3D DOWN-UNDER — WHAT ARE THE AUSTRALIANS UP TO IN 3D HYDROGEOLOGY

Bruce Gill, Don Cherry, Xiang Cheng, Jon Fawcett, and Mark Reid

Future Farming Systems Research, Department of Primary Industries, Victoria, Australia, Bruce.gill@dpi.vic.gov.au

INTRODUCTION

Water shortage is common in much of Australia. With the vast majority of the continent classed as semi arid (an overall average of 455mm rainfall per year) and the tropical north having monsoonal rains and long dry seasons, groundwater provides an essential buffer for many parts of the country. In recent years though, rainfall has been significantly below average, especially across the south east of the continent, which has affected vast areas of Australia's most important agricultural production region. The Murray Darling Basin, (which occupies 1/7th of the continent) supported average annual consumptive water use of 11,000 GL (to 1997), but last year, had fallen to less than half. This year, heading in to spring, the 22,600 GL of upstream basin storage is sitting at only 23% of capacity.

The increasingly precarious surface water supply situation is placing groundwater resources under greater stress. It is in this environment that 3D hydrogeology developments are gaining attention as a means of improving both the quantification and the management of groundwater resources. While the authors of this extended abstract are working on a three- year study to develop and test the capability of the new hydrogeology tools in three study areas in Victoria, several other groups and organisations in other parts of Australia are carrying out closely related work (Figure 4).

Being aware of the progress being made in 3D hydrogeology in both North America and Europe through this workshop and the 2nd British Geological Survey hosted 2nd International GSI3d conference of September 2008, (Mathers, 2008), it was timely to meet together with scientists undertaking similar work in Australia. To that end, a two-day workshop was held at the Geoscience Australia head office in Canberra on the 31st August and the 1st of September. Over 50 participants watched 23 presentations of a wide range of approaches and case studies from around the country. Demonstrations of 3D visualisations in both the purpose-built visualisation suite and using portable equipment were also included. A compilation of workshop extended abstracts (Gill, 2009) is available from www.ga.gov.au/3DHydro/workshop09/.

VICTORIAN 3D HYDROGEOLOGY PROJECT

The Victorian Geological Survey (now Geoscience Victoria) has been developing a fully attributed 1:250,000 scale 3D model of the whole crust of Victoria, incorporating the onshore and offshore geology since about 2004. Primarily focussed on developing improved understanding of the mineral and hydrocarbon resources of the state, the 3D framework being developed goes deeper than required for groundwater supply needs. Nonetheless, the upper most mapped units in many parts of the state are hydrogeological units and the basement rock generally constrains the base of the groundwater systems of interest. This 3D geology work helped catalyse 3D hydrogeology in Victoria.

Early in the life of the study, a literature review was carried out and completed in January 2009. This identified the growing body of knowledge accumulating overseas and was very helpful in highlighting a range of key learnings as to the potential benefits of 3D hydrogeology, such as:

- the value for building conceptual hydrogeology frameworks upon which more reliable numerical models can be constructed,
- making much better use of all the available data,
- building data sets that conform with national and international standards
- how they can be used to improve comprehension of hydrogeology
- the need to define the uncertainty of the 3D mapping renditions and not over-extend the technology

Another conclusion drawn was that there seemed to be limited documentation of the usage of 3D hydrogeology methods for groundwater resource quantification or examples where applications of visualisations for improving stakeholder comprehension of the resource had been trialled.

Three study areas were selected for 3D hydrogeology mapping on the basis of (i) having significant groundwater resources that are intensively used, (ii) having uncertainties regarding aquifer extent and stream connectivity, (iii) having reasonable data availability, and (iv) requiring management plans to be developed. These areas are called the Southern Campaspe Plains, the Upper Loddon and the Moorabool catchment (Figure 1). The Moorabool area has geology and groundwater systems that are feeding significant quantities of salt to surface water supplies downstream, hence an additional objective is to investigate whether the 3D mapping can help identify the source of the high salt loads.

