Regolith to the Rescue

Innovative application of regolith science and new geophysical techniques to natural resource management in upland and lowland regions of the Murray-Darling Basin

Dr R Dennis Gee
Dr K Lawrie
Dr Tim Munday
CRC LEME
17 February 2005

Summary

High-resolution, shallow-penetrating airborne electromagnetic (AEM) data, when processed using new 'constrained inversion' techniques, and integrated with other geoscientific data, delivers a powerful predictive tool to aid the management and mitigation of sub-surface salinity. That new tool is a three-dimensional model of regolith architecture, salt stores, and ground water salinity. Its application will bring tangible economic, environmental and social benefits to regional Australia.

The Scientific Base

Another promising dimension has been added to the fight against salinity. CRC LEME has successfully injected the new knowledge and technology of regolith science into salinity mitigation and remediation in rural and regional Australia.

Beneath our subdued and deceptively simple landscapes lies a carapace of regolith draped over complex and rugged palaeo-landscapes. Regolith is the surficial blanket of weathered rock, redistributed detritus, sediments, soils and biota that forms by the natural processes of weathering, erosion, transport and deposition. It has complex architecture, and may be hundreds of metres thick. Regolith underpins our economic, social and infrastructure systems. It hosts or hides mineral deposits, we live on it, we grow our food in it, it is the foundation of major engineering works, and much of our water supplies pass through it. It also holds – somewhat tenuously - the natural stored salts that have potential to degrade our rural lands and water resources.

A key to salinity mitigation is an understanding of the three-dimensional architecture of the regolith, so as to more reliably predict - at both regional and catchment scales - groundwater recharge and flow and secondary salt stores.

The electrical conductivity of the regolith can be used as a direct surrogate for determining its salt, water and clay contents. The spatial distribution of regolith conductivity can be mapped in three dimensions using electromagnetic (AEM) surveys from airborne platforms. This technology is borrowed from the mineral exploration industry and adapted to address natural resource management issues. Innovative three-dimensional mapping of conductivity that is constrained by sedimentological models and bore-hole data, and fully integrated with other geographic datasets, is producing spectacular results. In particular settings it can be regarded as the land management tool of the future. We illustrate this in two areas within the greater Murray Darling Basin. These innovations have been developed by a team led by Program Leader Dr Ken Lawrie

Blanchetown Clay, Riverland, South Australia

The Murray River winds its way serenely through the Riverland region of South Australia – notable for its high value agriculture and horticulture. Yet it is presently estimated that some 500 tonnes of salt are discharged into the river per day from this stretch of the Murray. There is a damage cost to this discharge which can be measured by engineering mitigation costs, damage to downstream infrastructure, lost opportunity for downstream agricultural use, and environmental degradation. For every tonne of salt load there may be a downstream cost of $65,000. Downstream damage from this stretch of river is of the order of $50m.

Discharge to the Murray River comes from the natural discharge of a highly saline groundwater but it is well established that these inflows have been exacerbated by irrigation development through the Riverland. Good quality river water (approx 400 mg/l) is drawn from the Murray and used for irrigation. A significant portion passes through the soil and regolith profile to the watertable where it builds a groundwater mound that increases the flow of high salinity groundwater (approx 30,000 mg/l) into the Murray. Further, dryland agriculture is likely to cause a significant increase to these inflows into the future.

Zones of high saline discharge have been mapped by a floating EM platform towed by a small dinghy. This system measures the three-dimensional distribution of water conductivity in the river volume. This can then be converted into a salt load. River EM added value to routine in-river salinity monitoring and to run-of-river EC measurements to locate salt discharge points. The worst discharge points relate to porous and permeable parts of the Loxton-Parilla Sand aquifer, and are beautifully portrayed on the EM conductivity images. The initial in-stream nano-TEM survey was carried out by the Department of Water, Land and Biodiversity Conservation SA (DWLBC) and Zonge Engineering using improved equipment and processing techniques from earlier work by a CRC LEME MSc student Brian Barrett at Adelaide University, for a modest outlay. The system was recently used in an operational survey commissioned by the Murray Darling Basin Commission and the Mallee CMA to collect baseline data in the Murray for a stretch over 650km.

