Flood control capacity of a large reservoir under moderate and extreme flood conditions

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Dams, prevalent globally as major hydraulic structures, play essential roles in water supply, hydroelectric power, and flood management. However, they are known to significantly transform hydrological regimes by, among others, regulating flood and base flow dynamics. This, in turn, necessitates a meticulous understanding of the nature of these alterations.

Focused on the Eupen dam in Belgium, this study examines its storage dynamics in relation to moderate and extreme flood events. The study analyses time-series of inflow and outflow discharges at the dam for the period from 1995 to 2023. The inclusion of the July 2021 extreme event provides valuable insights into the dam's performance (or lack thereof) during such mega-events. Notable aspects of the methodology include adjustments for an ungauged sub-basin, the use of a Savitsky-Golay filter to refine (field-)data quality without compromising peak details and a fundamental mass-balance approach to compute outflow data from the inflow time-series.

The examination of 18 flood events during this period reveals significant findings: the dam's ability to reduce peak discharge by 8.6 to 91%, delay peak discharge by up to 68 hours, decrease flood volume by 2 to 94%, and reduce the rising rate by 1.09 to 11.16 times. Distinctly, the study also reveals a strong correlation between the damping ratio of the flood wave and the ratio of the volumes of the incoming flood to that available in the reservoir (at the start of an event). The outcomes of the flood frequency analysis are also presented and interpreted in detail.

The present study features a marked shift from existing dam-effects research, wherein the analysis is often focused on mean annual flow characteristics or aggregated data across numerous dams. It highlights the rewards of such a singular case study, in terms of being able to scrutinise individual flood events. This, in turn, provides the scope to understand more complex underlying conditions that prompt a dam's effects on streamflow characteristics. Finally, this research evidences the benefits provided by dam reservoirs on flood wave damping, but also their limits in doing so.