

Salinity without rising watertables: salinity processes and risk assessment in south-west Victoria, Australia

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Introduction

The connection between the removal of native vegetation, rising watertables and the onset of secondary salinity has been established for many dryland agricultural regions across Australia (Ghassemi et al. 1995). These include south west Western Australia, the Victorian riverine plains, the central Victorian uplands and the northern Victorian dunefields and plains. This salinisation problem in Australia has resulted in the Federal and State Governments investing around AUD\$1.4 billion in the management of salinity through the National Action Plan for Salinity and Water Quality (2000 – 2007) (CoAG 2001). Much of this investment in salinity management is based on replacing the native vegetation to reduce groundwater recharge, and lower the shallow groundwater tables.

This paper presents four examples from south west Victoria where the onset of dryland salinity is not linked to rising groundwater following widespread vegetation clearance. In each example the salinity processes vary depending on geology, geomorphology, regolith, soil, environmental history and climate and is unique to each landscape. The paper argues the need to undertake rigorous risk assessments of the salinity threats to assets in each landscape so that effective remediation strategies can be developed that reflect the biophysical process occurring at the site.

Example 1. Stream salinity in the West Moorabool River

The single asset identified as threatened by salinity in the West Moorabool River catchment is the urban water supply to the cities of Ballarat (pop. 90,000) and Geelong (pop. 207,000) (Nicholson et al. 2006). The trend in surface water salinity is indicated by the electrical conductivity (EC) monitored at the Lal Lal Reservoir (Figure 1), which is partly due to the recent drought conditions increasing evaporation and water usage, and the low water levels have concentrated the salinity. However the rise is also reflected in salinity trend in the inflows from the West Moorabool River. A statistical analysis using the Generalised Additive Model of the EC measured at the Lal Lal gauging station between December 1976 and February 2005 shows a linear trend of $1.0 \pm 1.9 \mu\text{S}/\text{cm}/\text{yr}$. Although not statistically significant, the rise is of concern to the water authorities since the non-linear trend analysis (Figure 1) shows a significant rise in the past ten years (Nicholson et al. 2006). The exceedence curve shows that 96% of the time the EC values are below 700 $\mu\text{S}/\text{cm}$. However, EC greater than 600 $\mu\text{S}/\text{cm}$ have been recorded 28% of the time in the recent past (February 1999 to February 2005). This includes 5 occasions when the values exceeded 1000 $\mu\text{S}/\text{cm}$, and the three highest values ever recorded.

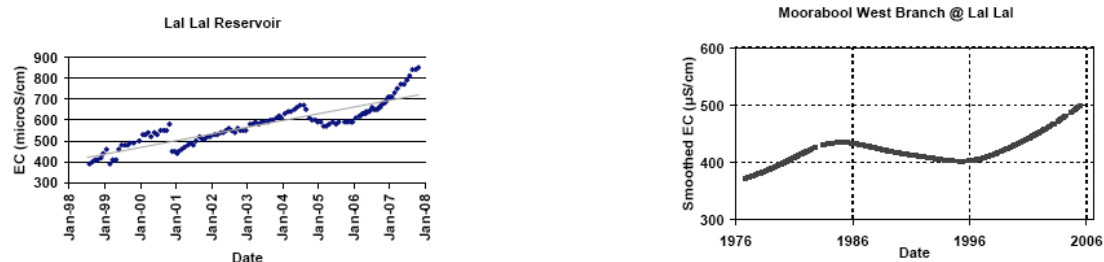


Figure 1 Salinity trends in the Lal Lal Reservoir and West Moorabool River (immediately upstream of the reservoir)

The West Moorabool River catchment occupies 33,760 hectares of the upper Moorabool River basin in southwest Victoria. The northern third of the catchment comprises gently

dissected volcanic plains and eruption points that constitute the most valuable agricultural land. Gently undulating landscapes formed on granites and sedimentary rocks of Palaeozoic age, surrounded by Quaternary volcanic plains and eruption points, make up the central third of the catchment. The southern third of the catchment comprises more dissected landscapes on Palaeozoic sedimentary and metamorphic rocks. The mean annual average rainfall for the catchment is 820 millimetres, with a maximum of 1020 millimetres and a minimum of 640 millimetres. Rainfall is greatest in August and September and the average monthly rainfall exceeds the average monthly pan evaporation from April to October.

