Seawater Intrusion in Australia – A National Perspective of Future Challenges

Adrian D. Werner[1]*, E. Nation*[2] and *M. A. (Rien) Habermehl*[2]
[1]School of Chemistry, Physics and Earth Sciences, Flinders University, Adelaide, SA, Australia
[2]Bureau of Rural Sciences, Dept of Agriculture, Fisheries & Forestry, Canberra, ACT, Australia

ABSTRACT
Extended periods of below-average rainfall combined with a rising population density in the Australian coastal margin has led to higher stresses on coastal water resources, and the risk of seawater intrusion has increased. Despite reports of seawater intrusion in the majority of states, comprehensive seawater intrusion investigations have only been completed for coastal systems in Queensland and to a lesser degree in Western Australia and South Australia. The most comprehensive studies include those of the Pioneer Valley and Burnett basins in Queensland, for which detailed conceptual and mathematical models have been developed at the regional scale. These studies have been used to underpin water resources management plans, which aim to control groundwater abstraction to protect the sustainability and supply reliability of the coastal groundwater resources of these areas. Seawater intrusion monitoring is widespread. In response to historical changes in seawater intrusion extent, artificial recharge and recycled-water schemes have been introduced or are planned in several areas (e.g. aquifers in the Bribie Island, Pioneer Valley and Lower Burdekin areas in Queensland) to alleviate the threat of seawater intrusion. A national-scale review of groundwater conditions in irrigation areas situated within Australia's coastal margins highlights high-risk areas. The level of seawater intrusion investigation of these high-risk areas was identified, and recommendations for prioritised (from a national perspective) further assessment are given.

INTRODUCTION
In Australia, groundwater contained in coastal aquifers represents a vital component of the freshwater resources available for urban, agricultural and industrial activities. Population increase and protracted periods of below-average rainfall have led to an enhanced dependency on coastal groundwater resources, and there is evidence of over-use in many major Australian aquifers (Ball et al., 2001). As a result of this, there is now evidence of the adverse impacts of seawater intrusion in several of Australia's coastal aquifers.

The deleterious impacts of bore salinisation resulting from seawater intrusion have caused significant losses in potable water supplies and in agricultural production globally (FAO, 1997). In some areas, the scale of seawater intrusion issues is expected to be exacerbated by sea-level rise and climate change. Despite evidence of widespread impacts of seawater intrusion, there is a lack of studies documenting the magnitude of the problem on a global, continental or national scale, and no studies have previously summarised the situation in Australia. While seawater intrusion is being assessed and managed in some areas, there is not a consistent approach to seawater intrusion investigation, monitoring, and management across the country. The aims of this study are to review the susceptibility of Australian coastal aquifers to seawater intrusion, to highlight important case studies, and to make recommendations relating to the investigation and management of seawater intrusion in Australia. This study is based on an overview of previous coastal groundwater investigations, combined with a nationwide analysis of available groundwater data.

A NATIONAL PERSPECTIVE OF SEWATER INTRUSION SUSCEPTIBILITY

Voice et al. (2006), in their gap-analysis of the vulnerability of Australia's coastal zones to the adverse impacts of climate change, identified increased seawater intrusion as a significant threat. However, no attempt to highlight areas of likely impact was undertaken. In the current study, available nationwide data relating to topography, groundwater condition and areas of irrigation were combined in a first-order assessment of the most likely regions requiring further investigation of their susceptibility to increased seawater intrusion. A somewhat simple analysis of potential sea-level rise impacts was also undertaken, but is not presented here for brevity.

A GIS-based approach was adopted in combining and analysing existing datasets. The analysis involved identifying overlaps between irrigation areas within the coastal fringe, regions of low topography, areas of intensive groundwater use, and indicators of groundwater system condition. Areas of low relief (<10 m AHD – i.e. 10 m above mean sea level) were identified using NASA SRTM (Shuttle Radar Topographic Mission) 90 m digital elevation model topographical information (see http://srtm.csi.cgiar.org). Groundwater information was obtained from the NAMS (National Agricultural Monitoring System) database (see www.nams.gov.au). Irrigation land-use types were defined according to Bureau of Rural Sciences data as at January 2007 (see http://adl.brs.gov.au/mapserv/landuse/land_use_data.html). Table 1 lists areas of irrigation in low-lying coastal zones on a state-by-state basis to provide an indication of the relative susceptibility (based on coastal proximity and topography) of the irrigation industry. The results indicate that 1.4% and 4.4% of the country's irrigation areas are situated near the coast and at elevations 0-5 m AHD and 0-10 m AHD respectively. Queensland (7.8%) and South Australia (6.2%) have the highest proportions of near-coastal, low lying (0-10 m AHD) irrigation areas.

