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International Commission for the Protection of the Danube River

Internationale Kommission zum Schutz der Donau

Floods in June 2013 in the Danube River Basin

Brief overview of key events and lessons learned

//// Deutschland //// Österreich //// Česká republika //// Slovensko //// Magyarország //// Slovenija //// Hrvatska //// Bosna i Hercegovina //// Србија //// Crna Gora //// România //// България //// Moldova //// Україна ////

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Flooding of the German federal highway A8 in Bavaria,
Exit Grabenstätt

1. Introduction

Extreme floods occurred in June 2013 on the upper and lower Danube and the strength and intensity of this flood event reminded to floods in 2002.

The flood impact was devastating in Germany, Austria, Slovakia, Romania and Hungary, remarkable consequences were observed in Bulgaria, Croatia and Serbia.

In other countries the flood extent was minor or no floods were observed.

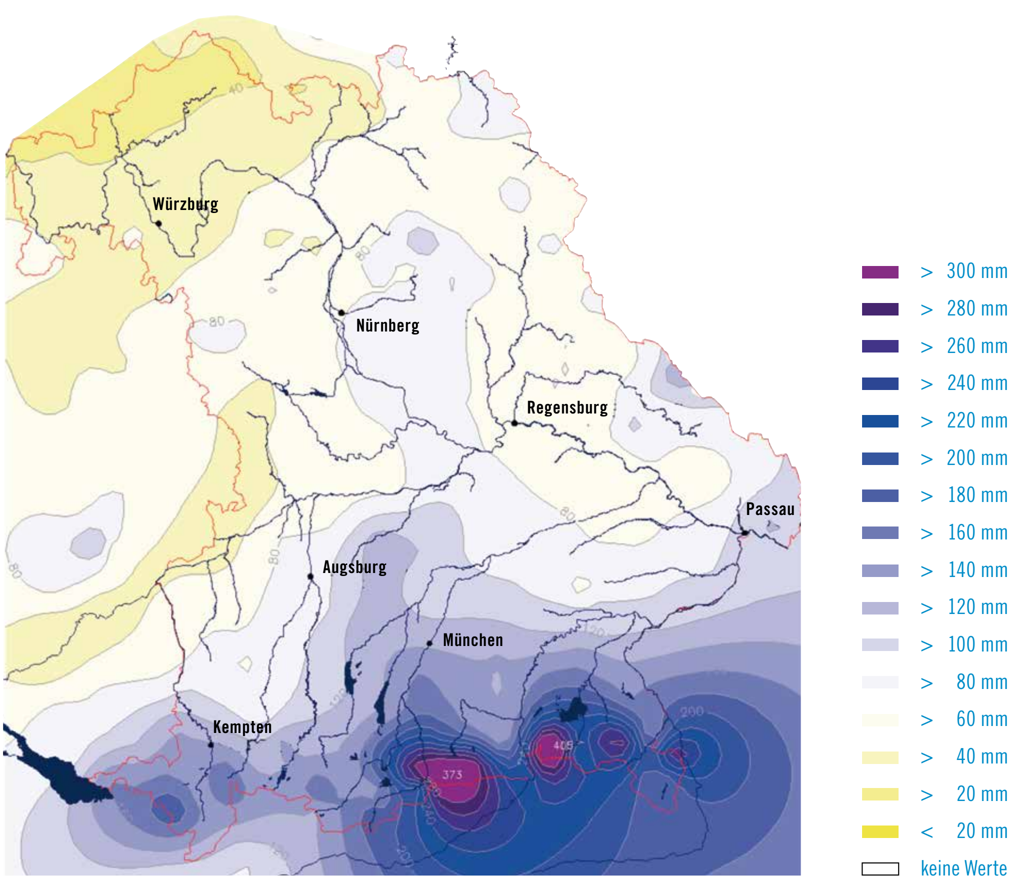
2. Meteorological situation/ precipitation

2.1 Upper Danube

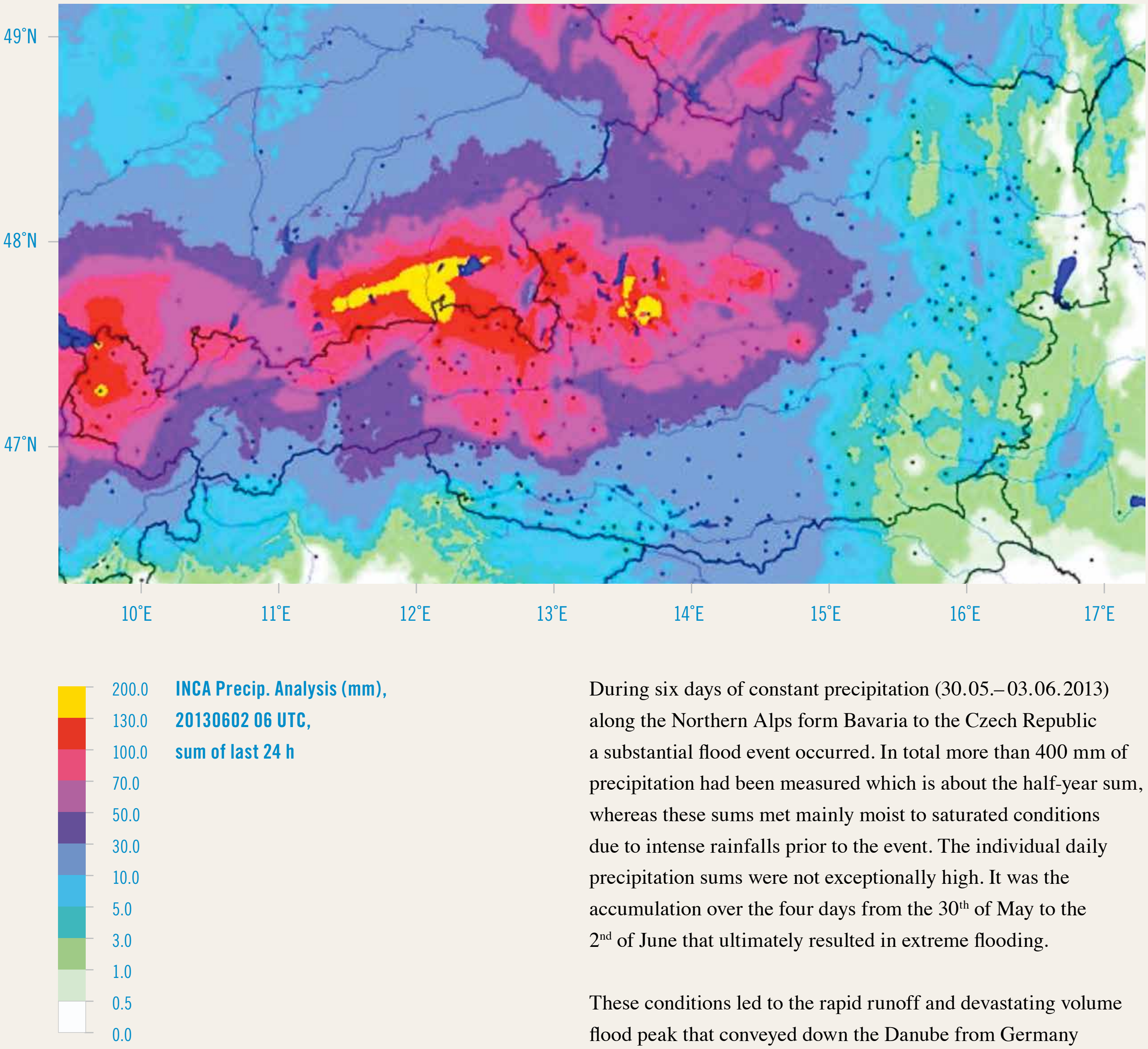
An isolated low-pressure area above the Adriatic Sea (so called Vb meteorological conditions) was enhanced by a Mediterranean low pressure area over northern Africa. At the same time – prior to the intense rainfall – the area from Romania to the Black Sea was very warm from the middle of May; therefore, the air mass was enriched by the moisture of the Black Sea area and the Mediterranean Sea area. These air masses were forced to Central Europe by a large-scale low-pressure area and by the Adriatic Sea low-pressure area at ground level transported to the North side of the Alps.

