Flood Forecasting and Flood Defence in Cologne.

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ABSTRACT: Cologne, 1,000,000 inhabitants, is Europe's most flood prone metropolis. Increasingly frequent floods put major parts of the historic city as well as large industry facilities at risk: The December 1993 flood striking the rather unprepared community caused damages of approximately € 75 million. Improvements in flood provision and flood risk management led to significantly reduced damages of € 32 million in the January 1995 flood which was of the same magnitude than the preceding one.
The closeness of the two events and the feeling that only some additional centimeters in the 1995 flood peak level would have affected about 125,000 inhabitants led to a mentality change and the introduction of a sustainable flood protection scheme in 1996.
The scheme involves provision of flood plaines as well as reconstruction of river embankments and further improvement of flood response. Significant effort was undertaken to merge flood forecasting and response measures into an electronically distributed emergency plan which facilitates rapid reaction and remedies communication deficiencies. Documentation of flood response will lead to a knowledge management system which alleviates transfer of know-how between consecutive generations of disaster managers. The integration of a geographic information system into the currently implemented flood management system will lead to a new generation of disaster mitigation tools for urban areas.

1 INTRODUCTION: THE 1993 AND 1995 FLOODS IN COLOGNE

The December 1993 flood striking the rather unprepared City of Cologne had desastrous effects: Material damages totalled at €75 million. The Cologne population hadn't experienced such a flood since 1926 and the Disaster Management was in quite a weak state. Therefore a reorganisation of the municipal disaster management was tackled after the 1993 flood. The outcome of this reingeneering process was excellent as the 1995 flood exemplified: The January 1995 event was of the same magnitude as the 1993 flood but good preparation of inhabitants and flood protection authorities showed impressive results: Damages totalled at "only" €32 million or roughly 40% of the '93 damages.

Several reasons for that success can be identified. Firstly, the optimized emergency management centre effectively deployed human resources. 125,000 man hours where invested in emergency measures during the flood. Secondly mobile flood protection walls were extensively used: 1,400m were erected in total. Furthermore 400,000 sand bags were used for local protection measures. Emergency management expense totalled at €3 million.

Nevertheless it became clear that the city averted a disaster: Only several additional centimetres in the flood peak level would have drowned major parts of the historic city centre necessitating the evacuation of about 100 000 inhabitants. Large production facilities like the ford plants, several chemical industry companies, refineries, and the cologne fair would have suffered large losses due to flooding. Enormous damages to natural environment in the vicinity of the city and along significant reaches of the rhine would have arisen as a consequence. The sewer network as well as the underground railway system would have led the water to distant areas with ground elevation below the rhine.

2 THE COLOGNE FLOOD PROTECTION SCHEME 1996

The closeness of the 1993 and 1995 events and anticipated potential damages of slightly larger floods led to a mentality change within the population and public authorities: Since 1995 flood protection gained sustainable significance. The cologne municipality developed a comprehensive flood protection scheme which passed the city council in February 1996 unanimously. The protection scheme emphasizes the equal importance of water retention, reduction of potential material damages, and preparedness of the inhabitants.

Water retention is improved through ecologically optimized technical measures like reconstructing embankments in the hinterland, reshaping brooks in a natural way, and unsealing areas for increasing seepage. In the vicinity of the city, 28km of embankments are to be newly constructed and 27km are to be reconstructed. The sewer network is to be protected by numerous constructive measures at the outlets and the runoff from waste water treatment plants is to be better controlled.

A cheap but effective measure for rising awareness throughout the population at risk of flooding has turned out to be the distribution of leaflets at the beginning of the annual period with high flood risk in November. In the areas at extreme flood risk posters inform about precaution, information centres and TV- as well as radio stations where up to date flood information is available.

The involvement of radio and TV in emergency management was particular successfull in 1995. Againts intense resistance of the fire brigades an other authorities concerned with effective work within the flood protection centre the head of the centre asserted to have journalists of Cologne Radio in the head office during disaster managent. Scepticism and the fear of having confidential information disseminated turned out to be pointless. Round the clock broadcasting provided flood prone inhabitants comprehensively, accurately and without time lag with information about e.g. rolling blackout and essential supply.

Nevertheless sound trucks are used to disseminate short-term warning in emergencies. Citizen's flood initiatives support precaution and contribute to emergency management in cooperation with the flood authorities.