Through the NAPSWQ-funded South Australian Salt Mapping and Salinity Management Support Project, CRC LEME partnered with a consortium of State and Commonwealth agencies to significantly improve the understanding and management of the complex Riverland system.

From existing bore-hole drilling data, the normally porous sand under the irrigation area is known to also contain relatively impermeable clay layers (Blanchetown Clay) lying above the watertable. It was important then to know the distribution of clay layers within the sand. This was done by using a helicopter AEM survey and specially developed data processing software (constrained inversion) to map the conductive layers. The AEM data picks up the salty watertable, but most importantly, the clay layers above the watertable. The clay layer has a higher electrical conductivity relative to sand. In effect the clay layer turned out to be a discontinuous patchy sheet looking somewhat like holey Swiss cheese. Our knowledge of its distribution has helped better determine areas where current irrigation loads can be sustained (that is above the clay), and areas where irrigation might be curtailed (holes in the clay). The clay map is also helping in irrigation zoning, and in improving efficiency of use of irrigation water.

Salt interception schemes (SIS) are the most economically viable engineering mechanism that can adequately meet salinity reduction targets. Nevertheless, capital cost is expensive – estimates range from \$42m and \$162m in this Riverland stretch. By identifying the salinity ‘hotspots’ along the Murray River bank using the floating EM system, and by using information on the variability of the Loxton-Parilla Sands aquifer obtained from the airborne EM data, we are now able to better advise on the development of these schemes, and maximise the effect of site-interception bores and then minimise cost. Information derived from CRC LEME’s science was integrated with existing information and other technologies to provide improved data for numerical groundwater models and the design phase of SIS, which are being developed collaboratively by CSIRO Land & Water, Department of Water Land and Biodiversity Conservation and SA Water. Long-term potential benefits in NPV terms may be of the order of \$300-400 million.

Balonne River Inland Fan

The lower terminal part of the Balonne River in southeast Queensland is a large inland alluvial fan with subdued surface expression. Its hydraulic underflows feed the head regions of the Darling Basin. It supports a burgeoning cotton industry that relies on irrigation. It is known to contain quality groundwater resources interspersed with saline lenses. There is currently minimal evidence of surface salinisation, but potential exists for a decline in quality of surface and ground waters. The challenge was to map this curious distribution and to understand the groundwater flow patterns.

LEME’s research was undertaken in conjunction with the Queensland Department of Natural Resource Management, the Australian Bureau of Rural Sciences, local catchment managers and cotton irrigators. Our demonstration project evaluated the use of airborne geophysics (time-domain AEM, and gamma radiometrics) for 3-D mapping of stacked flood plain deposits and groundwater flow systems. The AEM survey was the largest ever conducted in Australia for investigating salinity issues.

The derived landscape evolution model reveals complex regolith architecture, a fault controlled palaeo-valley at depth that hosts a fresh-water aquifer, and juxtaposition of fresh and saline aquifers near the surface. The 3-D regolith model when integrated with hydrogeochemical data, then allows interactions between surface water and ground water to be modelled. The model reveals disconnected aquifers in nested groundwater flow systems beneath the low relief landscape. However the characteristics of the groundwater flow systems are determined by the relief of hidden buried landscapes. High salt loads within the regolith have been highlighted, and some are near assets such as river systems and groundwater resources.

The project has shown that AEM data can be used to target groundwater resources. For example, the AEM delineated electrically-resistive lobes within the upper alluvial aquifer. Subsequent investigations showed these lobes contain low salinity groundwater. Derived salt load maps identified a number of areas with elevated salt loads that will require appropriate management and possible intervention. The new Balonne model will guide land management practices that should lead to reduction in salinity risks and more efficient water management. It highlights areas in danger of salinisation if current practices are maintained.