The precipitation situation that caused the June floods in the upper Danube resulted from an extended area of low pressure centered in Slovakia and in south-western Poland. Two types of macro-synoptic weather pattern („Großwetterlagen“) referred to as “Central European Trough” and “Central European Low” occurred and remained stationary over a long period of time. The continuous inflow and subsequent lifting of warm humid air led to a continuous rainfall event lasting almost 96-hours that began on the 30th of May.

Map of Bavaria showing the precipitation sum that fell during the relevant four day continuous rainfall period from 30.05.2013 to 02.06.2013 *FIGURE 1*



Map of Austria showing the precipitation during 02.06.2013 *FIGURE 2*



INCA Precip. Analysis (mm), 20130602 06 UTC, sum of last 24 h

During six days of constant precipitation (30.05.–03.06.2013) along the Northern Alps form Bavaria to the Czech Republic a substantial flood event occurred. In total more than 400 mm of precipitation had been measured which is about the half-year sum, whereas these sums met mainly moist to saturated conditions due to intense rainfalls prior to the event. The individual daily precipitation sums were not exceptionally high. It was the accumulation over the four days from the 30th of May to the 2nd of June that ultimately resulted in extreme flooding.

These conditions led to the rapid runoff and devastating volume flood peak that conveyed down the Danube from Germany to Romania.

2.2 Lower Danube

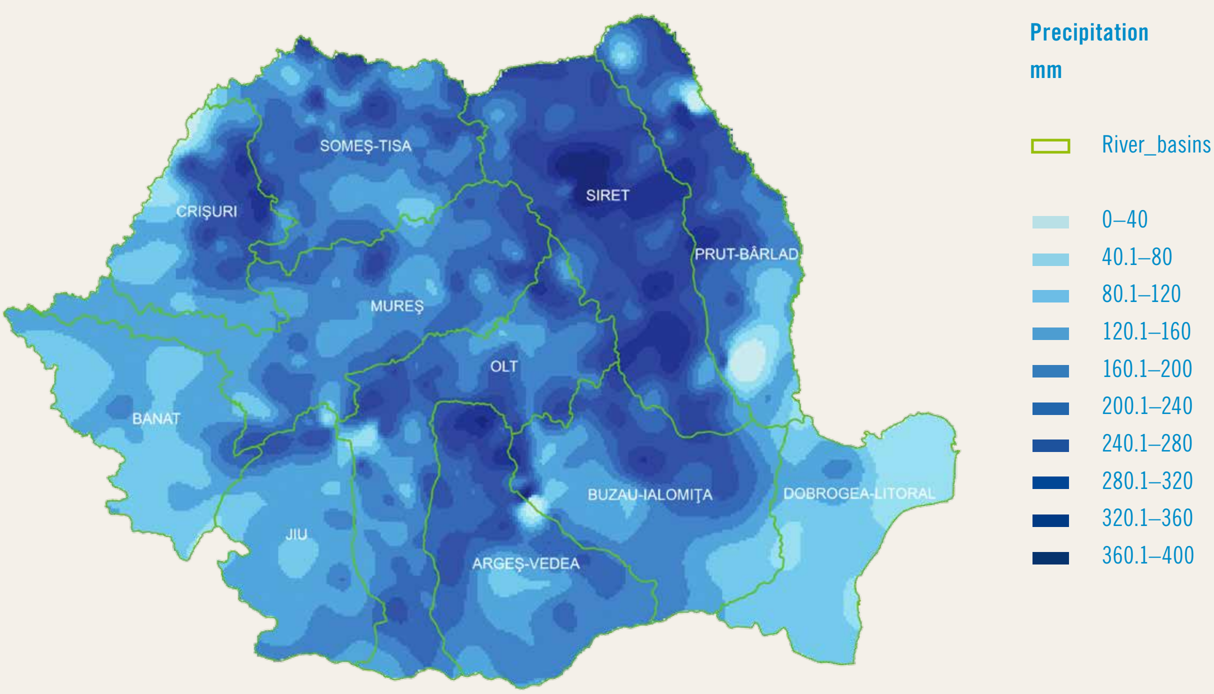
13 out of 41 counties in Romania had been hit by severe floods, mainly caused by a torrential rain. The most affected river basins were Siret, Prut, Barlad, upper and middle Mureş and upper and middle Olt. The cumulated precipitation in June in those counties ranged as following: 300–400 mm at 5 stations in central Siret basin, 200-300 mm at 37 stations in the upper Siret, Prut, Olt and Mures, 100-200 mm at 287 stations in Siret, Prut, Barlad, upper Argeş and middle Olt.

The examples of an extreme rainfall in a very short period of time are as folows: Capalnita in the upper Olt – 97 mm in 70 minutes, Leghin in the middle Siret – 100 mm in 40 minutes and 118 mm in 24 hours in Iasi city on the middle Prut.

Also in Bulgaria the total rainfall in June was about 40% above the long-term monthly average. The most intensive rainfall was registered during 30.06–01.07 in the Silistra-region (64 to 140 mm), in the Ruse-region (127 mm) and in the Tutrakan region (110 mm).

Cumulated registered precipitation in June 2013 in Romania

FIGURE 3



3. Key flood events

The overview of the return periods for the peak discharges on the Danube River during the floods of May and June 2013 is shown in Figure 4.

3.1 Germany

At first, the areas most affected by flooding were the basin of the river Main and the northern Danube tributaries, later there was a shift to the Danube River and its southern tributaries. In many places, built-up areas were flooded. The flood warning levels 3 and 4 were reached at numerous gauges all over Bavaria. Particularly affected were the catchments of the smaller lowland Danube tributaries ("Donauvorland") and the alpine river basins in south-eastern Bavaria, as well as the lower reaches of the Bavarian Danube, where new record maximum water levels were measured at some gauging stations. Renewed rainfall from the 9th to the 10th of June led to a second flood wave, especially in the Danube River Basin. The areas most affected were those located along the southern Danube tributaries, where, in some cases, the water levels exceeded those during the first flood wave.

Along the course of the Danube River the (statistical) return periods that correspond to the measured flood discharges rise continually from 2 to 10 years on the western border with Baden-Württemberg to over 100 years on the Austrian border. In Bavaria, practically all the tributaries to the Danube contributed to the flood, with discharges with return periods of 100 years or more occurring for the rivers Inn, Mangfall, Tiroler Achen, Saalach and Salzach. In Baden-Wuerttemberg the discharge in the tributaries Lauchert and Schmeie had a return period of 100 years or more.

