OPERATIONAL FLOOD FORECAST IN BAVARIA

Christine Hangen-Brodersen[1], Alfons Vogelbacher[2], Franz-Klemens Holle[1]
[1]Catchment Hydrology, Flood Forecast River Main, Bavarian Environment Agency, Hof, Germany
[2]Flood Information Centre, Bavarian Environment Agency, Munich, Germany
christine.hangen-brodersen@lfu.bayern.de

Abstract

The structure and organisation of the Bavarian flood information service is introduced with focus on the operational flood forecast. Five flood forecast centres corresponding to the main river basins (Main, Danube, Inn) and tributary basins where large reservoirs have to be operated (Iller-Lech, Isar) are responsible for the operational flood forecast. They closely co-operate with the co-ordinating main flood information centre and the state offices for water management. Within the framework of an innovation program launched by the federal state of Bavaria after the Whitsun flood 1999 a meteorological and hydrological information system and database with an automated data communication system has been built up during the last eight years. The measuring and communication systems are operated with redundancy. Additionally to the data of the monitoring network mainly numerical weather forecasts of the German weather service are used. Latest product is the short-term precipitation forecast using the results of online-adjusted radar. Development of snow cover and the total water release from snowmelt and rainfall is pre-processed by the results of the SNOW3-model. For large parts of Bavaria flood forecast models of modular structure have been developed, verified and adopted. For the main river courses the hydrodynamic models WAVOS (Danube and Main) and FLORIS 2000 (Lech, Inn and Lower Danube) are in operation. For the inflow of the tributaries rainfall–runoff models mostly based on the program LARSIM are implemented. They are grid or sub-basin oriented. The input data used for simulation are mainly hourly precipitation data, discharge data, precipitation forecast, snowmelt calculation and forecast. Flood forecasts of upstream hydrological services are taken into consideration. Future developments comprise the determination and illustration of the uncertainty related to the flood forecast.

Keywords: *flood forecast Bavaria, flood information system, rainfall-runoff model, Danube river, Main river.*

1 INTRODUCTION

According to the Constitution of the Federal Republic of Germany, the flood information service is assigned to the federal states. Before the Whitsun flood 1999 the flood information service in Bavaria primarily served as report service that collected water gauge records and forwarded these – supplied with a trend comment – corresponding to report schemes to those concerned. The amount of quantitative flood forecasts was limited. Simple methods were used, e.g. regression functions for gauges (Vogelbacher, 2007). Triggered by the Whitsun flood 1999 the Federal State of Bavaria initiated the innovation program ‘Quantitative Hydrology’ which was part of the ’Action Program 2020’ that aims at a sustainable flood protection. This program comprised the development of flood forecast models as well as the implementation of

an automatic online-raingauge network and an optimisation of the existing river gauge network. The dissemination of flood information based on means of modern communication and its reliability was improved (Vogelbacher, 2005).
The flood in August 2005 was the first test for the flood forecast centres in the Danube basin. Due to the numerical precipitation forecasts, a larger flood could be predicted 3 days in advance. Based on the forecasts of the flood forecast centre Iller-Lech and Isar, the reservoirs could be pre-released in time avoiding huge damages downstream (Bavarian Environment Agency, 2008). However, also specific problems in the operational flood forecast became obvious during this extreme event e.g. uncertainties in measured and forecasted precipitation, error-prone and uncertain water level- and discharge measurements, or exceeded resp. extrapolated rating curves. In addition, the forecast models often did not take into account the different process behaviour at extreme floods. As well, the internet server of the flood information service could not stand the rapidly increasing number of requests. Experiences of the 2005 August flood resulted in the enhancements of the models, optimisation of the internet service and enhancement in communicating uncertainties of flood forecasts (Vogelbacher et al., 2006)
The present state of the operational flood forecast in Bavaria is presented in this paper. The operational flood forecast is one component of the early flood warning system comprising the components data collection – meteorological forecast – flood forecast – flood information system – decision-making – disaster control - reaction of affected citizens and can not be seen isolated. Therefore, the structure and organisation of the Bavarian flood information service is introduced first, followed by the role and operation of the operational flood forecast, the monitoring network, the available data and information of the weather services, and the flood forecast models used.

2 ORGANISATION OF THE FLOOD INFORMATION SERVICE IN BAVARIA

According to the Bavarian flood information service decree of January 10th, 2005 (Bavarian Act and Decree Paper No. 2/2005 p. 11-13), the flood information service serves the defence of flood (and threats by ice). Main purposes and tasks comprise:

- Collection of precipitation-, water level- and further observation data necessary to produce flood information
- Evaluation and interpretation of data
- Dissemination of flood warnings and information

The flood warning should be received in time by those concerned and by the working forces.
Participants of the flood information service are the flood information centre at the Bavarian Environment Agency in Munich, the regional flood forecast centres, the state offices for water management as main reporting offices, offices of the administrative districts as local reporting offices and the recipients in the information schemes (Figure 1).

