl. eines Rückhaltebeckens geplant bzw. gebaut)

Alle relevanten Organisationen stimmten der **Leitlinie „Hochwassergefahr und Strategien zur Schadensminderung in Baden-Württemberg“** zu. Der Hochwasserschutz basiert dabei auf den drei Säulen

- Flächenvorsorge und Erhaltung der natürlichen Retention
- Technischer Hochwasserschutz
- Hochwasservorsorge.

Der zugehörige **Hochwasseraktionsplan** legt fest, wer was zu tun hat, um die Hochwasserschäden wirksam und dauerhaft zu mindern.

Um hochwassergefährdete Flächen zu identifizieren und so u.a. die Flächenvorsorge erst zu ermöglichen, sollen **Hochwassergefahrenkarten** für alle Einzugsgebiete von i.a. > 10 km_e erarbeitet werden. Zu diesem Zweck wird ein hochaufgelöstes Digitales Geländemodell DGM für Baden-Württemberg entwickelt. Die Karten werden die Überflutungen durch das HQ10, 50, 100 und z.B das HQ500 zeigen. Sie werden vom Städte- und Gemeindegtag und anderen Institutionen mitfinanziert. Die Erfahrungen aus der o. g. Donau – Untersuchung und anderen Pilotstudien werden berücksichtigt.

Zusätzliche Elemente des integrierten Hochwasserschutzes sind:

- es wurde eine Empfehlung erarbeitet, welchen Kosten-/Nutzenverhältnissen Hochwasserschutzmaßnahmen genügen sollen. In entsprechenden Fällen soll dabei auch ein HQ200 – Schutz in Betracht kommen
- für größere Flusssysteme werden sog. Hochwasserpartnerschaften gegründet, um die Hochwasser –Vorsorge der Kommunen und die gegenseitige Unterstützung vor und während des Hochwassers zu verbessern
- Hochwasserprognosen sind für Flüsse wie die Donau über das Internet verfügbar. Für kleinere Einzugsgebiete ist die Radar – gestützte Hochwasservorhersage in Entwicklung
- Strecken, wo der Hochwasserschutz verbessert werden sollte, wurden erhoben inkl. der zugehörigen Baukosten. Diese Aufstellung erlaubt eine langfristige Mittelplanung und Priorisierung der Maßnahmen
- Baden-Württemberg, Bayern und der Deutsche Wetterdienst erforschen die Auswirkungen der Klimaänderung auf die Abflüsse. Wichtige Ergebnisse sind bereits verfügbar.

I. Flood risk-analysis for the Danube-River in the state of Baden-Württemberg and the derived conception for flood-protection

After several damaging floods, the last occurrence in 1990, the communities along the Danube-river belonging to Baden-Württemberg, i.e. upstream of the city of Ulm, postulated the improvement of flood protection along the Danube including the rivers Brigach and Breg, the “wells“ of the Danube. In 1992 the state government decided for the Integrated Danube

Program (IDP) with the purpose to integrate flood protection and renaturalization of the Danube river, whereby the renaturalization itself should contribute to flood protection too.

To get the fundament for then planning the flood protection system a flood risk - analysis has been performed. Its objective was to determine the damages due to floods of various return periods. This had to be performed for the actual state and for 1,2,3 and 4 dams (flood reservoirs). It should indicate where additional local flood protection by walls and dykes would be necessary. Especially it should show

- the areas flooded by HQ 20, 50, 100 and HQ 1000
- the induced damages
- flood-maps of the endangered areas (“Hochwasser-Steckbrief“) in every community (→ webpages showing the danger for every building by the HQ 100 and the HQ 1000 (“remaining risk“))

Procedures and used techniques

The most advanced techniques have been used for the risk-analysis, thus getting a “pilot-project“ for other river-basins:

- Laser-scanning of the Danube river including its inundation-area (200 km_l) over a length of 265 km to get a DTM: 1 level-point per m_l with a reliability of ± 10 cm
- New determination of the runoffs for the Danube incl. HQ 1000 without and with the effekt of dams
- Calculation of the water-level for HQ 20, 50, 100 and HQ 1000
 - in the first calculation-range (72 km): 2-dimensional calculation
 - in the upper range: 1-dimensional calculation

The calculation has been calibrated by the measured level of the 1990-flood (appr. HQ 40)

- Determination of flooded areas and corresponding damages by GIS- tools
 - for 4 dams with a total volume of 12,5 Mio m³ (original conception)
 - for 3 dams
 - for 2 dams
 - for 1 dam with a content of appr. 5 Mio m³

For this purpose the following steps had to be taken:

- Determination of all buildings by use of the Official Digital Register of Buildings (including use, size and building-age)
- Establishing the extent of the damages of “standard-buildings“ and determination of damages in great factories by individual estimations
- Summing up all flood damages and comparing the flood damages found for HQ 50 with the known damages caused by the 1990 flood.

