Clever salinity management using the science, the policy, the people and the on ground actions

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Abstract The NSW salinity audit and subsequent modelling confirms that despite the past seven years of drought, the area of land affected by dryland salinity is increasing in the Murray catchment. The NSW Murray Catchment Management Authority has a philosophy of continuous improvement and is developing a prioritisation program so that on ground works and public investment is effectively targeted. The salinity strategy has adopted a whole of landscape approach that embraces sustainable management through; alignment with regional, state and national policy frameworks, informed understanding of the environment through data collection, collaboration with the scientific community to ensure new and emerging information is transferred and utilised within on ground programs and an initiative to include community in an education and monitoring program. Gathering information to improve current knowledge is fundamental to the salinity program as it is recognised that Electrical Conductivity is a limited measure. Hence, the current research within the catchment is seeking to identify the types of salts, relative ratios and how different concentrations of cations and anions can affect river and stream condition. Data collection projects to support activities are undertaken by sound rationalisation combined with methods to stratify soil and geological characteristics. The concept advocates efficient use of human and economic resources to improve the ecological systems upon which we all depend.

Introduction

Regional bodies require a clear and increasing understanding of the political, social, economic and ecological factors to enable them to act and effect positive change for the improvement of the natural resources. With severe drought conditions during the past seven years, dryland salinity in the Murray Catchment may not be considered a pressing issue in a contemporary sense. However, predictive modelling, and preliminary investigations indicate that the issue remains considerable with the potential to detrimentally affect the economic wealth of the region, and threaten the integrity of the natural resources. Clearly there is a need to advocate for scientific research that will answer questions that remain outstanding in regards to salinity management in the Murray Catchment. Neilson *et al* (2003) suggests that managers need to know more about the relationship between flow patterns, salt concentrations and environmental damage to predict consequences of management actions.

NSW Murray Catchment

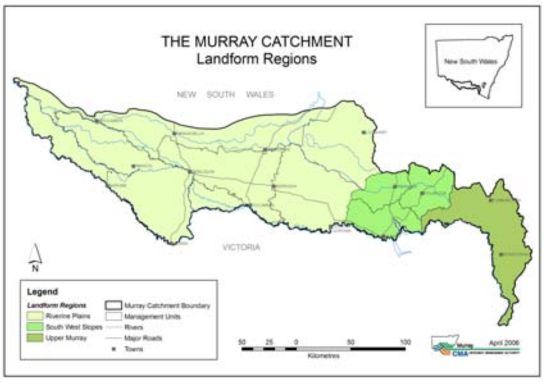

Figure 1 Landform Regions

The NSW Murray Catchment spans an area of 35,170 square kilometres and it is bounded by the Murray River to the south, the Murrumbidgee River catchment divide to the north, the Australian Alps to the east and the confluence of the Murrumbidgee and Murray rivers to the west (CAP 2007).

Three distinct physiographic regions have been identified in the Murray Catchment, the Upper Murray the South West Slopes and the Riverine Plains and according to GHD (2008) these regions are closely related to the underlying geology. 77% of the catchment has been developed replacing the natural vegetation in preference for agro ecological systems, i.e. cropping and grazing and also irrigation, horticulture and forestry industries prevail.

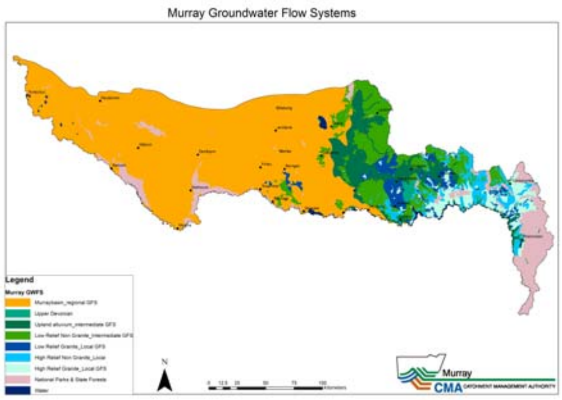

Figure 2 Groundwater Flow Systems

The total value of on-farm agricultural output in the Catchment in 2001 was estimated at $1070 M, which is 12% of the total value of agricultural output for NSW (ABS 2001).

