NSW WATER RESOURCE PLANS PROJECT

Groundwater Model Factsheet

April 2018

Introduction

Water resource plans are key requirements of the Commonwealth *Basin Plan 2012*. They will set out arrangements to share water for consumptive use, and will establish rules to meet environmental and water quality objectives. They will also take into account potential and emerging risks to water resources.

Modelling of surface water and groundwater sources can inform the development of some water resource plans. This factsheet addresses how groundwater models can inform groundwater water resource plans.

Q1: What groundwater models are being used for Water Resource Planning?

A groundwater model is an aquifer response estimator, suitable for predicting potential change to groundwater levels in response to changes in hydrological conditions. The Department of Industry – Water (DoI Water) has developed models for the major inland alluvial aquifers and selected coastal aquifers. The models used by DoI Water use different versions of MODFLOW, a hydrological modelling program developed by the United States Geological Survey (USGS). Models developed for the major inland alluvial groundwater sources, located within the Murray Darling Basin, will be enhanced and scenario-modelled to inform and advise the development of water resource plans.

These models enable reasonable estimations of spatial and temporal predictions based on sources of water (rain, floods, irrigation, rivers, through-flows) and sinks (pumping, rivers, through flows, evaporation, evapotranspiration) in groundwater systems. Put simply, responses to changes in these sources and sinks are modelled as changes in groundwater levels in space and time, supporting planning for the sustainable use of a groundwater resource.

Q2: What is the history of Groundwater Modelling at DoI Water?

In the mid-1980s DoI Water and its predecessors began using numerical models to simulate changes in groundwater levels in various groundwater resources. In the early 1990s MODFLOW became commonly used due to its modular structure. The USGS provides extensive technical support for MODFLOW and the program is now widely used by the global groundwater modelling community. There have been four major releases of MODFLOW since its initial release in 1984: MODFLOW-88, MODFLOW-96, MODFLOW-2000, and MODFLOW-2005. (Further details are available at http://water.usgs.gov/nrp/gwsoftware/modflow.html.)

DoI Water (and predecessors) has used MODFLOW based aquifer models for all NSW major inland alluviums and some coastal aquifers since 2000. These models are annually updated using newly available data. Models are redeveloped periodically as computer technology advances along with the increasing availability of extended and reliable groundwater extraction, rainfall and groundwater level data. All models created by DoI Water are internally reviewed and some are externally reviewed.

DoI Water aims to redevelop models for some major alluviums using a new version of MODFLOW known as MODFLOW-USG which uses Unstructured Grids. MODFLOW-USG uses a control volume finite-difference formulation providing greater flexibility to accommodate aquifer complexity. This also allows for more efficient cell accounting and traceability.

Q3: What are the key steps in developing a groundwater model?

Groundwater models used by DoI Water follow the Australian Groundwater Modelling Guidelines (Barnett *et al*. 2012). Key steps in developing a groundwater model are:

- Planning: Define objectives, assess data availability, determine the confidence level of the model, determine calibration process and formulate scenarios.
- Conceptualisation: A conceptual model summarises available data and knowledge in a schematic diagram, identifying potential sources of water to recharge the aquifer (rain, floods, irrigation, river, through-flows), sinks (pumping, rivers, through flows), and lithology and boundary conditions. Active aquifer layers are defined by lithology. All inland alluviums in NSW contain at least two aquifer layers (e.g. as in the Lower Gwydir) while most have three aquifer layers (e.g. in the Lower Murrumbidgee and Lower Murray). A few (e.g. Lower Macquarie) are conceptualised to have four aquifer layers.
- Design and construction: Involves the selection of numerical code for the simulator and determination of model dimensions. The inputs of known spatial and temporally varying data are decided at this step. MODFLOW permits simultaneous response of all active aquifer layers to spatially varying stresses at all time steps. Most models use square finite difference cells with dimensions varying from 0.5 km to 2.5 km. Time steps of these models vary from one to three months. Recently developed models use monthly time steps.
- Calibration: Is an iterative process by which model parameters are changed until a satisfactory match between simulated and observed groundwater levels is attained. Calibration has three stages.
    - Stage 1: Estimates made from literature are used as inputs
    - Stage 2: Inverse modelling using *Parameter ESTimation and uncertainty analysis* (PEST) (Doherty *et al*. 2005)
    - Stage 3: Final calibration to ensure values estimated by PEST are within the range of values reported in the literature.
- Sensitivity Analysis: A sensitivity analysis is conducted to identify parameters or processes that significantly influence model behaviour. Special attention is made to minimise the range of values for these parameters. DoI Water determines the sensitivity of all model parameters listed in Table 1**.** Sensitive parameters vary among models**.** In recent models, spatially varying parameters tend to be less sensitive due mostly to the knowledge and improved understanding of the resources accumulated since the 1970s. However, parameters or processes which vary spatially and temporally tend to be more sensitive due to errors associated with measurement, estimation (e.g. evaporation is estimated from climate data) and interpolation (e.g. point measurement of rainfall is interpolated across model domains).
- Prediction: At this step, DoI Water determines the response of a groundwater system in space and time for anticipated changes to sources or sinks using the simulator calibrated.
- Reporting and Archiving: DoI Water produces two types of groundwater model reports. The first is a comprehensive report with a chapter on each key step in developing a groundwater model. This report serves as a reference and for peer review. The second type of report is referred to as a Scenario Assessment Report and is made for every scenario assessed using the model.

