

Development of an operating rule model to simulate time series of reservoir releases for instream flow requirements

DA Hughes^{1*}, J O'Keeffe¹, V Smakhtin¹ and J King²

¹Institute for Water Research, Rhodes University, Grahamstown 6140, South Africa
²Freshwater Research Unit, University of Cape Town, Rondebosch 7700, South Africa

Abstract

The output from many of the instream flow assessment workshops, currently being held in South Africa whenever a major water resource development is proposed, is a matrix of monthly flow rates that describe the recommended nature of a river's modified regime (IFR) that will maintain the river in a pre-determined ecological condition after the development has been implemented. This paper describes a technique that may be used to translate the IFR information into reservoir release operating rules for both low-flow and flood event releases and that can generate a time series of releases. The technique is based upon the use of a reference time series of daily flow data to represent the prevailing climate and trigger the various releases. To avoid the necessity of having a reference flow time series available for the specific IFR site, the release trigger is based on duration curve percentage point data. These values are believed to be more closely equivalent across adjacent catchments than are weighted flows. Ultimately, the technique is expected to be used for planning purposes, to illustrate the effect of a given IFR on the likely day-to-day pattern of releases, as well as operationally, to control releases. This paper explains the technique and how it has been incorporated into a preliminary version of a model to simulate the pattern of releases that is expected to occur. The definition of the operating rules and the application of the model are illustrated using an example from the Luvuvhu River, Northern Province.

Abbreviations

BBM	Building block methodology
DWAF	Department of Water Affairs and Forestry
HYMAS	Hydrological modelling application system
IFA	Instream flow assessment
IFR	Instream flow requirement
MAR	Mean annual runoff
VTI	Variable time interval model

Introduction

It is becoming increasingly recognised that the large-scale abstraction of water from river systems cannot continue in an uncontrolled manner without having long-term repercussions with respect to the ecological status of the rivers and/or downstream users of water. To counteract the deteriorating condition of South Africa's rivers, DWAF now requires information on the quantity and patterns of flow that should be allowed to continue downstream of a proposed water resource development. The process of determining the nature of the required releases has been referred to as an IFA (King and Louw, 1995) and is commonly carried out during a workshop involving a multidisciplinary team of specialists. The purpose of the workshop is to define a modified flow regime that will maintain the river in a pre-determined condition. The modified flow regime is referred to as the IFR for the river and details the different flow conditions needed at different times of the year.

The IFR is commonly defined as a set of month-by-month low-flow and high-flow values for river maintenance and another set for drought years (Table 1 - LDC, 1995). In addition, some supporting information that describes the duration and other features of the required high-flow events, or the manner in which variations are expected to occur between wet, average and dry

years is frequently included. It has become clear that the workshop participants prefer to use a description of the natural flow regime of the river, with a daily time resolution, as the starting point for the IFA. The described IFR can readily be translated into required monthly release volumes and used, in combination with design water abstractions, to assess the feasibility of various reservoir design options. However, before this information can be effectively used to determine the day-to-day releases that must be made from a reservoir to satisfy the IFR, it must be translated into a set of reservoir operating rules. Those developing the IFR process consider it of the utmost importance that such operating rules should somehow be linked to the prevailing climate. If such a technique was available and could be used to illustrate the suggested modified flow regime, the authors consider that it would enhance the whole IFA approach. Specifically, it would allow the scientists to look beyond the rigid numbers in the IFR table, which take that form because of the requirements of the planners, and see a more normal-looking daily time series that reflects the IFR and is linked to natural climatic variations. This paper discusses some approaches that could be used to translate the IFR into operating rules and introduces a model that is being developed to allow the impact of the operating rules to be assessed during the planning phase and eventually to be used to determine the actual reservoir releases after the dam has been constructed.

The IFR determination method

The approach that is currently being used to assess IFRs for South African rivers is known as the BBM (King and Louw, 1995), so named because it aims to identify different components, or blocks, of the natural flow regime of a river, which are ecologically most significant, and build these into a skeleton of the natural flow regime. The methodology is constantly being refined and developed as it is applied to rivers in different parts of the country, and has been accepted for use when developments are planned and time and data are limited. The application of the BBM results in a recommended flow regime which defines the

* To whom all correspondence should be addressed.
8(0461) 22428; fax (0461) 24377; e-mail denis@iwr.ru.ac.za
Received 8 February 1996; accepted in revised form 15 August 1996.