# AIRBORNE GEOPHYSICS APPLIED TO GROUNDWATER MODELLING

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## INTRODUCTION

Effective natural resource management requires an understanding of the interactions between soil, water, flora and fauna. Through this understanding, resources can be augmented to meet the requirements of the land, whether agricultural, conservation or biodiversity. Natural resource management crosses many scientific disciplines (Lawrie *et al.* 2000). Looking specifically at the management of water, the disciplines include geology, geography, meteorology and hydrology. This PhD project looks at the role airborne radiometrics and magnetics play as cost-effective techniques for linking surface and sub-surface water movement controls, integrating geology, geography and hydrology.

## GROUNDWATER MODELLING, RADIOMETRICS AND MAGNETICS

Modern groundwater modelling software packages have the facility to use spatially variable data sets as input parameters to improve their modelling results (from The Waterloo Training Course Series 2002). These inputs include hydraulic conductivity, soil type and bedrock topography. Regrettably, the availability of suitable spatial data sets limits the application of this facility. With the available data, spatial variability is commonly generated from the interpolation of discontinuous sample points, including water bores and farm paddock soil monitoring. The interpolation of these sample points successfully represents spatial variability at larger regional scales (detail 100 m to 1 km). At smaller local scales (detail 10 m to 100 m), the number of sample points used to quantify surface and bedrock characteristics are insufficient to identify local variations. Consequently, the model accuracy is compromised.

Standard radiometric and magnetic airborne geophysical data is acquired at a scale suitable for identifying local “paddock scale” changes (George & Green 2000). Airborne geophysical techniques have the advantage over many ground-sampling techniques of generating a spatially continuous data set. As airborne collection is faster than the average ground-sampling program, the cost of an airborne survey is usually lower and the results available sooner.

The mineral exploration industry routinely collects airborne radiometric and magnetic geophysical data to map and interpret spatial surface and subsurface characteristics of the earth at local scales. However, the format of the geophysical data is not directly applicable to groundwater models and the interpretations are essentially qualitative. The qualitative and quantitative principles behind the interpretation are valid for identifying characteristics of the geology relevant to groundwater modelling. Utilisation of these principals, with new techniques that isolate radiometric signatures, will assist in developing three-dimensional models of the groundwater movement controls.

At present, hydrogeological models using the same input data, with different parameterisation, produce different solutions. Beven (2001) suggests, “*Additional data, or different types of data, might mean that we could reject more of the models that up to now have been*” indifferentiable “*on the basis of the data to hand*." The integration of geophysical data for groundwater modelling will provide groundwater models with additional, different data. It is expected the additional information will act to reduce the number of valid groundwater modelling solutions and refine modelling outcomes, thereby advancing the selection of appropriate land management techniques.

## RADIOMETRICS

Radiometric or gamma-ray spectrometry methods measure the decay signatures of the top 30 cm to 40 cm of the regolith (Cook *et al.* 1996 in Taylor *et al.* 2002). Gamma-ray energy produces scintillation within a detector crystal. The magnitude of the scintillation is proportional to the radiation energy, facilitating photoelectric measurement of the radiation energy. Corrections applied to the data remove excess radiation from background sources and reduce the data to a series of peak energy windows referred to as K (Potassium), Th (Thorium), U (Uranium) and TC (Total Count) channels.

Potassium, Th and U behave quite differently from one another during weathering and pedogenesis (Wilford 2002). Radiometric data is used to define regolith properties using combinations of the K, Th, U and TC

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channels with digital terrain data. Cross-referenced with established soil and rock radiometrics signatures (Bierwirth *et al.* 1996, Wilford 1992, Wilford *et al.* 2001), spatial continuity in regolith classification is achieved. Further interpretation, integrating *a priori* knowledge and field reconnaissance, identifies areas of preferential recharge (Baxter 1994), discharge (Arakal & McConchie 1982 in Dauth 1997, Dickson & Scott 1997), salt stores (Wilford *et al*. 1997) and clays (Bierwirth *et al.* 1996)

However, quantitative soil characterisation from radiometrics still lies just out of reach. Quantitative identification of sand fraction, clay fraction, recharge and discharge and potentially soil density, hydraulic conductivity and soil type are objectives of this PhD project.

