

THE GEOCHEMISTRY OF A COASTAL AQUIFER SYSTEM: MERIMBULA, NSW.

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INTRODUCTION

Salinisation of potable water resources is an emerging issue in Australia. Alteration of the hydrologic budget due to anthropogenic activities has resulted in changes to both the chemical and physical properties of groundwater recharge, in many cases severely compromising groundwater quality. Examples of this include the Western Australian Wheat belt (Salama et al., 1994), Eyre Peninsula, South Australia (Richardson and Narayan, 1995) and the Brisbane coastal plain, in Queensland (Arakel and Ridley, 1986).

Over three quarters of Australians live within 50 kilometres of the coast and rely on available freshwater resources for drinking water, domestic use, irrigation, and stock watering. Despite this heavy reliance, the effects of anthropogenic activities on coastal freshwater resources and ecosystems are poorly constrained.

Freshwater represents only 2.5% of the total water budget on Earth. Over three quarters of all freshwater is locked up in ice caps and glaciers and of the remaining 25%, a major proportion (23.5%) is ground water (Smith, 1998). Within Australia, groundwater, as a percentage of the freshwater resources, varies between drainage divisions. Groundwater can range from ~66% of the total freshwater resource in the Western Plateau division to about 10% for Tasmania. The field site for this study is situated in the south east coast drainage division, where groundwater contributes 15% to the freshwater budget (Smith, 1998).

The concentration of Australia's population along the coastline has placed a considerable burden on coastal aquifer systems. In many areas of the world, including Australia, over-exploitation of fresh groundwater in coastal aquifer systems has led to seawater intrusion. Consequently, groundwater salinities become too high for human and livestock consumption, as well as adversely affecting freshwater coastal ecosystems (Kishi and Fukuo, 1977; Whitehead et al., 1990).



Figure 1: Map of the Merimbula region, NSW.

Population increase along the coast generates additional problems. Both land management and waste disposal practices have traditionally resulted in a decrease in water quality and increase in land degradation (White et al., 1997).

The overall objective of this study is to understand the influence that sea water intrusion and anthropogenic contamination has on the chemistry and overall quality of potable resources along coastal Australia. This will be achieved through the characterisation of basic hydrogeological parameters such as recharge sources, recharge rates and flow rates to determine a sustainable yield for the groundwater resources of the Merimbula-Pambula aquifer system. Furthermore, the study intends to determine the effects of anthropogenic activities on physiochemical mechanisms such as evapotranspiration, saline intrusion, water-rock interactions, and in particular mixing between different waters of varying chemistry, pH and redox state. The process of mixing is

rarely simple; selective ion exchange may result from the mixing of waters due to variations in the physicochemical parameters identified above. This study intends to determine the effects of mixing has on the overall quality of this resource.

AREA DESCRIPTION

The groundwater system under study is situated between the small townships of Merimbula and Pambula, along the south coast of New South Wales. The aquifer system flows through relatively uniform beach sands, interbedded with clayey layers. The aquifer is unconfined although the clayey layers may result in semi-confined to confined conditions locally. The groundwater is composed of a number of endmember waters influenced by a limited area of abstraction and point source contamination. The water types include the regional groundwater, rain and seawater with groundwater pumping induced seawater incursion at the north eastern tip of the peninsula and sewage treatment ponds which have been constructed between the fore dune/back dune system as the primary anthropogenic forcings.

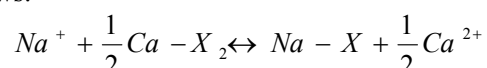
This primary focus region of the study is enclosed to the east by the Southern Pacific Ocean and to the north-west by a saline estuary, Lake Merimbula. An understanding of the interaction between the saline lake/ocean and the aquifer, including the effects of prolonged, extensive groundwater extraction is essential for future planning and management.

The uppermost section of the aquifer is unconfined, and therefore the overall chemistry of the system has the potential to be influenced by climatic events such as drought, rainfall events, and on a larger time scale, sea level rise. Merimbula receives an average rainfall of 837.5 mm per year (Bureau of Meteorology), which is summer dominant.

This study will investigate water rock interactions, and in particular the modification of these sediments through processes of metal adsorption and ion exchange to water chemistry. These changes are not restricted solely to the natural evolution of water from the recharge zone through the aquifer system, but also the addition of treated sewage with associated high concentrations of N, P, C and S.