3.2 Austria

First analyses showed that the event exceeded the dimensions of the 2002 flood, mainly along the Saalach River, Salzach River, the Bavarian Inn River, the upper reaches of the Danube River as far as Hungary. Flood events of similar dimensions had been recorded in the 1501. At the border from Bavaria to Austria water discharges of the Inn and the Danube lead to the highest records ever measured. The coincidence of peak flows of the Saalach River and Salzach River as well as the Inn River and the Danube River lead to a record of the Passau gauge that had been measured 500 years ago. Along the Austrian Danube gauge data show peak discharges that have not been recorded during the past 200 years.

3.3 Slovakia

Water level on the Danube started to rise on 31st of May. In next days, the water levels continued increasing and exceeded all levels of flood activity at all stations on the Danube River. Flood peak in Bratislava reached 1034 cm (10 641 $m^3.s^{-1}$) which is the new historic maximum (in 2002 only 991 cm level was reached). Water level records were exceeded at all stations on the Slovak section of the Danube. The last station on the Slovak Territory – Štúrovo has peaked on 9th June in morning hours. Heavy flooding on the Danube stopped inflowing water from tributaries and has caused backwater and very high water levels in lower parts of Morava, Vah, Nitra and Hron Rivers.

Return periods for the peak discharges on the Danube River during the floods of May and June 2013

FIGURE 4

This ICPDR product is based on the national flood information provided to the ICPDR. National borders data was provided by the Contracting Parties to the ICPDR and CH; ESRI data was used for national borders of AL, ME, MK;
Shuttle Radar Topography Mission (SRTM) from USGS Seamless Data Distribution System was used as topographic layer; Data from the European Commission (Joint Research Center) was used for the outer border of the DRBD of AL, IT, ME and PL.
Vienna, August 2014

3.4 Hungary

The flood event in June 2013 was the highest ever recorded flood level all along the Hungarian Danube section, except only one gauge at the most downstream part of the country (Mohács). Heroic fight of professionals and civilians were needed to keep the water between the dikes and protect the lives of thousands, since a small mistake could have caused a regional catastrophe. The massive flood volume had a surface peak which was the maximum of the water level that can be handled. Still tens of kilometres of temporary dikes had to be built up to prevent large areas from inundation.

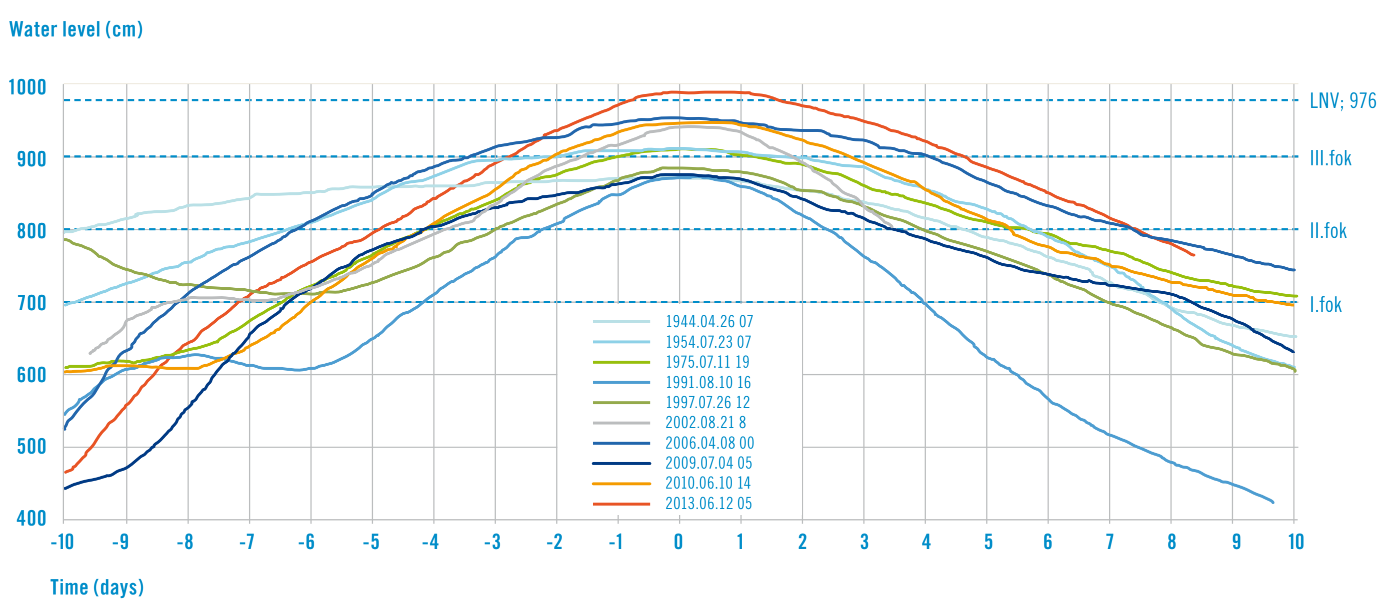
The flood propagation can be compared to the event in August 2002. The main difference is in the lower gross amount of water and the aerial distribution of the precipitation. It can be however assumed that even higher runoff (+300-500 m^3/s peak discharge) is possible if the same catchment conditions would coincide with the 2002 meteorological events.

Based on ADCP measurements the incoming peak flow was 10.640 m^3/s at Vámosszabadi, and 8.300 m^3/s left the country towards Croatia. The calculated return period based on the existing statistics is around 125-135 years in the upstream part, but if the 2013 event is taken into the sampling it could go down to 80 years.

Until 2013 the highest ever recorded flood levels were registered in 2002 in the Hungarian upper Danube section (Rajka-Nagymaros), in 2006 in the Hungarian middle Danube section (Nagymaros-Budapest) and in 1965 in the Hungarian lower Danube section (Dunaújváros-Mohács). Except of Mohács all these values were exceeded in 2013 with 13-44 cm overtop.

During the defence work the alerted dike length went over 800 km. The Hungarian Government announced emergency situation on 3rd of June and 540 km long dike turned into an extreme alert level. The effective defence work was carried out in between 31 May – 19 June, but because of certain damages and legislative rules the emergency situation lasted until 19 July.