Equally important is the improvement of emergency management and forecasting facilities. Flood protection is allocated at the municipal authority for civil engineering and transport. There the "task force flood" supervises the flood protection centre. Both assemble dependent on requirement. The task force flood has daily meetings if a flood wave is expected, whereas the flood protection centre works round the clock. The composition of the flood protection centre directly relates to water levels at the cologne gauge. Mean water level at the cologne gauge is 3,03m. At 4.5m the small flood protection centre is summoned, involving only some local authorities. Only if 7.5m are reached and there are forecasts for an ongoing increase, the large flood protection centre assembles. All local authorities are then involved in emergency management. If the water level exceeds 10,70m at the cologne gauge, the flood protection centre turns into a emergency task force for extraordinary events, which increases power and decreases the need for coordination.

3 THE INTEGRATED EARLY WARNING AND EMERGENCY MANAGEMENT SYSTEM

The need for a powerfull emergency management system was formulated by the flood protection centre. The purpose of the FLOod MAnagement SYstem FLOMASY is to combine flood forecasting and emergency management. It is under development since 1999 and currently in the test stage. Traditional emergency management is pursued in parallel. FLOMASY is designed as a computer based distributed information system. Terminals in all organisational units concerned with emergency management are online connected with a central data base. Measures to be carried out are taken from the system. Information about successful or unsuccessful execution are entered in the system and stored centrally. Communication is facilitated significantly and oral communication can be reserved for issues of high importance.

3.1 Flood Forecast

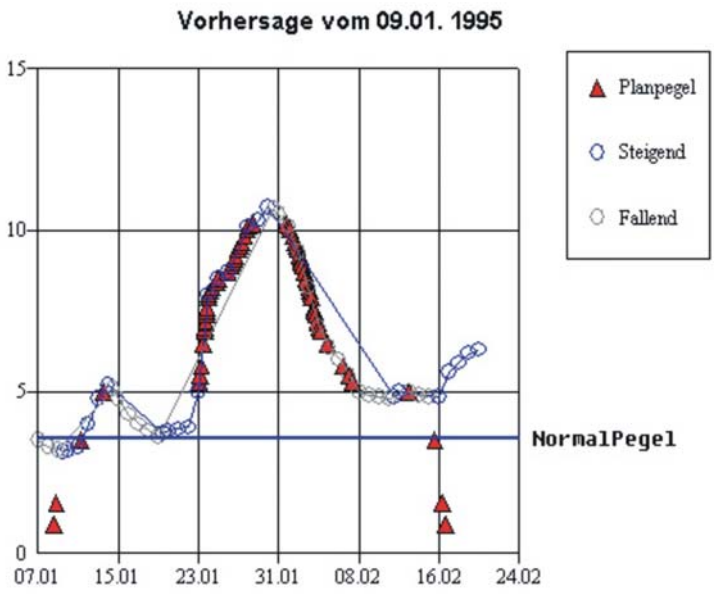

Figure 1. Electronically generated forecast

Traditionally flood forecasting involves inquiry of 24 gauges per telephone. Intervals between updates are subject to flood risk. If small flood waves are expected, gauges are monitored at three hour intervals. Large flood waves necessitate inquiry on a hourly basis. Gathered data are entered manually into a regression-based forecasting system which delivers forecasts for 24 hours in 6 hour intervals.

FLOMASY is based on an electronically generated forecast as shown in **Error! Reference source not found.**. Information sources remain as before, but the time-consuming telephone inquiry is substituted by electronic requests, which provides the flood protection centre with an efficiency gain. Forecast generation is faster and human resources are free for other preparatory work.

