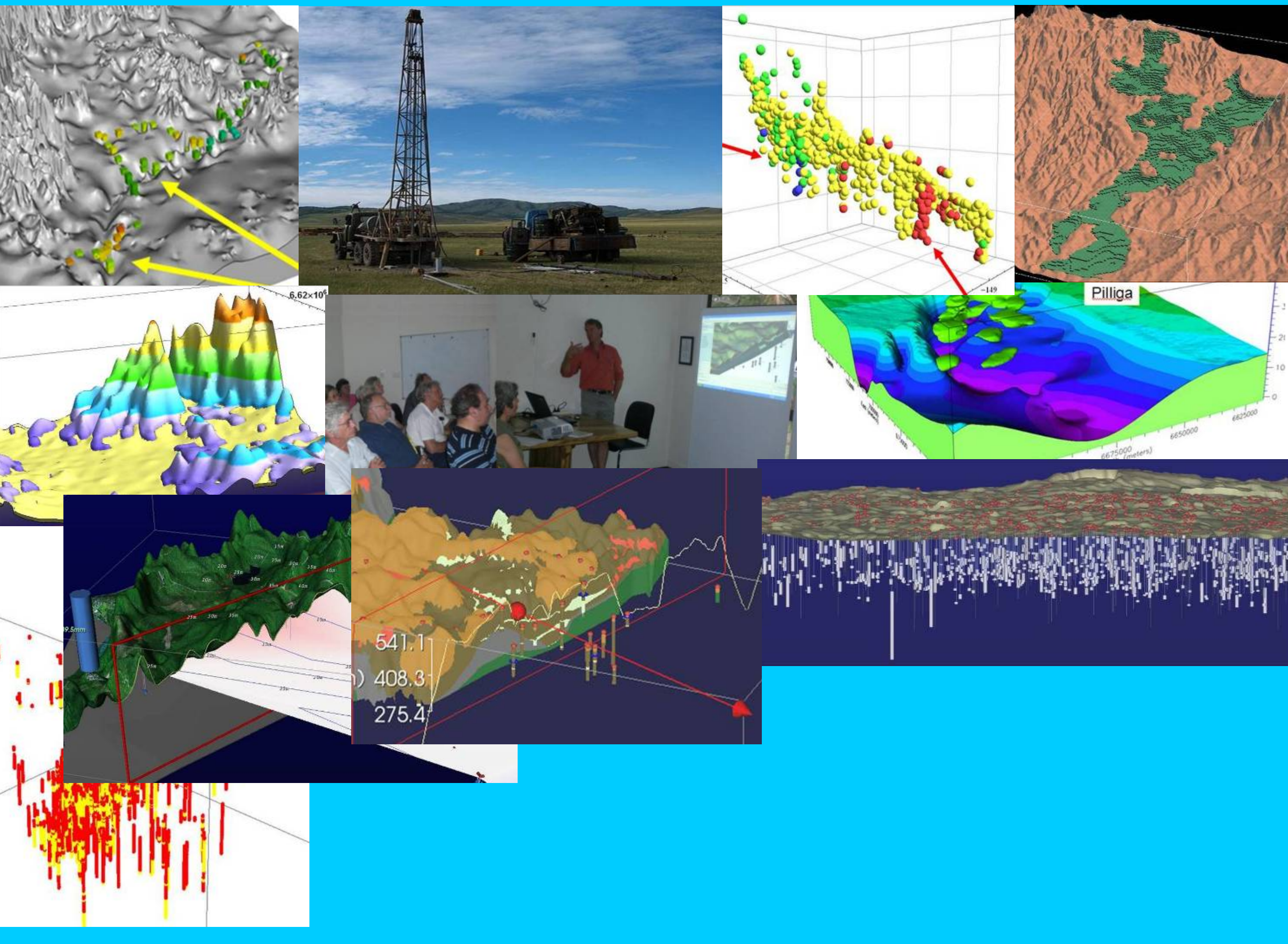


First Australian 3D Hydrogeology Workshop

Extended Abstracts

August 31 & September 1, 2009

Geoscience Australia, Canberra

Australian Government
National Water Commission

Victoria The Place To Be
Department of Primary Industries

Victoria The Place To Be
Victorian Water Trust

GEOSCIENCE AUSTRALIA

Forward

As part of a literature review on the development of 3D hydrogeology undertaken in late 2008, it became apparent to me that there were quite a number of people around the country who had not only been watching with interest the developments that have been going on overseas, but were already actively exploring these new technologies and methods for improving our understanding of groundwater systems.

This workshop was convened to bring these people from national and state geological surveys, universities, state and regional water agencies and consulting companies together to share their experiences with this relatively new area of hydrogeological science. It would seem that the capability offered by 3D Hydrogeology methods is the next leap forward in the science that has the potential to revolutionise how we deal with groundwater and give the community understanding of the nature of the resource.

With many parts of Australia facing serious surface water shortages, groundwater is also coming under increased pressure to sustain primary production and community water supplies. The high court challenge currently taking place in Canberra highlights the seriousness of the issue. The National Water Initiative recognises the role of groundwater in Australia's water planning future, and sees a major impediment to the sustainable management of groundwater is that Australia's groundwater resources are not well understood. How will 3D Hydrogeology developments change this?

In compiling this volume of extended abstracts for the workshop, I can certainly sense that this new area of the science will greatly improve our knowledge and understanding of groundwater and put us in a better position to manage our groundwater resources into the future.

Thanks to all who have contributed talks for the program and written extended abstracts for the workshop record. Thanks also to Geoscience Australia for hosting the workshop and to all our employer organisations and funding bodies for supporting our work.

For the 'workshop' component of these two days, please share and learn as much as possible, but also contribute to the discussion sessions, especially on the second day, where it would be valuable to document some thoughts about how we go forward in the 2 crucial areas of data standards and the development of a uniform national groundwater resource information system.

Bruce Gill

Workshop convenor.

Senior Research Hydrogeologist, Department of Primary Industries, Victoria. bruce.gill@dpi.vic.gov.au

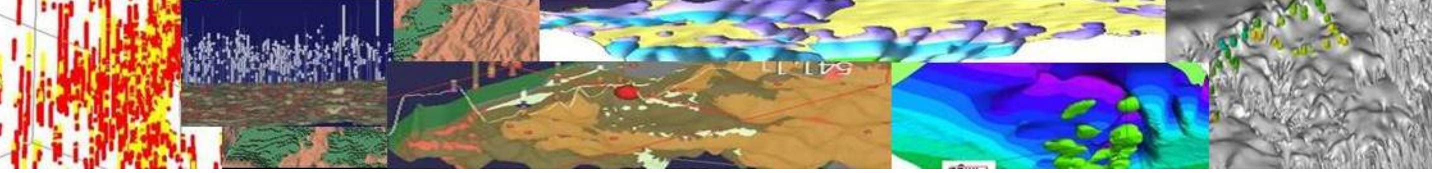


Table of Contents

Page

3D Victoria - The development of 3D Geology in Victoria

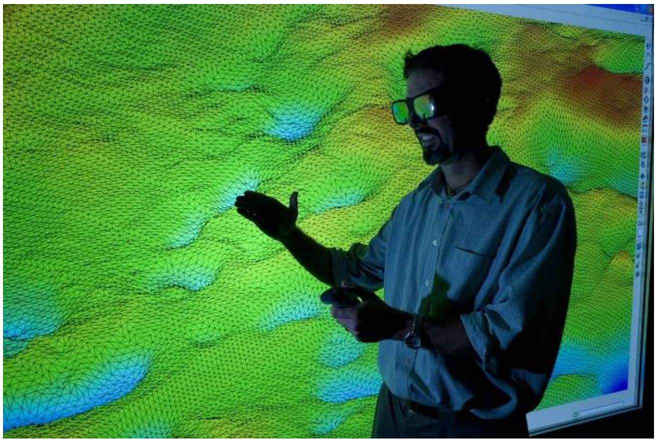
Tim Rawling
GeoScience Victoria (DPI)

Background

Geology is a three dimensional science. For decades exploration geologists in the coal, oil and gas industries, and more recently in the minerals industry, have been using sophisticated 3D modeling software to allow them to collate, visualise and analyse their datasets in three dimensions. Often however, this effort has been focussed at the reservoir/field or deposit/camp scale and few regional, full-crustal 3D geological models have been developed. Several years ago the Victorian Government committed to providing to industry, the next generation of tools to explore Victoria. After consulting exploration geologists, researchers and government geologists it was recognised that 3D geological models would provide a critical tool to explorers interested in understanding, not just the distribution and history of mineral deposits, but the entire mineral system that was responsible for their development. To that end, GeoScience Victoria established the $2.5M 3D Victoria project which was designed to develop a sophisticated, fully attributed 1:250 000 scale 3D model of the whole crust incorporating the onshore and offshore geology of the state.

Objectives

- provide a robust geometric framework for analyzing controls on the formation and accumulation of resource systems
- provide critical 3D data for existing minerals and energy exploration programs as well as next-generation exploration targets, including potential geothermal sources and geosequestration sites
- highlight the controls exerted by basement structures on basin evolution
- allow integrated studies of complex systems such as the pressure regime within a basin undergoing simultaneous irrigation from onshore freshwater aquifers, drawdown of offshore oil and gas reservoirs and injection of captured CO_2
- make available valuable 3D constraints for future "value-add" projects such as numerical deformation, fluid flow, maturity and heat-flow simulations, as well as 3D GIS analysis and prospectivity assessment.



Approach

Geoscience Victoria's 3D modelling team have developed a model building workflow that is applicable to both onshore and offshore model building as well as integration modelling between basement and basin blocks, based on the flowing steps:

Integrate all available surface mapping, drilling constraints, potential field datasets, 3D inversion models, seismic data, and other 2D and 3D datasets into a 3D storage and visualisation environment define an agreed stratigraphy for the model region construct serial cross sections based on surface geology and geophysical constraints perpendicular to major structural trend with some tie sections parallel to trend if there is sufficient structure to constrain the geometry in this direction.

Serial sections were then digitised into a 2¾D potential field forward modeling package. Application of common rock property attributes (density and magnetic susceptibility) to the units in the sections and forward modeling of the interpreted geometries then allows a first order assessment of the validity of the starting geometry.

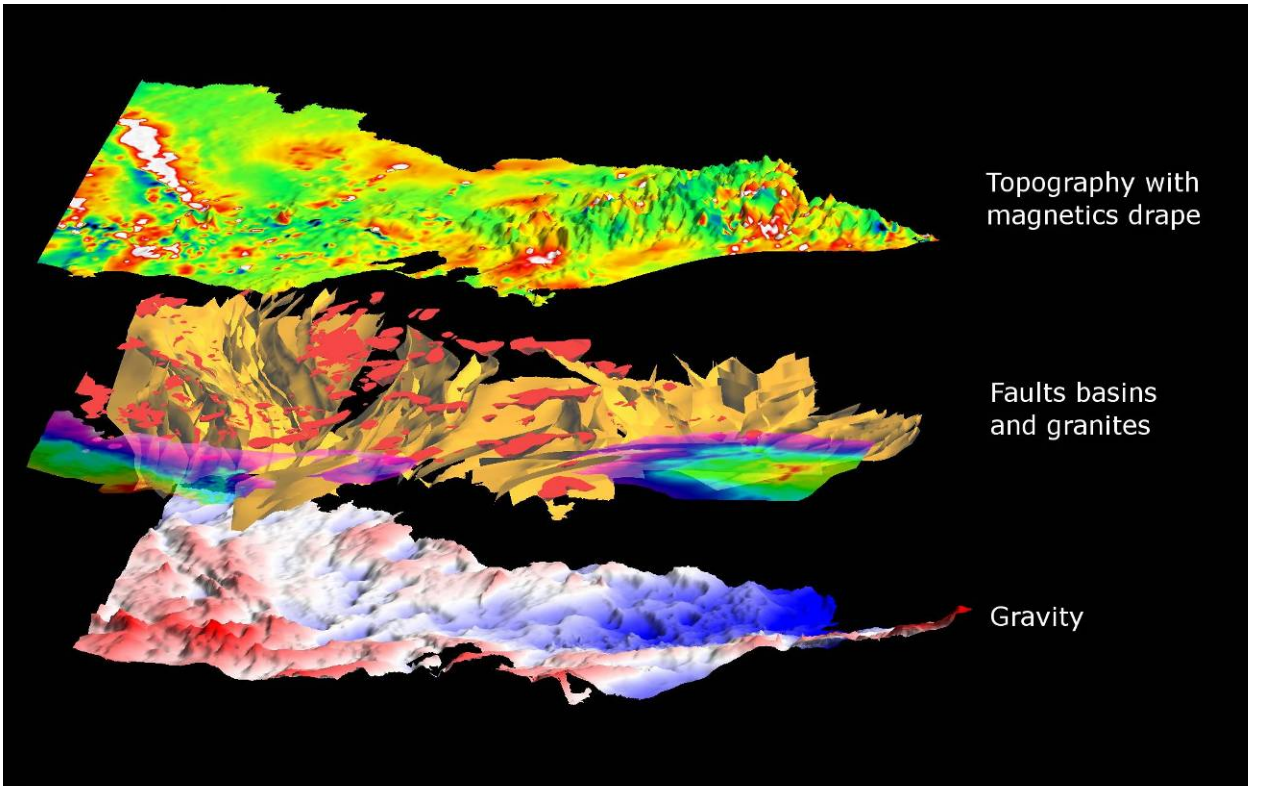
Modeling was undertaken using the GeoModeller program where a potential field is derived that is constrained by all available structural measurements, stratigraphic information, mapping, cross sections and drilling and the 3D model is then calculated from that mathematical description.

Visualisation of the modeling was primarily done using Gocad where the model, constraining serial sections and any other appropriate datasets and surfaces could be visualised and analysed.

Model storage and distribution

Model outputs are stored in GeoScience Victoria's 3D Model Management System (3DMMS) which is a geospatially aware database developed for the GSV by Runge Ltd. This system allows models to be stored with associated metadata and searched or queried accordingly. Importantly, the 3DMMS also provides a visualisation and delivery mechanism where an explorationist can visit our office, upload their own 3D data into a secure and confidential part of the database and then visualise their data with whichever of our model objects they choose (in stereo in our 3D visualisation room if they wish).

It does not matter what format the company data is in (Vulcan, Surpac, Minesight, etc) or what projection or coordinate system they use (AMG, MGA, local) as all of these conversions are handled on the fly by the 3DMMS and the user is able to look at any of the stored (open file) data, select useful objects and then download them in whatever format and projection they choose (again the conversion from our native Gocad format is handled on the fly).



Contact: Dr Tim Rawling, 3D Modelling Manager, GeoScience Victoria. Tim.rawling@dpi.vic.gov.au

Agreeing what to map – naming "aquifer units" for Victoria

Chris McAuley
Department of Sustainability and Environment, Victoria

Background

To manage groundwater resources effectively and efficiently, there is a need to define what it is that is being managed. The capacity to make good management decisions is enhanced by having a "spatially complete" framework – a 3D framework. But what are the building blocks for that framework?

Within Victoria, Southern Rural Water (SRW) successfully developed and implemented a 3D mapping project for the aquifers in their region. From a state-wide perspective, there is an advantage in having a consistent framework that covers the entire State. The Department of Sustainability and Environment (DSE) commissioned consultants SKM to develop the "aquifer framework" for Victoria.

Objectives

- To have a consistent naming convention for aquifers in Victoria for all management related works
- To get agreement between hydrogeologists on what a reasonable naming convention would be
- To build upon the work already completed

Approach

SRW had developed an effective approach to agreeing what to map as part of their southern Victoria mapping exercise. The basis of this approach was employed to develop the naming convention for the highland areas and the Murray Basin.

An initial framework was developed by SKM to provide a starting point. In agreement with DSE, a contact list for hydrogeologists both within Victoria and in neighbouring States was developed. Key considerations for the members on the list were their in-depth and detailed knowledge of Victorian hydrogeology. The hydrogeologists on the list were invited to attend a half day workshop to develop the framework.

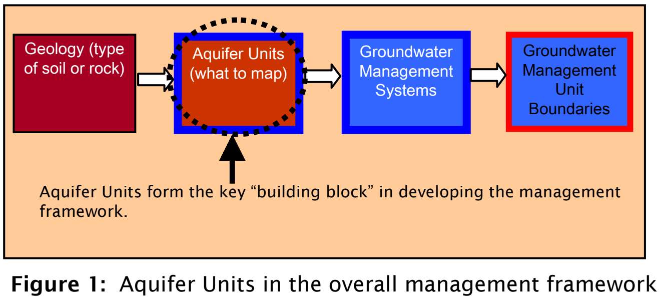


Figure 1: Aquifer Units in the overall management framework

Results and findings

The workshop brought together a range of opinions. Facilitation of the workshop allowed robust input from the workshop members. The majority of the decisions were agreed within the meeting. Some required further discussion and consideration outside the meeting. Further discussion with adjoining state representatives were required to ensure that the approach worked across State borders.

In comparison with the work done in the southern part of Victoria, modifications were needed to make it work across the State. Overall the outcomes were consistent, although refinement of some aquifers and the addition of others did require changes.

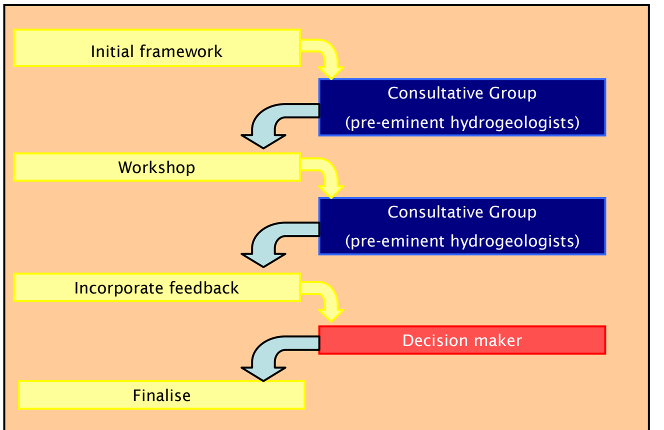


Figure 1: Development approach summary

Implications and Benefits

A consistent naming framework for aquifers enables consistency between projects within Victoria. It provides a consistent framework for any 3D mapping that may be undertaken. In addition, it provides the building blocks for defining groundwater management systems and groundwater management unit boundaries.
The challenge is that as you "scale up" the system to encompass more areas, there is a likely need to expand the aquifer definitions. This may provide a challenge for a National program.

Acknowledgements: The input from SKM as project managers, Southern Rural Water who initially developed this framework and to all the participants in the workshop is gratefully acknowledged.

Contact: Chris.McAuley@dse.vic.gov.au

Implications of 20 years of conceptual and numerical modelling on 3D hydrogeology developments

Xiang Cheng, Bruce Gill and Mark Reid
Future Farming Systems Research Division, Department of Primary Industries, Victoria

Background

A key reason for the exploration of the potential offered by the emerging 3D hydrogeological mapping and visualisation technologies is to see how they might improve groundwater resource management outcomes.

The DPI Victoria study has chosen three important groundwater resource management areas (Figure 1) to explore this potential. One of the realities of groundwater management is that numerical models have been available since the late 1980's, and in many parts of Victoria, they have been used as a way of gaining insights into groundwater processes and quantities for over 20 years. In the three study areas, various studies have used numerical groundwater models to investigate catchment management, salinity control and groundwater resource issues.

This paper describes the findings from a review of this past work and considers the implications for developments in 3D Hydrogeology.

Objectives

- To build an understanding of the existing resource estimation methods (permissible annual volumes)
- To document key findings from past GW modelling work
- To explore the potential for using 3D technologies to evaluate and improve future the GW models
- To inform development of products from the 3D visualisation and mapping process

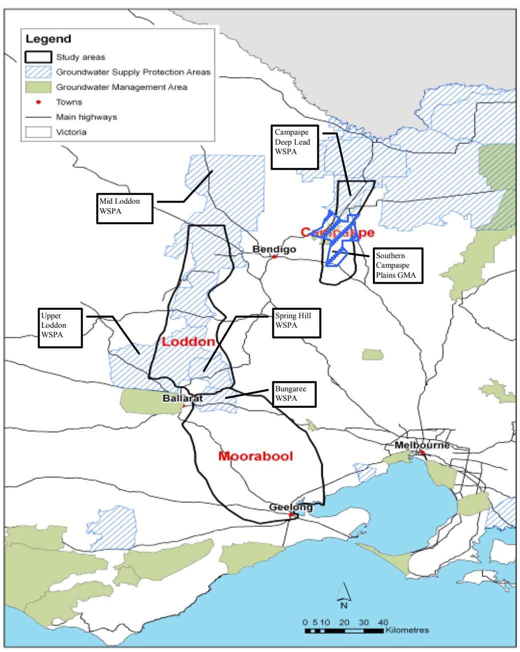


Figure 1: Study area locations

Approach

The review identified all past modelling work that had taken place in the vicinity of the three study areas. This identified the following :

- In the Campaspe area, at least 12 GW modelling studies have been conducted over 20 yrs, e.g. The Riverine Plain GW model (Nolan 1991; GHD 1992); The Campaspe GW model (Chiew 1991), and The MDB Sustainable Yields Project 'Southern Riverine Plains GW Model' (Goode & Barnett 2008).
- In the Loddon Valley, five GW modelling studies were reviewed, including the 3 regional models that cover both the Campaspe and Loddon area, as well as the Mid-Loddon WSPA Groundwater Model (URS 2003; 2006), and GW occurrence and Process in the Mid-Loddon WSPA (Macumber 2007).
- In the Moorabool catchment, at least 10 modelling studies have been carried out, including: several student projects. The DSE Corangamite 'ecoMarkets' project (Hocking 2007), GW assessment of the Bungaree WSPA (URS 2002), Geology and GFSs in Moorabool (Evans 2006), and The Victorian Volcanic Plains study (Cox et al 2007) have been reviewed.

A review of the methods initially used to define the 'sustainable groundwater yield', or Permissible Annual Volume (PAV) was also included in the review.