Peak Danube levels during major floods at Baja *FIGURE 5*



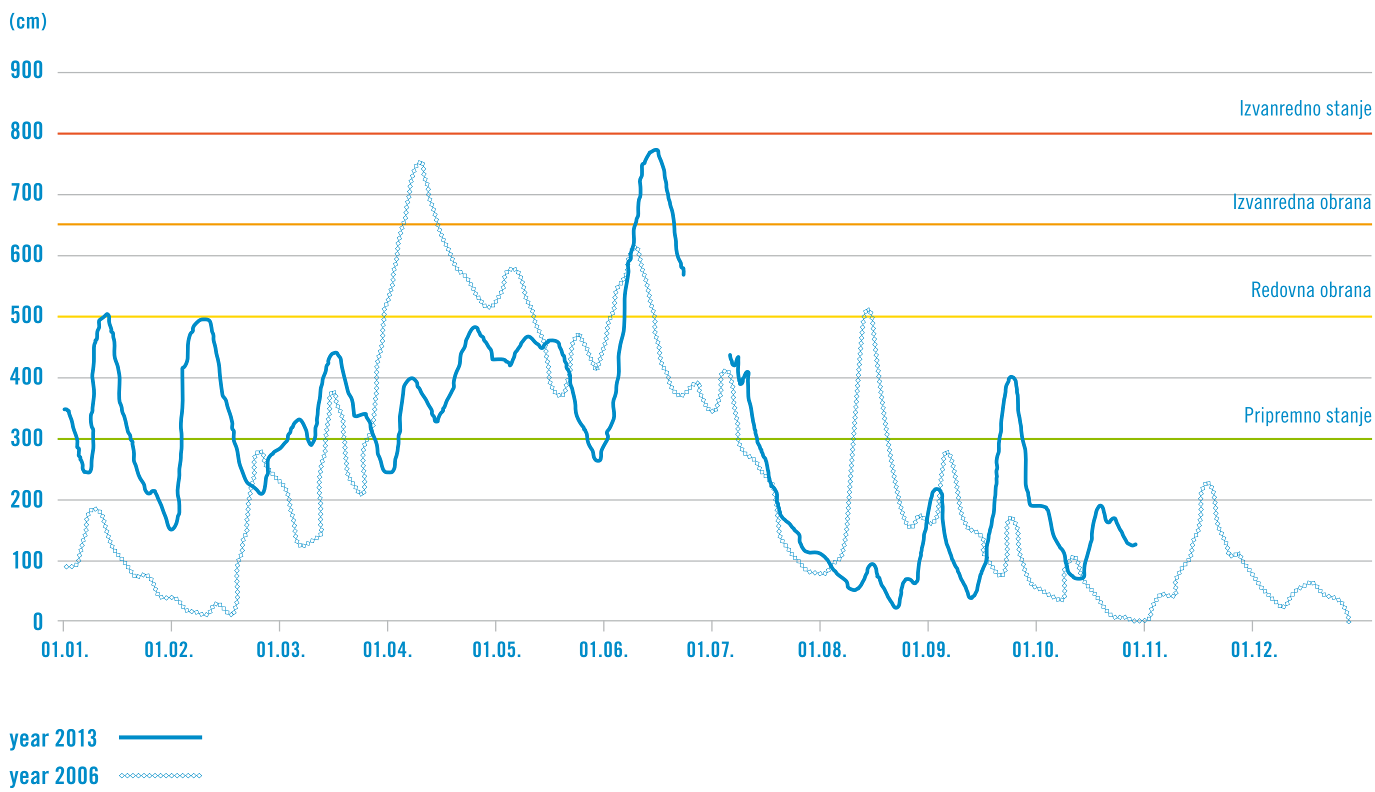
3.5 Croatia

At the Batina gauging station, on the entrance of the Danube River to Croatia, peak of flood wave was recorded on the 11th June with corresponding measured discharge of 8.374 m^3/s. This was the highest ever recorded discharge of the Danube River at this place (in June of 1965, almost equal discharge of 8.360 m^3/s was recorded). It is estimated that return period of this event was approximately 90 years.

Downstream of the Drava River mouth, at the gauging station Aljmaš, peek of the Danube flood wave of 8.643 m^3/s was measured on 14th June and it was the second highest discharge recorded at this location. Historical maximum of 9.250 m^3/s was recorded during flood event in June 1965. Return period of 2013 flood at this site equals 55 years.

Comparison of water levels in 2006 and 2013 with alert thresholds of the Danube River in Batina (upstream of the Drava River mouth)

FIGURE 6



3.6 Serbia

In June 2013 high flows occurred only on the Danube River, while the flows on the important tributaries in Serbia (the Tisza, Sava and Velika Morava) were on the average level or slightly above. Consequently, the Danube flood wave declined in the downstream direction: upstream of the Tisza River the peak discharge was 8350-8550 m^3/s (return period 50-100 years, the highest after 1965), between the Tisza and the Sava River 9400 m^3/s (return period 20-50 years) and downstream of the Sava mouth 10500 m^3/s (return period 5 years). Peak flows are registered between 14th and 17th June. The highest inflow (10700 m^3/s) and outflow in the "Iron Gate" reservoir (11000 m^3/s) was recorded on 17th June, and decreased afterwards.

After 6th June, when the regular flood defence was proclaimed on the most upstream levee section in Serbia, the length of affected structures gradually increased and reached 400 km on 14th June. Emergency defence was proclaimed only on levee sections upstream of Novi Sad, and lasted from 11th to 21th June. Downstream of Novi Sad, only regular flood defence was in force till 4th July.

3.7 Romania

In June, the hydrological regime in most of the Romanian river basins was about 50-80 % of the normal monthly value. Different situation was in the upper Mures, Tisa, upper and middle Siret and its tributaries, and in the lower Prut and Barlad having the discharges above the average. The warning levels had been reached in the second and third decade of June in Barlad and Buzau catchments (danger level), in the lower Siret (inundation level).

At Bazias (the Danube's entrance to the Romanian territory), the average flow in June was 8,650 m^3/s, (multiannual average being 6,400 m^3/s). The maximum Danube flow recorded in June was 10,600 m^3/s (17 June) which was less than 13,500 m^3/s recorded on 13 April 2013.

The highest level was in Bechet (1-9 cm over inundation level) on 18-20 June. The attention level were exceeded between 15–22 June in the Gruia-Zimnicea sector, on 24–26 June at Harsova and for 30 days in the Isaccea-Tulcea sector.

3.8 Bulgaria

Taking into account the incoming information about the raising of the Danube-level in the upstream countries and the expected increase of the water-level in the Bulgarian section of the Danube, the Ministry of Environment and Water triggered in the beginning of May the "yellow code" of flood-danger (increased attention). The first level of readiness of the rescue teams in the municipalities along the Danube was announced in the second decade of June. Due to the increased level of the ground water in some coastal areas, the drainage pumping stations have been activated.

Continuous monitoring of the level of inland rivers has been organized depending on the meteorological situation. The precipitation led to increased river level, but critical levels were not reached and no floods occurred along the rivers. Floods occurred only in some urban areas in the North-east region of the Bulgarian part of the Danube basin as a consequence of the heavy rains on 30. June – 1. July (flash floods).

4. Flood warning and monitoring

4.1 National systems

4.1.1 Germany

On Wednesday the 29th of May, the Bavarian Flood Warning Service with the flood prediction centres Danube, Inn, Isar and Iller-Lech were on an increased state of alert due to the rainfall forecasts by the global weather models of the German Weather Service (DWD), the U.S. Weather Service and the European Centre for Medium-Range Weather Forecasts for the period from 31st May to 2nd June.

The Bavarian Flood Warning Service had already increased its activities on the 26th of May and was manned around the clock from the 31st of May to the 5th of June. By the 13th of June the service had compiled 40 status reports as well as continually updated the flood forecasts for the affected areas, taking the continuing developments regarding the flood situation into account. Due to the relatively high level of agreement between the precipitation forecasts of the different weather services, it was possible to inform the Water Management Agencies about the imminent event in good time. Nevertheless, the exact magnitude and the spatial distribution of the most affected areas were difficult to predict.

The Flood Warning Service in Baden-Wuerttemberg (Hochwasser-vorhersagezentrale der Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg) has calculated and published updated flood forecast, consulted crisis management groups and emergency units and delivered information to the public from 31st May to 3rd June 2013.

4.1.2 Austria

Flood warning and monitoring systems worked well, however the predicted peak flows along the Danube River were inherent to uncertainty as the “system input gauge” in Passau did not work properly being affected by the 500 years flood and the gauge finally failed. Nevertheless, the peak flow has been predicted, accordingly.

4.1.3 Slovakia

Hydrological forecasting and warning service at the Slovak Hydrometeorological Institute (SHMU) recorded precipitation and increase of water levels on the upper part of the Danube and its tributaries.

