CENTRAL EUROPEAN FLOODING
AUGUST 2002

An EQECAT Technical Report

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1 METEOROLOGICAL CONDITIONS

The flood event was triggered by unusual, but not exceptional, meteorological conditions. Two rain-bearing depressions (Vb category of European cyclones) crossed Europe in close succession during the first half of August. The first high altitude, low pressure system formed in the Atlantic and crossed across northern England and Scotland on the 31st of July. Minor flooding resulted in northern England. By the 6th and 8th of August, the system had reached southern Germany and Austria, where torrential rainfall resulted. The system then moved eastwards along the southern side of the Alps, resulting in further heavy rain fell in Romania, The Czech Republic and the eastern coast of the Black Sea.

The first depression was followed rapidly by a second rain-bearing storm, “Ilse," which moved south-east from England and caused heavy rain in northern Italy, before moving to the north-east and causing further heavy precipitation in Austria, the Czech Republic and southern parts of Germany on the 10th and 11th of August. Exceptional rainfall also occurred in Spain during this time. Over Central Europe, the front was slow moving, and rainfall continued until the 14th of August. The track of the storm Ilse is shown in Fig. 1, along with the countries affected by flooding during and after the passage of both depressions.

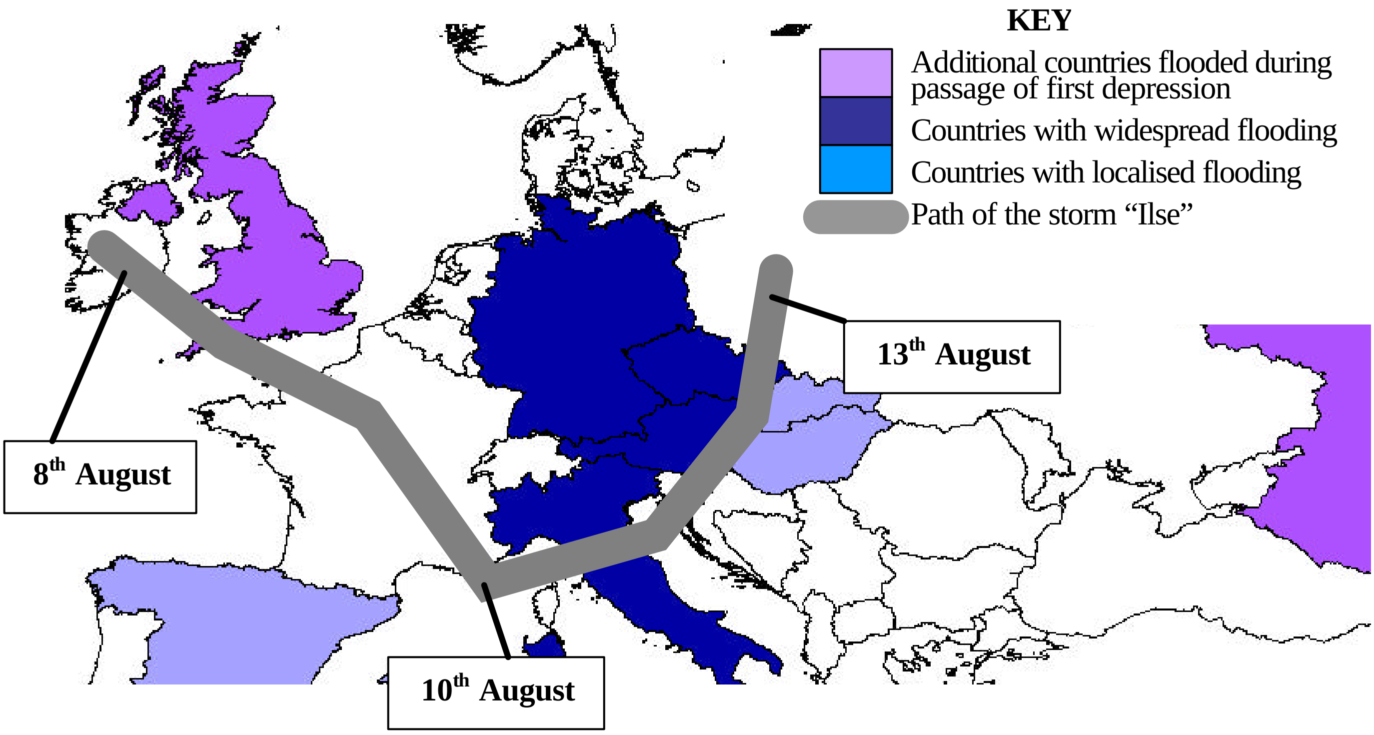

Fig. 2 shows an infra-red satellite picture of the situation on the 12th of August as Ilse passed over Eastern Europe. The resultant rainfall from the passage of the storm is shown in Fig. 3, a map of cumulative rainfall over Europe during the period 11th to 17th of August. The heaviest precipitation is centered over Austria and the south east Czech Republic.

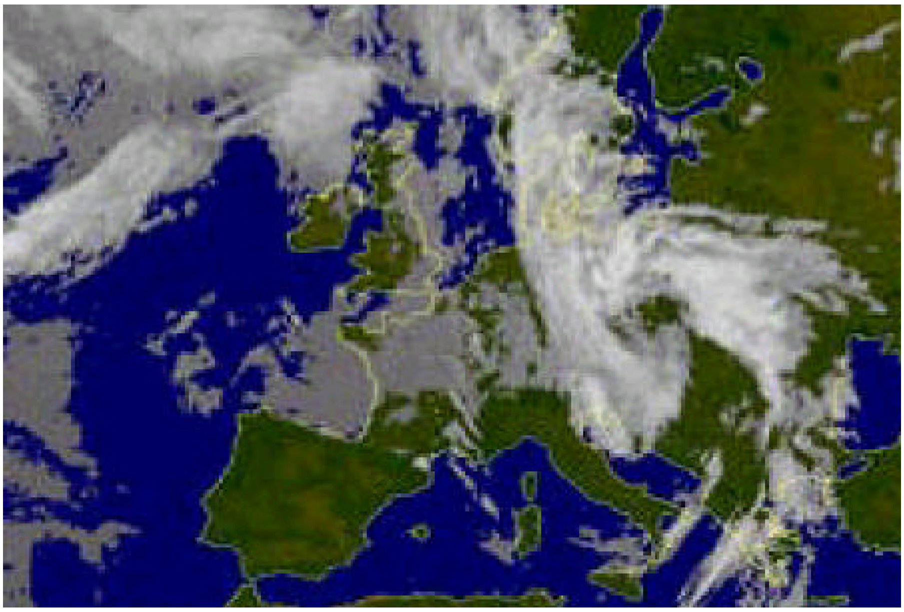

Fig. 2: The storm "Ilse" passes over Eastern Europe on the 12th August. *Source*: Deutscher Wetterdients, Offenbach A. M.

