Mathematical modelling of water resources at the University of South Australia

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WICKED WATER PROBLEM

The Murray Darling Basin, Australia's most important agriculture region, produces one third of Australia's food supply. In the past, water from the Murray-Darling River system has been allocated to irrigation and other human needs, and it has been assumed there will be sufficient water remaining in the system to repair and maintain river health. The southern Murray-Darling Basin has been suffering from drought for the past decade and inflows to the River Murray remain close to record low levels. Under these conditions, the first priority for the distribution of water in the basin is to ensure that states receive enough water for their critical human needs in 2010. However, in order to ensure the long-term sustainability of both our river systems and the availability of water for critical human needs in the future, the first call on water should be for environmental needs. The wicked water problem is: how do we solve the multi-criteria optimisation problem of supplying critical human needs while maintaining – or indeed enhancing – the environmental health of the system?

A group of applied mathematicians at the University of South Australia has been involved in modelling various aspects of water resource management for a number of years, funded by the Australian Research Council through one Industry Linkage Grant and two Discovery Grants. I report on the progress of present research undertaken by three PhD students under the current grant, focusing on the tools they are developing.

Recovery of a river system

A statement in the daily newspaper in Adelaide, near the end of the river system, prompted a research topic for one of our students, Andrew Plumridge. The editorial quoted a water expert as saying that it would require a number of years of above average rainfall for the river system to recover. We decided we would first have to define *recovery* of the system. Then, we would have to determine if the system could actually recover with current management practices. Then, if it could, how many years of how much above average would it take? If it couldn't, by how much would the management practices have to change to enable recovery? To begin, Andrew simulated the three main storages in the system under extreme conditions, but using present management policies. The initial state of all storages was taken to be empty and then he studied the best 10-year period of streamflow – see Fig. 1 where they all essentially filled within 10 years. He followed with starting them full and used the worst 10-year period of historical streamflow. Figure 2 shows that the two large upstream storages dropped dramatically in storage. He is now working on intermediate cases In order to understand whether there is a reasonable probability of the system recovering from the current low storage state under a variety of rainfall inputs using present management policies.

Catchment rainfall

The modelling of rainfall at a number of sites for which there is a significant inter-site correlation is a difficult mathematical problem. The goal we have is to be able to construct a model such that we can construct synthetic sequences of rainfall totals on various time scales so we can assess various management practices in a catchment. A PhD student, Roslina Zakaria, has been working on various approaches to this problem. One project concerns modelling a weighted sum of rainfall at correlated sites to give an estimate of the total volume of water as runoff from a catchment due to rain. The sum

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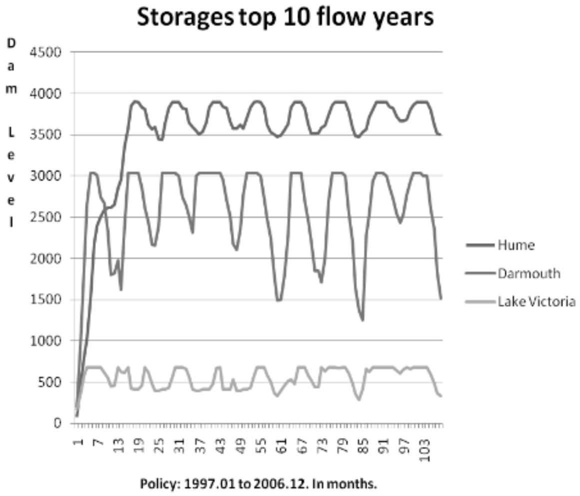

Fig. 1 Recovery with the best 10 years.

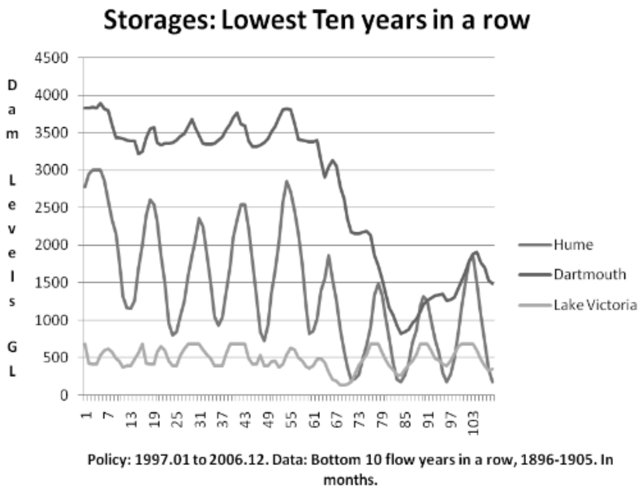

Fig. 2 Decline with the worst 10 years.

of correlated random variables is straightforward only in special circumstances, for instance if the individual variables are normally distributed. The standard assumption is that rainfall for a single site is best modelled with a Gamma distribution. We detail results based on the sum of correlated Gamma variables.

Stochastic dynamic programming (SDP)

Sara Browning is working on the application of SDP to water resource management. She is using a stochastic dynamic programming model to improve water management in a large river system. The starting point is a stochastic dynamic programming model proposed by Archibald *et al.* (2006) to determine an improved operating policy for a connected multi-reservoir system which maximises expected monetary value (EMV) and minimises Conditional Value-at-Risk (CVaR) where CVaR represents a penalty for increased environmental damage to the river system. The major challenge for future water resource management is optimising economic, social and environmental outcomes subject to achieving sustainable water resource use in the context of a changing and highly variable climate.

REFERENCE

Archibald, T. W., McKinnon, K. I. M. & Thomas, L. C. (2006) Modeling the operation of multireservoir systems using decomposition and stochastic dynamic programming. *Naval Research Logistics* **53**, 217–225.