Since 1st June the hydrological warnings on a danger of flooding and rainfall have been continuously updated and issued for the whole Slovak part of the Danube River Basin. The responsible flood protection institutions were warned about the very high water level already on 2nd June 2013 with an estimated water level of 950 cm at the station Devin.

From 2nd June the flood forecasting service at SHMU was on a continuous operation duty and had published the estimates of magnitude and time of flood peak since 3rd June.

High water levels on the Danube caused backwater on the lower stretches of the Morava and the Vah Rivers, therefore hydrological warnings against the dangers of flooding were issued for this part of the basin as well. Altogether 16 hydrological warnings were issued from 1st to 12th June 2013.

4.1.4 Hungary

Thanks to the internet-based information and data dissemination the Hungarian forecasting group estimated the peak wave at the first main water-gauge (Nagybajcs) 5 days earlier. This led to the time advantage of 7 days for Budapest and of 10 days for Mohács. The gauging system worked well (15 minute recordings on average), hundreds of discharge and water level measurements were carried out in addition to it. During the flood aerial photos and airborne observations were taken and satellite images have been recorded.

4.1.5 Croatia

National competent authorities received all relevant hydrological information from the upstream countries more than 10 days before flood wave peak entranced in Croatia.

4.1.6 Serbia

Republic Hydrometeorological Service of Serbia issued daily bulletins with observed water levels and flood forecasts, between 30th May and 4th July. Permanent monitoring along the Danube was instituted from the beginning of the regular flood defence. In line with the General and Annual Flood Defence Plans information was sent to all actors in flood defence, but it was also made available to public and media.

4.1.7 Romania

The National Meteorological Administration (NMA) is responsible for ensuring the weather forecasts. In addition, NMA prepares warnings on severe weather phenomena. In June 2013 NMA issued four national warnings and 115 nowcasting warnings (3-6 hours anticipation).

The National Hydrological Forecasts Centre (NHFC) acting in the frame of the National Institute of Hydrology and Water Management is charged with the operational hydrological short-range, medium and long-range forecasts and flood warnings at national-wide. NHFC issued 18 hydrological warnings (yellow and orange code) in June 2013.

4.1.8 Bulgaria

According to the Bulgarian Water act, the Ministry of Environment and Water (MoEW) is the authority in charge of flood-warning and monitoring. This function is being performed by a special operational unit according to order of the Minister which stipulates its responsibilities and functions. The unit performs daily analysis of the meteorological situation and hydrological information including prognosis about the water quantity and water-level of Danube, internal rivers and dams and informs other national authorities concerned in case of expected flood-danger. Similar units are operating at the Basin directorates.

Due to the complicated situation in June 2013, alert messages about an increased flood danger have been sent by MoEW to the Fire Safety and Civil Protection, Irrigation systems, Kozloduy nuclear power plant and River Basin Directorates. Danube River Basin Directorate (RBD) circulated instructions to all governors, mayors and to the regional subdivisions of “Irrigation systems” in the Danube RBD. Permanent monitoring of the rivers and of the hydraulic structures was being performed by the Danube RBD; information was sent to MoEW daily.

4.2 Danube EFAS response

Over the last week of May, EFAS forecasts showed a rapidly increasing probability of exceeding flood warning thresholds for wide areas in Central Europe including Germany, Austria, and Slovakia. Between the 28th May and 10th June, 13 EFAS flood warnings of different levels (namely, flood alerts and watches) were issued for parts of the Danube River and its tributaries, with varying lead times before the beginning of the extreme streamflow conditions. EFAS flood warnings were sent always to the principally affected authority as well as to all downstream located authorities in order to make sure that also the downstream located authorities were aware of the upcoming flood situation.

The EPIC index for flash flood early warning picked up the extreme character of the precipitation event over a large area centered along the Austrian-German border, indicating high probability of flash flooding in a number of alpine catchments. An EFAS watch for extreme precipitation and possible flash flooding was issued for this area on the 1st June, with 30–36 hour lead time on the event peak.

Feedback from the Bavarian Environment Agency as well as the Slovak Hydrometeorological Institute on the EFAS flood warnings sent for the Danube River Basin demonstrated that in general the location of the warnings was correct but that the warning lead-time varied significantly depending on the location. Furthermore, a general underestimation with respect to the peak flows was observed which was principally caused by an overall underestimation of the forecasted precipitation and the model initial conditions. Further updates of EFAS will address both of these issues.

5. Flood interventions and affected area

5.1 Germany

The Bavarian state has maintenance responsibility for embankments (1350 km), flood protection walls (80 km) and mobile flood protection systems (20 km) for category I and II water bodies. Between Ulm/Neu-Ulm and Vilshofen the Bavarian Danube is secured with almost uninterrupted flood protection. Downstream of Vilshofen, flood protection facilities are only in place for some individual locations. The historical city centre of Passau has no technical flood protection facilities.

As a rule, those flood protection facilities that fulfil current design standards were able to provide the necessary protection. Some flood embankments that do not yet entirely fulfil current requirements for a 100-year flood were only able to withstand the flooding with the help of emergency reinforcements, thus avoiding overtopping or breaks in the embankments. Neverthe-less, in a few isolated cases the protection systems did fail.

For the alpine torrents in Bavaria, the June 2013 flood only caused minor and limited damage due to the protection provided by almost 50.000 structural control measures. For lakes and reservoirs, the most affected areas regarding flood retention were eastern Bavaria and the alpine foothills. Here, in most cases, the available retention volumes were fully exploited. In total it was possible to retain some 129 million cubic metres of water in the course of this flood event.

In Baden-Wuerttemberg the return periods on the Danube River stayed throughout the flood event below 10 years. No negative impacts were recorded. However on some tributaries the return periods were higher and led in some cases to flooding.

At the tributary Iller a flood event with a return period of 50 years occurred. At the Eschach, a tributary of the Iller, the flood retention basin of Urlau and the Taufach-Fetzachmoos were flooded and stored around 4,5 Mio. m^3. The dikes at the Iller resisted the flood event. In total no critical incidents occurred in the river basin of the Iller.

Damaging flooding occurred at the tributary Lauchert, where in the town of Veringenstadt the historic centre was flooded. Approximately 100 buildings were affected and 200 people had to be evacuated. Several other towns at the Lauchert were also affected by this flood event.

Deployment of mobile flood protection walls in Austria FIGURE 7

5.2 Austria

In Austria particularly affected had been the area around the lake Constance (Vorarlberg), the regions of Kufstein and Kitzbühel in Tyrol, the federal State of Salzburg and Lower Austria, the Federal State of Upper Austria along the rivers Danube, Enns, Inn and Traun as well as the regions Braunau, Gmunden, Perg, Steyr and especially the regions Eferding, Schärding und Urfahr-Umgebung and some municipalities in Styria along the Enns and Mur River.

In Salzburg, Upper Austria and Lower Austria a disaster alarm had been released. Along affected rivers the available flood protection measures had been implemented (mobile protection elements, dyke defence) and endangered people had been evacuated.

5.3 Slovakia

The water levels increase in the Slovak section was recorded from 31st May 2013 to 01st June 2013, when the Danube River water level increased in the profile Bratislava – Devín during 24 hours by 248 cm. Consequently, significant increase of water levels also in all mouth sections of the Danube River tributaries – Morava River (subsequently Malina River), Váh River (subsequently Malý Dunaj), Hron and Ipel' Rivers occurred, caused by a backwater effect. On 02nd June 2013, II. flood protection activity degree (i.e. start of security works and installation works on mobile elements of the Bratislava flood protection system) was triggered in a number of flood protection sections.

