A review of the regional maximum flood and rational formula using geomorphological information and observed floods

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Abstract

Flood estimation methods in South Africa are based on three general approaches: empirical, deterministic and probabilistic. The "quick" methods often used as checks are the regional maximum flood (RMF) and the rational formula (RF), which form part of the empirical and deterministic methods respectively. A database of annual flood peaks was used in a probabilistic approach to review these methods and to provide preliminary insight into their estimates of flood peaks. This paper examines the following: the relationship between floods and landscape; the estimation of the return period of the RMF; the use of ratios in scaling RMF flood peak estimates to flow rates of shorter return periods; the applicability of the modified rational formula (MRF); the examination of the relationship between scaling parameters and regional parameters. It turns out that the RMF is the best of all methods examined in this preliminary study (other than statistical) in estimating the 200-year flood peak at an ungauged location.

Keywords:flood estimation, rational formula, regional maximum flood, generalised extreme value distribution

Introduction

The realistic estimation of the magnitude of a design flood peak with a chosen probability of exceedence that can be expected at a given site in a given region is fundamentally important in the planning, design and operation of hydraulic structures and for the preservation of human life and property. The basic approaches involved in flood estimation are the empirical, deterministic and probabilistic approaches. These methods are calibrated from historical flood records from gauged catchments and their relative usefulness depends on the accuracy with which they are able to predict flood sizes in ungauged catchments. In South Africa, reasonable estimates of maximum recorded flood magnitudes are derived from the use of the empirically-based approach of the regional maximum flood (Kovacs, 1988), and design floods may be determined using deterministic approachs such as the rational formula (RF), the SCS model or the unitgraph method and from the analyses of flood frequencies through a probabilistic approach.

Kovacs' **empirical method** is probably the most robust method available locally and, relatively accurately, predicts the regional "maximum" flood that can be expected from a given site based only on the site's catchment area and region. The advantage of the empirical method is its ease of use as it deals directly with the parameter of interest, namely the flood peak discharge, and avoids the assumptions involved in transforming rainfall inputs into flood outputs. The disadvantages of the RMF method are that:

- The recurrence interval (RI) associated with this "maximum" is not clear, although Kovacs estimated it to be greater than 200 years
- The regions defined by individual *K*-values have widely varying rainfall properties and
- It seems naive to estimate flood peaks on area and zone only.

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The **deterministic** rational formula (RF) approach involves (in a simple, but sound manner) the analysis of all the factors involved in flood prediction from converting rainfall inputs into flood outputs; it usually carries a caveat that it should not be used for "large" catchments, but recent work (Alexander, 2002 and Pegram, 2003) has shown that this caution is too conservative.

Flood **frequency analysis** involves the fitting of a probability model to the sample of annual flood peaks, recorded over a period of observation, for a catchment of a given region. The model parameters established can then be used to predict the extreme events of large recurrence interval. The advantage of this method is that the events of large recurrence interval, which are longer than the record period, can be determined through cautious extrapolation of the fitted distribution based on the model parameters. The disadvantage of this method is that it can only be applied where data have been collected and it is often not clear how the analysis can be extended to ungauged locations.

The question that arises is "which method is fair to use?" The answer depends on the availability of data. When no hydrological (rainfall and runoff) records exist for a catchment, the empirical methods provide the only means of flood prediction. This situation is the most common case in the design of hydrological projects. When estimates of design rainfall are available (Adamson, 1981; Smithers and Schulze, 2003) or rainfall records suitable for a frequency analysis are available from a nearby rain-guage, then the rational formula (RF) becomes applicable, in addition to the empirical. When flood records of sufficient length (>30 years or so) exist, possible future flood peaks of given frequency can be determined by modelling past floods with an extreme value distribution. Even in this fortunate situation, it is prudent to crosscheck the frequency estimate with deterministic and empirical estimates.

It is the aim of this exploratory study to provide a review of the above methods in order to determine the accuracy of the estimates of the design flood, where the design flood is the flood associated with a chosen return period or recurrence interval of exeedence. The base data are the set of annual flood peak records from 130 sites around South Africa that were used *inter alia* by Kovacs (1988) in his empirical study.