Environmental and cultural values of South Australia's outback water resources

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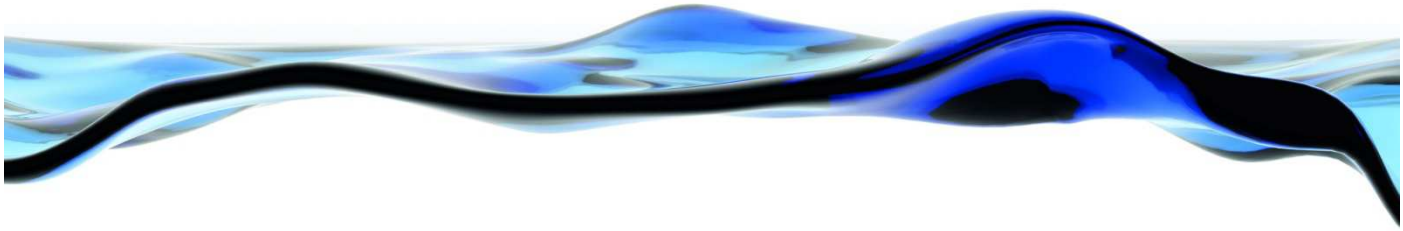

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List of abbreviations

AFCMP	Australian Feral Camel Management Project
ANSTI	Australian Nuclear Science; Technology Information
ANZECC	The Australian and New Zealand Environment Conservation Council
APY	Anangu Pitjantjatjara Yankunytjatjara
ARC	Australian Research Council
AWMSGAB	Allocating Water and Maintaining Springs in the Great Artesian Basin project
AWNRMB	Alinytjara Wilurara NRM board
CFOC	Caring for our Country
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEC	Western Australian Department of Environment and Conservation
DEH	South Australian Department for Environment and Heritage
DENR	South Australian Department of Environment and Natural Resources (now merged with DFW to become DEWNR)
DERM	Queensland Department of Environment and Resource Management
DEWNR	South Australian Department of Environment, Water and Natural Resources (formally DFW and DENR)
DFW	South Australian Department for Water (now merged with DENR to become DEWNR)
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
FLOWS	Facilitating Long-Term Outback Water Solutions
FNPWA	Far North Prescribed Wells Area
GAB	Great Artesian Basin
GABSI	GAB Sustainability Initiative Program
GAM	Generalised additive model
GDE	Groundwater dependent ecosystem
HEVAE	High Environmental Value Aquatic Ecosystems
ICCWR	Impacts of Climate Change on Water Resources project
IEK	Indigenous ecological knowledge
LEB	Lake Eyre Basin
LEBCAC	Lake Eyre Basin Community Advisory Committee
LEBRA	Lake Eyre Basin Rivers Assessment
LIDAR	Light Detection And Ranging
NCCARF	National Climate Change Adaptation Research Facility
NGO	Non-governmental organisation
NPA	National Partnership Agreement on Coal Seam Gas and Large Coal Mining
NRETAS	Northern Territory Government Department of Natural resources, Environment, the Arts and Sport
NRM	Natural Resource Management
NT	Northern Territory
NWI	National Water Initiative Inter-governmental Agreement
PACE	Plan for Accelerated Exploration
PIRSA	Department of Primary Industries and Resources of South Australia
QLD	Queensland
SA	South Australia
SAALNRMB	South Australian Arid Lands NRM board
SARDI	South Australian Research and Development Institute

SEB	Significant environmental benefit
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SKM	Sinclair Knight Mertz
TraCK	Tropical Rivers and Coastal Knowledge
WA	Western Australia

Executive summary

The South Australian Government's Facilitating Long-Term Outback Water Solutions (FLOWS) initiative was instrumental in establishing the Goyder Institute for Water Research FLOWS project in 2010. Through a multi-faceted research programme spanning the lifetime of the Institute, the project aims to provide data on the location, characteristics and sustainability of the South Australia's groundwater resources in arid regions of the state prioritised for future mining and energy industry development (i.e. Musgrave block, Northeast and Northwest Gawler Ranges, parts of the Frome Embayment). Ultimately, it is envisaged that this new information will create a platform to guide water management decisions whilst ensuring that environmental and cultural water assets are protected.

Understanding how communities, industry representatives, tourists, scientists and managers value water and water dependent ecosystems in these priority regions, where water is typically very scarce, is critical to directing water allocation strategies and industry development in these areas. In recognising this, a FLOWS scoping study - Task 7, was instigated, the outcomes of which form the basis of this report.

The overarching objective of Task 7 was to identify the environmental and cultural values of water and water dependent ecosystems across South Australia's arid zones, including the priority areas specified above, in addition to regions administered by the South Australian Arid Lands Natural Resource Management Board (i.e. South Australian portion of the Lake Eyre Basin and the Far North Prescribed Wells Area) and the Alinytjara Wilurara Natural Resource Management Board, namely the Anangu Pitjantjatjara Yankunytjatjara lands, the Maralinga Tjarutja Lands, Yalata and adjoining conservation zones, reserves and National Parks. Whilst the project was primarily focussed on South Australian resources, its findings also encompassed, and have relevance to arid zones in other Australian states.

Specifically, Task 7 aimed to:-

1. Capture and document present knowledge on values of groundwater dependent ecosystems (GDEs) and surface water dependent ecosystems in the South Australian arid zone;
2. Identify attributes for each value, and current and perceived threats to these attributes;
3. Provide recommendations on future opportunities for research investment and collaboration, and develop a research prospectus that could be fully realised in the next phase of FLOWS (FLOWS 2 - scheduled for 2012-2015).

To meet these aims, a literature and knowledge review was undertaken, and a two-day forum and workshop entitled 'Cultural and Environmental Values of Outback Water Resources: Forum and Workshop' was held at the South Australian Research and Development Institute (SARDI) on May 10 and 11 2012. Fifty two delegates from around Australia attended the event, reflecting the multidisciplinary and multicultural demographic that has experience of working and living within, studying and managing arid zone environments. Twenty two oral presentations were given over the two days and two workshop sessions were used to identify knowledge gaps and canvas opportunities for new linkages and research directions.

From the review of the literature, it is apparent that finding a definition of water's value that is acceptable to all people is extremely challenging, and made more so by water's relative scarcity in these regions and the multiple threats facing communities, industry and ecosystem processes that are reliant upon water under future predictions of a drier climate. Differences between Aboriginal and non-Aboriginal perceptions of water's meaning also adds complexity in attempting to adequately capture its value in a neat, compartmentalised way that is considered useful for water management purposes.

The review goes on to document the marked diversity of water dependent ecosystems that exist throughout arid regions of South Australia. It explores groundwater, surface water, the interactions between them and the dependence of particular aquatic and terrestrial ecosystems and livelihoods upon them. It then focuses more specifically on GDEs, both subsurface (e.g. cave and aquifer ecosystems) and surface (e.g. spring-fed ecosystems), providing definitions and information on the distribution, values and threats to these values through case studies.

Many different value types were identified during the review and workshop sessions as being associated with water and water dependent ecosystems in South Australia's arid zones. These are summarised as follows (in alphabetical order): *Aesthetic value* (i.e. artistic, personal, less tangible); *Amenity/Consumptive value* (i.e. domestic supply); *Cultural value* (i.e. historic, heritage, social, spiritual); *Economic value* (i.e. agriculture, mining, commercial fishing, science, tourism), *Ecosystem value* (i.e. physical, biological, ecological, conservation) *Educational value*, *Knowledge value*, *Political value*, *Legal value*, *Ownership value*, *Recreational value* (i.e. tourism, local use).

The threats posed to such values by climate change, mining and agricultural industries, tourism, community development, established invasive species and potential new incursions may be serious, cumulative and interactive. Increased groundwater abstraction for mining and agricultural activities was identified as a key risk to the quality, availability and ecological integrity of culturally and/or environmentally significant water features. When considered in conjunction with the latest climate model projections of decreased rainfall and groundwater recharge rates, and the total dependence of many remote communities located in areas earmarked as highly prospective for mining exploration on low yielding, groundwater-fed wells for their potable water supply, it is imperative to consider these threats and their interactions simultaneously as part of future risk assessments.

Based upon the feedback received during the workshop sessions and subsequent input from delegates and FLOWS partners, several future project ideas and collaborations were developed and these are documented in chapter 5 of this report. Outcomes from these projects could feed directly into risk assessment frameworks, but it must be stressed that they represent only a very small subset of the work required in this field. Below, we make some further general recommendations for future approaches to assessing water values.

Firstly, we recommend that the approach adopted in Task 7, which aimed to identify water values on a state-wide level, be downscaled to focus on individual mining and/or industry developments at specific sites and/or regions. This will have multiple benefits including: reduced complexity and increased accuracy in defining water values and determining attributes; better understanding of the cumulative and/or interactive nature of threats and solutions to these threats; greater opportunities for engagement with all stakeholders; and more tangible outcomes.

Secondly, a cross-jurisdictional approach to water science and management that draws on skills from multiple disciplines needs to be instilled at the outset and in the design phase of new projects.

Finally, we recommend strong investment in the continued engagement and inclusion of scientists, managers, community members, industry bodies, tourism operators and tourists in decision-making processes. Fostering relationships among user groups, and creating conduits for knowledge exchange through forums held both on and off country may be productive in building cross-cultural understanding of value systems - understanding that directly underpins the success of management strategies aimed at preserving water's value in arid zones.

1. Introduction

In South Australia's (SA) arid landscapes, water is typically in short supply. Indeed, it is perhaps because of this scarcity, coupled with the extreme hydrological variability in the region (Puckridge et al. 1998; Knighton and Nanson 2001; McMahon et al. 2008) that water is considered so precious to the humans, animals, plants and ecosystems that rely upon it. On the most fundamental level – as a resource for survival, water plays a key role in shaping the diversity, abundance and distribution of biota and is valued by humans for practical uses of drinking and cooking. Yet, the significance of water transcends simple life-sustaining needs, incorporating a complex mosaic of economic, historical, social, aesthetic, cultural, spiritual, ecological, hydrological, archaeological and geological values that are often interlinked (Box et al. 2008; Silcock 2010; Kimber 2011).