Background context

In 2002 the National Land and Water Audit (NLWA) predicted that NSW would contain land of high hazard or deemed to be at risk of dryland salinity increasing from 181,000 ha to 1,300,000 ha by 2050 (Commonwealth 2001). The 1999 Salinity Audit also predicted large rising trends across inland NSW however; the Audit update (due to be released in 2008) indicates spatial variability of salt mobilisation processes enabling more reliable estimates of the current status and future trends (Audit extract nd).

In 2004 the Murray Darling Basin Commission reported that approximately 40,000 ha of land (dryland) in the Murray Catchment had water tables at less than 2 m with a prediction that this would increase to 300,000 ha by 2050 (MDBC 2004). Within the irrigation district 70,000 ha of land had water tables at less than 2m in 2000 with a prediction that this would increase to 470,000 ha by 2020. The amount of salt exported from the catchment to the Murray River was estimated to be 126kt/yr and predicted to increase to 167kt/yr by 2020. The eastern part of the catchment or more specifically the South West Slopes (SWS) was estimated to contribute 80% of the total salt load with 17% exported from the irrigation areas.

Institutional arrangements

Over the past seven years the National Action Plan for Salinity and Water Quality (NAP) devolved a high proportion of resources directly to the regional bodies including the Murray CMA. NAP funding (June 2004 - June 2008) for dryland salinity management within the Murray Catchment totalled $37.8 M. 80% of the funding was directed to on ground works, 15% for administrative costs and 5% allocated to monitoring, evaluation and reporting to meet the 80:15:5 rule as required.

The initial investment was determined by targets set within the '*Murray Catchment Blueprint'*, a previous incarnation of the regional NRM investment plan. This has now been superseded by the *Murray Catchment Action Plan* (CAP), a strategic document deemed by the state of NSW to be a fundamental core business activity requiring state and federal approval. The CAP, approved in 2007 is the key policy document for the Murray CMA to guide investment until 2016.

Murray CMA investment context

Prior to the establishment of the Murray CMA in 2003 and the development of the CAP, the *Murray Catchment Blueprint* prepared in 2002 by the Murray Catchment Board determined the direction and agenda of regional natural resource management and included an end of valley water quality salinity target. The target aimed to return to average 2000 salinity concentration level at the Murray river downstream of the Wakool junction by 2020 (230 EC median and 285 EC the 80^{th} percentile). There was an objective to maintain and improve water quality but overall catchment health was to be enhanced through land based activities (Murray Catchment Blueprint 2002). The activities outlined in the *Blueprint* included areas to be enhanced where high salinity risk was reported, priority groundwater flow systems identified and targeted and on ground actions were designed to lead to landscape recovery. In addition a set of principles were applied to the end of valley target, i.e., dilution flows as a management option was not acceptable and addressing the cause of salinity through best management practice was a priority. Investigations to evaluate salt interception schemes, remediation works at known saline discharge sites, the establishment of woody vegetation in salinity priority areas, perennial pastures, plantation forestry and improving landholder knowledge were all key actions arising from the *Blueprint*.

To support the on ground works program a regional salinity risk mapping exercise was undertaken by Watson in 2001. This is now however considered to be generally large scale with extremely low resolution and only represents regions having a high salinity risk/hazard at some time in the future as apposed to actual salt outbreaks at a specified time (GHD 2008). Additional to the regional risk mapping a GIS based model was developed in 2002 to map salinity risk at the sub catchment scale however this has been assessed as limited in application as the output data is not useful for spatially explicit projects.

The development of priority setting for GFS systems within the Murray catchment for the *Blueprint* was originally developed via technical advice, an audit and modelling but it is now evident that the scarcity of accurate and reliable field data to complement the desktop reviews was critical and limiting.