The historical accounts of early settlers record three general native vegetation landscapes, *viz*: the northern third of the catchment comprising the heavily timbered Bullarook Forest; the central third being moderately timbered land; and the southern third being dense forest (Nathan 2004). The discovery of gold adjacent to West Moorabool River catchment in 1851 created a massive increase in the population and demand for timber for the mines. The transformation of the catchment from forest to cleared land was relatively rapid. The majority of the Bullarook Forest had been cleared by 1880 and when mining ceased around the time of the First World War (1914-1918), the transformation of the West Moorabool forests to agricultural land was complete. The reliable rainfall and fertile soils provided a productive agricultural landscape to supply the City of Ballarat and surrounding markets.

The history of exploitation of the water resources of the West Moorabool River over the past 200 years has been documented by Nathan (2004). Groundwater springs were noted in the earliest records of pastoral settlement and were an obvious and reliable source of water away from the river. Many are shown on the earliest maps and surveys, especially around the volcanic eruption points (scoria cones). The earliest geological maps (1870 & 1871) show the locations of 21 wells, 16 springs and one shaft in which groundwater was encountered. An archival document records a second survey of 74 wells and 14 springs in the upper West Moorabool catchment a decade later (1881). The watertables in the wells varied from 0.9 m to 12.2 m, with an average of 3.2 m (Nathan 2004).

Despite the fact that the river is increasing in salinity, the historical and contemporary data in this catchment finds no evidence of a link between land clearing and rising groundwater levels. Contrary to the contemporary salinity management theory, the groundwater levels in much of this landscape have relatively apparently unaffected by the dramatic changes in land-use over the past 150 years.

Example 2. Agricultural land salinity at Pittong

The Pittong area is an agricultural region of approximately 6,300 hectares, 35 km WSW of Ballarat in western Victoria. The area comprises the upper catchment of the Naringhil Creek, a tributary to the Woody Yaloak River. Average annual rainfall varies from 600mm in the south to 750mm in the north, with approximately 160 rain days per year. Average annual pan evaporation varies from approximately 1150mm (south) to 1050mm (north).

The basement rocks of the Pittong area are folded quartz-rich sandstones (arenites) and shales of Cambrian age, intruded by granite bodies during the Late Devonian, resulting in an aureole of hornfels, approximately one kilometre wide around the rim of the granites. Deep weathering of the granites occurred during the late Palaeogene and early Neogene Periods, resulting in a very thick regolith of sandy kaolin clay that is now commercially exploited. Higher in the landscape the granite regolith is largely made up of *grus*, which has been exploited for road-making sand.

The native vegetation landscapes were grassy woodlands with large Eucalyptus trees, estimated at 15 stems per hectare. Clearing of the native vegetation probably commenced with the early pastoral settlement around 1840, but would have accelerated rapidly after the nearby gold discoveries in the early 1850's. The supply of timber to the mines had denuded most of the native forests around the goldfields by 1870. In the current day landscape, 95% of the area is used for agricultural production, largely mixed farming, comprising wool growing,

cereal and oilseed cropping, meat production and timber plantations. Remnant native vegetation covers around 4% of the area. Over the past decade, the landholders in the region have been at the forefront of land rehabilitation and catchment management, and have been awarded National acclaim for their land management practices.

Salinity has been recognised as a limitation to agricultural production in the Pittong area from the early 1950's (Nicholson et al. 2006). The first significant study was conducted by the Soil Conservation Authority during the mid to late 1970's, when the extent of salinity in the granite landscapes comprised 1.8% of the land. In September 1996 a long-term monitoring site was established in the area and the topography, vegetation, soil salinity, apparent electrical conductivity (EM38), and groundwater levels at the site were recorded. The site was reassessed in September 2000, showing that the extent of the saline discharge has increased by approximately 8%. This increase had been recorded over a period in which the rainfall had been below average and the groundwater levels recorded at the site had fallen. The extent of land salinity in the Pittong area has subsequently been mapped by numerous research projects, using the standard vegetation indicators and EM38 surveys. In 2006, the sum total of mapped land salinity in the Pittong salinity target area was 286.5 Ha, or 4.5% of the target area (6305.5 Ha). This compares with 93 Ha or 1.8% of the landscape zone (5043 Ha) in the first survey in the late 1970's.

Thirty-eight groundwater monitoring bores were constructed as piezometers by government drillers in 1989 and 1994 for the purposes of monitoring standing groundwater levels related to land salinity. The bore hydrographs constructed from the monitoring data uniformly show a declining trend in groundwater levels over the past 18 years. The decline has been greatest in the deeper piezometers which intersect the watertable under the topographic higher elevations and less in the groundwater discharge areas. The linear trend of the groundwater levels in the deepest piezometer (#289, 32m deep) higher in the catchment has declined 38cm/yr whereas the standing water levels measured in the piezometers in the discharge areas (#5148 & #5149, both 17m deep) have declined 5cm/yr. The hydraulic gradient of the groundwater surface is quite low when compared to the topography.