With the predicted expansion of mining operations across a large portion of SA's arid zone facilitated through the Plan for Accelerated Exploration (PACE) Program, and given climate model projections of decreased rainfall and groundwater recharge rates across much of this region over the next 60 years (DENR 2010; Alcoe et al. 2012; Green et al. 2012a), pressure on groundwater resources and the ecosystems, livelihoods and values they support is undoubtedly rising. In light of this, in 2010 the Goyder Institute for Water Research embarked upon the FLOWS (Facilitating Long-Term Outback Water Solutions) project, phase 1 to be concluded in 2012. A major objective of FLOWS phase 1 (FLOWS 1) was to provide information on the location, quality, character and sustainability of groundwater resources in priority areas of arid zone SA where new mining and energy development is set to occur. It is envisaged that the outcomes of the work will inform policy and water-allocation decisions for mining and other industrial developments, and therefore help ensure the sustainability and protection of the state's groundwater resources and dependent ecosystems.

An additional component of FLOWS 1 (Task 7) involved a scoping study to identify the environmental and cultural values of water and water dependent ecosystems in SA's arid zones. Specifically, Task 7 aimed to:-

1. Capture and document present knowledge on values of groundwater dependent ecosystems (GDEs) and surface water dependent ecosystems in the South Australian arid zone;
2. Identify attributes for each value, and current and perceived threats to these attributes;
3. Canvas future opportunities for research investment and collaboration, and develop a research prospectus that could be fully realised in the next phase of FLOWS (FLOWS 2 - scheduled for 2012-2015).

The outcomes of Task 7 form the basis of this report. Chapter 2 describes the approach taken to address these three aims. Chapter 3 attempts to define the concept of *value* as it relates to water and water-dependent ecosystems of arid zones in SA, and goes on to identify values and threats to these values in ecosystem-specific and regional contexts based on a collation of currently available information. Chapter 4 summarises the approach to, and outcomes of the 'Cultural and Environmental Values of Outback Water Resources: Forum and Workshop' that was hosted by the SA Research and Development Institute (SARDI) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) on May 10 and 11 2012. Finally, chapter 5 sets out an agenda for future research opportunities and linkages (identified through the workshop sessions on May 10

and 11 and during this project) that reflect the delegate's views and informs the direction taken in FLOWS 2.

2. Approach

2.1. Project scope

This project aimed to identify the values of water and water dependent ecosystems (both groundwater dependent ecosystems (GDEs) and surface water dependent ecosystems) across the arid zone of SA. We expanded upon the initial brief, which was to focus specifically on three priority areas identified for industrial development by the Department of Primary Industries and Resources of South Australia (PIRSA) (i.e. Musgrave block, Northeast and Northwest Gawler Ranges, Frome Embayment) and have encompassed water dependent ecosystems in the Lake Eyre Basin (LEB) and the Far North Prescribed Wells Area (FNPWA), managed by the South Australian Arid Lands NRM Board (SAALNRMB), and the regions managed by the Alinytjara Wilurara NRM Board (AWNRMB), namely the Anangu Pitjantjatjara Yankunytjatjara (APY) lands, the Maralinga Tjarutja Lands, Yalata and adjoining conservation zones, reserves and National Parks. These areas were chosen primarily because they are considered highly prospective for mineral and petroleum exploration, but also to reflect the values of the broad diversity of communities and ecosystems that depend upon water in South Australia's arid zones.

In order to address the aims stated at the outset of the project, Task 7 was divided into two key activities.

2.2. Activity 1 – Desktop study

A review of existing knowledge was undertaken to capture key water values in arid zones of SA, identify attributes for each value and threats to these attributes. Information and data were collection from many sources. These are listed below:-

1. *Peer-reviewed scientific literature*: Sourced through web-based database searches (e.g. Web of Science, Current Contents), discussion with University, State and Federal Government agency colleagues and Goyder Institute partners (e.g. CSIRO, DEWNR, Flinders University, The University of Adelaide, University of SA, The University of Melbourne, Monash University, The University of Queensland).
2. *Published technical reports and management plans*: Sourced primarily from State and Federal Government agency websites, colleagues at these institutions and web-based searches using search engines within Google (e.g. Google Scholar).
3. *Unpublished reports and project databases*: Sourced from State and Federal Government agencies (CSIRO, DEWNR), Natural Resource Management boards (e.g. SAALNRMB, AWNRMB), Universities, the mining and pastoral industries, community groups, non-governmental organisations, Aboriginal ranger groups, tourist operators and other stakeholders either directly through interviews (see below) and subsequent email contact, or from web searches within Google.

4. *Interviews*: Informal interviews were also conducted by phone with representatives from all of the above groups in an attempt to capture the very latest information on current and future projects.

Given the relative abundance of information available on water values for some regions (e.g. dryland rivers of the LEB, Great Artesian Basin (GAB) springs), this review summarises work to date in these regions, directing readers to the relevant literature where required, whilst providing more detailed examples from somewhat lesser studied water dependent ecosystems in SA's arid zones. The review also aided in selecting delegates from around the country to attend the Forum and Workshop (see Activity 2).

2.3. Activity 2 – Forum and Workshop

A two-day forum and workshop entitled 'Cultural and Environmental Values of Outback Water Resources: Forum and Workshop' was held at SARDI on May 10 and 11 2012. The overarching aim of this event was to bring together a diverse group of scientists, managers, community members, tourism operators, landowners and other stakeholders to discuss key environmental and cultural values of water resources in central Australia. The focus was intended to be broad, encompassing arid zones throughout the country, with the hope of attracting the widest possible representation of people and views and facilitating information exchange both within and among states. In organising the event, we took the view that the challenges facing water resource management in arid zones throughout Australia, and the types of values associated with water in these regions are highly transferrable to the SA situation.

Fifty two delegates attended the event, reflecting the multidisciplinary and multicultural demographic that has experience of working and living within, studying and managing arid zone environments. Twenty two oral presentations were given over the two days and two workshop sessions were used to identify knowledge gaps and canvas opportunities for new linkages and research directions under the next phase of the FLOWS initiative (see chapter 4, Appendix 1).

2.4. Outputs

1. This document forms the main output for Activities 1 and 2 of Task 7. The report comprises findings and outcomes from three components:-
    i) A review of water values in arid zones of SA (chapter 3)
    ii) Forum and Workshop outcomes (chapter 4)
    iii) Future research directions and opportunities (chapter 5)
2. A poster entitled 'Capturing key cultural and environmental water values in Australian arid landscapes' that summarised the key findings of the work, was presented at the Goyder Institute for Water Research Annual Water Forum held on May 28 and 29 2012.
3. A forum proceedings document, comprising short papers from speakers at the Forum and Workshop (Activity 2), will be co-edited by CSIRO and SARDI and produced as a standalone document.

3. A review of water values in arid zones of SA

3.1. Defining the value of water

The Oxford Dictionary defines *value* as 'the importance, worth, or usefulness of something; one's judgement of what is important in life'. This definition infers a level of individual choice in valuing or not valuing something. Yet, the fundamental need for water for human survival implies that water is valued to some degree by everyone. Understanding what these values represent and how they are manifested is complex, as perceptions of water's significance can depend on the interplay between cultural philosophy, historical experience and people's relationships to specific features of the landscape (O'Brien & Guerrier 1995; Jackson 2006; Gibbs 2010).

Categorisation of values associated with water and water dependent ecosystems into distinct and often non-integrated classes such as 'economic', 'environmental', 'cultural' or 'spiritual' has often provided a framework for developing water management strategies throughout Australia (DIPE 2002; Murray et al. 2006). Whilst playing an important role in knowledge exchange and ensuring that viewpoints are tabled, such an approach can be viewed as typically Eurocentric – one often incompatible with Aboriginal peoples' connections to and relationships with water (Rose 1996; Yu 1999; Ah Chee 2002; Langton 2002; Jackson 2006; Gibbs 2010; Barber and Jackson 2011).

For many Aboriginal people, water is seen as an integral component in the expression of their relationship to their country and culture (Hercus and Sutton 1985; Hercus and Clarke 1986; Wirf et al. 1999; Kimber 2011). It is the most important feature of the landscape, providing food, drink, economic benefits and amenity (Pearce et al. 2008; Simpson 2008), sustaining spiritual and tangible connections between past and present, forming the basis of stories, artwork, dance and ideas, guiding customs and belief systems and linking generations through transfer of knowledge and practices (Yu 1999; Toussaint et al. 2005; Cooper and Jackson 2008; Barber and Jackson 2011; Woodward et al. 2012). This multi-faceted and dynamic connection with water places is captured neatly by Ah Chee (2002) who described Indigenous people's links with water in the GAB. His paper discusses the significance of Witjira-Dalhousie Springs, a mound spring supergroup in Witjira National Park in northern SA:-

'Dalhousie Springs is known collectively as *irrwanyere* or the healing springs. Well before my elders' time, it provided more than just a source of water for Indigenous people. For it was and remains a travel path, which connects many Indigenous groups within the trail of the GAB and is our *Tyukurpa*.'

'*Tyukurpa*', in this context, incorporates spiritual connections, law, culture and history which are the fundamental reasons behind the existence of water, fire and landscapes and integral to the conceptualisation of country (Yu 1999; Ah Chee 2002). He continues, describing Indigenous peoples' holistic approach to water:-

'This water is a source of healing when we are sick, and it provides us with many spiritual and cultural interests. For it is our lifeblood which we need to survive. It allows us to continue our ceremonies which incorporate our rich and unique culture that is still strong today. For it is these sources of water which provide an adequate and valuable food source rich in fish and other foods for my people.'

The Witjira-Dalhousie Springs, in addition to the mound spring complexes on the south western margin of the GAB near Lake Eyre and Lake Frome, are also seen as sites of great biological, ecological, archaeological, hydrological, geological and conservation and heritage significance (Lampert 1985; Ponder 1986; Harris 1992; Kodric-Brown and Brown 1993; Morton et al. 1995; Mudd 2000; Schmiechen 2004, 2012; Fensham et al. 2007; Gotch et al. 2008 – see also chapter 3.2). These springs are also central to tourism operations in the region, with the area having obvious aesthetic appeal (Dodd and Jenkin 2004; Hadwen et al. 2012). In recognition of their natural, historical and cultural importance for Australia (Harris 1981; Kinhill 1984; Hercus and Sutton 1985; Keane 1997; Ah Chee 2002), the Witjira-Dalhousie spring complex was awarded Australian National Heritage listing in 2009, and all communities of native species reliant upon groundwater discharge from the GAB are now protected under the *Environmental Protection and Biodiversity Conservation Act 1999* (Fensham et al. 2007).

