A monthly time step, multiple reservoir water balance simulation model

DA Hughes
Institute for Water Research, Rhodes University, PO Box 94, Grahamstown 6140, South Africa

Abstract

A monthly time step, multiple reservoir water balance model is described. The model is based upon the RESSIM model, but algorithms to control transfers between dams in the system have been added. The model has been formulated for use in conjunction with either observed inflow volumes or a monthly time step, catchment rainfall-runoff model. Two examples of how the model can be set up and used to assess water resource schemes are given. One of these relates to a small irrigation scheme, while the other looks at the dynamics of a municipal water supply operation.

Introduction

In water resource planning and management there is often a need for simulation models that allow long time series of available rainfall and evaporation data to be used to generate similar length series of catchment runoff data, groundwater levels or reservoir storage volumes. Once such models have been calibrated (if necessary) and validated they can be extremely useful to examine the effects of changes such as upstream land use, gross water requirements or the operating rules and management approach to water utilisation as well as examining such things as the frequency of drought conditions of different severities or storage-yield relationships.

There are a number of hydrological simulation models referred to in the literature (O'Connell, 1991) and they vary from very simple, single function empirical models to complex multi-function models whose parameters can be estimated from measurable physical characteristics of the system (catchment, aquifer or reservoir) being modelled. The degree of complexity is usually related to the time step used in the simulation procedure as well as the extent to which spatial variability is accounted for in the distribution approach used. Consequently, simple models tend to be spatially lumped and operate over coarse time intervals (one month) while more complex models tend to be spatially distributed and operate over much shorter time intervals (less than one day). The recent trend in the hydrological modelling literature has been to support the use of distributed models (O'Connell, 1991) which are made up of algorithms (model component equations) demonstrated to be realistic in terms of our current knowledge of physical hydrological processes.

In practice, the choice of which type of model to use is commonly constrained for several reasons. In the field of practical water resource planning, there may be insufficient available data to determine the parameter values of a complex model or insufficient time and funds to collect such data (Hughes, 1991). Similarly, the resolution, accuracy and reliability of the results obtained from the careful application of simpler models may be adequate for the purposes of long-term planning and the development of management strategies. It is extremely difficult to generalise, as the specific requirements and amount of available information will dictate the best choice of model. The extensive use and general acceptance of the "Pitman" model (Pitman, 1973) for water resource planning in South Africa is a testament to the principle that users will often prefer a relatively simple model with a proven track record to a more complex one whose abilities have not been thoroughly demonstrated. This may not be a very healthy situation from the point of view of future developments in hydrological science or modelling theory (James, 1991; O'Connell, 1991), but is nevertheless the inevitable result of the need to solve practical problems in the short term.

This paper discusses a reservoir simulation model based on a monthly time step and using the same basic water balance approach adopted by the developers of the RESSIM model (Middleton et al., 1981). The original model has been expanded to allow several closely linked reservoirs to be simulated together and incorporates a number of functions to describe the format of the linkages. In developing the model the author has attempted to avoid including unnecessarily complex algorithms and to use parameters whose values can be evaluated from generally available information. It therefore remains as relatively simple and easy to operate as the original RESSIM model, but contains additional functionality to allow more complex water resource schemes to be simulated.

The model and all the necessary programs to establish the time series and parameter data files and to summarise the results in numeric and graphic format are contained within a more generalised modelling system (HYMAS - Hydrological Modelling Application System) which is written in "C" specifically for DOS-based microcomputer systems. This system is being developed at Rhodes University as part of a Water Research Commission funded project to improve the general applicability of a range of hydrological models.

At present several models can be operated from within HYMAS, including a semi-distributed version of the monthly time step Pitman (1973) model, a variable time interval (1 d to 5 min) catchment simulation model, a simple design flood model, a phosphorus export model, a daily runoff and sediment yield model and the reservoir simulation model discussed in this paper. The advantages of HYMAS are that all the models share the same set of utilities that are used to prepare model input data, run the models and assess the model output. The selection of these utilities is driven by a set of user-friendly menus.

Basic water balance approach

The water balance of a single reservoir may be described by the

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