Predicting the interactions between rivers and groundwater pumping

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Abstract We summarise research that the eWater Cooperative Research Centre is carrying out incorporating groundwater-surface water interaction capabilities into the next generation of river management tools being developed for Australia's large river basins. We describe three simplified modelling approaches that are currently in development: (i) a reach scale 'Groundwater-Surface Water Link' model, which operates as a groundwater link to river models and accounts for interactions at the river-reach scale; (ii) a sub-reach scale 'Floodplain Processes' model, which dynamically models bank storage, evapotranspiration, and floodplain inundation. It enables more refined modelling of groundwater-surface water interactions, and can be linked to ecological response models; and (iii) a catchment scale model that estimates the surface and sub-surface flow components to streams.
Keywords groundwater; surface water; interaction; modelling; water security

INTRODUCTION

The National Water Initiative (NWI; http://www.nwc.gov.au/NWI/index.cfm) is Australia's blueprint for national water reform and has a key aim of more transparent and comprehensive water planning that deals with the interaction between surface and groundwater systems. In many of Australia's river basins extraction of large volumes of groundwater in close proximity to major streams and rivers has the potential to reduce stream flows (and in some instances already has). Basin-scale prediction tools that simulate these complex interactions are needed to assist in providing sustainable allocation of water. One of the core aims of the eWater Cooperative Research Centre is to develop the next generation of river planning, management and operation tools for Australia. The Groundwater Project in eWater is developing modelling tools which will provide the groundwater-surface water (GW-SW) interaction capability for the new RiverManager (http://www.ewatercrc.com.au/downloads/technologies/P2.pdf) and WaterCAST (http://www.ewatercrc.com.au/downloads/technologies/P5.pdf) products.

THE APPROACH TO MODELLING GW-SW INTERACTIONS IN LARGE RIVER BASINS IN AUSTRALIA

In an extensive literature review, Rassam & Werner (2008) found that a key challenge in modelling GW-SW interactions in large river basins (i.e. catchment areas > 20,000 km^2 are typical in Australia) is the spatial and temporal inconsistency of groundwater data that can be used to develop and test the models. They also found that GW-SW interactions are handled poorly in existing surface water models and groundwater models. In river models, these interactions are generally treated simply as a loss term. In groundwater models, the river is generally just modelled simplistically as a boundary condition. More sophisticated models that explicitly account for GW-SW interactions usually require more data, which are not always readily available. They also require a very high degree of modelling expertise and greater computational resources, which are not always available in water management agencies. Identifying the GW-SW interaction processes that are most relevant to the Australian landscape is very critical, as highlighted by the review of Reid *et al.* (2008).

When choosing modelling tools it is important to strike the right balance between surface water processes and groundwater processes. This balance can only be achieved when special-purpose custom-built models are developed to answer specific management questions. With these considerations in mind, the development of simplified modelling approaches is being carried out in this project, specifically: (i) a reach scale 'Groundwater-Surface Water Link' model, which operates as a groundwater link to river models and accounts for interactions at the river-reach scale. This will be a module in RiverManager; (ii) a sub-reach scale 'Floodplain Processes' model, which dynamically models bank storage, evapotranspiration, and floodplain inundation. It enables more refined modelling of groundwater-surface water interactions, and can be linked to ecological response models. This will also be a module in RiverManager; and (iii) at the catchment scale, the groundwater flow and salt transport concepts encapsulated in the existing 2CSalt model will be adapted for inclusion in WaterCAST.

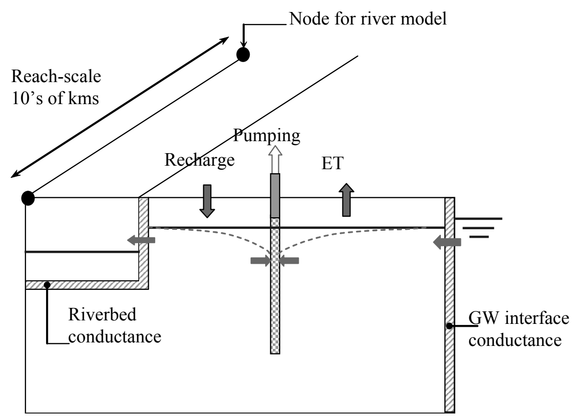

Fig. 1 Groundwater-surface water interactions for a gaining river system to be modelled in the Groundwater-Surface Water Link Model.

REACH-SCALE GROUNDWATER-SURFACE WATER LINK MODEL

This is a bucket-type model, which operates as a groundwater node for RiverManager. The scale at which it will operate is in the order of tens of kilometres and conforms to the node spacing of the RiverManager model to which it is coupled. The groundwater link to the bucket is derived from simple methods such as flow nets or more complex methods such as numerical models. The GW-SW processes are being added in stages to ensure individual processes are modelled correctly. The final model will be applied in the form of multiple spatially distributed buckets along the nodes of a RiverManager model of a river basin. A conceptualisation of this model (for a gaining stream) is shown in Fig. 1.