The example above illustrates just some of the diversity of values that are commonly linked to water in arid zones of SA and across the country. It is important to consider that these values are not necessarily static in space and time, nor culturally specific (Gibbs 2006; Jackson 2006), and that value systems can differ within cultures as much as among them (e.g. Strang 2008). The difficulties inherent in defining values in simple terms, highlights the complexity of protecting and managing these values appropriately (Gibbs 2009, Ens et al. 2012). The contention surrounding the very recent case of the successful native title claim on Lake Eyre is a case in point. After a 14 year legal campaign, the Arabunna people were granted native title to 69,000 km^2 of land including Lake Eyre and the Wabma Kadarbu mound springs on May 22, 2012. The Arabunna hold strong cultural and spiritual associations with Lake Eyre and its surrounds. In an interview with *The Advertiser* on May 22, 2012, Aaron Stuart, the chairman of the Arabunna Aboriginal Corporation stated:-

'Lake Eyre is a sacred and significant place to all Arabunna people … We care for that land and the lake and we want to see the land protected. This does not mean that we object to tourists ... we are happy to share our country.'

Although tourists are welcomed, the use of boats on the lake continues to be discouraged by both the Arabunna, and through the formal requirement to obtain written permission from the Department of Environment and Natural Resources (DENR) to boat on the lake.

'We are happy for people to come and enjoy this land and the lake, swim in it and see its beauty, but we do not want boats on the lake. We want the site protected and we want the whole of the lake protected ... we also worry about safety with boats.' (Aaron Stuart - excerpt from the interview with *The Advertiser* on May 22, 2012).

Perhaps not surprisingly, members of the Lake Eyre Yacht Club, who have sailed on the Lake periodically since 2000, have taken issue with these regulations, and contend that they breach common law rights to boat on navigable waterways. Bob Backway, the Commodore of the Lake Eyre Yacht Club writes:-

'While Native Title gives rights to continuance and control over traditional activities it cannot override common law rights. Federal Courts have already made decisions that native title rights and interests that are contrary to well established principles of common law can not be recognized if to do so would 'fracture a skeletal principle' of the Australian legal system.' (Backway 2012).

Clearly, the value of Lake Eyre is expressed in several ways by Indigenous and non-Indigenous user-groups, including tourists, local residents in nearby towns such as Marree, and people associated with the Lake Eyre Yacht Club. Backway (2012) argues that the marked ephemerality of the Lake, with complete filling occurring only a few times a century, provides visitors a 'once in a lifetime' opportunity to experience the lake and its water-dependent ecosystems in full bloom. He writes of the aesthetic appeal to tourists when the lake is in flood, and the feeling of being in an 'alien' landscape, and touches upon the historic and conservation values of the system. Equally significant are the biological, ecological, hydrological, geomorphological and conservation values of the area (see Morton et al. 1995 for review). The importance of Lake Eyre to waterbirds during flood cycles is perhaps most recognisable and well documented, with colonies of Australian pelicans, cormorants, black swans, terns and silver gulls establishing during floods (Kingsford et al. 1999).

Jackson (2006) suggests taking a collaborative and 'relational' view of water values, that, rather than simply categorising values into particular groups, will enable better understanding of the intrinsic relationships that Aboriginal and non-Aboriginal people have with water. Efforts to integrate Indigenous ecological knowledge (IEK – Berkes 2008) and western scientific and stakeholder knowledge into water resource management programmes (Ens et al. 2012; Weston et al. 2012; Woodward et al. 2012; Scholtz and White unpubl. data) have been suggested as a more productive way of assessing socio-ecological and socio-economic impacts of water management decisions. The signing in 2004 of the National Water Initiative Inter-governmental Agreement (NWI) by all Australian states and territories, demonstrated a nation-wide commitment to incorporating 'Indigenous social, spiritual and customary objectives' and ensuring indigenous representation in water planning. A recent project 'Cultural Water Management – Engagement, Consultation and Protocols' coordinated by DEWNR, aimed to engage Aboriginal communities in the Alinytjara Wilurara NRM (AWNRM) region in water resource management (G. Scholz unpubl. data), and is an example of how NWI commitments are being addressed. Such approaches, whilst often challenging due to cultural differences in philosophy around environmental management (see Ens et al. 2012) may have the dual benefit of increasing cross-cultural engagement in water resource management, while also bridging the gap between directly quantifiable values associated with water resources and more intangible, socially constructed values integrated from different cultural perspectives (Gibbs 2006; Jackson 2006; Moggridge 2010; Ens et al. 2012).

In the remainder of this section, we have attempted to balance such a relational approach, incorporating the marked variability in how people value water, with recognition of the benefits to research, management and policy development that formal classification of value types can bring. We describe the water dependent landscape of arid zone of SA, ecosystem by ecosystem, then identify and document the human, faunal and floristic relationships to it.

3.2. An ecosystem-specific assessment of water values

3.2.1 Water dependent ecosystems in arid zone SA

The economic values of surface and groundwater systems in arid zones have long been recognised, but it is only relatively recently that scientific interest in these systems has matched economic interest in utilising them. It is now widely accepted that hydrological connection is expressed in longitudinal, lateral and vertical planes across the landscape (Vannote et al. 1980;

Thorp et al. 2006; Datry et al. 2008; Boulton et al. 2010), and this view has reshaped traditional perspectives of physical and ecological functioning within and between surface and groundwater systems. In most landscapes, and at certain times, a degree of connection exists between surface water rivers, lakes and floodplains and the underlying groundwater contained in aquifers (Boulton and Hancock 2006). However, surface water-groundwater interactions are typically complex, and may be governed by local topography, geological characteristics, hydrology and climatic patterns (i.e. seasonality of recharge/discharge processes) as well as water use (i.e. supporting terrestrial vegetation or water extraction activities) or loss through transpiration and/or evaporation (Hatton and Evans 1998; Winter 1999; Costelloe et al. 2007; Cendón et al. 2010). For example, in intermittent arid zone rivers such as Cooper Creek in the arid north-east SA and Queensland, recent studies based on surface water level measurements, piezometer readings, stable isotope (i.e. δ^2H and $\delta^{18}O$) composition and modelled evaporation rates have shown that groundwater recharge is virtually non-existent under low- or cease-to-flow conditions (Hamilton et al. 2005; Costelloe et al. 2007; Cendón et al. 2010), but that some surface-groundwater exchange likely takes place via scouring of the bottom of waterholes immediately following large flood and rainfall events (Cendón et al. 2010; Tweed et al. 2011). Other water sources such as rain-dependent rockholes, ephemeral rills, clay pans and streams that flow only following recent rainfall or due to surface runoff, may have no contact with groundwater. These 'surface water dependent' sites may still support important ecosystems, and have substantial historic and contemporary value as water points in arid landscapes (Bayley 1997; Jenkin et al. 2009, 2011; Silcock 2009; White 2009; Watt and Berens 2011). Yet, given the critical importance of groundwater resources to industry development in arid zones of SA, we focus our attention in the next paragraphs on groundwater and its dependent ecosystems, returning to document values and threats to surface water dependent systems in the next chapter.

Groundwater can be defined as underground water that fully saturates fissures and pores below the earth's surface (Giordano 2009). More transient, shallow water, stored between soil particles near the land surface is excluded from this definition. Groundwater contained in aquifers is estimated to comprise 97% of the world's unfrozen fresh water (Gibert et al. 1994). In arid zones of Australia, increased utilisation of groundwater resources, both for human supply purposes and industry development, has led to concern around potential impacts that extraction may have on groundwater quality, recharge/discharge rates and the ecological, socio-economic and cultural values of ecosystems that depend upon it (see Murray et al. 2003). Yet, our understanding of the physical and ecological interactions occurring within aquifers and the risks to the values of GDEs posed through intensified water extraction activity remains limited (Kemper 2004; Hancock et al. 2005; Boulton et al. 2008; Tomlinson and Boulton 2010).

We adopt Clifton et al's. (2007) definition of GDEs as ecosystems that require access to groundwater to meet all or some of their water requirements so as to sustain their communities of plants and animals, ecological processes and ecosystem services. Ecosystem dependence on aquifers can be obligate or facultative (Bertrand et al. 2012), and may be described in relation to the availability, quantity, quality or pressure of groundwater required to maintain natural GDE functioning (Evans and Clifton 2001; SKM 2001; Murray et al. 2003). Perhaps the best example of obligate dependence is seen in subterranean cave and aquifer ecosystems. These systems typically harbour a highly diverse and specialised 'stygofauna' comprising species of invertebrates and fish that are intrinsically dependent upon the groundwater they inhabit (Humphreys 2001; Humphreys 2006; see Tomlinson and Boulton 2010 for an Australia-wide review). The communities of flora, fauna and bacteria supported by the surface expression of the GAB at mound spring complexes

and runoff channels are, in a similar fashion, entirely reliant on aquifer discharge to maintain species and ecosystem functioning (Andrews and Patel 1996; Fensham et al. 2007).

Partial dependence on groundwater is evident in some floodplain and riparian vegetation communities in the semi-arid zone of SA (e.g. stands of River Red Gum *Eucalyptus camaldulensis* – Mensforth et al. 1994; see also Tomlinson 2011), with the reliance on and use of groundwater resources found to vary seasonally and with distance from, or availability of surface water sources (Thorburn and Walker 1994; Mensforth et al. 1994). Similar seasonal fluctuations have been noted in more temperate *Banksia* spp. dominant woodlands (e.g. Zencich et al. 2002), where aquifer drawdown has resulted in extensive vegetation death (Groom et al. 2000) or marked changes in community composition from larger, deep-rooted species to more shallow-rooted, non-woody species less dependent on specific hydrological conditions (Sommer and Froend 2011). Facultative and obligate dependence can also occur simultaneously within a GDE. For example, the hyporheic zone the zone of saturated sediments below and alongside river channels where stream and groundwater exchange (White 1993; Boulton and Hancock 2006) can host and connect obligate aquifer dependent and surface water dwelling invertebrate species, in addition to providing critical functions in the biogeochemical transformation of water upon which periphyton growth and subsequent stream-bed productivity at 'upwelling' zones rely (see Boulton and Hancock 2006; Boulton 2007).

