Deltares

# FAQ

## How can heavy rain lead to flooding so quickly?

Update: 31-8-2021

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In July 2021, severe flooding battered the Netherlands, Belgium and Germany. Particularly in Belgium and Germany, the floods caused enormous damage and large numbers of casualties. Here, we briefly explain how floods are caused, and the similarities and differences between what happened in Belgium and Germany and the situation in the Netherlands.

**From rainfall to discharge**

The water in our rivers comes from rainfall (or, more accurately, precipitation). How rainfall develops into river discharges depends very much on, for example, the steepness of the area, the type of soil and how the land is used. Some rules of thumb include:

- The steeper the area, the faster the rain will run off.
- The fewer trees and other vegetation, the faster the rain will run off.
- The more impermeable the ground, the faster the rain will run off.
- The wetter the ground after rainfall in recent days and weeks, the faster the rain will run off.

The first and last of these rules in particular can explain why the discharge peaks in Belgium and Germany were so extreme. The steepness of the areas, in combination with the enormous amount of rainfall, make the rainfall-discharge process very fast and so the river discharge increases rapidly. The same was also the case in the Geul and the Roer (the Dutch tributaries of the Meuse).

During dry periods, rain can be stored temporarily in vegetation and evaporate again (this process is known as interception). Alternatively, rain can infiltrate the soil and evaporate (directly or via plants) or flow slowly via the groundwater to the rivers. During wet periods, these temporary buffers will often be full already. Leaves will already be completely soaked – they can no longer retain any water – and groundwater systems will already be completely full. If more rain comes, there will be surface run-off, a process that is many times faster than run-off via groundwater.

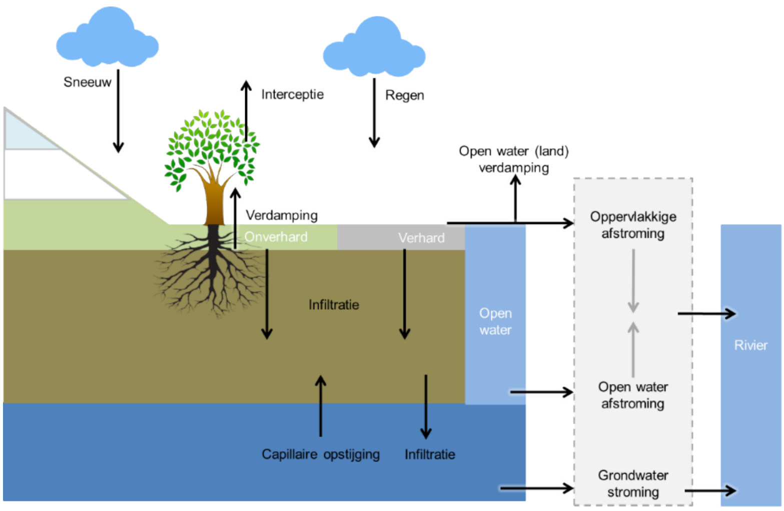


*Figure 1: Overview of hydrological processes*

# FAQ

Update: 31-8-2021

## High water of July 2021

This is very probably what happened in July 2021. The catchments have already been wet for some time as a result of regular rainfall. And low temperatures have also reduced evapotranspiration levels. Starting on Tuesday, 13 July, it starts to rain harder and harder, and all the buffers are full. The enormous amounts of rain therefore run off very quickly.

Because the catchments in Belgium and Germany in particular are also steep, the water concentrates quickly in the valleys of rivers such as the Vesdre and Amblève in Belgium and the Ahr in Germany. All the water from the valley comes together here at the same time and that leads to an enormous discharge peak that flows through the valley very rapidly. Figure 2 clearly shows that the Ahr, the Vesdre and the upper reaches of the Roer are very steep. So it is hardly surprising that it is precisely these rivers that are particularly vulnerable to the extreme rainfall in this area.