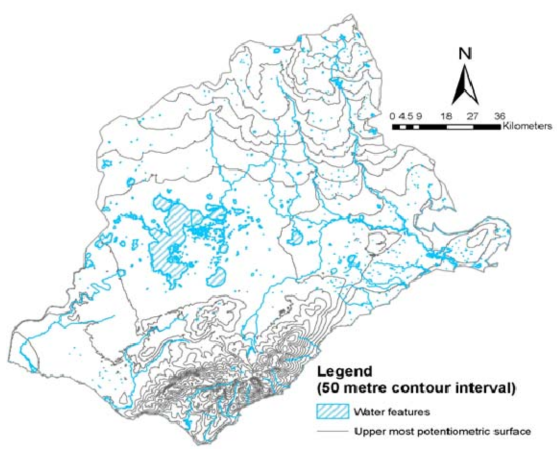


Figure 2: Simulated watertable contours from a model in the Corangamite CMA region (Hocking 2007)

Results and findings

The various models and studies were carried out primarily for groundwater resource and salinity investigation needs at the time. However, they were all different in respect to scales, boundaries, modelling approaches and software choices and in model inputs and outputs.

Implications of 20 years of conceptual and numerical modelling on 3D hydrogeology developments

Results and findings (cont'd)

It was also found that the many models collected, processed and generated a large amount of data (e.g. Figure 2, 3 and 4), but that it would now be a major task to capture 'iteratively significant' components of this work for use in developing the 3D hydrogeology datasets.

Each model was generally developed from 'scratch' and were built from only limited data available at the time, such as published geological maps and groundwater monitoring bore data and construction records.

They relied heavily on traditional methods for model development and outputs were also all communicated in traditional analogue form.

It is very difficult to make comparisons between any of the models, due to their different origins, purposes and boundaries. The post model data management has also been poor, especially for earlier modelling, with digital data unlikely to be found or viewed now.

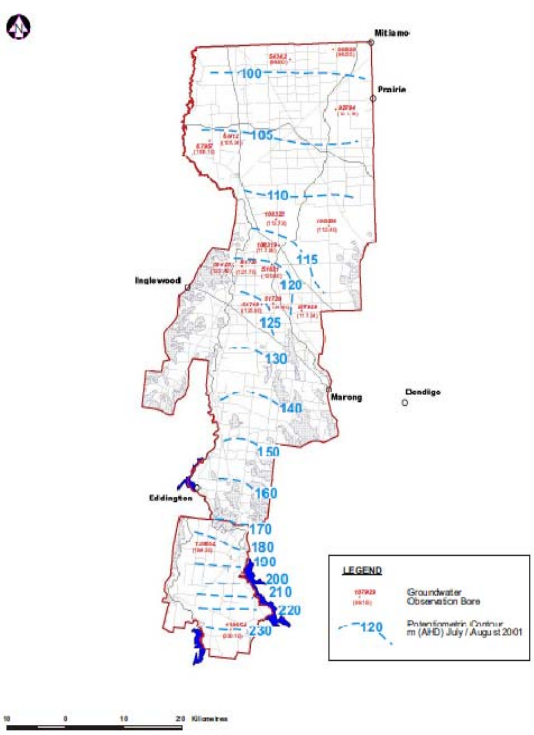


Figure 3: Inferred potentiometric level of Shepparton Formation Aquifer July/August 2001 (mAHD) from (URS 2006).

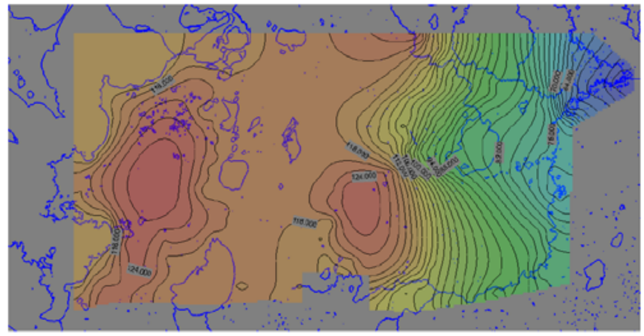


Figure 4: Watertable contours for the Victorian Volcanic Plains steady-state groundwater model (Cox et al 2007)

Implications and Benefits

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 modelling 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 modelling 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.

References

Cox J, Dahlhaus P, Herczeg A, Crosbie R, Davies P and Dighton J (2007) Defining Groundwater Flow Systems on the volcanic plains to accurately assess the risks of salinity and impacts of changed landuse. Final report to the Corangamite Catchment Management Authority. CSIRO Land and Water Science Report xx/xx (DRAFT)

Hocking M (2007) Corangamite CMA: Mean annual catchment water balance. A draft report prepared by Hocking et al P/L for Department of Sustainability and Environment.

Chiew FHS and McMahon TA (1991) Groundwater Recharge from Rainfall and Irrigation in the Campaspe River Basin. Aust. J. Soil Res., 29, 651-70.

Goode AM and Barnett BG (2008) Southern Riverine Plains Groundwater Model Calibration Report. A report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Australia. 138pp

Macumber PG (2007) Groundwater occurrence and Process in the Mid-Loddon WSPA. A report prepared by Phillip Macumber Consulting Services for Goulburn-Murray Water

GHD (1992) The Riverine Plain Groundwater Model Stage II Report: Further Calibration

Nolan J (1990) The Riverine Plain Groundwater Model Stage I Report, Investigations Branch Unpublished Report No. 1990/42, Rural Water Commission, Victoria

URS (2003) Mid-Loddon Groundwater Conceptual Model (Stage 1 Report), Unpublished, G-MW Ref 969664

URS (2006) Mid Loddon WSPA Groundwater Model. Stage 2 – Conceptual Model Refinement. A report prepared by URS Australia Pty Ltd for Goulburn-Murray Water.

Xiang Cheng: email xiang.cheng@dpi.vic.gov.au

Visualisation of data layers, the key to increasing integrity of geological based groundwater models

Don Cherry, Jon Fawcett and Bruce Gill
Future Farming Systems Research Division, Department of Primary Industries, Victoria

Background

Groundwater exists within the pore spaces and fractures of sediments and rocks that make up the landscape. Sustainable management of groundwater is helped greatly by knowing the location and size of the favourable geology (aquifers), their landscape setting and connection with recharge areas.

Traditional hydrogeological investigation and mapping has relied on geological interpretation and groundwater bore data producing paper maps, cross sections and numerical models.

Over the past few decades, the oil and minerals industries have been developing computer based 3D data management and visualisation systems (akin to GIS) to manage and interpret their geological data (Berg et al 2007).

This paper discusses the early findings of a Victorian project exploring the potential of these 3D technologies.

Objectives

The underlying need for this work is to improve groundwater resource management outcomes by

- investigating the potential tools available
- delineating 3D geology-based groundwater flow systems
- generating visualisation products to improve understanding

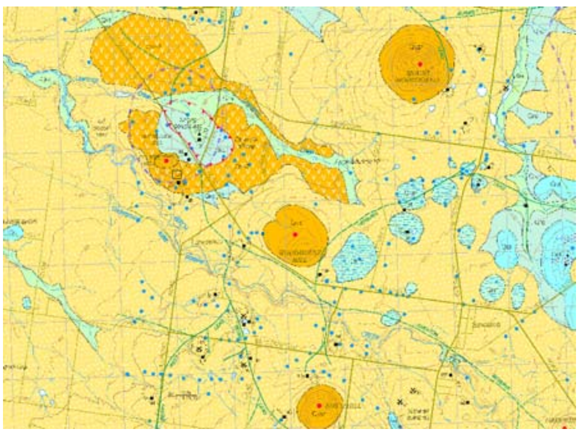


Figure 1: Traditional geological map

Approach

Three study areas across central Victoria were chosen with varying degrees of data type and quality. The Loddon, Campaspe and Moorabool catchments provide vital water resources from both the surface and subsurface sources. Bore log data, surface geology and any other relevant information was gathered, including geophysical datasets, groundwater geochemistry, imagery and previous modelling.

Data were transformed to a common projection, then managed and stored in an ArcGIS database (Fig 2). Preliminary modelling of data layers produced a number of raster surfaces indicative of dominant or important geological units. These were exported to Gocad (a CAD software package) for further manipulation and visualisation.

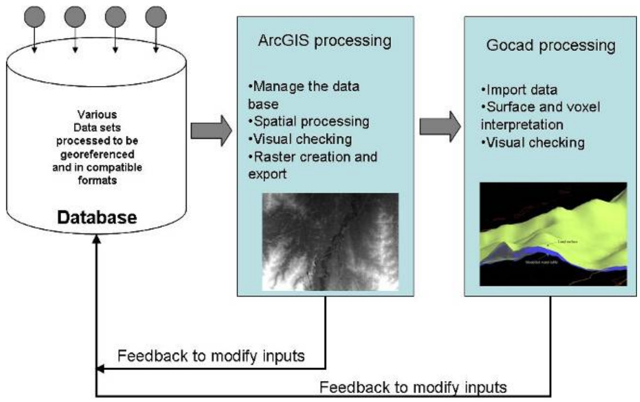


Figure 2: Conceptual workflow

Results and findings

Data density is not even, due to the types of investigations and needs of the past drilling programs. The density of bores across the study area highlights the concentration of bores along roadsides and clusters in areas of particular need with bores being tens to a few hundred metres apart in some places while in other areas there may not be a single bore for several hundred metres to kilometres. Anomalies are also noted in the quality of data including missing coordinates or logs, incorrect coordinates and poor interpretation resulting in spurious results in any modelling (eg Figure 3).

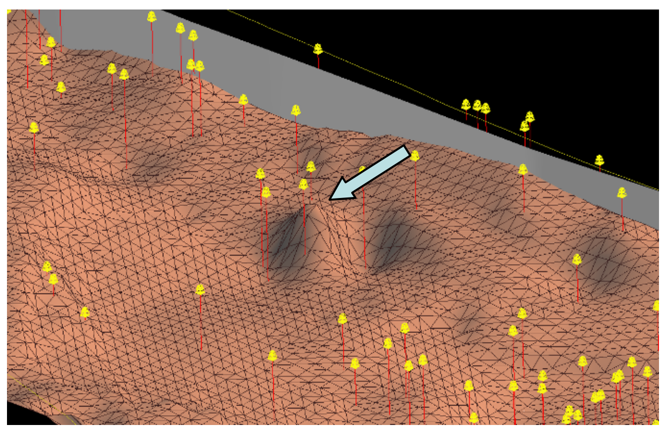


Figure 3: Poor bore logging resulting in spurious bedrock high (arrow)

Visualisation of data layers, the key to increasing integrity of geological based groundwater models

Results and findings (cont'd)

Modelling and visualisation also corroborated findings from a separate study (Holdgate et al 2006), which had proposed cross faults displacing subsurface aquifers. The 'deep lead' aquifer indicating the unit thickness (Fig 4) shows how the proposed faults may have influence the deposition of the aquifer along the valley floor.

Subsequent modelling into voxels (volume pixels) indicates the deep lead aquifer distribution and basalt flow landscape in the sequence of Figure 5.

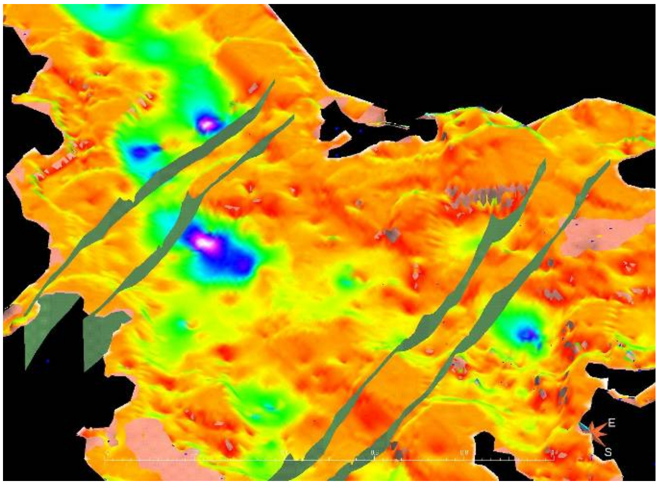


Figure 4: Deep lead thickness with interpreted faults impacting aquifer distribution.

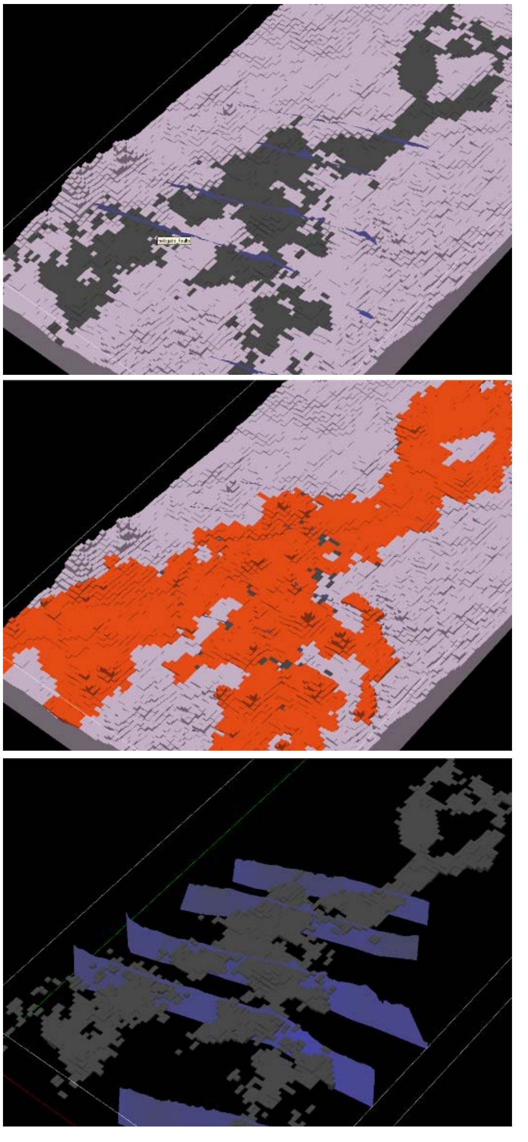


Figure 5: Voxel models showing deep lead aquifer distribution on bedrock (top) Basalt valley-infill (middle) and deep lead with interpreted faults (bottom).

Conclusions

Employing visual checking techniques to modelled surfaces and features is a worth while procedure in all processing of digital data. Such qualitative and quantitative analysis utilises the power of the human eye to evaluate the integrity of the data, modelling and subsequent interpretations. Multiple inputs bring the risk of errors and misinterpretations, where acceptance of a model could lead to further problems such as environmental damage, investment loss or loss of confidence in scientific investigation. Applying simple visual checks to make sure that a feature 'looks right' or fits a known and accepted geological interpretation is an easy task and something most investigators would be confident in.

References

Berg, R.C., H.A.J. Russell and L.H. Thorleifson, (2007), Introduction –Three dimensional geologic mapping for groundwater applications. Geological models for groundwater flow modelling.

http://www.isgs.uiuc.edu/reserach/3Dworkshop/2001/workshop.shtml

Holdgate, G.R., M.W. Wallace, S.J. Gallagher, R.B.Witten, B.Stats and B.E.Wagstaff, (2006), Cenozoic fault control on 'deep lead' palaeoriver system, Central Highlands, Victoria. Australian Journal of Earth Sciences.

Don Cherry, ph 03 54304343

Don.Cherry@dpi.vic.gov.au

Role of 3D visual conceptualisation of groundwater system models as a management support tool

Malcolm Cox[1] , Joseph Young[2], Allan James[2] , Amy Hawke[2] and Andrew Todd [1 3]

[1] School of Natural Resource Sciences [2]High Performance Computing [3]Institute for Sustainable Resources, QUT

Background

After the recent prolonged drought conditions in many parts of Australia it is increasingly recognised that many groundwater systems are under stress. Although this is obvious for systems that are utilised for intensive irrigation many other groundwater systems are also impacted.

Management strategies are highly variable to non-existent. Policy and regulation are also often inadequate, and are reactive or politically driven. In addition, there is a wide range of opinion by water users and other stakeholders as to what is "reasonable" management practice. These differences are often related to the "value" that is put on the groundwater resource. Opinions vary from "our right to free water" to an awareness that without effective management the resource will be degraded. There is also often misunderstanding of surface water-groundwater linkages, recharge processes, and baseflow to drainage systems.

Management requirements

These differing views often stem from rural myths or a lack of understanding of how a groundwater system functions. As a result users commonly cannot consider their bore/s in the context of a system at a catchment scale. Local and state agencies in most cases act responsibly, are highly aware of water resource issues and have adopted some level of management.

However, in many areas groundwater users resist monitoring as it is considered that the next step will be either regulation or charging.

Most agencies have established some network of observation bores, but often water level measurements are irregular. Data on groundwater extraction is mostly very limited. Of note, many agencies have produced simulation models (FDM and FEM) for the important groundwater systems. These models are all useful, but often are limited by poor conceptual hydrogeological models. Further, these numerical models are unavailable to most stakeholders, and are usually not understood and often not trusted by them.

We have developed 3D visualisation models as management support tools for use by different agencies and stakeholder interest groups using our in-house software GVS (Groundwater Visualisation System). The type of model developed, and the software functions required vary slightly depending on groundwater system type and complexity, amount, quality and form of available data, and purpose of the model.

For example, models have been produced for landcare/catchment groups concerned about water quality, catchments with intensive irrigation extraction, unregulated use in expanding rural subdivisions, and to test recharge processes. Many of these visualisation models are produced for systems for which a numerical simulation model already exists.

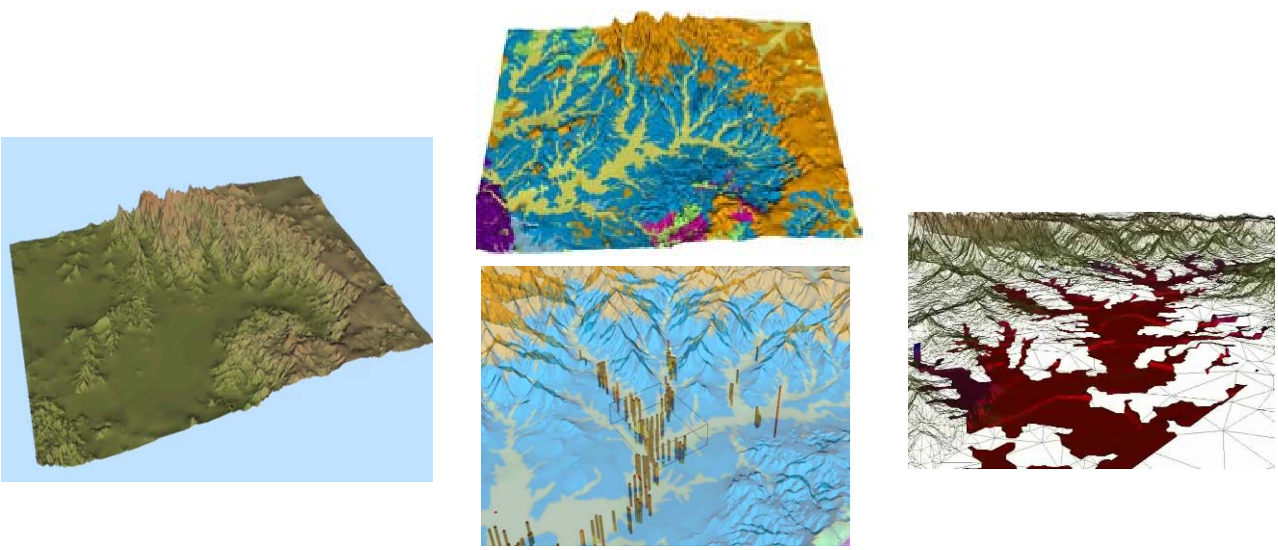


Figure 1: Example visualisation in 2.5D using DEM with draped geology and a 3D block with drillholes

Role of 3D visual conceptualisation of groundwater system models as a management support tool

Our experience shows that the response to 3D visualisation and animation is highly positive, and has enhanced cooperation between regulatory agencies and water users. An important feature is the ability to integration multiple data sets.

Objectives

Due to the many challenges with groundwater management our goal was to produce a software package that enables developing a better understanding of a groundwater system including its physical framework as well as hydrological processes. The main purpose of this is to support management which in most cases relies on user and stakeholder knowledge and understanding. An additional benefit is greatly improved conceptual models for developing simulation models.

We aimed at a visualisation model that did not require expensive licences and was relatively easy to learn to operate. Importantly, to provide a "take-home" output product. Our output product is a CD with install and software documentation that can be used on most desktop PC's. The software package is flexible enough to be applied to most groundwater systems and has the following features:

- display 2D and 2.5D images
- multiple layers of selected surface data
- 3D visualisation of a conceptual models
- display animation of lines, surfaces or other time series data
- display drillholes in space with downhole data
- enable variable viewing (zoom, rotation)
- enable interrogation such as cross-section slicing and dragging
- switching on and off of images, opacity variation
- linked database
- imbedded bore hydrographs and rainfall data

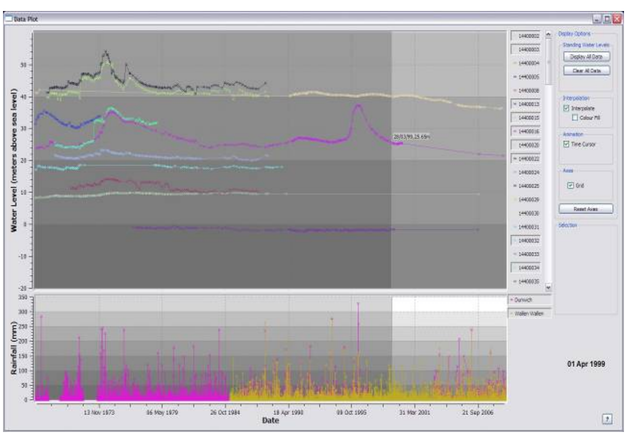


Figure 2. Bore hydrograph plots (top) and monthly rainfall (bottom). Individual bores can be selected and located

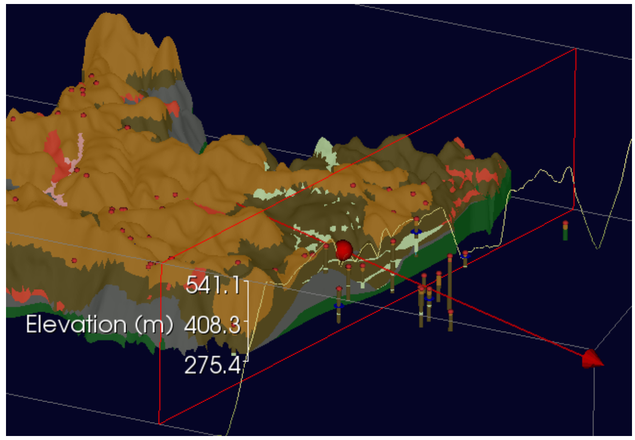
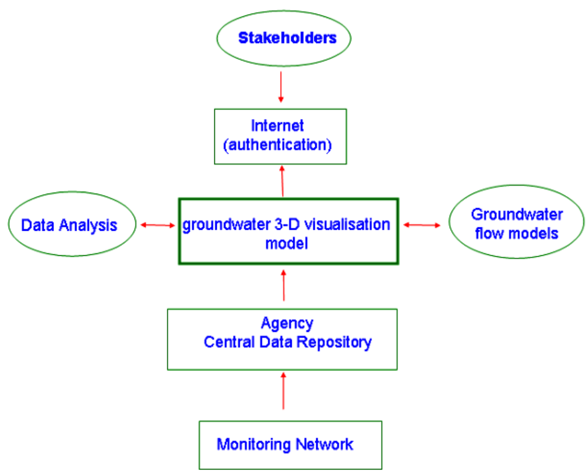


Figure 3. Example of GVS 3D visualisation with labelled bores, internal geology, and slicing image.

