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Quantifying high-flow rating shifts due to unusual floodplain roughness during the July 2021 European flood

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In July 2021, several western European countries were stricken by extreme floods due to exceptional rainfall events. In North-Eastern France overbank flows started to occur in several rivers on July 14th. The local field hydrologists of the national hydrological service (Vigicrues) managed to conduct mobile-boat ADCP discharge measurements during the floods at many hydrometric stations. They often observed dramatic high-flow rating shifts, typically with measured discharges being 20% to 60% smaller than the discharges computed from the stage-discharge rating curves. Such unusual rating shifts are substantially larger than the uncertainty of the ADCP discharge measurements (5%-10%). To avoid biases in flood forecast, the rating curves had to be recalibrated with limited information on the fly, which was uncomfortable. The local field hydrologists reported that the rating shifts may be due to the floodplain vegetation being very different from the winter conditions of the flood discharge measurements used to build the high-flow ends of the rating curves. In July 2021 indeed, floodplains were covered with high summer crops that had not been harvested due to the unusually cold and rainy weather.

To test this assumption on a hydraulic basis, the rating curves of seven stations on the rivers Aisne, Oise, Helpe Majeure, Chiers and Loison in North-Eastern France were re-analysed using the Bayesian method BaRatin implemented in the BaRatinAGE open-source software. At all of these stations, the identified controls include the main channel (and possibly other low-flow controls) and a relatively wide, rural floodplain. For each station, two rating curves and their uncertainty envelopes are computed: the “normal” rating curve using all valid discharge measurements except those of the July 2021 flood, and the “July 2021” rating curve using no flood discharge measurements but those of the July 2021 flood. For the “July 2021” rating curve, the prior height (offset) of the floodplain is usually taken as the posterior (calibrated results) of the “normal” rating curve, but the coefficient of the floodplain control is calibrated using the July 2021 ADCP discharge measurements. The obtained rating curves are consistent with the rating curves estimated manually by the local field hydrologists. The floodplain friction factors estimated by BaRatin for the “July 2021” rating curve are decreased by a factor of 1.6 to 14, typically (i.e. Strickler coefficients from 15-20 $m^{1/3}/s$ to 2-10 $m^{1/3}/s$), which is spectacular but consistent with available look-up tables for friction factors in bare or vegetated fields.

The proposed Bayesian analysis appears useful for field hydrologists to evaluate the possible

extent of rating shifts due to unusual floodplain roughness at their stations, and to be prepared for the recalibration of their rating curves would an overbank flood occur outside the winter season again. It is also a convenient way for them to inform and prepare the flood forecasters on the causes and occurrence of such rating shifts, and on the related discharge uncertainty they would have to take into account.