Planning the flood protection system

The objective of planning was a system generally assuring protection against the HQ 100, preserving natural retention areas and using technical flood protection systems. The conception has to fulfill the requirements of modern water management and has to be optimized to cost-benefit. The “Conclusive Comprehensive Conception for flood protection (“Abschliessendes Gesamtkonzept zum Hochwasserschutz“) for the Danube–river in the state of Baden-Wurttemberg“ was finished in 2003. It has been agreed by all communities who will be profiting by this project. This conception has as constitutive elements

- the preservation of the natural retention in inundaded areas
- no enhancement and no accereleration of the flood wave
- the construction of 1 dam containing 5 Mio m³

The 22 communities situated downstream of the dam agreed to pay 30% of the dam-building costs in acknowledgment of their advantage. In addition all communities acknowledged the "guidelines of flood-protection"; thus flood protection is based on 3 columns

- precaution of surfaces and preservation of natural retention
- technical flood protection
- precaution against flood.

Further Procedure

Planning the dam has been completed and submission to judicial approval will be finished shortly. The additional local flood protection systems are under planning for every community, respectively planning is completed. Some systems are under construction: local dykes, walls, mobile doors and special protection fixed at the buildings themselves. The state is financing a certain percentage of the flood protection. Pumping stations, which are part of the sewage system, and the protection against ground water are not the subject of planning and sponsorship by the state.

Further information by [www. 4gwd.de/riedlingen](http://www.4gwd.de/riedlingen), compare "Wichtige Projekte".

General conclusions from this project

- 1-dimensional-calculation of the water level is generally sufficient for the risk-analysis. Improved 1- dimensional calculations have been developed determining appropriate cross-sections automatically. 2-dimensional-calculation is advantageous only in complex local situations.
- Dams alone are not generally appropriate to get economic flood protection. Thus in addition to dams in general, local flood protection systems are needed. Dams should be planned only as far as absolutely necessary, since
 - they cause high costs for building and maintenance
 - they make natural retention areas malfunctionThus the costs can be reduced significantly by planning only a few dams. The local dykes therefore have to be heightened only a few centimeters which does not cause significant additional fees.
- Performing the flood-risk-analysis and establishing the final flood protection conception was expensive: 1 Mio € had to be paid to highly qualified consulting engineers. The Gewaesserdirektion (water management authority) itself had to do considerable additional work during 3 years. On the other hand costs of appr. 50 Mio € could be avoided by this investigation of the river-basin.
- For areas with significantly enhanced flood risk, for example HQ 200-flood protection should be planned. In contrary a HQ 20 - HQ50 - protection should be sufficient in situations with an unfavourable cost-benefit-relation.
- The flood-maps can be used as model for comparable maps for other rivers.

II. Flood-operation- plans for the Danube in Baden-Wuerttemberg

Purpose of the flood operation plan

The purpose of the flood-operation-plan ("Hochwasser-Aktionsplan") is to reduce the flood damages in an efficient and permanent way. This demands the cooperation of all people and organisations negotiating with the Danube-river and its catchment area: The Flood-Operation-Partnership (Hochwasser-Partnerschaft). An integrated flood management is called for. The objective must be: Let's take care together!

Every flood- protection is limited to a certain level (e.g. on the HQ 100).The flood-danger does not end at the dykes. Thus a risk remains; the so-called "rest-risk".The corresponding flood damages can only be reduced by the so-called Further-Reaching-Flood-Precaution, consisting of structural precaution as well as by appropriate conduct by the inhabitants and

the fire brigade. Thus a small expenditure can reduce the flood-damages considerably; this concerns danger, e.g. by the HQ 500.

