

When the flood came at night – July 14, 2021

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A few years ago I went to the annual fall meeting of the American Geophysical Union at San Francisco and met a Hawaiian geologist who was interested in the geology of planets, Mars in particular. Having a common interest in measuring gas fluxes with infrared gas analyzers, she from volcanic rock fissures, and me in plant leaf surfaces, we became curious about what motivated us to choose our fields of study. She mentioned at some point that one of her courses focused on the Eifel in Germany. That amazed me. How is it possible that a university course in Hawaii, which is a very interesting geological place, chooses a region located at roughly 12000 km distance for learning the principles of earth geology? She replied that the diversity and complexity of geological formations in the Eifel are so rich that it is particularly suitable for this purpose.

The Eifel forms a triangle between Aachen in the north, Koblenz in the east, and Trier in the south with an area of about 5300 square kilometers. It is a hilly region shaped by peneplain erosion and volcanism. Hohe Acht is the highest hill with an elevation of 750 m. Average hill heights in central Eifel are around 500 m and valley bottoms around 200 m. It is located in a temperate Atlantic climate zone with an average precipitation of 700 mm/year. It has a rich cultural history dating back as far as 40.000 years when Neanderthals dwelled in caves. Shaped by its unique morphology, the Eifel has numerous streams, rivers, and lakes. River Ahr is one of them. Its spring is located at Blankenheim in central Eifel at 470 m height and drains eastwards into the Rhine at an 85 km distance at Sinzig, 50 meters above sea level. It is a fast river with small and steep catchments dominated by shale rocks which prevent water from penetration into deeper layers. The picture below shows a meandering section at Mayschoß, famous for its wine production. The river is barely visible and runs between two hills in the foreground of the picture. It takes a sharp U-turn around the left hill before draining into the neighboring valley. Such morphological characteristics make villages adjacent to the Ahr prone to flood damages.

Meteorological observations of a large trough formation above central Europe suggested an extreme rain event in the Ahr region for July, 14 2021. Soils were soaked from previous rains and unable to take up more water. Warnings issued earlier this week were further substantiated in the afternoon when precipitation intensified and Ahr river gauges reported sharp water level rises far beyond their common ranges. At 6 pm I started monitoring the river gauge at Altenahr on a dedicated website. The water level was about 300 cm at this time, 230 cm above the common level, and sharply rising. It was obvious that something severe would happen.



Middle-Ahr at Mayschoß

The gauge stopped recording at 8:45 pm when the water level reached 575 cm. A statistical function was continuously fitted to the measured gauge data up to this time and predicted a maximum level of 700 cm for 5 pm the next morning. Someone operating the website later replaced the fitted curve by a deterministic model which simulated a peak level of 575 cm for 1 pm the next morning, 125 cm less and 4 hours earlier than the fitted function had predicted. As it turned out, discharge data from Müsch located 30 km upstream suggest that the actual peak level could have been 700 cm, as the statistical function had predicted. The model prediction was obviously wrong. This and numerous other examples demonstrate that calibrating deterministic models of natural processes is strongly limited by nature dynamics which cannot always be foreseen. As the Hawaiian colleague pointed out, geological processes shaped the Eifel into a complex terrain. Predicting non-linear fluid dynamics on its highly heterogeneous land-surface is a grand challenge. Considerable basic and applied research efforts are required to make Ahr flood predictions more reliable.

Investigations about the likely course of the Ahr flood on July 14, 2021 have just started and will take time. Weather forecasts predicted rainfall amounts between 100 and 150mm/day for the Ahr region, possibly 200mm/day for isolated places which eventually became true. It rained the whole day at high intensities until around 10 pm. What happened in the following night can only be reconstructed from eyewitness accounts. Extreme water towers in the upper catchment drained themselves into the Ahr, forming a substantial flood wave. Hay bales stored on meadows along the river were carried away and clogged bridges. Flood water accumulated in front of the bridges in consequence until they were destroyed by the

mounting water pressure, releasing high amounts of water to the following bridges where the same happened again in a chain reaction. Trees planted along the Ahr collapsed into the water due to the rapid buildup of kinetic energy which intensified its impact on any obstacle in its way. Two tributaries released additional amounts of water into the meandering wave loaded with trees and debris before it hit the small towns of Schuld and Insul, causing extreme destructions reported on all news channels around the globe. The wave came so quick that people had hardly any time to rescue themselves. There was a sudden power cut, leaving them in the dark. Enormous amounts of water poured into their houses. Many narrowly escaped drowning and made it to higher floors or roofs, if their houses did not collapse under the force of the river. It continued downstream until Adenauer Bach, a major tributary, which added additional extreme amounts of water into the Ahr. Passing Liers and Hönnigen, the wave crushed with additional amounts of trees into the small town of Ahrbrück, destroying its bridge, carrying houses away and flooding other houses to the first floor level. It continued further to Kreuzberg, a few kilometers downstream, taking a shortcut, leaving huge amounts of trees, debris, house items, cars, trucks, camping vehicles and any other imaginable material along the river edges, piled up to 10 meters during the following clean-up.