Features of the GVS system continue to be developed and further refined with each project. The GVS package also has the potential for future development that would enable externally generated models, such as groundwater flow simulations, to be imported into the system.

A major long term aim for the system is to develop remote capability, and we are working on a flexible access system. The flow chart below shows a possible schema for data collection, storage and model links, and the capability of access to both via internet, enabling remote Interrogation of the GVS model and conferencing.



Using open standards to deliver digital geoscience information for 3D modelling – the GeoSciML and OGC data standards

Ollie Raymond[1] and the GeoSciML Design task group [2]
[1] GeoScience Australia
[2] Commission for the Management and Application of Geoscience Information (CGI), IUGS

Background

Working with distributed digital spatial information is typically fraught with difficulties of data access and varying data formats. Governments and other data providers have data delivery systems built on different proprietary software formats and use different data structures. Using open source data transfer standards, compliant with Open Geospatial Consortium (OGC) schemas, scientific communities can share data using common protocols, data structures and vocabularies.

Objectives

- Use an agreed, OGC-compliant, standard data model to share hydrogeological data.

Figure 1: Drill hole locations, metadata, and downhole logs can be delivered using the agreed, open source data models.

Approach

An international consortium of geological surveys under the IUGS Commission for the Management and Application of Geoscience Information have developed GeoScience Markup Language (GeoSciML), to be an open source, extensible, geoscience data transfer standard. GeoSciML is OGC-standards compliant and, in concert with other OGC and ISO data standards like Observations & Measurements (O&M), can be used to deliver geoscientific mapping and sampling data.

Several geoscientific communities have already begun to extend the GeoSciML and O&M data models to suit their own needs, such as mineral occurrences (led by GeoScience Victoria), geochemical and geochronological analyses (led by GeoScience Australia), soils and terrain (eSOTER.org), and groundwater (led by the Geological Survey of Canada).

Data providers can deliver their data by mapping their local database sources to the agreed transfer model using freely available, open source software such as Mapserver or Geoserver. There is typically no need to change the structure of existing local databases.

Results and findings

The GeoSciML community have conducted three testbeds to test the useability of the GeoSciML data standard. in the most recent testbed, geological map, borehole and field site data was served from seven nations as Web Map Services (WMS) and Web Feature Services (WFS). These services were displayed and queried in a range of both open source or proprietary web clients. The WFS services were also consumed by, or imported into, a range of software applications including RDBMS (eg: Oracle), GIS (eg: ArcGIS) and 3D modelling (eg: GeoModeller) applications.

The most advanced use of GeoSciML in the groundwater domain is by the Canadian Groundwater Information Network (GIN). Using their extension of the GeoSciML data model, the GIN provides aquifer units and water bores from six disparate provincial databases through a single point of access and in a single agreed data standard using WMS/WFS services.

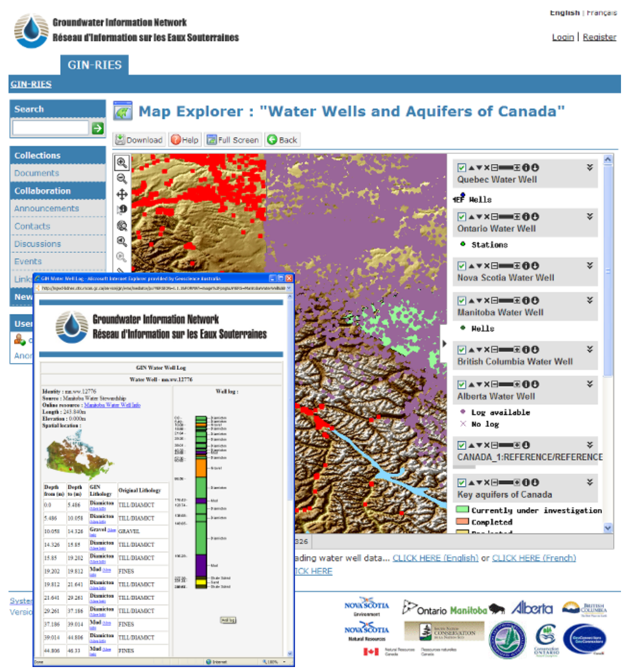


Figure 2: The Canadian Groundwater Information Network delivers water bore logs from six distributed provincial databases.

Implications and Benefits

The use of OGC-compliant standard data models to deliver data allows users to access data from a wide range of distributed sources in a single agreed format. Existing data models such as GeoSciML and O&M form the base on which the hydrogeology community can build their own agreed data standards.

AuScope and its role in the looming geoscience digital deluge

Bruce Simons[1], Robert Woodcock[2], Ryan Fraser[2]
GeoScience Victoria, GPO Box 4440, MELBOURNE, Victoria, 3001, Australia[1]
CSIRO Exploration and Mining, 26 Dick Perry Ave, Kensington, WA 6151, Australia [2]

Background

In 2006 the Australian Government announced a new funding initiative, the National Collaborative Research Infrastructure Strategy (NCRIS). NCRIS aims to provide Australian researchers with access to major research facilities, supporting infrastructure and networks necessary for world-class research. As a component of this strategy, $42.8 million was allocated to the Australian earth science research community to build an integrated national geoscience infrastructure system called AuScope.

Objectives

- To establish a world class research infrastructure to characterise the structure and evolution of the Australian continent in a global context from surface to core in space and time
- To understand the implications of this for natural resources, hazards and environment
- To contribute to future prosperity, safety and a sustainable environment for Australian society

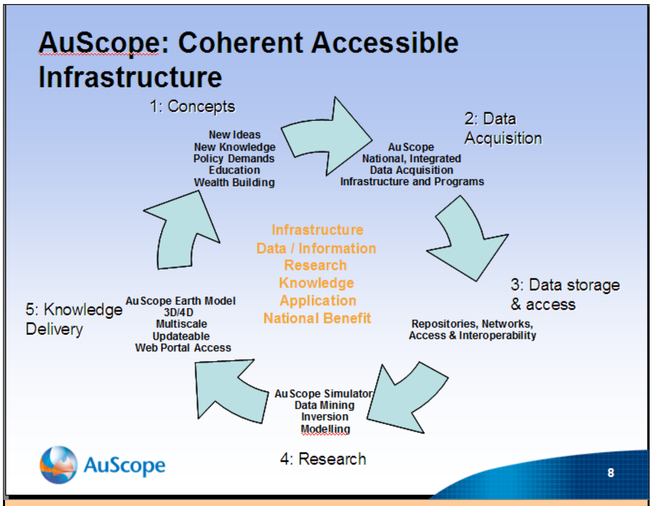


Figure 1: The AuScope Infrastructure System

Approach

The AuScope Project will provide for the establishment of the AuScope Infrastructure System - a geoscience and geospatial infrastructure system that combines traditional research infrastructure with applied science infrastructure. The AuScope Infrastructure System is a seamless, broadly accessible, fully integrated blend of technology, data and knowledge infrastructure designed to transform the practice and outcomes from geoscience for researchers, industry and the wider community.

The AuScope Infrastructure System is designed to enable the progressive construction, refinement and ongoing enrichment of an online four-dimensional earth model for the Australian continent and its immediate environs. What is unique about the model is its community construction, federation of contributions and data stores that are hosted by their custodians. AuScope is built from the five functional components enabled by AuScope Grid:

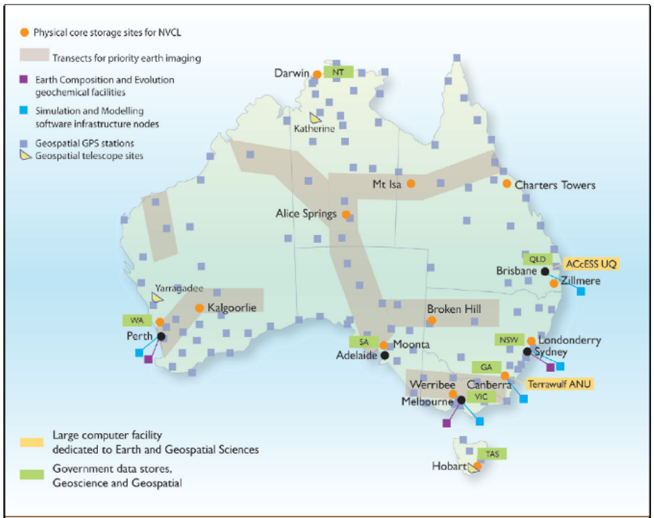


Figure 2: AuScope and its partners are creating a National Infrastructure Network for earth science research

- Earth Composition and Evolution – provide new geochemical instrumentation and improved access to existing instrumentation;
- National Virtual Core Library – provide hyperspectral and high resolution imagery of existing drill core samples;
- Earth Imaging and Structure – use state-of-the-art seismic and magnetotelluric equipment to image the Australian continent;
- Earth Simulation and Modelling – a toolkit of simulation, modelling, inversion and data mining software tools;
- Geospatial Framework and Earth Dynamics – establish and operate a comprehensive national geodetic infrastructure;
- AuScope Grid – to federate nationally distributed data sets and develop tools to manipulate large data volumes.

Implications and Benefits

AuScope is likely to be involved with the establishment of research infrastructure for the National Centre for Groundwater Research and Training through the Australian Continent NCRIS capability. This shows the high level recognition of the critical links between traditional earth and geospatial sciences and groundwater science /hydrogeology in the shallow crust.

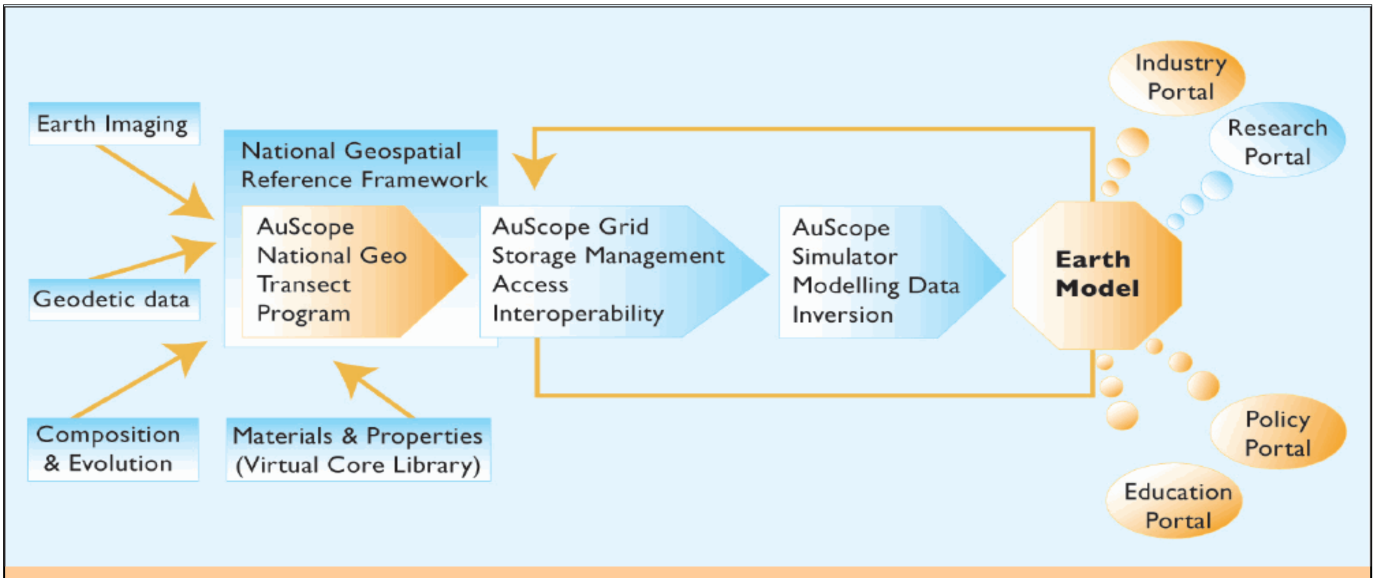


Figure 3: AuScope and the Earth Model for the Australian continent. The blue components are investments in infrastructure under the AuScope agreement, while orange components are activities outside but related to AuScope.

Groundwater Visualisation System (GVS):

A software framework for developing low-end, scalable and robust software for 3D visualisation and animation of groundwater conceptual models

Allan James[1] , Amy Hawke[1] , Malcolm Cox[2] , Joseph Young[1] , Andrew Todd[3]

[1] High Performance Computing and Research Support, QUT [3] Institute for Sustainable Resources, QUT

[2] School of Natural Resource Sciences, QUT

Background

Effective management of groundwater requires stakeholders to have a realistic conceptual understanding of the groundwater systems and hydrological processes. However, groundwater data can be complex, confusing and often difficult for people to comprehend.

A powerful way to communicate understanding of groundwater processes, complex subsurface geology and their relationships is through the use of visualisation techniques to create 3D conceptual groundwater models. In addition, the ability to animate, interrogate and interact with 3D models can encourage a higher level of understanding than static images alone. While there are increasing numbers of software tools available for developing and visualising groundwater conceptual models, these packages are often very expensive and are not readily accessible to majority people due to complexity.

The Groundwater Visualisation System (GVS) is a software framework that can be used to develop groundwater visualisation tools aimed specifically at non-technical computer users and those who are not groundwater domain experts. A primary aim of GVS is to provide management support for agencies, and enhance community understanding.

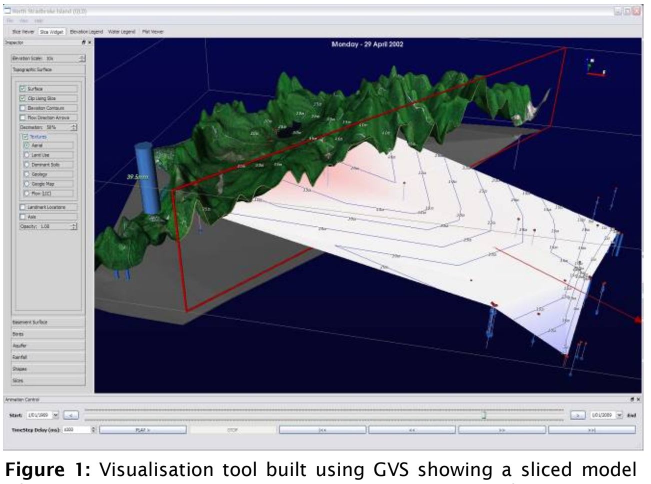


Figure 1: Visualisation tool built using GVS showing a sliced model of North Stradbroke Island (QLD) with a contoured surface depicting the water table

Objectives

A number of objectives were set for the development of the GVS software:

- To develop an extensible framework for building software that allows integration of data from different sources to produce interactive 3D visualisation of groundwater conceptual models
- Provide a simple yet robust data model and database for the organisation and storage of groundwater-related data and a c++ code library to access the data for display and interrogation
- Provide support for animation of associated time-series data
- Develop effective methods for displaying and interacting with the data within a 3D visualisation scene
- Enable stand-alone models to be packaged along with the software and documentation to form a deliverable product output that can be used by stakeholders and community

Approach

GVS has been developed using open source tools and libraries: MySQL for the database, Qt for user interfaces, database access and object communication, Qwt for plotting of graphs, and VTK for the visualisation graphics and scene interaction capabilities. The framework can be used to develop software that can access a range of data and produce interactive 3D visualisation and animation of conceptual groundwater models.

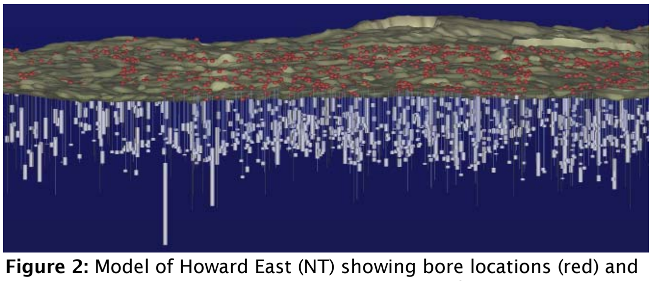


Figure 2: Model of Howard East (NT) showing bore locations (red) and screened sections (white) located beneath the surface

GVS uses the concept of "feature objects" (Figure 3) which in this case represent physical or real-world objects related to groundwater. Current feature objects represented in the system include bores, observation sites, aquifers and catchments. Attributes and datasets can be linked to feature objects to provide a relationship between data and the conceptual features being modelled. Attributes represent data variables stored within the database that can be associated with a single feature, including time-series data such as water levels and rainfall. For example, a bore linked to time-series attribute data representing standing water levels observed within the bore. Further development will include adding improved support for other attributes such as water quality, chemistry and hydraulic conductivity. Datasets allow for integration of additional data not suitable for ingestion into the database, such as shapefiles, geometry meshes and overlay images, and these can be prepared using existing software packages (such as ArcGIS, GMS and GoCad) and imported into the system. Simulation data (such as produced in MODFLOW) has not yet been supported and will be investigated in the next development phase of the system.

The system employs a modular structure to provide flexibility and scalability by allowing additional feature types, attributes and dataset types to be added to the system relatively easily.

Groundwater Visualisation System (GVS):

A software framework for developing low-end, scalable and robust software for 3D visualisation and animation of groundwater conceptual models

Results and findings

Visualisation tools based on GVS can integrate a variety of datasets, including pre-processed outputs from external models, and these tools are able to display 3D conceptual groundwater models built from the data accessible via the GVS database. The models can be rotated, zoomed and sliced to produce cross sections. Animation capabilities can be provided using a familiar VCR-like interface, allowing time-series data to be displayed within the spatial context of the scene. GVS has been used to successfully develop visualisation models of Obi Obi Catchment (QLD) and North Stradbroke Island (QLD – Figure 1), and we are currently involved in projects to develop models for Howard East (NT – Figure 2), Mount Tamborine (QLD), Upper Condamine catchment (QLD) and Bribie Island (QLD).

Observational data has been used to construct the models, however the results are highly dependent on the data available. Generally data quantity and quality is a real issue that requires much expert interpretation. Therefore, a fundamental is that trained hydrogeological skill is essential for developing the initial interpretations of the internal aquifer framework. For example, one major challenge involves classifying the lithological descriptions in the geological bore logs, and interpolating the data to produce 'solid' subsurface geometry.

The development of the various projects have so far provided valuable insight into what features are more useful than others, and what additional features would benefit the software. The information gained from these projects has been invaluable to further develop and improve the system.

Implications and Benefits

Our approach couples interactive visualisation and animation to enhance actual scientific interpretation and understanding of conceptual groundwater models. A groundwater visualisation tool developed using the GVS framework has much potential to disperse community and stakeholder understanding and knowledge of groundwater systems. This provides enhanced management support for the sustainable use of groundwater resources.

We have found that a number of useful hydrological processes can be reflected such as the response of groundwater levels to rainfall, trends of water levels over time, and intersections of the water table with topography. Surfaces can be produced to represent water levels, however, this depends on the density of data (in time and space). Colouring techniques and contours shown across these surfaces can highlight temporal variations in the water levels. With adequate data, it is also possible to indicate the direction of groundwater flow using a number of graphical methods such as contouring and flow texturing.

Further development of GVS will focus on finalising the current design, refining and optimising existing code to improve load times, scene interactivity and lower memory usage, as well as implementation of new features. Some redesign of the system is also required to facilitate support for loading/saving complete models, improve data querying, simplify the data model and enhance the visualisation methods. This next development stage will commence once sufficient time and resources become available.

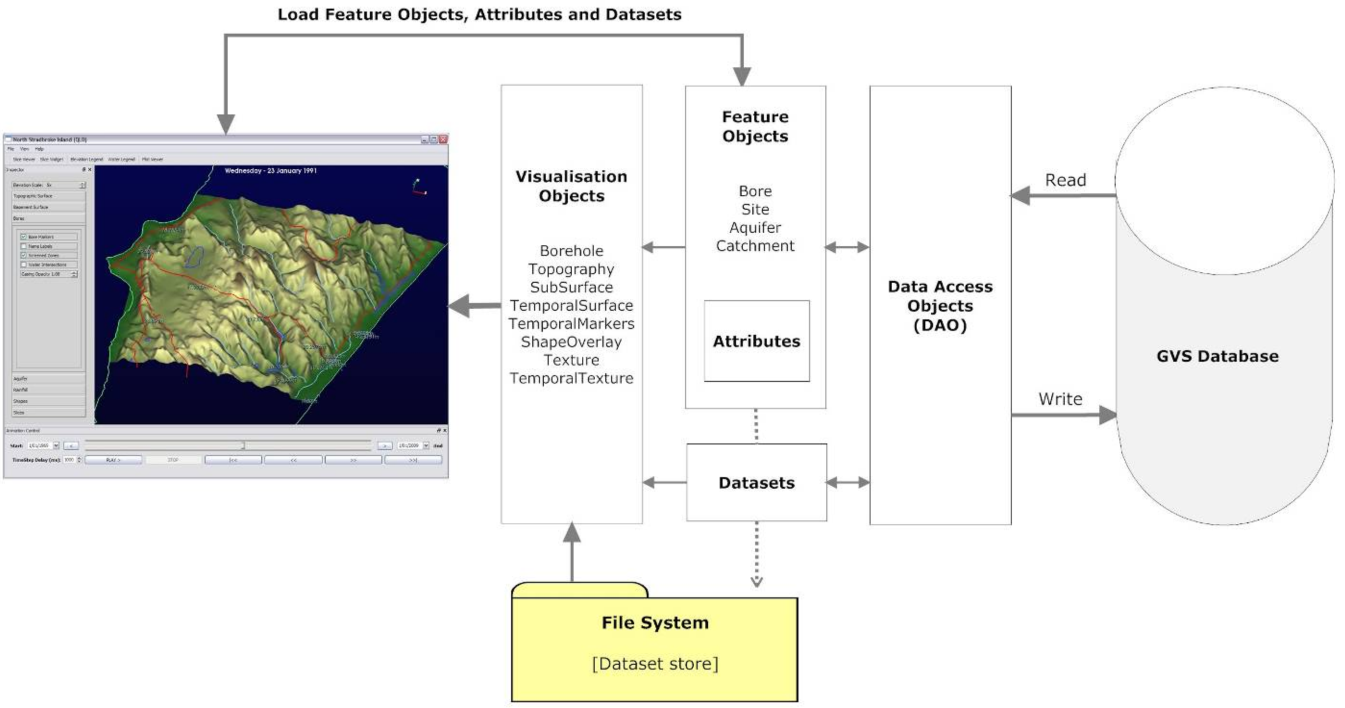


Figure 3: System overview diagram for GVS

Hydrogeological conceptualisation; the first stage in 3D model development

Jon Fawcett, Don Cherry, Bruce Gill and Mark Reid
Future Farming Systems Research Division, Department of Primary Industries, Victoria

Background

Sustainable management of groundwater can be helped greatly by groundwater models that provide predictions and analyses of the impact of climate and extraction use on resource condition. The aquifer dimensions within groundwater models are generally developed using geological drill hole data, with hydrogeological data used as a calibration data set. Unless evident within the drill hole data, many geological structures that control aquifer dimensions are not identified. Subsequently, many models inadequately represent aquifer dimensions and may misrepresent groundwater flow dynamics. This paper uses the Upper Loddon region of Victoria as a case study to illustrate the importance of developing hydrogeological conceptual models prior to model development. It also highlights the advantages in using additional hydrogeological data sets to assist identification of subsurface structures and assist interpretation of aquifer dimensions.