The flood operation plan represents the Agenda of a Partnership for the flood-precaution, concerning the whole catchment-area of the Danube in Baden-Wurttemberg. The guideline "Flood-Danger and Strategies for the Damage-Reduction in Baden-Wurttemberg" has been established to determine the flood-endangered areas and the dealing with it. This guideline has been elaborated by:

- the city and community confederacies
- the environmental planning
- the disaster control
- the insurance association
- the industry
- the water management authority

Who is doing what?

- The water management authority (Gewaesserdirektion) is elaborating the below mentioned flood risk -maps on the scale of 1 : 10.000. The water levels there are associated with levels at gauging-stations. These maps will be handed over to the communities and will be shown in the internet.
- The regional planning associations transfer the endangered areas onto maps for land use for the purpose of precaution concerning areas and buildings.
- The county's head-quarters (Regierungspraesidium) in their function as authorities for the regional planning make sure, that the building by-law is legitim and that the possibilities of precaution, concerning areas and buildings, are really used.
- The county's administration makes sure that oil-tanks and comparable tanks will be secured appropriately
- The communities
 - publish the flood-endangered areas outside and inside of settled areas on maps
 - are updating alert - and action-plans
 - do not use flood-endangered areas as building-sites. On the contrary, they preserve them as natural retention areas
 - make sure appropriate types of construction and use of flood endangered areas inside of existing building-sites
 - inform the inhabitants about the flood-danger and set flood-marks at exposed points
- In settled areas the inhabitants should build new buildings only appropriately and provide supplements to the existing buildings with things necessary to reduce flood-damages. The inhabitants take out insurances.

According to this procedure several Flood-Protection-Partnerships have already been founded for river basins in Baden-Wurttemberg. The communities and the other partners will discuss every year how the flood protection can be improved. The experiences made from floods have to be taken into consideration.

III. Flood risk-maps

Summary: At present the state of Baden-Wurttemberg is producing so called flood risk-maps for all greater rivers and streams. They should show the inundation due to HQ 10, HQ50, HQ100 and for example HQ 500. Thus settled and nonsettled flooded areas can be identified as endangered. Areas endangered by the HQ 100 should not be settled.

The intensive use of valleys is the reason for increasing flood damages. Therefore it seems necessary to know the endangered areas to avoid flood damages from the start or, at least, to minimize them. Thus an urgent need for flood risk-maps for whole the state has

been emphasized by all persons involved. These maps should show the flooded areas and the corresponding water depths during floods of various return periods and - further more - they should show by means of extrem historic events the threat of additional areas. On the basis of such maps optimized conceptions can be elaborated for flood risk precaution and for an appropriate flood risk management .

In the future the following efforts for the technical flood protection are required:

- The **municipal environment planning** has to fix areas for the precluding flood protection to match different claims and to balance conflicts at different levels of planning.
- Framework for the communal environment planning should be given by fixing objectives and principles for flood endangered areas in the **state's environment planning**.
- Especially the **communities** have to consider the flood-endangered areas of their settlements. They must improve security measures for men and buildings. Precaution and disaster prevention have to be prepared appropriately to save men and values during floods. Alert plans and action plans are required and in addition exercises to guarantee fast action during floods and a good interaction with other authorities and officials. The people in endangered area can contribute to damage reduction using the homes and buildings in an appropriate way and using insensitive building materials.
- A technical protection for extreme levels of flooding cannot be financed; therefore it is necessary to take precaution by regional planning and by sharpening the **flood-consciousness** of the population. The representatives of the above mentioned organisations have proposed a programme with 10 points concerning Flood-Partnerships and Flood-Operation-Plans. Thus the flood-danger should be kept permanently in mind.

Content of flood maps

A modern flood management needs to know where areas are which will be flooded, and in which periods of return this will happen again. These areas need to be protected by flood-protection-measures:

- Within HQ 10-areas agriculturable land should not be ploughed to avoid erosion by floods. Within HQ 10-areas the flood danger is so great, that an insurance of buildings against damages caused by floods is not possible
- Buildings outside of HQ 50-areas can be insured against flood damages by insurances with normal insurance-costs
- HQ 100-protection is commonly seen as sufficient for settled areas
- For objects wit high damage potential flood precautions should be advised even on areas flooded by HQ 500 or HQ 1000. The damages can be reduced to a tolerable extent by taking relatively cheap measures of construction and management ("minimizing the damage"). Such objects are central computer-systems, transformers of electricity, switchboards, precious files, libraries and oil/ fuel-tanks.

