AIRBORNE GEOPHYSICAL DATA, INCLUDING ELECTROMAGNETICS, ENHANCES RAPID CATCHMENT APPRAISAL IN THE UPPER KENT RECOVERY CATCHMENT

Simon Abbott

CRC LEME, Department of Exploration Geophysics, Curtin University of Technology,
PO Box U1987, Perth, WA, 6845

INTRODUCTION

The Upper Kent Catchment is located northwest of Albany in southwest Western Australia (Figure 1). The catchment covers 110,000 ha, of which approximately 36,000 ha is cleared, mostly in the upper 50% of the catchment. Average annual rainfall ranges from 800 mm in the south-west to 550 mm in the northeast. In the late 1960s increased river salinity was noted and average river salinity has risen from 300 mg/l TSS to 1,500 mg/l TSS in 2000 (Water and Rivers Commission river monitoring data). The state government responded to rising stream salinity by imposing clearing controls in 1978.

Agriculture in the catchment is mixed grazing and cropping with a substantial shift towards cropping and tree farming in recent years. The Upper Kent Catchment is an NDSP Focus Catchment and a Recovery Catchment under the WA Salinity Action Plan, as it is considered a potential potable water resource (Marchisani 1993). In 1994, 39 farmers from the Kent Catchment were interviewed for their opinions about the achievements the NDSP project should deliver in 5 years (Porritt 1994). The desired achievements included a feasibility study of an integrated drainage system for the Kent River and a system of pooling and sharing information via a readily accessible and understandable database of land information. However, farmers have received little of what they desired in the 1994 survey, yet they have been expected to contribute large amounts of time, money and land resources to solutions (Robinson *et al.* 1996). A long history of projects funded by both federal and state agencies have resulted in it being one of the most data-rich catchments in Australia.

Figure 1: Location of the Upper Kent Catchment.

PREVIOUS WORK

Data assembled for the Upper Kent Catchment include the Following:

- Cadastral property and road reserve boundaries;
- Land ownership data;
- Catchment boundary;
- Sub-catchment boundaries;
- Social grouping areas;
- 1 m vertical interval topographical contours from Land Monitor Project;
- 5 m vertical interval contours from World Geoscience Digital Elevation Model (DEM);
- Surface drainage patterns – main streams, creeks and lakes;
- Stream monitoring and gauging sites;
- Data records from stream monitoring and gauging sites;
- Properties for which compensation had been paid for clearing restrictions;
- Bore/drilling sites attributed with location, salinity and depth to basement;
- Rainfall isohyets;
- Road centre lines attributed with road names;
- QUESTEM survey boundary and flight lines;
- Vegetation map attributed with vegetation type and condition;
- Geological interpretation of magnetic data;
- Aerial photo interpretation of shear zones;
- Airborne radiometric data;
- Soils (Churchwood);
- Soils (Farmers) plus radiometric interpretation;
- Landform patterns;
- Land Management Units;
- Depth to groundwater map interpreted from piezometer data;
- Saline scalds – aerial photo interpretation;
- Airborne magnetic data;
- Airborne electromagnetic data.

In 1988 a QUESTEM airborne electromagnetic survey was conducted by World Geoscience Corporation funded by a number of farmers in the catchment, World Geoscience Corporation and the National Soil Conservation Program. The image of apparent conductivity from this survey is displayed in Figure 2 with the surface drainage and catchment boundary. In 1996 The Western Australian Department of Minerals and Energy (DME) published a hydrogeological map of the Albany-Mount Barker area which covers the Upper Kent catchment. This mapping was based on a combination of drill log information and aerial photograph

In: Roach I.C. ed. 2004. *Regolith 2004*. CRC LEME, pp. 2-6.

interpretation. It identified areas of relatively thick alluvial deposits. In 2000 the Water and Rivers Commission produced an orthophoto mosaic of the catchment from colour aerial photography. The Land Monitor Project produced a high resolution DEM of the Upper Kent Catchment capable of producing 1 m interval topographical contours. The Land Monitor Project also produced maps of historical and predicted land salinity in the Kent Catchment.

PREVIOUS INTERPRETATIONS

Most authors agree that most discharge is occurring on or near the valley flats and suggest that the saline water is flowing into the river. However, it is also noted that there are few drainage lines on these flats leading to the river. To resolve this hydrological dilemma it is necessary to identify the main pathways of groundwater movement and the mechanisms that result in saline discharge to the river.