Approach

Examples of modelled Tertiary aquifer (deep lead) dimensions in the Upper Loddon region are provided in Figure 1. The two examples were essentially developed from the same drill hole data set, the degree of geological interpretation being the essential difference. Interpretation of the aquifer was further developed by integrating groundwater chemistry, groundwater hydrographs and regional scale geological features. The total aquifer system is comprised of a series of Newer Volcanics basalt flows overlying the deep lead alluvial sediments.

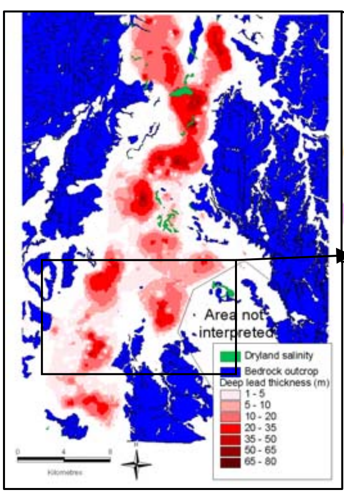


Figure 1a: Loddon deep lead isopach developed at more local scale

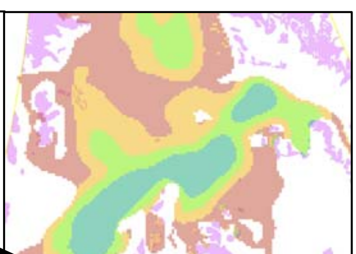


Figure 1b: Loddon deep lead isopach developed at regional scale, (brown to green = increase in thickness)

Figure 1: Two different interpretations of aquifer dimensions using geological drill hole data only

Additional Data sets

Hydrogeological interpretation of **groundwater pressures** identified basement highs as a major control on groundwater flow direction and the cause of groundwater discharge zones (Fawcett et al 2006).

Changes in **groundwater chemistry** indicated that the hydrogeological relationship between the basalt and deep lead varies. In the upper reaches of the Loddon catchment, the basalt aquifer recharges the deep lead aquifer, but further downgradient this relationship is reversed (Haggerty 2007). Holdgate (2006) identified large scale **faults** that altered the depositional environment of the Loddon deep lead sediments. This discovery reinforced the importance of looking beyond the bore hole data.

The spatial distribution of the deep lead is structurally controlled, and the hydrological relationship with overlying aquifers alters spatially depending upon the location of faults and other subsurface structures.

Several conceptual models of groundwater flow were developed using the new hydrogeological information (Figure 2).

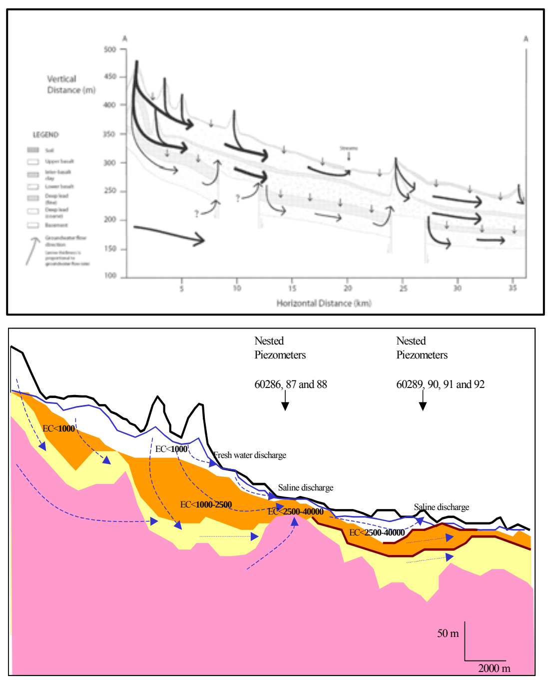


Figure 2: Conceptual models highlighting the influence of subsurface structures on groundwater flow and aquifer dimensions (top: Haggerty 2007; bottom: Fawcett et al 2006)

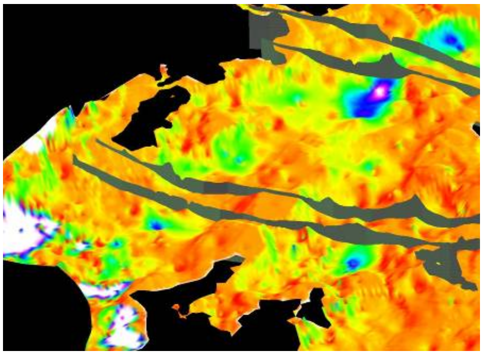
Hydrogeological conceptualisation; the first stage in 3D model development

Results and findings

Subsequent interpretation and modelling has developed a significantly different spatial representation of the Loddon deep lead aquifer. The major components of the re-interpretation are centred around the location of faults and where limited geological data existed, combined with the inherent knowledge of the aquifer dynamics in constructing groundwater conceptual models.

The spatial distribution of the deep lead aquifer in the Upper Loddon is now interpreted to be confined to isolated or semi-isolated deposits. This is supported by the presence of large scale faulting (Figure 3a), where the deep lead is absent to sparse along the uplifted block. Previous work generally viewed the deep lead as a continuous layer and joined the known deposits along assumed palaeochannels.

Groundwater chemistry data supports the new assessment by indicating a change in aquifer dynamics adjacent to the identified fault lines. Where geological drill core data are absent or sparse, the additional information provides a platform for significantly improving interpretation of aquifer dimensions and connection, providing greater confidence in groundwater resource estimation and decision making.



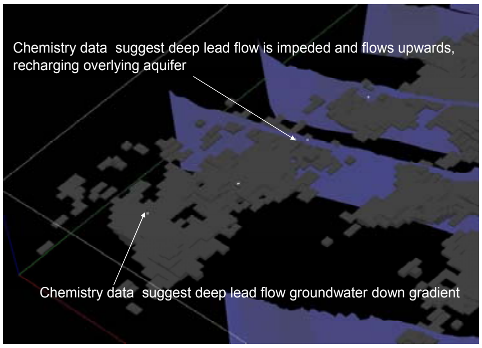


Figure 3: top – Deep Lead distribution (blues and greens) influenced by presence of large scale faults. **bottom** – 3D interpretation of deep lead sediments (voxels), large scale faults and location of groundwater chemistry data points.

Conclusions

Utilising additional data sets (e.g. exploration bore hole, geophysics, hydrochemistry) significantly improves the capacity of modellers to interpret aquifer dimensions and connectivity.
The impact on modelling outcomes is illustrated by demonstrated differences in predicted volume and distribution of the Loddon deep lead aquifer.
The approach of developing conceptual hydrogeological models and interpreting subsurface structures from additional data sets enables better alignment of model development to actual groundwater flow dynamics. 3D models that have more rigorously derived aquifer dimensions will produce more reliable outcomes.

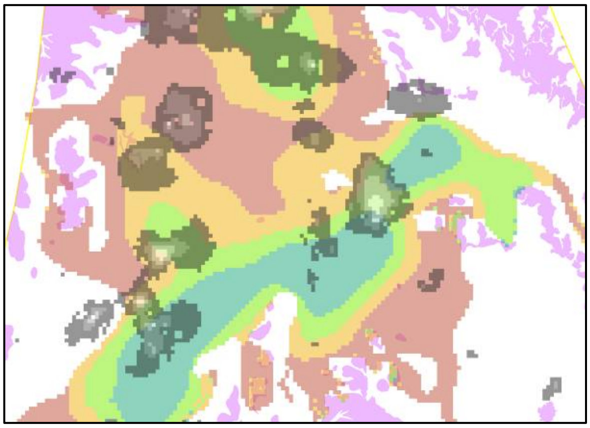


Figure 4: Comparison of two interpretations of Loddon deep lead thicknesses. The coloured distribution was developed by drill core data only. The grey distribution was developed by combining hydrogeological knowledge and interpretation of aquifer dimensions using additional data sets.

References

Hagerty S (2007) Groundwater – Surface Water interaction in the Tullaroop catchment, Central Victoria. Latrobe University, Department of Environmental Sciences, Faculty of Science, Technology and Engineering, Bundoora, Victoria (Honours Thesis Unpubl).

Fawcett J, Cherry D and Reid M (2006) Hydrogeological units of the Upper Loddon and Spring Hill Groundwater Management units. Department of Primary Industries Victoria.

Holdgate, G.R., M.W. Wallace, S.J. Gallagher, R.B.Witten, B.Stats and B.E.Wagstaff, (2006), Cenozoic fault control on 'deep lead' palaeoriver system, Central Highlands, Victoria. Australian Journal of Earth Sciences.

Jon Fawcett, ph 03 54304425

jon.fawcett@dpi.vic.gov.au

Mapping groundwater and salinity using airborne electromagnetics in the Lower Macquarie River Valley

Scott, Macaulay[1]
Bureau of Rural Sciences,
Australian Government Department of Agriculture, Fisheries and Forestry.[1]

Background

Airborne electromagnetics (AEM) maps the bulk electrical conductivity of the material that makes up the earth. There have now been a number of AEM studies which have demonstrated a strong correlation between high quality (fresh) groundwater and a low bulk conductivity (resistive) AEM signature.

Because AEM produces continuous, three-dimensional datasets it is able – under the right conditions - to produce detailed mapping of groundwater resources and groundwater surface-water interaction.

Objectives

The design phase of the Lower Macquarie River Valley survey identified a number of groundwater focussed questions that stakeholders were interested in. The major (groundwater) objectives of the project were to:

- understand the extent of known existing groundwater resources
- identify any additional water that may be suitable for irrigation water supplies
- determine whether there is any indication of upwards leakage from the Great Artesian Basin into the iconic Macquarie Marshes.

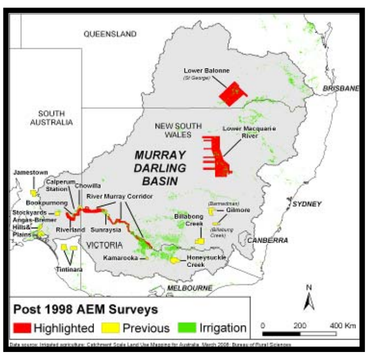


Figure 1: Map of existing AEM surveys in the Murray Darling – including the Lower Macquarie River Valley.

Approach

While AEM is capable of mapping fresh groundwater with a high degree of accuracy, this is only possible under conditions where there is a sufficiently high bulk conductivity contrast between the groundwater and the background regolith material. This is because AEM mapping shows fresh groundwater as having a low bulk conductivity (resistive) signature, as do a number of other materials.

Therefore while AEM is a powerful mapping tool for hydrogeology, it should not be used without some degree of ground-truthing and interpretation.

Results and findings

1) The Southern Palaeovalley: The lower slopes and plain between Narromine and Dandaloo (on the Bogan River) are underlain by a buried palaeovalley (the 'Southern Palaeovalley'). Prior to the survey, the configuration of the Southern Palaeovalley was reasonably well understood east of 'Waterloo' but was virtually unknown to the west. The AEM determines that the Southern Palaeovalley terminates against a ridge of Hervey Group Sandstone near Dandaloo.

2) Additional groundwater supplies: With declining flows in the Macquarie River over the past several years, attention from irrigators has focussed on the possibility of obtaining alternative groundwater supplies. The AEM mapped the extent and volume of a previously unknown groundwater resource, the 'Trangie-Nevertire Palaeochannel'. However further work (outside the scope of this project) is necessary to fully understand the palaeochannel and it's connection with the Macquarie River if it is intended to utilise the resource sustainably.

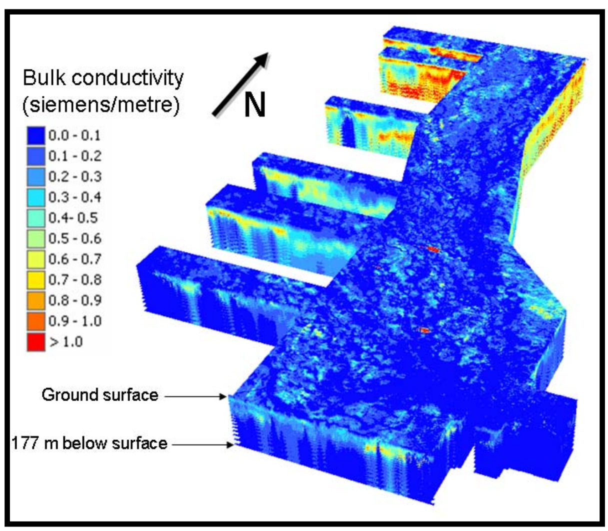


Figure 2: The 3D Lower Macquarie River Valley AEM dataset.

3) Recharge from the Great Artesian Basin into the Macquarie Marshes: The Macquarie Marshes overlie the Great Artesian Basin (GAB). There has long been speculation that the Marshes may derive some of their water from upward leakage from the underlying GAB aquifer (the Pilliga Sandstone). The AEM data has demonstrated that there is no groundwater recharge into the Macquarie Marshes from the underlying GAB.

Implications and Benefits

The Lower Macquarie River Valley AEM survey demonstrates the significant benefits of collecting and using continuous 3D datasets in understanding the geology and hydrogeology of systems such as the Lower Macquarie River Valley.

For example:

- The western extent of the Southern Palaeovalley was poorly understood despite decades of ‘traditional’ hydrogeological investigation. The AEM defined the western extent and identified a number of previously unknown ridges restricting groundwater flow (Figure 3).

- Previously unknown irrigation quality groundwater resources have been identified and their extent mapped. While there is some evidence of the Trangie-Nevertire palaeochannel in the literature, the AEM provided the first clear mapping of the feature. While the AEM mapped the extent and path of the palaeochannel, further work is required to determine the sustainable yield of the aquifer and it’s connection to the Macquarie River.

- Continuous 3D AEM data was used to demonstrate that previously theorised groundwater recharge from the underlying Great Artesian Basin into the Macquarie Marshes is not occurring (Figure 4).

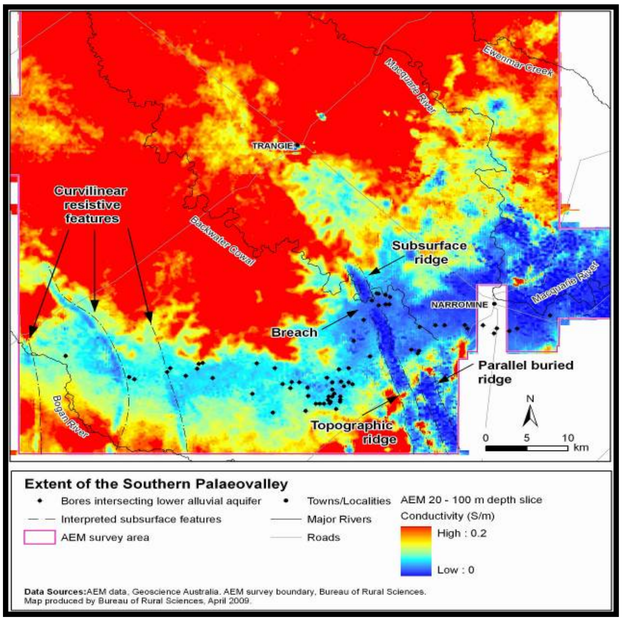


Figure 3: The extent of the Southern Palaeovalley and constricting sandstone ridges as mapped by the AEM.

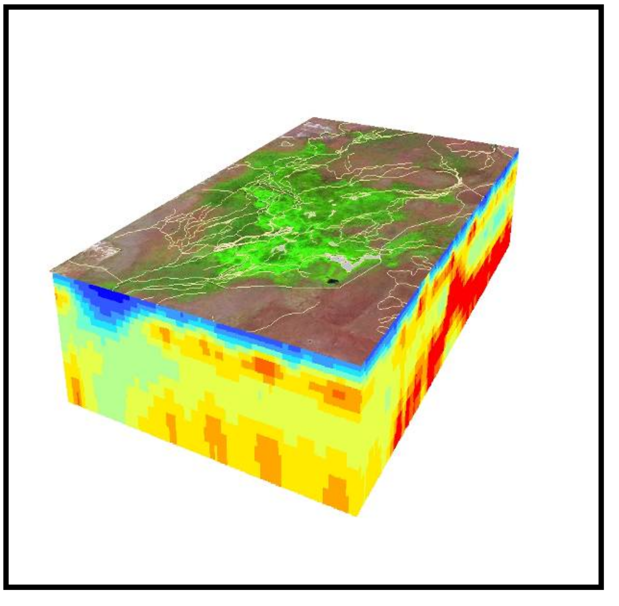


Figure 4: 3D AEM block-model through the area of Macquarie Marshes.

Contact : Scott Macaulay (Bureau of Rural Sciences)
Email: Scott.Macaulay@brs.gov.au
Phone: 02 6272 4883

3D Hydrograph Analysis for Constraining the Construction of Hydrogeological Models

B.F.J. Kelly[1,2], B.M.S.Giambastiani[1,3], W. Timms[1,2] and C. The[4]
[1]The University of New South Wales
[2]National Centre for Groundwater Research and Training
[3]Connected Waters Initiative
[4]Australian Government Bureau of Meteorology

Background

Groundwater is an important resource for irrigation agriculture. To monitor the irrigation extractions various NSW state government departments installed monitoring boreholes and the measurements are available on the 'Historic data CD "PINNEENA" for groundwater works': http://waterinfo.nsw.gov.au/pinneena/gw.shtml.

Borehole hydrograph data from this CD were analysed to provide insights into the 3D geometry and connectivity of the aquifers throughout the Namoi Catchment (Figure 1). This could be done for all catchments throughout the Murray-Darling Basin. Borehole hydrograph analysis provides an independent methodology to map recharge zones, access aquifer connectivity, and delineate areas of groundwater mining or recovery. The impact of historical groundwater extractions and current water sharing plans can then be analysed in the context of the mapped aquifer connectivity.

Objectives

The major goals of the 3D hydrograph analysis are to:

· map hydraulic connectivity throughout the alluvial sequence,

· develop a 3D conceptual site model,

· examine the long-term impact of irrigation extractions,

· compare zones of declining groundwater head to the connectivity interpretation, and

· examine the changes in groundwater head since the introduction of the water sharing plan.

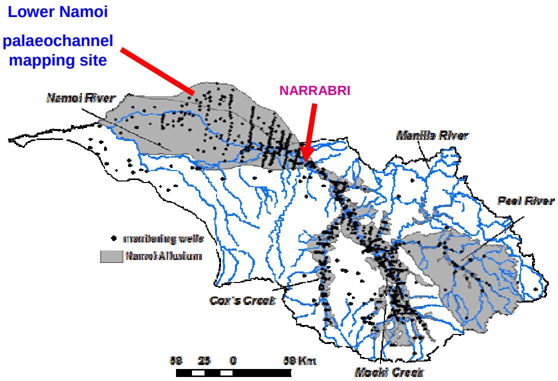


Figure 1: Namoi Catchment, NSW, Australia.

Approach

The PINNEENA data were reorganised in Microsoft Access and queried using scripts written in either the Python or *Mathematica* programming languages. The final results were plotted in 3D for visual analysis and presentation using either *Mathematica* or EarthVision.

Hydraulic connectivity within the unconsolidated sedimentary sequences was analysed using two approaches. First, collocated hydrographs were indexed as either low connectivity or high connectivity based upon the degree of divergence between hydrographs recorded at different depths (Figures 2, 3). There are n-1 indexed values for any given collocated hydrograph set. Second, the yearly fluctuation in head was determined for each borehole hydrograph and gridded using ordinary kriging (Figures 4, 5, 6 and 7). The 3D connectivity plots were then compared to the temporal change in groundwater head (Figures 8, 9 and 10).

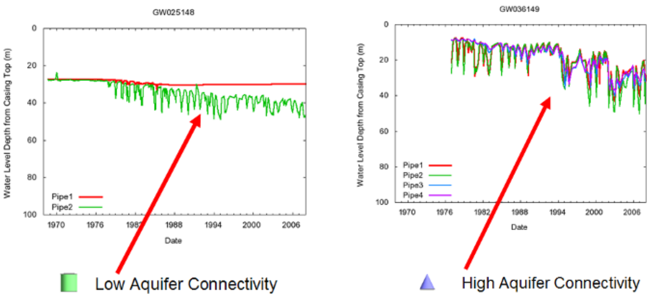


Figure 2: Connectivity indexing of borehole hydrographs.

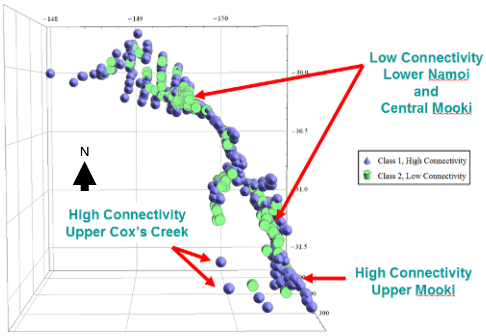


Figure 3: Aquifer connectivity in the Namoi Catchment.