Clean-up of flood debris near Kreuzberg three weeks after the flood

Sahrbach, another large stream, loaded additional extreme amounts of water into the Ahr before it continued through the small town of Altenburg which was double-affected by the wave, first when it released its destructive force into downstream direction, and later into upstream direction when it bounced back from a bridge blocked with flood material at Altenahr at Altenahr, setting the entire village under water. Altenahr was declared a disaster area at midnight, allowing the army to move in and help with heavy machinery, as it did later along

the entire Ahr on land and from the air. Once the wave swapped back downstream to Altenahr, it partially flowed with huge force through 3 tunnels of the natural barrier and otherwise took a sharp U-turn through the picturesque Langfig valley before continuing further downstream through a wine production region between Mayschoß and Walporzheim. All villages were heavily affected and most wineries destroyed, a tragedy to the Ahr wine culture dating back as far as the 8th century. The wave eventually hit Ahrweiler and Bad-Neuenahr, larger towns near the Rhine, which were also heavily affected by the flood.

The morning after the flood appeared surrealistic to me. Our village on a hill near the Ahr was unaffected except being cut off from power, water, road access and telecommunication. The landscape looked idyllic as always. It was almost silent. Just birds were singing. Almost everyone in our village has relatives along the Ahr. They were in deep shock trying in vain to reach their relatives in the Ahr valley in spite of a malfunctioning telecommunication network. As I have a PhD in cultural engineering and water management, I felt the need to contribute to documenting the disaster and decided to walk to Ahrbrück which was heavily affected. Major parts of the village were flooded to the first house floor level. Pumps, if available, were pumping water out of cellars. People shuffled large amounts of mud onto the streets and tried to bring their houses into order. The brief eye contacts and words we exchanged were very moving. A car was washed into someone's front garden at a considerable distance from the river. What I then saw near the old bridge over the Ahr was disturbing. It had collapsed under the impact of trees and debris. The houses on the left were washed away including most of their inhabitants. People walked stunned on the adjacent road. The only sound to be heard was flowing water of the Ahr.



The morning after the flood at Ahrbrück

Walking in deep thought in meadows upstream from Ahrbrück, I noticed plenty of household items and debris. A former train embankment was completely eroded and I had to climb over all kinds of obstacles. There was suddenly a distinctive smell. I thought the unthinkable. Are there corpses in this place? Do they start smelling just a few hours after the disaster? A police helicopter was circulating above me with special cameras. I decided to return to our

village. It was later confirmed that bodies, some of them shredded into pieces, were found in this and many other places along the Ahr. The largest numbers were found in Bad-Neuenahr and Altenahr. Corpse detection dogs and forensic analyses were used to identify the bodies, as far as this was possible. Few people will be missed forever.



Altenburg, inundated twice in a short period of time by a flood wave that bounced back from a natural barrier at nearby Altenahr.

Emotional discussions evolved during the days after the flood, wild opinions were voiced, and there was a strong search for those who could possibly account guilty for the disaster. Some of the arguments were appalling. I felt that they were expressions of helplessness and anxiety. Does it make sense to look for someone to blame in a natural disaster situation at all? Three weeks after the flood it became clear that it would have happened irrespective of any human influence. Many claim that the extreme weather event that has caused this flood resulted from human-induced climate change. That is only partially true. Geographers from University of Bonn found that there was a similar Ahr flood event in 1804, long before the onset of industrialization, and another in 1910.

Nevertheless, there are a number of human influences that could mitigate the dimension of such disasters when they reoccur. Renaturation of Ahr floodplains and creation of flood dams are useful measures. Replacing spruce forests through deciduous forests and understory would increase the water holding capacities of catchment areas. They have been anyway damaged by severe drought and bark beetles during the previous years. Rethinking agricultural land use towards higher water retention capacity could be another measure. Hydrological mistakes made during land consolidation in vineyards in the 1970s need to be reverted. Integrated hydrological catchment management would provide further flood

control options. Collapsing trees into the flood wave were a major source of destructive energy exerted on houses and infrastructure. Tree planting along the Ahr should hence be discouraged. Camping places from which a considerable number of dead originated should better be located at reasonable distances from the river and be prepared for possible flood events. Those who build their houses too close to the Ahr or in flood prone areas were heavily affected by the flood. Rural and urban development policies need to be adjusted to avoid such dramas. Meteorological and hydrological nowcasting must be improved to provide more accurate flash flood warnings. Coordination problems were revealed during disaster management which needs to be fixed. Discussions about the Ahr flood on July 14 were highly politicized across the entire political spectrum. Improving linkages between environmental science and policy could potentially lead to more informed and responsible decisions about Ahr catchment and river basin management. Short-term projects are ill-suited for this purpose. Long-term cooperation in institutional settings is required.

Something wonderful happened after the flood, a huge wave of solidarity evolved within the Ahr community and quickly spread to entire Germany and beyond. It should serve as a role model for future disaster areas.

"It is not nature that humans cannot command, but themselves, in all their insignificance and world-altering might" The Economist, July 24, 2021