Consistent with the assumptions and hypothesis presented by the National, State and Regional bodies, strategies were developed for the SWS where saline groundwater discharges from more localised and intermediate Groundwater Flow Systems (GFS) exist. The recharge control options focused on the reinstatement of perennial based systems (perennial pastures and strategic native revegetation) as this was considered to be cost effective when compared to the difficulties presented with the management of the large, regional alluvial aquifers of the Riverine Plains.

From June 2004 – June 08 the Murray CMA committed funds to an extensive portfolio of activities, in particular on ground programs have encompassed; perennial pasture projects, strategic woody vegetation, the Green Gully salinity remediation project, the sustainability with saltbush project, the Tuppal Creek Management Plan, Meeting in the Middle (a collaborative and innovative program, to improve soil health and soil biology), discharge site management, remnant vegetation management, western catchment sodic soils project, Slopes to Plains Conservation and precision agriculture, seed bank services, revegetation, riparian works and engineering and earthworks projects.

Changing management and policy environment

In four years since the publication of the collective national, state and regional salinity strategies there has been a shift in policy, management approaches and the level of understanding regarding predictive modelling and the application of knowledge. There is now support given to multiple criteria management options which are increasingly being applied by the NSW Murray CMA to achieve natural resource condition improvement.

The Murray Darling Basin Salinity Audit (nd) and the NSW Audit reveals that in the southern half of the state rising EC trends are widespread in all but the steep areas. The Billabong Creek at Walbundrie in the Murray Catchment continues to record a rising trend. The Audit notes that there is a need to more closely monitor areas where saline outbreaks are causing problems, but from a management perspective, the challenge is not so much about managing the advent of future problems but to contain or reduce existing problems (Murray Darling Basin Salinity Audit nd).

The key policy drivers of the Australian Government are more inclusive than previously stated and include the following areas; water scarcity and demand, impacts of groundwater extraction on surface water, stream salinisation, groundwater connectivity and environmental water needs and ecosystem health (www.connectedwater.gov.au/water' accessed 26 March 2008).

The Murray Catchment faces a challenging future as climate models indicate there will be a decline in rainfall, and reductions in water availability predicted to impact on all sectors of the economy, with particular industries such as agriculture being affected. In addition the impacts of unseasonable and intense rainfall events such as those events recorded during late 2007 in parts of the catchment present a whole new challenge for managing salinity and understanding methods to minimise salt mobilisation.

There is also growing recognition that the provision of a quality assurance system is fundamental to the certification of public investment in order that strategic landscape recovery programs deliver to the optimum expectation of the community and investors.

Building on the past

As it was recognised by the Murray CMA that insufficient data existed to enable investment decisions to be made at the optimum level, a range of activities have been initiated during the past 3 years to improve the situation. These include; fostering partnerships with key research and scientific bodies, a data collection and surface water quality salinity study, a hydrogeological data review and a community based education and participation initiative. It is these initiatives that provide the basis for improved salinity management within the Murray Catchment in the future.

MCAS-S

In 2006 a spatial prioritisation process was undertaken for the West Hume area. The purpose was to trial a method that could support investment in landuse change aimed at achieving multiple environmental benefits (Hill, Cresswell and Hubbard 2006). The study area was approximately 86,000 ha and includes previously identified salinity and biodiversity priority areas. MCAS-S, a multi criteria analysis shell for spatial decision support constructed by the Bureau of Rural Sciences (BRS) was utilised as it has significant advantages for data visualisation, it is a simple tool for integrating and exploring spatial information (Commonwealth 2007) and may be applied at any scale from paddock to catchment. MCAS-S is also particularly useful for the allocation of financial grants to individual landholders.

The study area was sufficient in scale to include groundwater flow systems with relevance to landuse mosaics necessary for biodiversity enhancement.