Table 1. Key Parameters for groundwater models.

Parameter Type	Parameters	Parameter Source
Spatially varying	• hydraulic conductivity • storativity or specific yield • leakance • conductance of river beds	• Pumping tests, • Lab tests • Scientific literature
Spatially and temporally varying	• recharge and discharge (as a function of rainfall) • potential evaporation • irrigation • floods • groundwater pumping • river stages	• Australian Water Availability Project • Scientific Information for Land Owners, Department of Science, Innovation, Technology and Innovation (Government of Queensland) • DoI Water databases (Hydstra, Groundwater Data System, Water Accounting System)

Q4: How does DoI Water assess calibration of a groundwater model?

DoI Water undertakes qualitative and quantitative assessments of calibrated models. Qualitative assessment is made by visual analysis of observed and simulated groundwater models to ensure that simulated groundwater levels follow major trends in observed groundwater levels, especially during pumping seasons and periods of extreme climate (floods and drought). Quantitative assessment is by:

- Regressing observed groundwater levels against simulated groundwater levels, and forcing the regression line through the origin. The ideal slope of the regression line will be 1. Most DoI Water groundwater models have a slope greater than 0.90; and
- Estimating Scaled Root Mean Squares (SRMS). The Australian Groundwater Modelling Guidelines (Barnett *et al*. 2012) consider that an SRMS less than 5% is an indicator of a well-calibrated model. All groundwater models developed by DoI Water have an SRMS less than 5%.

Q5: What are the limitations of a groundwater model?

Models are only approximations of natural systems and when groundwater models are used for predictive purposes, the results produced are only as good as the data and assumptions that underpin the models. In the future, reliability of predictions from DoI Water groundwater models can be improved when they are calibrated for longer periods so as to include several extreme climate events, but obviously, data must first be collected for this to occur. Model outputs require careful examination for them to be used in decision making. For example, models are checked as being 'fit-for-purpose' prior to being used to develop water sharing plans.

Q6: What are the scenarios assessed to support Groundwater Resource Planning?

Water sharing plans include a long term average extraction limit for each groundwater source. This is the limit to which groundwater extraction will be managed.

Currently, DoI Water is running two scenarios to provide information on potential changes in groundwater levels and groundwater flow patterns in the long term (i.e. 50 and 100 years), and after the first 10 years of the Basin Plan. The two scenarios will use climatic data from 1915 to 2015, and are:

- Scenario 1: Considers groundwater levels and flow changes in years 2065 and 2115 from pumping at the long-term average annual extraction limit with the modelled pumping distributed across existing production bores nominated to access licences. This scenario is referred to as the LTAAEL Scenario; and
- Scenario 2: Provides a prediction of groundwater levels in 2028/2029 from pumping among current active production bores, and reflecting the average pumping patterns at these bores over the last 10 years. Pumping in this scenario is also capped at the long-term average annual extraction limit as past pumping exceedances would not be allowed under future plan rules. This scenario is referred to as the History of Extraction Scenario.