Based on the best understanding of the GW-SW interaction processes that could take place in a given reach, this model estimates those interactions as an in-out flux to and from the river model links. The various fluxes, such as loss of groundwater via evapotranspiration (ET) and groundwater pumping, are not spatially explicit within a node-to-node bucket, but represented as a total volumetric loss or gain for each time step in the river model.

SUB-REACH SCALE FLOODPLAIN PROCESSES MODEL

Based on the approach of Knight & Rassam (2007) and Rassam *et al.* (2008), this model aims to simulate floodplain processes at a high spatial resolution, in addition to the processes previously outlined in the Groundwater – Surface Water Link Model. A conceptualisation is shown in Fig. 2.

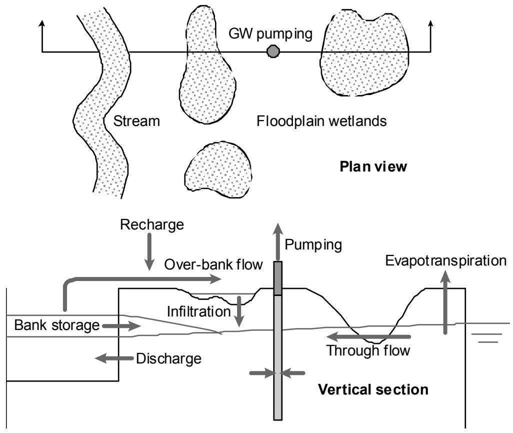

Fig. 2 Conceptualisation of the Floodplain Processes Model.

The groundwater link to the floodplain model is similar to that used in the Groundwater – Surface Water Link Model. Flow of river water into the aquifer can occur via bank storage when flows are within bank, or via flood recharge when infiltration of over-bank flows occur. Groundwater can be lost by pumping, ET (see Rassam *et al.*, 2007) and flow back into the river when river stages drop below the groundwater level. Changes in recharge over time due to land use changes are estimated and applied in the model accordingly. In contrast to the Groundwater – Surface Water Link Model, the temporal modelling of all of these processes in the Floodplain Processes Model is spatially explicit.

CATCHMENT SCALE WATER GENERATION MODEL

This component is adapting and improving the GW-SW interaction concepts from the 2CSalt water and salt generation model (Stenson *et al.*, 2005, 2006; Littleboy, 2006; Gilfedder *et al.*, 2007; Cheng *et al.*, 2007) to WaterCAST. The aim of WaterCAST is to provide daily water and constituent generation to the node-link network of the RiverManager model. Functional Units (FUs) are defined within each sub-catchment to represent areas of similar hydrological behaviour. Water balances for each FU are determined either from lumped catchment rainfall-runoff models or by summing one dimensional water balance models. In order to capture variation across a sub-catchment important for groundwater delays and constituent delivery, each sub-catchment is divided into multiple contour bands based on factors such as elevation or distance from stream. These bands (typically 3-5 in each sub-catchment) are used to lump the water balance outputs from multiple FUs which are situated partially or fully within them. Each band has its own groundwater store which is connected directly to the river by a response function which is related to hydrogeology (groundwater flow systems, topography, distance to stream) and can incorporate groundwater pumping. The water in the river is then routed downstream as part of the node-link network structure of River Manager. Fig. 3 illustrates the structure of the model.

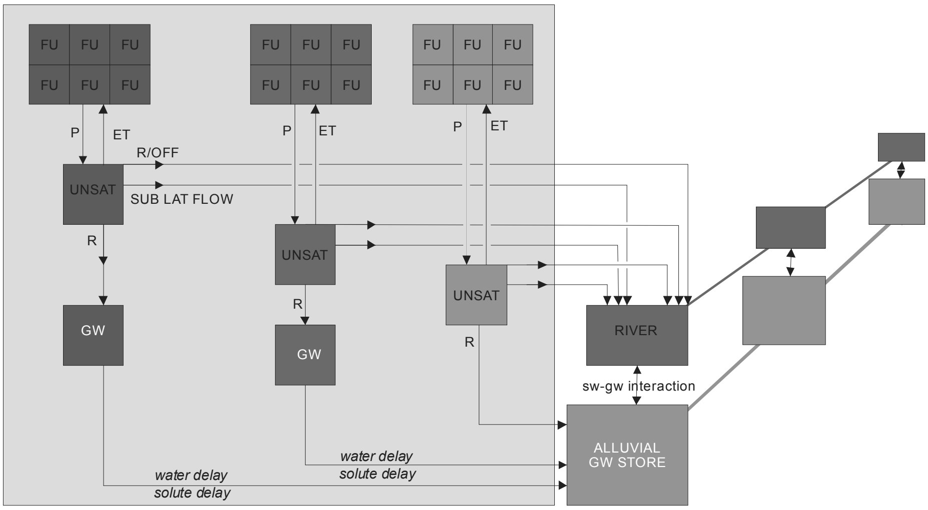

Fig. 3 WaterCAST structure, showing lumped water balance results for each band, contributing to the river and the alluvial groundwater store. It also shows the connection with downstream river links and downstream groundwater links.

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