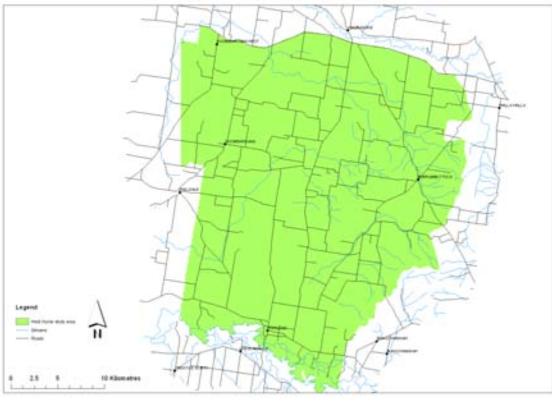

Figure 3 West Hume study area location map

The planning process identified a land use pattern integrating a number of landscape 'themes' (e.g. biodiversity, salinity, commodity production) and explored the opportunities and patterns to achieve multiple benefits (increasing the net benefit to society).

The West Hume study involved identification of areas within the landscape where trees or perennial pastures could be planted to efficiently to achieve environmental targets ((Hill, Cresswell and Hubbard 2006).

Ten biodiversity and nine salinity guidelines were used in the analysis. The salinity guidelines include; revegetating areas with responsive GFS, protection of high valued water resources, revegetating soils with high salt stores, revegetating high recharge potential areas and protecting high value biodiversity assets.

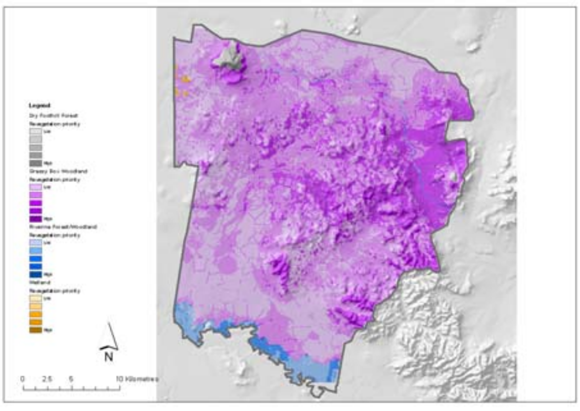

Figure 4 Combined biodiversity and salinity map

One of the most important values attributed to MCAS-S is its ability to utilise existing spatial data sets and therefore has significant advantage for the Murray catchment which is considered to be data poor.

The Community Stream Sampling Project

The Community Stream Sampling (CSS) project is a community monitoring initiative funded by the Australian Government (Bureau of Rural Sciences). The Murray CMA and other NRM organisations in the Murray Darling Basin participate in the project, each tailoring the project to meet the needs of their catchment.

The aim of the CSS project is to identify salinity hotspots and assist with prioritisation of on ground works and management options in the Murray Catchment. A technical team provide expert advice throughout ensuring project officer support, continuous improvement and interpretation of data collected. The project was developed with guiding principles based on integrated approaches to resource use and management and, involving community participation in natural resource improvement (e.g., RAC 1993). The Murray CMA developed its funding bid based on a Participatory Action Research (PAR) model, a process that includes research, education and action activities usually applied by educators, community organisations and facilitators. PAR is considered to be a community organising and problem-solving tool. This method increases awareness and understanding and helps to develop a shared sense of purpose. The interactions involved in carrying out a joint inquiry help to transform a diverse set of people and organisations into a group with a shared perspective, whose members have agreed upon a number of tasks and responsibilities.

In its infancy the CSS project employed a range of techniques and included both ‘soft’ and ‘hard’ systems analysis, reviews were undertaken of previous studies i.e. the Eastern Dryland Salinity Project, the Livingstone Creek Project (Murrumbidgee Catchment), the Murray Blueprint and Catchment Action Plan and numerous water quality monitoring projects.