Table 1. Summary of a GIS-based analysis of irrigation areas and coastal proximity

State	Total Irrigation Area	Major Land-use	Area at 0-5 m AHD	Area at 0-10 m AHD
NSW	867,516 ha	Cropping	7,663 ha	10,198 ha
NT	29,899 ha	Tree fruits	136 ha	402 ha
QLD	1,080,787 ha	Sugar	15,706 ha	84,749 ha
SA	271,319 ha	Sown grasses	9,481 ha	16,839 ha
TAS	128,795 ha	Cropping	2,922 ha	6,837 ha
VIC	837,886 ha	Modified pasture	9,624 ha	23,018 ha
WA	55,789 ha	Vine fruits	528 ha	2,814 ha
Total	3,271,991 ha	Cropping	46,060 ha	144,858 ha

The simple assumption was made that near-coastal groundwater conditions of high-salinity and/or low water levels are indicative of a higher likelihood of seawater intrusion susceptibility. It proved difficult to quantitatively assess seawater intrusion trends because the location and density of monitoring sites varies. Only a qualitative first-impression of "hot spots" was obtained. Decadal-minimum groundwater levels were obtained to illustrate temporal trends in groundwater conditions. The results for 2000-2008 are given in Figure 1. Maximum groundwater salt concentrations were also obtained, and these are illustrated in Figure 2.