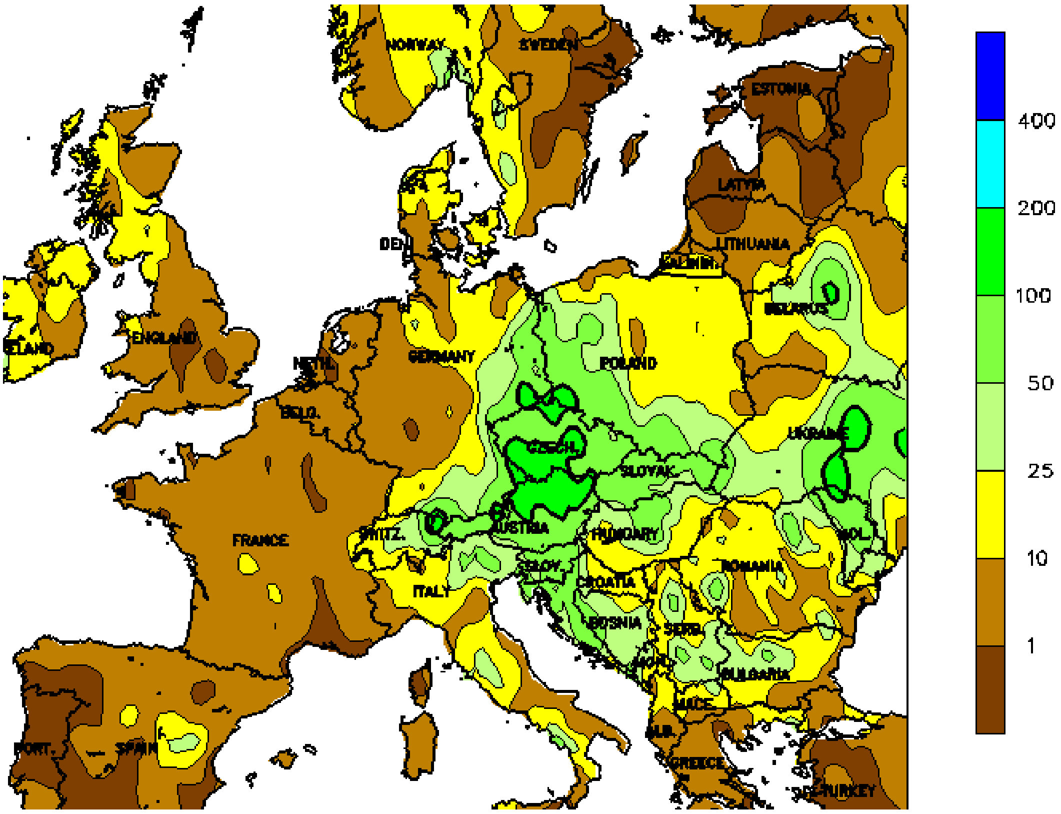

Fig. 3: Precipitation in Europe, August 11-17. *Source: NOAA.*

Rainfall, mm

The effect on rivers of the passage of the two storms may be illustrated by the water level-time trace from the Berounka River in the west of the Czech Republic (Fig. 4). The catchment area for the Berounka includes both the northwest and the southwest of the Czech Republic, where much of the rainfall from the two events was concentrated. Rainfall from the first event reached intensities as high as those seen in the second storm, but occurred over a less widespread area. The resulting water level on the Berounka was just short of 400cm and the flood peak on the river is relatively flat. Water levels in the river did not have time to return to normal levels before the onset of the storm Ilse. This gave rise to precipitation over a greater area of the catchment, and over a longer time period. The resultant flood peak is stronger (800cm) and well defined.

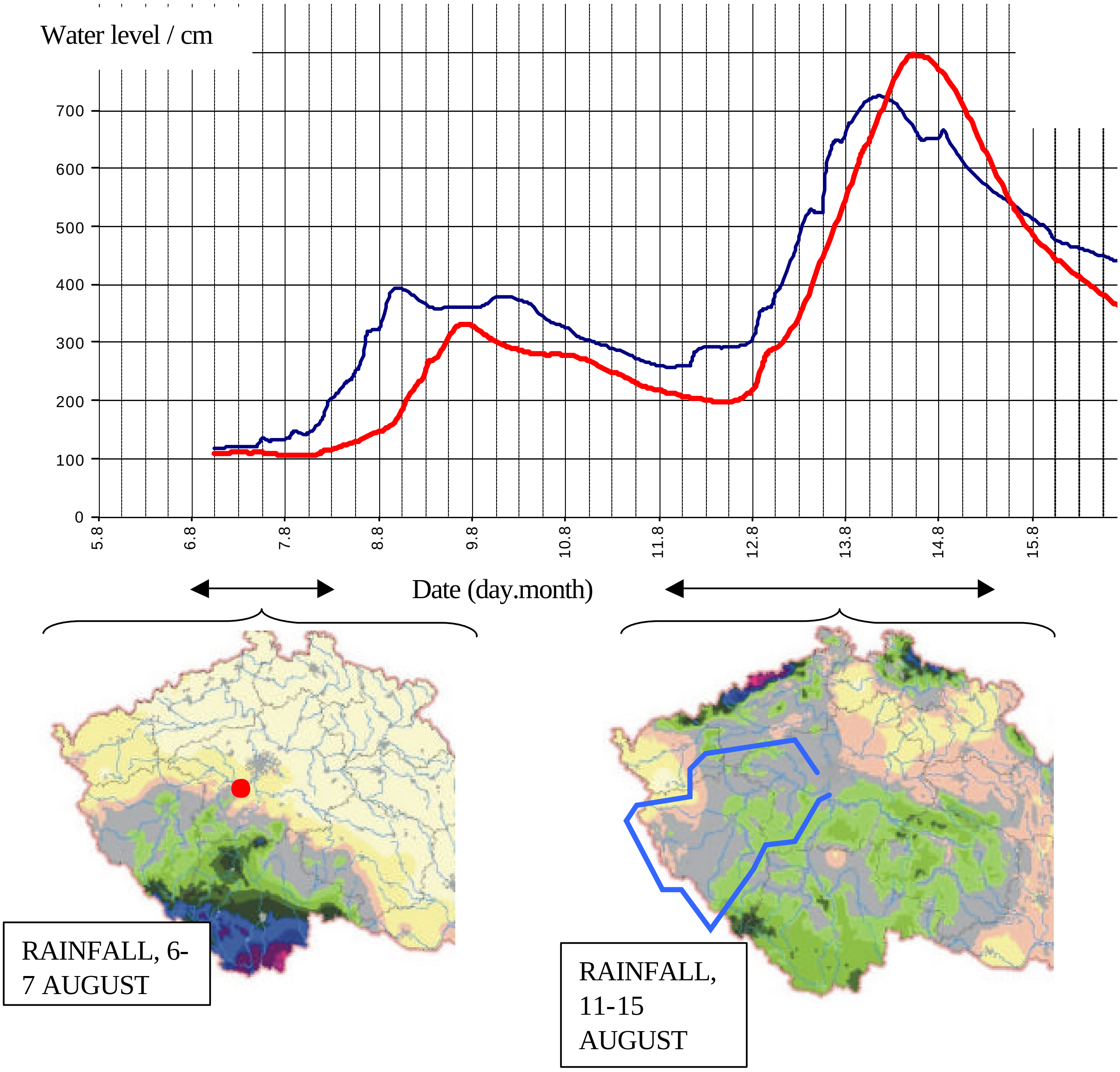

Fig. 4: Water levels on the Berounka River (at Beroun in red and Bílá Hora in blue) as a result of precipitation during the periods 6-7 August and 11-15 August. The approximate location of the gauge station is shown on the left-hand map and the catchment of the river illustrated on the right. *Source*: Czech Hydrometeorological Institute.

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The resultant rainfall for the two events reached 410mm in the week beginning 6th August in the southeast of the country. The rainfall here, and in other areas, was some two to three times greater than the normal level for this time of year. Fig. 5 shows the monthly rainfall leading up to the 19th of August in Prague. The cumulated rainfall is compared to normal levels for this time of year. Following a relatively dry late July, rainfall began to exceed normal levels at the start of August, and by the end of the first week of August, twice as much rain as normal had already fallen. A short respite was followed by 55mm of rain in a day on the 11th of August, and after further rain on the 12th, the cumulated rainfall level was close to three times the average level for August.