A gap analysis and stratification of the Murray Catchment identified where monitoring points would provide the most effective information. The Catchment was stratified by geology, groundwater flow systems (GFS), watershed sub-catchments and gaps in salinity knowledge. The major geological types of the Murray Catchment are represented by at least one CSS site. A weighted multi criteria analysis using the above stratification, access, connectivity to groundwater, high valued water resources was used to justify site selection. While most of the previous dryland salinity investigations focused on the SWS the technical team included a particular area within the western part of the catchment, where limited data existed. The technical team considered that investigations adjacent to the ancestral Murray River reported in the literature to follow the Bullitale Creek and Green Gully before switching to a course now occupied by the Edward River (Harris, 1939; Bowler, 1978) may unfold salt stores previously unidentified. The present Murray rejoins its ancestral course some 400 river km downstream at Wakool Junction.

The technical team identified two discrete monitoring projects, an ephemeral stream investigation and the perennial streams monitored by the community under the SaltCHECK component of the project. Currently the CSS project has 22 sites on perennial streams that are monitored monthly by community members and 14 ephemeral streams sites that are monitored using Rising Stage Samplers.

Due to the sporadic nature of ephemeral streams i.e. erratic flows and the difficulty presented by monitoring the gap analysis determined that not only was there little if any information in existence but potential salt loads within these systems required investigation. The CSS technical team recommended that a number of representative ephemeral streams in the Murray Catchment be included in the project. Rising Stage Samplers (RSS) designed by the Dept of Water Resources in the 1970s were built for the CSS project with the purpose of supporting preliminary investigations. These are a cost effective tool able to remotely collect water instream and as the flows increase samples are collected at known heights. Whilst unable to estimate salt load over time the investigative system does enable salt load estimates at a given point in time. The application of RSS is an efficient method in terms of resources, both cost and human. The ephemeral stream project will provide the CMA with sufficient data for analysis and will support the justification of further research if warranted.

Participants within the SaltCHECK project sample surface water on a monthly basis. Electrical Conductivity (EC), Temperature, pH and Turbidity data is being collected. These parameters were chosen for the ease of operation and the quality control measures could be established. Importantly SaltCHECK monitors are required to calibrate their EC meter using a standard solution prior to each use. The project officer completes six monthly checks on the monitoring methods and the equipment used by the community. The Murray CMA has confidence in the community data as all QA/ QC checks indicate data being collected by the community is of a high quality.

Preliminary results from sites that are being monitored by SalthCHECK basis indicate:

- Salt is being expressed from granitic geology types in the Upper Murray and mobilising into steams during moderate- high rainfall events.
- There are potentially active saline sites in the Upper Murray and Upper Billabong catchments.
- There are numerous saline groundwater/ surface water interactions that require further investigation.

- o In stream vegetation possibly buffering salinity at one site in the South West Slopes.
- o A significantly saline (>50,000µS/cm) permanent base flow in the Murrakool region. It is expected that with a flood event a major salt slug will be mobilised into the Wakool and Murray Rivers.
- o Significant salt store in the Wakool area that has the potential to seep into the Waddy River system.

Volumetric and cross sectional assessment of ephemeral streams was required to help the Murray CMA estimate flows and salt loads. Consequently a survey (stream transects) of the ephemeral stream monitoring sites was undertaken, and water samples undergo laboratory analysis for cation and anions; TP, TN, Total Suspended Sediments, EC, pH and Turbidity. Data collected from the RSS in ephemeral streams indicates:

- o A high amount of sediment and nutrients are being mobilised in ephemeral streams following rainfall events far in excess of the ANZECC guidelines and trigger values.
- o The composition of salts exported is primarily NaCl dominated, and recognised as being more toxic then the Carbonate type salts (D. Nielson pers. communication Sept 2007).

The preliminary results of the CSS project combined with the NSW salinity audit demonstrates that surface water quality in the Murray Catchment remains poor. However, continued data collect is necessary to enable trend analysis and for the Murray CMA to further refine and prioritise works for resource condition improvement.