The Innovations

Hitherto, most salinity research has looked exclusively at the surficial soil-riverine environment. For the first time in natural resource management, CRC LEME has applied regolith science to analyse the total systems within thick regolith below the surficial environments. We have used helicopter-borne electromagnetic techniques to map groundwater aquifers in three dimensions, and have deployed new constrained-inversion software to identify salt stores within groundwaters and clays. We now have the tools to understand the three-dimensional dynamics of groundwater recharge and discharge in environmentally sensitive areas. The floating EM is technology totally new to the practices of natural resource management.

National Benefits

These two studies apply to contrasting settings in the greater Murray-Darling Basin – one in the headward region, and the other in the lower riverine environment. Both settings are subject to their own bio-physical processes that create salinity hazards and prescribe different salinity mitigation approaches. But the understanding gained from the application of regolith science and new-generation geophysics, can be applied to total riverine-groundwater systems over large parts of inland Australia.

This will enable more informed decisions to be made on land management practices, which will bring considerable socio-economic benefits to many regions affected by salinity. Economic benefits will include: preserving and enhancing groundwater resources, constraining the scope and lowering the capital costs of major engineering mitigation projects, optimising land-use practices, and reduction of environmental degradation costs. Quantifiable benefits are of the order of many hundreds of millions of dollars.

The role of the CRC Model

These successful developments spring from two important ingredients. Firstly, the bringing together of multi-disciplinary researchers, including post-graduate students from several parties, fosters a true collaborative approach. Secondly, the contractual nature of the projects requires close liaison at all stages with the clients and stakeholders, which ensures practical applications of research and outcomes of national value. The CRC model brings together the multi-parties and multi-disciplines, and is the ideal mechanism for effective delivery of this type of research.

Figures to complement the article

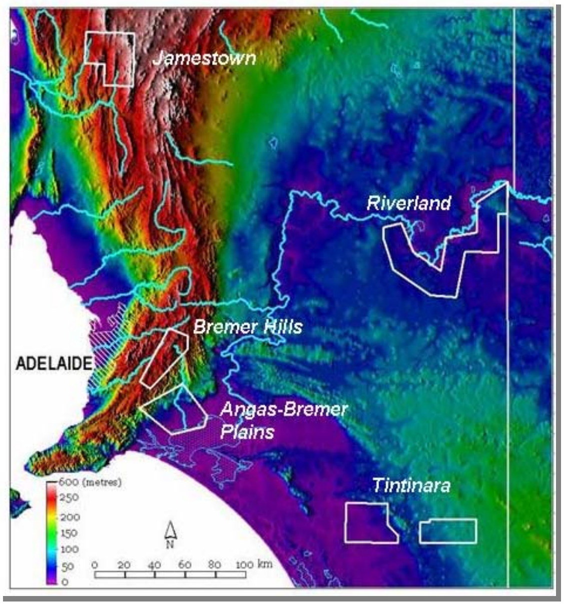

Figure 1: Locality Map of the Riverland area, South Australia, on a digital elevation model (DEM)

