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Combining uncertainty-estimation techniques and cost-benefit analysis to obtain consistent design-flood estimators

A. Botto, D. Ganora, F. Laio, and P. Claps
Dipartimento dell'Ambiente, del Territorio e delle Infrastrutture, Politecnico di Torino, Turin, Italy

Traditionally, flood frequency analysis has been used to assess the design discharge for hydraulic infrastructures. Unfortunately, this method involves uncertainties, be they of random or epistemic nature. Despite some success in measuring uncertainty, e.g. by means of numerical simulations, exhaustive methods for their evaluation are still an open challenge to the scientific community.
The proposed method aims to improve the standard models for design flood estimation, considering the hydrological uncertainties inherent with the classic flood frequency analysis, in combination with cost-benefit analysis. Within this framework, two of the main issues related to flood risk are taken into account: on the one hand statistical flood frequency analysis is complemented with suitable uncertainty estimates; on the other hand the economic value of the flood-prone land is considered, as well as the economic losses in case of overflow.
Consider a case where discharge data are available at the design site: the proposed procedure involves the following steps: (i) for a given return period T the design discharge is obtained using standard statistical inference (for example, using the GEV distribution and the method of L- moments to estimate the parameters); (ii) Monte Carlo simulations are performed to quantify the parametric uncertainty related to the design-flood estimator: 10000 triplets of L-moment values are randomly sampled from their relevant multivariate distribution, and 10000 values of the T-year discharge are obtained ; (iii) a procedure called the least total expected cost (LTEC) design approach is applied as described hereafter: linear cost and damage functions are proposed so that the ratio between the slope of the damage function and the slope of the cost function is equal to T.
The expected total cost (sum of the cost plus the expected damage) is obtained for each of the 10000 design value estimators, and the estimator corresponding to the minimum total cost is selected. In general, this estimator will not correspond to the one obtained with the standard statistical inference, because the expected damages (and the LTEC estimator as a consequence) will depend on the estimation uncertainty. The method has been applied to 10 series of annual maxima, having different lengths and different statistical characteristics; two different probability distribution functions have been used.
Results obtained show that the presence of uncertainty in design flood estimation entails an increment of the minimum-cost design floods. This increment is marginal when low return periods are considered, but becomes substantial for return periods larger than 100 years. For example, when a 1000- year return period is considered, the LTEC estimator corresponds to the 0.73 quantile of the T-year discharge distribution obtained with the Monte-Carlo approach (the standard approach produces an estimator corresponding to the median). Difference in magnitude between the two estimators can be as large as 100% when small samples (15-30 years) are considered. In the considered case, the standard flood frequency analysis always produces underestimation of the design flood and entails total costs significantly larger that those obtained with the LTEC approach.