Estimating continuous monthly baseflow time series and their possible applications in the context of the ecological reserve

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Abstract

The paper describes a simple technique for baseflow separation from continuous monthly streamflow records which are widely available in South Africa. The technique employs a digital filter algorithm, which has been previously used only with more detailed daily streamflow records. The example applications of the separation technique in three gauged catchments are illustrated and its possible applications in the context of groundwater and estuarine components of the ecological reserve determination are discussed.

Introduction

Baseflow is an important genetic component of a streamflow hydrograph, which comes from groundwater and/or shallow subsurface storages. Through most of the dry season of the year, the streamflow discharge is composed entirely of baseflow. During a wet season, discharge is made up of baseflow and quickflow. The latter represents the direct catchment response to rainfall events.

Baseflow may be characterised by its hydrograph, which is derived from the total streamflow hydrograph by various baseflow separation techniques. A variety of event-based separation methods are avaible, which focus on separating baseflow from a flood hydrograph and are eventually aimed at the estimation of the surface runoff component of a flood. The descriptions of such methods may be found in many classical hydrology textbooks and are not examined in this paper.

Other types of baseflow separation techniques are designed to generate a baseflow hydrograph for a long-term period - a year, several years or for the entire period of observations. These techniques (referred to further in the paper as "continuous separation techniques") normally make use of a filtering procedure of some kind, which allows a streamflow time series to be disintegrated into quickflow and baseflow. Perhaps, the most well-known techniques of this type are the UK "smoothed minima" method (FREND, 1989) and "recursive digital filter" (Nathan and McMahon, 1990) although other methods to separate baseflow on a continuous basis have been reported (Sittner et al., 1969; Birtles, 1978; Boughton, 1988; Smakhtin and Hughes, 1993; Sloto and Crouse, 1996). Continuous baseflow separation techniques do not normally attempt to simulate baseflow conditions for a particular flood event, nor are they always appropriate for the identification of the origin of baseflow. These methods are rather aimed at the derivation of objective quantitative indices related to the long-term baseflow response of a catchment (e.g. baseflow index (BFI) – the ratio of baseflow to total streamflow) and at the estimation of continuous time series, which specifically characterise baseflow regime.

Baseflow may be separated from either daily or monthly streamflow time series. Traditionally, most of the continuous separation techniques dealt with the separation of baseflow from more detailed daily streamflow records. However, given a wide availability and use of monthly streamflow time series in South Africa, it is logical to develop a technique, which will focus specifically on baseflow separation from monthly flow data. Continuous monthly baseflow time series may be useful for the development of catchment management strategies, the establishment of relationships between aquatic organisms and their environment, the estimation of small to medium water supplies, water quality and salinity management, the estimation of groundwater recharge, etc. This short paper describes one simple technique for continuous baseflow separation from monthly flow time series and discusses some possible applications of this technique in the context of the estimation of the ecological reserve.

Developing and testing the continuous monthly baseflow separation technique

The description of the algorithm

The most straightforward approach to estimate a continuous monthly baseflow time series is to identify a suitable daily baseflow separation method and to adjust it for application specifically with monthly flow records. The adjustments are necessary due to the obvious differences in flow variability displayed by daily and monthly flow records. The "prototype" daily separation technique, which has been selected for this study uses a recursive digital filter, which originates from signal analysis. It is designed to separate "high-frequency" signals from "low-frequency" signals. Nathan and McMahon (1990) pioneered the use of this technique in hydrology, considering daily streamflow time series to be a mixture of quickflow (high-frequency signal) and baseflow (low-frequency signal). Smakhtin and Watkins (1997) tested this method intensively on daily streamflow data from South African catchments. In the context of monthly baseflow separation, the formulae of the digital filtering technique may be re-written as:

$$q_m = a\, q_{m-1} + 0.5(1+a)(Q_m - Q_{m-1}) \quad (1)$$

$$QB_m = Q_m - q_m$$

where:

q = part of the monthly flow which can be attributed to high-flow events (quickflow or high-frequency signal),

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