The Murray CMA recognised the need to correlate salt composition with mobilisation pathways. The Piper Plot example below (Figure 5) is representative of one rainfall event and 5 different streams in the SWS. The Murray Darling Fresh Water Research Centre (MDRFC) construct piper diagrams of cation and anions from water samples collected by RSS sites for analysis. The majority of salts present from this flow event are sodium bicarbonate type salts. The first flush was dominated by NaCl but was becoming more bicarbonate over the sampling period (pers communication D. Neilson 26 March 2008).

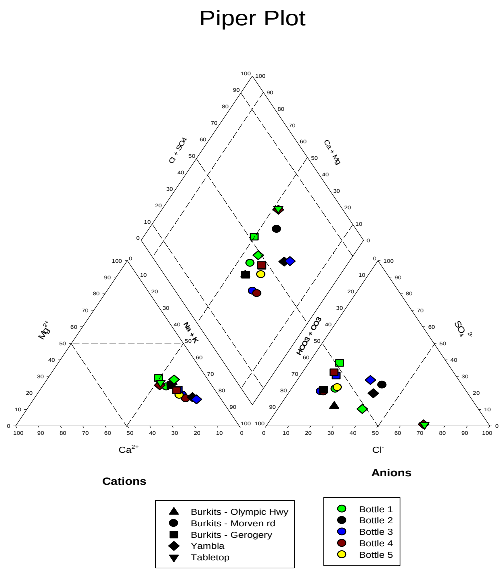

Figure 5 Piper Plot

Hydrogeological study

Traditionally groundwater data capture in the Murray Catchment has been collected by a number of different agencies and information stored in separate repositories. This has made it very difficult to fully appreciate data sources or access groundwater data. Therefore to rectify the situation the Murray CMA commissioned a review of all available groundwater and bore network data in 2007. No previous attempt had been made to integrate information into one report to provide an overall perspective of the major hydrogeological issues in a spatial context.

The study provides the Murray CMA with a valuable resource that documents the catchment wide systems. In addition the review has provided an evaluation of groundwater monitoring programs (particularly community based programs), identified key hydrological issues, knowledge gaps and salinity hotspots across the catchment. The review reported that water levels in the Eastern Murray (dryland farming and high recharge area) have be steadily declining since 2005, however it is believed the prolonged drought during 2006/07 is influencing the system and reduction in available recharge. Importantly high relief granite and high relief non-granite systems are under represented in the data sets.

Priority salinity risk areas in the Murray Catchment include: Central Billabong, West Hume (Burrumbuttock, Majors Creek and Long Plain Creek), Murray River Corridor, Bowna, Ten Mile, Urana, Urangaline, Yarra Yarra and the Irrigation districts, Berriquin, Deniboota, Denimein, Moira and Wakool.

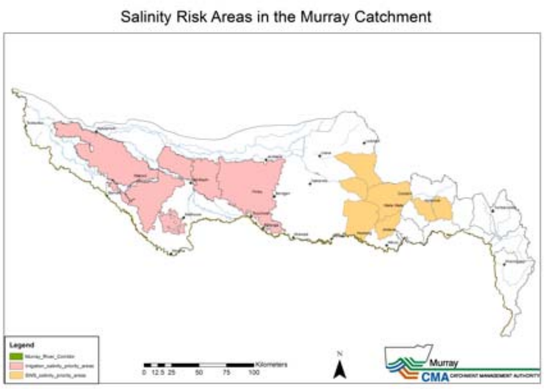

Figure 6 Salinity Risk Areas

The review provided a number of recommendations in including:

- The general storage and distribution/availability of all monitoring data needs to be addressed. Currently community data can not be accessed without permission from the Eastern Dryland Salinity Management group (now defunct) and while most other data is stored within GDS (managed by DWE) it is not readily available (such as internet access).
- Any future Murray catchment wide monitoring networks needs to establish the controlling GFS.
- Detailed investigations and bore selection are required for any specific future monitoring network. The specific driver influencing the system is required to be identified to accurately monitor changes in the system.
- Future monitoring should be focused on long term trends with the ability to interpret trends after 5 years.
- Any new monitoring network should consider changing the temporal monitoring intervals to responsive event based or monthly to capture any climate variations.
- There is the potential to expand salinity investigations within high relief zones, however there does not appear to be a requirement to expand on previous salinity investigations, especially within the mid- upper catchment. Focus should be on selecting bores which will enable a regional style of salinity assessment with more work focused on water table surface and any drivers which may affect change over time (i.e. climate change).