Determining the groundwater regime required to ensure the persistence of particular GDEs (i.e. quantifying their degree and timing of groundwater dependency) has been identified by Eamus et al. (2006) as a key element in managing groundwater use sustainably and conserving the ecosystem values that depend on it. This task has proved difficult, and made more complicated due to: 1) impacts of groundwater extraction on dependent species or ecosystems may not be seen immediately, or for several years (e.g. response of long lived trees); and 2) multiple and interacting aspects of the groundwater regime may be ecologically relevant, and consequently, there is a current lack of suitable response curves to predict the ecological outcomes of particular water management decisions (Howe et al. 2007; Boulton 2009; Tomlinson 2011). Tomlinson (2011) stresses the need to implement long-term approaches to developing ecological response functions that measure changes in ecological processes across a broad range of hydrological conditions, and incorporate multiple ecological characters. Until such research programmes are instigated, adoption and testing of some assessment tools presented in the Australian GDE Toolbox (SKM 2011) that focus primarily on vegetation responses, may be a productive way forward.

In acknowledging the need for a more coordinated approach to groundwater and GDE management, the Australian National Water Commission has recently published a series of reviews detailing key groundwater issues across the country (e.g. Tomlinson and Boulton 2010; Barron et al. 2011; Parsons et al. 2011; Tomlinson 2011; RPS Aquaterra 2012). The Commission also contributed funds to the project 'Allocating Water and Maintaining Springs in the Great Artesian Basin' (AWMSGAB) which aimed to better understand the hydrogeological and ecological systems at the western margin of the GAB in SA. This four-year project, due for completion at the end of June 2012, was a collaborative of researchers from SAALNRMB, Flinders University, University of Adelaide, DEWNR, NRETAS and CSIRO. The primary output from this work is a six volume report series that will provide new understanding of the GAB groundwater systems (including hydrogeology, recharge/discharge rates, hydrodynamics and hydrochemistry – Keppel et al. 2012; Love et al. 2012; Wohling et al. 2012), springs and spring ecology (Gotch 2012; Lewis et al. 2012), in addition to detailing a risk assessment process for evaluating water use impacts on

GAB springs (Green et al. 2012b). The large research investment by SAALNRMB over the past few years has also added greatly to the knowledge base on surface water and groundwater assets in arid zone SA, and in effect, reflects the high value placed on water to these regions. Silcock (2009) for example, compiled a comprehensive inventory of permanent surface waterbodies throughout the Cooper Creek, Diamantina and Georgina River catchments in the LEB, classifying the permanence and values of waterholes, lakes, rockholes and springs and on the basis of interviews, reference to primary and secondary literature and fieldwork. Further, work by Jenkin et al. (2009) and White (2009) identified and assessed the ecological and cultural values of Gawler Ranges rockholes (see also Bayly 1999), while Ehmann (2009) benchmarked the diversity, distribution and abundance of frog and fish communities of the Flinders Ranges and White and Scholz (2008) prioritised Flinders Ranges spring systems of ecological significance. The Neales River, to the west of Lake Eyre has also received significant attention in recent times, with a series of reports documenting the hydrology and geomorphology of the catchment (Costelloe 2011; Wakelin-King 2011) and the ecological and cultural values of, and threats to, key refuge waterholes in the Neales and Peake catchments (see Lee 2011; McNeil et al. 2011a; Scholz and Deane 2011).

These works provide a helpful platform for understanding the ecological, economic, social and political issues surrounding groundwater management at a nationwide scale and in relatively data-rich regions of SA. However, in the much of the non-prescribed region, a major impediment to managing groundwater and water dependent ecosystems sustainably, has been the paucity of data on their location, physical characteristics and values (Buxton 2005; Harding and O'Connor 2012). Watt and Berens (2011) recently collated information on the non-prescribed groundwater resources in the AWNRM Region, and provided a breakdown of resources by hydrogeological unit (see also Australian Groundwater Technologies 2010a, b). This area has very few permanent surface waters, and the widely dispersed Aboriginal communities rely almost exclusively on groundwater supply from low yielding wells (Buxton 2005). Historical use for groundwater resources in the AWNRM region has been comparatively low, with requirements only for community use and limited pastoral activities. However, the area has been tagged as high priority for mineral exploration (Australian Groundwater Technologies 2010a, Watt and Berens 2011), and consequently, groundwater demand is expected to rise dramatically over the next 40 years to cater to mining developments (Watt and Berens 2011). The cumulative risk posed by increased mining activities, agricultural expansion and predictions of decreased rainfall and groundwater recharge-regenerating rainfall events in the AWNRM region and other priority zones under the latest climate change projections (DENR 2010; Green et al. 2012a; Alcoe et al. 2012) to potable water supplies, ground and surface water dependent ecosystems and the myriad values associated with them remains unquantified. Yet, attempts to identify water values across SA arid zones (see Hale 2010 for an application of High Ecological Value Aquatic Ecosystems (HEVAE) criteria in the LEB) could provide a framework for better understanding and prioritising these risks (Wood and Green 2011; Harding 2012; Harding and O'Connor 2012).

3.2.2 GDEs in arid zone SA: definitions, distribution, values and threats

Eamus et al. (2006) categorised GDEs into three broad classes: aquifer and cave ecosystems; ecosystems dependent on the surface expression of groundwater; and ecosystems dependent on the subsurface presence of groundwater. For the purposes of this report, we simplify this classification into two categories: 1) subsurface GDEs; and 2) surface GDEs. The definition, distribution, characteristics and values of ecosystems within each category are detailed below.

3.2.2.1 Subsurface GDEs

Definition and distribution

The simplest definition of a subsurface GDE is a subterranean aquatic ecosystem reliant on groundwater. Parsons and Wetzel (2007) add that such a system would be 'significantly altered by a change in the chemistry, volume and/or temporal distribution of its groundwater supply'. Ecosystems associated with, and operating within karstic, calcrete, alluvial, fractured rock and paleovalley aquifers, anchialine pools, caves, and transitional hyporheic, vadose and psammo-littoral zones can be defined as types of subsurface GDE (Tomlinson and Boulton 2010). Few data exist on the distribution and ecological functioning of these ecosystems in arid parts of SA. However, increased recognition of the high biodiversity value of subsurface GDEs has led to significant research effort on these systems in other parts of Australia, particularly Western Australia (WA), where surveys of groundwater fauna have often formed part of mining impact assessment studies (EPA 2003; Eberhard et al. 2009). We have decided to focus here on ecosystems operating solely *within* aquifers, and while acknowledging that aquifer-hyporheic-surface water systems do not function independently, we refer readers to papers such as Cooling and Boulton (1993), Gibert et al. (1994), Gibert and Deharveng (2002), Malard et al. (2002), Hancock et al. (2005), Boulton (2007), Boulton et al. (1998, 2010), Stubbington (2012) that review stream–groundwater interactions in the hyporheic and vadose zones, and discuss ecological, hydrological and biogeochemical processes within them. It is important to note that all but one of these studies (i.e. Cooling and Boulton 1993) were not undertaken in SA and therefore, may not be directly relevant to SA systems. Clearly, more work is required to fill knowledge gaps around the location and functioning of hyporheic ecosystems throughout the state, and in particular, those regions where mining development is set to increase.

The western extension of the GAB which underlies a large part of SA's north-east corner, consists of alternating layers of permeable sandstone aquifers, and impermeable siltstones and mudstones. The lower confined Cadna-Owie Formation and Algebuckina Sandstone aquifers (i.e. Cadna-Owie- Algebuckina aquifer), and an upper confined, non-artesian aquifer consisting of sediments of the Winton and Mackunda Formations, comprise the two major aquifers in the SA portion of the GAB. A discrete aquifer of high salinity and low yield, named the Coorikiana Sandstone, occurs within the confining beds separating the two main aquifers (SAALNRMB 2009). The Cadna-Owie-Algebuckina aquifer meets most of the water demand in the Far North Prescribed Wells Area (FNPWA) and also supports the mound spring ecosystems along the western margin of the GAB (see chapter 3.2.3). Extensive networks of paleochannels - ancient river channels that are no longer active - exist in parts of the Musgrave Block, From Embayment and AWNRM region. The remaining aquifers in the arid zone are generally porous and of low to moderate productivity, with deep fractured rock systems underlying the Gawler Ranges area parts of the Frome Embayment and North Flinders Ranges (Sundaram and Coram 2009; SAALNRMB 2010) and some karst features on the far west coast (Holmes et al. 2001; Guzik et al. 2011).

Values

Knowledge of the significant ecological and physical values of subsurface GDEs has increased markedly in recent times, as has the importance of aquifers (and the microbial communities within them) in providing key biogeochemical processes that sustain hyporheic and surface GDEs (Chapelle 2000; Boulton and Hancock 2006; Boulton 2009). Despite the current paucity of publicly

available data on aquifer ecosystems and processes in arid regions of SA (but see Leys et al. 2010), work in WA, and to a lesser extent in the eastern states (e.g. Hancock and Boulton 2008) has uncovered the astonishing biodiversity existing within cave and aquifer ecosystems (Eberhard et al. 2005; Humphreys 1989, 1999, 2000, 2001, 2006, 2008; Thurgate et al. 2001; Boulton et al. 2008; Guzik et al. 2011), whilst also voicing concern over threats that groundwater mismanagement may pose to these systems (e.g. Boulton et al. 2003; Boulton 2005). A comprehensive review by Tomlinson and Boulton (2010) reported that the Australian stygofauna is dominated by highly specialised crustaceans including numerous endemic amphipod species (see also Bradford et al. 2010; King et al. 2012) and a large diversity of isopods, copepods, ostracods, anapsids and dytiscid beetles (see also Wilson 2003; Karanovic 2004, Reeves et al. 2007; Karanovic and Eberhard 2009; Leys et al. 2010). Members of the Bathynellidae are also common and are increasingly garnering attention from invertebrate biologists (e.g. Camacho and Hancock 2010), as are arachnids, that comprise the majority of the described arid zone troglofauna - air-breathing terrestrial animals that live underground in caves and meso-caverns (see Edward and Harvey 2008; Burger et al. 2010). Two species of fish, the blind cave gudgeon (*Milyeringa veritas*) and the blind cave eel (*Ophisternon candidum*) live in sympatry in groundwaters of Cape Range peninsula and Barrow Island, northwest WA and are Australia's only known stygobiotic vertebrates (Humphreys 2001). It is estimated that over 4000 species of subterranean fauna are present in the western half of arid zone Australia (Guzik et al. 2011) with only a few small percentage of these species described to date.