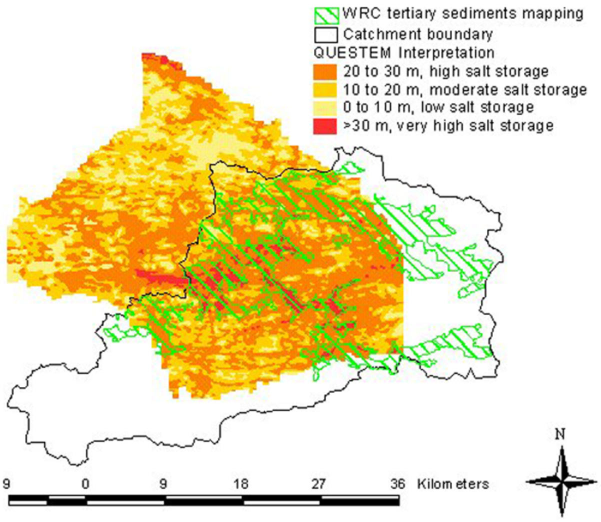

Figure 2: Interpretation/classification of QUESTEM data into four depth/salt storage classes. Department of Minerals and Energy mapping of deep alluvial sediments overlaid on the QUESTEM interpretation showing good agreement.

Palaeovalley sediments occupy 25% of the Upper Kent Catchment (Geological Survey of Western Australia 1996). Ferdowsian & Ryder (1997) noted the capacity of lakes to change from sites of recharge to sites of discharge depending on the relative levels of groundwater and the lake surface. The most comprehensive analysis of the hydrology and hydrogeology of the Upper Kent Catchment was produced by Salama *et al*. (1997) who noted that some of the lakes had become perennial and were operating as discharge sites as a consequence of high groundwater levels. This analysis produced an interpretation of catchment hydrological zones. Although use was made of airborne electromagnetic data, the analysis tended to focus on the two-dimensional distribution of conductance and made little reference to the qualitative information on regolith thickness that the data contained (Figure 2), which represents information that can only otherwise be obtained from extremely expensive drilling programs. Qualitative regolith thickness information, such as that contained in the QUESTEM data, can be used to model basement topography and improve our understanding of catchment groundwater hydrology.

INTERPRETATION METHODOLOGY

Where necessary, data was converted into formats suitable for display in ArcView GIS. The DEM produced by World Geoscience Corporation was used to produce a three-dimensional image of the land surface using the 'Spatial Analyst' and '3D Analyst' extensions to the ArcView GIS. Once made, the DEM can be draped with any co-located raster or vector file and can be viewed from various angles.

Basement topography is a major controlling factor of groundwater behaviour (George 1990, Salama 1997), particularly where the regolith consists of relatively transmissive sedimentary aquifers, as in 25% of the Upper Kent. Drilling provides accurate point information on depth to basement but the low data density (1 drill hole per 1,375 hectares in the Upper Kent) leaves much of room for error. The QUESTEM data provides regolith thickness information over a 25 metre grid. The interpretation (Figure 2) represents landscape conductivity ranging from the lowest (displayed as pale yellow) to the highest (displayed as red). The QUESTEM data is uncalibrated and is, therefore, qualitative. Interpretation involved dividing the data into four regolith thickness/salt storage classes. To add quantitative value to this data, drillers logs and reports for 80 bores were reviewed for information on depth to basement and salt storage. These were obtained from the Water and Rivers Commission's AQWABase data-base, CSIRO and Department of Agriculture drilling records. Based on the known depths to basement and salt storage, the four QUESTEM interpretation classes were allocated (see key in Figure 2).

Good correlations between the DME map of deep alluvial sediments and the QUESTEM interpretation were noted in areas of deep weathering and high salt storage (Figure 2). Drilling sites within the QUESTEM survey area and attributed with depth to basement were plotted in the GIS to further check that the depth classifications were reasonable (Figure 3). This showed that the interpreted depth ranges agreed with depths to basement obtained by drilling.

