BEYOND 2D-HYDRAULICS – LOGISTICS AND ORGANISATIONAL MEASURES OF REGENSBURG'S FLOOD PROTECTION PLAN

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Abstract

Flood events in very last decades showed the necessity of improving flood protection measures along German rivers. Next to prevention activities also structural measures will play a major role in the upcoming years. Hereby in urban areas more and more mobile flood protection systems will be used. Supporting local decision makers in protecting the city of Regensburg and their inhabitants against floods, most crucial questions occur beyond pure hydraulic analysis. Hence this paper presents an overview of essential questions and problems that have to be answered when using mobile flood protection systems and setting up a customized flood protection plan.

Introduction

Several severe flood events took place in the very last decades (e.g. 1988 and 2002) and led to considerable economic losses in downtown Regensburg. Protection measures against floods with a 20-year return period are already finished. Those mainly include mobile flood protection systems along nine river sections with a total length of ~1.400 m and an area of ~1.800 m². The installation of the protection systems was successfully proved during the last flood event in January 2011. In contrast measures against a 100-year flood include mobile flood protection systems with a total area of ~7.500 m² at 21 different river sections. Those measures are in the process of planning. Analogical to the 20-year flood event a detailed logistical analysis was carried out, detecting enormous future challenges for the city's decision makers and employees. This paper presents, how all analysis carried out are merged in a digital flood protection plan. To achieve this goal many different aspects in the fields of logistics, employment law and time management have to be considered.

2D-hydraulics carried out

Large areas in the center of Regensburg are endangered by floods of river Danube and river Regen. 2D-hydraulics were carried out for return periods from 20 to 100 years. Those are based upon on steady state boundary conditions and a completely 2D-approach. Flood areas in downtown Regensburg are significantly influenced by the concurrence of different discharge values of both rivers leading to varying discharge combinations.

Return period of 20 years

Since protection measures against 100 year floods will not be finished within the next couple of years, the city of Regensburg decided to set up preliminary flood protection measures against floods with a return period of approximately 20 years. For this purpose nine river sections were determined, where relatively small protection measures allow for a maximum of flood protected areas. By simulating 196 discharge combinations of river Regen and river Danube, flood areas covering the whole range of possible discharge values of both rivers were detected.

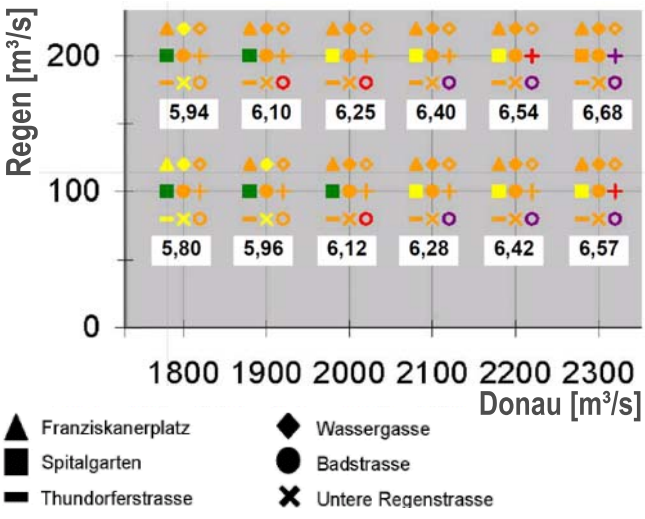

Figure 1: Matrix of discharge combinations and their impact on flood protection elements (excerpt; compare figure 2), (Øverland et. al., 2011)

Additionally for each of the nine spatially separated protection systems a analysis of critical water levels was performed. This analysis allows for specific information on e.g. when a protection system has to be installed, when the evacuation of flood protected areas behind the protection

system has to start or when the protection system will be overtoped. Figure 1 and figure 2 illustrate the impacts on nine different river section corresponding to specific discharge combinations on river Danube and river Regen. For example at river section “Spitalgarten” (indicated by a quadrilateral in figure 1) at discharge combination 2.100 / 100 or 2000 / 200 the impact on the flood protection system turns from green (“below construction height”) to yellow (“above construction height”). Additionally to each combination the water level at gauge Eiserne Brücke is provided.