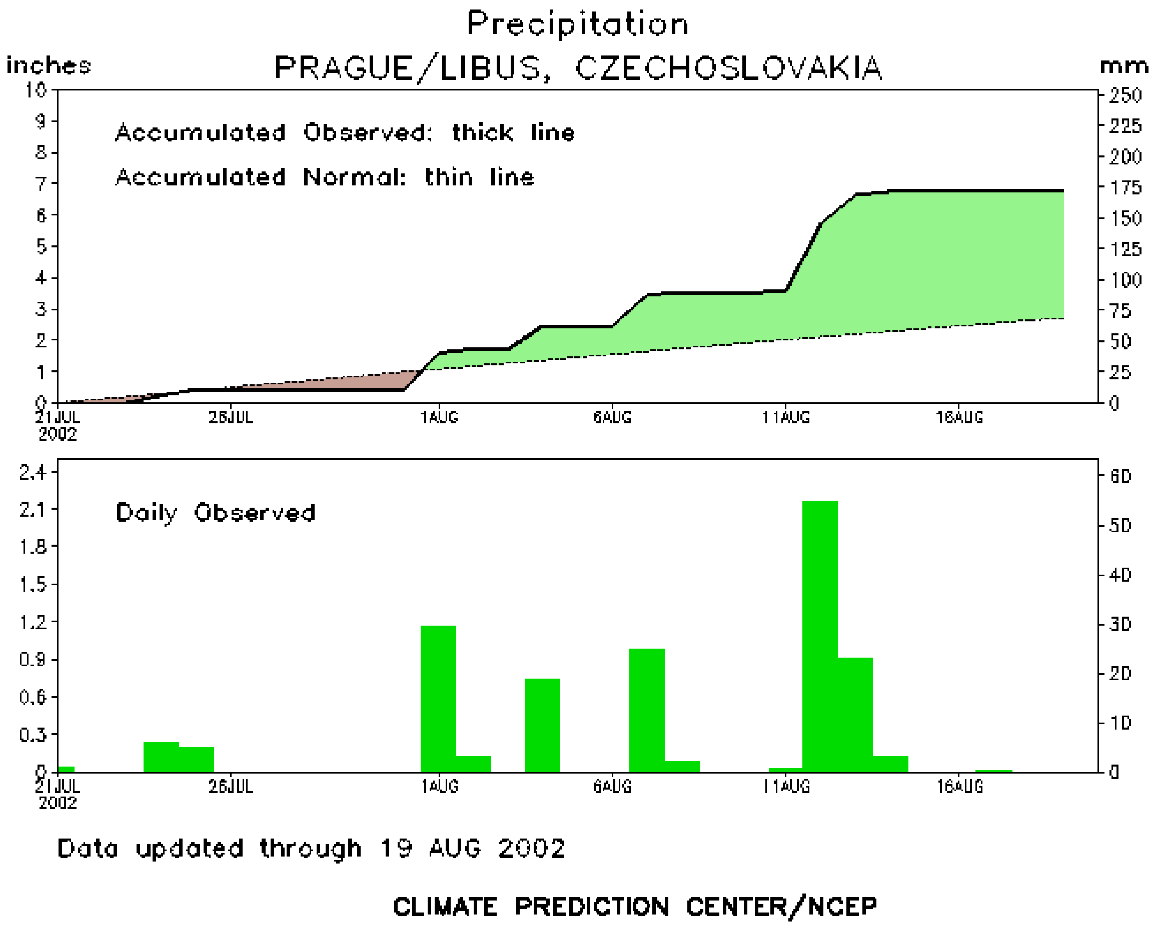


Fig 5: Daily observed rainfall and accumulated observed rainfall compared to average levels in Prague for the period 21st to 17th August. *Source: NOAA.*

2 FLOODING

The first wave of precipitation caused flooding in the northern tributaries of the Donau river, notably on the Kamp and Krems. Water levels in the Czech Republic reached 10- to 20-, or more rarely, 100-year levels at this stage. Rivers in the southwest of the country were the worst affected, but no major flooding was caused. This first event was not enough to trigger flooding further downstream the Donau, and flooding was limited to smaller catchments. The first event was, however, enough to raise water levels in the rivers, and also to raise saturation levels in the soil of the catchment area of both the Elbe and the Donau. As a result, at the onset of the second event, many smaller catchments in Austria were unable to absorb any of the extra precipitation and flooded immediately. As the rainfall continued, water levels in the larger rivers began to rise quickly. Flooding occurred on the Moldau, Mulde, Elbe and Donau.

The total area affected is shown in Fig. 6. Flooded rivers are highlighted.

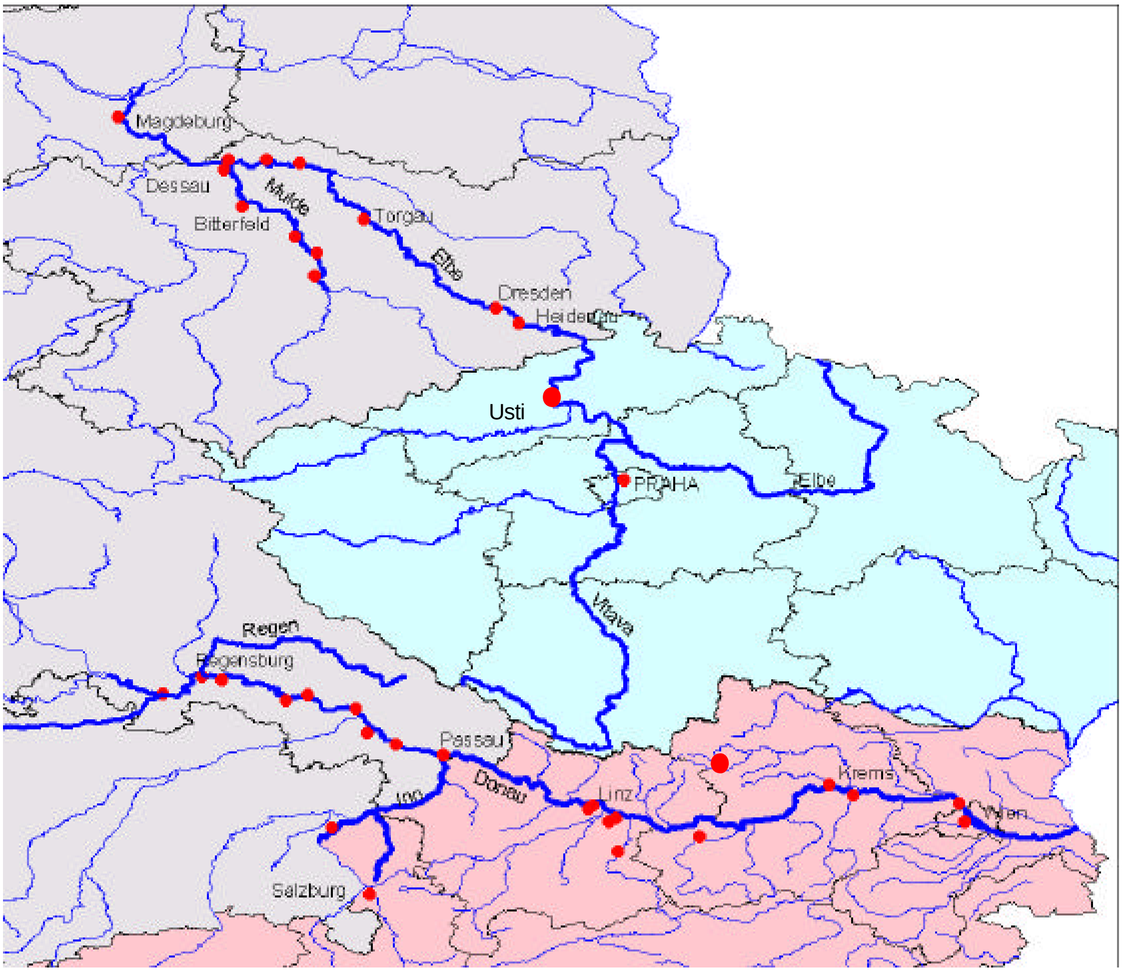


Fig. 6: Flooding on the Donau, Moldau, Mulde and Elbe. Flooded rivers are shown by thick blue lines. Selected towns in the flooded area are shown.

2.1 Flooding in the Elbe catchment

In the Czech Republic, water levels in the Elbe, Berounka and Vltava reached heights corresponding to between a 500-yr (upstream) and 25-yr (further downstream) return period. The capital, Prague, lying at the confluence of the Vltava and Berounka Rivers, was especially badly hit. The flood peak from both rivers coincided here, and the resultant water level exceeded all previous measurements made in 175 years of data. (Fig. 7a). On the Elbe, the peak attained in the1845 floods was not quite surpassed (Fig. 7b).

