Extreme floods in Belgium

The July 2021 extreme floods in the Belgian part of the Meuse basin

By Benjamin Dewals, Sébastien Erpicum, Michel Pirotton and Pierre Archambeau

The floods which occurred in July 2021 in the Belgian part of the Meuse basin were the highest on record along many tributaries. The combination of such extreme flows with a floodplain vulnerability comparable to the current one is unprecedented. This led to a high number of casualties, partly due to substantial surprise effects. In this article, the exceptional nature of the floods is highlighted, and some implications for flood risk management are discussed.

Credit: J. M. Lambotte, University of Liege

Context and impacts

The Meuse is a transboundary river, which flows from south to north across parts of France, Belgium, and Netherlands[1]. Exceptional rainfall which affected several European regions in July 2021 led to disastrous floods along a number of tributaries of river Meuse, including river Ourthe, Amblève and, above all, river Vesdre (**Figure 1**).

The flood-induced impacts in Belgium led to 39 fatalities due to drowning, more than 20 of them in the Vesdre catchment alone. Hundreds of buildings were either washed away or faced so extensive structural damage that they need to be demolished. Thousands more residential buildings were substantially damaged, leading to extensive intangible damages, especially for younger people. Not only the housing sector, but also companies and public infrastructures faced unprecedented damages. More than 200 bridges need repair, many railway tracks were disrupted and kilometres of gas, drinking water and electricity supply networks were destroyed. This leads to indirect impacts which extent far beyond the affected valleys and will last for months until reconstruction of infrastructures is over. Damages to infrastructures can be related to a great extent to bank failures, scour, and other morphodynamic effects.

In this article, we quantify the event in terms of rainfall intensity and river discharge, and we reflect on the causes of such record-high impacts as well as on some implications for improved flood risk management.

Extreme long duration of high intensity rainfall

In the South East part of Belgium, the maximum cumulated precipitation volumes over 24 hours between 13 and July 16 July reached almost 200 mm at some locations. This value corresponds roughly to twice the monthly precipitation. Return periods estimated by the Belgian meteorological institute exceed by far 200 years in the upper part of the Vesdre catchment. Precipitation volume cumulated over 48 hours was slightly below 300 mm, and it was record-high not only in the Vesdre catchment, but also further south-west in the Amblève and Ourthe catchments (**Figure 1**).

Figure 2 shows Quantity – Duration – Frequency curves corresponding to the location of one of the rain gauges in the upper part of the Vesdre catchment. The circle symbols represent the cumulated volumes during the July 2021 flood event. They reveal that precipitations cumulated over relatively short durations, such as 10 min, 20 min… up to about one hour, did not lead to exceptional quantities. Most of these markers do not even reach the curve corresponding to a two-year return period (Figure 2). In contrast, for precipitation volumes cumulated over one to two days, the values skyrocket, and they greatly exceed the 200-year return period. This unprecedented long duration of high rainfall intensities is what made the July 2021 meteorological event extreme and exceptional.