Interpreted QUESTEM depths to basement were subtracted from the surface digital elevation model to produce a representation of basement topography. This subtraction process produced a new 3D surface, which was assumed to be the bedrock surface (Figure 4). Slope analysis of this surface in 'Spatial Analyst' produced flow direction arrows across the model. Some noise spikes appearing as isolated highs and lows are present, but the main directions of flow are clear and are summarised by the light blue lines in Figure 4. The surface drainage only partially conforms to the basement slope pattern. The Kent River flows over a basement high at approximately the location of the point marked A. This explains the reversed flow direction of the basement flow path under this part of the river channel. The basement flow paths are considered to represent the original palaeodrainage system of Nash (1989).

For confidence in the interpretation we looked for an independent dataset. Figure 5 shows the interpreted palaeo-drainage system overlaid on the magnetic data for the Upper Kent area. The magnetic data indicates that the interpreted palaeodrainage has a strong relationship to geological structure (Figure 5). Similar strong relationships in weathering were seen in the neighbouring Frankland River Catchment by Anderson *et al.* (1995). Structures evident in the magnetic image clearly coincide with the interpreted palaeodrainage lines. This is strong support for the interpretation of the palaeodrainage lines. As expected, weathering and the development of river valleys has been strongly influenced by the east-west metamorphic fabric and cross cutting faults.

IMPLICATIONS FOR GROUNDWATER MOVEMENT

The interpreted palaeodrainage line exits the Upper Kent catchment to the north of the surface drainage channel in a westerly

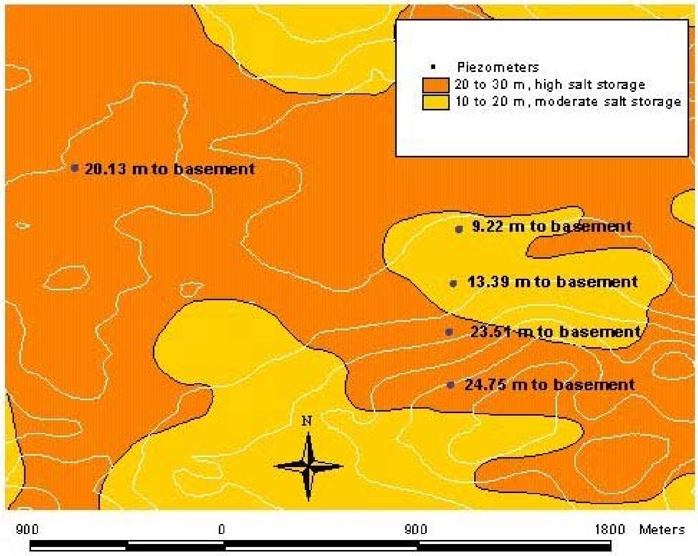

Figure 3: Located drilling sites with known depths to basement plotted on the interpreted depth to basement map showing good correlation.

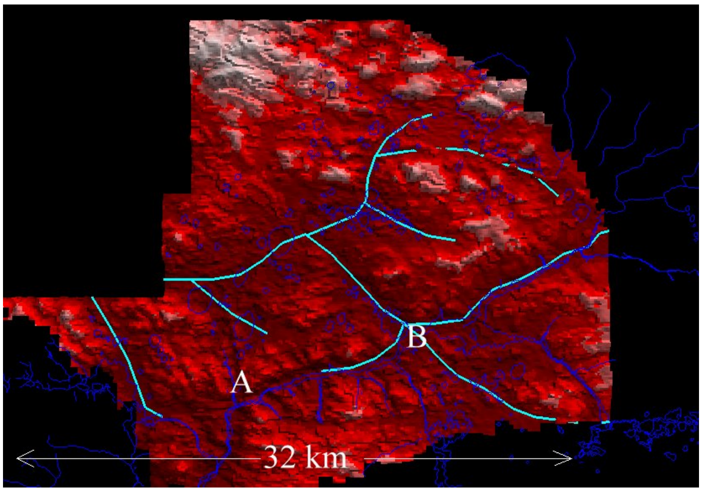

Figure 4: Plan view of bedrock Dem with principal basement flow paths (light blue) and surface drainage (dark blue) overlaid.

