A simple flow-concentration modelling method for integrating water quality and water quantity in rivers

H Malan[1]*, A Bath[2], J Day[1] and A Joubert[3]

[1]*Freshwater Research Unit, Department of Zoology, University of Cape Town, Private Bag, Rondebosch 7700, South Africa*

[2]*Water Corporation, Leederville, WA6007, Australia*

[3]*Department of Statistical Science, University of Cape Town, Private Bag, Rondebosch 7700, South Africa*

Abstract

As part of the determination of the ecological Reserve for rivers in South Africa (National Water Act, 1998), flow requirements are assessed for maintenance low flow, drought low flow and flood conditions. Since water quantity and water quality are often closely linked, it is necessary to ensure that in setting the recommended flow regime, the appropriate water quality will be attained. This paper presents a simple method (based on solute rating curves) for predicting the instream concentrations of chemical constituents that will arise from different flow regimes. The method uses monthly mean flow (discharge) at a given site plotted against monthly median concentration of each chemical constituent. This is carried out for both the reference condition (the natural, or least-impacted state) and for the present state. The flow-concentration relationships obtained are used to predict the expected monthly concentrations under the recommended flow regime. The computed concentrations can be compared with the reference condition and present state values to assess the degree of river modification. This paper outlines the modelling protocol to be followed, considers the limitations and assumptions inherent in the approach, and the application of the resultant information. It is concluded that the modelling method is a useful screening tool for identifying sites where, without reduction of pollution, the water quality component of the Reserve is unlikely to be attained under the recommended flow regime.

Keywords: water quality modelling, ecological Reserve, rating curves

Introduction

South African rivers are naturally variable in their patterns of flow, in addition to which abstraction of water, and regulation by means of impoundment, frequently modify the natural hydrological regime. It is well known that alterations in flow can lead to changes in water quality, although such changes are often complex and difficult to predict (Smith et al., 1996). Alterations in the concentrations of chemical constituents and in the values of physical variables present in the system can, in turn, exert a profound effect on the aquatic biota (Dallas and Day, 1993). Methods have been developed to calculate the quantity and timing of discharge required to maintain a given level of ecological functioning in a riverine ecosystem, commonly referred to in South Africa as the "environmental", or "instream flow requirement" (IFR) of a river (King and Louw, 1998; Hughes, 1999; 2001). The question of water quality is currently inadequately addressed within the process of calculating the IFR, however, and until recently, only qualitative predictions were made of the water quality likely to result from a proposed change in flow. Since efficient functioning of aquatic ecosystems is dependent not only on a suitable hydrological regime, but also on provision of water of a suitable quality (King and Louw, 1998), it is essential that quantitative predictive methods for water quality be incorporated in instream flow assessments. This reasoning is reflected in the National Water Act (No. 36 of 1998) which requires specification of both the amount (i.e. the volume and timing of flow), and the quality of water that will maintain adequate biotic integrity and functioning of a river (DWAF, 1999). The water quality requirement prescribes, for a given resource protection level, the concentration of chemical constituents and values of physical variables that should not be exceeded. The National Water Act also calls for a system of classification of water resources, from those that are extremely impacted (class E or F) to those that are largely natural (class A). The degree of protection that is afforded to a river, or reach thereof, is dependent on the current state of the river and particularly on the class for which it will be managed (called the "ecological Reserve class"). The more protective the management class, the more stringent the water quality requirements. A system of assessment categories has also been devised for the common water quality variables (e.g. TDS, total inorganic nitrogen) ranging from A to F. Concentrations or values typical of un-impacted rivers are assigned to an "A" category. Increasing concentrations (in the case of chemical constituents) represent the boundary values that demarcate each category. At the time of writing this paper, the method for setting assessment categories for water quality within Reserve determinations is undergoing revision (DWAF, 2002).

This paper outlines a simple method (the "flow-concentration" or "Q-C" modelling method) developed to inter-relate water quality and water quantity. It has been developed to be used within the context of Reserve determinations, but may be useful in other situations where the effect of changing streamflow on water quality needs to be assessed. The steps were developed using data from actual Reserve assessments for several rivers in South Africa namely; the Palmiet River (Western Cape) and the Pienaars River (near Pretoria in Gauteng Province). The method was refined during the workshops that comprised the Olifants River Ecological Water Requirement Assessment Project (Malan, 2001) and the Breede River Basin

* To whom all correspondence should be addressed.
☎ +2721 650 3872; fax: +2721 650 3872;
e-mail: hmalan@botzoo.uct.ac.za
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