Spatio-temporal variations in floodplain soil/sediment conductivity: Great Darling Anabranch

Kevin Cahill
CSIRO
26 Dick Perry Avenue,
Kensington, WA 6151
kevin.cahill@csiro.au

Tim Munday
CSIRO
26 Dick Perry Avenue,
Kensington, WA 6151
tim.munday@csiro.au

Tania Abdat
CSIRO
26 Dick Perry Avenue,
Kensington, WA 6151
tania.abdat@csiro.au

SUMMARY

Spatio-temporal information on the distribution of salt in floodplain soils and groundwater is integral to effective floodplain management strategies along the Great Darling Anabranch in NSW. Geophysical technologies have the potential to provide detailed spatial information on the variability of salt stored in the near surface and for monitoring surface water -groundwater interactions across the floodplains, and in particular looking at the spatial controls on those processes. The research sought to examine the role of hydrogeophysical methods in monitoring changes in floodplain sediment condition, linked to ecological investigations.

A two stage investigation, to examine the role of a low cost, near surface, geophysical method for monitoring changes across several sites located adjacent to the Anabranch. It represented a short term spatio-temporal investigation of inundation on salt in the floodplain.

Our results clearly show changes in the near-surface conductivity distribution at the sites surveyed. These changes are attributed to variations in the flows over the year, pumping of groundwater and changes in vegetation.

The survey shows that EM techniques are a useful tool in aiding our understanding of floodplain processes resulting from changes in flows along the Anabranch and can be applied in other floodplain environments as a low-cost survey to observe changes in conductivity in the near surface.
It is an effective method to monitor variations in conductivity in the floodplains due to changes in environmental flows and can aid in understanding changes in sediment conditions and be used to validate floodplain processes, contributing to ecological investigations of river floodplains.

Key words: Electromagnetics, floodplains, Darling River Anabranch.

INTRODUCTION

Spatio-temporal information on the distribution of salt in floodplain soils and groundwater is integral to the development of effective floodplain management strategies along the Great Darling Anabranch in NSW. It is particularly important as an aid to our understanding of the links between surface flow manipulation, groundwater pumping and artificial recharge on soil salinity and floodplain vegetation health. Geophysical technologies, and most notably electromagnetic methods, have the potential to provide detailed spatial information on the variability of salt stored in the near surface and for monitoring surface water – groundwater interactions across the floodplains; and in particular looking at the spatial controls on those processes. In a collaborative investigation, CSIRO and the Murray-Darling Freshwater Research Centre sought to examine the role of hydrogeophysical methods in monitoring changes in floodplain sediment condition, linked to ecological investigations.

There are a range of geophysical techniques that measure the conductivity (or resistivity) of different parts of the subsurface profile. For fine-scale studies, supporting vegetation management on salinizing floodplains, these methods are most appropriate. There is a broad literature describing applications of land-based electromagnetic methods for identifying contrasting electrical conductivities between fresh and saline-saturated materials (e.g. McNeill 1990; Ruppel et al., 2000; Stewart 1999; Berens et al. 2007) which is essentially the issue being addressed on the floodplains of the Great Darling Anabranch in NSW. Ground based electromagnetic (EM) techniques provide information in the spatial sense of between 1 and 100m depending on the system used and sampling procedure adopted. For studies such as vegetation health investigations on salinised floodplains that rely on spatial detail, they compare well with airborne methods (see Munday et al., 2004). Ground EM is also well suited to resolving conductivity variations linked to salinity in the top 5m of the ground surface.

METHOD AND RESULTS

In floodplain settings, the depth of the sediment penetrated and the signal received by the ground EM system depends on the type of electromagnetic induction equipment used and the water, clay and the total soluble salt content of the material (e.g. Williams and Baker 1982; Williams and Hoey 1987). In studies conducted over many landscape in Australia, detailed investigations have revealed that the total soluble salt content as it relates to the effective depth of penetration of the electromagnetic (EM) signal, commonly accounts for 70 to

80% of the variation observed in the apparent conductivity values.

The ground EM surveys at each location provide fine scale spatial information of variations in conductivity across the sites. Variables that may influence the observed conductivity include: variations in water levels, variations in groundwater salinity, presence of perched freshwater lenses, variations in moisture and salt content due to downward leakage of applied surface water during artificial flooding or evapotranspiration, and the texture of the near surface sediments (although in saline environments like the Murray-Darling floodplains this is a less significant component). Changes in topography also need to be considered, as resistive areas can be attributed to an increase in elevation resulting in an increase in the distant between the surface and conductive groundwater (Fitzpatrick et al., 2007).