**MAGNETICS**

Magnetics is a technique that measures the magnetic field of the earth. Magnetic field variations identify structures and anomalous geological bodies that may not be visible from the surface (Telford *et al.* 1990). The strength of the magnetic field reduces with increased depth. This enables the depth to the magnetic source to be determined through a series of mathematical calculations (e.g., Reid *et al.* 1990).

The bedrock, unweathered solid geological basement, is usually the strongest magnetic field source. Other subsurface magnetic sources, including dykes and sills, are also identifiable in the magnetic data. Whether impermeable to water or simply altering the subsurface hydraulic conductivity, bedrock, dykes and sills influence the flow direction of water movement (Street *et al.* 2002). The degree of influence varies with groundwater depth. As an impermeable layer, bedrock topography is an important hydrogeological modelling boundary.

The distribution of magnetic materials in the regolith assists in identifying subsurface changes that do not reveal themselves at the surface. Inhomogeneous distributions of magnetic materials in the regolith separate texture in a region. Changes in the texture reflect geological changes. If the changes result in alterations to the hydraulic conductivity, flow direction and/or rate of flow are changed. Locating and understanding these changes increase our ability to manage water, reduce water logging and limit salinisation.

There has been significant research in designing programs to identify depth to source and locate textural boundaries over the past two decades (e.g., Reid *et al.* 1990, Buckingham *et al*. 2001). However, the programs developed require expert knowledge of the program algorithm limitations and external qualitative assessment of the results. To advance the application of these programs for hydrogeological modelling, this PhD project aims to identify a robust process for combining available textural filters and depth to source algorithms, to map bedrock topography and other geological changes.

**PROJECT AIMS**

Surface and bedrock topography data sets available for three-dimensional groundwater modelling have limited spatial resolution. The limited resolution compromises the accuracy of the modelling results at local scales. Available airborne geophysical radiometric and magnetic data has the capacity to map local surface and bedrock variations over large areas with detailed, uniform sample density.

In a multi-disciplinary approach, this project aims to improve groundwater modelling by incorporating properties extracted from radiometric and magnetic airborne geophysical data. New techniques for classifying radiometric data will enhance and isolate radiometric soil signatures relevant to land management and groundwater modelling applications. Spectral decay and spatial analysis techniques will extract additional radiometric signatures from the full, acquired radiometric spectrum, outside the standard K, Th and U channel processing range. Correlation between ground control points, such as drill holes and soil samples, and the radiometric signatures will define rules for: i) classifying groundwater recharge/discharge zones; ii) linking hydraulic properties to radiometric data; and iii) potentially enable direct soil element identification from radiometric decay signatures. Commercial and academic magnetic three-dimensional inversion modelling routines will be trialed with available textural filters to assess their ability to generate bedrock topography of the porous regolith suitable for groundwater modelling.

The project will incorporate radiometric and magnetic data acquired from areas in the northern and central Wheatbelt of Western Australia, Elashgin and Toolibin Lake surveys, and the Swan Coastal Plain, Southern Yaragadee survey. Calibration with reserved ground control data over the project areas will verify the accuracy of radiometric soil classifications and assess the accuracy of the bedrock topography model. Predictive uncertainty analysis of groundwater models in the Lake Toolibin and Southern Yaragadee areas will assess the influence of the airborne geophysical data products on the groundwater model results.

Completion date for this PhD project is 2006.

**REFERENCES**

BAXTER J.T. 1994. *Remote Sensing in Victoria Assessment of Various Remote Sensing Techniques for the Mapping of Salinity*. Land and Water Resources Research Corporation **Occasional Paper Series 10/94**.