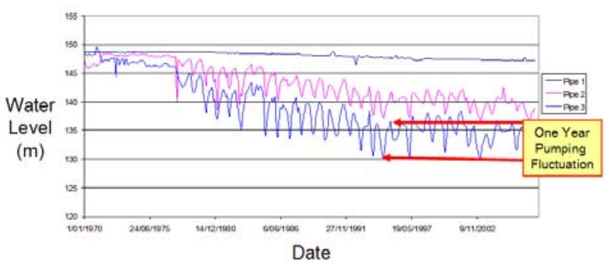


Figure 4: Yearly head fluctuation of a borehole hydrograph.

3D Hydrograph Analysis for Constraining the Construction of Hydrogeological Models

Results and Implications

This 3D borehole hydrograph spatial and temporal analysis shows that the largest zones of decline in the Namoi Catchment correspond to semi-confined aquifers with low connectivity to the unconfined aquifer and thus recharge from streams, floods, diffuse rainfall or irrigation deep drainage.

3D hydrograph analysis of pumping induced groundwater head fluctuation maps unconfined and semi-confined aquifers (Figures 5 & 6). It also delineates palaeochannels (Figure 7).

An implication of the 3D aquifer connectivity analysis is that managed aquifer recharge will be required to replenish some portions of the Namoi Catchment.

3D borehole hydrograph analysis is another tool to enhance the conceptualisation of aquifers. It complements other methods including gridding lithological logs, palynology studies, water chemistry investigations and geophysical surveys. These conceptual site models will guide the future construction of water balance models and provide an important visual representation of the catchment for communicating changes to a non-scientific audience.

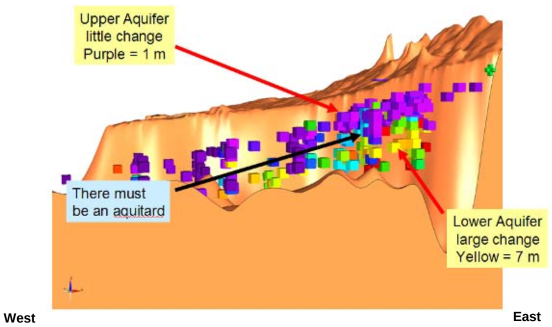


Figure 5: Yearly groundwater head fluctuation data in the Lower Namoi.

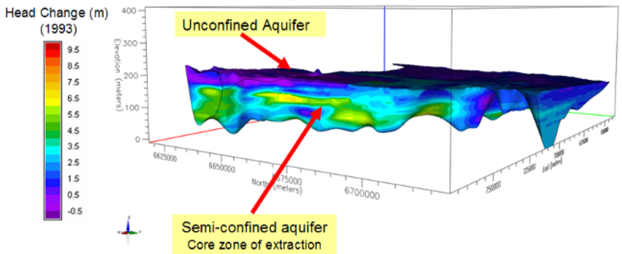


Figure 6: Gridded yearly groundwater head fluctuation in the Lower Namoi.

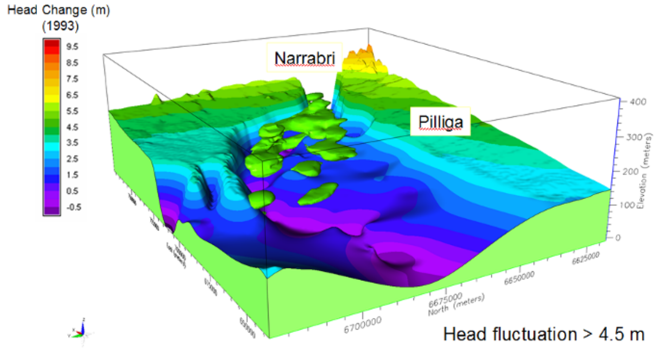


Figure 7: Mapped palaeochannels from the groundwater head fluctuation data.

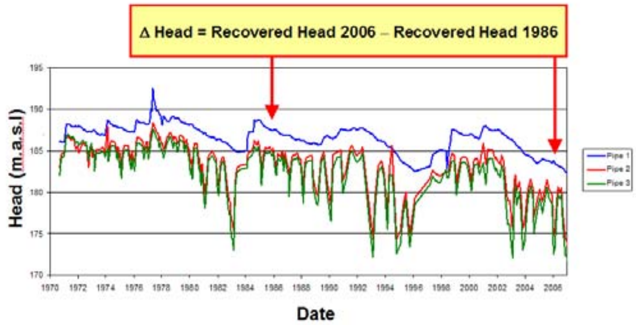


Figure 8: Change in groundwater head over time.

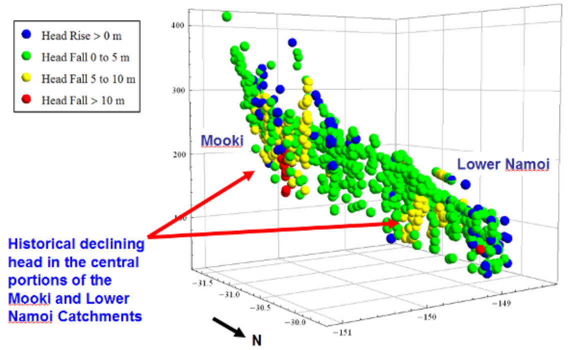


Figure 9: Historical change in groundwater head throughout the Namoi Catchment.

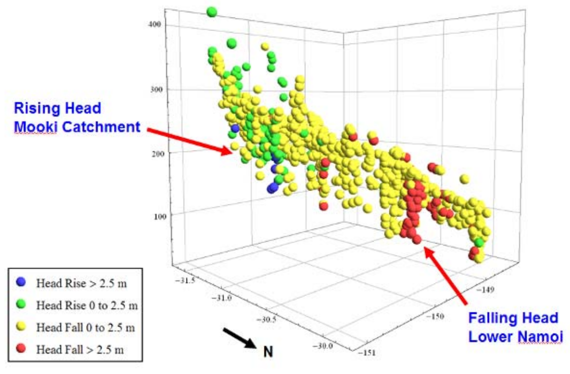


Figure 10: Recent change in groundwater head throughout the Namoi Catchment.

Associate Professor Bryce Kelly,
UNSW, National Centre for Groundwater Research and Training
bryce.kelly@unsw.edu.au

Eromanga 3D map – killing several birds with one model

Alison Kirkby [1], Simon Van der Wielen[1], Alison Britt[1], Anthony Schofield[1], Roger Skirrow[1], Evgeniy Bastrakov[1], Andrew Cross[1], Malcolm Nicoll[1], Terry Mernagh[1], and Andrew Barnicoat[1].

Geoscience Australia[1]

Background

The Eromanga Basin is a Mesozoic, intracratonic sag basin that covers an area of some 1,000,000 km^2 of central-eastern Australia, forming part of the larger Great Artesian Basin (Fig. 1). The Eromanga Basin is rimmed by a series of Proterozoic terrains (Gawler Craton, Mt Isa, Mt Painter, Georgetown and others) and unconformably overlies various older basins (Fig. 1). Deposition in the Eromanga Basin did not occur until the Early Jurassic and was continuous until the mid-Cretaceous.

The overall structural trend in the Eromanga Basin is northeast with a series of troughs (the Poolowana, Patchawara, Allunga, Tenapperra and Yongala Troughs) and ridges (i.e. Birdsville Track, Tibooburra, Eulo and Nebine Ridges). Broad domes (the Betoola, Gason, Cooryanna, Curalle and Morney Domes) are also present and appear to control the location of artesian mound springs.

Previous workers (Gravestock et al., 1986 and Krieg, 1995; Radke et al., 2000) have compiled a detailed stratigraphic framework for the Eromanga and adjacent basins (Fig. 2). The Eromanga Basin has been subdivided into three main stratigraphic sequences: a lower non-marine sequence, a middle marine sequence and an upper non-marine sequence. The lower non-marine sequence consists of medium-grained sands (i.e. Hutton and Precipice Sandstones) that were deposited in a braided fluvial environment, followed by fine grained lacustrine sands, silts and shales of the Injune Group. The middle marine sequence comprises basal sands (i.e. Cadna-owie Formation, Algebuckina Sandstone, Hooray Sandstone and others) that prograde into deeper water shales and muds (the Bulldog Shale, Allaru Mudstone, Toolebuc Formation and others). The upper non-marine sequence (the Winton Formation) comprises a ~1,000 m thick package of sediments (sandstones, shales and siltstones) that was deposited in a low-energy fluvial to lacustrine environment.

Objectives

The objective of this study was to generate a 3D map of the Eromanga Basin that incorporates major structural trends and stratigraphic boundaries. The aim was that the model would provide a framework for displaying and interpreting geochemical and physical property data in 3D. The model would also provide a framework for regional or local scale modelling of groundwater flow and/or geochemistry, and for numerous other studies, including thermal modelling (for geothermal power potential), uranium systems analysis, petroleum studies and carbon sequestration studies.

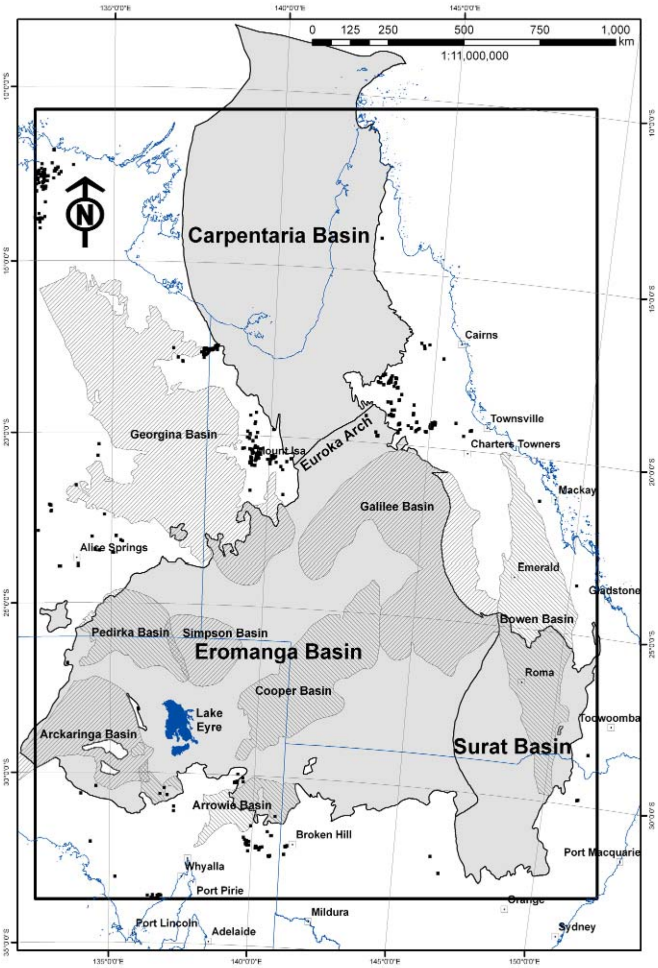


Figure 1. Map showing the study area (bold rectangle), the extent of the Great Artesian Basin (Eromanga, Surat and Carpentaria Basins) and underlying Palaeozoic Basins (light shading).

Methodology

Data required to construct a 3D map of the Eromanga Basin were imported into Gocad™. A series of 10 geological surfaces were chosen (Fig. 2) for their lateral extent across the basin. Geological and fault surfaces were built in Gocad™ using surface geology, stratigraphic markers from drilling and seismic picks as constraints. The watertight surfaces (i.e. no gaps at surface intersections) were converted into a geological block model (Gocad™ voxet) with a 5,000 x 5,000 x 100 metre cell size. Various datasets (wireline geophysical logs, geological logs, geophysical, hyperspectral, and hydrochemistry data) required for the uranium mineral system assessment, were also imported into Gocad™. The datasets were then used to populate the geological block model, resulting in a series of properties (pH, temperature, permeability, porosity, etc) for each voxel.

Eromanga 3D map – killing several birds with one model

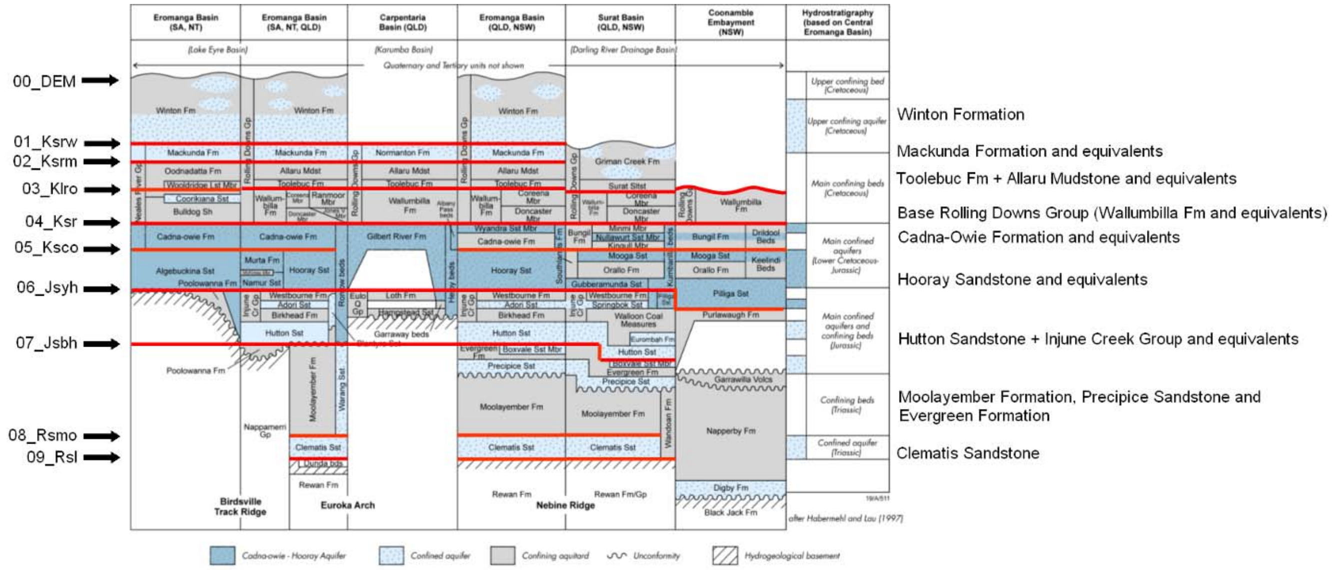


Figure 2. A time-space plot showing the correlation between the Eromanga, Surat and Carpentaria Basins. Main sandstone aquifers and confining aquitards for the Great Artesian basins are marked. The bold lines and text represent geological surfaces in the 3D map (adapted from Radke et al., 2000).

Results and Discussion

The 3D model is presented in Figure 3. It contains regions representing the nine lithological groupings shown in Figure 2, allowing their distribution to be visualised in 3D. The model shows the thickening of the major units in the three major depocentres: the Eromanga, Surat, and Carpentaria Basins. The model has been populated with physical property and geochemical data, allowing this data to also be visualised in 3D, and to be interrogated with respect to lithological groupings.

The model has the potential for application in a number of other research areas. It can provide a framework for 3D temperature modelling to better understand the potential for geothermal energy utilisation, and mineral systems analysis for uranium mineralisation potential. The model may also have applications in understanding the onshore petroleum and carbon sequestration potential of Australia.

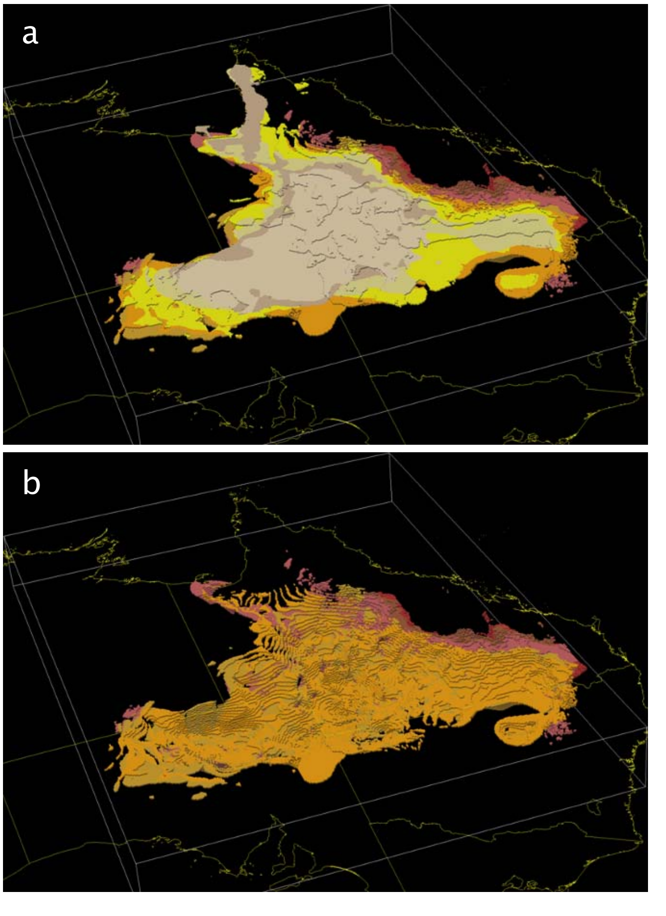


Figure 3. A perspective view of the 3D map of the Eromanga Basin, a) showing all units, and b) view from the top of the Cadna-Owie Formation.

References

Gravestock DI; More PS, Pitt GM (1986) Contributions to the geology and hydrocarbon potential of the Eromanga Basin. Geological Society of Australia, Special Publication 12, 184 pp

Krieg GW (1995) Mesozoic. In: Drexel JF, Preiss WV (eds): The geology of South Australia. Volume 2, The Phanerozoic. South Australia Geological Survey. Bulletin 54, pp 92-149

Radke BM, Ferguson J, Cresswell RG, Ransley TR, Habermehl MA (2000) Hydrochemistry and implied hydrodynamics of the Cadna-owie – Hooray Aquifer Great Artesian Basin. Bureau of Rural Sciences, Canberra, 229pp

Alison Kirkby. Email:alison.kirkby@ga.gov.au

Approach to developing a 3D conceptual hydrogeology model, in a system with multiple bore logs, Howard East, Darwin, using in-house software (GVS)

Amy Hawke [1], Allan James [1], Malcolm Cox [2], Joseph Young [1]

[1]High Performance Computing and Research Support, QUT [2]School of Natural Resource Sciences, QUT

Introduction

The Howard East rural area has experienced a rapid growth of small block subdivisions and horticulture over the last 40 years, which has been based on groundwater supply. Early bores in the area provide part of the water supply for Darwin City and are maintained and monitored by NT Power & Water Corporation. The Territory government (NRETAS) has established a monitoring network, and now 48 bores are monitored. However, in the area there are over 2700 private bores that are unregulated. Although NRETAS has both FDM and FEM simulations for the region, community support for potential regulation is sought. To improve stakeholder understanding of the resource QUT was retained by the TRaCK consortium to develop a 3D visualisation of the groundwater system.

Background

The Howard East groundwater area is centered on the Howard River catchment around 20 km southeast of Darwin. Hydrogeologically, the area is characterised by 30-50 m of Cretaceous age layered sedimentary formations overlying an extensive area of metamorphosed dolomite. Groundwater supplies have been derived from various aquifers: shallow lateritised zones, sand-rich layers in the Cretaceous sequence, and the transitional zone between the Cretaceous and the dolomite. This interface zone, formed of broken, sand-rich and weathered material, is probably the most continuous water-bearing zone, but is difficult to map from drill returns. Within the hard dolomite there are localised zones of fracturing and karstification which produce good flows, but are difficult to locate. Although mostly in the upper sections of the dolomite they have been reported at depths of 160 m.

Within this setting only extraction from the Power & Water bores is recorded. The total extraction from the system is now beginning to be reflected by the response of the groundwater levels.

Objectives

The development and application of the 3D visualisation model is aimed to provide management support, refinement of the conceptual model, enable the stakeholders to understand the system, and also appreciate the location of their own bore within the area. The main objectives specifically are to :

Figure 1: Howard East project area relative to the City of Darwin. Groundwater bores are shown as red dots.

- Provide an independent, scientific and educational tool that improves community understanding of the groundwater resources in the Howard East aquifer system.
- Assist stakeholders and community understanding in the impact of bore extraction on groundwater resources so that they can then make informed decisions on the management of the system in forthcoming water allocation planning.

Approach

Geological, drill hole and water data for the project area was available from various sources. NRETAS has a well organised database with drill logs, bore information and monitoring records, plus some stream gauge data. Power & Water has good records of water supply extraction from their bores. Different surface data layers were also available.

A major project objective is the production of a final visualisation model on CD, which can then be used on individual PC's. The product must therefore be easy to distribute, not require commercial licencing plus be relatively simple to install and use, after some instruction. The Groundwater Visualisation System (GVS) has been developed to satisfy these requirements. GVS has a MySQL database schema, and the various data was consolidated into the database. The DEM, topographic overlays and shape files were cut accordingly to the selected project area.

Approach to developing a 3D conceptual hydrogeology model, in a system with multiple bore logs, Howard East, Darwin, using in-house software (GVS)

The drillers lithological logs for all the bores were categorised by a hydrogeologist into 15 discrete categories (over 22000 descriptions) for visualisation. These categories were then further adjusted to produce six representative geological units within the area. A 3D mesh was generated (Figure 2) from these categorised bore logs. Various groupings of bores and interpolation methods were trialed. The detail of the conceptual model was optimised by ongoing testing, discussion and assessment and by using the "nearest neighbour" interpolation. The final mesh was generated using 200 optimal logs. The bore data (including standing water levels), rainfall data, DEM, topographic overlays and 3D geometry have all been incorporated into the GVS model as feature objects.