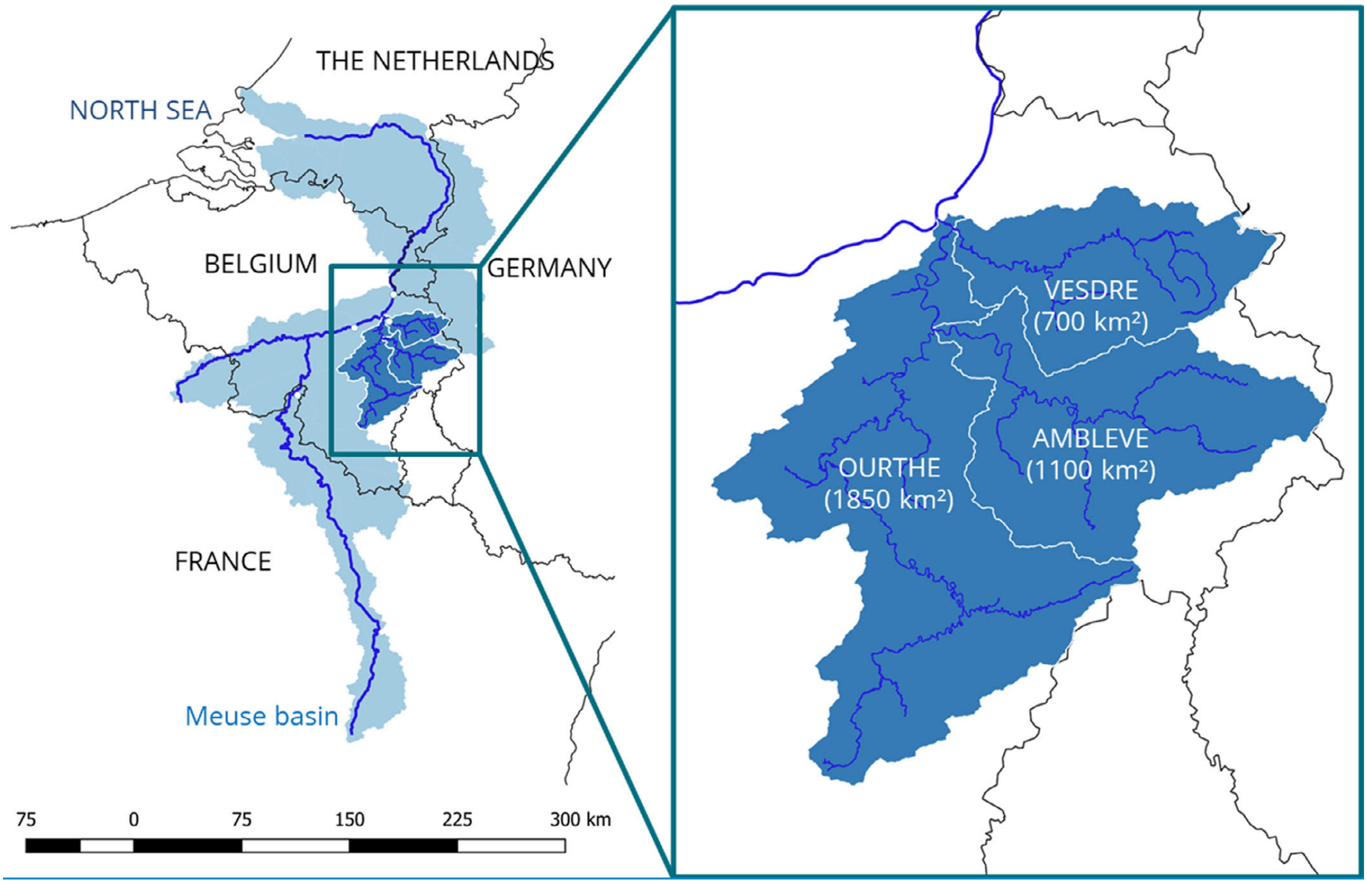

Figure 1 | Transboundary Meuse basin, and details of three of the most affected catchments: Ourthe, Amblève and Vesdre (data: European Environment Agency, Eurostat).

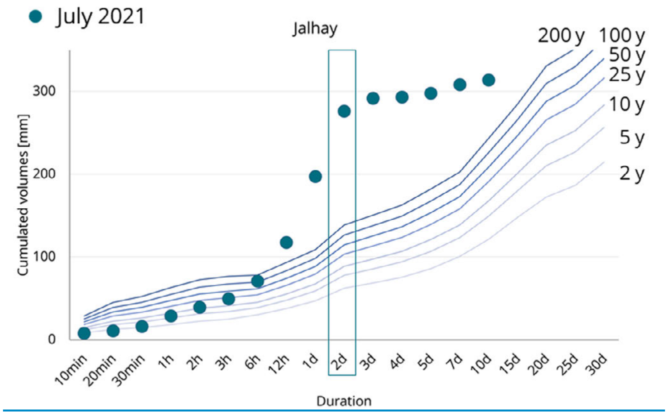

Figure 2 | Quantity-duration-frequency curves at the rain gauge "Jalhay" in the upper part of the Vesdre catchment, and cumulated volumes (circle markers) observed during the flood event in July 2021 (data: Service Public de Wallonie SPW-MI, Belgian Royal Meteorological Institute).

Extreme flows in the tributaries

In the upper part of the Meuse basin (southern part in **Figure 1**), the flood wave was not exceptional. For instance, at the French-Belgian border, the peak discharge was about half of that during another major flood event in 1993, which corresponds roughly to a 100-year flood. In contrast, further downstream, the peak discharges observed in July this year are comparable to those of 1993. At the Belgian-Dutch border, the currently estimated 100-year flood was even exceeded. These patterns are perfectly consistent with the spatial distribution of rainfall, which lead to higher rainfall volumes over the catchments of the tributaries situated in the middle part of the Meuse.

While the peak discharges in the Meuse were not extreme, the flow gradient over time was exceptional. During the summer flood in 2021, the discharge in the Meuse rose by 3000 m^3/s in just two days. In contrast, in winter 1993, the rise was 2000 m^3/s in about three days.