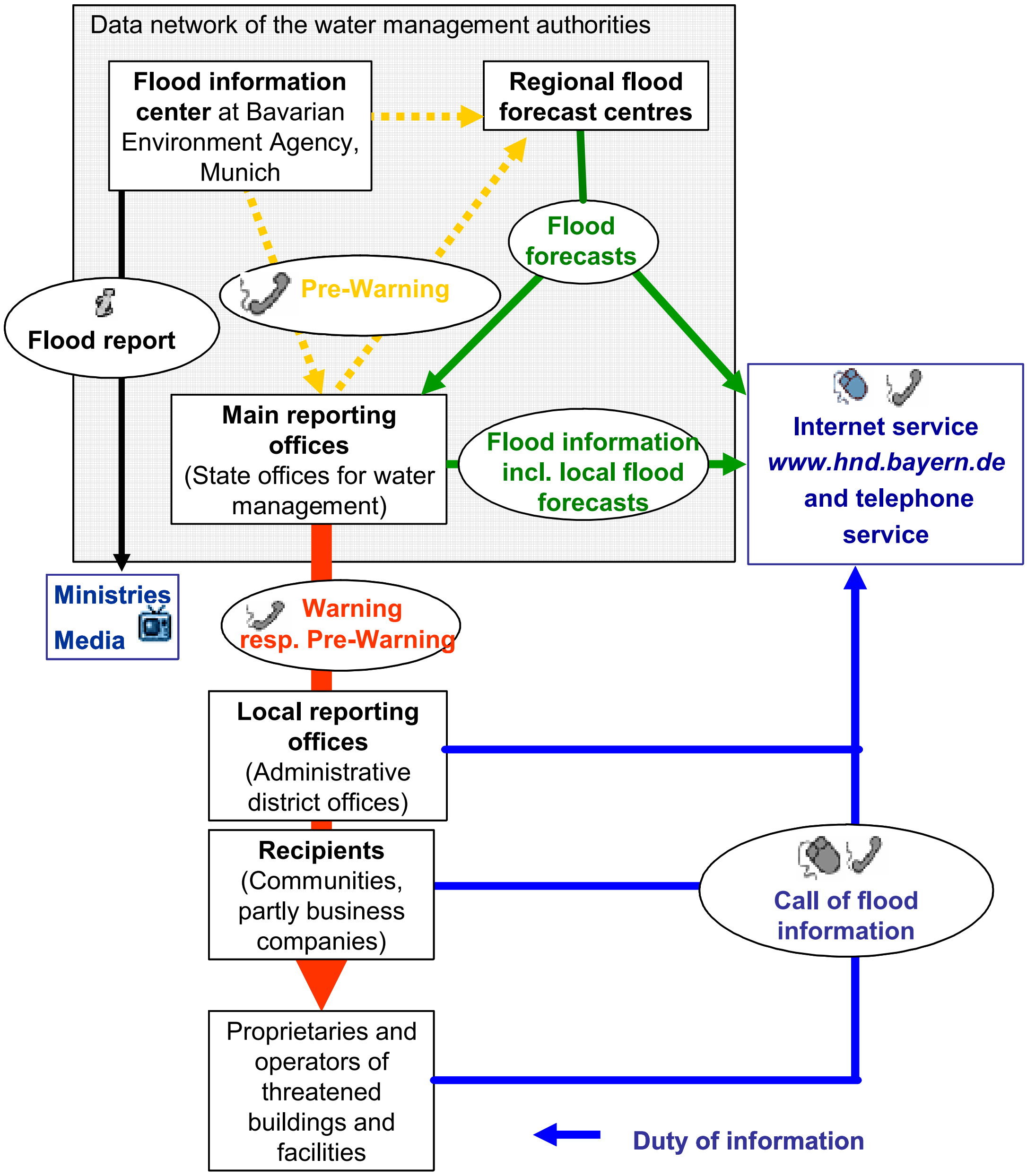

Figure 1. Report and information scheme of the Bavarian flood information service

The state offices for water management, the flood information centre and the regional flood forecast centres warn each other mutually in case of an upcoming flood.

The Bavarian flood information service differentiates between alert limits and alert levels. The latter describe the impact of the flood in the area of a river gauge, while the first serve as criteria for the release of flood warnings.

The flood information service starts operations, when the alert limit at one main river gauges, or at more than one river gauge is exceeded or is expected to be exceeded soon. The main reporting offices issue a flood warning of 'Overflowing and inundation' to the local reporting offices by any communication means. When the higher alert limit at a river gauge is exceeded or is expected to be exceeded the warning of 'Danger of flooding of housing area' is issued. A pre-warning of flood

danger can be issued, if the flood forecasts show an exceedance of alert limits but the situation is still too uncertain. The flood warnings have to be actively transmitted to the concerned recipients. Starting with the (signed) reception of a (pre-) warning, the recipient bears the responsibility to inform himself about the threatening flood. For this purpose, the state offices for water management, the regional flood forecast centres and the flood information centre provide updated data, forecasts and flood reports via website (www.hnd.bayern.de) as well as flood news via telephone service to the public and authorities.
Just in case the flood information cannot be supplied by internet it has to be disseminated to the reporting offices and recipients via fax (with recall) or telephone according to the flood information schemes.