Guzik et al. (2011) considers the Australian subterranean fauna to be globally unique, both in terms of its contemporary biological value, in addition to its evolutionary, geological and paleoclimatic significance. Guzik et al. (2011) base this uniqueness on three key points: 1) 'the range and diversity of subterranean habitats is both extensive and novel'; 2) 'direct faunal links to ancient Pangaea and Gondwana are evident, emphasising their early biogeographic history'; and 3) 'Miocene aridification, rather than Pleistocene post-ice age driven diversification events (as is predicted in the northern hemisphere), are likely to have dominated Australia's subterranean speciation explosion.' Subterranean faunal diversity in SA is predicted to be lower than that of WA (Guzik et al. 2011), but this may be a simple function of the differing research commitment in each state. The recent discovery by Leys et al. (2010) of a new species of groundwater diving beetle *Paroster extraordinarius* sp. nov. (Dytiscidae: Hydroporini) from a well in the semi-arid Flinders Ranges, the collection of several stygobiotic crustaceans, oligochaetes and hydracarids and an undescribed chiltonid amphipod during the same surveys, and strong evidence of bacterial activity in calcite formation within Nullarbor Plain cave systems (Contos et al. 2001) suggests that the biological values and ecological roles of SA aquifer ecosystems may currently be underestimated, and warrant further attention.

Aquifers are also critically important for providing water to communities in arid zone SA as well as major towns throughout central Australia (e.g. Alice Springs) where surface water is scarce or non-existent, and potable or non-potable supply is sourced from low yielding wells (e.g. Nepabunna – Pearce et al. 2008; AWNRM region – Watt and Berens 2011; FNPWA – SAALNRMB 2009). In the AWNRM region for example, 11 major Aboriginal communities and several smaller settlements rely almost solely upon groundwater for their water supply. Wells tap fractured rock aquifers and alluvial outwash aquifers throughout the northern ranges, or are sited on dunefields where localised recharge creates defined fresh water pockets (Australian Groundwater Technologies 2010a). Existing mining and pastoral holdings also depend heavily on groundwater, and thus place considerable economic value on the groundwater resource. Its value to industry is set to increase

into the future, with water demands, particularly from the mining sector, expected to rise dramatically as mineral exploration expands (Watt and Berens 2011).

The social, cultural, spiritual and historic connection between groundwater and Aboriginal and non-Aboriginal residents and tourists is significant in many arid areas of the state (Hercus and Sutton 1985; Moggridge 2005; Pearce et al. 2008; SAALNRMB 2009; Lee 2011; Schmiechen 2012). For example, the groundwater-fed wells or *mikiri* in the Simpson Desert, were crucial to the Wankangurru people, the traditional inhabitants of that land (Hercus and Clarke 1986). According to a Wankangurru man interviewed as part of the study by Hercus and Clarke (1986), following large rains, when all surface water had dried, the Wankangurru relied upon the permanent water of the *mikiri* and spent large periods of time near these well sites. These same wells were also important for explorer D. Lindsay, providing a pathway through the Simpson Desert on his expedition in 1886 (Lindsay 1893, cited in Hercus and Clarke 1986). Lindsay was guided to these wells by Wankangurru men, illustrating an example of cross-cultural knowledge exchange in an era where such concepts were not often considered (see other excerpts from explorer's journals describing 'native' wells in Bayly 1999). Groundwater has provided the basis of dreaming stories and intergenerational knowledge transfer on the formation of spring waterholes in the Flinders Ranges (see Moggridge 2005), and is central to traditional ceremonies, healing, and the constructing and maintaining customs and belief systems throughout arid zones of SA (Ah Chee 2002; Lee 2011). In a more contemporary sense, Pearce et al. (2008) reports on some of the 'cultural challenges' that stem from differing perceptions of the value of water in the context of the groundwater supply to Nepabunna Aboriginal Community, in the Northern Flinders Ranges. Economic benefits derived from groundwater via tourism or employment in industry development may also be substantial in certain regions (Schmiechen 2006, 2012), but opportunities to reap these benefits may be tied to cultural background. Varying cultural perceptions highlight the inherent complexity in effectively capturing the value people place on groundwater and its associated ecosystems. Yet equally, such differences demonstrate the need to consider all value systems in developing groundwater management plans in arid zones.

3.2.2.2 Surface GDEs

Definition and distribution

We have modified the definition of Eamus et al. (2006), and consider surface GDEs to be aquatic and terrestrial ecosystems existing on, or above the ground, that are at least partially dependent on groundwater. In the arid zone of SA, this definition includes ecosystems associated with base-flow rivers and creeks, lakes, artesian mound spring systems and non-artesian spring systems. These are iconic surface water features in the arid landscape and therefore, rather unsurprisingly, there has been substantial investment in research into the formation, structure, functioning and values of several of these ecosystems types. The vast majority of this work has been focussed on the mound spring complexes that are natural surface expressions of the GAB (e.g. Harris 1981; Habermehl 1982; Ponder 1986; Harris 1992; Morton et al. 1995; Keane 1997; Mudd 2000; Ah Chee 2002; Fensham et al. 2007; Keppel et al. 2011; Parsons et al. 2011). The Dalhousie, Lake Eyre and Lake Frome spring supergroups in SA contain more than 4000 individual springs (Gotch 2007; Fig. 1), and these are considered environments of international significance. The spring ecosystems support over 50 species of flora and fauna, many of which are relict and/or endemic (Ponder 1986; Glover 1989; Kodric-Brown and Brown 1993; Ponder 2003; Fensham et al. 2007; Gotch et al. 2008; T. Gotch pers. comm.), and in recognition of their value from ecological, cultural, hydrological,

spiritual, archaeological, economic and conservation standpoints, they were recently listed under the Commonwealth's EPBC Act 1999 (Fensham et al. 2007).

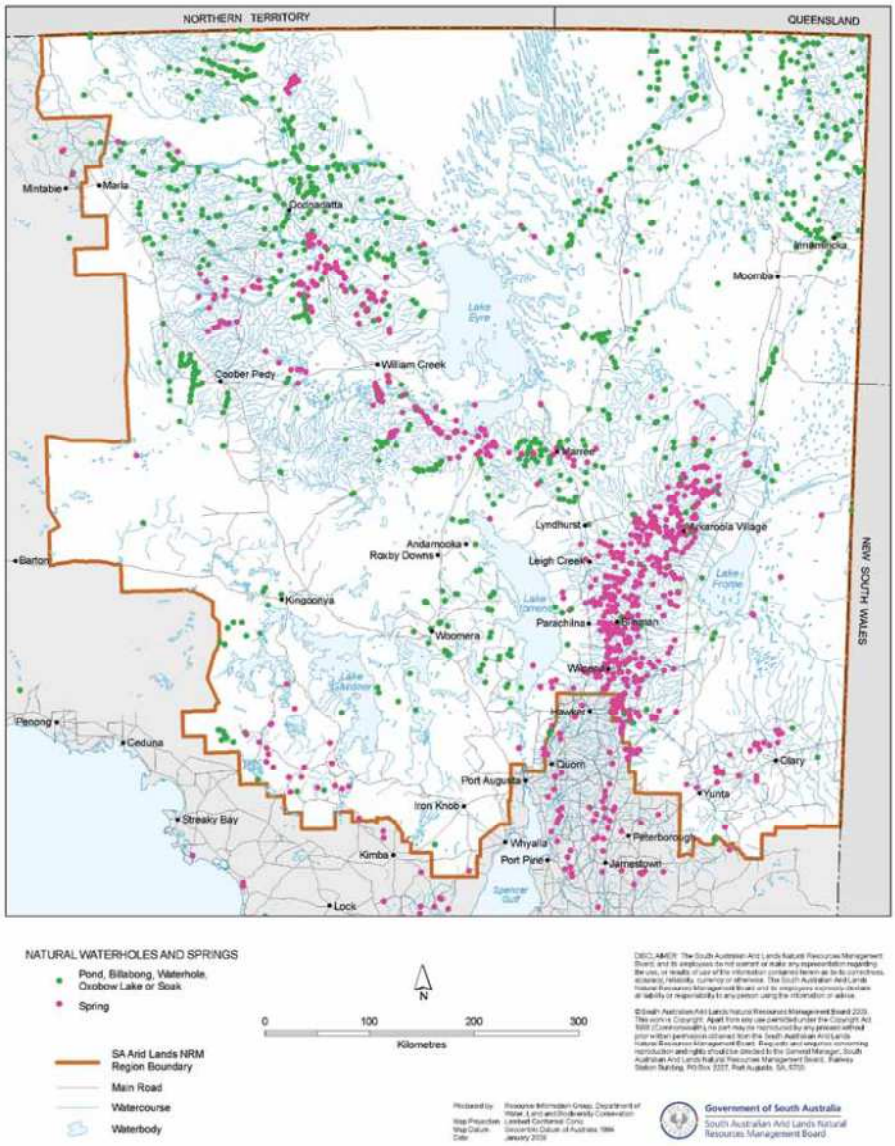


Fig. 1. Waterholes and springs in the SAALNRM region, reproduced from SAALNRMB (2010).