Considered rivers and rivulets

In a state the size of Baden-Wurttemberg (35.000 km₂, 11 Mio. inhabitants) not every flow can be considered. Thus the flooded areas should be elaborated for the following areas:

- Rivers or rivulets, as soon as the catchment areas are bigger then 10 km₂. Where settled areas are endangered, even catchment-areas of > 2 – 3 km₂ can be considered. If the banks are settled, or a settlement can also be imagined, the hydrostatic backwater of these waters into the tributaries has to be considered
- in special cases additional areas can be also considered, especially where settled areas are flood-endangered
- dry water courses, except in raining seasons ("wadis")

It is not necessary to take into account rivers

- in purely forestal regions
- in deeply carved-in river beds
- in national parks and in water protection areas where ploughing is prohibited.

Procedure of work

The work has been prepared by establishing a DTM (Digital terrain Model). Baden-Wurttemberg has been scanned by laser. The corresponding data will partly be available only in 2005 or 2006. If needed, the raw data can fastly be transformed into usable data by consulting engineers.

The flood risk maps will be done essentially by consulting engineers, conducted by the water management authorities (Gewaesserdirektion). Good support by the communities is needed.

1st step: An analysis of necessity shall show which data are available and can be seen in fact as reliable. Points of interest are

- hydrology, e.g. precipitation-runoff-modells
- local DTMs
- cross-sections of bridges
- cross-sections of rivers

Thus it can be derived where terrestrial measuring is needed to gain the flow profiles of a river combining the DTM and the cross-sections of the river. Inside of settled areas and in potential settlement areas, cross- sections in distances of 50 - 100 m are generally needed (with greater rivers eventually in greater distances), in purely agricultural areas, where a settlement can be excluded, profiles in a distance of e.g. 200 m are sufficient to gain "typical profiles", which can be "hanged in" in the DTM. - This analysis is being worked out at present.

2nd step: Survey

The areas to be handled contain 500 – 1.200 km² with a river length of 50 – 150 km. For pilot-areas the survey has been ordered already. The costs are estimated to 100.000 €.

3rd step: Hydrology and hydraulics

The discharges will be determined by means of data given by the LfU (Landesanstalt fuer Umweltschutz = Institute for Environmental Protection of the State of Baden-Wurttemberg). For very small catchment-areas and very great return periods as e.g. $T_x = 500$ or 1.000 years the LfU will give an appropriate procedure.

The water levels have to be determined for HQ 10, 20, 50 and 100 and for example HQ 500. Some consulting engineers are planning 2-dimensional calculation.

4th step: Representation through maps

In 4 pilot-projects showing all configurations of interest the most efficient procedure, and especially the graphical GIS-supported representation, has been developed. Thus the form is fixed of how to represent the flooded areas and the depth of inundation. - The consequences of overflow over dykes and of dyk-breaking should be mapped, too.

Time schedule and available resources

It is planned to finish this work within 8 years. Thus it would be possible that a consulting engineer works on 3 areas in succession.

For this project approximately 20 Mio. € are available. From this, 5 Mio € are expected for survey work and proportionate financing of the DTM. – It concerns a very great and ambitious project. From the point of view of the author, in 2 years an assessment will be possible, if the chosen procedure can be kept unchanged.

IV. Flood-prediction by the HVZ

The Hochwasser-Vorhersage-Zentrale (HVZ = Flood-Prediction-Headoffice) of the state of Baden-Wurttemberg gives prognosis for floods to be expected in greater rivers as soon as

certain discharges are exceeded. The prognosis is published in the internet (www.lfu.baden-wuerttemberg.de/lfu/hvz/). For measuring stations with a long flow-time, prognoses are possible for 6 – 24 hours.

The prognoses are given as diagrams. Therein historic flood-levels are noticed. They allow the inhabitants and the officials to estimate the magnitude of the expected flood and to take appropriate measures to protect the buildings.

For rivers with a small catchment-area this kind of prognosis is not possible. However the HVZ tries to measure the rain-intensity by radar and to give a flood prognosis with the aid of a precipitation-runoff-model, so that the population can be warned.

V. Climate Change

Baden-Wuerttemberg, Bavaria and the German Weather Forecasting Service are investigating the long term tendencies of climate change on runoffs. Some results are already available.