3 ROLE AND OPERATION OF THE FLOOD FORECAST CENTRES

Five flood forecast centres (Figure 2) corresponding to the main river basins (Main, Danube, Inn) and tributary basins where large reservoirs have to be operated (Iller-Lech, Isar) are responsible for the operational flood forecast. The decentralised and river basin related organisation of the flood forecast has the advantage to use the experience in local peculiarities and to operate large reservoirs in-situ.
The flood forecast centres deal with:

- the setting-up, testing and further development of forecast models for water level and discharge in respective catchments in co-operation with the flood information centres at the Bavarian Environment Agency;
- operational calculation of flood forecasts for selected river gauges

The model-based flood forecast service supports the services of the regional water authorities and the flood information centre. In the case of the flood forecast centres Iller-Lech and Isar, respectively, the flood forecast service additionally assists in the management of reservoirs.
The flood information centre is the central institution that co-ordinates the flood information service. It supervises the development of flood forecast models, co-ordinates the forecasts, and disseminates flood reports.
The state offices for water management are responsible for flood forecasts and the dissemination of flood information in the regional flood information service, the application of models for reservoir operation and for the data service (collecting and providing data of the river gauge network) (Figure 3).
Usually, the flood forecast centres produce water level and discharge forecasts once a day based on the 4 UTC measurement data except on weekends and public holidays. The forecasts are published in the intranet.

The flood forecast centre starts flood forecasting:

- after the exceedance of defined threshold values of areal precipitation amount given by the numerical weather forecast
- after the reception of a relevant weather and storm warning (e.g. intense rain, extended rain periods, snow melt)
- after the exceedance of alert limits at more than one river gauge in the subjected area.

