European Club of ICOLD – Working Group on Levees and Flood Defences

The Ahrtal Flood in 2021

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In 2021 a devasting flood struck Europe. During 13th and 15th July 2021 a low-pressure front named "Bernd" (picture 1) moved relatively slowly across France, via Belgium through Germany to East Europe. In France, Belgium and Germany major floods resulted from the occurring heavy precipitation. The floods developed fast, thus, those floods could be defined as "flash floods" (Dallmeier, 2017) for which the development period is less than 24 hours. In Germany 188 fatalities are documented of which 135 were in the county of Ahrweiler where the river Ahr is located. The financial damage announced by the insurer Münchner Rück reached 46 billion Euro in total and, exclusively, 33 billion Euro in Germany and was, by these numbers, the second biggest natural disaster ever regarding insurance damage (see also picture 2).

Picture 1: Low-pressure front „Bernd" over Europe (Source: CEDIM, 2021)

Picture 2: Flood damage in Erftstadt Blessem (Source: https://rp-online.de/)

In Belgium and Western Germany precipitation intensities reached values of 271,5 mm/48 h and 154 mm/24 h to 207 mm/9 h, respectively. Within the Rhine catchment area related to Rhineland-Palatia the medium rivers such as Kyll and Sauer, tributaries to the Mosel reiver, showed flood incidents with a recurrence period $T > 100$ a whilst the bigger rivers such as Mosel and Rhine "only" revealed floods with periods of $T \approx 10$ a and $T \approx 5$ a, respectively.

One of the driving causes for the local extreme rainfalls could be the "weak" northern polar jet stream/vortex (figure 1) which is a result of climate change effects. The uneven temperature distribution above the northern polar area does not provide enough atmospheric pressure difference so that strong winds do not concentrate on the west east corridor but move to the south unpredictably. Thus, the event "Bernd" was driven south and stayed within the referred flood areas for a critical period.

The Ahr is a river in Rhineland-Palatia and a contributary to the Rhine River. It is located in the mountain range Eifel, left side of the Rhine. It shows a catchment area of approx. 900 km² and a mean flow of $MQ = 7{,}5$ m³/s. The mean flood discharge is $MHQ_{1946\text{-}2007} = 91{,}7$ m³/s. Along the river course the Ahr collects discharge at a relatively high plateau before the river crosses the Ahr mountains where the river shows a meandering course between relatively high and steep rock slopes. In the year 2016 a flood occurred with a discharge of $HQ = 236$ m³/s which corresponds more a less to a 100-year flood.

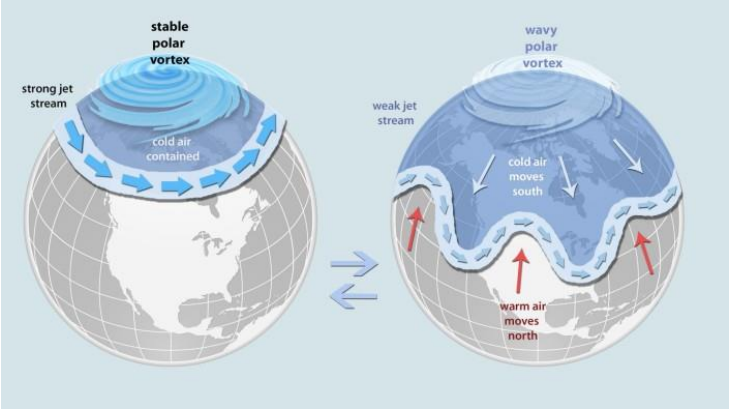


Figure 1: Polar vortex system (Source: https://www.vindte-knikk.com/)

Flow gauges during the 14th July at the Ahr began to record rising water levels in the late afternoon. Within a few hours most of the flow gauges failed because the flows exceeded the applied measurement instrumentation. Later flood reconstruction modelling revealed that a peak flow at selected flow gauges should have reached a flow of HQ_{Peak} = 1,000 to 1,200 m³/s which is four to five times higher than the former HQ_{100} value of 2016, also much higher than estimated briefly after flood (figure 2). Officially, the peak discharge 2023 is declared to be $HQ_{Peak,2023}$ = 854 m³/s at the flow gauge Ahrweiler, which does not correspond to scientific results (Roggenkamp & Herget, 2022).