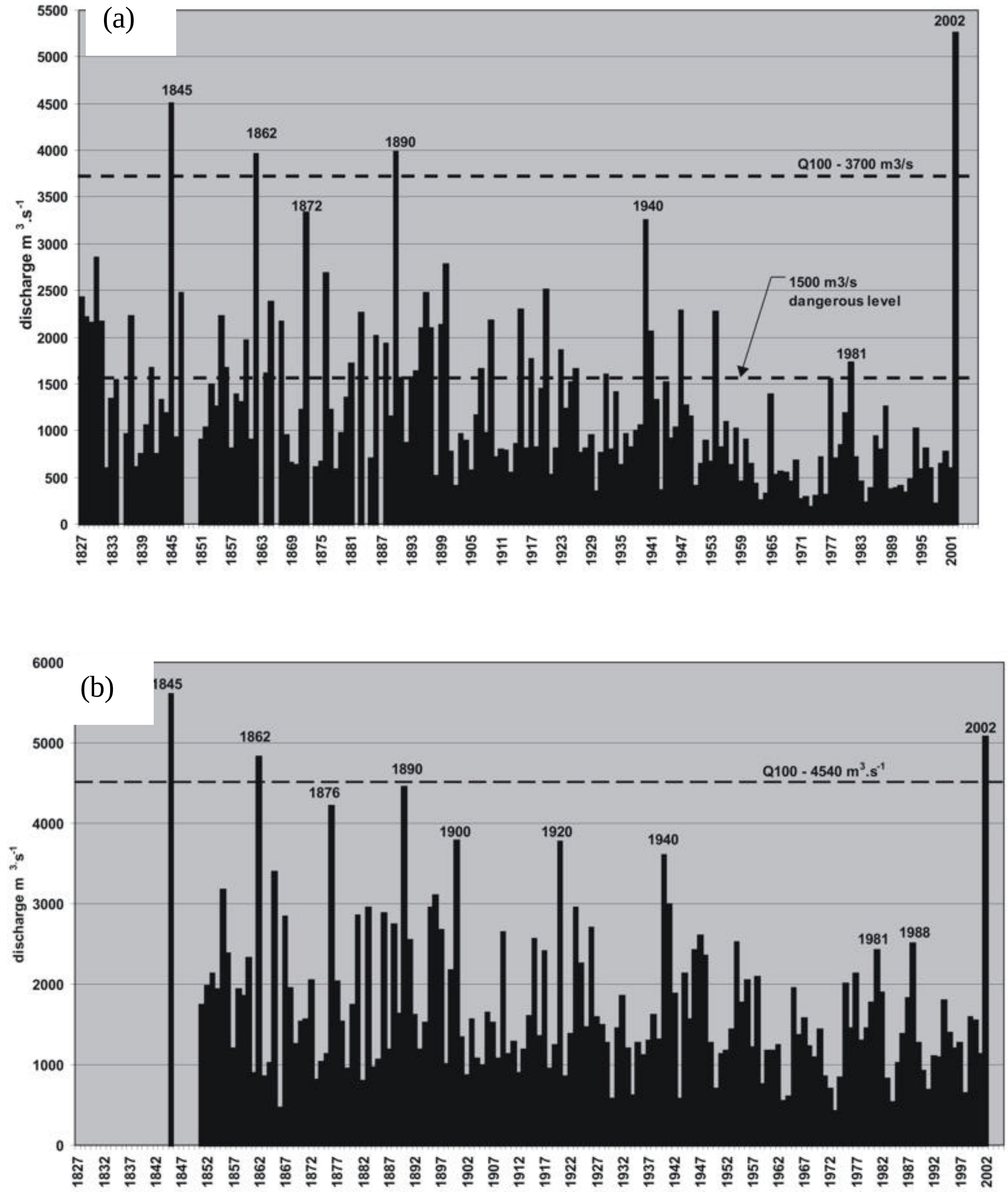


Fig. 7: Comparison of 2002 water level with historical data on (a) The Vltava at Prague, and; (b) the Elbe at Decíne. *Source*: Czech Hydrometeorological Institute

Fig. 8 shows water level against time on the Vltava River in Prague, the Elbe at Melník and the Elbe at Ústí, downstream of the confluence of the two rivers. The water level-time traces show the effect of the coincidence of the flood waves from the two rivers at Ústí. Flow rates were somewhat lower in this area due to the flooding of large areas of agricultural land, but flooding still resulted in the towns of Ústí and Decin.

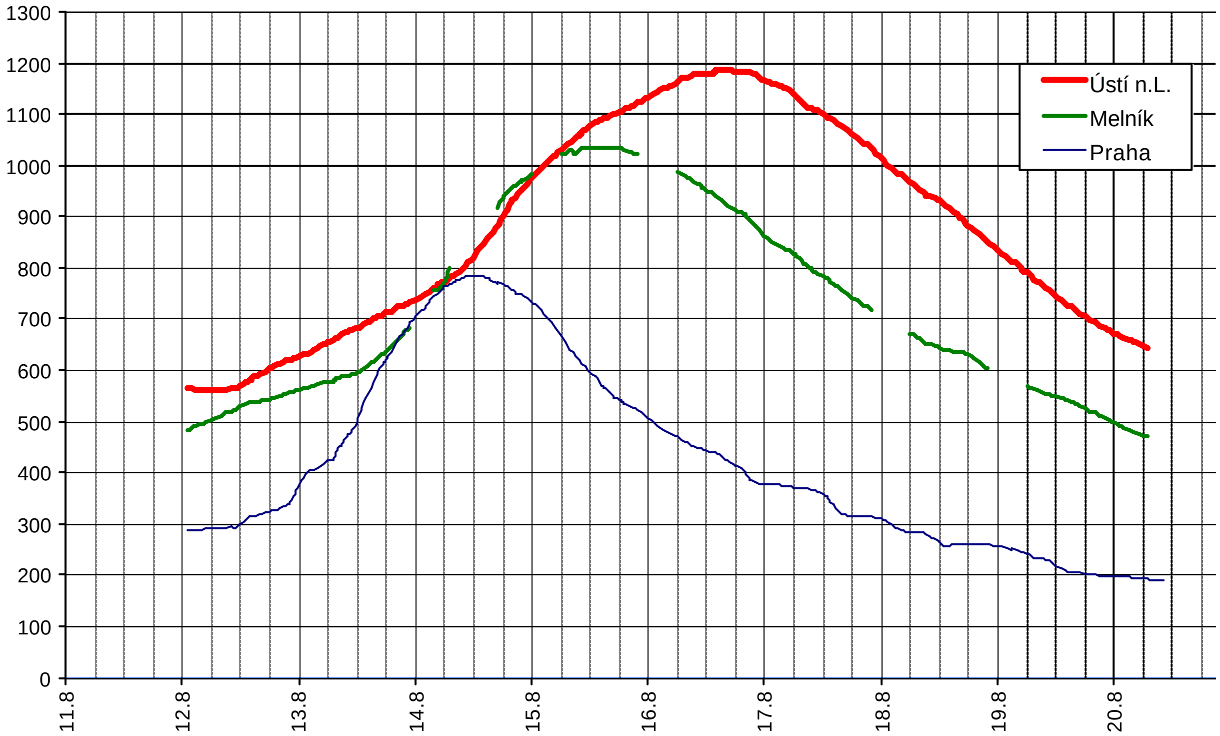
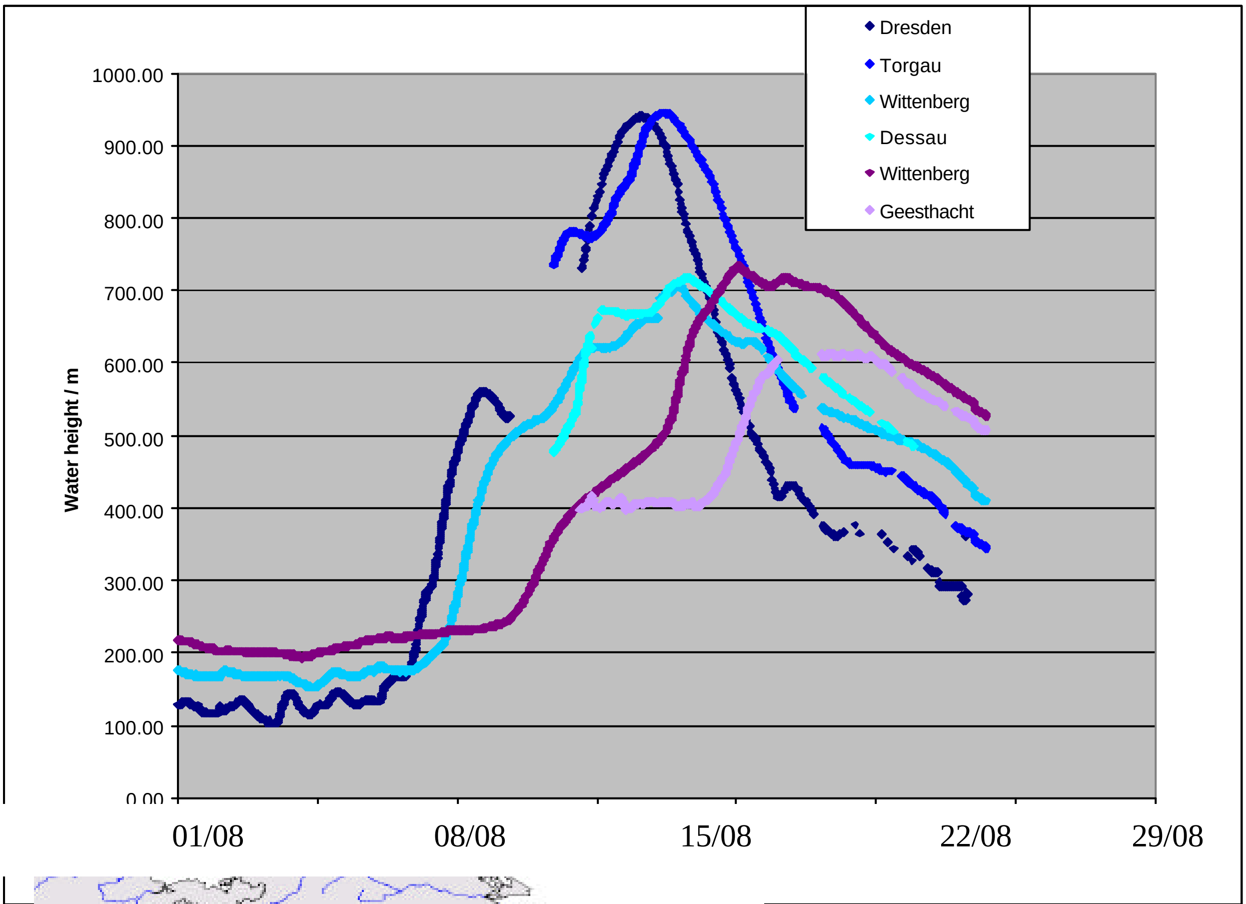