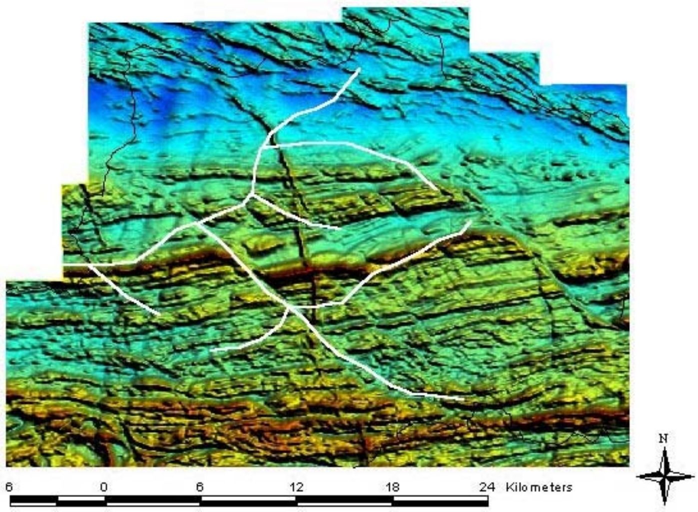

Figure 5 (right): Interpreted palaeo-drainage system overlaid on the total magnetic data for the Upper Kent area. Structures evident in the magnetic image clearly coincide with the interpreted palaeodrainage lines.

direction (Figure 4, 5). Hydraulic head in this direction is provided by groundwater levels being close to the surface in the palaeochannel and more than 30 m depth of sedimentary material providing potential flow paths. Evidence of actual movement of groundwater out of the catchment via the palaeochannel is provided by aerial photography. Figure 6 shows the aerial photograph of an area to the west of the interpreted Kent palaeochannel. This area is located on the eastern side of the adjoining Frankland River Valley. Aerial photographic interpretation of this area indicates a series of hanging swamps and wetlands, occupying an area of approximately 800 ha, perched above the more deeply incised Frankland River and in line with the interpreted palaeochannel. This seepage zone provides the headwaters of two tributary streams to the Frankland River. Unlike the Upper Kent, the Frankland River at this point is a rejuvenated stream with an actively eroding valley. The Frankland River valley has cut through the Kent palaeochannel and the large seepage zone is located at the point of intersection.

Discharge from the palaeochannels also occurs within the boundaries of the Upper Kent Catchment. The interpreted palaeo-flow lines help to identify the most likely locations of such groundwater discharge. Points of convergence of groundwater flow will tend to have higher piezometric heads and potential for discharge. The aquifers in the palaeo-sediments of the valley flats behave as unconfined aquifers (Salama 1997). Thus, high rates of discharge can occur without high piezometric heads. Within the channel of the Kent River the groundwater convergence zone marked by the point B in Figure 4 is most likely to be a site of significant groundwater discharge to the river.

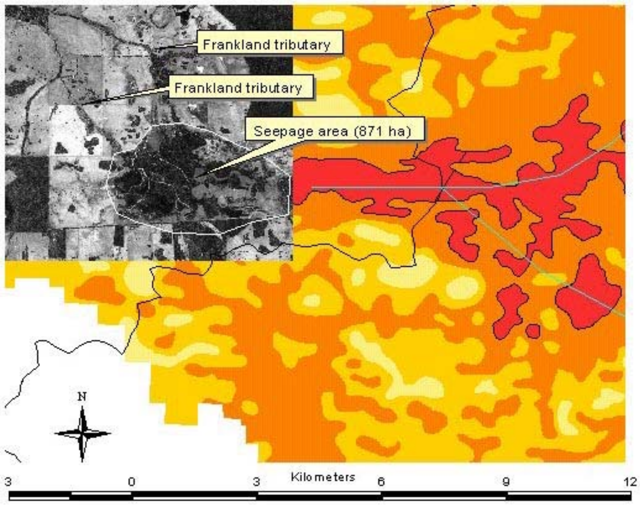

Figure 6: Aerial photograph of an area to the west of the interpreted Kent palaeo-channel.

DISCUSSION

Existing management strategies for the Upper Kent Catchment do not consider the existence of significant palaeochannel aquifers and salt storages. It is important for strategic management of the catchment to know the relative contribution to river flow of groundwater discharge and surface runoff respectively.