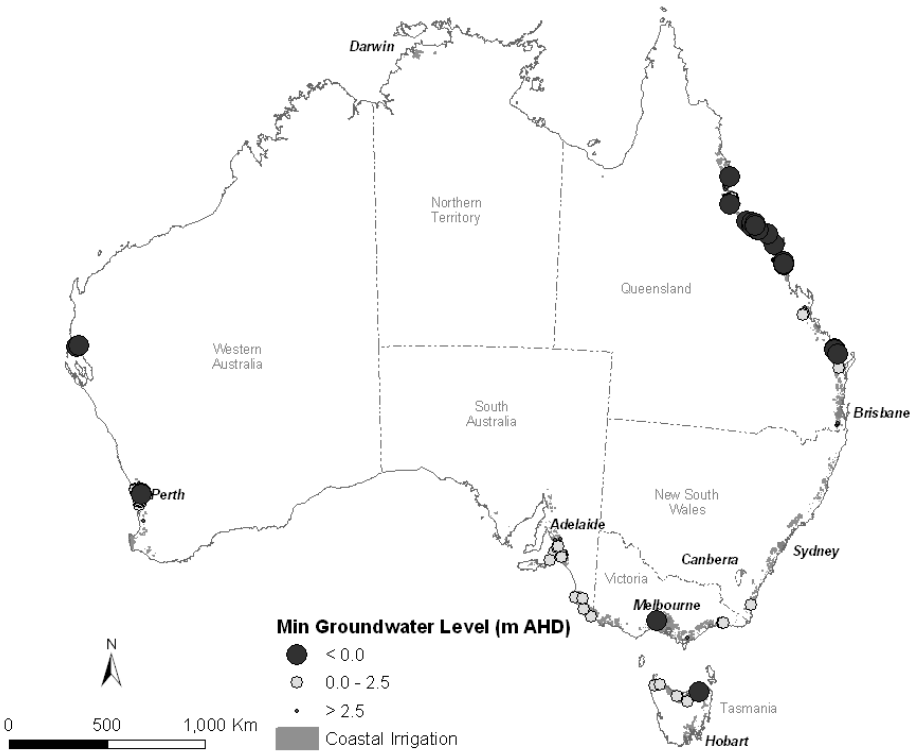

Figure 8. Minimum (lowest) groundwater levels during the period 2000-2008

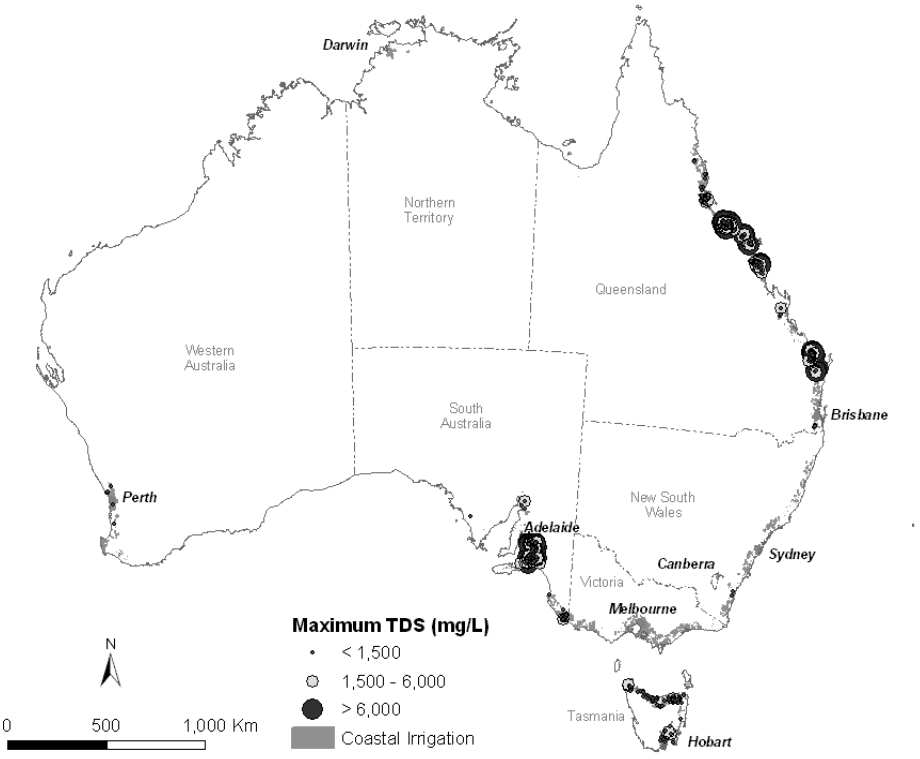

Figure 2. Maximum groundwater total dissolved solids (TDS)

PREVIOUS INVESTIGATIONS

Typically, an investigation of seawater intrusion for the purposes of water resources management requires activities related to: 1. data collection, 2. conceptualisation, and 3. computer modelling. Only a few investigations of Australian seawater intrusion include all three phases, despite many reports acknowledging significant threats of seawater intrusion degradation. The review indicated that the most advanced seawater intrusion investigations have been undertaken in Queensland, including investigations of the Pioneer Valley, Burnett and Lower Burdekin aquifers (Werner and Gallagher 2006; Bajracharya et al. 2006; Narayan et al. 2007). Seawater intrusion management studies of Western Australian systems have also been completed, although these typically do not progress to the development of computer models. There are several examples of management responses to seawater intrusion susceptibility, including targeted monitoring programs, groundwater pumping controls and artificial recharge schemes (e.g. Narayan et al. 2007).

CONCLUSIONS AND RECOMMENDATIONS

There is evidence of extensive seawater intrusion problems in Australia, most noticeably in Queensland and South Australia (SA), but also in regions of Western Australia (WA), Victoria and Tasmania. The extensiveness of near-coastal irrigation areas in Queensland has led to more detailed and comprehensive seawater intrusion studies being undertaken on Queensland aquifers. It is strongly recommended that a national framework for best-practice seawater intrusion monitoring, investigation, management and remediation be developed, based on experiences in Queensland. The dissemination of "lessons learnt" from Queensland studies would benefit other water resource management authorities, who are likely to soon require solutions to similar issues.

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Contact Information: Adrian Werner, Flinders University of South Australia, School of Chemistry, Physics and Earth Sciences, Sturt Road, Bedford Park, Adelaide, Australia, Phone: 6-188-201-2710,
Email: adrian.werner@flinders.edu.au