The aim of Scenario 1 is to provide a long term outlook of potential changes to groundwater levels and flow. This can inform assessments of risk to environmental assets, groundwater quality changes and also significant groundwater pressure reductions that could lead to sediment compaction. Given the long time frames and likely changes to pumping distribution over this time frame these long term predictions provide information on potential issues on the overall sustainability of these pumping levels rather than identify potential management actions.

The aim of Scenario 2 is to provide groundwater levels and flow patterns in the short term that reflect current pumping. The use of current pumping patterns incorporates the current trading patterns and knowledge of existing irrigation with groundwater. These scenarios can inform potential management actions that may be required over the next 10 years.

Q7: How does the DoI Water use groundwater models to support Water Resource Planning?

A key output from a calibrated model is the quantification of annual pumping from a groundwater source to enable the maintenance of volumes of water stored in aquifers. No change in the volume stored implies that the determined level of pumping is sustainable into the future.

For each of the two scenarios described above, DoI Water also uses groundwater models to assess the potential impact on:

- the productive base of the aquifer
- the hydraulic behaviour of the aquifer and development of ‘hot-spots’
- groundwater dependent ecosystems
- base flow to rivers, and
- groundwater quality.

Q8: What are the model outputs?

Model outputs for each scenario in each aquifer will include changes in:

- groundwater levels over space and time
- groundwater pumping
- regional groundwater flow directions
- vertical fluxes between two aquifers, and
- exchange between groundwater and river water.

Examples of model outputs for the Lower Gwydir alluvium are given in Figures 1 and 2. Figure 1 shows the areas where groundwater levels may rise or fall in the deeper aquifer system. A value >1 shows where groundwater levels rise, and a value <1 shows where groundwater levels fall if the extraction limit is pumped for 50 years. Figure 2 shows that the regional groundwater flow directions will not change considerably in the deeper aquifer system if the extraction limit is pumped for 100 years.

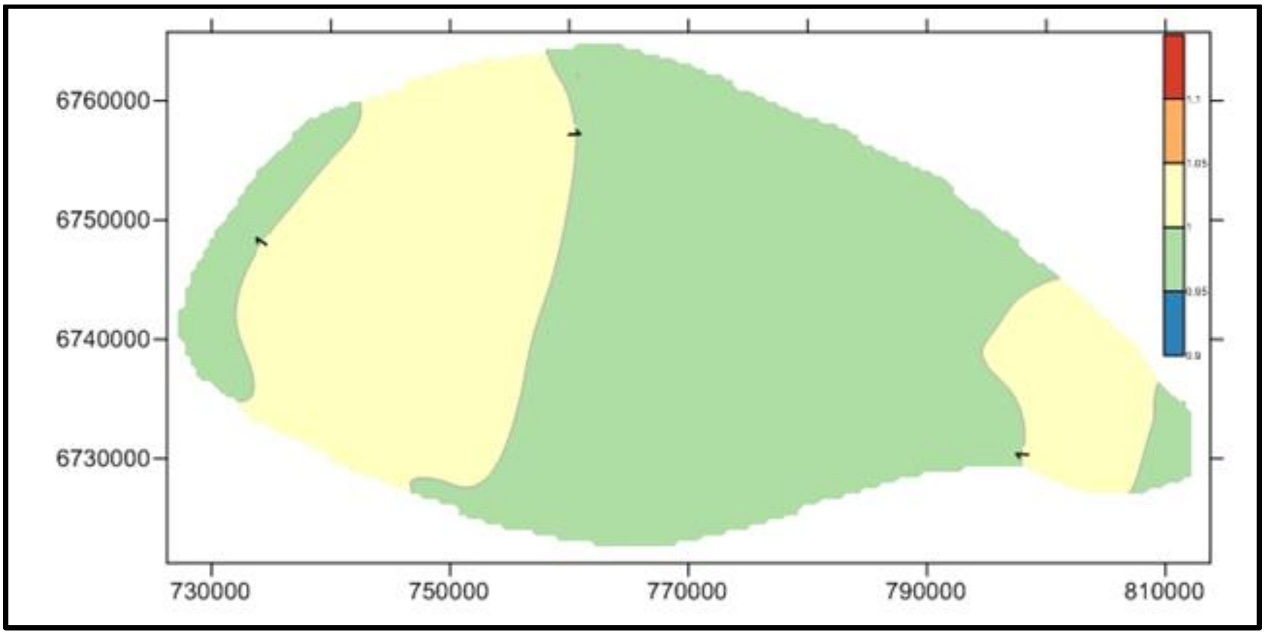

Figure 1. Groundwater level changes predicted for the deep aquifer system in the Lower Gwydir alluvium.