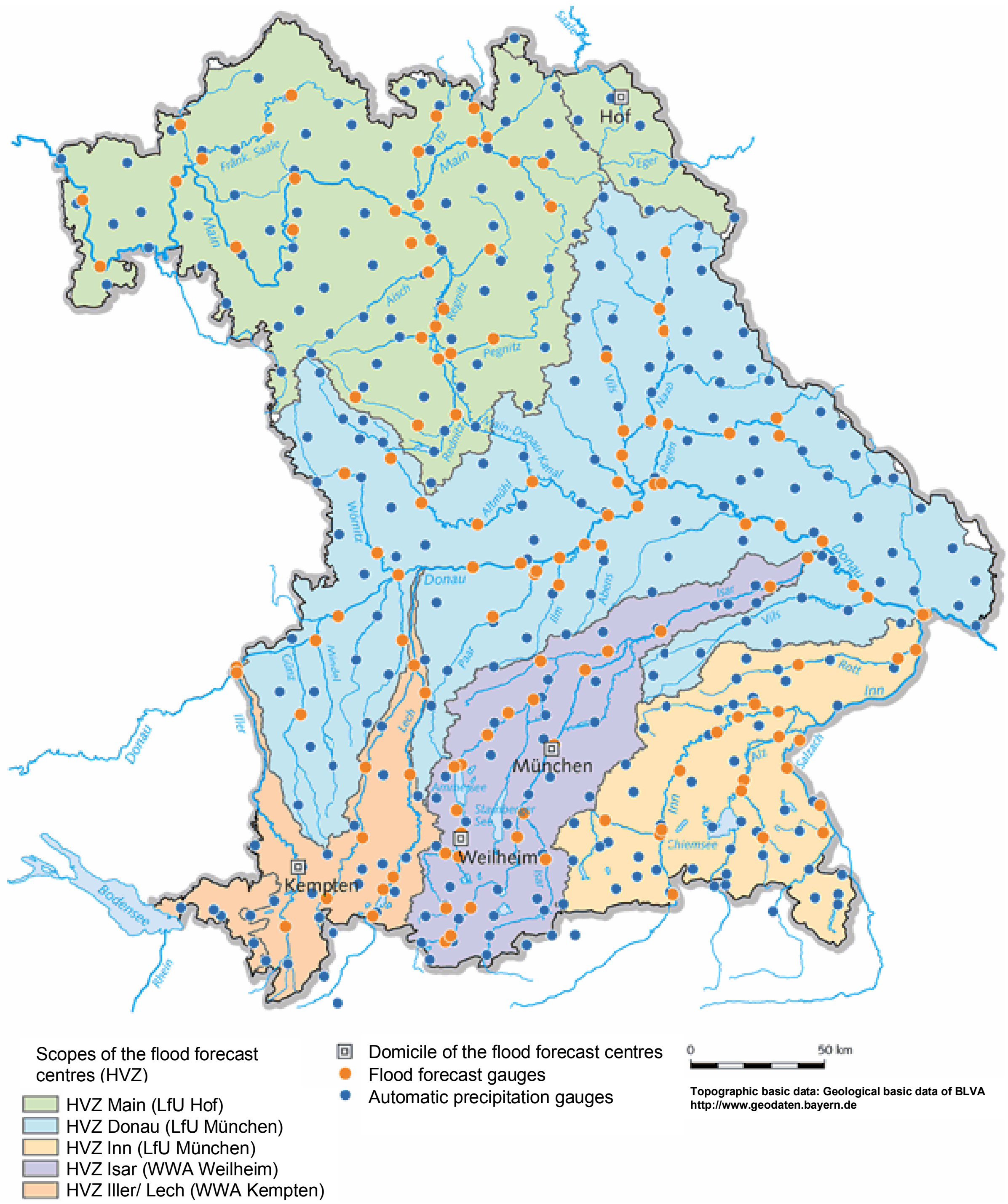

Figure 2. Flood forecast centres in Bavaria

The flood forecast centre informs the main information offices within the forecast area and the flood information centre, if due to the flood forecast an extensive exceedance of the alert limits has to be expected. After receiving this information the main information offices have to provide the river gauge data on an hourly basis.
In case of a flood event the flood forecasts are calculated 3 or 4 times per day to defined points of time. If necessary, the flood forecasts are updated every hour.
The forecast centres calculate forecasts for all river gauges implemented in the flood forecast models. The complete flood forecast simulation results are made available

for the regional water authorities, regional governments and ministries by a Java-Client application (FLIPPER) within the data network of the Bavarian water management administration. In the intranet and internet only forecasts at selected river gauges and for a reduced forecast time are published. The regional water authorities have access to the flood forecasts for all river gauges and can use these results for own forecasts (Figure 3).

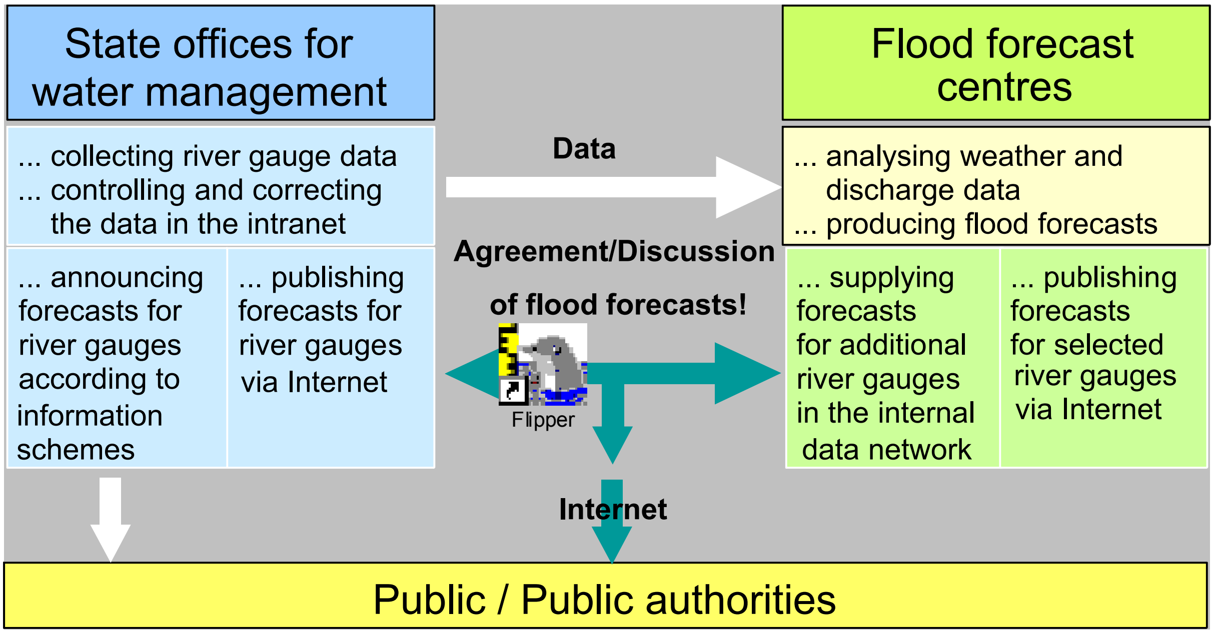

Figure 3. Co-operation of the main flood reporting offices (state offices for water management) and the flood forecast centres

4 MONITORING NETWORK AND HYDROMETEOROLOGICAL INPUT DATA

Water level and discharge data

The river gauge network in Bavaria consists of about 600 stations, 560 of which are equipped with telemetric data transmission. 320 river gauges are so-called 'report river gauges' for the flood information service. The extreme flood events in the Danube river basin in May 1999 and August 2002 as well as in January 2003 in the Main river basin revealed that equipment and data transfer were not sufficient. Failures and breakdowns of the measurement installation and data supply occurred. To ensure the data supply, meanwhile most of the river gauges were equipped with redundant measurement devices and telecommunication channels. For the telemetric data transfer the conventional telephone network or mobile telephone system GPRS resp. GSM are used. The remaining river gauges in the flood information service have at least redundant measurement devices. Furthermore, there were numerous river gauges where the extreme flood water stages could not be assessed. Constructional measures will be taken within the next years.
For the flood forecast models discharge is the central parameter, and thus reliable stage- discharge-relationships are needed. However, often discharge is not measured during flood situation and additionally it is associated with large uncertainties. To limit these uncertainties alternative measurement methods, such as ultrasonic, acoustic Doppler current profiler, tracer and radar measurements are

tested in a pilot phase. Partly, the implementation of the new methods has already been accomplished. E. g, discharge tracer measurements are already in operation in the alpine areas (see Roth, 2008).
To check and improve the rating curves especially in the extrapolation section, a project has been started at the Bavarian Environment Agency where hydraulic simulations for about half of the Bavarian river gauges shall be conducted.
There are also water level data available of the Hydrographical Services of Austria, of the Federal States of Baden-Wuerttemberg, Thuringia, Hesse as well as of the Federal Waterway and Navigation Administration for the national waterways. For the flood forecast models the discharges at the power stations are required. These data are obtained in a data exchange between E.ON Hydropower Inc. and other operators of water power stations. The data of most of the external partners are imported per ftp – or http-request via internet into the data base of the flood information service.