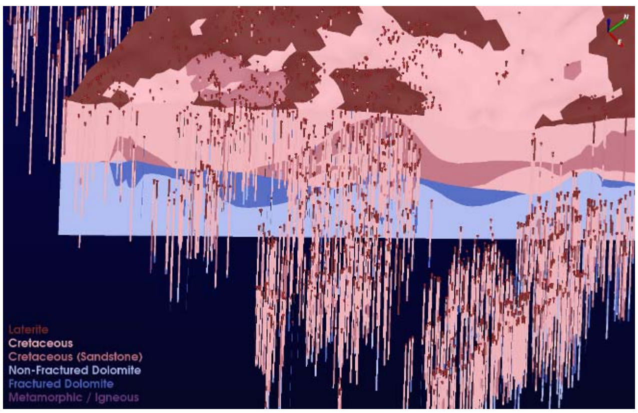


Figure 2: Internal 3D geographic geometry sliced to reveal bores in the south-east corner of the project

Aquifers for monitoring bores with recorded standing water levels were determined from the location of the bores screens or slots. Initially two aquifer systems (Cretaceous and dolomite) were considered, but in the final model, one water level was chosen to best represent variations. We initially displayed this as a water surface/s, but due to inadequate points which gave a false impression, the final model has markers which indicate water levels for each monitoring bore. The GVS software allows animation of the water levels (Figure 3) and surfaces.

Interactive hydrograph plots (Figure 4) of the standing water levels show seasonal variation of water levels. For many bores there is a decrease in levels over time. Individual bores can be selected, and referenced back to their labeled position in the 3D scene. The model also displays the height of the water level (relative to sea level) in different parts of the catchment. The visualisation allows users to compare the location of the bore features like high yielding extraction bores, and natural features such as rivers and lagoons. This provides more context for the high level of water level variation.

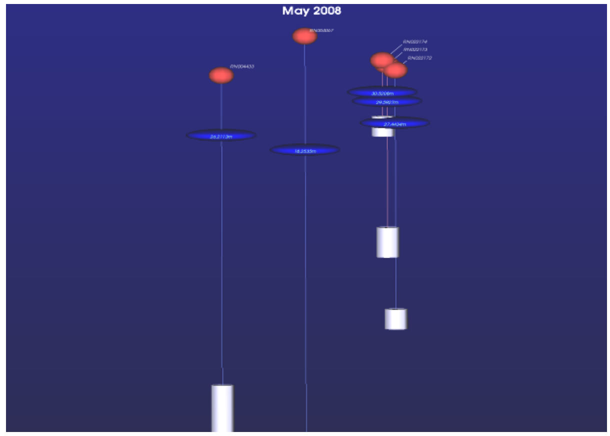


Figure 3: Slotted casings and water levels in May 2008 for selected bores

Summary comment

The model provides an effective tool by which water planners, department officials, community members and other stakeholders can better appreciate the structure and functioning of the total system. (Although it has been noted that the groundwater system extends further to the east and north). It gives individuals the ability to interrogate the data to view facets of the system that are of particular interest to them.

Local water planners have already commented that these tools will make water planning and management much easier.

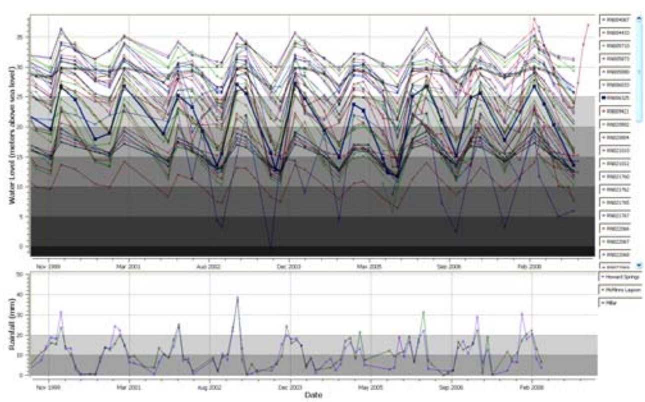


Figure 4: Interactive plots of the water levels and rainfall.

Acknowledgements:
The model was developed within a funded collaborative project and we thank the following: TRaCK (Sharna Nolan, Poh-Ling Tan); NRETAS (Des Yin Foo, Chris Wicks, Steve Tickell), Power & Water (David George); and hydrogeologist Peter Jolly. We thank the numerous local water users and drillers who provided comment and ideas.

Amy Hawke

amy.hawke@qut.edu.au

3D Hydrogeology in Western Australia - aquifer mapping, regional models and stratigraphic analysis

David Schafer and Jon-Philippe Pigois
Department of Water, Western Australia

Background

The application of 3D hydrogeology depends on need and purpose. In Western Australia (WA), 3D representation and appreciation of the hydrogeology within the Perth Basin is well advanced. However, there is little need for 3D hydrogeology for the remainder of the state which has localised, shallow aquifers such as fractured rocks.

In the Perth Basin, a quasi-3D aquifer management tool (DWAID) was created in 2000 where geologically mapped 2D aquifer shapes are superimposed at different levels.

More recently, from 2004, the WA Department of Water (DoW) has developed a number of regional and sub-regional 3D groundwater models for water resource management. The layers from these MODFLOW models are available on an internal GISViewer system for management purposes.

Presentation outline

- Aquifer mapping for resource management
- Major groundwater resource models
- Stratigraphic analysis using PETREL

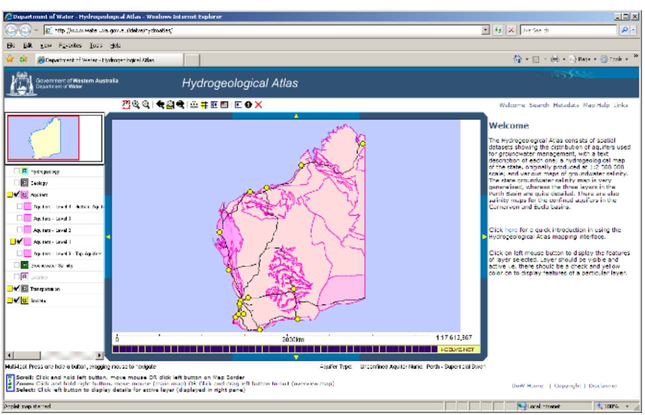


Figure 1: Hydrogeologic Atlas webpage

Approach

All 3D models created by DoW were based on geology and developed to support the water resource management function.

Current investigations have included 3D seismic surveys to supplement traditional groundwater monitoring bore installation for improved spatial aquifer understanding.

Applications

- DWAID groundwater management system
- 3D aquifer surfaces are currently used for management purposes via an internal DoW GISViewer system.
- PRAMS is a 3D, 12 layered numerical model representing the aquifers beneath the Perth metropolitan area. This model is continuously updated following new investigations.
- The integration of 3D software (eg PETREL) has greatly improved stratigraphic interpretations. It has also allowed 3D sand percentage maps to be generated which have been used to develop conductivity zones in groundwater models.
- Current groundwater investigations are incorporating shallow seismic surveys to aid stratigraphic interpretation and site selection.

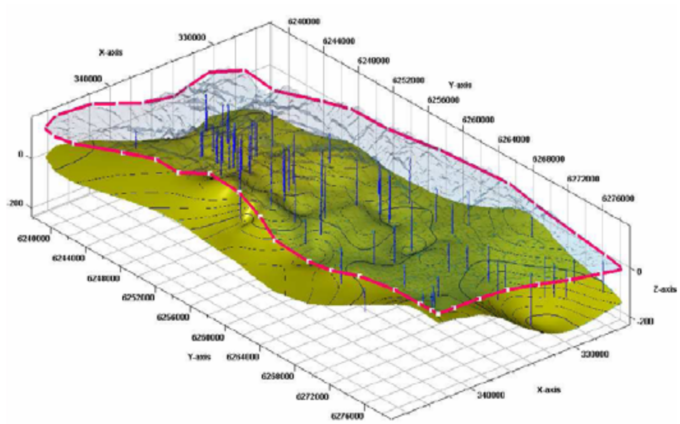
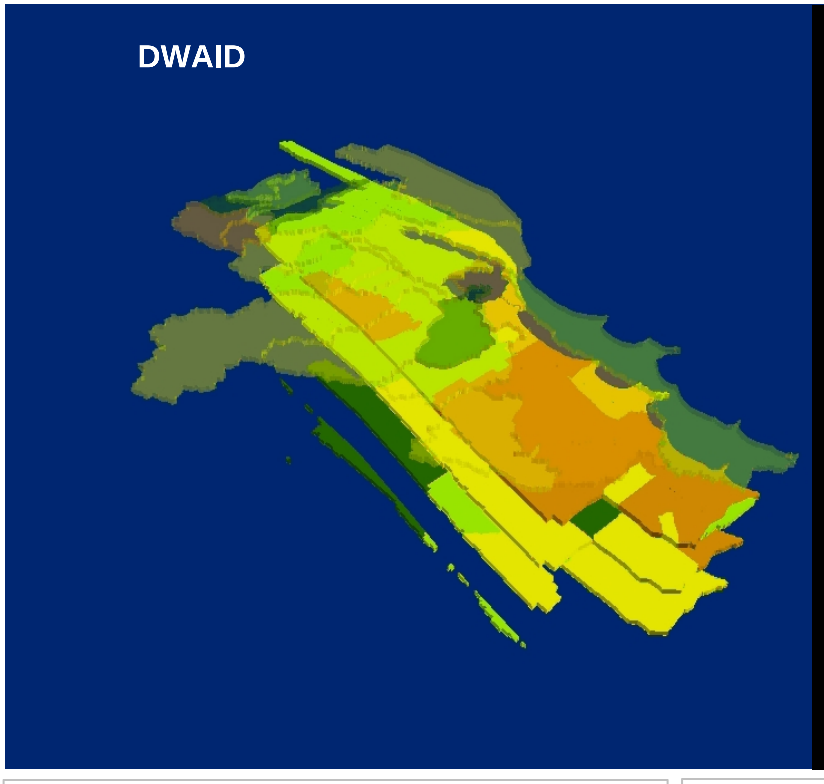


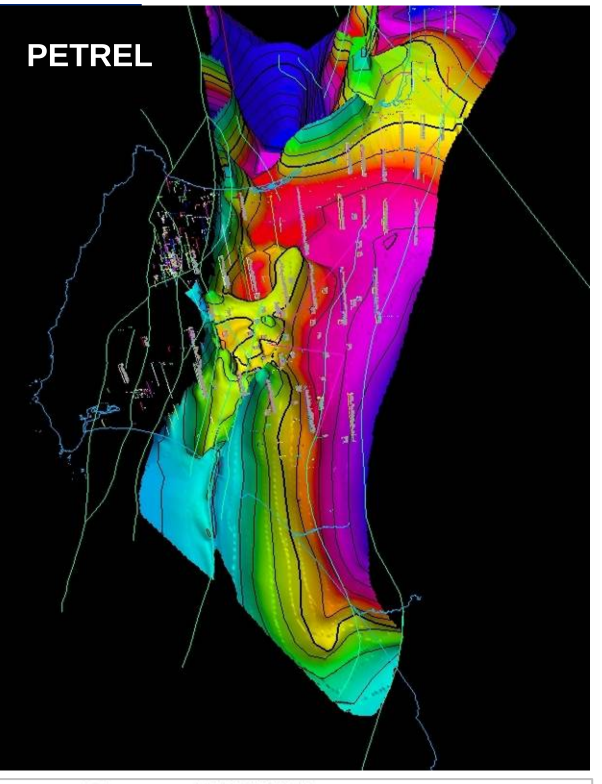
Figure 2: 3D Image of the base of Leederville formation In the western Busselton-Capel model domain

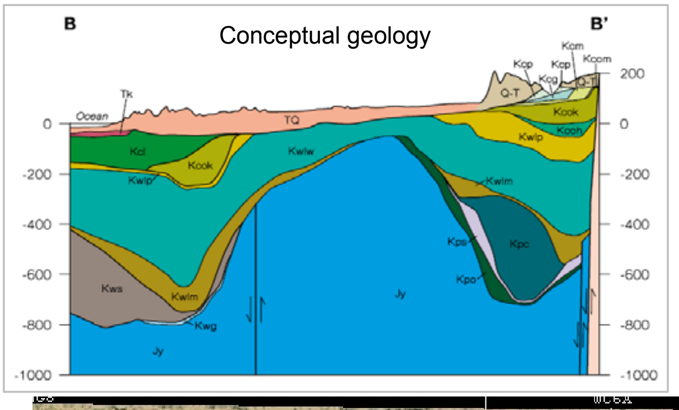
Implications and Benefits

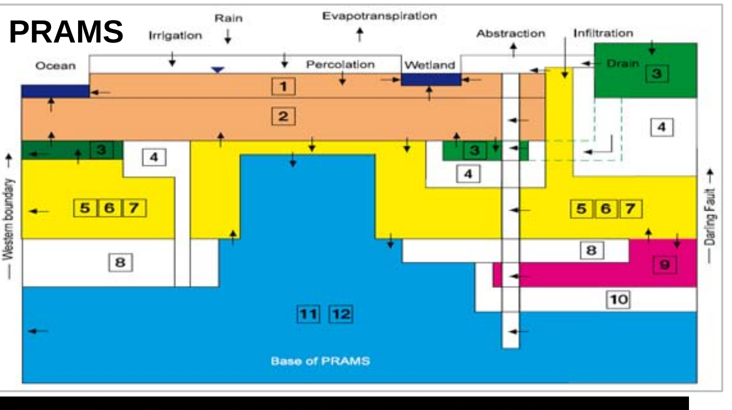
- The development of 3D hydrogeology at DoW has been driven by hydrogeologists to improve our understanding and better manage the complex hydrogeology of the Perth Basin, which is the major source of Perth's water supply.
- DoW is implementing the use of PETREL for 3D stratigraphic analysis and creating conceptual models.
- Regional and sub-regional 3D groundwater models are in use for resource management.
- 3D seismic surveys are being incorporated into hydrogeologic investigations to aid site selection and geologic interpretation.

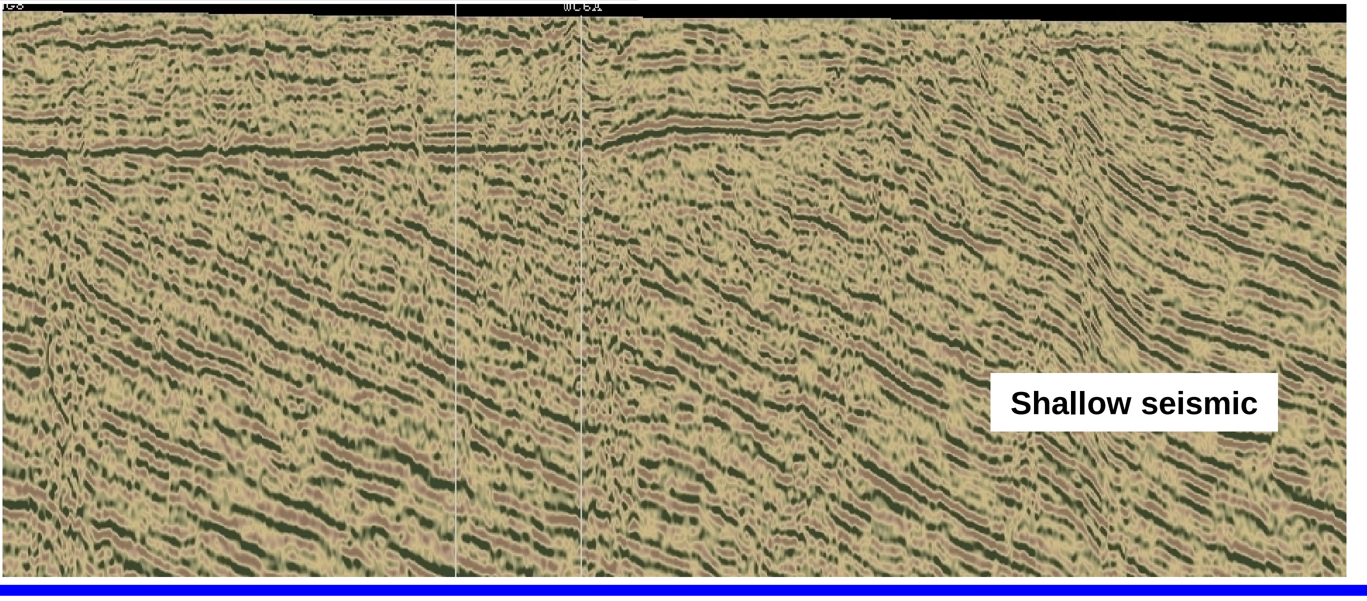
3D Hydrogeology in Western Australia -
aquifer mapping, regional models and stratigraphic analysis











Three Dimensional Temporal Analysis of Surface and Ground Water Interactions

B.M.S. Giambastiani[1,3], B.F.J. Kelly[1,2], A. McCallum[1,3] and C. The[4]
[1]The University of New South Wales
[2]National Centre for Groundwater Research and Training
[3]Connected Waters Initiative
[4]Australian Government Bureau of Meteorology

Background

Understanding exchanges between surface and ground water systems is critical for good management of water resources. This study uses 3D spatial and temporal analysis of hydrological data to examine the impacts of groundwater irrigation extractions and to map flood recharge zones in two sub-catchments of the Namoi Catchment (Figure 1). In the Maules Creek area the coupling between rainfall, streamflow, groundwater usage and groundwater head is explored. In the Lower Namoi region the difference in groundwater head before and after flooding is mapped in 3D to elucidate recharge pathways. Since the 1960s, as irrigation agriculture expanded in the region, various NSW state government water departments installed more than 550 groundwater monitoring boreholes to observe the impact of the groundwater extractions. At each borehole site from 1 to 7 piezometers were installed and set at different depths in the unconsolidated sediments. Water levels in these boreholes are manually recorded four or more times per year. This is the primary data set used.

Objectives

The major goals of this research are to:

- examine the temporal visual correlations between groundwater extractions, streamflow, rainfall and groundwater head;
- map in 3D the change in groundwater head due to flood events in order to demarcate hydraulic connections and the pathways of recharge; and
- provide catchment management authorities with a visual communication tool for community meetings about water management.

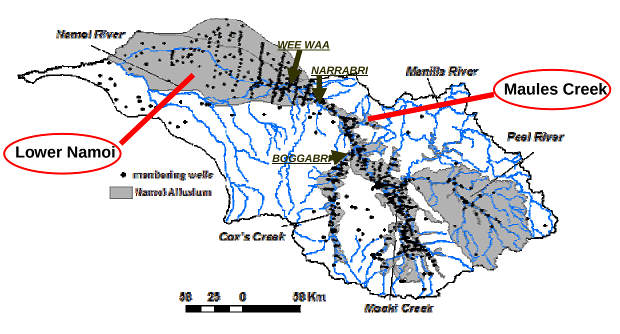


Figure 1: The Namoi River Catchment.

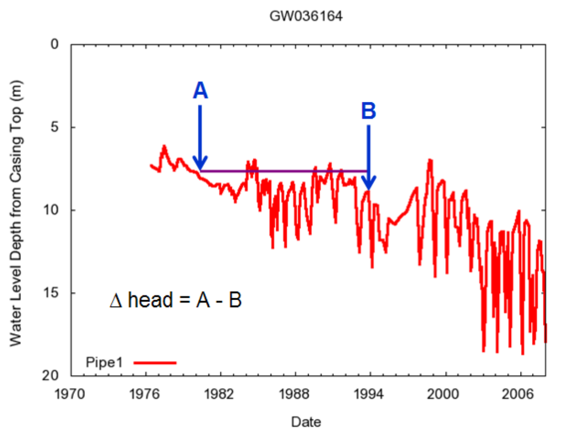


Figure 2: The relative change in recovered head since 1980 is used in Figures 3,4,5 and 6.

Method Maules Creek Analysis

In the Maules Creek catchment, and adjacent reach of the Namoi River, for each borehole the relative change in recovered groundwater head since 1980 was determined for all years up to 2008 (Figure 2). These data are plotted at the mid-point of the slotted interval. Graphs of rainfall at Boggabri, streamflow at Boggabri and groundwater usage were calculated over the cotton growing year (which runs from October to September). To place the data in their hydrological setting, they were plotted on a 3D model of the bedrock surface. The images for each year were then converted into a movie. The complete time-lapse movie is available online from the UNSW Connected Waters Initiative web site:
http://www.connectedwaters.unsw.edu.au/resources/video/video_maules.html
Selected images from the movie are presented in Figures 3,4,5 and 6.

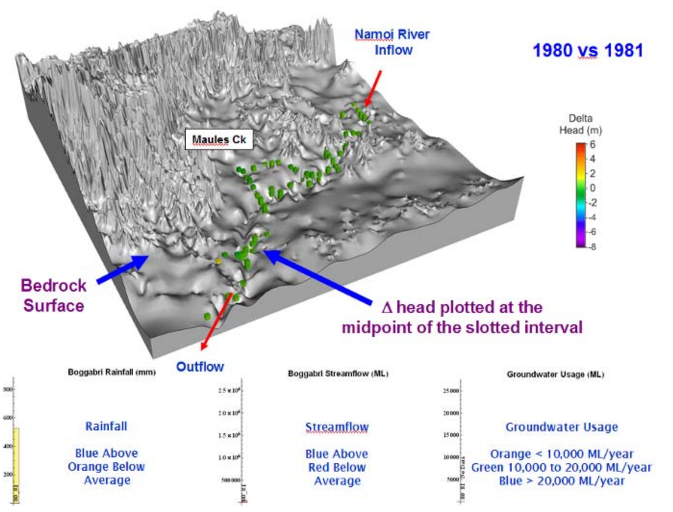


Figure 3: Relative change in groundwater head since 1980 and reference information.

Three Dimensional Temporal Analysis of Surface and Ground Water Interactions

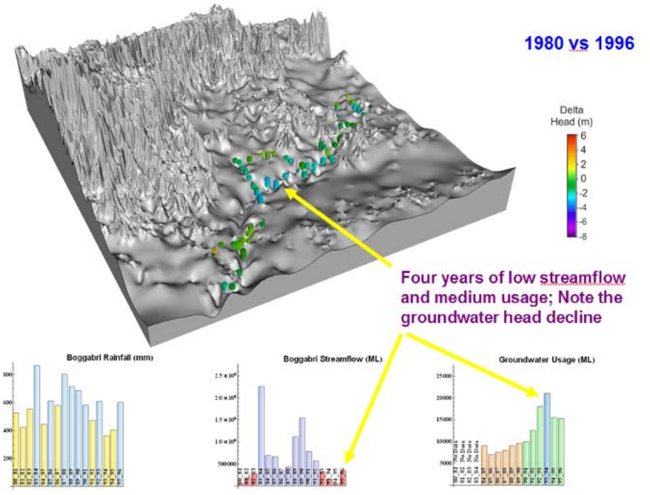


Figure 4: Change in groundwater head between 1980 and 1997 after a period of low streamflow.

