

## **On the suitability of the copula types for the joint modelling of flood peaks and volumes along the Danube River**

Silvia Kohnová (1), George Papaioannou (2), Tomáš Bacigál (3), Ján Szolgay (1), Kamila Hlavčová (1), Athanasios Loukas (2), and Roman Výleta (1)

(1) Slovak University of Technology Bratislava, Faculty of Civil Engineering, Department of Land and Water Resources Management, Bratislava, Slovakia (silvia.kohnova@stuba.sk), (2) Laboratory of Hydrology and Aquatic Systems Analysis, Department of Civil Engineering, University of Thessaly, PedionAreos, 38334 Volos, Greece, (3) Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Department of Mathematics and Constructive Geometry, Radlinského 11, 810 05 Bratislava, Slovakia

Flood frequency analysis is often performed as a univariate analysis of flood peaks using a suitable theoretical probability distribution of the annual maximum flood peaks or peak over threshold values. However, also other flood attributes, such as flood volume and duration, are often necessary for the design of hydrotechnical structures and projects. In this study, the suitability of various copula families for a bivariate analysis of peak discharges and flood volumes has been tested on the streamflow data from gauging stations along the whole Danube River. Kendall's rank correlation coefficient ( $\tau$ ) quantifies the dependence between flood peak discharge and flood volume settings. The methodology is tested on two different data samples: 1) annual maximum flood (AMF) peaks with corresponding flood volumes, which is a typical choice for engineering studies and 2) annual maximum flood (AMF) peaks combined with annual maximum flow volumes of fixed durations at 5, 10, 15, 20, 25, 30 and 60 days, which can be regarded as a regime analysis of the dependence between the extremes of both variables in a given year. The bivariate modelling of the peak discharge - flood volume couples is achieved with the use of the following copulas: Ali-Mikhail-Haq (AMH), Clayton, Frank, Joe, Gumbel, Husler-Reiss, Galambos, Tawn, Normal, Plackett and FGM, respectively. Scatterplots of the observed and simulated peak discharge - flood volume pairs and goodness-of-fit tests have been used to assess the overall applicability of the copulas as well as observing any changes in suitable models along the Danube River. The results indicate that, almost all of the considered Archimedean class copulas (e.g. Frank, Clayton and Ali-Mikhail-Haq) perform better than the other copula families selected for this study, and that for the second data samples mostly the upper-tail-flat copulas were suitable.