Meteorological data

Most of the precipitation data are provided by the common automatic monitoring network operated by the German Weather Service and the Bavarian Environment Agency with about 285 stations (107 of the Bavarian Environment Agency in co-operation with the State Offices of Water Management).
Additionally, data of the monitoring networks of the private company Meteomedia, of the Bavarian Agency of Agriculture and of the Bavarian Avalanche Warning Service are used.
Due to the transboundary tributaries also precipitation data of the Central Institute of Meteorology and Geodynamics, Vienna, and the Austrian hydrographical services as well as of the federal states of Baden-Wuerttemberg and Hesse are called up. All in all, precipitation data of 700 stations are available online (Vogelbacher, 2007).
Besides precipitation, snow height, water equivalent of the snow cover, air temperature, wind speed and radiation are the most important meteorological parameters for snow melt calculation. However, these quantities are measured in a lower resolution. The snow measurement network has considerably been increased within the last years. At present, the snow water equivalent is measured at approx. 120 stations in Bavaria in a 1 to 3-diurnal interval. Three automatic stations record the snow water equivalent continuously.
The spatial assessment of precipitation can be improved by using weather radar measurements. The adjustment of radar signals to the measurement data of the ground precipitation network allows a spatially high-resolution assessment of rainfall events. First operational products of the German Weather Service project RADOLAN (radar online-adjustment) were available in 2005 (DWD, 2008). The composite data of the radar echoes and the products adjusted to the ground monitoring network are received each hour per FTP from the German Weather Service. Since 2008 the RADOLAN-data can be used directly as input data for the operational flood forecasts.
Several weather forecasts are available for the operational flood forecast simulation in Bavaria (Table 1). Usually, the results of the numerical weather forecast models of the German Weather service are used. COSMO-EU is the main product of the German Weather service for the forecast period of 3 days (DWD, 2008). The most recent product is COSMO-DE, which is used for the operational flood forecast in Bavaria since 2008. The high horizontal resolution of 2.8 km allows the simulation of thunderstorm cells of the size of only a few kilometres. The forecast gets started every 3 hours. Within the model runs also updated radar measurements are

integrated. If this can help to improve the flood forecast simulations still has to be investigated.

Table 1. Numerical weather forecasts used for operational flood forecast in Bavaria

Model	**Weather Service/ Organisation**	**Grid step** [km]	**Time step*** [h]	**Forecast time** [UTC]	**Forecast lead time** [h]	**Delay** [h]
GME (Global Model Europe)	German Weather Service	40	3	00 12	174 174	5 5
COSMO-EU	German Weather Service	7	1	00 06 12 18	78 48 78 48	5 3 5 3
COSMO-DE	German Weather Service	2.8	1	00 03 06 ….	21 21 21	1-2 1-2 1-2
COSMO-LEPS	German Weather Service	10	3	12	132	5:30 UTC next day
SNOW 3	German Weather Service	1	1	00 06 12 18	42 72 66 72	1-2 1-2 1-2 1-2
GFS (Global Forecast System)	NOAA (National Oceanic Atmospheric Administration)	appr. 50	3	00 06 12 18	180 180 180 180	6 6 6 6
ALADIN Austria	Central Institute for Meteorology and Geodyna-mics (Austria)	9.6	1	00 12	48 48	4-5 4-5
MOSS (Model Output Statistics on Station)	Meteomedia	station based	3	00	96	5-6

* time step used in Bavaria

For Southern Bavaria the results of the ALADIN-Austria model operated by the Central Institute of Meteorology and Geodynamics in Vienna are available (Vogelbacher, 2007). Meteomedia provides a 4-days station-based precipitation forecast using a statistical correlation between the output of a ‘coarse-meshed’ weather forecast model and the data of a ground weather station (www.meteomedia.ch). For the purpose of comparison, forecast products such as the American GFS (Global Forecast System) –model or of the ECWMF (European Centre for Medium-Range Weather Forecasts) in Reading (England) are used at times (Vogelbacher, 2005).
To spatially assess the water release from snow melt and rainfall the simulation results of the snowmelt model SNOW 3 of the German Weather Service are used. Water yield and water equivalent of the snow cover are given in a spatial resolution of 1 km x 1 km in an hourly time step (Vogelbacher 2005). The model is run from November to April and for the area of the federal states of Baden-Wuerttemberg, Rhineland-Palatinate, Saarland, parts of North Rhine-Westphalia, Hesse, Saxony