PRELIMINARY WORK

Seawater intrusion is influenced by numerous features of the aquifer, which may include the lithology, groundwater flow paths and anthropogenic activity (pumping). In addition, saline intrusion on fresh groundwater systems, produces a distinct geochemical signature. The mixing of different water types can induce reactions which lead to a water composition that is different from a conservative mixture, (Appelo and Postma, 1996). Sodium and chloride are the dominant ions in seawater, however, ion exchange occurs when this saline water comes into contact with a fresh groundwater system where the clays are dominated by Ca on the exchange complex, as follows:



where X indicates the soil/sediment exchanger (Appelo and Postma, 1996). During cation exchange, the dominant Na ions are adsorbed and Ca ions released, so that the resulting water moves from a NaCl water to a CaCl₂ water (Jones et al., 1999, Barker et al., 1998). Other effects on the water chemistry include mineral precipitation/dissolution such as carbonate dissolution (Smart et al., 1988).

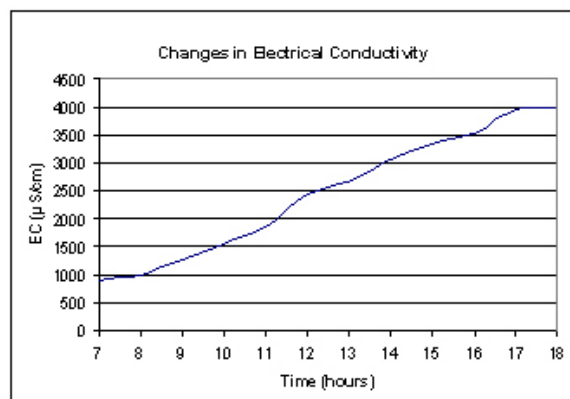


Figure 2: Electrical conductivity plotted against time, in an individual bore, in the Fishpen region, Merimbula NSW

Preliminary reconnaissance of the study area has resulted in a limited, but promising, dataset. Samples were taken in the Fishpen area of Merimbula (highlighted on Figure 1). Six groundwater bores were sampled, each at least twice during the trip. The short term temporal evolution of the groundwater composition was tested through sampling hourly from a bore over a twelve hour period. Groundwater was extracted from the aquifer at a rate of 16.2 litres per minute or 972 litres per hour. Figure 2 shows an increase in total dissolved solids (TDS) with time from the bore during pumping. Low tide occurred at 0800 hours and high tide occurred at approximately 1500 hours. It is evident from Figure 2 that there was no impact on this particular occasion by tidal influences

at this location. Chloride is the dominant ion in all waters sampled and is likely to be chemically conservative during mixing. As a result, it has been used as a seawater tracer (Hem, 1992) and a means for normalising other element concentrations.

An additional method for investigating saline incursion is the use of piper diagrams. Piper diagrams plot samples based on the relative proportions of major ions rather than the bulk concentrations. It is therefore useful in studying changes in water types and mixing relationships.

Figure 3 shows that samples taken from the Fishpen area are indicative of seawater intrusion into a fresh groundwater aquifer. Furthermore, the data trends also suggests that geochemical processes more complex than simple conservative mixing are occurring, This is in agreement with predicted cation exchange that occurs during seawater incursion (Appelo and Postma, 1996). The effects of ion exchange and mineral dissolution/precipitation reactions, in addition to the role of contamination from anthropogenically introduced pollutants, all have the potential to influence the observed groundwater chemistries. Additional investigation is required to determine the extent to which these factors play a role.