In spite of varying information about the flow data the recurrence period of the flow exceeded T = 100 years by far and according to different sources should have reached a value of T > 1,000 to 10,000 years. Those discharges resulted in water depths of locally over 11 m. Especially, in the Ahr mountains where narrow valleys dominate the flow local infrastructure such as roads, bridges, railways were soon flooded so that the people were trapped. Many moved to the first or second floor remembering the flood 2016 where the flood hardly reached the basement. The flood levels also overtopped the roof of two-storey houses and buildings where the people entrenched themselves waiting for help and evacuation measures, and many people perished this way.

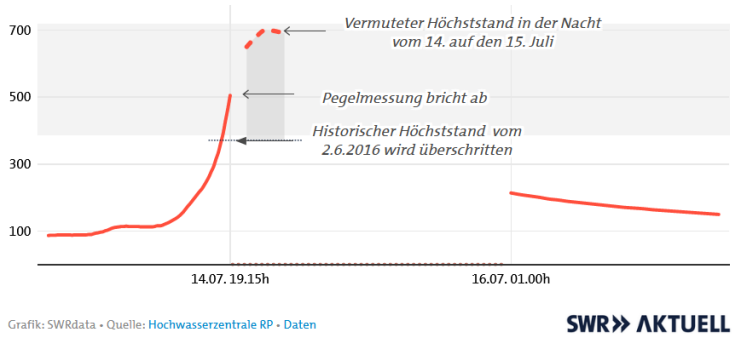


Figure 2: Preliminary discharge hydrograph after flood incident shows missing measurement data, flow gauge Ahrweiler (Source: https://www.swr.de)

Within six hours between approx. 6 to 12 pm the flow increased from Q = 100 m³/s to over 1,000 m³/s. Within a very few hours the affected settlements were completely cut-off from escape roads and were isolated/trapped in the narrow valley not able to go anywhere. The mobile communication network failed. Attempts of the flood responsible institutions and persons to perform measures such as flood warnings and evacuation were effectless or inefficient. The analysis and evaluation of the flood event, of the activities or misbehavior of responsible persons and institutions is continuing also in form of legal prosecution.

The impact of the flood was evaluated after the flood, e. g., by the Copernicus Emergency Management Service. In figure 3 the Ahr river loop in the vicinity of Altenburg and Altenahr is shown including documented damage spots (left). The picture on the right provides a comparison between the situation before and after the flood for the village Altenahr. The flood did exceed the

existing riverbed and embraced the settlement area so that the people were trapped between two flood flows.