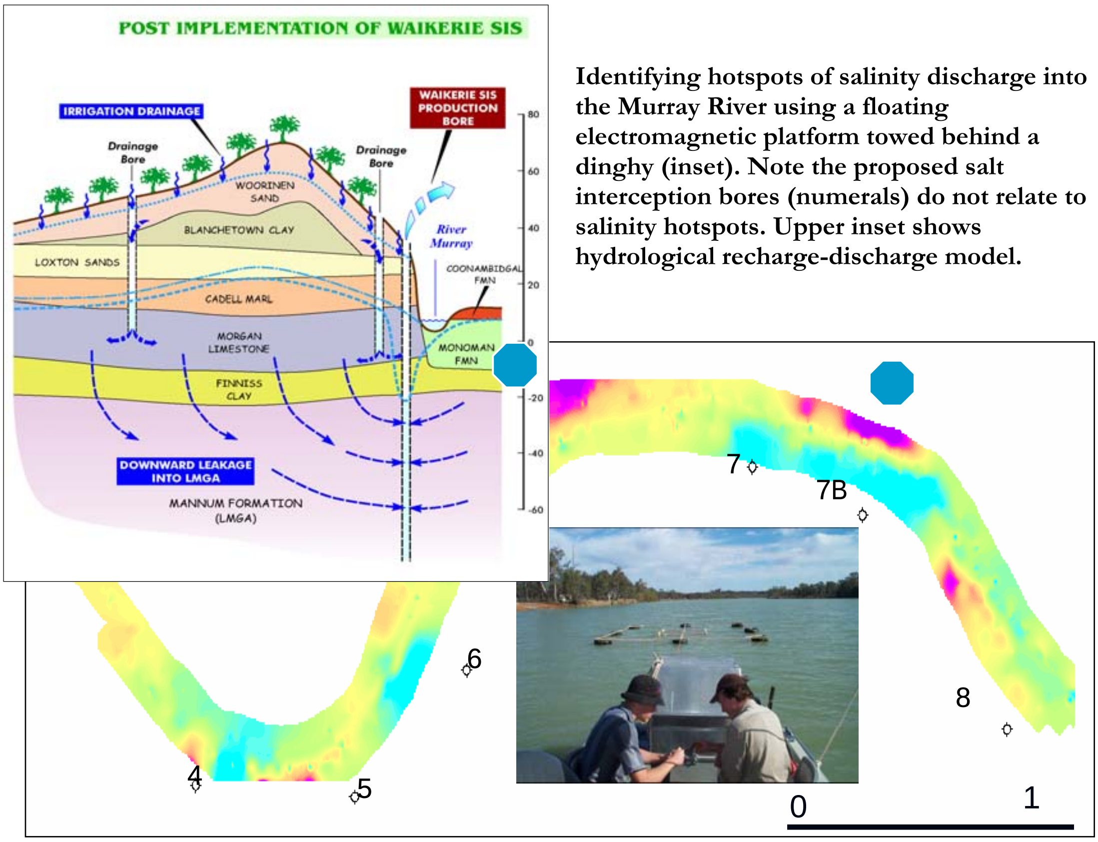

Figure 2: Composite illustration showing the high salinity discharge points (red) into the sinuous Murray River, deduced from the three-dimensional distribution of electrical conductivity of river water, measured remotely from a floating electromagnetic pontoon towed behind a dinghy. The upper inset shows the deduced hydrogeological model.