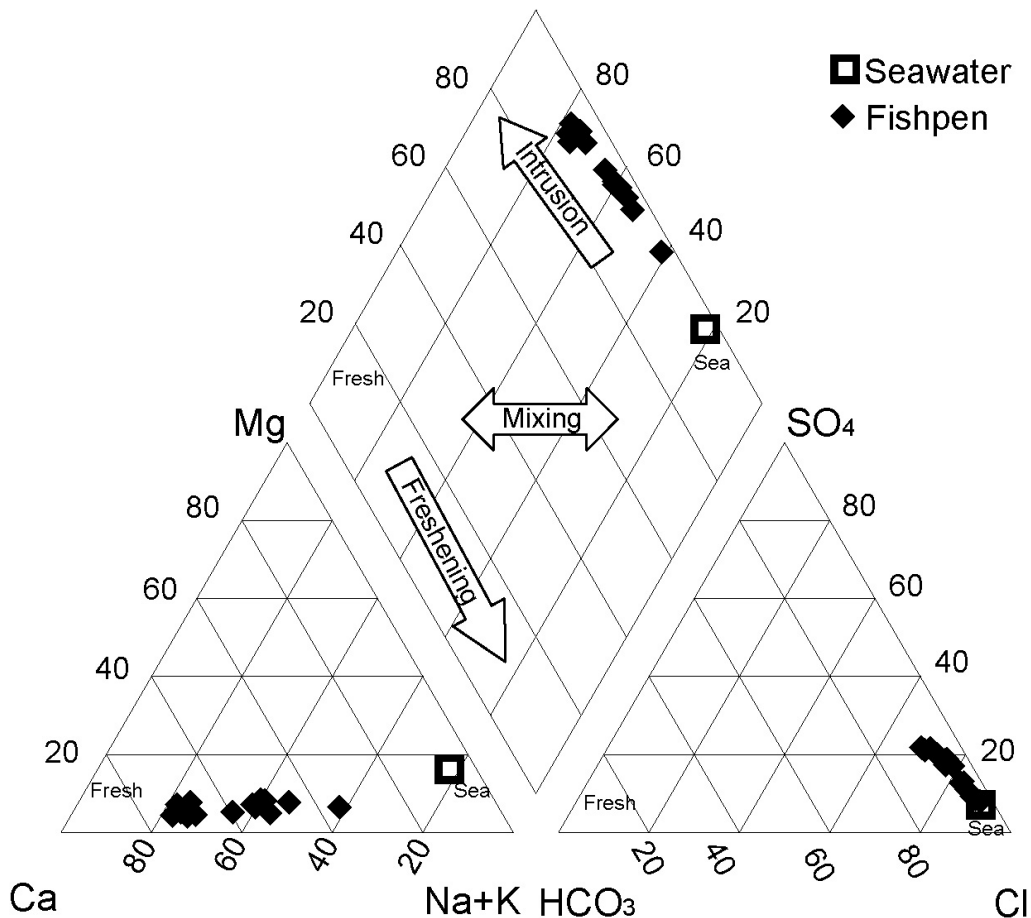


Figure 3: Piper diagram, seawater values have been taken from (Hem, 1992), Trend lines have been taken from (Appelo and Postma 1996).

Further sampling was completed at a bore over a two hour period. The first sample (4a) was taken in the morning prior to pumping, and the second (4b) after the bore had been pumped for two hours. Figure 4 shows variation in the chemistry of the water between the two sampling times plotted on a Stiff diagram. Significant increases in both the Na and Cl of the groundwater were observed, with only slight increases in the other major ions.

Appelo and Postma (1996) demonstrated that during seawater incursion, Ca concentration increases with respect to Na in groundwater. This trend is not observed over the pumping period at this location and the change in chemical composition may be attributed to additional processes, possibly mixing with a different end member water compositions other than seawater.

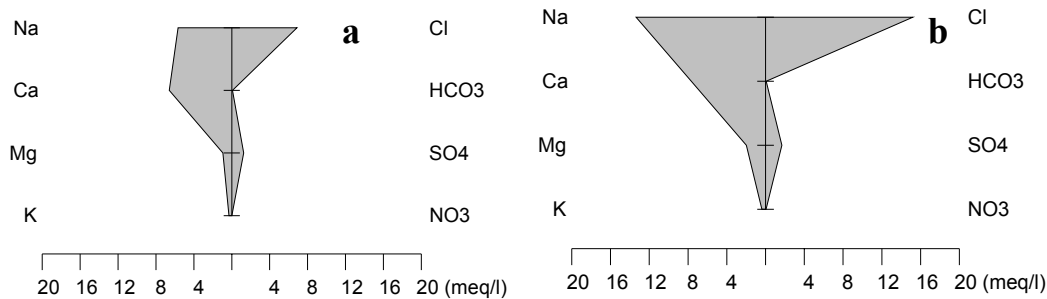


Figure 4: The same bore sampled over a two hour period: figure 4a was taken prior to pumping; figure 4b was taken two hours after figure 4a.

CONCLUSION

Initial data interpretation indicates possible saline incursion and ion exchange. However, a greater understanding of the hydrogeology and hydro-geochemistry is required to properly assess the origin, nature and mobility of solutes within this aquifer system. Further investigation is also required to understand the full environmental implications of anthropogenic contamination, especially wastewater seepage from a water treatment plant located in this region and its role in the chemical variations within the area.

Future work

The following is an outline of future work aimed at understanding the hydrogeochemistry of this coastal aquifer system:

- A primary requirement to understanding mixing between waters is to establish end member compositions. We currently have a small amount of data within the Fishpen area. To properly understand the processes affecting the overall chemistry and subsequent quality of the groundwater, each of the proposed end members (regional groundwater, rain, ocean, lake and treated sewage) must be characterised.
- Basic assumptions have been made on the lithology of the region, based on soil and geological maps. Cores will be taken and materials analysed to provide a better knowledge of the mineralogy, geochemistry and hydrogeologic properties of regolith materials in this region. Column experiments may be performed to give an insight into amount and type of ion exchange that may be taking place.
- In addition to the introduction of contamination from the treated sewage ponds, the sources of other pollutants associated with urban areas will be investigated. The use of stable and radiogenic isotopes have been used successfully as environmental tracers (Freeze and Cherry, 1979), and may prove useful for distinguishing individual contaminant sources in this study area.

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