Much attention has also been paid to documenting the substantial biophysical values associated with dryland rivers, lakes and waterholes of the LEB, particularly the Cooper and Strzelecki Creeks, Diamantina, Georgina, Neales, Peake, Finke River catchments (e.g. Morton et al. 1995; Walker et al. 1997; Kingsford et al. 1998; 1999; DEH 2002; Sheldon et al. 2002; Costelloe et al. 2003, 2004 (ARIDFLO), 2005; Duguid et al. 2005; Gibbs 2006; McMahon et al. 2008; McNeil and Schmarr 2009; Puckridge et al. 2010; Lee 2011; McNeil et al. 2011a; Scholz and Deane 2011; Wakelin-King 2011). The socio-cultural and economic values of these systems are less well defined, but have been explored to a certain extent in relation to the threats posed by water abstraction activities in the LEB (Walker et al. 1997; Kingsford et al. 1998, 1999). Surface-groundwater connections within these systems may be sporadic, occurring only during large scale floods in some regions (Hamilton et al. 2005; Bunn et al. 2006; Costelloe et al. 2007, 2009). However, most perennial or semi-permanent systems have at least some interaction with underlying aquifers (e.g. North Freeling

spring group on the Neales River - Costelloe 2011), which in turn can shape both ecological processes within and adjacent to waterbodies, and human use of these resources.

We direct readers to the references listed above (and other works cited therein) for further information on ecosystem dynamics and values of arid-zone rivers in the LEB and the GAB springs. Below, we focus our assessment of surface GDE values on the comparatively lesser studied ecosystems of the non-artesian fed springs and creeks originating in the Flinders Ranges, that lie to west of Lake Frome (Fig. 1). This region lies partly within the Frome Embayment, home to existing large-scale uranium mining operations (e.g. Beverley) and one of SA's most highly prospective areas for mining exploration as defined by PIRSA.

It is also important to note that aside from the culturally and ecologically significant rain-fed rockhole and 'apron' features of the Gawler Ranges (see Harding and Blesing 2008; Jenkin et al. 2009, 2011; White 2009), no known surface GDEs are present in that region (SAALNRMB 2010) and hence, it is not considered further here. The AWNRM region in the west of the state is thought to possess only very few permanent surface waters, but some do exist (AWNRMB 2012). The region is not discussed further in terms of surface GDEs, but the AWNRMB plan 2012-2013 specifies a programme to assess cultural and environmental values of five surface waters that is to be implemented in the next financial year (2012-13). Such work is clearly needed to determine the nature, groundwater dependencies and values of these surface waters in light of predicted expansion of mining activities in the region.

Values

Lake Frome is a large, endorheic salt lake, that is inundated only very rarely from creeks flowing down from the Northern Flinders Ranges (Morelli and DeJong 1996). The lake itself has received IUCN classification in 1991 for its regional geological value, contains an isolated group of mound springs on its eastern side (DEH 2002) and holds Dreaming significance for the traditional custodians, the Adnyamathanha (rock people). One Dreaming story involves the Rainbow Serpent *Akurra*, and his passage from Mainwater Pound down Arkaroola Creek to Lake Frome, where he proceeded to drink all of the water in the lake (transcribed from a 2003 ABC interview with Kristian Coulthard, a ranger from Vulkathunha-Gammon Ranges National Park). The Adnyamathanha people, who include the Pirlatapa, Yardliyawarra, Ngadjuri, Nukunu, Pankarla and Kunyani peoples (Jones and McEntee 1996), are thought to have occupied the Lake Frome region since the early Holocene based on archaeological evidence (see Walshe 2005). The lake has been central to traditional law and customs, and despite it's aridity, provided important sources of water in times of high rainfall that allowed passage from the Ranges to the lake shore (e.g. Eudlia Wagloona waterhole at the lake's south-eastern shore – see Walshe 2005). This connection continues today through the Adnyamathanha Cultural Use Zone, a 40 km long zone abutting Lake Frome that is set within the Vulkathuna-Gammon Ranges National park and is used for traditional hunting purposes. Balcanoona Creek, that originates in the Gammon Ranges and flows west to Lake Frome through the Cultural Zone, is the only arid catchment in Australia that lies completely within a protected area (DEH 2002). Weetootla Spring, a tributary of Balcanoona Creek, supports the only known native population of the endemic and critically endangered Flinders Ranges mogurnda (*Mogurnda clivicola*), the other translocated population occurring at Nepouie Spring, slightly to the east (McNeil et al. 2011b). Recent surveys suggest that the population size of *M. clivicola* is relatively stable compared with previous surveys undertaken in the late 1990's (Pierce et al. 2001). However, a high proportion of the adult fish captured during the most recent surveys (approx. 20%) exhibited marked discolouration and growths on the caudal peduncle, tail, flanks

and lower jaw that were suggested as manifestations of melanoma-type skin cancer as previously reported by Pierce (1996). As these populations depend on permanent spring water to persist, the interactive impacts of climate change, a small gene pool across extant populations and background radiation levels in spring water derived from rich local uranium deposits, need to be quantified in order to ensure long-term survival of the species (McNeil et al. 2011b).

Several expressions of groundwater and surface water exist in the Flinders Ranges. Fractured rock aquifers supply waterholes and spring ecosystems in the northern part of the range, and groundwater is also stored in unconsolidated sediments at the base of the range. Numerous ephemeral rock holes and clay pans hold water following rainfall events, and subsurface stream flow is common. In the region to the west and southwest of Lake Frome, there exists an extensive series of aquifer-dependent spring and creek systems (White and Scholz 2008; Ehmann 2009; McNeil et al. 2011b). These springs are permanent to semi-permanent, with spring flow controlled largely by local and/or regional groundwater recharge rates. Historically, such springs served as the primary water source for Aboriginal people and early settlers in the region, and some abstraction to service pastoral and domestic needs still occurs (White and Scholz 2008). A study by White and Scholz (2008) used a rapid qualitative assessment method to prioritise 13 springs for protection in the region based on several categories of hydrological, ecological (e.g. water permanence, uniqueness, riparian vegetation diversity, refuge potential for aquatic an terrestrial biota) and cultural value (i.e. importance as a designated cultural site). They found a high degree of permanence amongst these springs, and identified substantial biological, historical, cultural, economic and amenity values associated with particular sites (e.g. Yadnapunda Spring on Willow Springs Station). The recent discovery by Leys et al. (2010) of *Paroster extraordinarius* sp. nov. and other undescribed stygofauna from a well on Reedy Creek, also on Willow Springs Station is indicative of the potential, and as yet, unquantified ecological values that these spring systems may possess. Phylogenetic analysis suggests that this beetle is part of a clade of subterranean species originating from the Yilgarn area of Western Australia, which in turn has important evolutionary and paleoclimatic consequences for understanding stygobitic diving beetle biogeography. Many springs are located on private land, and were traditionally used as watering points for stock. Recognition of the value of these systems by landholders, both ecologically and for the tourism opportunities that intact, aesthetically pleasing springs can bring, has resulted in strategies to reduce grazing pressure by stock and feral animals around high value springs (i.e. fence construction). Moreover, investment in the provision of off-channel water points to some properties has had the duel benefit of limiting stock access to springs and reducing water extraction for pastoral and domestic use (White and Scholz 2008). However, management of grazing pressure can in itself have unforeseen impacts if not approached in a holistic manner. For example, fencing off of several springs in the Witjira-Dalhousie complex reduced total grazing pressure significantly. Yet, the subsequent response of emergent vegetation led to a loss of open water habitats which has been linked to a loss of key endemic species from those springs (Kodric-Brown and Brown 2007).

Ehmann (2009) quantified some of the biological values associated with surface GDEs in the Flinders Ranges, through field-based surveys of frogs and fishes from 26 springs and waterholes (of the approx. 250 currently mapped) situated along east, west and north flowing watercourses. High species diversity was observed at these sites. Eight fish species were recorded (of the 11 known to be extant in the region), including the endemic and critically endangered *M*. *clivicola* described above (see McNeil et al. 2011b), native flyspecked hardyhead (*Craterocephalus stercusmuscarum*) (although taxonomic status is uncertain at present), spangled perch (*Leiopotherapon unicolor*), carp gudgeon (*Hypseleotris* spp.), bony bream (*Nematolosa erebi*), Lake

Eyre hardyhead (*Craterocephalus eyresii*), desert rainbowfish (*Melanotaenia splendida tatei*) and alien eastern gambusia (*Gambusia holbrooki*). Three frog species were captured or observed (of the eight extant species): the endemic Flinders springs froglet (*Crinea* sp. nov.), the widespread desert tree frog (*Litoria rubella*) and spotted marsh frog (*Limnodynastes tasmaniensis*). The study by Ehmann (2009) was preliminary in nature, and expanding the spatial scale, frequency and intensity of sampling was recommended to accurately benchmark species' distributions and abundances in the region, and to help forecast the impacts that changes in grazing pressure, land use, rainfall and discharge rates may have on particular species and GDEs.

3.2.2.3 Threats to water values

Given the strong physical and ecological linkages that often occur between subsurface and surface GDEs, many of the processes that threaten the values of surface waters are equally relevant to groundwater, although the consequences are not as easily visible. In this section, we consider threats to all water dependent ecosystems together.

Water abstraction

Water abstraction from mining and agricultural activities has been identified as a key risk to the quality, availability and ecological integrity of culturally and/or environmentally significant water features in arid zones of SA (Hatton and Evans 1998; SAALNRMB 2010). Particular concern has been raised for ecosystems associated with the GAB, where aquifer draw-down and decreases in potentiometric potential have resulted in drastic decline in mound spring discharge (Harris 1981; Habermehl 1982, 1986; Parsons et al. 2011) and, in some cases, complete extermination of spring flows (Fensham et al. 2010). Draw down has been associated with significant losses of biota from spring ecosystems in SA, including local extinctions of endemic ostracods, isopods and hydrobiid snails (Kinhill-Stearns 1984; Kinhill 1997); and it is conceivable that several groundwater-dependent, and/or as yet undiscovered species, have recently gone extinct or are seriously threatened by excessive abstraction in combination with other stressors (e.g. climate change, grazing pressure, invasive species - Fensham et al. 2010; Morrongiello et al. 2011; Driscoll et al. 2012).

