XXXVIII IAH Congress

Groundwater Quality Sustainability
Krakow, 12–17 September 2010

Extended Abstracts

Editors:
Andrzej Zuber
Jarosław Kania
Ewa Kmiecik

University of Silesia Press 2010

abstract id: **346**

topic: **3**
Aquifer management

3.3
Geophysical, geological and geochemical methods in groundwater exploration

title: 3D aquifer characterisation: integrating depositional facies architecture and downhole geophysical logs to map heterogeneity and salinity in the Leederville Aquifer, Perth, Australia

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keywords: 3D aquifer characterisation, depositional facies architecture, salinity distribution, downhole geophysical logs, western Australia

Groundwater management of heterogeneous sedimentary aquifers can be difficult due to complex patterns of porosity distribution, groundwater flow and recharge. In such cases a combination of depositional facies architecture and downhole geophysical logs can be used to characterise the aquifer. Depositional setting, interpreted from available drill core, can help predict the geometry and distribution of porous sedimentary units. 3D interpretation and correlation of porous sedimentary units using downhole gamma-ray logs is also aided by the application of depositional facies models. 3D salinity distribution, calculated from downhole resistivity logs, can be used to highlight preferential flow and recharge patterns. We present a 3D model of the Leederville Aquifer, a heterogeneous sedimentary aquifer located in the northern Perth metropolitan area, Western Australia, where this approach has been applied (Fig. 1).

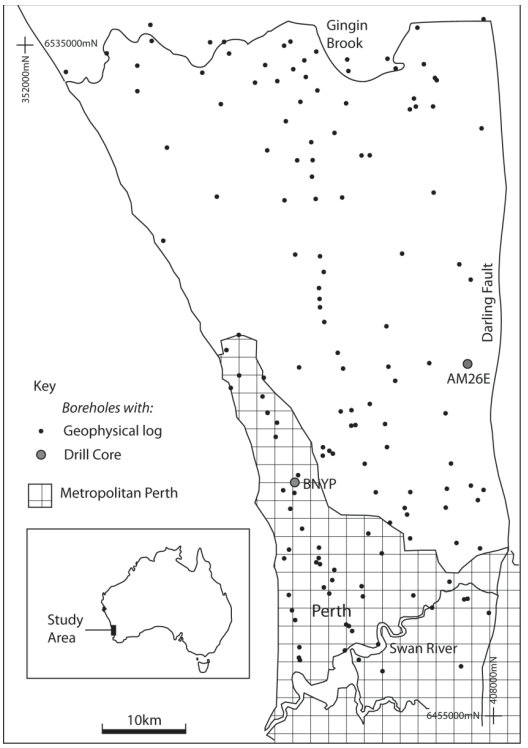

Figure 1. Map showing study area and borehole locations.

The Leederville Aquifer sediments comprise interbedded sand and silt with geological heterogeneity on scales from a few mm to several km. Previous work by the Western Australia Department of Water has identified an irregular salinity distribution that reflects the complexity of recharge and flow patterns. The aquifer is a vital groundwater resource that provides 20% of Perth's water supply and artificial recharge is being trialled in the aquifer as a groundwater management tool. It is one of several sedimentary aquifers within an extensive aquifer system, and is composed of ~300m of Early Cretaceous sedimentary strata deposited in the Perth Basin following break-up of India and Australia, currently divided into 3 members according to geophysical signature. The aquifer is semi-confined and recharge occurs north of Perth where overlying confining beds are absent.

Facies analysis based on sedimentary logging of two cores (140 and 190m long) though the Leederville Aquifer led to the identification of ~20 lithofacies, including clean well-bedded sands, bioturbated silty sands, heterolithic silty sands and silt. These lithofacies are grouped into seven associations that we interpret as representing deposition in tidal, fluvial and shoreface settings in an overall tidally influenced deltaic system (Fig 2). Tidal sand bodies are sand flats with sheet geometry, while fluvial sand bodies are lenticular channel fills and lobate crevasse splays (Fig. 3b). The tidal and fluvial associations have distinct gamma-ray signatures that we have used to map the distribution of these associations in ~180 boreholes across the basin. The tidal signature is common throughout the study area, while fluvial signature is confined to the eastern margin of the basin (Fig. 3a).