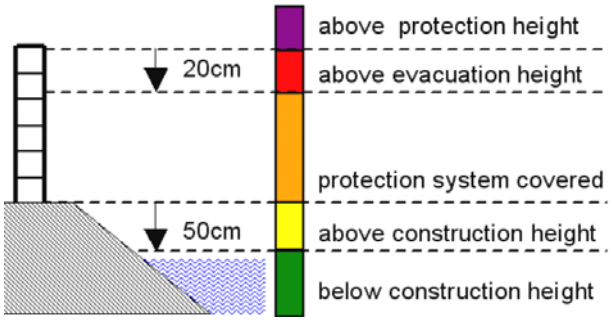

Figure 2: Schematic cross section of a flood protection system and its division of water levels into impacts (Øverland et. al., 2011)

Return period of 100 years

The areas which are affected by a flood with a return period of 100 years were determined by 2D-hydraulic water level analysis by Dr. Blasy - Dr. Øverland Beratende Ingenieure GmbH & Co. KG in the year 2005 (Dr. Blasy – Dr. Øverland, 2005). A huge amount of different planning measures in and near the city of Regenburg are based on this simulation. Step by step the protection measures against 100 year floods will be planned and built in the upcoming years. All of those measures will be based on further hydraulic analysis.

Flood forecasting

Detailed information on water levels and amounts of discharge along Bavarian rivers are provided by the Bavarian Environment Agency (LfU). The information on hydrological data in the area of Regensburg accessible by public users is provided by the gauges “Marienthal” (Regen), “Eiserne Brücke” and “Schwabelweis” (Danube). The gauge “Marienthal” offers data about both water level and discharge, but is located approximately 30 kilometers in the north of Regensburg. As a rule of thumb this relatively long distance was summed up to time slot of approximately six hours. After this time slot discharge values originally recorded at gauge “Marienthal” were used at the city limit of Regensburg. As for flood protection measures as accurate hydrological data as possible were needed, this huge spatial gap between Regensburg and gauge “Marienthal” was not optimal.

Along river Danube within downtown Regensburg the data of the gauges “Eiserne Brücke” and “Schwabelweis” are provided by the LfU, where gauge “Eiserne Brücke” only records water levels. As flood protection measures are based upon discharge values (compare section “2D-hydraulics carried out”), the information on water levels is not sufficient. In contrast gauge “Schwabelweis” provides information on both water levels and discharge values, but is located downstream the concurrence of river Danube and river Regen, which makes it difficult to separate the portions of discharge between both rivers. To sum up the public accessible hydrological information by the LfU on the one hand is very detailed, fast accessible and supplemented by statistical and historical data. On the other hand this public accessible data doesn't fulfill the specific needs on hydrological data for local decision makers.

Hence in cooperation of the city of Regensburg and the LfU two customized virtual gauges at river Regen and river Danube were set up. These gauges are placed close to the city's boundaries and provide calculated data on discharge values (compare figure 3). The gauges data is not accessible for public users, instead being only provided for local decision makers.

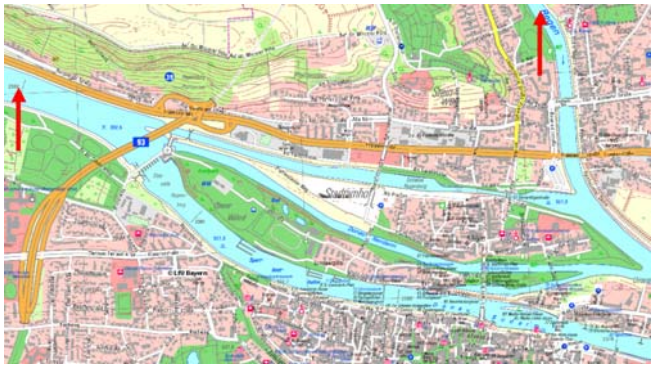

Figure 3: Location of virtual flood forecast gauges (Øverland et. al., 2011, © LVG Bayern)

Next to the recording of actual discharge values, the more importing information is those on forecasted values. Up to a forecast period of three days respectively 72 hours the development to higher or lower discharge values can be observed via tabular data or a graphic in form of a diagram. The diagram is composed of three branches. Starting from the latest available measurement the branches represent the same discharge value. The upper and the lower branch correspond to the maximum and minimum value of expected discharge, representing the 90 % and 10 % percentile. The more the forecast heads to future periods of time, the more the upper and the lower branch diverge,

which illustrates the increasing uncertainty of the forecast.

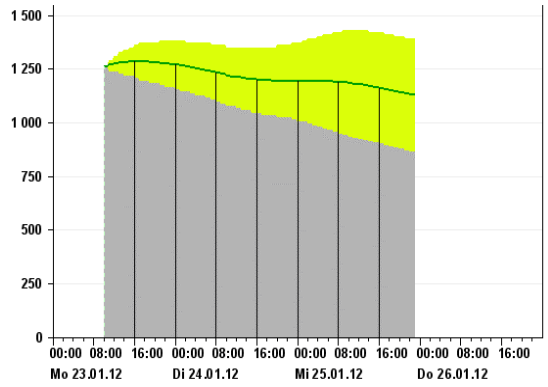

Figure 4: Diagram of flood forecast at virtual gauge Danube (© LfU Bayern, 23.01.2012)

The statistical median of the upper and lower branch is shown by the third branch placed in the middle of the area of uncertainty (compare figure 4).

