Storage management in urban drainage based on runoff prediction

HARALD SOMMER, FRAUKE JAKOBS, ZHENGYUE JIN & HEIKO SIEKER

Ingenieurgesellschaft Prof. Dr. Sieker mbH, Hoppegarten, Germany

Abstract Intense rainfall events are a major cause of flooding problems in urban and non urban areas. They are due to increased sealing of areas resulting in high runoff volumes. Especially in urban areas and small catchments the time interval between rainfall event and flood peak can be very short. This paper describes the integrated hydraulic precipitation runoff modelling system STORM.Control using predicted rainfall data to manage urban water systems and/or whole water sheds. It gives the opportunity to integrate an alarm system for civil protection forces to react in short term and prevent relevant constructions from damages. Coupling virtual data and measured data enables the steering of storages in order to lower peak flows in sewers and water courses. The system is using the open SOS standard for data collection and delivering. A web based Viewer HydroWebView is enabling "real time viewing" of the data in the sewer and river system.

INTRODUCTION

The big flood events in Germany with severe damages which occurred in the last 10-15 years are still in mind. Due to strong medial reflection the sensitivity was raised esp. after the floods at the rivers Elbe in 2002, Oder in 1997 and Rhein in 1993 and 1995.

Flood events don't occur only in big rivers but also in small streams and creeks and can cause severe local damages. Sewer systems are affected too. Reasons are heavy rainfall events, which cannot be handled by the drainage system (Sewers, rivers, streams). Conventional measures like retention basins and higher runoff capacity or other measures like infiltration and area management are in most cases only a partial solution of the flooding problem. Therefore a warning is necessary because the time period between rainfall event and runoff can be very short in small catchment areas in contrary to large river basins. A possible solution is the simulation of runoff based on predicted rainfall data.

RAINFALL PREDICTION

There are several ways to integrate rainfall into modeling. First method is to have online rainfall gauges delivering actual data a modeling station which then can produce immediate outputs which can be visualized. The disadvantage of this system is that the reaction time is only very limited.

The enhanced method is to use predicted rainfall data. So called "Virtual rain gauges" delivering predicted rainfall data are of offered as a service via Internet based on rainfall data of weather service Meteomedia. [HST, 2007]. The data can be viewed via web browser interface or directly downloaded via ftp. The data is processed from radar data and calibrated with a dense net of terrestrial rain gauges. This data can be provided for the whole area of Germany in high resolution for past and future prediction for 72 h in 1h time steps and for 2 hours in advance in 5 min time steps.

RUN OFF SIMULATION

Based on the predicted rainfall data the runoff can be simulated with the simulation model STORM. (IPS, 2009) STORM is a hydrological model with the ability to simulate rainfall-runoff-processes for urban areas as well as for natural and rural areas (Soil water balance model). Pollution load can be modelled too.
These models have to be established and calibrated in advance with past rainfall events of different heights and reoccurrence. Even rainfall events leading to flood events have to be considered for calibration.
The connection to the „virtual rain gauges“ is realised by the STORM-module STORM-Control. This module reads the rainfall data from the ftp-server and runs the simulations with specified time intervals. With new available predicted data the simulation is started too. For larger catchments multiple rain gauges can be used for catchment wide rainfall. The runoff will be calculated within minutes and available as a “virtual runoff gauges” or “virtual water gauges”.

VISUALISATION

To realise a data retrieval independent from software and hardware the predicted and simulated data will be stored in a SQL data base (PostgreSQL) located on the internet. Via freely available web browsers (i.e. Firefox, Internet Explorer etc.) the actual and the predicted runoff data can be visualised and viewed from any point with internet connection within offices or out in the field. The graphical view includes a map with the position of the location of existing or virtual gauges. A diagram with graphs of the actual and predicted data can viewed too. If a predefined water level or runoff limit at any existing gauges is exceeded a warning can be send via email and/or SMS. Data integration and transfer is realised via open standards as Web Map Service (WMS) and Sensor Observation Service (SOS) defined by the OGC Consortium. (OGC, 2009). By using open standard interfaces integration in other systems can be realised very easily.