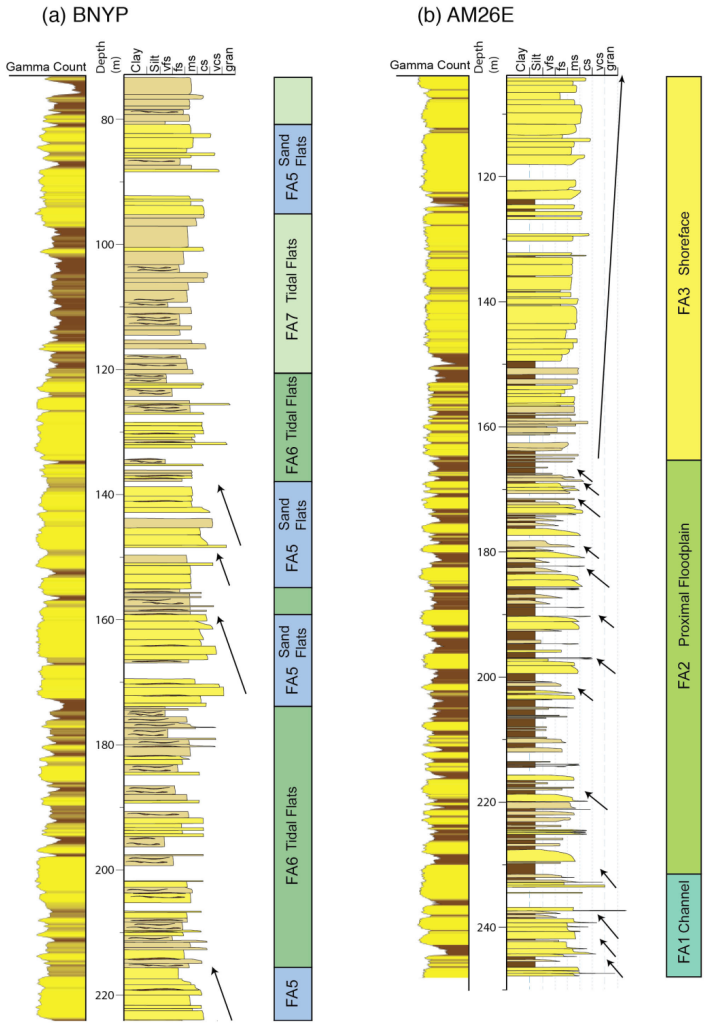

Figure 2. Graphical sedimentology logs of drill cores (a) BNYP and (b) AM26E (dark brown – silt, light brown – silty sand/sandy silt, yellow – sand) showing grainsize trends (arrows) and interpreted facies associations FA1 to FA7. Accompanying gamma-ray logs showing blocky tidal signature and zig-zag fluvial signature.

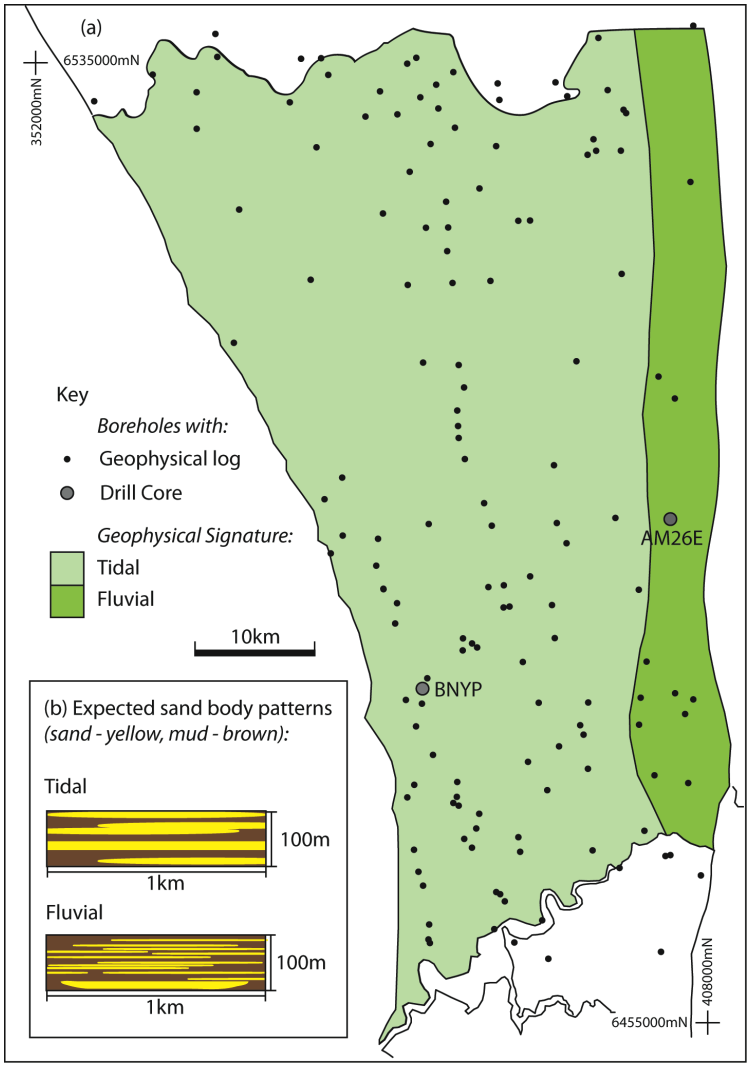

Figure 3. (a) Map showing zones of tidal and fluvial geophysical signature. (b) Cross sections showing expected heterogeneity.

Borehole gamma-ray logs were categorised, interpreted and correlated in 3D, and we outline zones (~10km wide and ~100m thick) of uniform geophysical signature. We redefine the geophysical signature of the three geological members, recognising lateral changes in signature due to variation in depositional setting. Isopach modelling has helped identify previously unrecognised faults and an improved structural model for the aquifer has been constructed, suggesting increased connectivity between the Leederville and overlying and underlying aquifers. The relationship between formation resistivity and pore-water salinity has been established, and synthetic salinity logs have been used to recognise hydrofacies and map a network of water-quality bodies in 3D. Ultimately these geological and salinity models will provide a basis for reassessment of the existing Department of Water numerical groundwater management model.

International Association of Hydrogeologists

AGH University of Science and Technology

2-vol. set + CD
ISSN 0208-6336
ISBN 978-83-226-1979-0