On 06th June 2013, the evacuation of residents of residential area between old and new inlet structure Malé Pálenisko took place. The Danube River water levels culmination (Devín 974 cm, Bratislava 1034 cm) was observed on 6th June 2013 in the evening hours.

In compliance with flood protection safety work plans, particularly the following measures were carried out:

- Continuous pumping of internal waters by pumping stations,
- Removal and disposal of debris and biomass from drainage channels,
- Bank lining stabilization and scours remediation,
- Installation of flood protection mobile elements in Bratislava in compliance with operating regulations and with the approved flood protection plan,
- Pumping water by mobile pumping units,
- Outflows remediation using jute bags and sand.

979 operatives took part in performing the necessary flood protection measures using a wide range of vehicles, machines and devices and utilizing e.g., 134 910 sand bags, 3000 tons of quarry stone and 3600 tons of gravel.

5.4 Hungary

The flood affected mainly the Danube valley (8 counties) and the connected riverbed network because of the backwater effect. The potentially exposed area was around 4.100 km^2 with 2,2 million inhabitants and 52 directly affected, summa 199 endangered settlements. In one 12-hour duty the official manpower were max. 4.200 persons, but there was a high number of additional civil volunteers.

The load on the defence structures was very high and several sections, which were under construction, needed a special attention. Settlements on “high banks” had to build up defence lines in locations where it was never needed before, so huge resources were directed to those areas, too.

The main task was to complement the height deficits on the dike crests and discover low terrestrial formations or ridges to build temporal earth dike lines. Usual routine was to cover the wet side of the dikes with plastic foil and stabilize the embankments with extra load on the dry side to avoid dike breaches or slides. Due to the high water pressure several boils appeared which had to be supported with counter-pressure pools. In some places mobile elements were placed that worked well. Seepage generally appeared everywhere and slowed down the material transport.

Military support to dyke reinforcement at Györújfalu *FIGURE 8*

Flood protection measures in the Vukovar port *FIGURE 9*

5.5 Croatia

Due to timely flood warnings and information from upstream countries, there was enough time for the application of preventive operative flood defence measures along the Danube River and its tributaries affected by the Danube backwater.

All organisations involved in operative flood defence were operating adequately and information to the public was provided on a regular basis. The existing flood defence structures were additionally strengthened by earth and sandbag (500.000 units) dykes and by removable flood barriers (cca. 2.000 metres of "box" type barriers). The outlets of sewerage systems were closed.

Before and during the high-water period, operative flood defence procedures were carried out including seepage control and pumping of excess water on several locations. Few minor incidents occurred on 14th of June near the inflow of Vučica River to the Drava River and in the city of Osijek, but due to prompt intervention there were no significant damages.

5.6 Serbia

Due to short duration, the flood impact was small. The negative phenomena on levees (water logging sources, leaks, etc.) were permanently monitored, and emergency measures were taken where needed.

5.7 Romania

The most affected counties in June were: Arges, Bacau, Dambovita, Harghita, Hunedoara, Iasi, Mures, Neamt, Sibiu, Suceava, Tulcea, Vaslui and Vrancea.

Following the meteorological and hydrological warnings, the institutions responsible for operative interventions (Romanian Water, County and Local Committees for Emergency Situations and General Inspectorate for Emergency Situations) took specific actions such as:

- emptying reservoirs in order to increase their capacity for flood mitigation;
- dykes strengthening with sandbags, flood tubes and geotextiles;
- permanent surveillance of affected river sectors and fishponds;
- water pumping from houses, households and courtyards;
- unclogging the street gutters and canals;
- excess water elimination from canals and from drainage systems by pumping stations;
- eliminating bottlenecks caused by floating debris, particularly in the areas of bridges, culverts and water intakes.

5.8 Bulgaria

Interventions were undertaken in the regions flooded by flash floods. Emergency-teams of the Main Directorate Fire Safety and Protection of the Population at the Ministry of Interior were activated to carry out the rescue operations and to drain the flooded residential areas.

The residential areas in the Sofia-region and Lovech were flooded due to the heavy rainfall on 11th and 25th June. Torrential rainfall between 30th June and 1st July caused flooding and damages of properties in the residential areas of Silistra, Dobrich and Russe municipalities in the north-eastern part of the country. The most affected area was the municipality of Glavinitsa and Valchi dol where many streets, private properties and public buildings have been flooded and damaged.

There were isolated cases of evacuation of people from flooded buildings and cars.

Besides the emergency interventions, disinfection works were carried out in some flooded settlements in order to avoid further adverse consequences related to the environment and human health.

6. Casualties and assessment of damages

6.1 Casualties

In Austria there had been 5 casualties directly related to the flood event. Four victims were reported in Romania.

No casualties were recorded during 2013 flood events in the Danube River Basin part of Germany, Slovakia, Hungary, Croatia, Serbia and Bulgaria.

6.2 Damages

6.2.1 Germany

In Bavaria the flood event caused damage worth of 1.3 billion €, mostly in the western Danube region. The damage to state owned flood protection facilities amounts 111 million € in total.

Damages to alpine torrent control facilities are estimated at approx. 4,3 million € with additional costs arising from material loss caused by the event.

In Baden-Wuerttemberg the flood event caused damages of approximately 23 million €.

6.2.2 Austria

The total monetary losses are estimated at 870 million €. Whereas (in million € rounded sums) 425 are documented by the Länder, 70 by the Austrian Federal Railways, 1 by private Railways, 80 for flood protection measures of the Federal State, 27 for waterways, 10 for forestry, 2 for national defence, 2 for telecom, 0.5 for road networks and 15 for energy suppliers. In total an estimated 235 million € are insured losses.

6.2.3 Slovakia

The floods directly endangered 742 persons, roofless stayed 245 persons out of which 171 children. Floods caused evacuation of 150 persons. No one died during floods, 1 person was injured. The water flooded 1.951 buildings out of which 1.778 family houses and 51 apartment blocks. The floods inundated 527 non-residential premises.

The verified flood damages amount to 12.136 million € out of which the documented damage of properties was as follows: 1.2 million € for properties owned by personal entities, 4.2 million € for properties owned by legal entities and companies, 1.8 million € for properties owned by municipalities, 3.3 million € for properties owned by regions and 1.7 million € for properties owned by state.

6.2.4 Hungary

The damages occurred mostly in the embanked floodplains or in the defence structures. The high groundwater tables resulted in crop failures and the material transport to the flood protection structures generated agricultural losses. In settlements the groundwater movements caused problems with the public works in some places.

Based on the available information the cost of the defence work was 58 Million €.

6.2.5 Croatia

There were no direct damages caused by floods, except of few (weekend) houses built in flood-prone areas of the Drava and Danube Rivers.

6.2.6 Serbia

Only undefended areas between levees were flooded, and damages were low. The cost of flood protection activity was 32.5 million RSD (280,000 €).

Oil pollution caused by floods in Bavaria *FIGURE 10*

6.2.7 Romania

The total value of the damages in all 13 affected counties was 206.2 million lei (46.1 million €).

The floods affected 336 houses, 544 households, 16 social and economic objectives, 822 bridges and footbridges, 2225 km of roads (national, county and local), 16190 ha of agricultural field and 52 hydraulic structures.