Pre-warning periods

In the preface of a flood event many different things have to be considered by decision makers in order to guarantee the flood protection measures to be as optimized and well organized as possible. The most crucial question coming up when facing a flood being forecasted is "How long do we have time to do that?" Having carried out an analysis of historical flood events, the mean rising times of water levels within flood events on river Danube and river Regen were determined as approximately 5 cm/h (Øverland et. al., 2011). Looking at the daily work of the local decision makers there is a huge difference in when a possible flood is being forecasted for the first time and when the maximum amount of discharge values are expected to occur in Regensburg.

As an ideal constellation a possible flood is being forecasted at the beginning of a week with the maximum amount of discharge occurring on Wednesday or Thursday. This constellation allows the decision makers to have access to all employees that are working during the week. Possible changes within the ongoing flood forecasts (either forecasted discharge amounts more and more increasing or turning out to be a "false alarm") can be dealt with easily, since the whole pool of employees is present anyway.

What can be seen as the worst constellation in the time line of a flood event, is a flood being forecasted at the end of the week (e.g. Friday). This leads to the necessity of putting employees to standby service during the weekend, which results to higher costs, since employees are eligible for a higher salary and the time period of standby service has to be compensated during the upcoming "normal" working days. Since the number of employees needed for flood protection measures vary accordingly to the expected amount of discharge values, decision makers permanently have to observe the flood forecasts.

Deployment law

An analysis of deployment laws valid for employees working as civil servants can be summed up to following major regulations:

- at maximum 10 hours per day as long as overtime is reduced within the next 6 month
- a break of 30 minutes after 6 to 9 hours of work; 45 minutes break after more than 9 hours of work
- at least 11 hours of uninterrupted break after daily working time

But as soon as a emergency comes up, those regulations can be overruled. Since preventing a city and their inhabitants against a flood event can considered as an emergency, the regulations mentioned above are no longer valid and overruled as long as the flood event is going on.

Training on installing mobile flood elements

If no flood causes the installation anyway, the city of Regensburg initiates their employees to install the mobile flood protection systems for training purposes at minimum once a year. During those trainings for each of the protection systems a form has to be filled, in order to derive some logistical parameters. The form contains information on following points:

- beginning and end of the installation (i.e. duration)
- number of men needed to install the protection system
- trucks and special devices needed
- time needed for transportation from the depot
- problems coming up during installation

Since the area of each protection systems is known, statistics concerning the performance achieved during the installation of each protection system can be derived. Until now the training installations were only performed with the protection systems of the so called basic protection against floods with a return period of 20 years.

Types of mobile flood protection systems

Mobile flood protection systems in Regensburg are either of the type "mobile wall" or "catastrophe protection system" (compare figure 5).

Figure 5: Catastrophe protection systems (left) and mobile walls (© IBS, 2012)

The type “mobile wall” equals the German definition “Dammbalken- /Dammtafelsystem”, whereas the type “catastrophe protection system” corresponds to “Klappbares System” (BWK, 2005).

The average work performance in installing mobile flood protection systems of the type “mobile walls” during training sessions is approximately 4,5 m² per man and hour. This kind of mobile protection type is used for full protection against a 100 year flood. Evaluations assume that the complete set up of the approximately 1.800 m² in basic protection can be done with 50 men in 12 hours.

Full protection - 100 year return period

A planning competition of the year 2006 defines mobile flood protection measures at 21 spatially separated river sections. The mobile protection systems vary from small-scale so called gap closing to the extensive protection of long-range river sections. The total area of the mobile flood protection measures for full protection amount to approximately 7.500 m².

The personnel and time requirements to set up the necessary mobile protection devices for full protection can be roughly determined from the logistic evaluations carried out within basic protection (compare section “Training on installing mobile flood elements”).

The determination is based - among other things - on the following assumptions:

- The work performance by installing protection systems above 2 m altitude decreases by 25% since loader or scaffoldings are needed or it is necessary to work over one’s head.
- A construction crew consists of at least six men.
- A crew can work in several setting up places.
- The timeline of a construction sequence is divided into sections of 6 hours.
- The activities within logistic (transportation of containers, cleaning of foundations, enforcing the parking ban, monitoring, etc.) and the installation of the protection elements are evaluated separately.

