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# Bivariate Hydrologic Risk Assessment of Flood Episodes using the Notation of Failure Probability

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**Abstract**

Floods are becoming the most severe and challenging hydrologic issue at the Kelantan River basin in Malaysia. Flood episodes are usually thoroughly characterized by flood peak discharge flow, volume and duration series. This study incorporated the copula-based methodology in deriving the joint distribution analysis of the annual flood characteristics and the failure probability for assessing the bivariate hydrologic risk. Both the Archimedean and Gaussian copula family were introduced and tested as possible candidate functions. The copula dependence parameters are estimated using the method-of-moment estimation procedure. The Gaussian copula was recognized as the best-fitted distribution for capturing the dependence structure of the flood peak-volume and peak-duration pairs based on goodness-of-fit test statistics and was further employed to derive the joint return periods. The bivariate hydrologic risks of flood peak flow and volume pair, and flood peak flow and duration pair in different return periods (i.e., 5, 10, 20, 50 and 100 years) were estimated and revealed that the risk statistics incrementally increase in the service lifetime and, at the same instant, incrementally decrease in return periods. In addition, we found that ignoring the mutual dependency can underestimate the failure probabilities where the univariate events produced a lower failure probability than the bivariate events. Similarly, the variations in bivariate hydrologic risk with the changes of flood peak in the different synthetic flood volume and duration series (i.e., 5, 10, 20, 50 and 100 years return periods) under different service lifetimes are demonstrated. Investigation revealed that the value of bivariate hydrologic risk statistics incrementally increases over the project lifetime (i.e., 30, 50, and 100 years) service time, and at the same time, it incrementally decreases in the return period of flood volume and duration. Overall, this study could provide a basis for making an appropriate flood defence plan and long-lasting infrastructure designs.

*Keywords:* Flood; Copula Function; Bivariate Hydrologic Risk; Return Period; Failure Probability.

## 1. Introduction

Nowadays, flood events are characterized as one of the most severe and disastrous naturally occurring hydrologic consequences across the world, and the risk of their occurrence will increase in the future due to the global and regional climate-changing scenario [1-3]. In the operational planning, management or flood defence infrastructure design of water resources, it is often demanding to accurately estimate the flow exceedance probability or return periods for assessing the hydrologic risk. Flood frequency analysis or FFA is a statistical approach to establishing an interlink between the magnitude of flood episodes (or flood design quantiles) and their return periods (or non-exceedance probability) using the most logical and parsimonious probability distribution functions [4-6]. Flood is a

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