This vulnerability is clear to see in Figure 3, which shows the measured water level at the Altenahr monitoring station on the Ahr. The water level rose by no less than 4 m in just 6 hours (from 100 cm to 500 cm) before the monitoring station failed. Estimates suggest that the water continued to rise after that: to well above 700 cm. In other words, a total rise of more than 6 m in half a day! Table 1 shows that this was very extreme high water, with a peak water level of more than 3 m higher than the highest recorded high water.

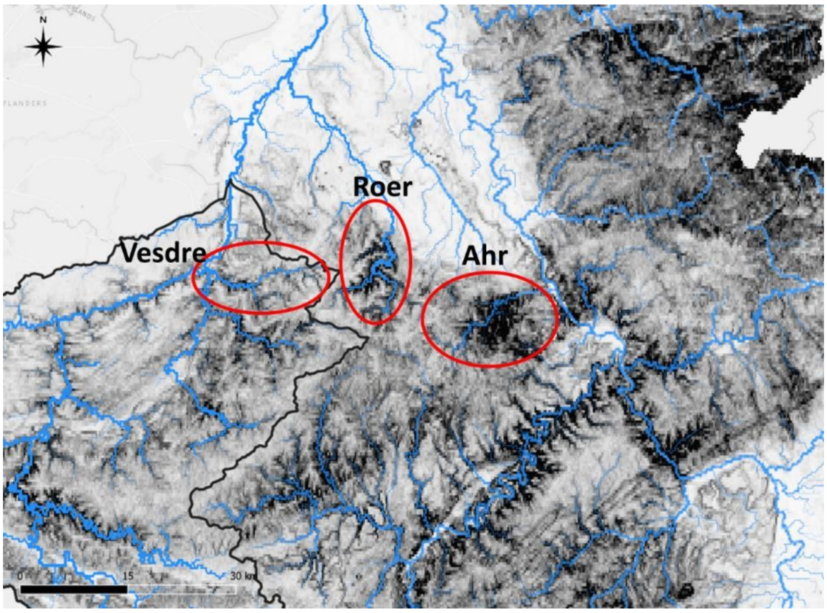


*Figure 2: Slope (black = steep, white is flat)*

## Effect of human activity

The current structure of the rivers in these valleys is not designed to cope with such extreme discharges. The room the river needs during the discharge peak is occupied by buildings. The pictures of Schuld, a village on the Ahr River in Germany which was completely flooded during the peak, show this clearly. On aerial photographs, we can see that most of the village is located in the old bed and natural floodplain of the Ahr (Figure 4). The room the river needs is no longer available.

# FAQ

Update: 31-8-2021

It should be pointed out that this is not a unique phenomenon: there are numerous locations around the world where the rivers have been “built up”.

This used to be the case in the Netherlands as well (and it still is in some places), with the familiar example of Nijmegen aan de Waal. That is why the “Room for the River” project was initiated and why more room has been made for the river near Nijmegen. Valkenburg aan de Geul is another example of a town with limited room for the river, with unfortunately disastrous consequences in 2021.