and Bavaria as well as for Luxembourg and the French part of the Moselle river basin and the river basin Bregenzerach (Vorarlberg) (DWD, 2008).
Weather and storm warnings of the German Weather Service are sent via FAX, e-mail or are made available per internet. Further information can be obtained by telephone contact with the meteorologist in charge at the regional office of the German Weather Service in Munich (Bavarian Environment Agency 2008). For defined geographical regions in Bavaria the evaluation for areal precipitation amounts are given by the meteorologist.
Since December 2007 the model output of COSMO-LEPS (limited area ensemble prediction system of the consortium for small-scale modelling) (DWD, 2008) of 16 ensemble members is available. The ensemble forecasts are in a test phase for the operational use and applied for pilot areas.

Data flux within the flood information system

Measured data are automatically forwarded to a central server and imported into a central data base, after they have been retrieved by the data retrieval unit. Simultaneously, other data protocols are imported, e.g. data of adjacent countries and weather services, which were sent per e-mail or are made available on external FTP-servers. In case of failure of the central master database, its function can be performed by 4 other databases, which are located at the forecast centres in Munich, Kempten, Weilheim and Hof. Their data status is continuously updated by replication of the master database (Vogelbacher, 2007).

5 FLOOD FORECAST MODEL SYSTEMS

Until 2000, methods used in the flood information service were limited to empirical and empiric-synoptic approaches. Nowadays, forecast models are used that almost completely cover the area of Bavaria (Vogelbacher, 2005) (Figure 4, Table 2).
Basis for the flood routing model at the Main and Bavarian Danube rivers is the hydrodynamic model WAVOS (Wilke & Rademacher, 2002). At the Main river the flood forecast using the hydrodynamic model WAVOS is carried out for the total navigable river course, also outside of Bavaria for the Hessian section according to contracts. The forecasts at the border area between Bavaria and Baden-Wuerttemberg are accomplished by both federal states in parallel and have to be harmonised in case of flood situation.
The hydrodynamic model FLORIS 2000 (Pellegrini et al., 2006) is run for the lower Bavarian Danube, Lech and for the Bavarian stretch of the Inn river from Kufstein to Passau. The standard operating regulations of the run-of-river power stations are included (Vogelbacher, 2007). Linked to the hydrodynamic models are forecasts for the tributaries based on rainfall-runoff models. The rainfall-runoff model predominantly used is LARSIM (Large Area Runoff Simulation Model, Bremicker 2000). Due to its robust and relatively simple components the model is suitable for operational application (Gerlinger & Demuth, 2000). At several German flood forecast centres LARSIM is in operational use.
LARSIM can be applied as an event-based flood model as well as water balance model for continuous simulations. For the time being, in Bavaria the operational LARSIM flood forecast models are implemented in event-based mode. The water balance model mode is currently introduced. For the Iller basin the water balance mode of LARSIM is already implemented, and now in the operational pilot phase. For

the Danube stretch downstream the Lech tributary to Kelheim the water balance mode is currently built up. The Danube sub-basin from the river gauge Neu-Ulm to the Lech tributary shall be assigned in the course of 2008.