Spatial mapping of salinity in the Murray Catchment was summarised by GHD (2008) and includes; Dryland salinity mapping, sub catchment attribute mapping (10 projects), regional salinity mapping, GIS based model, Ground based EM and Airborne EM (AEM) for the Billabong catchment which is assessed as a high priority sub catchment.

Airborne Electromagnetic Surveys

AEM (airborne electro magnetics) is an ideal tool for regional mapping and it is important for assessing spatial patterns within regolith associated with palaeochannels and subsurface drainage flow.

In 2002, the Australian Government (Bureau of Rural Sciences) flew the West Hume area with AEM equipment, aimed at supporting the CSIRO Heartlands program.

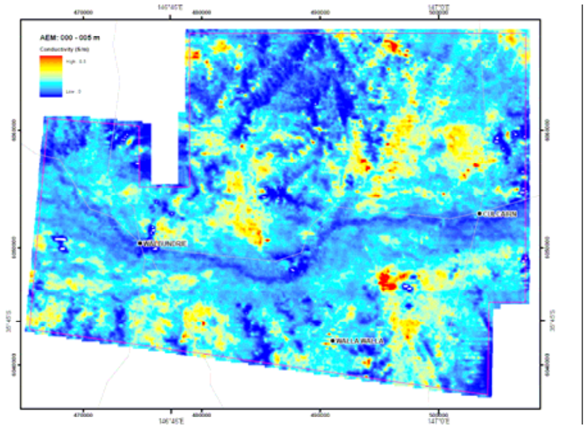

Figure 7 Surface Salinity (0–5 m)

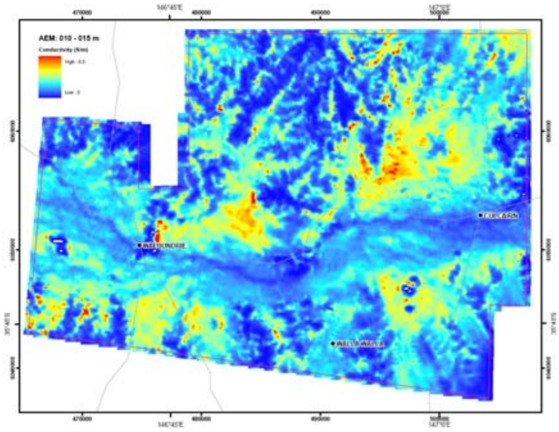

Figure 8 (10-15 m)

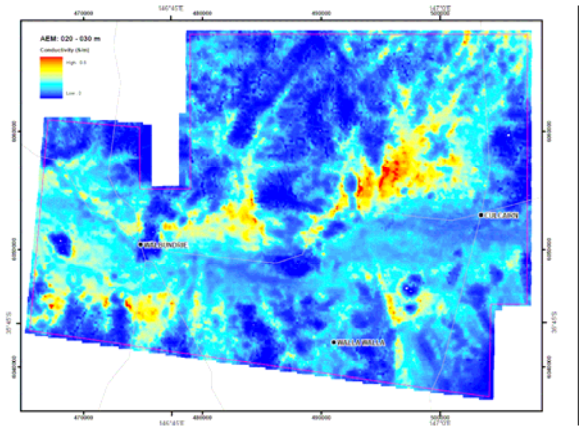

Figure 9 (20-30 m)

The AEM survey as presented above (Figures 7 to 9) has enabled the Murray CMA to identify potential hotspots previously unknown and also to validate ground data where sites were known but depth data of salt storage potential was not.