The conceptual model of salinity processes published by Dahlhaus & MacEwan (1997) accounts for many of the observations in the Pittong landscape. Small volumes of highly saline groundwater discharge from fractures, joints, faults or other geological structures in the underlying granite. Anecdotal observations by the landholders suggest that some of these discharge springs are permanent, as the issue of saline groundwater has been continuous for at least thirty years. The discharge volumes are variable with no apparent seasonal cycle, and at least two have been observed to be flowing (<1L/min) even during drought periods (2003-2006). The majority of springs appear as permanently saturated areas of soil, rather than flowing springs. The number of saline springs has been slowly increasing, with at least two having emerged since 2000.

Salinity in the Pittong landscapes results from the point-discharge of highly saline water from a regional groundwater flow system. The salt is spread by the mixing of the regional discharge with local groundwater flows and perched, ephemeral soil-water flows. This model can satisfactorily explain the apparent paradox of increasing land salinity and falling watertables.

Example 3. Agricultural land salinity on the eastern Dundas Tableland

In a very similar process to that at Pittong, salinity on the eastern Dundas Tableland has been related to spring discharge from a fractured volcanic aquifer (Fawcett et al. this volume). The most severe land salinisation is associated with saline discharge from gravity-driven regional groundwater flow systems, and the salinity is spread downslope by local and seasonal groundwater flows. Historical records confirm the presence of shallow saline watertables and saline discharge in the native vegetation landscapes of grassy woodlands at the time of the first pastoral settlement.

Despite the clearing of native vegetation and the introduction of pasture grasses, there has been little effect on the groundwater levels (Fawcett et al. this volume). The onset of agriculture has exposed many of these saline discharge areas, changing the soil chemistry and exacerbating land degradation.

Example 4. Wetland salinity on the volcanic plains

South-western Victoria is dominated by an extensive volcanic plain which features hundreds of shallow lakes and wetlands, many of which are saline. Dozens of these wetlands are global assets, being listed under the Ramsar Convention and international migratory bird treaties. Geomorphic, archaeological and historical evidence shows that many of these lakes have been episodically saline throughout the Quaternary, and the earliest historical records make frequent mention of saline springs, shallow groundwater tables and saline lakes (Dahlhaus & Cox 2005). At the time of the earliest pastoral settlements (1838), the plains were dominantly grasslands and were rapidly exploited for grazing. Less than 1% of the native grasslands now remain. The plains are a very productive agricultural area, with cropping of cereals and oilseeds, and wool growing as the main enterprises.

Over the past 30 years the changing salinity of these wetlands has been identified as a threat to their ecological health, putting some at risk of losing their environmental value (Nicholson et al. 2006). These changes have been variously attributed to surface water diversions away from the lakes, surface water diversions into the lakes, drainage schemes, and groundwater extraction for irrigation. In contrast to the national axiom for salinity management, maintaining shallow saline groundwater tables is seen as essential to maintaining the values of these global assets.

Salinity risk management

An assessment of risk includes both the likelihood and the consequence of salinisation, and evaluates the asset elements at risk. In some landscapes the risk mitigation strategy must take into account the potential consequences on nearby salinity assets, such as Ramsar listed wetlands. In each example presented above, the use of vegetation to reduce recharge is assessed as a relatively ineffective strategy to mitigate the risk, and may even increase the risk. Alternative risk mitigation such as the management of land salinisation through drainage and site rehabilitation, and the control of ephemeral soil water flows and soil waterlogging are suggested as more appropriate. More effective management of surface water salinity (rivers and wetlands) may require restoring water by reducing the volumes of surface water diverted and groundwater extracted.

In the most recent Australian (Federal and State) salinity management frameworks, the emphasis is on the protection of community and catchment assets. In this context, the Australian Risk Management Standard (AS/NZS 4360:2004) is being adopted as providing a systematic, disciplined and rigorous approach to salinity risk management (Dahlhaus 2006). Apart from providing a logical and defensible process for the assessment of salinity risk, the standard provides the management strategies to protect all classes of assets which are threatened by changes to salinity processes, even those where the salinity itself is the asset (e.g. a saline wetland or estuary).

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