Fig. 8: Water level *vs*. time at Melník (Elbe), Prague (Vltava) and Ústí, downstream of the confluence of the two rivers. *Source*: Czech Hydrometeorological Institute

On reaching Germany, the flood water on the Elbe inundated the city of Dresden, causing inundation of residential and commercial properties and damaging many historical buildings in the city centre. Fig. 9 shows selected gauge station data from the Elbe in Germany. The locations of the various stations are shown. Dresden is the furthest upstream. From here the Elbe travels northwestwards through Meissen, Torgau and Wittemberg, before joining with the Mulde at Dessau. A further, smaller, tributary, the Elster tributary joins the Elbe between Meissen and Wittemberg. The two stations Wittemberge and Geesthadt lie significantly further downstream, beyond the effects of the flooding in this event.

The flood peaks reflect the gauge station order on the river, with the peak of water arriving first at Dresden, then passing through Torgau and Wittemberg soon afterwards. At Dresden and Torgau, the flood trace is a well-defined peak. No major tributary joins the Elbe between these two gauges, and hence the flood trace is similar at both. The small peak seen in the water height-time trace at Dresden on the 11th of August, corresponds to the arrival of flood water from the passage of the first storm some 5-6 days after rainfall in Austria and the Czech Republic. The peak from the second event is seen in Dresden on the 17th of August, a similar lapse time after the second precipitation event. The highest water level reached in Dresden was 9.4m, exceeding the previously recorded high of 8.77m in 1845. Fig. 10 compares the level of the 2002 event at Barby, near Dresden, to events in the historical record.



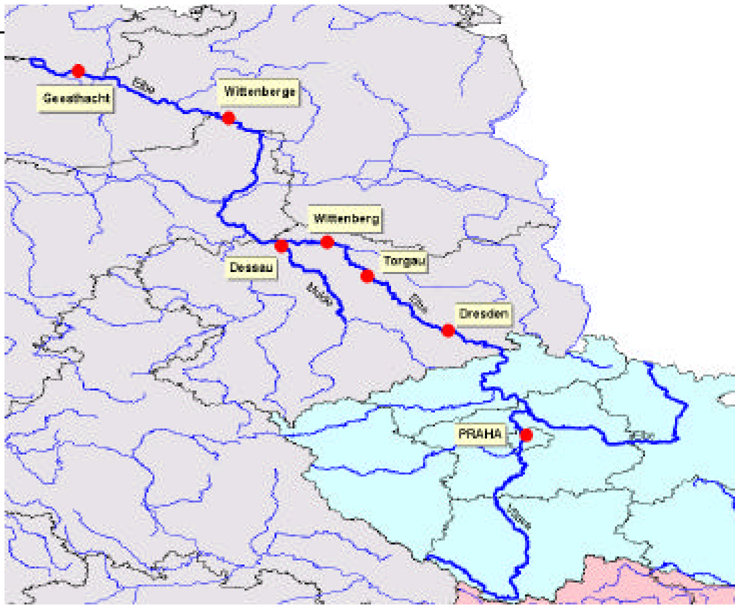


Fig. 9: Water levels *vs*. time as recorded on the Elbe at selected German gauge stations (Dresden, Torgau, Wittenberg, Dessau, Wittenberge and Geesthacht). The location of the various stations is shown.

North-east of Dresden, the Elbe flows through low-lying agricultural land and is joined by several major tributaries, notably the Ester and the Mulde. The water level-time traces in this area are less intense and flatter in character (e.g. Wittemberg), reflecting influx of flood water at a slightly different time from tributaries, and the ability of the flood plain to retain some water and further reduce flow rates. Nevertheless, damage in this area was particularly severe, largely due to the concentration of property in floodplain areas. At Wittemberg, several river defences were broken, resulting in inundation of properties adjacent to the river.

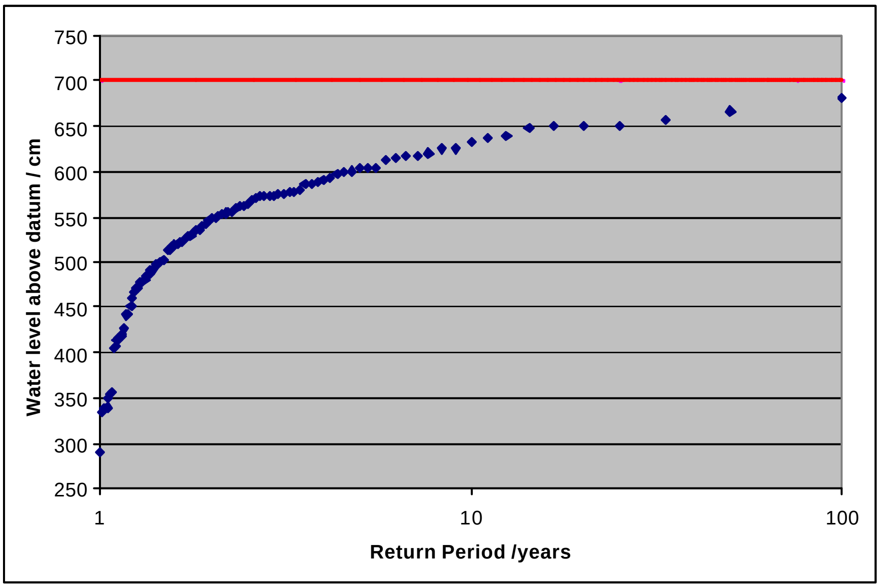


Fig. 10: Water level – frequency relationship at Barby, near Dresden. Annual maxima data for the 100-year period 1900 – 2000 are shown. The level of the August 2002 flood is indicated by the red horizontal line.

Torgau and Dessau lie close together on the Elbe floodplain, and flooding occurred at a similar time at both points. By this stage in the river, flood water was slow moving and almost the entire floodplain upstream of Dessau was filled during the flooding. The water trace at Dessau is also affected by the influx of water from the Mulde river, which itself flooded upstream of the confluence with the Elbe, inundating the town of Bitterfeld. The extent of flooding in the region surrounding Dessau, Wittemberg and Torgau is shown in Fig. 11.

Further downsteam, the flood peak was further attenuated by the effects of water retention upstream and increasing river capacity. Major flooding did not occur downstream of Magdeburg. The water peak at the station furthest downstream, Geesthacht, is flatter and less intense than seen further upstream. The flood wave passed this point on the 24th August.