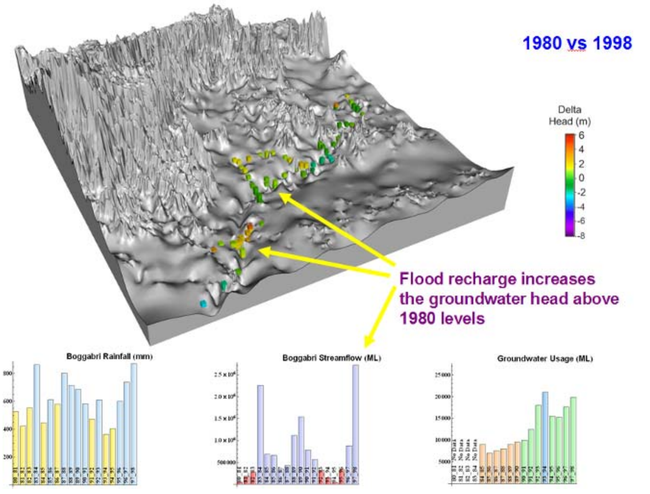


Figure 5: Change in groundwater head between 1980 and 1998 after flooding along the Namoi Rv.

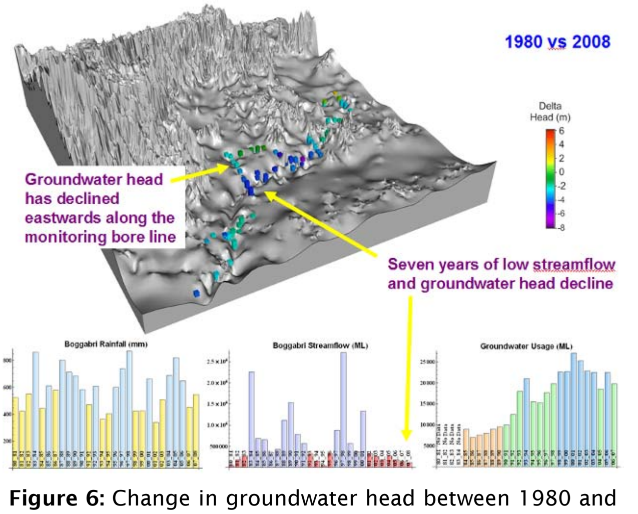


Figure 6: Change in groundwater head between 1980 and 2008 after seven years of low streamflow.

Method Lower Namoi Analysis

Groundwater head changes in the unconsolidated sediments due to flooding in the Lower Namoi were mapped in 3D to explore hydraulic connectivity in the catchment. For each borehole the difference in head before and after the flooding was determined (Figure 7). These data were then gridded using ordinary kriging. Head rise above the 2.0 m isosurface maps in 3D the peak response to the flood waters (Figure 8).

Figure 7: Borehole hydrograph flood analysis steps.

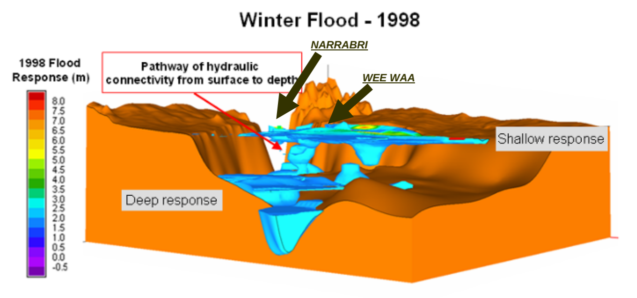


Figure 8: 1998 winter flood response model of the Lower Namoi aquifer system (looking towards Narrabri). Evident are a shallow and deep aquifer response and a weak connection between the palaeochannel and the unconfined aquifer.

Implications

Visual analytical techniques provide a simple but power method to convey the connectivity between various hydrological data sets.

The Maules Creek catchment time-lapse presentation demonstrates that groundwater head is correlated to streamflow. Surface and ground water in this region needs to be managed as a connected resource.

In the Lower Namoi catchment the unconfined aquifer is coupled to the Namoi River and adjacent floodways. However, the deep aquifer that follows the northern palaeochannel is poorly connected to the Namoi River. This aquifer would require managed aquifer recharge to be replenished.

Beatrice M.S. Giambastiani
UNSW Connected Waters Initiative
b.giambastiani@unsw.edu.au
Phone: +61 2 9949 4488

Software for 3D simulation of variable-density flow and transport in coastal groundwater systems

Ben Cumming, Ian Turner and Timothy Moroney
School of Mathematical Sciences, Queensland University of Technology (QUT)

Background

Computer simulations of seawater intrusion and water flow in a coastal aquifers are important for both the development of accurate conceptual models and for making predictions for water resource management.

Seawater intrusion is governed by a complex physical process of density-driven flow in a heterogeneous porous media whose structure can be highly irregular. Efficiently and accurately performing simulations based on mathematical models of such porous flow and transport is very challenging, and requires considerable computational resources.

A simulation code called finite volume method for porous media (FVMPor) is being developed to take use of modern computer hardware and accurate mathematical techniques for simulating density-driven flow in porous media.

Objectives

The development of the mathematical formulation and initial implementation of the library is part of an ongoing PhD project with the objectives:

- Formulate a discretisation of the governing conservation laws using the finite volume method.
- Develop Efficient algorithms for accurately solving the discretised equations.
- Implement the methods in a software library using C++ and C languages that can run on desktop machines and also scale well for large-scale simulations in high-performance computing environments.

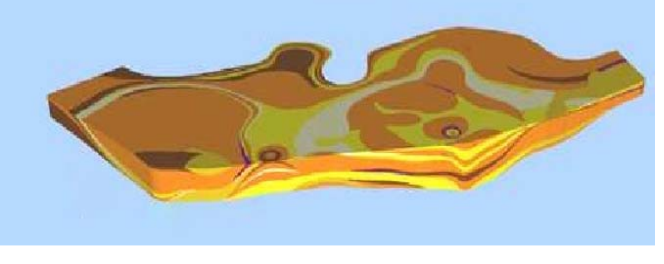


Figure 1: Conceptual model of Gooburrum aquifer which shows the irregularity of the computational domain.

Approach

FVMPor uses a control volume finite element spatial discretisation of the governing equations. This discretisation is ideal for heterogeneous media and respects the conservation laws that the governing equations are derived from.

A novel approach for formulating the discretised equations in terms of differential algebraic equations (DAEs) has been developed. Such an approach is suitable for higher-order methods for timestepping, handles complex boundary conditions and guarantees conservation of mass.

The DAE system is solved using a matrix-free solution strategy that is ideal for implementation on parallel computers, and can be implemented efficiently using affordable graphics card-based hardware, which greatly improves performance on desktop computers.

Results and findings

Initial investigations with challenging two-dimensional benchmark tests have validated the proposed methods. Because the formulation respects the governing conservation laws, the solutions are mass-conservative to machine precision.

We have found that with flux limiting, simulations on coarse meshes show very little numerical diffusion, which is important for accurately predicting the location and width of interfaces between saltwater and freshwater.

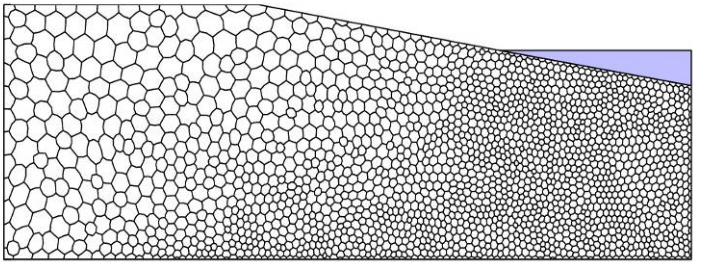


Figure 2: A computational mesh for a cross- section of an aquifer, with refinement near the coast.

Implications and Benefits

The design of FVMPor is very modular and open source, allowing it to be easily extended for simulating different porous media models. As such it will be useful not only for seawater intrusion modelling, but general modelling of groundwater pollution.

Integration of the library with the groundwater visualisation system (GVS) software framework developed at QUT (also presented at this workshop) will provide a readily available suite of software for simulating and visualising groundwater models.

Author contact: b.cumming@qut.edu.au

QUT

Hydrogeological Mapping of Southern Victoria

Andrew Harrison
Sinclair Knight Merz

Background

The management of groundwater resources relies heavily on knowledge of aquifer geometry in three dimensional space. Although there are some existing hydrogeological maps of Southern Victoria, they are designed for hard copy use, are static formats and have significant cross-boundary issues.

This project provides a 3 dimensional aquifer framework for use in making informed decisions about sustainable groundwater management in Southern Victoria. This project was conducted for Southern Rural Water by SKM in partnership with GHD.

Objectives

- To undertake 3-dimensional spatial mapping of the key aquifers and aquitards across Southern Victoria including the geometry of aquifer surfaces and the spatial variation in salinity, potentiometry and yield; and,

- To provide a digital framework for the storage and analysis of bore data used to interpret the aquifer geometry and properties.

Approach

An aquifer definition and naming framework was developed for the study area based on the outcomes of workshops of hydrogeological professionals. The framework developed is broadly consistent with the 'ArcHydro-Groundwater' concept where a large number of geological units are grouped into a smaller number of 'hydrogeological units (HGUs)' which are then grouped into a smaller number of aquifers/aquitards. Unlike other mapping projects in the area, this project maps the aquitards separating the aquifers thus providing a full 3 dimensional aquifer definition.

A database was developed which provides a consistent format for the storage of raw and interpreted data. The raw data includes bore information such as groundwater levels, groundwater salinity, bore construction, lithology and stratigraphic interpretations. The database has been built on a SQL platform to allow access by multiple users concurrently and allows users to assign layer elevations from raw lithological data and tracks the authors of the interpretation. The database and associated spatial products are designed to be up-dated and refined over time.

Results and findings

The outcome of this project is a 3-dimensional representation of the main aquifers in Southern Victoria integrated with the associated bore data. The following surfaces were created:

- elevations of aquifer/aquitard surfaces (see Figure 2 – next page)
- aquifer salinity (see Figure 1)
- aquifer potentiometry
- approximate bore yields for a given pumping time and drawdown based on outputs from the Theis equation
- water table depth and elevation

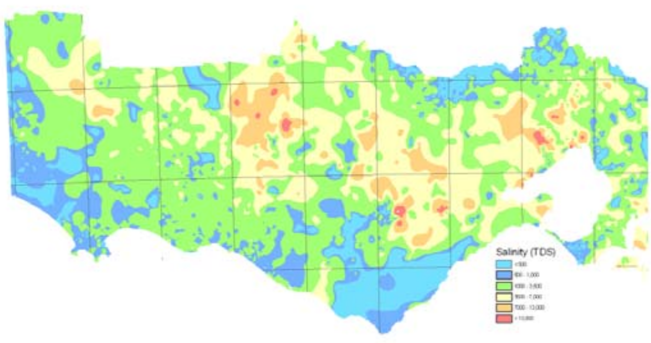


Figure 1: Water table salinity in SW Victoria

Implications and Benefits

For the first time, this project provides a consistent framework for the definition of aquifers across Southern Victoria and management of the associated bore data. The information can be used to conceptualise aquifer geometry and behaviour, and allow bore usage and licence information to be assigned to aquifers. It could also facilitate redefinition of the lateral and vertical boundaries defining Groundwater Management Units.

The data model also has the ability to be expanded to link, store and interpret other related data such as surface water flow and quality for rivers, rainfall, evaporation and recharge information. Such an approach allows groundwater (and associated surface water) to be viewed and managed in the context of the full water cycle.

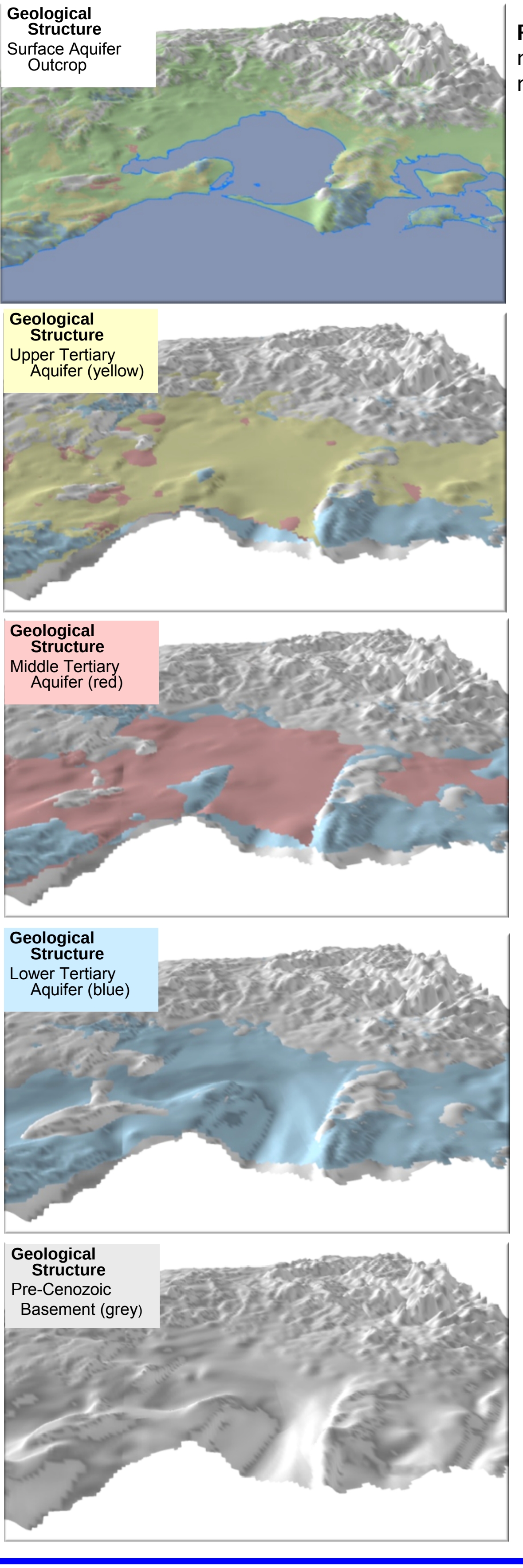


Figure 2: 3D depiction of layers mapped in the greater Melbourne region

3D Hydrogeological Mapping for Improving Groundwater Management in southern Victoria

Terry Flynn
Southern Rural Water

Background

Southern Rural Water (SRW) regulates groundwater in southern Victoria. Greater demand for water brings a greater expectation from the community and Governments that groundwater is well managed. To show groundwater is managed we need to answer; how much water is being taken and from where? how much new water is available and where? how will extraction impact on existing users and the environment? how is/will climate impact on its availability? In the absence of simple answers to these questions SRW embarked on a project to map hydrogeology in its region to improve the management of groundwater.

Objectives

- Map groundwater
- Provide information to governments and community
- Improve management
- Protect our business

Figure1. Lower Tertiary aquifer potentiometry in south-west Victoria

Approach

SRW wanted a map that was technically robust and could be updated and improved.
The specification included the construction of separate GIS based layers containing hydrogeological information (e.g. potentiometry, salinity yield) for specific aquifer units at 1:250,000 scale shapefiles. Work was tendered to SKM/GHD and completed in June 2009.
Project engaged with industry experts to ensure conceptualisation is valid and will be accepted. The maps are based on interpretation of existing bores, academic studies, geological surveys, geological and hydrogeological maps, and geophysical logging.

Results and findings

3D Hydrogeological mapping:

- allows us to manage to aquifers rather than the incomplete management area coverage that currently exists.
- Provides an opportunity to quickly analyse the hydrogeology.
- Dramatically improves the presentation of groundwater information.
- The process of developing the maps creates a new understanding of groundwater and organisation of data.
- Is a new platform for storing, interpreting and reporting data.

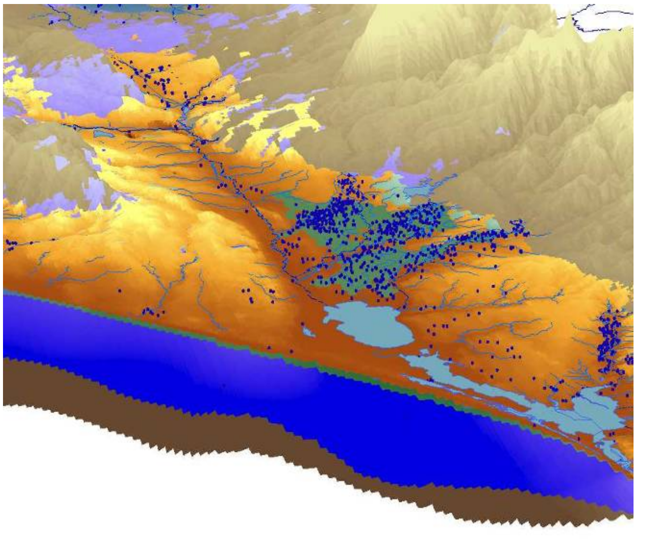


Figure 2. 3D View along the Latrobe Valley showing bores, outcropping aquifers and bedrock

Implications and Benefits

The mapping is the start of a groundwater strategy for southern Victoria.

The maps will be used in the development of a groundwater atlas of our region.

The underlying database offers a systems based approach to groundwater resource management. When combined with licence data and other information e.g. landuse, the mapping is a very powerful tool for communication and analysis. The project also goes a long way toward establishing SRW's credentials as an effective groundwater manager.

Southern Rural Water
Managing Water. Serving Communities.

The Need for Better 3D Conceptual Models of Aquifers in the Murray-Darling Basin

B.F.J. Kelly[1,2] and B.M.S.Giambastiani[1,3]
[1]The University of New South Wales
[2]National Centre for Groundwater Research and Training
[3]Connected Waters Initiative

Background

There are many challenges ahead as we learn how to better manage the allocation and movement of water throughout the Murray-Darling Basin (MDB). A significant step towards better management is acknowledging the complexity of the alluvial aquifers and working out how to capture this complexity in our water management models.

The Need for Complex Models

MODFLOW models currently used for sustainable yield estimates throughout the MDB consist of 1 to 3 layers. These models may be suitable for water balance estimates but other questions cannot be answered:

· At what rate and along what pathways is the shallow saline water, which commonly occurs throughout the MDB, being drawn towards the extraction zones?

· What is the pathway of connection between the recharge zone and the zone of extraction, and what is the transit time?

· Is managed aquifer recharge possible?

3D Geological Modelling Environments

There are many advanced 3D geological modelling packages on the market. However, the algorithms behind many of the processes are not public, and the direction of development is driven by commercial interests. Students and researchers need an accessible 3D geological modelling environment to allow for the evolution of ideas and processes. Many of the pieces exist. There are scripting languages like Python, Maple, *Mathematica*, and Matlab that have good database connectivity and come with high quality 3D visualisation tools. These scripting environments allow for the rapid construction of 3D geological structural models (Figure 2), and are ideal nonparametric modelling environments (Figures 3, 4 and 5). Stochastic modelling of the facies can be done using GSLIB or SGEMS. These models can then be imported into MODFLOW or FEFLOW. The skills required to use all these components at the level necessary to model our catchments has traditionally not been widely integrated into our University courses. These skills will be taught through the National Centre for Groundwater Research and Training.

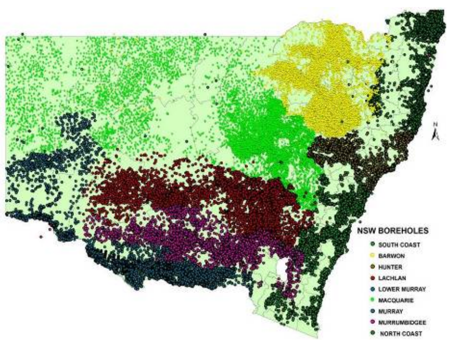
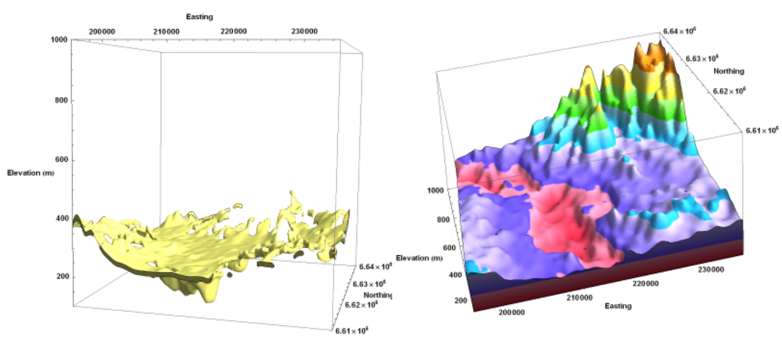


Figure 1: Borehole locations in New South Wales, Australia.

Modelling Complex Aquifer Geometry

The New South Wales State government has extensive borehole data records (Figure 1). Driller logs can be interpolated to yield a comprehensive 3D facies model. Geostatistical methods are often used for modelling facies (Deutsch 2002). The major steps are 1) establish large scale geological structures, 2) within each zone use object-based simulation to model palaeochannels (Keogh et al. 2007, Pyrcz et al. 2009) 3) populate each facies using an appropriate geostatistical or nonparametric classification technique (Dubois et al. 2007, Tartakovsky et al. 2007). Research within the NCGRT will be validating the appropriateness of existing algorithms and developing new methods for predicting facies at locations where samples have not been taken.



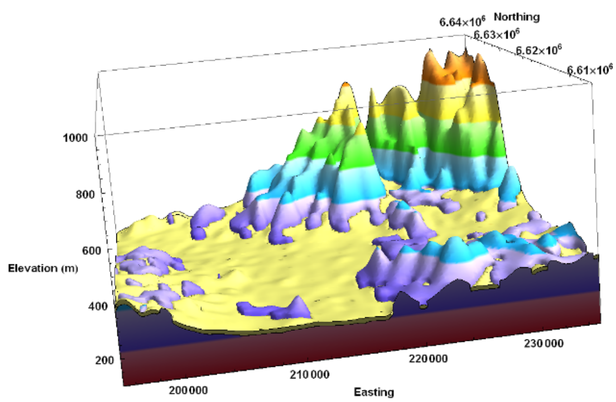


Figure 2: A 3D geological structural model of the Maules Creek Catchment, constructed using *Mathematica*.

The Need for Better 3D Conceptual Models of Aquifers in the Murray-Darling Basin

Implications and Benefits

In Australia, the application of 3D conceptual aquifer models has been limited, compared to the level of adoption throughout Europe and North America. Through the development of accessible software and procedural documents it is hoped that the use of 3D geological conceptual models will be common for:

- data integration,
- conveying the complexity of alluvial aquifer systems throughout the MDB and other alluvial aquifers throughout Australia,
- characterising contaminated sites,
- developing framework models for input into groundwater flow modelling packages, and
- communicating groundwater processes to all stakeholders.