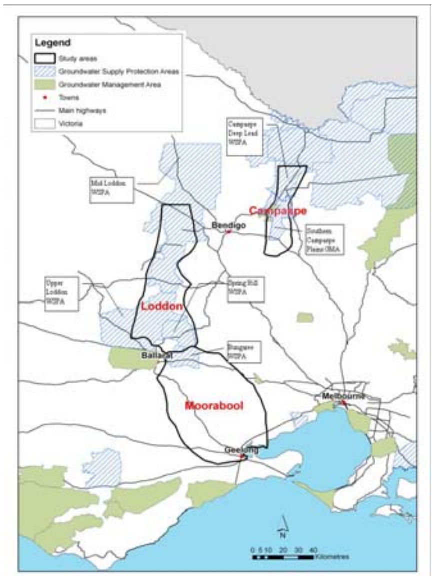

Figure 1. Location plan of the three study areas being used to explore the potential of 3D hydrogeology in Victoria.

The three study areas chosen have varying degrees of data density, data types and data quality. Bore log data, surface geology, and any other relevant information were gathered, including geophysical datasets, groundwater geochemistry, imagery, and previous modeling. This data was transformed into a common projection and stored in a GIS database and dominant hydrogeological surfaces developed from the data.

A key finding early on in assembling the geological data is the value in using the 3D visualisation power available to ensure the data and surfaces built from them are reasonable interpretations. Anomalies in the data such as missing or incorrect coordinates for logs, poor logging data or geological interpretations were worked through to derive 3D models of the study areas. Applying simple visual checks to make sure that a feature ‘looks right’ or fits a known and accepted geological interpretation improved confidence in the models.

3D modeling and visualisations also have been used to corroborate findings from other studies. Figure 2 highlights part of the Upper Loddon study areas, where cross cutting faults (Holdgate et al, 2006) are thought to be responsible for displacements down the valley that controlled the depositional thickness of sands and gravels of the main regional aquifer system that is overlain by Quaternary basalts. Until this time, earlier interpretations had mapped considerably more extensive and continuous alluvial deposits in the area.

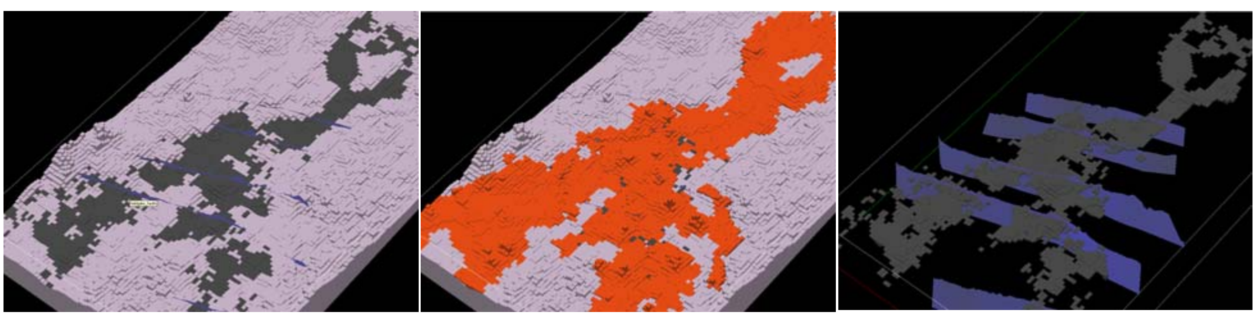

Figure 2. Voxel models showing deep lead aquifer distribution on bedrock (left) Basalt valley-infill (middle) and deep lead with interpreted faults (right) of the Upper Loddon study area.

NUMERICAL MODELING REVIEW

Another investigation undertaken as part of the study has been a review of all the past numerical groundwater models within or surrounding the three study areas. The first major numerical groundwater model covering the Campaspe and Loddon study areas was undertaken in 1990 as part of a coarse scale assessment of the Victorian Riverine Plain groundwater system. Since then, numerous other groundwater modeling studies have been carried out, each seeking to improve understanding of the groundwater systems for a range of reasons, including salinity, land management or water resource issues.

A key finding from the review was that all the models were different in respect to scales, boundaries, modeling approaches, software choices, and in model inputs and outputs. While the results may be considered useful with regard to improving general understanding of the specific systems being studied at the time, they left little of value in terms of legacy data sets or directly comparable results. Each modeling study tended to start from first principles in respect to developing the conceptual models of the groundwater flow systems. Surface geology mapping and available groundwater drilling data were the main inputs for model grid construction, and little, if any, iterative development occurred during successive modeling studies. A key conclusion then is that the building of a state owned 3D geological / hydrogeological data set will greatly improve subsequent numerical groundwater model studies by removing a major source of inefficiency and uncertainty at the conceptual model development stage.