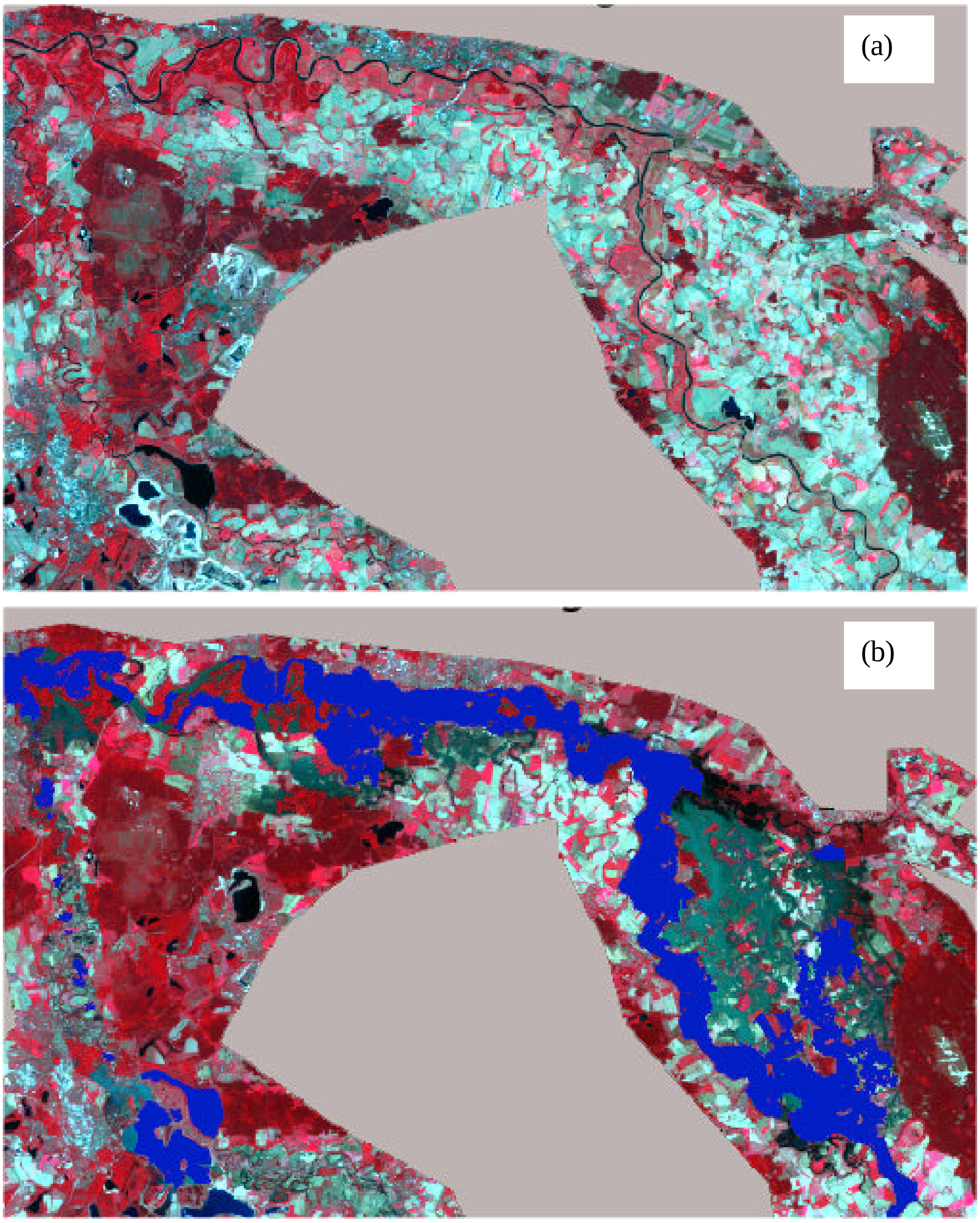


Fig. 11: Satellite pictures of the Elbe upstream of Dessau (a) under normal conditions and (b) during the August 2002 floods (14th August). *Source: German Remote Sensing Data Centre.*

2.2 Flooding of the Donau

Serious flooding also resulted on the Donau in Germany and Austria, along with the Inn and the Regen. Further downstream, water levels were lower, and only minor flooding resulted in Vienna and Hungary. In the upper reaches of the Donau in Germany, the towns of Regensburg, at the confluence of the Regen with the Donau, and Passau, at the confluence of the Inn and Donau, were flooded. Fig. 12 shows gauge traces from Kelnheim (upstream of Regensburg), Deggendorf and Passau in Germany.

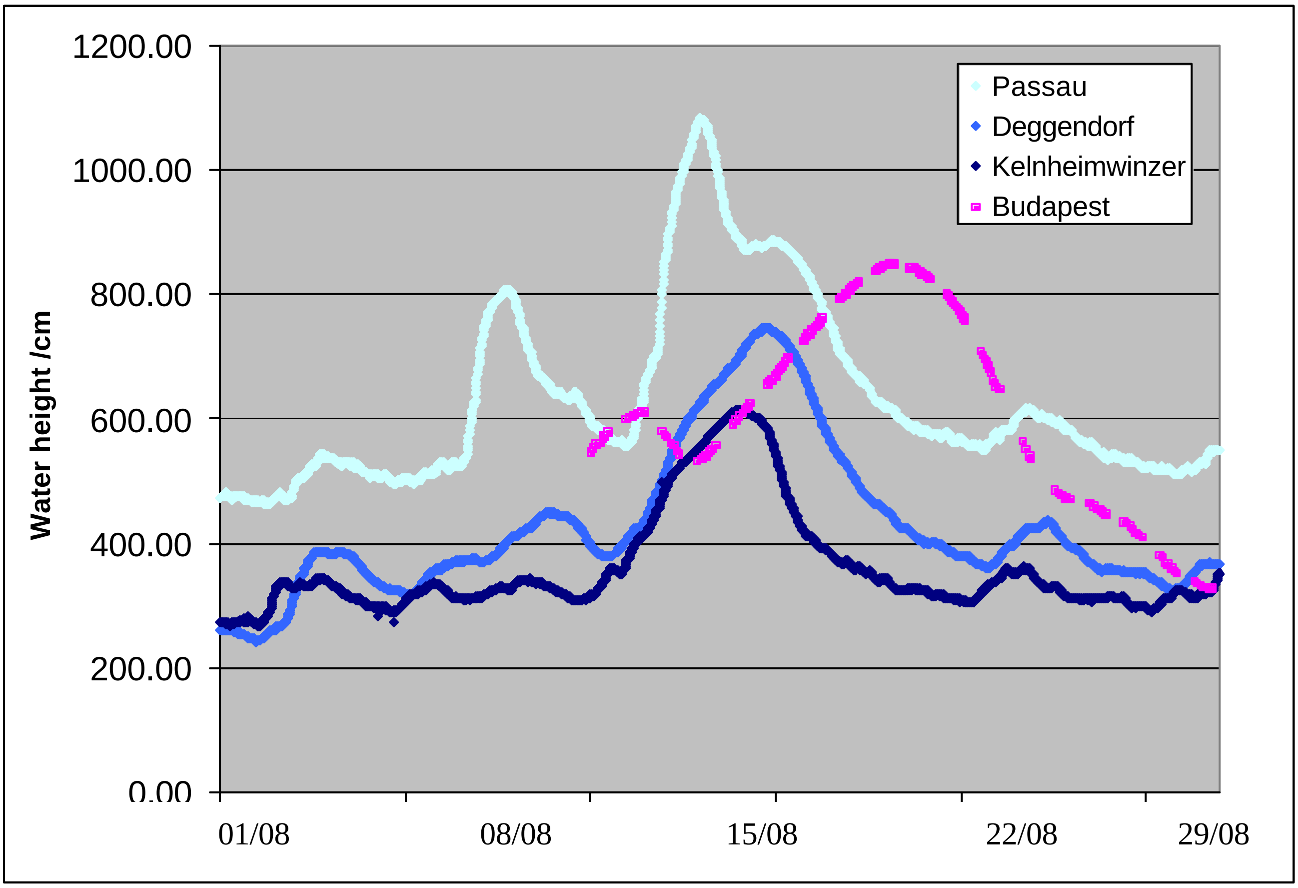
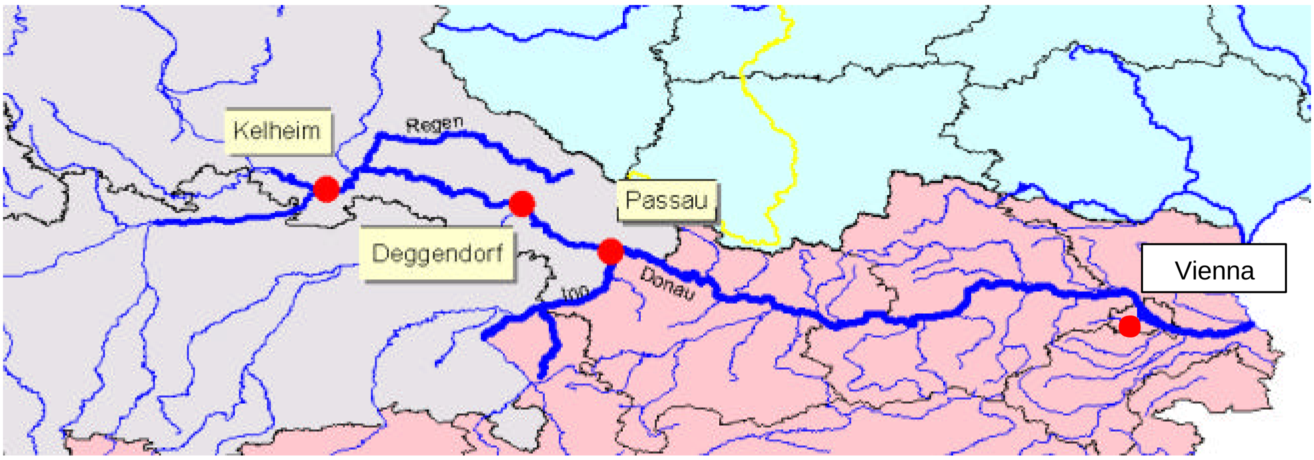


Fig. 12: Water level *vs.* time on the upper Donau, at Passau, Deggendorf and Kelnheim. The locations of the stations are shown below:



As on the Elbe, the two water level resulting from the two events can clearly be distinguished; on this part of the Donau, however, water levels were able to return almost to normal levels before the onset of the second event. The flood peak from the Donau moved downstream from Kelnheim, through Deggendorf to Passau. The double peak at Passau results from the influx of water from the Inn river prior to that from the Donau. The water level seen at Passau during the event broke all historical records.