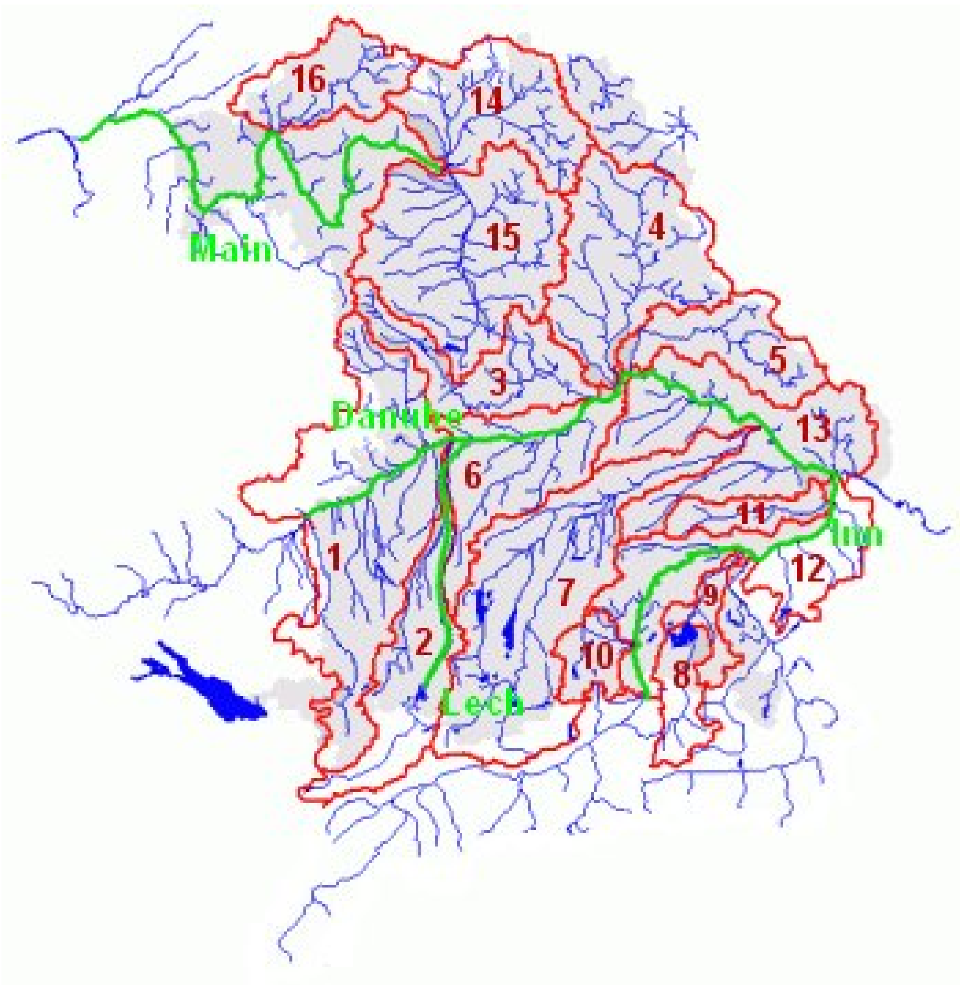

Figure 4. Overview about the hydrodynamic and rainfall-runoff models used for operational flood forecast in Bavaria (see Table 2)

Rainfall-runoff models are deterministic models, which calculate discharge rates as response to precipitation input. In the easiest case, the effective precipitation is determined with a runoff-coefficient depending on the antecedent moisture content of the area. According to non-linear relations between precipitation and resulting discharge the runoff-producing precipitation is adjusted by superposition calculations. The basins parameters can be in grid- or shape format, depicting the sub-basins. Each sub-basin is characterised by coordinates, elevation, length of water courses and schematic cross-section with roughness coefficients. On a grid or sub-basin basis the relevant runoff processes are calculated using specific hydrological methods. Table 3 contains the methods applied in most of the LARSIM models used in Bavaria.

Table 2. Rainfall-runoff models based on LARSIM used for the operational flood forecast in Bavaria (* see Figure 4)

Description (No.)*	River basin	Sub-basins (sb) or grids (gr)	Connection	Connecting river gauge
Danube river basin				
(1) Danube upstream of Lech	Danube upstream of Lech (incl. Iller)	11268 gr	Danube upstream Iller (Baden-Wuerttemberg)	Donauwoerth/ Danube
(2) Lech	Lech	177 sb		Augsburg/ Lech
(3) Altmuehl	Altmuehl	2638 gr		Beilngries/ Altmuehl
(4) Naab	Naab	6362 gr		Heitzenhofen/ Naab
(5) Regen	Regen	3091 gr		Marienthal/ Regen
(6) Danube incl. Paar	Danube downstream Donauwörth up to Regensburg (without Lech, Altmuehl, Naab, Regen)	7228 gr	Donauwoerth/ Danube Beilngries/ Altmuehl Heitzenhofen/ Naab Marienthal/ Regen	Regensburg Schwabelweis/ Danube
(7) Isar	Isar	1055 sb		Plattling/ Isar
(8) Chiemsee	Chiemsee incl. Tiroler Achen	7195 sb		Seebruck/ Alz (Outflow of Lake Chiemsee)
(9) Traun	Alz downstream Lake Chiemsee	77 sb	Seebruck/ Alz	Burgkirchen/ Alz Guffham/ Alz channel
(10) Mangfall	Mangfall	97 sb		Rosenheim/ Mangfall
(11) Rott	Rott	62 sb		Ruhstorf/ Rott
(12) Inn	Inn downstream Oberaudorf (without Mangfall, Alz, Salzach, Rott)	2682 sb	Oberaudorf/ Inn Rosenheim/ Mangfall Burgkirchen/ Alz Guffham/ Alz channel Burghausen/ Salzach Ruhstorf/ Rott	Passau Ingling/ Inn
(13) Danube downstream Regensburg	Danube downstream Regensburg without Isar	7931 gr	Regensburg Schwabelweis/ Danube Plattling/ Isar Passau Ingling/ Inn	Passau Ilzstadt/ Danube
Main river basin				
(14) Upper Main	Upstream of Regnitz	362 sb		Kemmern/ Main
(15) Regnitz	Regnitz	700 sb	Kemmern/ Main	Trunstadt/ Main
(16) Fraenk. Saale	Fraenk. Saale	352 sb		Wolfsmuenster/ Fraenk. Saale Mittelsinn/ Sinn

Snow accumulation and snowmelt can be considered as well as artificial influences (e.g. storage basins, diversions, water transfer between different basins).The model calculations are based on hourly data of precipitation, discharge, precipitation forecasts, as well as on snowmelt calculations and forecasts.