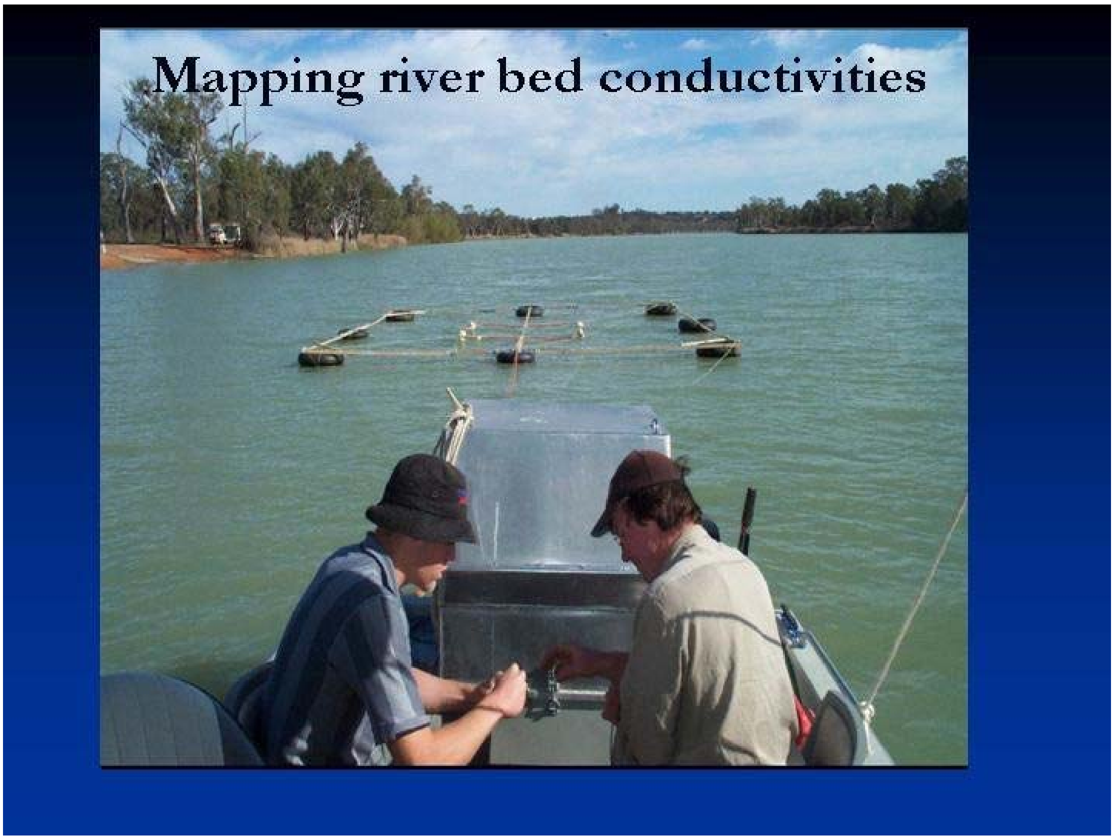

Figure 3: Close view of the floating electromagnetic pontoon. The larger outer square loop is the electrical input loop, in contact with the water, and the smaller inner square loop is the receiving loop. The computer is on board the dinghy.

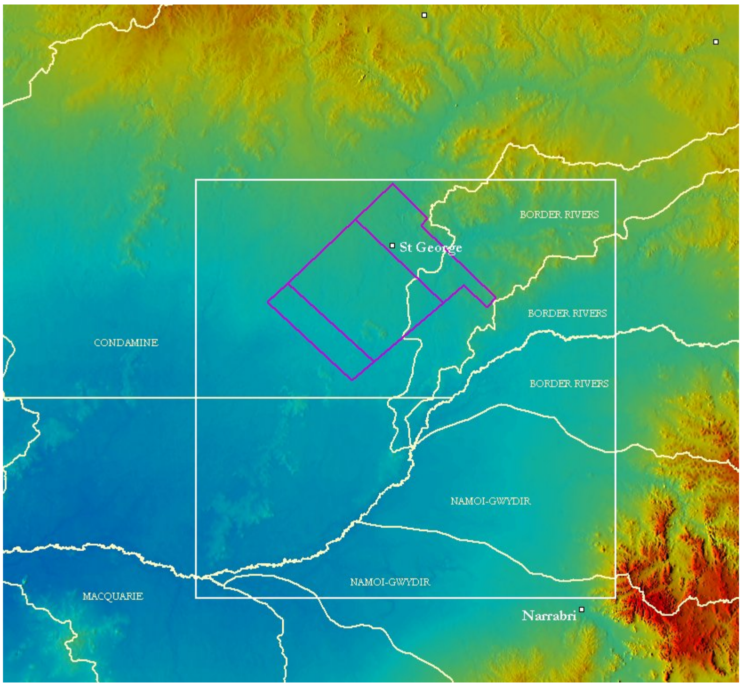

Figure 4: Locality map of the inland delta of lower Balonne River, shown on a DEM.