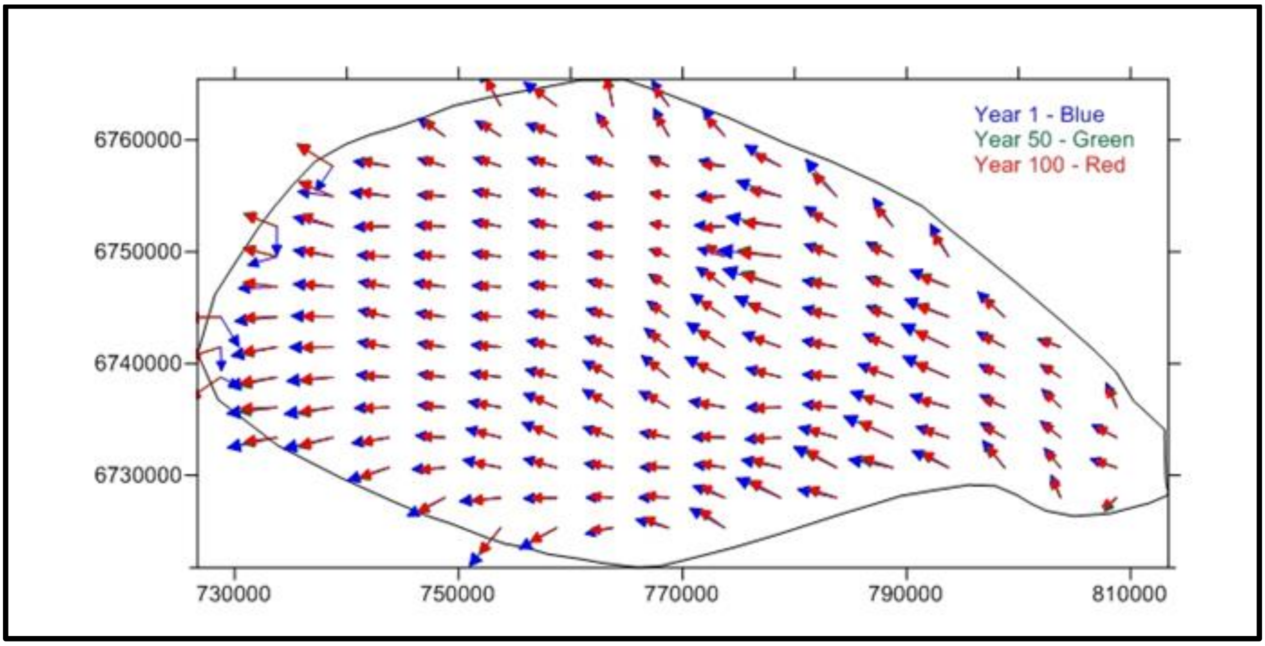

Figure 2. Predicted changes to regional groundwater flow directions in the deep aquifer system in the Lower Gwydir alluvium due to pumping the extraction limit over 50 and 100 years.

Q9: What are other applications of groundwater models to manage groundwater resources in NSW?

Other applications of groundwater models by DoI Water include:

- Annual update of water accounts within the State
- Support of the Murray-Darling Basin's Basin Salinity Management Advisory Panel
- Assessment of the impact of new irrigation developments on Murray River salinity, and
- Assessment of operational requirements of Salt Interception Schemes at Mallee Cliffs, Buronga, Billabong Creek and Glen Villa.

Groundwater models provide important data to inform water resource planning and groundwater resource management across NSW. Numerous other sources of information, such as monitoring and ecological data, are considered with this modelling to inform and achieve balanced planning and management outcomes for the state's groundwater resources.

Figure 3 Groundwater pumping from the Lower Lachlan alluvium

References:

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More information

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