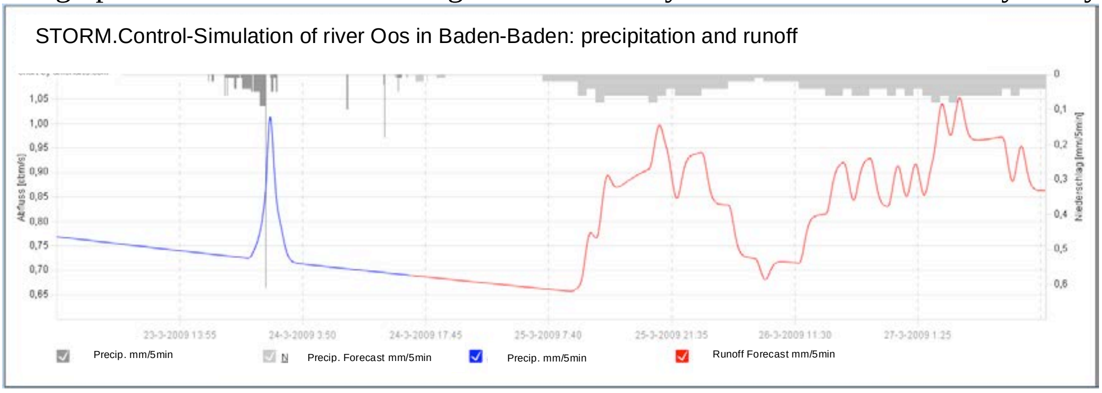

Figure 1: First Graphical view of predicted or simulated time series via Web browser.

„VISUAL“ CALIBRATION

Like other precipitation runoff models the models have to be calibrated. Via SOS-interface existing water gauges can be compared with „virtual runoff gauges“. This enables a validation of the precipitation-runoff-model. Additionally runoff simulations for different prediction periods can be compared. This enables an evaluation of the runoff prediction.

INTEGRATED SYSTEM

The developed integrated system consists of several parts:

- Virtual rain gauges (others gauges can be used too)
- STORM.Control as the modelling heart of the system which allows also to deliver steering commands
- Database collecting the virtual, modelled and real data
- Steered measures
- Sensors, delivering data
- Web based Viewer: HydroWebView

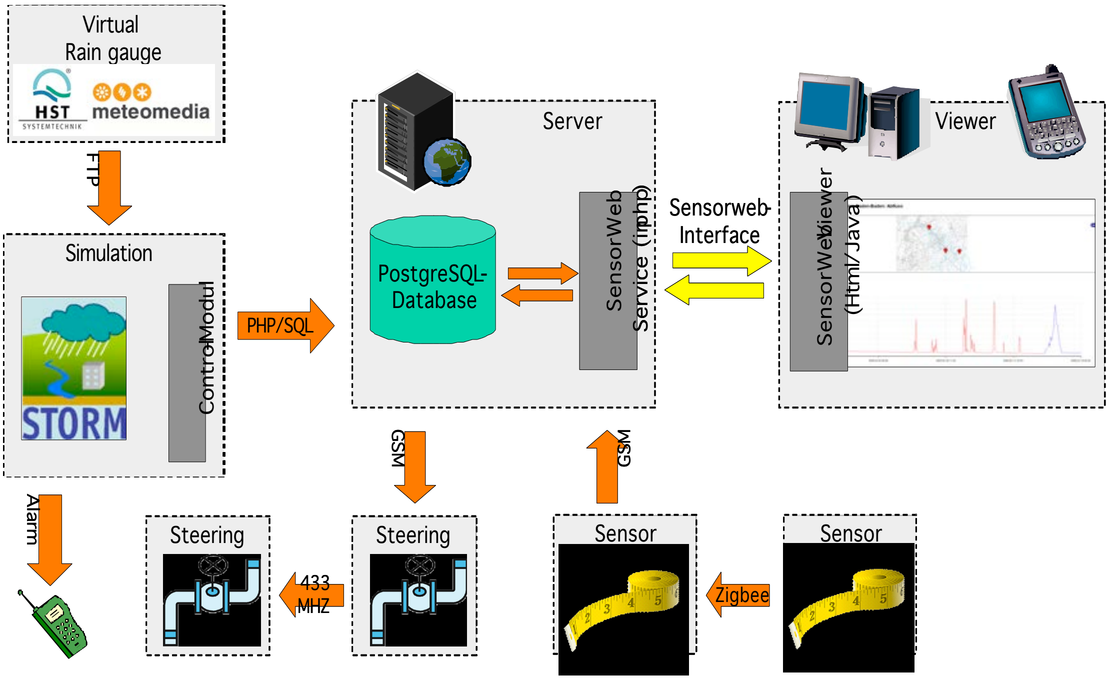

Figure 2: Rainfall prediction based runoff modelling and visualisation

The figure describes the system. The predicted rain data is fetched by the simulation model. The model will calculate runoff volumes and water levels and store them in a predefined data base. Steering commands for valves etc. can be integrated too. Independent sensors are delivering measured data. The visualization is realized by a web based viewer (HydroWebView). (Steering of small storages, 2006), (HydroSensorWeb, 2007)

EXAMPLES

The system is tested in 2 catchment areas.

