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Development of RiverOperator: a tool to support operational management of river systems

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Abstract: The tools used to support daily operational management of river systems in Australia are generally different from those used to inform policy and planning decisions. Operational tools typically assess management options over a time scale in the order of weeks to months. Planning tools typically look at the impact of management decisions over a decadal to multi-decadal time scale. Operational tools currently being used around Australia are largely based on spreadsheets designed to aid operators in tracking regulated flows. These spreadsheets do not use the sophisticated physical models and forecasting tools which exist and are under development in the long-term planning models. The underlying physical system, processes and management are essentially the same for both the operational and planning time frames. Modelling techniques used in planning models have considerable potential to advance the accuracy and usefulness of daily operations tools.

RiverOperator is a new product being developed to support river operations. RiverOperator is being developed in parallel with a long-term planning tool called RiverManager. The parallel development enables the same underlying model to be applied to the same system to support both operational and planning decisions. Linking to RiverManager has many advantages over existing operations tools. The new tool will explicitly model complex physical processes and management concepts, aid the operator in the derivation of an optimal release plan, assist in report generation and data management, and provide the operator with the ability to model water ownership if required. RiverOperator has a tailored interface designed to support daily operational use. This interface is designed to reduce the time overheads required for an operator to implement an entirely new way of making operational decisions, without losing the advanced functionality provided by the more complex underlying model.

RiverOperator presents a number of new software development challenges not encountered with traditional long-term modelling applications. Planning models typically focus on long-term historical data sets whereas operational models are much more focused on short-term historical and forecast data sets. Daily operations require up-to-date observed data, forecast data in combination with long-term seasonal patterns. Operators will often override both observed and modelled data at various points in the system based on experience. Supporting the integration of forecasting models into the interface which then serve as the input to the underlying model is one of the new features in RiverOperator. The forecasting models vary in complexity and are used to predict various inputs into the river system model such as unregulated inflows, short term demands and unaccounted losses. Examples of inflow forecast models being built into the product range from simple regression models to complex models using the latest climatic forecast data available to generate tributary inflow. The system can also use historic data to aid decision making by making predictions based on historic events. The handling of historic and forecast data which require regular update and user modification present new design challenges as they represent a departure from the way traditional modelling tools manage their data. By incorporating the latest data management techniques, forecasting techniques and physical modelling, RiverOperator aims to provide daily operators with a more accurate tool with which to regulate their river systems.

Keywords: *RiverOperator, RiverManager, river operations*

1. INTRODUCTION

Water sharing plans have been developed for the major river systems in Australia to define the entitlements of different users (including the environment) to access both regulated and unregulated water resources. Water sharing plans are developed using planning models, which simulate the river water balance over long time periods. River operators are responsible for the day to day operation of river systems, subject to the rules and sharing arrangements defined in the water sharing plan. River operations typically involve:

1. daily operations (storage releases) to meet water user requirements subject to environmental and physical constraints (e.g. minimum flow requirement),
2. seasonal planning to minimise losses and overcome delivery constraints during high demand periods, and
3. flood management.

Current operational tools model the river system in a manner which is distinctly different from the long-term planning tools used to develop water sharing plans. This creates a number of inconsistencies between the planning and operational management of river systems. Existing tools rely heavily on operator experience and a detailed knowledge of the specific river system being operated. The ability for the operator of a complex river system to make optimal operational decisions is in part related to the capabilities of the available support tools.

The support tools used by river operators in Australia are largely legacy products, which have evolved to replicate how operators used to manage rivers prior to computers. The current tools used in the Murray Darling Basin are based on the original operating system, where daily system data was recorded on butcher's paper and a cardboard cut-out was utilised to determine daily storage releases and forecast system flows.

A new tool to support river operations, called RiverOperator, is being developed to bring the physical and management modelling capabilities present in modern planning tools to the daily operator. The RiverOperator tool will explicitly model complex processes which were previously approximated using operator experience. This paper focuses on the present development of RiverOperator and its potential adoption as a key river operation support tool.

