Investigation and improvement of joint probability modelling of flood variables for the design of flood hydrographs in South Africa

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Accurate design flood estimates associated with high return periods are essential for the design and management of hydraulic structures such as dams. These estimates are typically derived through univariate flood frequency analyses, primarily focusing on peak flows. However, floods are inherently multivariate phenomena, making it crucial to consider representative flood characteristics, such as flood peak, hydrograph volume, and hydrograph duration, to conduct a comprehensive analysis. Multivariate flood frequency analyses have traditionally employed standard bivariate distributions to model correlated variables, such as peak and volume. Yet, these methods only study the joint probability of flood peak and volume alone, a design flood hydrograph cannot be summarised by the two scalars only. Still, these approaches have limitations, including the requirement to use the same type of marginal distribution for all variables and the assumption of a linear dependence relationship between them. Recently, the use of copulas has gained traction in hydrology due to their advantages in handling the multivariate context, as they overcome the shortcomings of the traditional approach. A copula is a function that captures the dependence structure of the studied variables and enables the determination of their multivariate frequency distribution using their marginal distributions, regardless of the types of marginal distributions considered. The estimation of multivariate return periods, and consequently multivariate quantiles, is also facilitated by the formulation of copulas. The research question of this study stems, firstly, from the recognition that the South African design flood estimation is univariate, mostly focusing on the flood peak alone and that the current bivariate distribution approaches have rarely gained widespread adoption in South African flood design practice. Secondly, the most widely used design event approach does not reflect real-world variability where high peak flows may not be associated with large runoff volumes and vice versa. The motivation for the research resides in the need to update and improve the traditional approaches used by hydrological practitioners and create a joint distribution function between flood variables through multivariate flood frequency analysis.