For the size of the country and the number of groundwater management issues Australia is confronting there are too few hydrogeologists. Through the new ARC/NWC co-funded National Centre for Groundwater Research and Training we aim to increase the number practitioners with the skills required to analyse, communicate and manage our groundwater resources. Providing accessible software is critical for the universal adoption and practice of constructing 3D geological conceptual models to advance the management of Australia's aquifers.

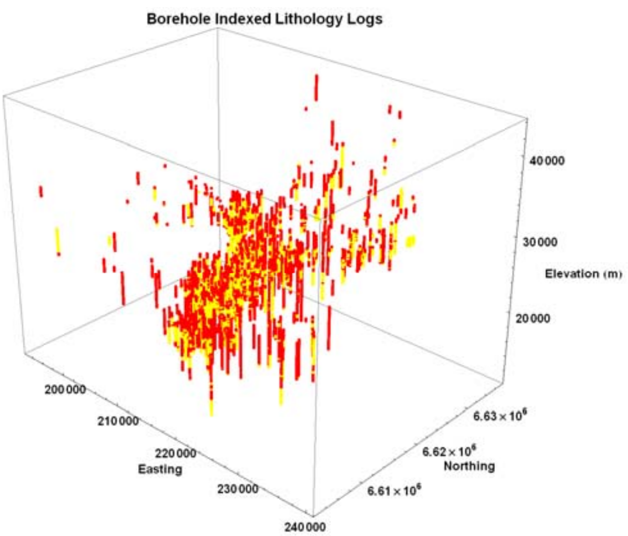


Figure 3: Indexed driller logs in the Maules Creek catchment. Yellow high and red low hydraulic conductivity.

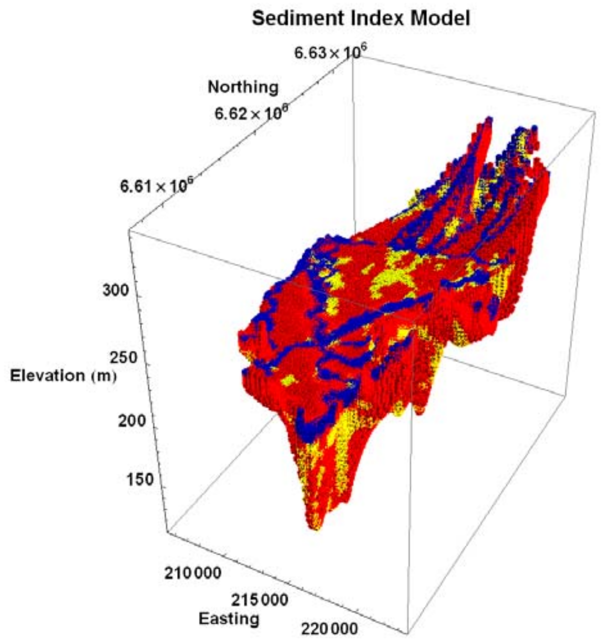


Figure 4: A 3D geological categorical model of the Maules Creek Catchment constructed in *Mathematica* by gridding the indexed driller log data using k-nearest neighbour. This model provides the framework for a groundwater flow model. Streams indicated by blue cells.

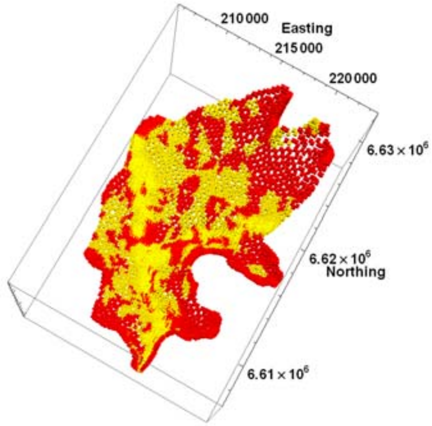


Figure 5: A layer from the k-nearest neighbour model shown in Figure 4. Yellow high and red low hydraulic conductivity.

References

Dubois M.K., Bohling G.C., Chakrabarti S. (2007) Comparison of four approaches to a rock facies classification problem. Computers and Geosciences, V33, 599-617.

Deutsch C.V. (2002) Geostatistical Reservoir Modeling. Oxford University Press.

Keogh K.J., Martinius A.W., Osland R. (2007) The development of fluvial stochastic modelling in the Norwegian oil industry: A historical review, subsurface implementation and future directions. Sedimentary Geology V202, 249-268.

Pyrcz M.J., Boisvert J.B., Deutsch C.V. (2002) ALLUVSIM: A program for event-based stochastic modeling of fluvial depositional systems. Computers and Geosciences doi:10.1016/j.cageo.2008.09.012.

Tartakovsky D.M., Wohlberg B., Guadagnini A. (2007) Nearest-neighbor classification for facies delineation. Water Resources Research, V43 W07201, doi10.1029/2007WR005968.

Associate Professor Bryce Kelly,
UNSW, National Centre for Groundwater Research and Training
bryce.kelly@unsw.edu.au

3D Hydrogeology for engaging groundwater users and managers

Bruce Gill[1,2], Dr John Webb[1] and Dr Peter Sale[1]
[1]Latrobe University and [2]Future Framing Systems Research, DPI, Victoria

Background

As part of the Department of Primary Industries Victoria 3D hydrogeology technologies project, a PhD running in parallel is exploring the 'human interactions with the technology' side.

The study is primarily researching the question "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 in going ahead with 3D mapping and visualisation technology, it seems a valid question to ask; 'What sort of visualisations will be more effective and valuable in building understanding?

Objectives

- Understand current groundwater management needs and processes and best management practices
- Understand groundwater users and managers needs
- Survey user and manager to measure current understandings and perceptions of the groundwater resource
- Record responses and reactions to 3D hydrogeology outputs in respect to the research question.

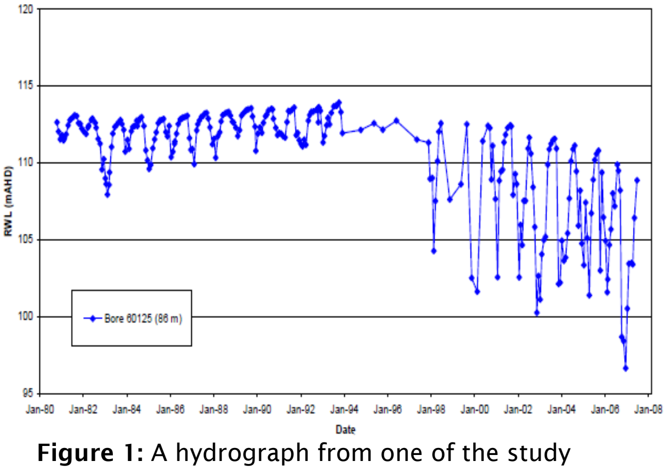


Figure 1: A hydrograph from one of the study areas showing increased pumping stress on the aquifer.

Author: bruce.gill@dpi.vic.gov.au

Approach

Gaining a sound understanding of current best management practices in groundwater resource management from around the globe through the literature review is currently underway.

Understanding how the groundwater users and responsible authority are currently managing groundwater, their current understanding of the aquifers and groundwater processes and possible gaps in understanding are to be investigated through interaction at groundwater management plan meetings and through designed survey methods.

Results and findings

The study is in its early stages now, so findings to date mostly relate to building understanding of the study areas, best management practices from literature and building relationship with groundwater users and the groundwater regulatory authority.

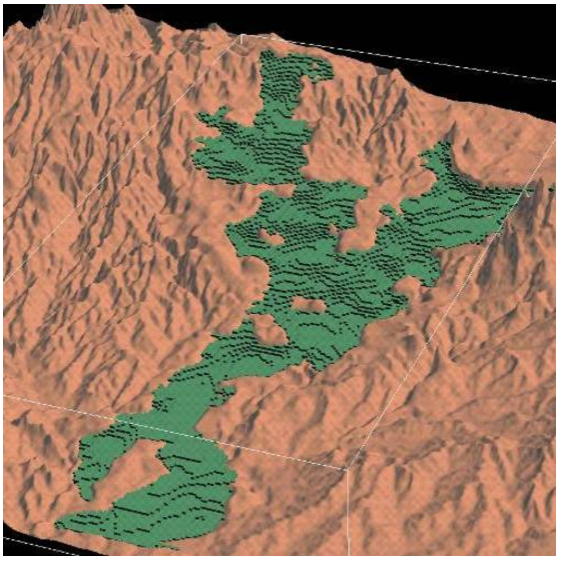


Figure 2: Will stakeholders be satisfied that 3D visualisations DO represent their resource?

Implications and Benefits

There is a real risk that 3D hydrogeology maps and visualisations could be viewed in the same way as numerical models – Mysterious Black Boxes, so there would seem to be good reason to be careful to not over-sell the potential of the new technology. Being explicit about how the images are constructed, their limitations and reliability needs to be considered. The importance of testing products and outputs with real stakeholders to learn about potential pitfalls in the development stages of 3D should help avoid some.

Community Engagement for Development and Application of 3D Visualisation Models – a two edged

Andrew Todd[1 2], Malcolm Cox[1] and Allan James[3]

[1] School of Natural Resource Sciences, QUT; [2] previously SEQ Catchments Ltd; [3]High Performance Computing, QUT

Background

SEQ Catchments Ltd and QUT are collaborating on groundwater investigations in the SE Qld region, which utilise community engagement and 3D Visualisation methodologies. The projects, which have been funded by the Australian Government's NHT and Caring for our Country programmes, were initiated from local community concerns regarding groundwater sustainability and quality in areas where little was previously known.

Objectives

- Engage local and regional stakeholders to tap all available sources of information;
- Establish on-going (2 years +) community-based groundwater / surface water monitoring programmes;
- Develop 3D Visualisation from all available data; and
- Involve, train and inform the local community for improved on-ground land and water use management.

Figure 1: Public demonstration of project results.

Approach

Crucial elements of the community engagement process include a focus on local issues and establishment of a collaborative group that includes both local and regional stakeholders.

A network of private bores (production) was established for regular monitoring of SWL and water quality, and a network of rain gauges was also established. Volunteers measuring SWL were trained in accordance with national groundwater monitoring standards, and supported by a paid coordinator.

Drillhole logs from all available sources were used to map the hydrogeology, and a 3D visualisation model was compiled using GVS software (James et al, this workshop). SWL response to rainfall, triangulation of piezometric surfaces and groundwater geochemistry were used to distinguish between aquifers.

Community participation and the 3D visualisation model were key to raising groundwater awareness and communicating new understandings.

Results and findings

Respectful community engagement yielded information, access to numerous monitoring sites and education opportunities at low cost, which would otherwise be unavailable. A Framework for Community-Based Groundwater Monitoring has been documented (Todd, 2008).

A 3D visualisation models have been developed for basaltic settings, which relate surface features familiar to the local community with the interpreted sub-surface hydrogeology. Groundwater surface movements have been animated and compared to local rainfall using the time-series monitoring data.

An important 3D visualisation feature of particular interest to the community was the interaction between groundwater and surface water. This factor was crucial in raising awareness of potential impacts of land and water use on groundwater and surface water resources.

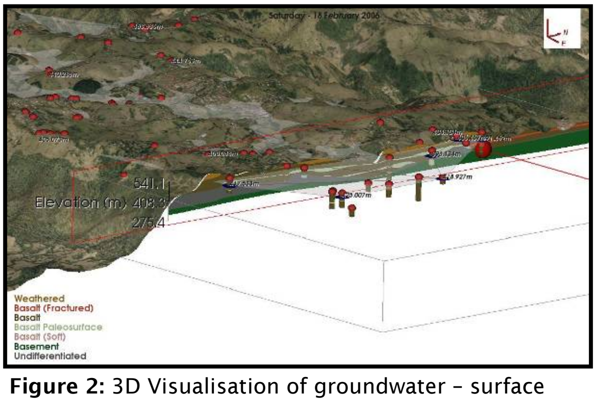


Figure 2: 3D Visualisation of groundwater – surface water interaction.

Implications and Benefits

While groundwater and surface water resource management in SE Qld may be guided by water authorities and/or catchment organisations, the day to day impacts of water and land use are usually determined by the land holder. An effective first step toward improving land and water use practises, is to improve land holder's understanding of sub-surface water movement.

Use of community engagement and 3D visualisation techniques have implications for:

- low cost collection of reliable data for populating 3D visualisation models and improving knowledge of groundwater systems, land use impacts and groundwater-surface water interaction;
- better communication of this knowledge back into the community.

References: Todd AJ, 2008; "A Framework For Community-Based Groundwater Monitoring". South East Queensland Catchments Ltd report.

Contact: atodd@qut.edu.au

Condamine headwater sub-catchments, Queensland – 3D geologic modelling for groundwater applications

Pauline English[1], Steven Lewis[1], Malcolm Nicoll[1], Chris Fitzgerald[1], Jen Levett[2], Julie Sandow[1].
Geoscience Australia[1]
Mira Geoscience[2]

Background

Geoscience Australia has generated a 3D model to conceptualise the key hydrogeologic components of the Hodgson and Kings Creek sub-catchments in south-eastern Queensland (Figure 1). These are headwater tributaries of the Condamine River, situated in the agriculturally important Darling Downs south-west of Toowoomba. Groundwater is an important resource for rural communities and landholders in the area and is used extensively for crop irrigation, stock and domestic purposes, and town water supplies (Figure 2).

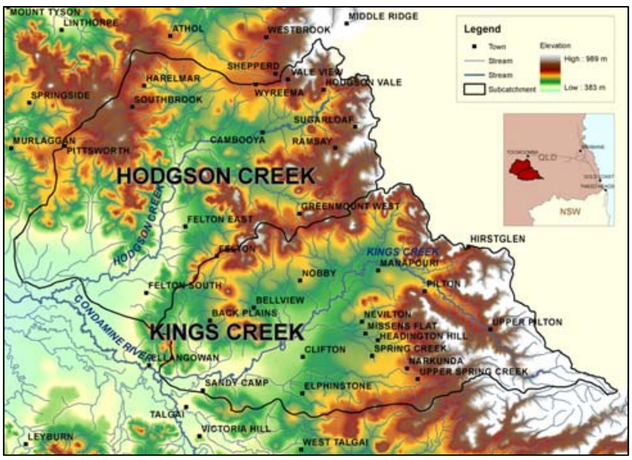


Figure 1. Hodgson Creek and Kings Creek sub-catchments in the upper Condamine River drainage system. Map dimensions 100 km E-W and 80 km N-S.

Hydrogeology

Approximately 80% of groundwater extracted from these sub-catchments is derived from the Main Range Volcanics (MRV). The MRV comprises Tertiary basalts and minor tuffs which are widespread across the Darling Downs and have a nominal thickness of up to 200 m in the study area (and likely up to ~300 m beneath the nearby Great Dividing Range). A significant weathered basalt profile typifies the landscape surface, comprising fertile soils and lateritic material. Sub-horizontal water-bearing zones are predominantly hosted in weathered or vesicular basalt, commonly in the upper parts of individual layers. Local and intermediate groundwater flow systems occur in the fractured rock aquifers of the MRV.

The Jurassic Walloon Coal Measures of the Clarence-Moreton Basin unconformably underlie the MRV and provide locally important aquifers that are regional in scale.

Figure 2. Main Range Volcanics Hills, including eruptive centres; QDNRW staff and a monitoring bore. Sprinkler irrigation, shown, draws on groundwater, Hodgson Creek sub-catchment.

Objectives

The principal objective in building the relatively simple 3D model was to help promote greater understanding and appreciation of the region's groundwater resources among the landholders and communities in the upper Condamine that rely on groundwater but who may not be familiar with concepts and principals which govern it's behaviour and functioning. Thus the aim was to provide a graphic conceptualisation of aquifers and a communication tool within these densely populated, intensively farmed sub-catchments.

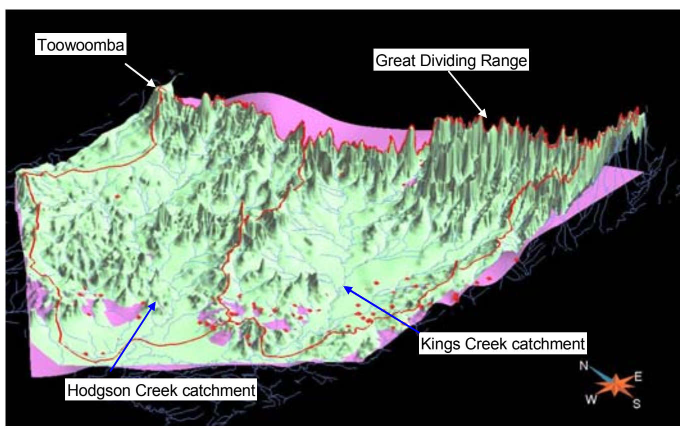


Figure 3. Tilted view looking towards the north-east. This Gocad image shows the disposition of the DEM topographic surface (green) and the uppermost surface of the Walloon Coal Measures (pink).

Condamine headwater sub-catchments, Queensland – 3D geologic modelling for groundwater applications

Methodology

Data from 1100 water bores were selected to build the hydrogeologic model in GoCad™. Data from approximately an additional 1100 bores were excluded because the information contained was deemed unreliable or inconsistent. Critical parameters include borehole collar locations and total depths, the significant water bearing intersections (aquifers) in each hole, and the boundaries or contacts of the hydrostratigraphic units, such as the unconformable contact between the Walloon Coal Measures and the MRV.

The 3D model accurately incorporates the highly heterogeneous surface topography of this distinctive volcanic terrain (Figure 3). Examples of the generated model are shown in Figures 4 to 6. Bore data from outside the sub-catchment boundaries were included to help construct the disposition of the MRV-Walloon surface geometry.

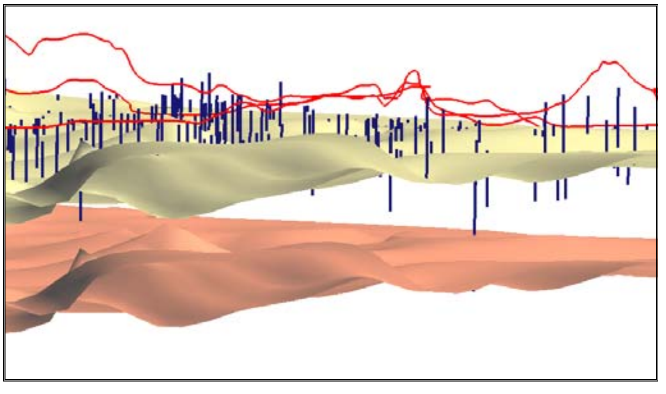


Figure 4. Topographic relief as red outlines which largely represents the top of the MRV. Boreholes are shown in dark blue, the MRV-Walloon contact in yellow, and a base of the model in pink-orange (a theoretical surface).

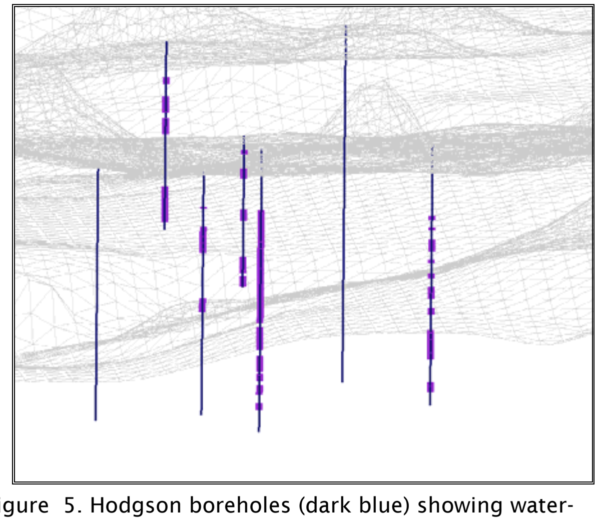


Figure 5. Hodgson boreholes (dark blue) showing water-bearing layers (purple). Dry bores are present, as indicated.

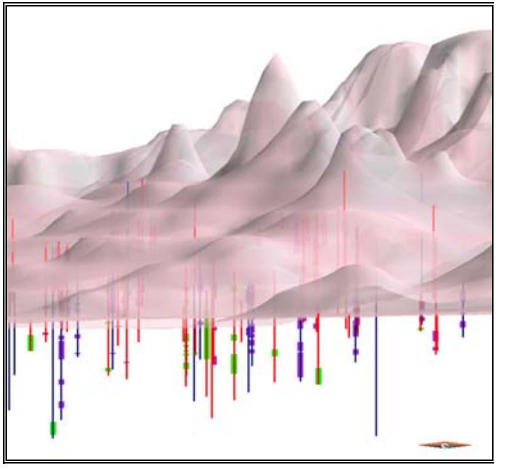


Figure 6. Semi-transparent DEM. Hodgson boreholes (dark blue) , Kings boreholes (red), MRV aquifers (purple) and Walloon aquifers (green).

Results and Discussion

Standing Water Level (SWL) measurements for the sub-catchments proved to be haphazard, spanning some 50 years of observations and encompassing seasonal and decadal-scale fluctuations, and highly variable extraction rates. Creating a single catchment-wide SWL surface was unrealistic; the model would require measurements taken at approximately the same time to generate a 'typical or representative' water table surface (if such an entity exists in these highly heterogeneous basaltic sub-catchments).

Ideally, 3D modelling in the Condamine would best be continued at the sub-catchment scale, given the inherent complexities of the MRV and upland areas and for which there is high density data, rather than a whole-of-catchment scale.

The preliminary 3D hydrogeological model of the upper Condamine sub-catchments has shown the feasibility of building such models in heterogeneous terrain. Importantly, their usefulness as conceptualisation and communication tools, particularly to non-technical audiences, has been demonstrated. The Condamine 3D Model was taken to the Hodgson and Kings Creek sub-catchments and shown to numerous diverse groups across the catchments --- landholders, catchment managers and interested townsfolk --- using Geoscience Australia's portable 3D Visualisation system. These community-based demonstrations were extremely well attended and well received, and promoted unprecedented cross-communication and understanding amongst the key stakeholders using local groundwater resources.

Reference

English, P., Levett, J. Lewis, S. and Sandow, J., 2008. 3D Geologic Modelling for Groundwater Applications in the Condamine headwater Sub-catchments, Queensland. Geoscience Australia Record 2008/03.

Pauline English. Email: Pauline.English@ga.gov.au