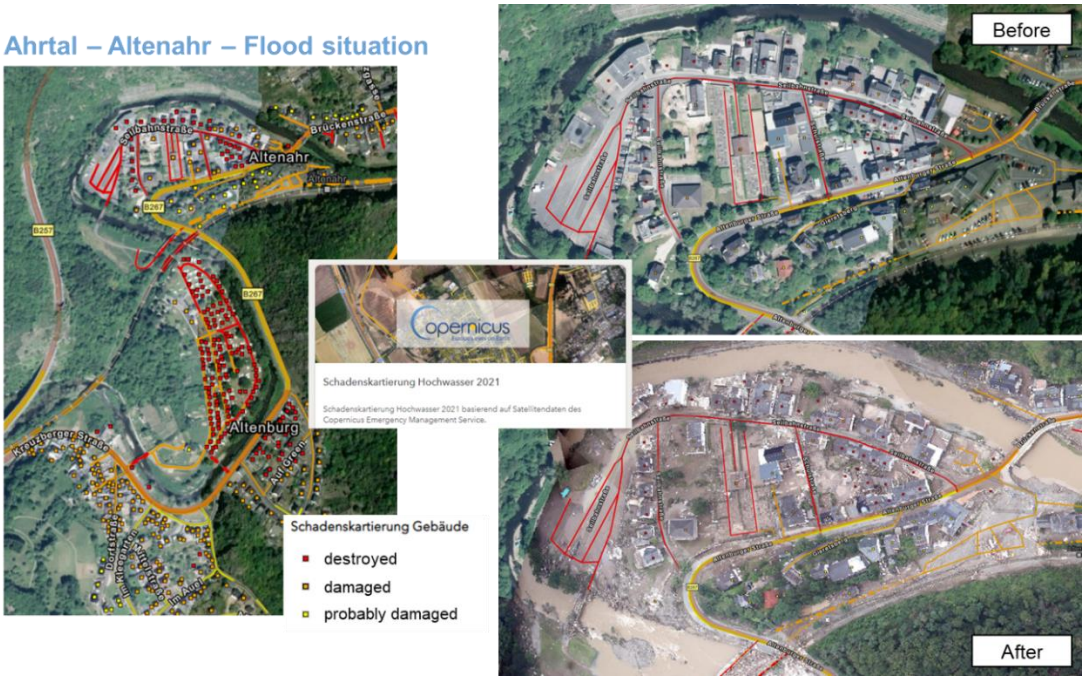


Figure 3: Documented flood damages at the Ahr within vicinity of the villages Altenburg and Altenahr

The recurrence period of floods exceeded the design criteria for flood protection and retention works by far. The future concepts for the Ahrtal must not focus on local protection measures such as the construction of walls, levees or flood retentions dams in the upstream catchment area. Especially for the Ahrtal region with its very special hydrological catchment situation, effective measures for flood warning, precaution and prevention have to be developed. The authors hold the opinion that evacuation plans with a very short reaction period must be implemented so that the people are able to escape the hazardous area within a few hours and less.

The Ahrtal flood 2021 was not unique. In 1804 a historic flood was documented which should show similar discharges of more the 1,000 m³/s (Roggenkamp & Herget, 2022). Thus, a second 1,000 to 10,000 year flood occurred within only a 200 years period which again challenges the correctness of flood statistics based on measurement data with relatively short measurement periods and special catchment characteristics such as for the river Ahr. Also, the effect of ongoing climate change effects is not represented by measurements of the past. Here, a correction needs to be implemented which also implies a resilient prognosis for the future development of flood events.

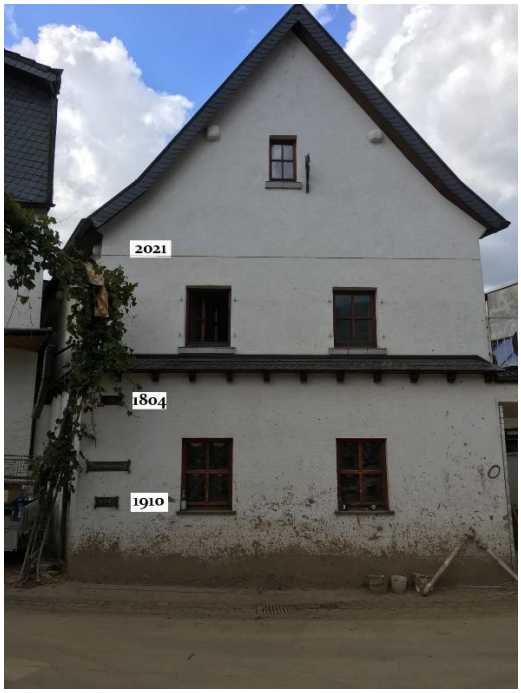
The flood caused harm on houses and infrastructure for which the reconstruction will take extraordinary investments and time (pictures 3 and 4). The discharge capacity of the flow section/riverbed was insufficient, erosion of the riverbed and banks as well as adjacent slopes caused slope failures, etc. Houses were flooded and flow velocity and forces resulted in many houses collapsing. The reconstruction of the roads, bridges and railways will take years and decades.

Natural hazards such as floods are not the primary cause for fatalities or damage. The primary cause is the infrastructural and urban developments which increases the vulnerability of affected areas, critically. This fact is documented by flood marks at a house in the village Dernau where the water level reached the first floor during the flood event 2021 (picture 5).

Picture 3: Damages on houses and infrastructure close to the villages Altenahr
(Source: www.swr.de)

Picture 4: Erosion and destruction of houses in the village Dernau
(Source: www.deutschlandfunkkultur.de)

The house was already existing in 1804 but the flood level was much lower in spite of similar discharges. In the year 2016 the flood did only exceed the pavement elevation in front of the house and affected the basement which also led to the fact that many inhabitants made a critical under-estimation of the imminent flood risk during the 2021 floods



Picture 5: Flood marks at a house in the village Dernau (Source: Mr. Matthias Habel, see also Roggenkamp, 2021)

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