2. DEVELOPMENT OF RIVEROPERATOR

2.1. User Requirements

A review of the user requirements for an operation tool was undertaken in 2006 (Nicholls, 2006). This was reviewed in 2008 (eWater CRC, 2008). The key user requirements of the product are summarised below:

- Forecast and monitor river system behaviour in the short term (weeks) and medium term (up to 3 years).
- Calibrate daily river system parameters based on observed daily data and current system behaviour, to accurately route system flows.
- Inform decisions on how the system should be operated to deliver water in the short and medium term to consumptive and environmental users.
- Inform decisions on water transfers between catchments, rivers and reservoirs, as specified in operation and management plans.
- Inform changes in water delivery requirements as a consequence of external drivers, e.g. water trading.
- Decide the optimum storage and weir operations to meet target watering regimes for consumptive and environmental demands.
- Track and account for water shares through river systems on a daily basis.
- Provide a rapid response capacity for decision making with regard to flood operations and surplus flow events.
- Provide a highly productive and efficient framework for tool development, operation and management.
- Integrate the modelling of processes relating to hydrology, ecology, economic and social impacts.
- A product that can be adopted by all operators, allowing improved data transfer and linkages between related catchment models and model functionality developed by other parties.
- A product that will form the basis of a training and accreditation program for river operators.
- A product that will continue to meet user needs for the next 15 years.

No existing operational tools meet these user requirements (Barma, 2009). End users of the product have also expressed a strong desire for a tighter link between operational and planning tools (Nicholls, 2006). On this basis, a decision was made to link the development of the next generation of operations (RiverOperator) and planning (RiverManager) models.

2.2. A Common Modelling Engine

TIME and E2

RiverOperator and RiverManager are being developed in The Invisible Modelling Environment (TIME) (Rahman et al., 2003), an environmental software library, and on E2, a catchment modelling platform (Argent et al., 2005). By building on TIME and E2, the products are able to utilise many existing advanced environmental modelling components. TIME contains both Domain and GUI components designed to support environmental modelling applications. Code for efficiently handling large datasets, data IO, data visualisation and analysis are all included in the TIME framework and are directly utilised by the RiverOperator product. E2 provides a specific river system modelling capability to the product, including a node/link network representation of a river system and a suite of flow routing models.

RiverManager – A planning model

RiverManager is a river systems model of water and management in river systems, designed for use by river planners and managers. The model will enable users to simulate the physical aspects (natural and constructed, such as dams, canals, pipes and farming) of any river network, and also the management aspects (ownership, allocations, demand, etc.). RiverManager uses a schematic diagram to display a river network's structure. This diagram is composed of a series of nodes and links which interconnect to form a river system (Figure 1). Nodes represent physical and managerial concepts such as tributary inflows, irrigation demands, physical flow constraints, gauging stations and storages. Links are river reaches which use parameterised flow routing models to model flow between nodes. This view is a direct representation of how RiverManager represents and models a river system.

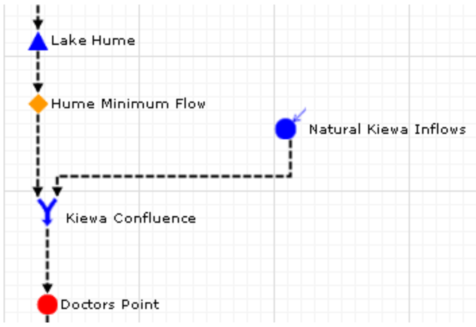

Figure 1. Schematic diagram of river system.

RiverOperator – An operational model

RiverOperator is a river systems model designed to support river operations at daily (or smaller) time-steps, typically forecasting ahead weeks to months. RiverOperator builds on the functionality that exists in RiverManager. Differences between RiverManager and RiverOperator largely relate to how the model is used and how the user interacts with the model. The key functions that an operator will undertake while using the RiverOperator product are shown in Figure 2.

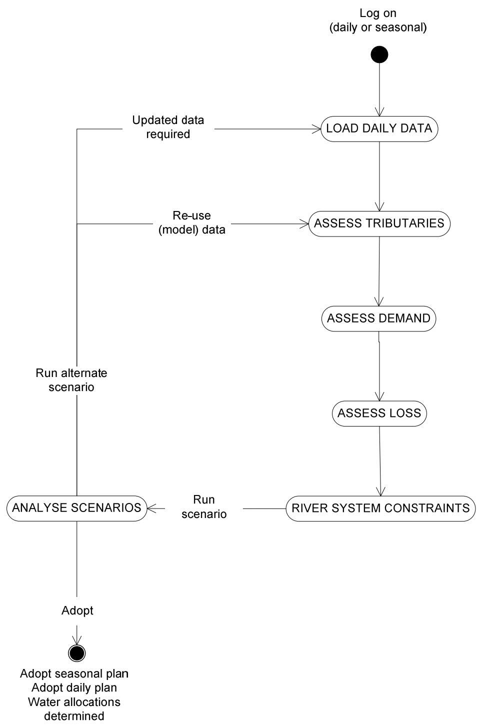

Figure 2. Typical functions and workflow undertaken by a river operator.

