

A Hydrologic Modelling Tool for Investigating Environmental Flow Options

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INTRODUCTION

The major issue in water resources management in Australia is the need to stop the degradation of the rivers that is occurring chiefly as a consequence of the diversion of water for consumptive use. This issue is most important in the Murray-Darling Basin (Figure 1) where diversions for consumptive use are greatest. Median outflows from the basin are now approximately 20% of natural outflows (MDBC, 1995). Seasonal flow patterns, low flows and the frequency, volume and duration of small to medium floods have been most affected.

Major water resources developments have occurred in the Murray-Darling Basin since the late 19th Century, principally since 1948. These have been mainly intended to provide reliable water supplies for irrigated agriculture, and also to provide water for hydro-electric power generation in the case of the Snowy Mountains Scheme. Developments include major storage dams, re-regulating weirs and irrigation infrastructure. Main irrigated crops are cotton in the north of the basin and rice, horticulture and pastures in the south. Publicly funded structural development is now largely complete and emphasis is now on improvements in the management of existing systems and resolution of conflicts between users competing for the scarce water resources.

In the state of New South Wales (NSW), which includes approximately two thirds of the basin area and accounts for almost 60% of the water

use, environmental flow policies are being developed which aim to improve the health of the rivers and wetlands through a partial restoration of the flow regime to that which existed prior to development. Policy options under consideration include rules for sharing of small to medium flood flows between consumptive users and the environment, augmentation of floods to prolong wetland inundation, and reproducing low flow patterns, including complete cessation of flow where appropriate. Simulation modelling is extensively used for development of these environmental policies and to assess the trade offs involved. This paper discusses the major environmental flow related issues and the model being used for carrying out the studies needed.

ENVIRONMENTAL ISSUES

The major environmental issues of concern are:

Increasing frequency of algal blooms due to the progressive reduction in river flow and consequent increased concentration of nutrients.

Increasing salinity levels due to the reduction in river flows and increase in saline inflows into rivers from rising groundwater levels and irrigation drainage.

C.Reduction in the volume and effectiveness of water reaching the wetlands due to changes in volume and seasonal pattern of flow. The biological diversity of wetlands is also reported to be in decline.

Decline in the numbers of native fish, birds, amphibians, insects and plants, while many introduced species have flourished.

C.Inadequate minimum flow releases from the dams to ensure sustenance of aquatic life.

C.Maintenance of flow patterns to assist in the breeding and spawning of platypus and native fish species.

The relative importance of these issues varies between valleys within the basin.

MODELLING TOOL

To develop water management policies for sustainable management of water resources which take into account the water requirements of both consumptive water users and environmental needs it is imperative that adequate information on tradeoffs involved should be estimated. The NSW Department of Land and Water Conservation (DLWC) had historically used monthly time step models for water allocation related decision making. These models, however, are not suited to addressing environmental issues which require consideration of the short duration variability of flows. To take this into account a daily time step Integrated Quantity/Quality Model (IQQM) (Department of Water Resources, 1994 and Black et al, 1995) is being developed by DLWC.

IQQM OVERVIEW

IQQM is a generic, hydrologic, river system simulation package for investigating water resources management policy options. The model is a strategic planning tool that is designed for investigating water sharing issues at the river basin, inter-state or international level, and between competing groups of users including the environment. It is able to simulate water quality behaviour and water quantity behaviour in an integrated manner, and is applicable to both regulated and unregulated streams. The main components are shown in Figure 2 and the instream components are described in the following paragraphs.

IN-STREAM WATER QUANTITY

This module forms the backbone of the model as it controls the movement of water down a river system. This is achieved by simulating many different processes and their interaction within river systems. The major processes that are simulated include:-

Flow routing in rivers, effluent systems and irrigation channels, using either Muskingum routing (Miller and Cunge, 1975) or non-linear routing (Laurenson, 1986) with lag. Both of these procedures include a feature for varying routing characteristics with depth, for simulating over bank flows.

Reservoir operations, for which there is a wide variety of options and features available including modelling of on and off river storages, en-route storages and re-regulating weirs; storage routing; gated spillway operation; rule curves; airspace operating policies; water transfers between reservoirs in series, and harmony rules for reservoirs in parallel.

Irrigation demands, which are modelled in detail because of the importance of irrigation as it is a large water user. The irrigation module in IQQM includes features for: soil moisture accounting; modelling a range of different crop types including cotton, pasture and other crops, including rice; simulating decisions of farmers regarding area of annual crop to plant and irrigate; simulating water ordering and usage, taking into account on-farm storages and groundwater access where available;

C. Water sharing and water use accounting, including interstate water sharing and use accounting as well as water sharing between groups of users and accounting usage by user groups. This is achieved via a resource assessment module which evaluates the volumes of regulated water available to each state and user group in storage (with an allowance for water expected from unregulated tributaries) and how small to medium floods are to be shared taking account of diversion caps and quotas as required. Water usage is accounted using either annual or continuous accounting with release sharing, or using capacity sharing.

C. Fixed demands (e.g. industrial and urban water supplies); hydro and thermal power station demands; riparian and minimum flow requirements; replenishment flow requirements for effluent streams;

wetland and environmental flow requirements; diversion rules for unregulated streams; flood plain storage behaviour and transmission losses.