6.2.8 Bulgaria

The damages include flooded and damaged private and public buildings, roads and streets. Due to a landslide a local road was closed. The regional library in Ruse has been flooded and about 50,000 books had to be evacuated.

108 households have been affected after the flooding in Glavinitsa-Municipality. Four houses were assessed as being in danger of collapse and some other as needing fortifications. A drainage channel spilt over; agriculture areas have been inundated and the crops were destroyed. The total damage in Glavinitsa is being assessed to be over 300,000 €.

All the streets in Municipality of Valchi dol have been flooded and many of them have been damaged. Almost all residential buildings have been affected. Many public buildings, including 3 schools and the Municipality's cultural club have been damaged. The sewerage have been blocked up by silt and has been disabled. The total cost of the damages has been assessed to be more than 1 million €.

7. Lessons learned

This most recent flood event has again confirmed the necessity for modern and effective flood protection measures to protect the population and secure economic activities. It also reiterated the basic fact that even the most up-to-date protection systems can only provide a certain level of security and that there is always the residual risk. The flood protection measures must be therefore considered as a part of an integral flood risk management, taking into account the occurrence of extreme flood events being a natural phenomena. The widespread use of flood hazard and flood risk maps in the different fields of action has during 2013 floods again proved to be a basis for a successful and efficient flood risk management.

Application of properly designed measures helped to reduce the flood risk. Austria can be given as an example as despite that floods in 2013 were hydrologically similar or even more extensive compared to floods in 2002, the damages recorded in Austria in 2013 were lower (the estimation shows a decrease from 3.2 billion € to 870 million €). This means that the lessons learnt from 2002 floods and targeted investments (2 billion € for Austria) lead to a substantial reduction in losses.

Structural flood protection such as dykes and demountable barriers may however lead to transferring more water downstream during extreme flood events. This type of measure, therefore, needs to be compensated by providing additional retention areas. Hence, the application of the solidarity principle, which is one of the objectives of the Flood risk management plan for the Danube River Basin, is essential.

The castle in Weltenburg an der Donau protected by the mobile flood protection system *FIGURE 11*

7.1 Land Use and Spatial Planning

The damages caused by 2013 flood event only 11 years after the major floods in 2002 proved that the prevention of new building areas in flood zones in Germany is the most effective way to avoid new flood risks. The German Federal Water Act (Wasserhaushaltsgesetz) stipulates that in the zones of floods with a return period of one hundred years there are restrictions concerning the land use and the spatial planning in these areas. Using the structural and non-structural measures the existing flood risks can also be decreased.

In Hungary along the Danube the "high banks" (areas above the design flood level) near settlements became insufficient for long sections, especially upstream Budapest. In these areas reconsideration of the defense strategy is needed. Due to the highest ever water levels in the Hungarian reach of the Danube the available theoretical extent of the flood hazard areas has remarkably expanded and the defense line extended significantly. This has to be taken in account in the upcoming land developments. The key issue for the future is the properly planned floodplain management maintaining and/or developing the conveyance capacity of the riverbed and the connected floodplains on both banks.

Due to the new historically recorded high water levels the design flood level is under revision for the complete Danube section in Hungary.

In Croatia it is estimated that Kopački rit, the large floodplain and wetland upstream the Drava mouth, had a significant positive influence on flood wave attenuation and reduction of flood risks downstream. This underlines the importance of the natural water retention for reduction of flood risks and provides also an excellent opportunity for linking the flood risk management to the environmental objectives of the EU Water Framework Directive.

Coping with flash floods in Bulgaria underlined the necessity of careful consideration of the terrain specifics within spatial planning with a view of mitigation of the consequences of torrential floods.

7.2 Structural measures

In Bavaria by means of water retention in state-owned reservoirs it was possible to avoid damages to residential areas located directly below the reservoirs. The water storage also contributed to an overall mitigation of the flood situation downstream of the reservoirs. The experience made during the flood event have led to the recommendation that efforts to identify further locations for flood retention and to build regulated flood polders should be increased, especially along the Danube. The realignment of flood embankments and other structural measures in natural rivers to create flood retention spaces should be planned and carried out with an increased emphasis on fish and water ecology.

The structural measures applied to the smaller lowland tributaries in Bavaria had a very positive effect on the water levels of the Danube from Straubing to Vilshofen. As a result of waterway restoration in the lowland Danube tributaries (Abflussertüchtigung der Donauvorländer), being performed since 2004, water levels during the 2013 floods were reduced effectively. This leads to a recommendation that the continued maintenance, monitoring and restoration of water management and flood control facilities (reservoirs, flood polders, flood retention basins, dams and flood embankments) must be ensured on a long term basis. Similarly, the approval procedures for planning and building flood protection facilities should be simplified and accelerated wherever possible.

The safety and operational readiness of the entire system of regulated retention in Bavaria relies heavily on employees with the necessary local and technical knowledge. Therefore, the staff of the state water management agencies should be further trained on the basis of recent experience. The spatial density and the overall future concept for the precipitation measurement network should be subject to critical review in cooperation with the German Weather Service (DWD).

In order to maintain a fully operational drinking water supply in Bavaria, targeted risk assessment for supply wells and shallow groundwater abstraction sites that are used by water utilities companies and are potentially exposed to flooding must be initiated.

In Baden-Wuerttemberg the continuous investments in flood protection measures have proven their worth during this flood event. Many retention basins were flooded and the dikes withstood the flood. However for the successful management of floods it is not only important to carry out structural flood protection measures but also to ensure the cooperation between responsible authorities, emergency forces and responsible water management officials.

The lessons learned from 2013 flood in Bavaria and Hungary indicate that the existing flood protection programmes as well as the ongoing and planned projects should be adjusted based on the recent experience. In Hungary new measures were suggested to be carried out such as building flood protection for settlements on “exhausted high banks”.

Although existing flood defense structures have provided sufficient protection during flood of 2013 in Croatia, it was evident that the existing structures are of heterogeneous quality and undergo ageing, which necessitates additional activities concerning their maintenance and monitoring especially during the flood events. One of the main activities during flood event in 2013 was the seepage control. Therefore a comprehensive program of embankment monitoring and assessment is recommended to be established in Croatia. The construction of reservoirs in small Croatian tributaries would enable more efficient control of excess water behind the dykes during prolonged high water levels of the Danube and reduction of pumping operations.

In Romania the future river development plans will take into account the priority for improvement the upper part of the basin. As alternative measures, zones for controlled flooding next to rivers will be made.

7.3 Non-structural measures

The importance of the removal of debris from the rivers to avoid log jam was proved during 2013 floods in Baden-Württemberg. The log jam can lead to locally increased water levels and can therefore increase the flood risk in the affected areas. In consequence to the extreme flood events gaps and conflicting items were recognized in current Hungarian legislation and suggestions for revision were made. The water sector in Hungary was facing huge deficits in human resources during floods and even though volunteers could replace the missing man-power in some cases the technical capacities have to be reinforced. A comprehensive hydrological measurement was carried out during peak wave conditions in Croatia producing a very important dataset for future improvements of the flood protection system. This opportunity should be used also during future extreme floods.

There was a very successful transboundary cooperation during flood events between Croatian competent authorities and competent authorities from Hungary and Serbia contributing positively to flood abatement activities.

The importance of a good contact with stakeholders including volunteers for the quality of flood preparedness and efficiency of flood mitigation was proved in Romania.