Baden-Baden

The first one is the catchment of the rivers Oos and Grobbach. In the lower catchment area the city of Baden-Baden is located. This catchment has a total size of 80.9 km². The overall average sealing rate is 7.9%. The catchment starts in the Black Forest Mountains at 800 m above sea level. In this area the land use is mainly forest (Wald). The city of Baden-Baden itself is located in the valley at app. 200 m above sea level. For the settled area is located closely aside the river banks this area is affected by flooding.

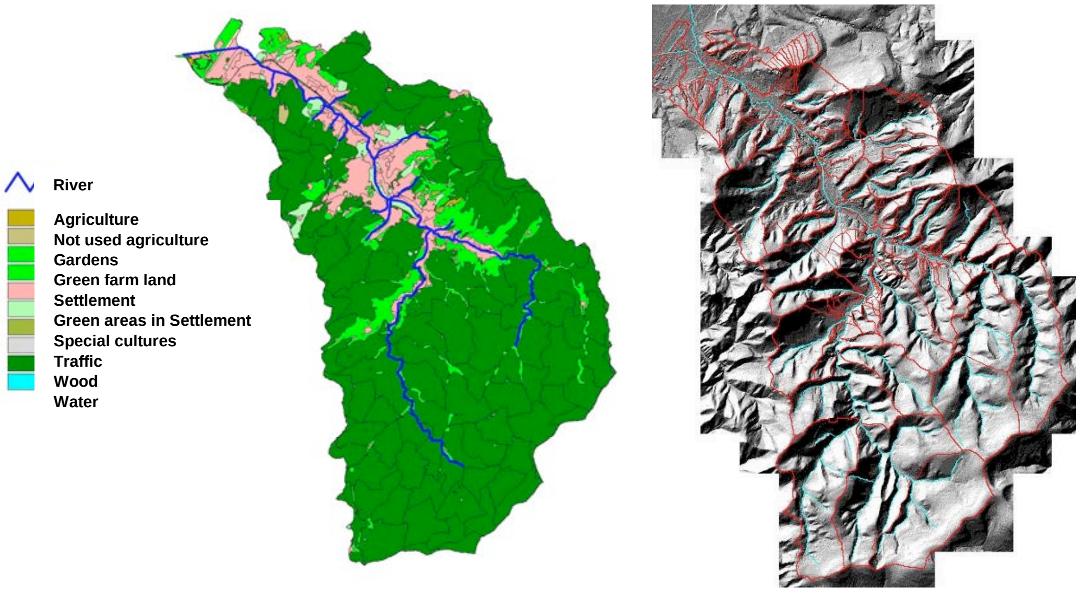

Figure 3: Land use and elevation model in catchment of rivers Os and Grobbach in Baden-Baden

For this catchment a precipitation runoff model was established and calibrated. The calibration was realised with several rainfall events. One major calibration event was causing extreme flooding on Jan 13th 2004. The time from rainfall resulting in a flood event in the urban area is 0.5-1 h.

To enlarge the reaction time for fire brigades and other civil protection forces the aim was to establish an alarm system. This can be done using the already established and calibrated model for the catchment and integrating rainfall and temperature prediction for better prediction of runoff.

A flood level prediction is made with STORM.Control using 8 “virtual rain gauges”. Additionally 2 temperature gauges, one in the upper mountain area and one in the lower part of the city) are integrated into the forecast.

With the Script based Internet software HydroWebView it is possible to visualise the measured and the predicted precipitation and runoff “on the fly”. This enables the relevant people in the city to react in a sufficient time frame.

If a simulated water gauge is reaching a certain determined level, the system sends an automated Alarm-SMS if a certain water level will be reached.