For the purposes of this study we employed two continuous single frequency systems, specifically a CMD- Explorer and a CMD 4. Data acquisition was via walking or quad-bike. In areas of relatively open country, the quad-bike facilitated the rapid acquisition of conductivity information in the near surface, and was the most commonly used mode of data acquisition. A Bluetooth GPS connected to a PDA was used to log GPS positions and apparent conductivity data simultaneously. Two surveys were conducted in December of 2011 and 2012 over eleven sites (cf Figure 1).

The observed ground response of the three coil spacing's for the CMD Explorer and the Vertical and Horizontal Magnetic Dipoles of the CMD-4 were gridded and where appropriate the observed response was corrected for the Low Induction Number (LIN) effect using the methodology described by Reid and Howlett (2001).

Results from each survey at each site were gridded (Figures 2 and 3), and a difference grid made by subtracting the earlier survey from the latter survey.

At sites where there was little interaction between the anabranch and the bank very little changes in the distribution of conductivity were observed. Sites located on changes in the anabranch direction shifts in the distribution of conductivity were observed that are consistent with gaining or losing banks. Small scale features indicating movement of water along channels from high ground to the anabranch were observed in the data. At some sites these channels correlated with observed erosion having occurred between the period of the two surveys.

.

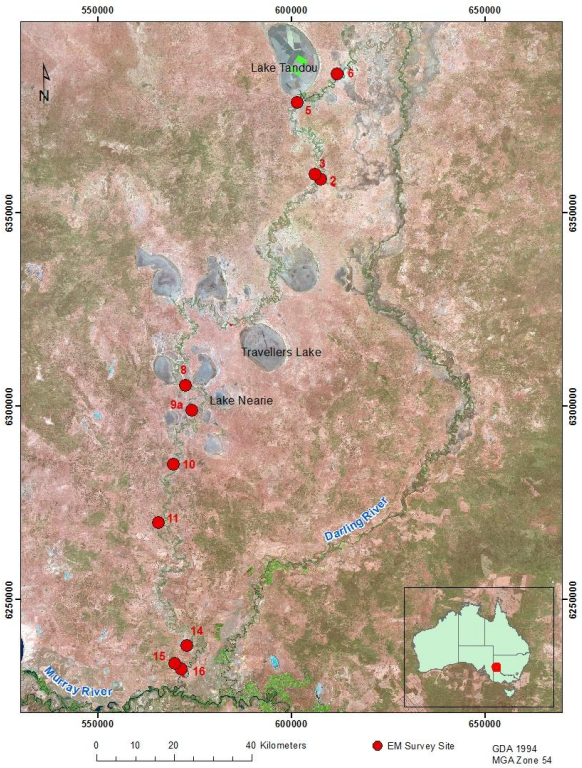

Figure 1. Location of the study sites along the Great Darling Anabranch.

CONCLUSIONS

The survey showed that EM techniques are a useful tool in aiding our understanding of floodplain processes resulting from changes in flows along the Anabranch and could be applied in other floodplain environments as a low cost survey to observe changes in conductivity in the near surface.

Even though these types of systems are self calibrating the precision of this type of temporal survey could be improved by calibration of the system at the start of each survey especially in areas where high conductivity values are anticipated.

It is an effective method to monitor spatial variations in conductivity in the floodplains due to changes in environmental flows and can aid in understanding changes in sediment conditions and can be used to validate floodplain processes, contributing to ecological investigations of river floodplains.

ACKNOWLEDGMENTS

We gratefully acknowledge the assistance of Deborah Bogenhuber in helping set up the project and for her ongoing help in to the field program. Funding for this project was provided by the Murray Darling Freshwater Research Centre and CSIRO Water for a Healthy Country National Research Flagship.

REFERENCES

Berens, V., White, M.G., Souter, N.J., Jolly, I.D., Holland, K.L. McEwan, K.L., Hatch, M.A., Fitzpatrick, A.D. and Munday, T. J., 2007, Surface Water, Groundwater and Ecological Interactions along the RiverMurray. A Pilot Study of Management Initiatives at the Bookpurnong Floodplain, South Australia, Near Surface 2007 conference proceedings, Istanbul, Turkey.