The five-year moving average flow volume for the Upper Kent is approximately 32 Gigalitres (Gl). If the whole area of the Upper Kent Catchment had a runoff coefficient of 3% it would produce approximately 21 Gl on 650 mm of rainfall (average of rainfall range across the catchment). Much of the catchment is too flat to produce this rate of runoff. This is supported by local knowledge of water harvesting projects in the area and Clark & Mitchell (1987). The upland parts of the catchment would produce 3% runoff, which would amount to 16 Gl on the same 650 mm. This leaves 16 Gl to be produced from the palaeochannel areas. To do this they would need a runoff coefficient of approximately 10%. The absence of visible surface drainage lines in much of the palaeochannel area indicates that a significant proportion of the measured flow must come from high runoff coefficient of the saturated river bed and groundwater discharge within the river bed. Palaeochannel groundwater has an average salinity of 11,000 mg/l TSS. Therefore a significant proportion of the salt measured in the river is also being delivered by groundwater discharge in the river bed.

CONCLUSIONS

The information on basement slope derived from the electromagnetic data has improved our understanding of the groundwater hydrology as well as the surface water hydrology of the Upper Kent Catchment. The current strategy of encouraging revegetation on the uplands is likely to reduce the quantity of fresh water entering the river. Surface water management structures, although providing production and economic benefits to farmers, are unlikely to influence the fluxes of water and salt described above. This information should be communicated to the Upper Kent Community and particularly to the Kent Recovery Team. The role of the palaeochannel as a reservoir of water and salt should be investigated in more detail.

Acknowledgements: Thanks are due to Mr Argen Ryder (Department of Agriculture, Albany) who provided copies of drillers notes for many of the Department of Agriculture bores. Associate Professor Keith Smettem (Centre for Water Research, University of Western Australia) provided valuable suggestions and encouragement. Mr Greg Street (Senior Geophysicist, Sinclair Knight Merz Pty Ltd) provided critical reviews of the work in progress and this was much appreciated. Thanks must also go to Mr Tom Walsh who provided local knowledge and support for aerial photo interpretation in the Frankland catchment. Thanks also to Mr Brett Ward (Kent-Frankland Salinity Coordinator, Water and Rivers Commission) for permission to use data held by the Commission.

REFERENCES

ANDERSON S., STREET, G.J. & ANDERSON H. 1995. The use of airborne geophysics to understand salinity processes and develop a farm plan on a farm in the south-west of Western Australia. *Proceedings 4th National Conference on the Productive use of Saline Lands*. Albany WA .

BARTLE G.A. WILLIAMSON D.R. SALAMA R.B. & WATSON G.D. 2000. A field study of groundwater in the Upper Kent Catchment in the south-west of Western Australia. *CSIRO Land and Water* **Technical Report 4/00**.

CLARK R.D.S. & MITCHELL N. 1987. Annual rainfall-runoff relations in Mount Lofty Ranges catchments near Adelaide South Australia. *Engineering and Water Supply Department South Australia*. **EWS Library Reference 87/19**.

FERDOWSIAN R. & RYDER A. 1997. Salinity and hydrology of Wamballup Swamp Catchment. *WA Department of Agriculture* **Resource Management Technical Report 160**.

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA 1996. *1:250,000 Hydrogeological Series Sheet SI 50-11 and part of SI 50-15, Mt Barker-Albany*. Compiled by R.A. Smith, WA Department of Minerals and Energy.

GEORGE R.J. 1990. The nature and management of saprolite aquifers in the wheatbelt of Western Australia. *Land Degradation & Rehabilitation* **2**, 261-275. John Wiley & Sons Ltd.

MARCHISANI P. 1993. Albany-Denmark Region Source Review. *Water Authority of Western Australia* **Report No. WP 187.**

NASH C. 1989. *QUESTEM interpretation report*. World Geoscience Corporation, unpublished.

PORRITT S. 1994. *Landholders views of the Kent Catchment and the National Dryland Salinity Research, Development and Extension Program*. Western Australia Department of Agriculture.

ROBINSON B., REES D. & ABBOTT S. 1996. *A consultancy for the identification of the factors affecting the implementation of farm plans from a private consultant's perspective*. Report Commissioned by Department of Agriculture under National Dryland Salinity Research, Development and Extension Program.

SALAMA R.B. 1997. Geomorphology, geology and palaeo hydrology of the Salt River System, W. Australia. *Australian Journal of Earth Sciences* **44(6)**, 751-765

SALAMA R.B., BARTLE G.A., YE L., WILLIAMSON D.R., WATSON G.D. & KNAPTON A. 1997. Hydrogeomorphology and hydrogeology of the Upper Kent River Catchment and its controls on salt distribution and patterns of groundwater discharge. *CSIRO Land and Water* **Technical Report No. 27/97**.