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Evaluation/Optimization of reservoir operation rules for flood management using an integrated hydrologic-hydraulic framework

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Some reservoirs play a major role in flood protection, managing the floods and reducing or delaying the peak discharges in the river downstream. However, the changing environment (natural and anthropological changes) requires the development of more elaborated strategies for reservoir operation. Three factors are relevant: 1) the natural variability of inflow hydrographs, 2) the competition for reservoir storage capacity between flood control and other uses, and 3) the existence of built-up areas on downstream river reaches. A framework for evaluation/optimization of reservoir operation rules for flood management in a changing environment is presented in this study.

The study was carried out using an integrated hydrologic – hydraulic model in a Monte Carlo framework. A simple hydrological scenario generator is used based in aggregated and integrated models, forming a hydrometheorological model chain: 1) precipitation scenario generation in the basin, 2) runoff generation, and 3) flood hydrograph generation. Subsequently, the reservoir operation can be determined using two different modules: a) one that evaluates a predefined dam operation strategy (by default the operation rule named MEV [Girón F., 1988]), and b) a new model for flood management developed in this study, named "PLEM". PLEM is an optimization model based on mixed integer linear programming and developed using GAMS software. The objective function is the sum of two linear penalty functions that depend on the flow discharge and volume storage, respectively. This function is minimized using CPLEX solver.
This tool has been tested in four sites: Puentes, Talave, Fuensanta and Cenajo reservoirs, in the Segura basin (Spain). The results show the usefulness of the tool in comparing the behavior of the two reservoir operation modules (MEV and PLEM); the peak attenuation effect of both modules downstream of the reservoir is assessed for a wide range of input hydrographs. Additionally, the results of the case studies highlight the potential of optimization models like PLEM for flood management and determination of the most convenient reservoir operation rules. Finally, analysis of sensitivity of the impact of different variables such as the initial level in the reservoir, search of thresholds from which the flood protection capacity decreases, evaluation of the effect of climate change scenarios or planned spillway works, among others, are possible by applying the proposed tool.