Fitzpatrick, A.D., Cahill, K.J., Berens, V., Hatch, M.A., and Munday, T.J., 2007, Ground Electromagnetic Surveys: Chowilla Floodplain, South Australia. CSIRO EM Restricted Report No: P2007/565

McNeill, J.D., 1980, Electromagnetic Terrain Conductivity Measurements at Low Induction Numbers: Mississauga, Ontario, Canada, Geonics Ltd. Technical Note TN-6, 15 p.

Reid, J.E. and Howlett, A., 2001, Application of EM-31 terrain conductivity meter in highly-conductive regimes: Exploration Geophysics, 32, 219-224.

Ruppel, C., G. Schultz, and S. Kruse. 2000. Anomalous fresh water lens morphology on a strip barrier island. Ground Water 38, no. 6: 872–881.

Stewart, M.T., and R. Bretnall. 1986. Interpretation of VLF resistivity data for ground water contamination surveys. Ground Water Monitoring Review 6, no. 1: 71–75.

Williams B.G, Baker G.C, 1982 An electromagnetic induction technique for reconnaissance surveys of salinity hazards. Australian Journal of Soil Research 20, 107–118.

Williams B. G, and Hoey D., 1987 Electromagnetic induction to detect the spatial variability of the salt and clay contents of soils. Australian Journal of Soil Research 25, 21–27.

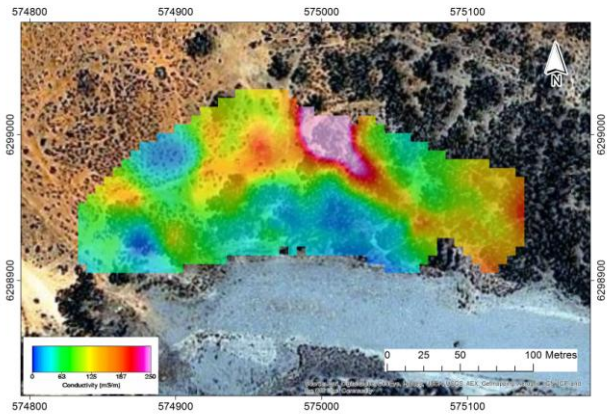

Figure 2. Gridded results from December 2011

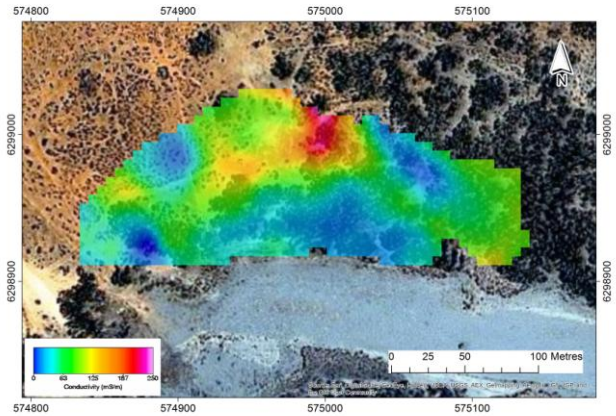

Figure 3. Gridded results from December 2012

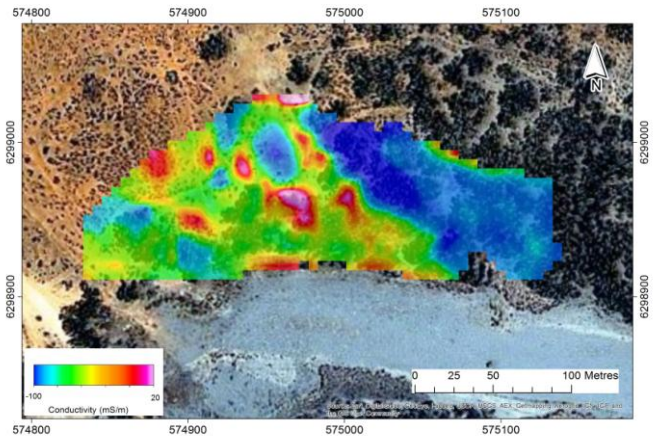

Figure 4. Difference grid obtained by subtracting 2011 survey observations from the 2012 observations highlighting changes in bulk conductivity to a depth of approximately 6 metres.