Further downstream, flooding of the Donau was relatively minor compared to that seen on the middle reaches of the Elbe. Only minor flooding resulted in Vienna and further downstream in Hungary. The trace of the flood peak for Budapest is also shown in Fig. 12.

3 COPING WITH THE FLOODS

3.1 Preparing for the floods

Prior to flooding, extensive emergency operations were undertaken in all the affected countries to improve existing flood defences, protect buildings and evacuate areas at risk. Water levels in the Donau and Elbe exceeded all expectations as to the level of flooding possible on the two rivers, and existing defences were simply not high enough to withstand water levels in many places. In Germany, both the police and the military were heavily involved with the effort to build emergency defences. The general public were also involved in constructing both defences along riverbanks, as well as in protecting their own home from flood waters. In Germany, large dumps of sand and bags were provided for public use in areas at risk from immediate flooding, along with emergency medical care facilities and communication centres.

Fig. 13: Coping with the floods. (a) Emergency defences on the bank of the Elbe at Dessau. (b) Sandbag protection in an evacuated area of Magdeburg. (c) Preparation of sandbags in Magdeburg

In addition to flood defences, retention dams were in operation on the upper parts of the Vltava River in Czechoslovakia (The Vltava Cascade). However, the close proximity of two waves of flood water reduced the effectiveness of these during the larger, second event. During the first event, the peak of the flood was captured by the dams, and the water level in Prague successfully reduced, but during the passage of the second depression, the dams overflowed before the peak of the flooding had occurred.

3.2 Social impact

Although relatively minor in terms of economic damage, the greatest number of fatalities (58) was caused by flooding resulting from the first depression on the eastern coast of the Black Sea.

In the Czech Republic, 15 people died and 220 thousand people were evacuated. Of these, around 70,000 lived in Prague, where evacuation lasted for many weeks after the flooding, whilst damaged buildings could be stabilised and made safe. Areas of Prague protected by removable flood defences were spared the worst of the floods, although the defences were not able to prevent flooding in basements. In areas not protected by such defences, water levels of up to 3m resulted. In total, an estimated 1.6 million people were affected by the floods within the Czech Republic; 100 towns and villages were entirely flooded, and an additional 350 partially flooded.

In Austria, the damage occurred mostly in smaller towns and villages, with an estimated 10,000 private properties being affected. 60,000 and 100,000 people were evacuated in Austria and Germany, respectively, and over 100 fatalities have been reported across Europe.

3.3 Clean-up operations

An even larger effort is required once flooding has passed, although without the time pressure. Disposal of sand bags and damaged property creates a problem in addition to the clean-up of property and streets required. In many areas, the deposition of tens of centimetres of mud, sometimes polluted, has made streets impassable. This mud must be cleared away, and drains unblocked, before the water remaining in many basements can be pumped away and damage can be repaired. Considerable loss due to business interruption is inevitable, especially in badly hit areas where the services required for a quick clean-up of buildings are over-stretched.

Fig. 14: Street in the centre of Dresden after the floodwaters receded

3.4 Aid

The European Investment Bank has pledged €1 billion in loans to help rebuild damaged infrastructure, and the European Commission has set aside a similar amount to help victims of the floods. The European Union intends to free billions of dollars of regional aid in the inundated areas. Emergency relief from the EU is currently available only for non-EU countries, but if this rule is amended, aid will be made available for flood victims. There has been some debate regarding equality of aid for EU and applicant-EU countries (Czech Republic and Slovakia). As a result of the flooding, the EU is considering starting a Disaster Relief Fund; if this plan goes ahead, some of the funding could be used for aid following the floods.

Fig. 15: Clearage of sediment from drains in Dresden

4 DAMAGE

4.1 Residential properties

Extensive losses have occurred related to residential districts in floodplain areas. In many areas, more modern properties are especially badly affected since these have a higher tendency to be located on the flood plain. Losses to contents are particularly large, especially in single storey properties such as bungalows or ground floor apartments. Structural failure has been more common in upstream areas (Austria, Czech Republic), and close to the river channel, where water velocities have been higher. In parts of Prague, building collapse commonly resulted in buildings with sandy foundations that could be undermined by the flood waters. Further downstream (Germany), building damage is primarily due to the depth of water to which a property has been subjected. Failure of the main part of the structure is rare, but in some cases, low level windows have been broken. Damage to electrics and other utilities located in basements is widespread, as is minor damage caused by debris (e.g. trees and cars) carried by flowing water. Some collapses of weak retaining walls (e.g. garden walls) have also occurred where a wall has been sufficiently impermeable to allow water to build up on one side only.

Fig. 16: Damage to housing in Dresden and Meissen. Ground floor flats were the most severely affected, with close to 100% loss to contents.

4.2 Commercial and industrial properties

In city centre areas, damage was concentrated in ground floor, single-storey commercial properties. Damage to glass-fronted small commercial properties was common. Warehouses lacking a second storey were also badly affected.

Large industrial facilities were generally less badly affected; these tend to be better protected against flooding, and also became the focus of emergency floored defence measures due to their potential to cause pollution.

Fig. 17: Damage to commercial properties in Dresden. Large panes of glass at street level were particularly prone to damage.

4.3 Motor vehicles

Motor vehicles, both privately owned and belonging to hire companies and in sales showrooms suffered a great deal of damage. In areas where there is evidence of flowing water, cars were transported tens of metres, resulting in further damage to nearby vehicles and property.

Fig. 18: Damaged vehicle in Dresden.

4.4 Lifelines

Lifelines have been severely affected in many regions, with many areas suffering loss of electricity and water supplies. The transport network has also suffered due to structural damage to bridges as well as direct flooding of roads and railways. The German railways have reported losses of several hundred million euros, and many routes across the Elbe river were blocked. In Prague, all bridges across the river bar one were closed by the flooding, and the metro was severely affected.

Fig. 19: Flooded railway lines in Wittemberg

5 LOSS ESTIMATES

5.1 Economic loss

Estimates of the economic loss have varied, with totals for the event as a whole ranging from €15 billion to >€20 billion. More recent figures suggest that early estimates may have been low. The range of recent available figures per country are presented in Table 1:

Country	Estimate euros
Germany	10 - 15 billion
Czech Republic	3 - 3.6 billion
Austria	3+ billion
Italy	3.6 billion
Slovakia	35 million
Also damaged: Hungary, Bulgaria, Romania, Ukraine	

Table 1: Estimates of economic loss for the floods. Sources are the European Union, Czech Hydrometeorological Institute, Munich Re., Partner Re., Swiss Re.

5.2 Insured loss

Flood insurance penetration is generally low in the countries affected, with the result that the total insured loss is likely to be on the order of €3 billion. A summary of the available cover per country for Austria, the Czech Republic and Germany is as follows:

Austria: Only about 50% of households have flood insurance, which is provided as an extension to household, commercial and industrial properties. The cover provided is often limited to the first €5,000 – 10,000.

Czech Republic: In the 1997 floods, approximately 20% of the economic loss was insured, and although the insured proportion increased by ~3% in the months after this event, a similar proportion is expected to be covered today. Older policies commonly include flood damage, but more recently, only damage from stagnant water is included.

Germany: Cover for river flood is available as an extension to buildings and contents policies in areas that do not flood regularly. Only about 3% of policies in Germany include the extended perils coverage that includes flood, but the proportion varies from area to area. A major proportion of older policies from East Germany do include flood, since the former East German insurance had no exclusions.

Reinsurers are likely to cover two-thirds of the total insured cost of the flooding. Munich Re. estimate that this value will be split ~€200m in Austria, ~€700 in the Czech Republic and ~€1 billion in Germany.

The two main reinsurers covering the event are Swiss Re., who estimate a loss of €170 million and Munich Re., for whom a report by Merril Lynch estimates a loss of €217 million. The same report estimates €149 for the German insurer Allianz, who took over coverage of many of the old flood-inclusive policies from East Germany expects its non-life unit to show lower profits because of the in this area. The Czech subsidiary (Allianz Pojistovna) is expected to show additional flood losses of $320,000. Further loss estimates have been issued by Partner Re. ($110-120 million), Assicurazioni Generali (€90 million), Hannover Re. ($50 million), Converium ($50 million) and General and Cologne Re. (€50 million).