The GAB Sustainability Initiative Program (GABSI) has gone some way in remediating this situation through a staged program of bore rehabilitation across the GAB (SKM 2008; Fensham et al. 2010; Parsons et al. 2011). This program, which is scheduled for completion in 2014, has involved capping previously free-flowing bores that were first sunk in the 1880's (see Mudd 2000), and replacing earthen bore drains with piped reticulation systems. The work to date has succeeded in markedly reducing evaporation rates, restoring artesian pressure and encouraging sustainable water use for industry development across the basin (Ponder 2004; SKM 2008). However, development of robust relationships between aquifer pressure and bore remediation activities has been hampered by the lack of a formal state-based reporting structure for GAB pressure recovery trends, making GABSI's achievements in recovering aquifer pressure difficult to gauge (SKM 2008). Understanding the nature of such relationships is critical at present, as predicted expansion of mining operations for both mineral and coal-seam gas resources (e.g. Olympic Dam expansion – Government of South Australia 2011; Arckaringa Basin) is expected to place increased demands on GAB and other groundwater resources (e.g. Andamooka Limestone and Tent Hill aquifer at Olympic Dam – Government of South Australia 2011) and, by consequence, the ecosystems they support.

The issues revolving around water abstraction are not restricted to the GAB. In the AWNRM region, where communities rely primarily on low yielding wells for their potable supply, increased groundwater pumping rates for proposed mining operations may threaten the quantity and quality of water extracted from wells, with obvious flow-on effects to community amenity (Watt and Berens 2011). At present, there is minimal information available on water use for agricultural purposes within the AWNRM and SAALNRM regions, but groundwater demand, both now and into the future, may be considerable. Contamination of shallow aquifers via seepage of pollutants from tailings dams and other surface water features (see Government of South Australia 2011) can also act to alter water table levels, affect groundwater quality and reduce biodiversity in subsurface GDEs (Notenboom et al. 1994; Hancock 2002). In base-flow river systems, interactions between groundwater and surface water that are critical to surface and sub-surface biota and GDE functioning can also be unbalanced by water abstraction or diversion, riparian zone modification and disturbance, soil compaction, sedimentation and changes in land-use that may arise, for example, through intense grazing pressure at water points or infrastructure development for mining, urbanisation or irrigation purposes (Walker et al. 1997; Kingsford et al. 1999; Hancock 2002).

Climate change

Decreased rainfall and increased rainfall variability are predicted across much of SA over the next approx. 60 years, according to the latest climate change projections (Suppiah et al. 2006; CSIRO and Bureau of Meteorology 2007; DENR 2010; Green et al. 2011, 2012a; Alcoe et al. 2012). This scenario is thought to pose a significant threat to the state's water security into the future. Hydrological modelling studies conducted through the Department for Water's 'Impacts of Climate Change on Water Resources' (ICCWR) project have established that surface runoff and groundwater recharge is closely correlated with variations in seasonal rainfall totals (Northern and Yorke NRM regions – Green et al. 2011), or annual rainfall totals and the frequency of recharge-generating rainfall events (Eyre Peninsula NRM region – Green et al. 2012a; AWNRM region – Alcoe et al. 2012). Substantial reductions in surface run-off and groundwater recharge are predicted throughout the Northern and Yorke NRM region and the Eyre Peninsula region under both greenhouse gas emission scenarios considered (B1 'low' emissions and A2 'high' emissions). Decreased groundwater recharge is expected to lower groundwater levels across these regions, and when coupled with the predicted increase in evapotranspiration rates due to rising temperatures, the long-term sustainability of future groundwater extraction seems uncertain. In the north of the AWNRM region, emerging work suggests that the frequency of recharge-generating rainfall events and the intensity of extreme rainfalls will both be markedly reduced in the next 60 years. These scenarios are considered to present a serious risk to the future security of community water supplies in Yunyarinyi (Kenmore Park), Pukatja (Ernabella) and Kaltjiti (Fregon) (Alcoe et al. 2012).

The consequences of a warmer and increasingly dry climate for SA's arid zone GDEs are difficult to isolate given the natural climatic variability that characterises the region. Reduced recharge to, and discharge from aquifers has clear implications for species that have obligate dependence on groundwater or its surface expression for survival. However, many arid zone aquatic biota, including some fishes, are remarkably well adapted to persist under environmentally harsh conditions (see Balcombe and Arthington 2009; McNeil and Schmarr 2009; Macdonald et al. 2012). Nevertheless, in isolated spring systems under threat of reduced discharge, significant risks of range contraction and potential extinction of endemic and endangered fishes and other fauna do exist. Some examples are the endemic and critically endangered Flinders Ranges mogurnda, which

is currently known from only two spring systems in the Flinders Ranges (see above and McNeil et al. 2011b), and five endemic fishes from Witjira-Dalhousie Springs: the Dalhousie mogurnda (*Mogurnda thermophila*), Dalhousie catfish (*Neosilurus gloveri*), Dalhousie hardyhead (*Craterocephalus dalhousiensis*), Glover's hardyhead (*C. gloveri*), and Dalhousie goby (*Chlamydogobius gloveri*) (Fensham et al. 2007). The direct impacts of a changing climate on such groundwater-dependent species may be exacerbated by other biological (e.g. invasive species, disease) and human-induced factors such as habitat degradation, unsustainable grazing pressure or excessive water abstraction for industry development that may act alone or interactively to magnify impacts (Roshier et al. 2001; Morrongiello et al. 2011; McNeil et al. 2011b; Driscoll et al. 2012).

Invasive species

The spread of invasive species is considered one of the most pressing threats to global biodiversity (Lambertini et al. 2011), and is of major concern to water dependent ecosystems in Australian arid zones (White and Scholz 2008; Kerezy 2009; Brim-Box et al. 2010; Edwards et al. 2010; McNeil et al. 2011a). Many animal and plant species have established across arid zones of SA outside of their native range. These include camels, goats, rabbits, pigs, foxes, cats, wild dogs, three species of fish (i.e. eastern gambusia - *Gambusia holbrooki*; common carp - *Cyprinus carpio*, goldfish - *Carassius auratus*), and several plant species (e.g. buffel grass - *Cenchrus ciliaris*, date palms - *Phoenix dactylifera*, bamboo sp. and athol pine - *Tamarix aphylla*) (Norris and Low 2005; SAALNRMB 2009; Fensham et al. 2010). The relative impacts of these species on the values of waterways probably varies in space and time, but extensive damage to surface GDEs has been reported through grazing and trampling by goats, camels, pigs and rabbits (as well as domestic stock), causing compaction of soil, erosion, destruction of native riparian and aquatic vegetation, pollution and reduction in water quality (White and Scholz 2008; Brim-Box et al. 2010; Fensham et al. 2010). The detrimental impacts conferred by camels, in particular, to the ecological, cultural and aesthetic values of waterholes in central Australia have been well documented in recent times (e.g. Brim-Box et al. 2010; Edwards et al. 2010), and substantial funds continue to be invested in evaluating various management options (e.g. Drucker et al. 2010; Lamb et al. 2010; Lapidge et al. 2010).

The threats posed by invasive aquatic organisms to water values are often more difficult to quantify. Eastern gambusia, a small poeciliid fish native to south-eastern North America and northern Mexico is perhaps the most pervasive invasive fish in arid zone SA. Eastern gambusia's aggressive nature, high reproductive capacity and broad environmental tolerances account for their remarkable success as invaders (Courtenay and Meffe 1989; Howe et al. 1997; Caiola and de Sostoa 2005) and the species is now established in several major LEB river systems and springs, although populations are patchy (Puckridge 1999, 2010; Costelloe et al. 2010; McNeil et al. 2011a). Eastern gambusia can impact upon freshwater ecosystems through a variety of mechanisms including predation of, and competition with native fishes (Arthington et al. 1983; Barrier and Hicks 1994; Howe et al. 1997; Ivantsoff and Aarn 1999; Warburton and Madden 2003; Rincón et al. 2002; Caiola and de Sostoa 2005; Pyke 2005, 2008; Rowe et al. 2008), altering macroinvertebrate and zooplankton community structure (Margaritora et al. 2001; Cardona 2006), increasing primary productivity (Hargrave 2006) and triggering trophic cascades (Ho et al. 2011).

Some families of smaller-bodied native fishes present in SA arid zone waterbodies, particularly the Ambassids (glassfish), Melanotaenids (rainbowfishes), Atherinids (hardyheads), Eleotrids (gudgeons), may be highly susceptible to impact by eastern gambusia (Macdonald and Tonkin 2008). However, recent experimental work in Murray Darling Basin suggests that generalist life-history strategies that permit niche segregation may release some native species

competitive/predatory pressures, allowing coexistence with eastern gambusia in resource-limited, environmentally harsh habitats (Macdonald et al. 2012). In the LEB, there is a current management focus on the feasibility of eradicating eastern gambusia populations from GAB springs where they can impart strong control on the diversity and abundance of endemic fauna (Kerezy 2009; McNeil et al. 2011a).

Additionally, some invasive species have recently expanded their distributional range within the central Australian arid zone and the LEB. These include the cane toad - *Bufo marinus*, red claw - *Cherax quadricarinatus* and sleepy cod - *Oxyeleotris lineolatus*. The risks posed to the ecological values of SA water assets by the invasion, establishment and range expansion by such species are presently unknown.

Tourism and recreation

The rapidly expanding outback tourist industry may also pose a substantial threat to the values of water in particular parts of the arid zone (Hadwen et al. 2012). In the LEB for example, tourism is now a major land use, yet unlike mining, pastoralism and other community/industry developments in the region it is hardly recognised as such, with minimal regulative frameworks currently in place (Schmiechen 2012). Water sources are primary attractants for tourists in arid landscapes (Dodd and Jenkin 2004; Backway 2012; Hadwen et al. 2012). With increased access to prime sites through road upgrades and tourist infrastructure, in conjunction with the proliferation of four wheel drive vehicles and tour operators, the pressure on the natural values of waterholes and iconic water places is growing. Ironically, the biological, aesthetic, cultural, spiritual and amenity values that often draw tourists to water in the LEB are in fact the very values that they can threaten. Whilst providing substantive economic benefits to towns like Innamincka, Marree and Coober Pedy and supporting local entrepreneurs, tourism can sometimes threaten the economic water values held by other stakeholders (e.g. pastoral and mining operations). With the rate of visitation to the region likely to rise in the coming years, Schmiechen (2012) argues that management strategies must be holistic and consider the needs of all user groups in order to best protect waterways and their values in the arid zone.