Tasks during flood events

A flood event causes a lot of different tasks to be carried out in the preface, during and afterwards the mere flood.

Allocation of no parking zones

The installation of mobile flood protection elements within the closely settled areas of downtown Regensburg can only be carried out if enough space is accessible. The transport activities, the placing of the containers storing the components of the flood protection elements and the installation itself need sufficient space. Therefore as soon as a flood forecast turns out to be severe enough for the mobile elements to be installed, the allocation of no parking zones along the corresponding river section has to be carried out. As soon as the no parking zones are defined, those zones have to be monitored, since some of the car owners could absent. If in the very preface of the beginning of the installation still cars were present, they have to be towed away.

Cleaning of surface and defrosting or cleaning of fittings

Catastrophe elements are fixed to the ground via vertical nails put in small fittings. Those fittings have a quite small diameter and are anchored in the ground. If those pegs are filled with dirt or in wintertime with ice, the cleaning respectively the defrosting could be necessary if the vertical nails of the catastrophe elements can’t be put into some pegs.

The sealing of the lowermost horizontal layer of the mobile flood protection system against the ground surface is done by a rubber lip. This lip is able to compensate smaller vertical changes on the surface, but doesn’t work with major obstacles like e.g. stones or branches. Therefore the foundation of the protection elements has to be cleaned before their installation.

Transportation of containers

The containers storing the different components of the flood protection systems are stored in different depots outside the city center. For basic protection 23 containers are needed, each of them uniquely prepared and transported to a specific flood protection system. The transportation times of each container depending on its destination point was calculated.

Installation flood protection elements

Once the above mentioned prerequisites are fulfilled, the installation of the flood protection elements can start. Depending on the specific characteristics of the single protection systems (height, length, accessibility, manpower needed) the time needed for installation varies.

Surveillance of flood elements

Once mobile flood protection systems are installed, they have to be monitored for the whole period they are installed. On the one hand they have to be checked for the sealing to be working and on the other hand vandalism has to be prevented.

Managing of tasks

The tasks described above have to be arranged in a way that the manpower needed is as minimal as possible. Additionally the tasks have to follow a logical sequence. As soon as the parking zones are allocated and the corresponding surfaces were cleaned, the transportation of containers can start. Once the containers are available at the designated areas, the installation of the protection systems can be initiated. Finally the surveillance of the erected protection systems has to last as long as flood event continues (compare figure 6).

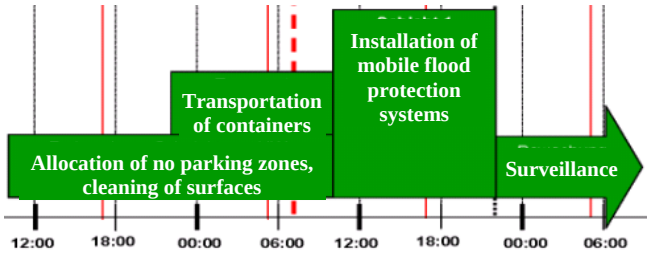

Figure 6: Schematic arrangement of necessary task during a flood event (compare also figure 7) (Dr. Blasy – Dr. Øverland, 2009)

Determining the manpower needed by full protection

According to the average rise time of a flood wave on the Danube (approximately 5 cm/h; compare section "pre-warning periods") and the available flood forecast, (24 and 48 hours) the timing of the high water deployment is outlined.

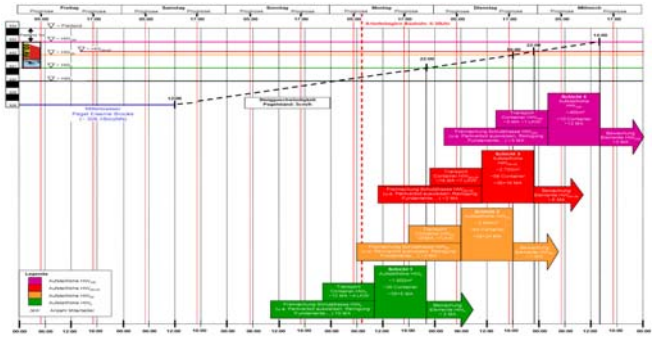

Figure 7: Operation schedule of using mobile flood protection systems during a 100 year flood (Dr. Blasy – Dr. Øverland, 2009)

The time scale covers a period of 5 days beginning with receiving the first hydrological forecast (compare figure 7). The ordinate shows, starting from the middle water level at gauge "Eiserne Brücke", a constantly rising water level up to a 100 year flood, regarding the mentioned average rising time of 5 cm/h.