IN-STREAM WATER QUALITY

The water quality features being included are:

- Movement of solutes, such as salinity and pesticides,
- C. Sediment transport,
- C. Nitrogen cycle,
- C. Dissolved oxygen,
- C. Biochemical oxygen demand,
- C. Phosphorus cycle, and
- C. Algae.

MODEL APPLICATIONS

IQQM has been implemented in the Border Rivers System (refer Figure 1 for locations of various river valleys), the Barwon-Darling River from Mungindi to upstream of Menindee Lakes, Macquarie River System, Clarence River System and Lachlan River System. The model is also being implemented in the Namoi, Hunter, Gwydir and Murrumbidgee River Systems of NSW.

Model implementation involves calibration and validation for flow routing, transmission losses, effluent systems, and irrigation demand computations. In addition the model is tested for correct operation of rules for sharing small to medium floods, rules for operation of storages and resource assessment calculation procedures. The model calibration and validation is usually constrained to approximately ten years due to paucity of data. Once the model calibration and validation has been successfully completed, most model studies are carried out using 100 year simulations for the river system under specified operating rules and development conditions.

Since 100 years of recorded data is rarely available for contributing tributaries and inflows into storages, these have been derived using rainfall-runoff modelling. The Sacramento Model (Burnash, 1973), which constitutes the rainfall-runoff modelling component of IQQM has been used for deriving the long term streamflow sequences required.

INVESTIGATIONS FOR ENVIRONMENTAL FLOW OPTIONS

IQQM has been used extensively in the development of various environmental flow related policies. The policies investigated include:

Fish passage rules

To maintain and improve the population densities of native fish in the Lachlan River System (Figure 1), rules for management of unregulated flows have been implemented. These fish passage rules specify periods when flood flows in the river downstream of headwater storages may be stored in the re-regulating storages in the system for later consumptive use, and are:

If flows are less than a specified minimum threshold then no water may be stored in re-regulating storages.

If the flows are greater than the specified minimum threshold then storage of water in re-regulating storages is allowed provided that within a specified preceding time, flow events exceeding specified peak and duration criteria had occurred at prescribed downstream locations in the system.

If the river flows are greater than the specified minimum threshold, and the above mentioned downstream flow criteria are not met then the feasibility of making supplementary releases from the re-regulating storages to enable the downstream flow criteria to be met is investigated. If this is feasible then supplementary releases are triggered.

Flow patterns to maintain platypus populations

In the Macquarie River Valley (Figure 1) when transferring water between the two major reservoirs in the system, which are in series, there is a danger that if the river water is maintained at a high level over an extended period, platypus will drown. Consequently, these transfers need to be planned sufficiently far in advance to enable a flow pattern to be used that does not endanger the platypus, but still enables downstream water requirements to be met. For developing transfer strategies, IQQM forecasts future water demands and timing and volume of transfers, making due allowances for prescribed flow patterns. This procedure also takes into account contributions from tributaries between the storages.

Minimum flow requirements downstream of storages

To maintain minimum flows immediately downstream of major headwater storages during periods of low or no downstream demands options for releasing proportions of storage inflows are being investigated and the impact on existing users is assessed. Typically the rules are based upon releasing specified proportions of inflows within defined flow ranges.

A variation to this requirement is to restore flows at a specific location downstream of the dam where inflows and outflows may occur between the dam and the point of interest. In this case the objective is to restore the flow regime in a range between specified lower and upper flow thresholds at the point of interest. Under this approach, storage inflows and estimated inflows and losses between the dam and point of interest are combined to determine if the net total is above the lower threshold at the point of interest. If so storage inflows are released such that the upper flow threshold at the point of interest is not exceeded. Otherwise no release is made for this purpose.

Wetland water requirements

The wetland water requirements are determined with the objective of ensuring completion of a bird breeding cycle and the maintenance of core wetland areas and plant water requirements. Options being investigated to meet these requirements are augmentation of small to medium floods and the generation of inundation events. For example, where a flood is sufficiently large to trigger a bird breeding cycle but the duration is too short for the bird breeding cycle to complete then releases are made to augment the duration of the event. Releases are also made for supplementing floods or generating inundation events to meet core wetland requirements in circumstances where these areas would otherwise be excessively stressed.

Event analysis

Event analysis is used to investigate the impacts of management options on the frequency of occurrence of floods of various magnitudes and duration of periods between floods. The deviations from natural conditions are used in assessing the stress imposed on various instream and floodplain plant and animal species due to changes in flooding behaviour. The results are used in deriving rules for sharing and augmenting small to medium floods. Event analysis is also used to investigate the comparative rates of fall of hydrographs, between management scenarios. The results are used as indicators in bank stability analysis.

CONCLUSIONS

Environmental degradation of rivers as a consequence of the diversion of water for consumptive use is a major issue in water resources management in Australia. Policy options for restoring key features of the flow regime are being investigated with the aim of improving river health. Options under consideration include rules for sharing flood flows between consumptive users and the environment, augmentation of floods to prolong wetland inundation, reproducing low flow patterns, including complete cessation of flow where

appropriate, and rules for maintenance of flow patterns to assist in breeding and spawning of platypus and native fish species.

The DLWC NSW is developing a daily time step Integrated Quantity/Quality Model (IQQM) for water management planning purposes and is progressively implementing it in regulated and key unregulated river systems in NSW. IQQM has proved to be an essential tool for investigating environmental flow rules as these are dependent on the short duration variability of flows. This has assisted the DLWC in formulating rules and policies for improving the health of NSW rivers, while minimising the impact on consumptive water users.

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