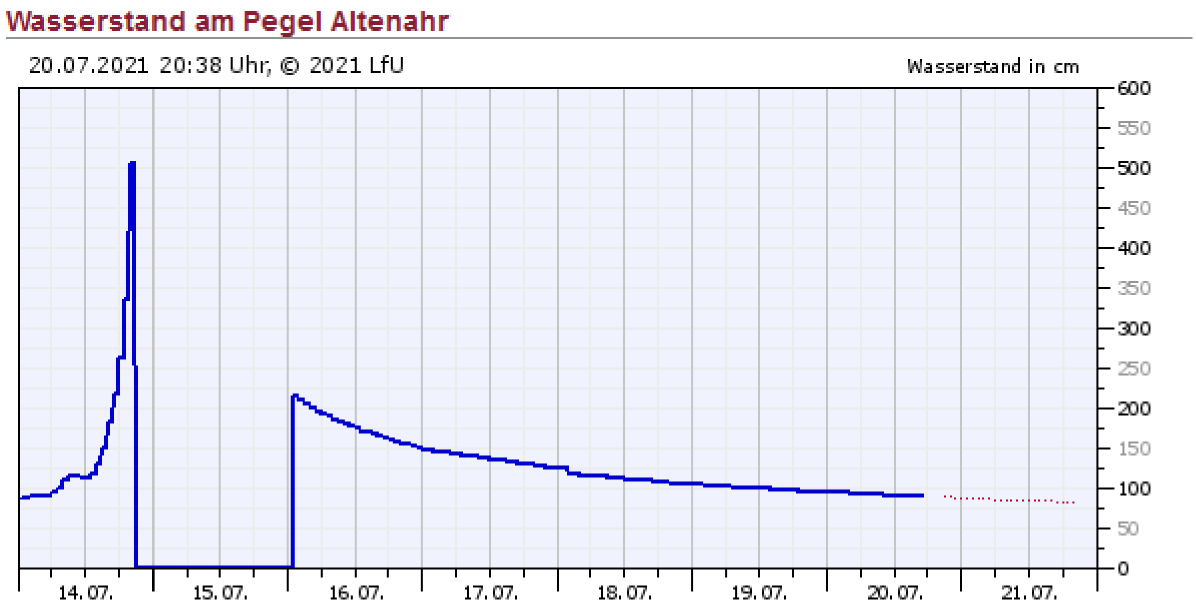


*Figure 3: Measured water levels at the Altenahr monitoring station on the Ahr in Germany. Late on 14 July, the monitoring station failed. The values from 16 July onwards are values calculated using computer models for indicative purposes. The estimated water level at the high-water peak was higher than 700 cm. Source (consulted on 20/7/2021):*

*https://www.hochwasser-rlp.de/karte/einzelpegel/flussgebiet/rhein/teilgebiet/mittelrhein/pegel/ALTENAHR*,

*Table 1: Highest measured water levels at the Altenahr monitoring station on the Ahr Source (consulted on 29/7/2021):*

*https://www.hochwasser-rlp.de/karte/einzelpegel/flussgebiet/rhein/teilgebiet/mittelrhein/pegel/ALTENAHR*, .

| water levels | | |
|---|---|---|
| cm | date | ranking |
| Approximately 700 | 15-07-2021 | 1 |
| 371 | 02-06-2016 | 2 |
| 349 | 21-12-1993 | 3 |

# FAQ

Update: 31-8-2021

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|---|---|---|
| 311 | 23-01-1995 | 4 |
| 293 | 12-01-1993 | 5 |
| 291 | 08-01-2011 | 6 |
| 288 | 03-01-2003 | 7 |
| 272 | 13-02-2002 | 8 |
| 254 | 28-09-2007 | 9 |
| 233 | 31-12-1993 | 10 |


*Figure: The situation at Schuld, Germany, before (left) and after (right) the flood*

*Source: [https://www.dw.com/en/flooding-in-germany-before-and-after-images-from-the-ahr-and-eifel- regions/a-58299008](https://www.dw.com/en/flooding-in-germany-before-and-after-images-from-the-ahr-and-eifel-regions/a-58299008)*

Another factor in the Roer was the fact that some of the high-water peak could possibly be stored in the reservoirs in the upper reaches of the river. However, we do not yet know whether these reservoirs actually retained water during the high-water peak. Given the enormous amounts of rain that had fallen previously, it is entirely possible that the reservoirs were already full when the peak arrived and that the peak was therefore not reduced by the reservoirs.

**Analyses with simulation models**

Precipitation-discharge models are often used to calculate expected discharge levels in the rivers. These models use rainfall forecasts to predict which proportion of the rain will be stored, which will evaporate and which proportion will eventually run off. These models are used operationally to produce “real-time” discharge forecasts but they can also be used to perform specific analyses. For example, analyses can be made of the possible effects of climate change or changes in the landscape (deforestation, urbanisation) on discharge levels.