3.2 Measures Data-Base

Nr	Name	Beschreibung	Dienststelle	Abteilung	Arbeitsplatz	Stad	Stadtteil
220	Information BM Bau	Bundesbauministerium Deichmann:	Amt für Feuer- und Kata	37	Einsatzstab	Bonr	Bad Godes
175	Information DRK	Information an DRK zwecks Einrich	Amt für Feuer- und Kata	37	Kontaktpers	Bonr	Beuel
52	Infos an Fw LSt	Information der Feuerwehrleitststell	Tiefbauamt	66	Arbeiter 66-3	Bonr	Stadtgebiet
134	KatS-Unterkunft BN	KatS-Unterkunft Bonn besetzen, B	Amt für Feuer- und Kata	37	Einsatzstab	Bonr	Stadtgebiet
178	Kontrolle Plittersdorf 8,1	Kontrollen des Wasserfassungsgeb	Stadtwerke	81	Techn. Werk	Bonr	Plittersdorf
193	Kontrolle Plittersdorf 8,2	Kontrollen des Wasserfassungsgeb	Stadtwerke	81	Techn. Werk	Bonr	Plittersdorf
17	Lautsprecherdurchsagen	Lautsprecherdurchsagen veranlass	Amt für Feuer- und Kata	37	Einsatzstab	Bonr	Stadtgebiet
127	Lautsprecherdurchsagen	Lautsprecherdurchsagen in Rheina	Amt für Feuer- und Kata	37	Amtsleiter 37	Bonr	Beuel
191	Lfd. Kontrollen	Lfd. Kontrollen durchführen, Meldu	Tiefbauamt	66	Arbeiter 66-3	Bonr	Stadtgebiet
109	Linie 615 verkürzt	Überflutung der Wendeschleife Fäl	Stadtwerke	81	Techn. Werk	Bonr	Bad Godes
253	Massnahmen 81-6	Überflutung der Buswendeschleife	Stadtwerke	81	Techn. Werk	Bonr	Grau-Rhein
40	Material-Vorratshaltung	Überprüfung der KatS-Läger auf Ve	Amt für Feuer- und Kata	37	Kontaktpers	Bonr	Stadtgebiet
21	Materialbedarf	Sicherstellung des Materialbedarfs	Amt für Feuer- und Kata	37	Einsatzstab	Bonr	Stadtgebiet
230	Müll Rüdigerstr.	Müllbehälterleerung entlang Rüdige	Amt für Stadtreinigung (	70	Amtsleiter 70	Bonr	Bad Godes
15	Müllentsorgung	Abstimmung mit Amt 70 über die M	Amt für Feuer- und Kata	37	Einsatzstab	Bonr	Stadtgebiet
138	Müllentsorgung Rheinaus	Müllbehälterleerung entlang Rheina	Amt für Stadtreinigung (	70	Abt.-Leiter St	Bonr	Beuel
233	Notwasserwerk Gronau	Kontrolle des Notwasserwerkes Gr	Stadtwerke	81	Techn. Werk	Bonr	Gronau
14	Pegelabfrage	Abrage der Pegelstände von Oberr	Amt für Feuer- und Kata	37	Einsatzstab	Bonr	Stadtgebiet
39	Pegelentwicklung	Beobachtung der Pegelentwicklun	Amt für Feuer- und Kata	37	Kontaktpers	Bonr	Stadtgebiet
232	Personennahverkehr	Sicherstellung des Personennahve	Stadtwerke	81	Techn. Werk	Bonr	Stadtgebiet

Figure 2. Measures Data-Base

The knowledge about measures to be carried out at a certain water level at the cologne gauge is traditionally hold by flood protection officials only. Therefore a significant hazard exists that knowledge about how protecting the city effectively is lost when flood protection officials retire. FLOMASY therefore is designed to serve as a knowledge management system. As **Error! Reference source not found.** depicts, measures are stored in a data base combined with responsible authorities as well as the officials who have to act and to be informed in emergency respectively. The combination of the forecast and the measures data-base results in so called "planpegels". A planpegel describes certain actions which have to be carried out if a certain water level is reached.

3.3 The Emergency Plan

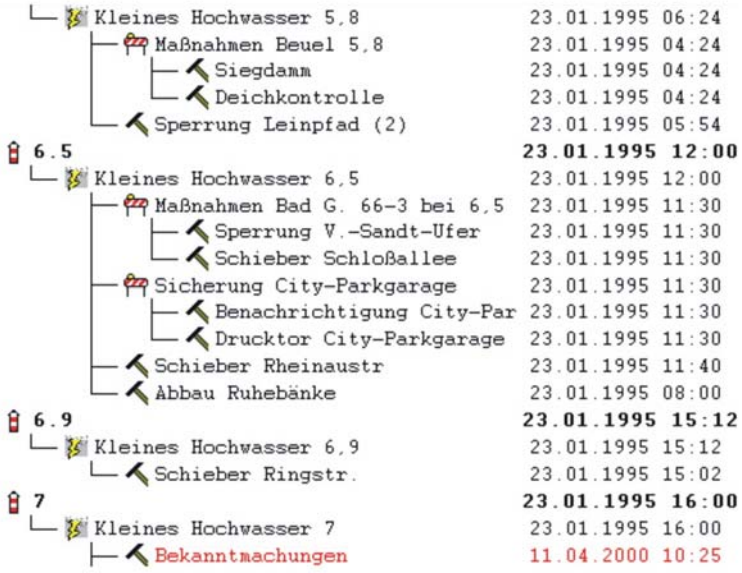

Figure 3. Emergency plan

The emergency plan is defined by a set of planpegels as **Error! Reference source not found.** shows. The emergency procedure is discussed with the help of this figure.

Imagine it is January 22. 12:00 am. A water level of 6.5 metres at cologne gauge is forecasted for January 23. 12:00 am (line 6 in **Error! Reference source not found.**).