BEVEN K. 2001. How far can we go in distributed hydrological modelling? *Hydrology and Earth System Sciences* **5(1),** 1-12.

BIERWIRTH P., HARDY S., WILSON P., PHILIP S., SMITH D., HEINER I. & GRUNDY M. 1996. Radio Ga-Ga - Integrating gamma-radiometrics into landscape modelling of soils attributes; results of an ACLEP exchange. *ACLEP Newsletter* **5**, 15-18**.**

BUCKINGHAM A., DENTITH M. & LIST R. 2001. Ridges in magnetic image interpretation. *Future directions in analysis of potential field data: inversion, signal processing, interpretation conference 2001*, Perth, Western Australia.

COOK S.E., CORNER R.J., GRAVOES P.R. & GREALISH G.J. 1996. Use of gamma radiometric data for soil mapping: *Australian Journal of Soil Research* **34**, 183-194.

DAUTH C. 1997. Airborne magnetic, radiometric and satellite imagery for regolith mapping in the Yilgarn Craton of Western Australia. *Exploration Geophysics* **28**, 199-203.

DICKSON B.L. & SCOTT K.M., 1997. Interpretation of aerial gamma-ray surveys – adding the geochemical factors. *AGSO Journal of Australian Geology and Geophysics* **17,** 187-200.

GEORGE R.J. & GREEN A. 2000. Sustainable Land and Water Resources Management Committee (SLWRMC): Position paper on airborne geophysics for salinity and land management, Airborne Geophysics Advisory Group, 1-26pp.

LAWRIE K.C., MUNDAY T.J., DENT D.L., GIBSON D.L., BRODIE R.C., WILFORD J.R., REILLY N.S., CHAN R.A. & BAKER P. 2000. A geological systems approach to understanding the processes involved in land and water salinisation - The Gilmore project area, central-west New South Wales, *AGSO Research Newsletter* 13-32.

REID A.B., ALLSOP J.M., GRANSER H., MILLETT A.J. & SOMERTON I.W. 1990. Magnetic interpretation in three dimensions using Euler deconvolution. *Geophysics* **55**, 80-91.

STREET G.J., PRACILIO G. & ANDERSON-MAYES A.-M. 2002. Interpretation of geophysical data for salt hazard identification and catchment management in southwest Western Australia. *Exploration Geophysics* **33,** 65-72.

TAYLOR M., SMETTEM K., PRACILIO G. & VERBOOM W. 2002. Relationships between soil properties and high resolution radiometrics, central eastern Wheatbelt, Western Australia. *Exploration Geophysics* **33**, 95-102.

TELFORD W.M., GELDART L.P. & SHERIFF R.E. 1990. *Applied Geophysics*. Cambridge University Press, Cambridge.

THE WATERLOO TRAINING COURSE SERIES 2002. Groundwater Modelling, Theory and hands-on applications, 2002. Centre for Groundwater Studies, Perth, Australia, December 9-11.

WILFORD J. 1992. Regolith mapping using integrated Landsat TM imagery and high resolution gamma-ray spectrometric imagery – Cape York Peninsula. Bureau of Mineral Resources Report **Record 1992/78**.

WILFORD J. 2002. Airborne gamma-ray spectrometry. *In:* PAPP E. ed. *Geophysical and remote sensing methods for regolith exploration*. CRC LEME **Open File report 144**.

WILFORD J.R., BIERWIRTH P.N. & CRAIG M.A. 1997. Application of airborne gamma-ray spectrometry in soil/regolith mapping and applied geomorphology. *AGSO Journal of Australian Geology and Geophysics* **17,** 201-216.

WILFORD J.R., DENT D.L., DOWLING T. & BRAATEN R. 2001. Rapid mapping of soils and salt stores using airborne radiometrics and digital elevation models. *AGSO Research Newsletter* 33-40.

WOODS J. 1996. The *Geomorphological Characterisation of Digital Elevation Models.* Ph.D. thesis, Department of Geography, University of Leicester, Leicester, UK.