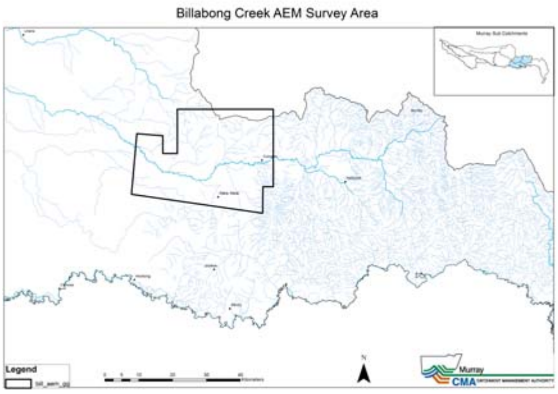

Figure 10 AEM survey area

Discussion

Caring for our Country is the Australian Government's new natural resource management program, (www.napswq.gov.au/ accessed 25/03/2008). The AG has signalled a different approach to NRM as indicated by its six national priorities:

- the national reserve system
- biodiversity and natural icons
- coastal environments and critical aquatic habitats
- sustainable farm practices
- natural resource management in remote and northern Australia
- community skills, knowledge and engagement.

Aligning and incorporating all aspects of sustainable land management relies on awareness of the political, social, scientific, economic and ecological factors. Management in NRM is complex and often challenging but at the same time it can also be highly rewarding. The Murray CMA has built on the work of its predecessors to deliver a catchment wide program over the past 4 years. Investment decisions have been based on the best available information and in an environment where on ground outcomes were expected. It is evident that the Murray lacked sufficient data in a range of areas and this paper reflects some of the endeavours undertaken to rectify the knowledge gaps. Not dissimilar to other analytical projects burning questions and actions remain. For the Murray this will include:

- The development of MCAS-S for the entire SWS
- Innovative delivery mechanisms such as tendering and MBIs within spatially explicit high priorities areas
- A community groundwater monitoring project with data to be accessible (web-based) to a wide range of users
- Investigation of groundwater/surface water interactions
- Advocacy for expert investigations into acid sulfidic sediments and salinity (pers. comm. Darren Baldwin March 2008)
- Climate change and impacts this will have on salinity eg, intense rainfall events and potentially higher seasonal recharge.

There is also recognition that for landscape recovery to occur at the scale necessary then people must continue to work together from the paddock to the halls of high office in the country. When people are able to share concerns and explore possible new alliances they begin to formulate positive action proposals.

Twidale (2004) suggests that rivers are self sustaining, and self augmenting positive feedback systems; if this is so then the health report card indicates that many of the water systems in the Murray Catchment are under considerable stress and are a cause for concern. Pasteur is often quoted for his insightful words 'in the fields of observation chance only favours those who are prepared". As edifying as this may be, understanding the health of a catchment does not happen by chance, rather it results from dedication, planning and commitment.

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Attachment A

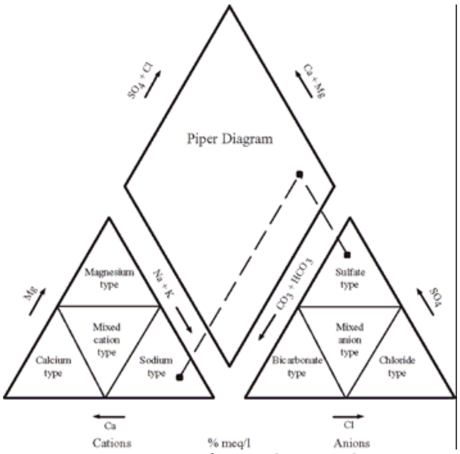

Figure 11 Description of Piper diagram showing representation of hydro chemical data. *In this diagram, the points plotted in the sodium and sulphate dominated regions in the triangles*

Notation

AEM images as presented in the document are still considered to be in draft format. The Murray acknowledges BRS for enabling the use of the AEM images for this paper.