The need of additional research on the mechanism of, warning on and response to flash floods was recognized in Bulgaria. Special attention should be paid on raising the public awareness about the preparedness and reaction in flash flood situation.

7.4 Preparedness and mitigation (rapid disaster response)

Recent events have shown in Germany that even the concerted efforts of the state and the municipal authorities have their limits and that each individual can make a significant contribution to damage reduction with a combination of appropriate behavior and effective preventive measures. To this end, risk dialogue must be intensified in order to increase risk awareness. For an effective damage prevention and/or reduction an effective civil protection task force is critically important. The civil protection units should continue to perform joint exercises with the emergency services, and local deployment plans should be reviewed and if necessary optimized on a regular basis.

The special computer-based flood simulation models currently in use in Bavaria must be reviewed and improved wherever possible. Data flow and system stability and reliability have to be optimized continually. In order to achieve an improvement in flood forecasting, the properly qualified staff must be committed on a long term basis.

The rise in ground water levels in Bavaria led to an increase in requests for information. There is a demand for a short and mid-term forecasting service as well as for improvements of the existing public information services in this field.

Flood protection should be considered holistically, at the river catchment scale. Studies relating to the potential effects of an integrated management approach for flood retention areas (“Wirkungsanalysen zur vernetzten Bewirtschaftung von Rückhalteräumen”) are useful tools for identifying the possibilities and potential within individual watersheds. They also open up the possibility of detecting and securing further areas for flood retention and regulated flood polders, especially for the Danube.

For flood protection planning, so-called “worst-case-scenarios” (overload scenarios) should be taken into account, in order to be able to reduce the damage caused if such an event were to take place (especially the sudden failure of protection systems). This can be achieved by opting for constructions that are not prone to erosion and by installing flood relief channels, flood polders and identifying areas available for emergency flooding (“Notflutungsräume“).

Similarly, there is a need for integrated protection concepts for mountain torrents and alpine natural hazards which consider the catchment area as a whole and which take into account the issues of maintenance and extension as well as overload scenarios. In this context, the continued development of methods and procedures for describing the processes in mountain torrent dynamics are of key importance.

Dyke reinforcement at Györújfalu *FIGURE 12*

In Hungary it became obvious in the beginning of the flood that the settlements (authorities) were not prepared for handling such emergency situations and that the available defense plans have serious deficiencies. The update of these plans was needed and it is being carried out with a financial support by the government. An appropriate training programme for municipalities and stakeholders has to be organized.

Because of timely flood warnings in Croatia there was enough time for activating all actors in operational flood defense and performing all required preventive activities including providing information to the public. However due to dynamic development resulting in an increase of flood vulnerability and infrastructure growth it is necessary to develop more comprehensive, flexible and "up-to-date" plans. In order to reduce or maintain response time, additional efforts should be put in training and to an increase of number of active participants in operative flood defense activities. In Romania finalization of WATMAN project in 2015 will provide an integrated information and decision-making system in the event of disasters.

The supreme importance of the availability and exchange both on the national and transboundary level of comprehensive information on floods as a basis of an adequate early-warning was recognized in Bulgaria. The communication, coordination and interaction of the national and regional authorities play a key role in the flood response.

7.5 Financing aspects

Since 2001 Bavaria has already invested 1,6 billion € in flood protection measures. The measures in place serve to protect approximately 400 000 people from flooding up to events with a 100-year return period. During 2013 floods the reaction of the State of Bavaria was speedy and resolute. To accelerate the implementation of a comprehensive flood protection for Bavaria, the Action Programme 2020plus was adopted. This stipulates investments of twice the amount previously allocated to flood protection. Between 2001 and 2020 Bavaria will invest 3,4 billion € for improved flood protection.

In Baden-Wuerttemberg the widespread concluding of insurance policies against damage by natural forces has proven its value. With around 95 % of the private households in Baden-Wuerttemberg having concluded such an insurance most of the financial burden for the private households caused by this flood event has been covered by the insurance companies.

In Austria it has been agreed that for the next 10 years 200 Mio. € / year will be invested in flood protection and mitigation by the Federal Ministry of Agriculture, Forestry, Environment and Water Management. As the Federal Ministry of Transport is the competent authority for the waterway Danube and the Federal Provinces as well as municipalities substantially contribute financially, there are investments of approximately 300–400 Mio.€/year expected until 2020.

The costs of operative flood defence on the Croatian part of the Danube River during June 2013 are estimated at 12,4 million kn (approximately 1,7 million €). To have such budget operatively available good financial planning of water management activities is a must.

In Romania the expected costs of the implementation of Flood Protection Strategy until 2035 are about 17 billion €.

7.6 Climate change impacts

The more frequent occurrence of major flood events in the years since 1999 raises the assumption that the danger of flooding may also be increasing as a consequence of climate change. The possibility of an increased threat of flooding needs to be further analyzed regarding the hydrological impacts of climate change combined with an assessment of the expected range of possible changes. For future planning, the range spanned by such results should be adequately taken into account. The hydrological design parameters of flood defenses should also be reconsidered carefully.

Building adapted to a flood risk in Austria *FIGURE 13*

8. Conclusions

The specific meteorological situation in Central Europe in the end of May 2013 led to massive floods in the Upper Danube catchment in the beginning of June which had an impact further downstream. Later in June the torrential rains caused flash floods and fluvial floods in several regions of Romania and Bulgaria.

In many tributaries of the Upper Danube the return periods of 100 years or more were recorded. The coincidence of peak flows of the Saalach River and Salzach River as well as the Inn River and the Danube River led to a record water level at the Passau gauge that had been measured 500 years ago. Along the Austrian Danube gauge data showed peak discharges that have not been recorded during the past 200 years. In Hungary the highest ever Danube water levels were observed.

National flood warning and monitoring systems worked properly and informed the responsible water management and flood mitigation authorities on time. In addition, the European Flood Awareness System (EFAS) issued 13 flood warnings of different levels between the 28th May and 10th June for parts of the Danube River and its tributaries.

Substantial flood interventions took place especially on the Upper Danube but flood protection activities were carried out in all affected areas and they employed thousands of operatives and volunteers as well as a large number of vehicles, machines and devices.

Floods in June 2013 caused 9 casualties in Austria and Romania. The total financial consequences of floods in June 2013 in the Danube River Basin amount to 2.4 billion € which includes the financial losses and costs of the flood protection works.

This most recent flood event has again confirmed the necessity for modern and effective flood management measures to reduce the risk to people and economic assets. The role the Natural Water Retention Measures can play in this context became apparent in Croatia where Kopački rit, the large floodplain wetland upstream the Drava mouth, was estimated to have a significant positive influence on flood wave attenuation and reduction of flood risks downstream. Maintaining and restoring the existing or former floodplains as identified in the Danube River Basin Management Plan provides an excellent opportunity to fulfil the requirements of both EU Floods Directive and EU Water Framework Directive.

Even the most up-to-date structural protection systems can only provide a certain level of security and residual risk in terms of dam overtopping or dam failure will always remain. Flood protection measures must therefore be considered as part of an integral flood risk management system, and it needs to be accepted that the occurrence of extreme flood events are a natural phenomenon.

Structural measures against floods in the upper part of the Danube basin may lead to transferring more water downstream during extreme flood events. To avoid such development in future the application of solidarity principle, which is one of the objectives of the Flood Risk Management Plan for the Danube River Basin, is essential.

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