Specific differences between a planning and operation model include:

- Operators prefer to see a tabular view of the river system to see both temporal and spatial aspects of river operations.
- Operational models use a combination of observed and predicted data. Observed data is loaded at the start of each day (or more often) to identify the current state of the river system. This observed data is used to forecast future demands, inflows and losses.
- The operator is able to override some rules and data on the run.
- The internal state of the model is reset at the start of each day to reflect observed gauge levels and storage in a river system.

The majority of these differences relate to the user interface. Consequently, a key element in developing RiverOperator is the construction of a new user interface. This new interface specifically targets daily operations, but still uses the same underlying river network definition to define and parameterise the river system being modelled. This approach not only unifies RiverOperator and RiverManager by means of a shared network definition, but it also allows the products to share generic components used for data analysis and results presentation.

2.3. Daily Operations Interface

The major components developed to date have been those primarily responsible for the visualisation of operational data, the generation of forecast data and the mapping of model data to external data sources. These components are essential in order for RiverOperator to be able to replicate key functionality found in exiting tools.

Temporal View

RiverOperator uses a tabular view to present the system to the user. This allows an operator to simultaneously look at both temporal and spatial aspects of the river system. The tabular approach uses a temporal y axis and a spatial x axis. Time is represented on the y axis with observed data at the top running down to the predicated future data below. The x axis running from left to right shows the various network elements (nodes and links) starting upstream and heading downstream. The view provides the individual data points, which are of interest to operators, in an easily accessible way. The use of such a visualisation technique is in contrast to long-term planning tools which tend to be primarily focused on averages, trends and other statistical properties of the data, rather than on the individual data points themselves.

Time	Inflow 1 : Inflow	Storage 2 : Volume	Storage 2 : Level	Storage 2 : Release	Time Series Demand 2 : Demand	Gauge 4 : Flow
23/12/1999 12:00	87.078	0	0	172.8	0	259.2
24/12/1999 12:00	87.078	0	0	172.8	0	259.2
25/12/1999 12:00	87.078	0	0	172.8	0	259.2
26/12/1999 12:00	87.078	0	0	172.8	0	259.2
27/12/1999 12:00	87.078	0	0	172.8	0	259.2
28/12/1999 12:00	87.078	0	0	172.8	0	259.2
29/12/1999 12:00	87.078	0	0	172.8	0	259.2
30/12/1999 12:00	87.078	0	0	172.8	0	259.2
31/12/1999 12:00	87.078	0	0	172.8	0	259.2
01/01/2000 12:00	0.2	0.2	0	0	3	0
02/01/2000 12:00	0.38	0.58	0.001	0	4	0
03/01/2000 12:00	0.542	1.122	0.001	0	5	0
04/01/2000 12:00	0.688	1.81	0.002	0	0	0
05/01/2000 12:00	0.819	2.629	0.003	0	0	0
06/01/2000 12:00	0.937	3.566	0.004	0	0	0

Figure 3. An example of the temporal view. Time is shown running down the leftmost column with a network consisting of an inflow, storage, demand and gauge in series. Today’s row is highlighted blue with historical data above it and forecast data below. The yellow row is the user selected row which shows network flow travel times.

Forecast models

A river operation support tool needs observed and forecast data. Relevant observed data comes in many forms, including storage releases, storage levels, recorded rainfall and gauged flows. Forecast data refers to a prediction of future occurrences produced by a model which may utilise observed data, mathematical routines and or forecasts derived by other external models, such as predicted rainfall. Forecast models range in complexity from simple regression models to more complex models which use data such as rainfall predictions to approximate future tributary inflows.