6 PERSPECTIVES

6.1 Historical floods in Europe

The August 2002 flood event in Central Europe is not the first such significant event. Most recently, the 1997 floods in the Czech Republic gave an economic loss of ~€60,000 billion Crowns (~€2 million). The insured loss was estimated to be $750 million. Figure 8 shows that although there has been some respite in recent years, flood events above the “dangerous level” are not unusual in this area, and significant water levels have occurred 6 times since records began in 1827.

In the north of Europe, (France, Germany, Belgium and the Netherlands), major floods were experienced in 1993 and 1995. Again the flooding was caused by lengthy rainfall over a large area, combined with high pre-existing soil saturation. In 1995, snow melt and frozen ground were also contributory factors. The 1993 event caused flooding of the Maas, Oise, Rhine and Mosel rivers. In many places the previous record water level was exceeded, notably at Maastricht, where the previous record was surpassed by 10cm. The 1995 flood was of a comparable size to the 1993 event, and resulted in evacuations in many areas adjacent to dikes in the Netherlands. The damage would have been much greater had these dikes failed. The economic loss for these two events were $955 million and $2.9 billion, respectively.

Other recent events in Europe have been the October 2000 floods in Italy[1] and the UK, and even since the August 2002 event, serious flooding has occurred in the south-east of France.

6.2 Potential for future events

The primary cause of flooding is rain, possibly caused with snow melt at certain times of year. The effect of Global warming and the El Niño climate oscillation are frequently debated whenever extreme meteorological events occur. However, the extent to which global warming is occurring remains a subject of great debate amongst climatologists, and predictions of the effect it may have on weather conditions over Europe vary widely. Even assuming that significant climate change is underway in Europe, the estimation of frequencies

[1] The 2000 flooding on the Po is the subject of a separate EQECAT report.

of extreme events, as opposed to seasonal or yearly averages, is notoriously difficult. There is less doubt as to the effect of El Niño, but links of this to European weather appear to be weak.

The generally poor weather conditions seen in Europe during 2002 were caused by the generally weak high pressure system that formed over Europe. In normal summers, Central and Southern Europe is covered by a ridge of high pressure that deflects low-pressure weather systems to the north. This year, the high pressure system was weak, allowing storms such as those that caused the August floods to penetrate into central and southern Europe.

If we consider the potential for damage during extreme flood events, we must consider not only the likely frequency and strength of such events, but also the vulnerability of the affected area. The location of risks, their vulnerability to flooding, and the effect of man made defences and flood management schemes are every bit as important in estimating potential losses as knowledge of the climatological and meteorological phenomena leading to flooding.

Faced with an expanding population, there is growing pressure on governments in Europe to allow development in flood plain areas, and the combined effect of this with growing wealth in areas at risk is likely to have a far greater effect on losses from flood events than climate change. Further problems associated with flood plain development are the straightening of river channels, removal of "overspill" areas such as agricultural land and marshes. Flood prevention schemes may involve increasing channel walls and defences, but on large river systems such as the Elbe and Danube, this means that flood water is carried more efficiently to downstream area, thus increasing the likelihood of flooding in downstream portions of the catchment.

The flooded area of the Elbe in the area surrounding Dessau and Torgau shown in Fig. 11 is compared to a land use map of the same area below in Fig. 20.

The river flood plain is a mixture of agricultural (orange/yellow) and built up land (red). Many smaller villages were entirely inundated during the flood, and the larger towns on the edge of the floodplain (e.g. Wittemberg) were flooded where conurbation spills onto the floodplain. The town of Dessau, which lies entirely on the floodplain at the confluence of the Elbe and Mulde rivers was especially badly affected. Any further development in these areas will increase the vulnerability of the region to flooding and lead to higher losses in future similar events.

Signs of river straightening can also be seen in the land use diagram; in the top left of the diagram, the grey semi-circle on the land use map is an old river meander that is no longer followed by the Elbe.

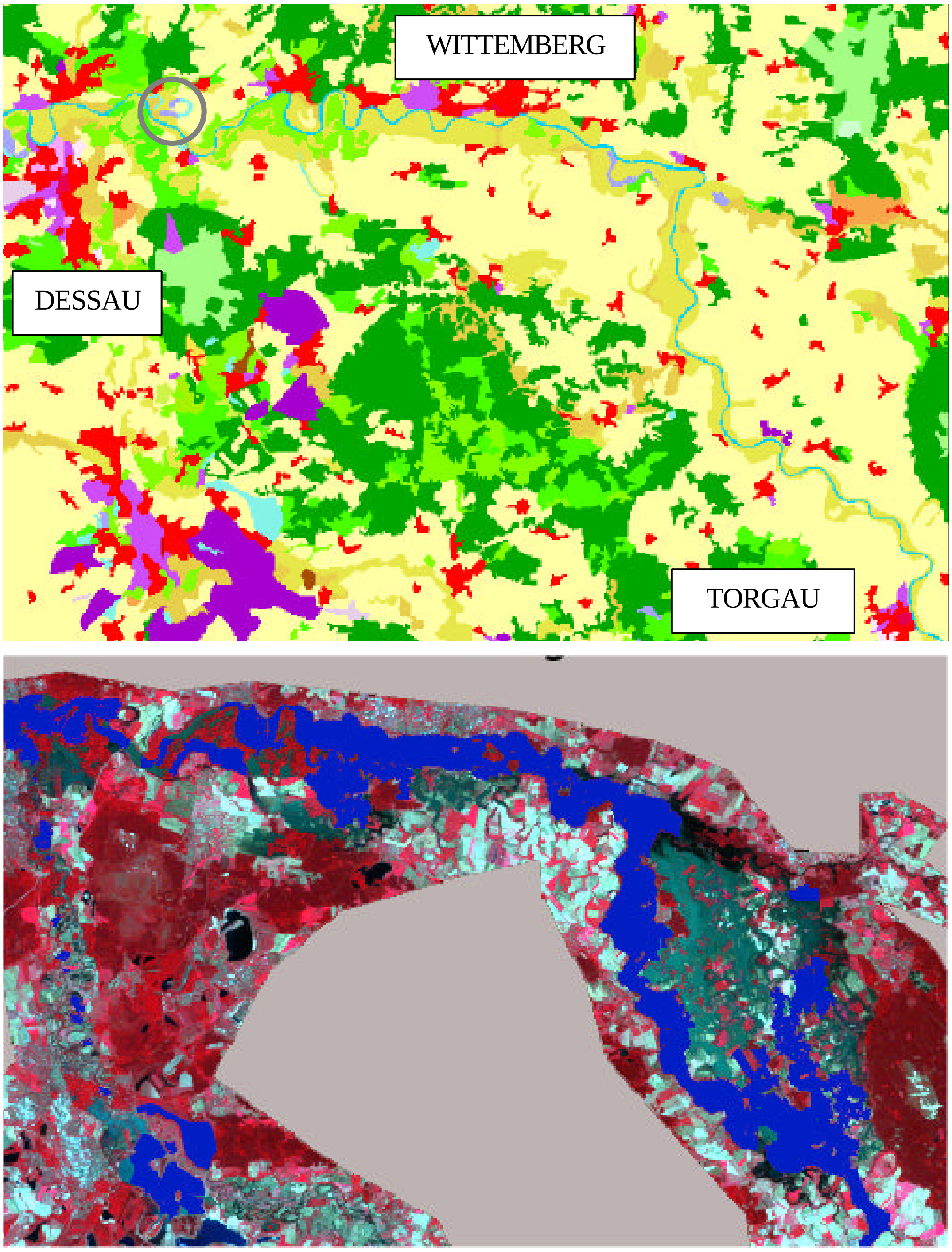


Fig. 20: Land use map (a) and satellite picture (b) of the flooded area between Dessau and Torgau. On the land use map, built up areas are shown in red; agricultural land is yellow/orange. Forested areas are shown in green and the path of the Elbe is visible (light blue). The inundated area is shown in dark blue on the satellite picture (b). The grey circle on the upper diagram highlights an old meander in the Elbe.

7 ENQUIRIES / FURTHER INFORMATION

For further information regarding the August 2002 floods, EQECAT's flood modelling capabilities or our EUFlood software, please contact Jane Toothill (E-mail jtoothill@absconsulting.com; Tel. +44 (0)1925 287390) or Henry Bovy (E-mail hbovy@absconsulting.com; Tel. +33 (0)1 44 790101).