Table 3. Methods applied in most of the LARSIM (Bremicker, 2000) models used for the operational flood forecast in Bavaria

Module	Method
Areal precipitation for sub-basin	Modified grid-point method
Snowmelt model	Snowmelt according to Knauf method, Snow compaction according to Bertle
Effective Precipitation	Runoff-coefficient (constant or non-constant)
Base flow	Base flow yield (constant)
Runoff separation into overland flow and interflow	Interflow-index rate
Runoff concentration in sub-basins	Modified Clark method for overland flow Linear storage for interflow
Channel flow	Translation-retention method Constant translation Williams method Volume/Discharge relation

The operational flood forecast model system works in a so-called served operation. First, the rainfall-runoff models have to be run to the connecting gauge for the hydrodynamic model. Besides forecasts of the own rainfall-runoff models for the Bavarian region, external flood forecasts for tributaries are needed. E.g. in the Main river basin, the flood forecast for the Tauber tributary provided by the state of Baden-Wuerttemberg, is incorporated in the forecast for the Main river course. For the Hessian tributaries Nidda and Kinzig the flood forecast models are under construction. For the Danube forecasts upstream of the Iller tributary is produced by the Federal State of Baden-Wuerttemberg. For the Inn basin, flood forecasts are needed for the Inn upstream of Kufstein from the federal state of Tyrol (Austria) and for the Inn tributary Salzach from the federal state of Salzburg (Austria). The Salzach river is in the responsibility of the federal government of Salzburg using HYDRIS (Hydrological information system for flood forecast) (Vogelbacher, 2007). If the forecasts are missing, the flood forecast centre is roughly estimating for the next days.
Using rainfall-runoff models, the forecast period is limited by the weather and precipitation forecast. To adjust to the COSMO-EU model of the German Weather Service 72 hour forecasts are produced by default. However, forecasts for shorter periods are published in the internet. At present the hydrodynamic models are run for 48 h forecasts (Vogelbacher, 2007). Since December 2007 ensemble precipitation forecasts are used operationally for the pilot basins of the Rivers Regen, Fraenkische Saale, Upper Main, and Regnitz and are currently evaluated.

6 CONCLUSION AND OUTLOOK

In the last years several measures were conducted to improve the Bavarian flood information system. The existing monitoring network and data transmission have been modernised and expanded. Flood forecast models have been implemented and put into operation. Activities are ongoing concerning the improvement of discharge measurements, the implementation and use of new meteorological (forecast) products in the operational service and the further improvement and development of the flood forecast models. However, despite all these measures flood forecasts are and will be associated with uncertainties. Therefore, one of the main tasks being present is the estimation and communication of the uncertainties of the flood forecasts (see Laurent et al., 2008).

References

Bavarian Environment Agency (2008): Gewässerkundlicher Bericht – Hochwasser August 2005. http://www.hnd.bayern.de/ereignisse/hw220805/Gewaesserkundl_Bericht_HW200508.pdf

Bremicker, M. (2000): Das Wasserhaushaltsmodell LARSIM – Modellgrundlagen und Anwendungsbeispiele. Freiburger Schriften zur Hydrologie, Volume 11, p. 119

Gerlinger, K. & Demuth, N. (2000): Operational flood forecasting for the Moselle River Basin. In: PIK-Report No. 65 (1/2): Proceedings of the European Conference on Advances in Flood Research 2000. Potsdam Institute for Climate Impact Research, 546 - 558

DWD (German Weather Service) (2008): www.dwd.de - Link to Special User \ Water Management. (comprises information about products of the German Weather Service for water management) (accessed on 17th of March 2008)

Laurent, S., Ehret, U., Meyer, I., Moritz, K. & Vogelbacher, A. (2008): Dealing with uncertainty of hydrological forecasts in the Bavarian Danube catchment. Proceedings of the 24th Conference of the Danubian Countries, 2. – 4. June 2008, Bled, Slovenia

Pellegrini, M., Reichel, G. & Senfter, S. (2006): Bayerischer Inn – Entwicklung eines hydrodynamischen Modells. Ergebnisbericht der Phase II des Projektes; unpublished

Roth, C. (2008): Quality management of discharge measurements in Bavaria. Proceedings of the 24th Conference of the Danubian Countries, 2. – 4. June 2008, Bled, Slovenia

Vogelbacher, A. (2007): Unsicherheiten bei der Abflussvorhersage. In: Beiträge zur Fachtagung „Flutpolder – Hochwasserrückhaltebecken im Nebenschluss“, 19.-20. July 2007 in Wallgau, Upper Bavaria

Vogelbacher, A., Daamen, K., Holle, F.-K., Meyer, I. & Roser, S. (2006): Hydrological aspects of the flood in August 2005 in the Bavarian Danube Catchment. 23nd Conference of the Danube Countries on the Hydrological Forecasting and Hydrological Bases of Water Management. 28 – 30. August 2006. Belgrade, Republic of Serbia.

Vogelbacher, A. (2005): Sonderthema – Stand der Hochwasservorhersage in Bayern. In: Bavarian Environment Agency: Gewässerkundlicher Jahresbericht für Bayern 2005. http://www.lfu.bayern.de/wasser/daten/gewaesserkundliche_ jahresberichte/doc/jb2005.pdf

Wilke, K. & Rademacher, S. (2002): Operationelle Wasserstand- und Durchflussvorhersagen im Rheingebiet. Österreichische Wasser- und Abfallwirtschaft 54 (9/10), 154 - 162