In order to facilitate the incorporation of new and existing forecast models for use by RiverOperator, a flexible and extensible forecast model software framework had to be developed. This framework defines a generic software interface for a forecast model. The implementation details of the forecast model are specific to the individual model, but because they utilise a common interface, RiverOperator can use any of them to extract forecast data.

For any given forecast variable, RiverOperator defines two different forecast models. The first model generates a forecast of the near future (typically one week out) and the second generates a forecast from the end of the first onwards. This enables the user to specify a suitable model for use in the immediate future, such as a simple regression model to predict stream flow and to then revert to a model which uses might use historic monthly or seasonal averages to produce its forecast.

Data Import

RiverOperator needs to be able to accept various types of input data from a range of different sources. Data sources could vary from industry databases such as Hydstra, to text files and web services. As the sources of data will vary from agency to agency, a flexible software interface capable for supporting interactions with any data source is under development.

This interface will define a set of possible interactions with a data source. For each different data source the product is required to interact with, a new component which adheres to the software interface is developed and acts to provide a gateway from RiverOperator to the data source. Behind this component can lay any possible configuration of data sources. By implementing the defined interface, all components are capable of taking a standard set of data retrieval commands used by RiverOperator and converting them into instructions for its data sources and returning the requested data to RiverOperator. These data sources would typically be databases, but could be anything from local files to web services.

3. EVALUATION AND TESTING

RiverOperator is still in the prototype phase of development and is not yet able to fully replicate the functionality of existing and competing tools. A prototype version is due for release in June 2009. Industry partners will be supported to run this prototype in parallel with their existing products to build confidence and refine the user requirements. Users will have the ability to setup historic scenarios and test the tool's performance, comparing its output with that of the decisions made at the time. This iterative approach of user testing as new features are added during the development cycle is crucial to ensuring that the end product will meet the needs of all users.

4. DISCUSSION

RiverOperator represents a significant and positive advance in daily river system operations modelling. This advance is largely due to the fact that whilst long-term planning tools have been using complex physical and management models, daily operations tool have not. Instead they have been based on a much simpler model which is entirely dependent on input from an experienced user familiar with the nuances of the river system being modelled. The experience of the operators is still required if an optimal management of a river system is to be successful. The goal of RiverOperator is to attempt to aid the user by explicitly modelling the system in much more detail than was previously done, utilising the available data more effectively. The inclusion of more available data into the modelling process is significant as, although additional data was previously used in the decision making process, it was not formally captured because the model did not use it in its raw form. This more effective use of data will make the operations modelling process more transparent and aid the capturing of the decision making process which is a legal requirement for many organisations.

In addition to formally capturing more inputs into the decision making process, RiverOperator adds new capabilities such as a comprehensive ownership tracking system. This feature is not often found in most common operational support tools. The use of climatic forecast data such as rainfall is made easier using the RiverOperator tool. The tool supports the option for the user to overwrite system computed values, but for significant changes, requires the user to provide an adequate explanation for the overwrite. This feature will serve to capture the user's reasons for straying from the model's proposed solution. The user will always need this ability as the model is only a support tool responsible for aiding the operator, not making decisions for them.

Multiple state and federal agencies currently use different support tools to operate different stretches of the same regulated river system. The desire for a single tool, developed in consultation with all major operator agencies, would serve to harmonise the way in which Australia's major river systems are managed. The use of a single tool would simplify the transfer of information across jurisdictional boundaries. Decision support information and model input could be shared more easily if both agencies were using the same tool to model their sections of the river system.

New policy initiatives such as the National Water Initiative (2004) and the *Water Act 2007* (Cwlth) mean that there is a requirement for greater accountability and transparency of operational decisions. Additionally, there will be greater scrutiny of water use data and operational accounts. The development of RiverOperator will provide a robust, defensible and consistent modelling platform to support agencies implementing these new initiatives.

5. CONCLUSION

The development of RiverOperator represents a step towards a more unified approach to managing regulated river systems over a range of time scales. By creating a tailored operation-centric interface to a common modelling framework, RiverOperator is able to deliver much of the functionality which has been developed for long-term planning tools to the short-to-medium term decision maker. The tool has been designed on an inherently flexible framework, which allows for the inclusion of new hydrologic models and forecasting techniques as they are developed in order to more accurately simulate the modelled river system. The functionality included in the product will provide operators with a more comprehensive modelling toolset with which to better assess and evaluate different operating scenarios.

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