To prevent the city from flooding, several measures must have been performed until this date. In Bonn-Bad Godesberg two gate valves have to be closed to protect the sewer network. As the time needed for closing a gate valve is somewhat below half an hour, the starting point for valve closure is 11:30 am on January 23. At the city parking garage a gate has to be closed. Therefore the garage owner has to be informed at 11:30 am. A small gate valve at Rheinaustraße has to be closed at

11:40. Because the benches at the Rhine bank have to be removed and the process for doing that is time-consuming, starting point for benches removal is 8:00 am.

The time span until the earliest measures starting point (8:00 am on January 23.) is 20 hours as calculated from January 22. 12:00 am. The management system therefore provides emergency managers with generous time reserves for human resources allocation.

4 FURTHER DEVELOPMENTS

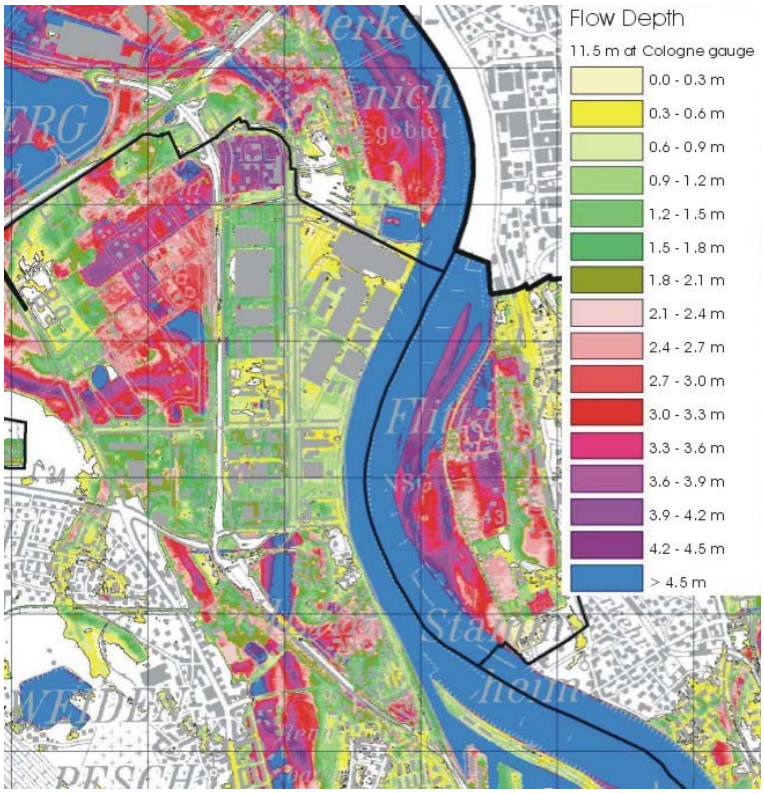

Figure 4. Flood map for a catastrophe scenario

A further step in developing the management system is its integration into a geographic information system (GIS). The Cologne municipality already undertook the endeavor of developing flood maps as shown in **Figure 4.**. A catastrophe scenario is depicted for a water level of 11.5m at the Cologne gauge, corresponding with a return period of approximately 150 years. The map shows an industrial area 6.8km north of the city centre. As can be taken from the scale at the right hand side, water depths around 3 metres (dark red) are to be found in a distance of 2km from the river whereas 1m (light green) is hardly exceeded at the river bank itself. A static map is shown where the river's water level is extrapolated on a digital elevation model. In a first step, the locations where protection measures are to be performed could be integrated into the GIS. Disaster managers then could anticipate the impact of a protection measure's failure.

A dynamic map would show the location of a protection measure, e.g. a gate valve to be closed, the effect if the closure fails and the time until the maximum water level is reached in the affected area. It is a point for discussion if the benefit from such dynamic maps outweighs the cost of producing them.

5 CONCLUSIONS

The Cologne flood management system is expected to enhance the efficiency of emergency management significantly. Following benefits will be derived from the system:

- Acceleration of protection measures execution
- Information about measure's interdependence
- Enhancement and improvement of emergency management supervision

- Improvement of visualisation
- Introduction of effective reporting
- Description and maintenance of responsibilities
- Effective evaluation opportunities for responsible officials
- Centralised data storage
- Standardisation of Forecasts
- Effective knowledge transfer between consecutive generations of disaster managers

As shown in the beginning of the paper, the management system is a part of a comprehensive flood protection scheme and not the protection scheme itself. It is perfectly possible to significantly improve emergency management without involving elaborated management systems as the 1995 flood has shown. Nevertheless provide management systems disaster managers with greater time spans for resources allocation and facilitate communication if used efficiently.

6 REFERENCES

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