A fundamental requirement of any attempt to define the possible ‘safe’ or ‘sustainable’ annual yield from any defined aquifer or area is to start with as good a geological framework and hydrogeological conceptual model as possible. Not only can logical boundaries and areas be better defined to start with, but whenever any calculations are performed using any of the possible numerical modeling methods, the best geological and hydrogeological framework available will reduce the likelihood of missing important factors and enable the basis for the determination to be clearly understood. The review has highlighted the benefits that completion of a 3D hydrogeological framework would provide as the basis for any future modeling work. Transparency of model conceptual design, repeatability, iterative improvement, and a basis for the projection of model outputs will all be facilitated by the development of 3D hydrogeology mapping.

IMPROVING HYDROGEOLOGICAL CONCEPTUALISATION AND NUMERICAL GROUNDWATER MODEL DESIGN

A recently completed comparison of model grids developed using earlier methods compared to those developed using 3D hydrogeology methods was undertaken in the Upper Loddon study area. The Upper Loddon system is characterised by incised fractured rock valleys in-filled with Tertiary alluvial sands and gravels, overlain by up to 150 metres of Quaternary basalts and scoria. The sands and gravels are considered an important water resource, especially in channelling water further to the north, and earlier interpretations had surmised that the sands and gravels were more extensive than 3D based methods are now showing.

The left hand map in Figure 3 shows the basement rock outcrop (blue) and shades of red indicating thickness of the sands and gravels. This mapping was developed in 2005 (Fawcett et al, 2006), and has subsequently been refined using Gocad and additional data sets. This data includes interpreted faults (Holdgate et al, 2006) and groundwater chemistry data (Hagerty, 2007). The green to pink toned map (top right) is the thickness of the sand and gravel aquifer layer used for a regional scale groundwater model, whereas the map below it shows the same image with the 3D derived sand and gravel isopachs (grey shading) over the top. The contrast in size of the aquifer can clearly be seen and the groundwater resource estimates from models based on these maps would be vastly different.

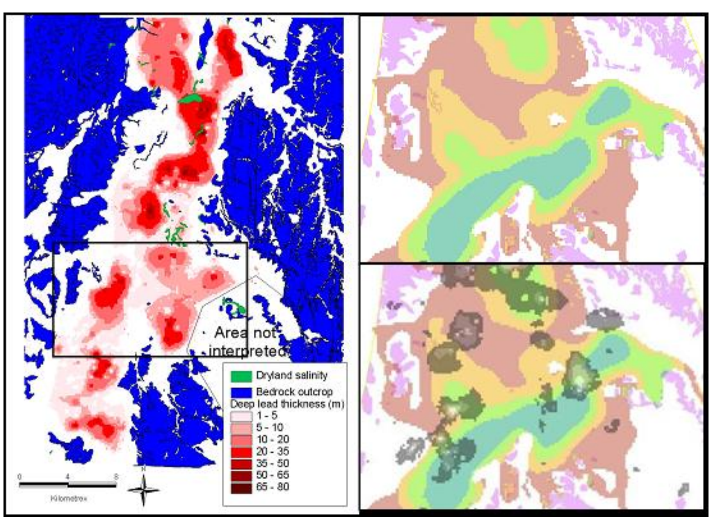

Figure 3. Isopach maps of the sand and gravel alluvial aquifer in the Upper Loddon. The left hand map was derived using 3D modeling methods, while the regional scale model isopach map (top right) was generated from drill logs only. The bottom right maps shows the 3D isopachs (grey) overlain on the regional scale model map.

As an adjunct to the main study, a PhD study is researching the hypothesis “That 3D hydrogeology mapping, resource assessment methods and visualisations can lead to improved groundwater resource management outcomes". Findings from relevant literature highlight that the more successful implementations of groundwater management plans have occurred where there is good cooperation between users and the responsible authority. A key factor in establishing this cooperation is a shared understanding of the resource. Traditional analogue renditions of the subsurface are clearly limited for a lay audience, so using 3D mapping and visualisation technology, the study will investigate how various visualisations may be more or less effective in building understanding of the resource in two of the study areas.