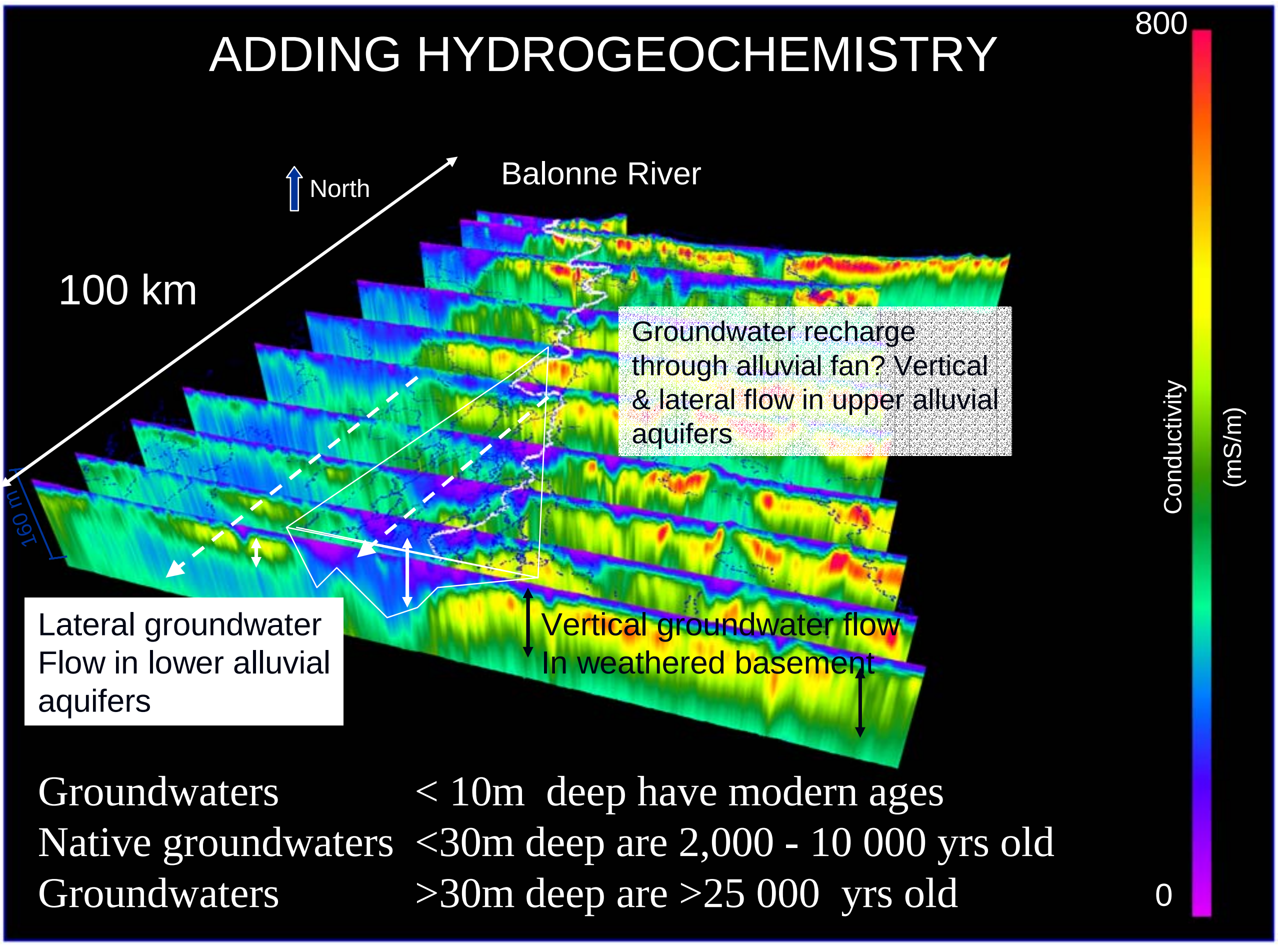

Figure 5: Airborne electromagnetic conductivity-depth sections across the Lower Balonne study area, assembled to show geological and hydrological features in three dimensions. The moderate and high conductive zones (green and red) are shallowly buried weathered basement rocks, capped by shallower saline groundwaters. The blue resistive volumes on the left define the thickening of quaternary sediments which hosts a deeper permeable aquifer of good quality groundwater. Note the sinuous and braided course of the current Balonne River, whose interactions with groundwaters can be predicted.