The mobile flood protection elements needed to be installed by facing a 100 year flood can be divided into four groups. Each group is defined by the water level, at which the elements have to be installed the first time. Those water levels represent the return period of a 5 year flood ("HW_5", green) and a 20 year flood ("HW_{20}"; yellow). Additionally the red color represents the virtual water levels of a 20 year flood plus 25 cm in height ("$HW_{20+25cm}$"), which was used within the planning competition in 2006. The purple group sums up all other protection elements with heights above the red group, almost all of them representing a 100 year floods water level ("HW_{100}"). Each of the groups is arranged as shown in Figure 6. To each of the tasks the manpower needed was derived.

The total area of the mobile flood protection measures for full protection is ~7.500 m². Hereby the protection elements HW_{20} and $HW_{20+25cm}$, which have to be set up immediately after each other, contribute already with 80% of the total area. Therefore the installation of all protection systems needed is not feasible in a single day of construction. A shift operation is necessary. The installation of the protection element groups presupposes that the transport, the containers as well as other preparatory measures are completed when starting the installation.

This means e.g. for a forecasted 5 year flood, that at latest 48 h after receiving the first forecast the installation of the mobile protection systems (11 different installation places, total area ~1.200 m²) has to be initiated. Before starting the installation (42 h after the forecast was received), the transport has to be completed, which in turn requires finishing the preparatory measures 32 h after the forecast. After completing the construction the monitoring of the

protection elements starts. In case of a constantly rising flood wave the construction of all protection element groups is done according to this scheme, so that at each step of the time scale the manpower requirements for construction and logistics can be derived.

The total manpower needed can be calculated from the maxima of people required within group "HW_{20}" (67) and group "$HW_{20+25cm}$" (87) which can be summed up to 154.

Consequences for further planning

The total area of the mobile flood protection measures for facing a 100 year flood is about 7.500 m² and can be dealt by a manpower of 154 people (compare section above). By far the number of available employees of the city of Regensburg is not sufficient. And a recruitment of additional staff is critical since next to flood protection tasks, a lot of other things have to be coped with during a flood event (e.g. evacuations, police work, etc.). Hence the installation of ~7.500 m² of protection systems regarding the available manpower and the time slots available, seems to be a goal that can't be achieved.

As a consequence within the upcoming planning of protection measures a general order to minimize the amount square meters of the mobile flood protection elements seems to be reasonable.

Digital flood management plan

During the work on the hydraulics and logistical considerations a lot of documents and maps were produced. In case of a flood event occurring, local decision makers need to have access on all required data as quick and comprehensive as possible. As one possible solution to achieve this goal a digital management tool seemed to be appropriate. Hence based upon different schematic maps a fully linked digital document was developed (compare figure 8).

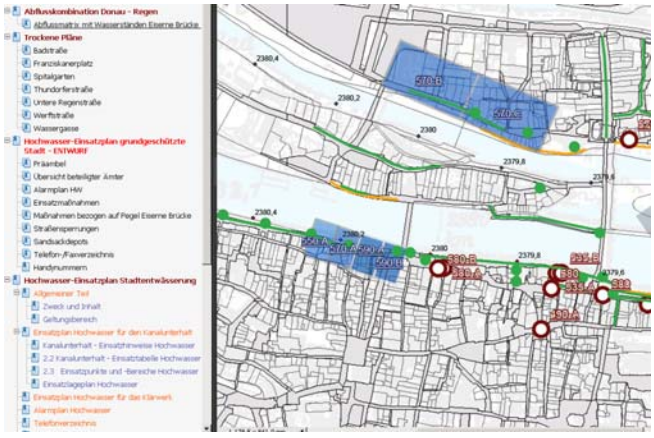

Figure 8: Digital flood management plan (section) (Dr. Blasy – Dr. Øverland, 2009)

This document allows for a quick access to flood forecasts and for evaluating the specific impacts of the forecasted flood event on the mobile flood protection systems. Additionally further information on e.g. the sewage system, different construction plans, address data etc. is available.

Conclusion

It could be shown that based upon and beyond pure 2D-hydraulic computations and detailed analysis a customized support for local decision makers in the city of Regensburg could be achieved. Problems occurring within the use of and the daily work with mobile flood protection systems are shown. Logistical requirements in the preface, during and afterwards a flood events are stated. Based upon the local decision makers experience possible solutions and guidelines for flood protection measures are identified.

Future developments could be carried in the field of a increased using of GIS technologies to exploit the huge data base of hydraulic computation for customized decision maker needs.

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