INTERSTATE AND NATIONAL PROJECTS

From a national perspective, 3D hydrogeology is being used to investigate a number of areas of groundwater stress in urban, semi-urban, and agricultural regions. Figure 4 shows the locations of some of these projects and more details and contacts for these and other projects are contained in Gill (2009).

In the Perth Basin of Western Australia, annual rainfall has dropped dramatically in the last 20-30 yrs. Groundwater investigations by the Department of Water (DoW WA) are focussed on gaining a greater understanding of the large groundwater resource of the Perth Basin in order to manage increased demand from the deep aquifers in this basin.

In New South Wales, the University of NSW (UNSW) is investigating the long term impact of surface irrigation, recharge, hydrologic connectivity, and the temporal interactions of ground and surface waters of the Namoi River catchment. Elsewhere in NSW, studies have been using airborne electromagnetic surveys to map subsurface salinity, aquitards and freshwater plumes.

The Queensland University of Technology (QUT) is developing software to model, visualise, and manage groundwater data, as well as exploring the role of groundwater system visualisations as a management tool. Their principal areas of investigation are the heavily utilised groundwater systems in the Condamine River catchment near Toowoomba, west of Brisbane. A semi urban area near Darwin (Howard East) has also been a test area for the Groundwater Visualisation System (GVS) software package they are developing.

Also in Victoria, the state and regional water authority are exploring the use of ArcHydro and are in the process of defining statewide standardised hydrogeological units. The national geoscience research organisation, Geoscience Australia, has a national role and has been involved in several studies, including 3D mapping of the Great Artesian Basin and Murray Darling Basin and development of national hydrogeological mapping protocols.

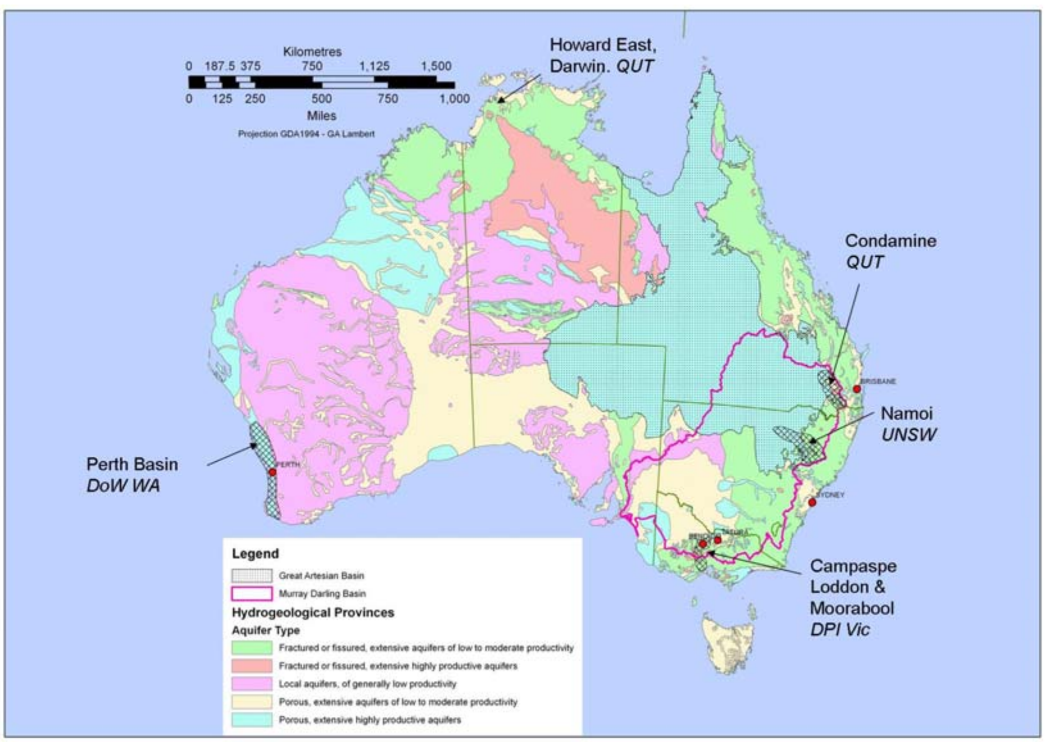

Figure 4. Hydrogeological provinces of Australia with the locations of some current 3D hydrogeology projects indicated.

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