In the river Ourthe, which is the main tributary of the river Meuse, the observed peak discharge upstream of the Vesdre river confluence was by far the highest on record. The observed peak is estimated to have exceeded 1,100 m^3/s, which is about a quarter more than the currently estimated 100-year discharge, and it is 50 % above the second highest observed peak discharge (1993). Such extreme flood peaks were also recorded along nine other rivers in the Belgian part of the Meuse basin, for which the observed peak discharges in July this year were the highest on record at virtually all gauging stations.

Along the river Vesdre, which was most affected, all four existing gauging stations were either washed away by the flood, or failed for another reason (e.g., loss of power supply).

Nonetheless, the partially available time series suggest also a very extreme flood wave. This is also confirmed by on-going hydrological assessment of the event which suggests that the currently estimated 100-year flood may have been exceeded by a factor of three at some locations along this river. Similarly to the situation on the Meuse river, flow gradients were also exceptional compared to what was already measured on this river. These elements certainly led to surprise effects at various levels.

Surprise effects and implications for flood risk management

Available flood hazard maps display four levels of hazard, ranging from very low to high hazard[2]. These levels of hazard are defined based on a combination of estimated submersion depths and frequency of occurrence of floods. In many floodplains, the flood extent displayed on the existing flood hazard maps matches well the inundated areas observed in the field. However, there are also remarkable exceptions, particularly in a town (Verviers) of roughly 50,000 inhabitants situated along river Vesdre. This town is currently not mapped as a flood-prone area, not even in the category "very low" hazard; but on 14-15 July, the centre of the town was terribly devastated, with flow depths above 2 m, and significant flow velocities, leading to the entrainment of tens of vehicles. This acted as a surprise, not only for the citizens who were not aware of the risk, but also for a number of authorities, including those in charge of deciding and organizing emergency evacuations from the floodplains. This may have contributed to the increase in the death toll in this area.

There are several explanations for the mismatch between the flooded extent and the hazard maps. First, the hydrometeorological event was indeed extreme. It was far beyond all the scenarios considered in the current flood hazard mapping procedures. This hints at the possible need for a revision of current flood hazard maps, considering more extreme scenarios as they are becoming more frequent, as well as for improved communication about the true meaning of scenario-based flood hazard maps and about inevitable uncertainties affecting these maps. This may foster substantial gains in risk awareness.

Another aspect may be related to the effect of dams located further upstream[3], and particularly how these effects are incorporated in flood frequency analyses delivering inputs for inundation mapping. The effects of dam operation are known to differ significantly between relatively frequent floods and extreme events. The flood control capability of the dams is reduced when events become more extreme. This may lead to strongly nonlinear effects in the flood frequency distributions, which need to be accounted for to enable reliable estimation of extreme discharges in river reaches located downstream of large reservoirs.

In terms of crisis management, there is also room for improvement in the management of large reservoirs, to maximize the chance that these reservoirs succeed in reducing the peak flows, delaying flood waves to avoid superposition of the peaks, and reducing the flow gradients to facilitate evacuation and the setting up of precautionary measures. In the current configuration of the Vesdre valley, pre-releases at the dams one or two days before an event are likely to cause substantial damages in the downstream valley. At the time of reconstruction, rethinking the spatial planning in this valley so that emergency releases from the dams are made possible without damage may help avoiding another disaster. In the case of reservoirs aimed primarily for drinking water supply, widely accepted tools for balancing flood risk and risk of water scarcity are needed to achieve more objective decision-making during an event.

Figure 3 | Role of debris in damming part of the river section, affecting flow depths upstream and leading to flow contraction, scour, and high local damages (river Vesdre, upstream of Verviers). Credit: J. Mawet

This highlights the need to integrate flood and drought risk management.

Evidence from the field shows that debris and floating objects played a major role in damming a portion of the river section upstream of many bridges, which affected flow depths upstream and caused damage through severe scour at many nearby bridges (Figure 3). How to properly account for these effects in hazard mapping and risk assessment is another important question raised by the recent events. Similarly, hundreds of cars and fuel tanks were washed out by the flood, leading to pollution of large agricultural areas… Progress is needed on how to predict and model such widespread contamination.

Overall, exceptional floods should act as an agent of change. They give a unique opportunity for improvement at multiple levels, including in crisis management and flood-resilient urban planning. This will require considerable means so that reconstruction moves indeed in the direction of less vulnerable and more resilient floodplains.

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