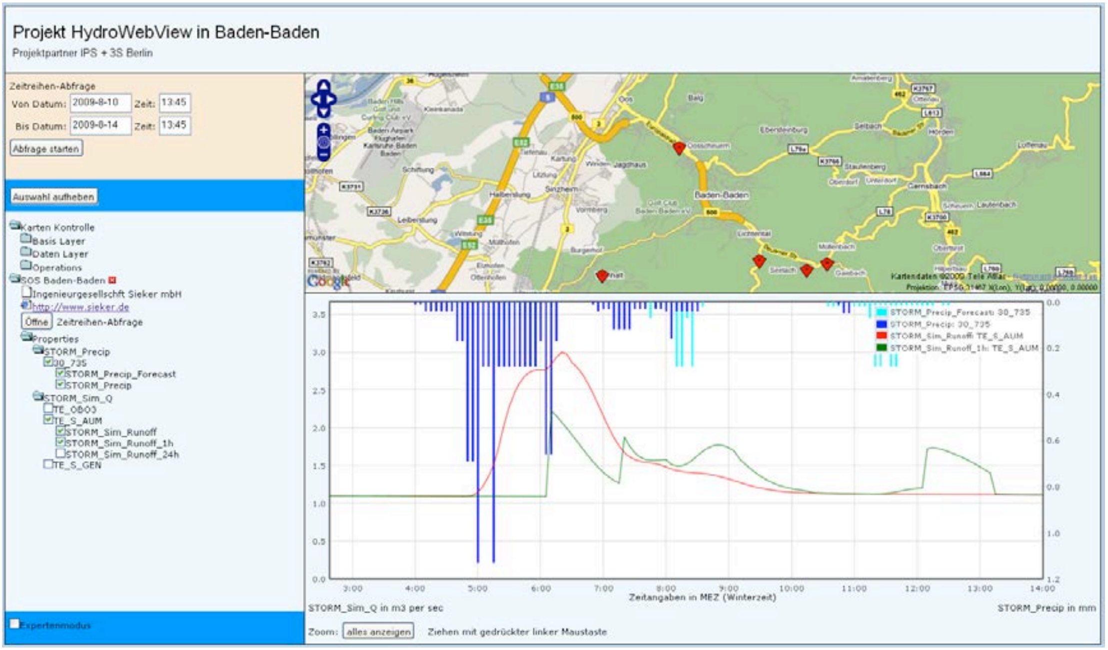

Figure 4: HydroWebView, precipitation and runoff data in the catchment of Baden-Baden.

The figure shows the web based viewer HydroWebView. In the map several points of measurement are shown. From these points available data is presented and can be downloaded from the SOS sensor or from an SOS compatible database. After selecting the time period the graph present the data. On the top the measured (dark column) and predicted (light columns) are visible. The lines represent the simulated data with measured and predicted rainfall data.

Prenzlau

The separate sewer system in the city of Prenzlau is overloaded in rainfall events. In the past it was not possible to get online information of the runoff status in the sewer system especially in manhole in streets without power supply.

Figure 5: HydroWebView showing the available runoff data (water level) in 2 manholes in the catchment of Prenzlau.

A new type of measuring system was used to establish a measurement in manholes which would be usually due to manual service. A data logging system is integrated sending the data at defined intervals via GSM from the inside of the manhole to the internet based server. So with STROM.Control overloading of sewer systems can be measured online. A prediction of the overloading is possible too if the water level prediction is coupled with a hydrodynamic model driven by predicted rainfall.
The figure shows the separate sewer network of Prenzlau 2 measurement points are installed in 2 manholes. From inside these manholes runoff data is provided via GSM network to the database (pictures). HydroWebView visualises the runoff data of both points of measurement.

POSSIBLE FUTURE APPLICATIONS

There are various applications where these methods will be suitable:

- Flood warning systems in urban and non urban areas
- Alarm system for civil protection forces
- Online visualisation of the status in sewers and open water systems
- Automated management of sewer system by determined steering of storages

CONCLUSION

Flood control and management in urban areas is one of the major aspects in urban and rural storm water management. With conventional management systems the reaction time in heavy rainfall events is too short for effective warning and protection of people and buildings.
This inspired the development of a management system driven by rainfall prediction. With STORM.Control it is possible to manage and steer large storages like flood retention basins or storage tanks as well as small scale storage elements and rural drainages. This allows viewing and managing urban and non urban water systems. With HydroWebView based on the open SOS standard different measurement data can be visualised in one screen. The data is available wherever an internet connection is possible.

ACKNOWLEDGEMENT
The project “Steering of small storages” was funded by the Ministry of Economics of the German Federal State of Brandenburg. The project HydroWebView was funded by the German Federals Ministry for Economics and Technology.

LITERATURE

HST (2007), Virtuelle Regenschreiber – flächendeckende Niederschlagswerte für die Wasserwirtschaft, Brochure, download via www.systemtechnik.net

IPS (2009), Manual STORM, Version XXL, Ingenieurgesellschaft Prof. Dr. Sieker mbH

OGC (2009), OpenGIS Standards, Open GIS Consortium, www.opengeospatial.org

Steering of small storages (2006), Project Description, funded by the Ministry of Economics of the German Federal State of Brandenburg, 2007-2009, unpublished

HydroSensorWeb (2007), Project Description, funded by the German Federals Ministry for Economics and Technology, 2008-2010, unpublished