In summary, under future scenarios of increased groundwater abstraction and decreased rainfall and recharge rates in SA's arid landscapes, the risks posed to GDEs by climate change, mining and agricultural industries and other anthropogenic factors, established invasive species and potential new incursions may be cumulative and act interactively (Driscoll et al 2012). Considering these factors together, and exploring the interactions as part of risk assessments (see Tomlinson 2011; Wood and Green 2011; Harding 2012; Harding and O'Connor 2012) may provide a robust platform to allow more accurate forecasts to be made on the nature and magnitude of threats to water values in arid zone SA.

4. Forum and Workshop outcomes

4.1. Overview

The Cultural and Environmental Values of Outback Water Resources: Forum and Workshop was held on May 10 and 11 2012. The event was structured around a series of oral presentations that were each classified into one of six themed sessions reflecting key environmental and cultural water values in Australian arid zones. At the conclusion of talks on each day, a workshop was held to capture the delegates' thoughts on definitions, attributes and threats to values (10 May), and to air ideas on where knowledge gaps exist, where new research opportunities lie and how funds should be invested (May 11). See Appendix 1 for the Programme and Abstracts from each presentation.

4.2. Day 1: Environmental Values

The oral presentations on May 10 aimed to capture current understanding of environmental values associated with water in arid zones of Australia. The three sessions differed somewhat in their focus. **Session 1: 'Hydrology and geomorphology: water's role in shaping the landscape'** included talks from Justin Costelloe and Gresley Wakelin King, who discussed the hydrological and geomorphological significance of some well known, and some lesser-studied dryland rivers in SA in the context of their substantial and sometimes multifaceted value to all user groups. Tanya Doody described some of the new remote-sensing methods being developed to map water dependent ecosystems across Australia and provided an update on progress of the national atlas of GDEs project, and Travis Gotch spoke on the many physical, evolutionary, ecological and cultural values of mound spring systems of the GAB.

In **Session 2: 'Ecological values associated with water'**, Dale McNeil stressed the critical role that iconic fishes of the LEB play in engaging people with water and protecting outback water values, and Jenny Davis outlined some ongoing work that aims to identify the scales, sites and processes (i.e. refugia, connectivity, dispersal, colonisation and establishment) that support persistence of freshwater biota under a changing climate. Chris Purnell talked birds, and highlighted the importance of flooding and drying to waterbird migration in the context of successional changes associated with 'boom' and bust' periods in arid wetlands, while Angus Duguid couched the myriad natural values of the mid-Finke River system, and provided background into the HEVAE framework for ranking biologically significant places.

Session 3: 'Managing water values and assessing threats' comprised a package of talks on the issues surrounding feral camels, their impacts on surface waters in central Australia and the work currently underway to minimise these impacts. Andy Bubb set out the objectives of the Australian Feral Camel Management Project (AFCMP), and explained the complexities and benefits associated with multidisciplinary and cross-jurisdictional pest management programmes. Jayne Brim-Box defined the major impacts of camels on wetland habitats, and through a case study, illustrated the advantages of using multiple approaches to quantify impacts including riparian vegetation, water quality and macroinvertebrate surveys, motion-detecting surveillance cameras and depth loggers. Pat Hodgens continued this theme, demonstrating the value of camera traps in assessing waterhole usage by birds, mammals and reptiles and providing Traditional Owners and rangers with visual documentation of camel impacts. Veronica Perurrle Dobson gave the final presentation of the day on a project to rehabilitate the Mparntwenge (Hayes Springs) and

Ilkerteye (Salt Springs) near Santa Teresa from the damage done by feral animals and cattle. The talk highlighted the benefits of a '2-way approach' incorporating traditional Arrernte and western scientific knowledge in fostering learning and ensuring protection of these springs.

Workshop 1: 'Identifying values, attributes and threats' followed the Session 3 talks, and began with a presentation from Henry Mancini on the approach taken by SAALNRMB to the management of water and water dependent ecosystems across their jurisdiction. His talk provided context for the workshop sessions on both days by conveying the values of water that are deemed most important to SAALNRMB and natural resource management agencies across the state, and identifying future research needs. The benefits of taking a holistic approach, that engages and incorporates Indigenous, scientific, management and stakeholder knowledge were emphasised, and better dissemination of this information was flagged as crucial to optimise water management strategies.

A discussion was then held with the whole group with the aim of defining and documenting the types of value that people place on water. Delegates were then divided into small groups, assigned a particular value type (e.g. cultural, environmental, economic) and then asked to complete two tasks: 1) identify the attributes (i.e. characteristics) that they associate with that particular value type, and 2) identify current and potential threats to these attributes. At the end of session, the data were entered onto a spreadsheet and the whole group ranked the importance of various value types, attributes and threats. This information was collated and is summarised in Table 1. The values, attributes and threats presented in Table 1 are not meant to be exhaustive. The data simply reflects the views and knowledge of the delegates that attended.

Table 1. Value types, attributes and threats identified during the workshop session on May 10 2012.

Aesthetic value (Artistic, Personal, Less tangible)	
Attributes	**Threats**
• Naturalness: aquatic environments largely undisturbed by humans or invasive species • Extreme aridity • High climatic and hydrological variability • Stability/familiarity of water sources • Aesthetics can be valued either at the site or from afar • Water provides opportunities for contemplation, reflection, creativity • Water is a subject of painting, photography, film, written and spoken word, dance, customs, ceremonies, traditions, ideas, belief systems • Provides a basis for connecting past with the present • Allows observation of alteration of the landscape over time (e.g. human-induced or natural changes)	• Excavating springs to allow greater stock access and enhance flows • Poorly regulated tourist access and use • Riparian vegetation loss, erosion, soil compaction and pollution from high grazing pressure and uncontrolled stock access • Water abstraction for mining, agriculture, consumptive purposes and flow on effects (i.e. water quality decline, changes in ecosystem processes) • Biodiversity loss • Invasion and establishment by alien animal and plant species • Climate change: lower rainfall, decreased groundwater recharge and increased evapotranspiration leading to reduced 'beauty' of site/region • Paucity of work on understanding the importance of aesthetic values • Water and visual pollution from rubbish disposal • Excessive infrastructure development related to tourism
Amenity/Consumptive value	
Attributes	**Threats**
• Food supply in the form of fish and yabbies • Potable and non-potable water supply to remote communities, homelands, properties and urban centres • Required to meet washing, cleaning and industrial needs • Long-standing community connection with groundwater dependent wells in some areas	• Groundwater abstraction near to critical wells and bores • Climate change: decreased rainfall, surface runoff and well recharge • Many wells in remote regions are old, have low recharge rates and are non-renewable • Lack of funding to site and sink new wells • High salinity and dissolved mineral concentrations in bore water • Limited water resources limits on community and economic growth

Cultural value (Historic, Heritage, Social, Spiritual)

Attributes	Threats
• Communication tool • Binds communities together • Mythical significance for Aboriginal people • Most important part of the landscape • Integral to maintaining connection between past and present • Intertwined with 'Dreaming' stories, creation sites, ceremonial sites, burial sites and teaching sites • Central to historic and contemporary scientific discoveries • Fundamental to livelihoods of early explorers and settlers • Historically provided a mutual point of understanding between Aboriginal groups and early setters/explorers • Principal guide to customs and belief systems • Stability/familiarity of water places important for intergenerational knowledge sharing • Cultural hero stories linking with spiritual significance along a song line • Allows continuation of, and information transfer about hunting and fishing traditions • Forms a basis of language • Connects culture to place • Resource for bush food, water and medicine, now and in the past • Gender specific valuation of water fosters understanding of traditional roles • Massacre sites where frontier battles occurred with traditional groups • Provides tribal boundary indicators • Sustains culturally specific totemic species • Provides tangible evidence of occupation: middens, campsites, artefacts, scarred and carved trees, stone arrangements, fish traps	• Destruction of significant sites due to industry development • Water extraction for agricultural, mining and domestic needs • Pollution • Climate change: dewatering of significant water dependent sites • Inadequate cross-cultural and cross-disciplinary knowledge exchange • Poor dissemination of scientific, managerial and Indigenous knowledge of cultural values to tourists and wider public • Poor regulation of tourist access and use • Lack of tourist infrastructure at significant sites • One-dimensional natural resource management decisions • Unauthorised collection of artefacts (souveniring) • Lack of publicly available documentation on cultural values from an Aboriginal perspective • Eurocentric approaches to management of water values • Loss of language and traditional stories • Technology and urbanisation severing young Aboriginal people's connection with country • Invasive species altering culturally important ecosystems • Biodiversity loss which can limit opportunities for transfer of knowledge through fishing and hunting • Loss of connection with the land through changes in land use, and people's increasing preference for risk averse, comfortable urban-based lifestyles

• Formalised through asset registry (e.g. Witjira-Dalhousie Springs complex, Burke's waterhole on Cooper Creek, Coongie Lakes)	
Economic value (Agriculture, Mining, Commercial fishing, Science, Tourism)	
Attributes	**Threats**
• Essential resource for mining • Water supply critical for pastoralist and agricultural interests • Resource for commercial and domestic supply and associated industries • Provides 'social' infrastructure • Provides a basis for scientific research • Tour operators' need for water for drinking and amenity needs of tourists • Fish need water, so do commercial fisheries (e.g. Lake Hope and Red lake fisheries) • Provides employment opportunities across a wide range of fields e.g. bore rehabilitation (GABSI), National park management, science, mining, agriculture, tourism • Water sites used for TV & film sets • Water sites as a subject of art and photography	• Pollution leading to poor water quality • Ignorance of user groups regarding the value of water to others • Ecosystem values/attributes can be threats to industrial water use • Intact ecosystem values also critical to several other industries • Conflicting community requirements • Over-allocation • Habitat degradation and poor management of access, use and education • Poor infrastructure e.g. superseded groundwater extraction technology - leading to water loss, reduced aquifer pressure • Community and widespread 'anti-development' backlash due to poor water management • Climate change leading to reduced water availability and increasing the cost of water
Ecosystem values (Physical, Biological, Ecological, Conservation)	
Attributes	**Threats**
• Biological diversity • Endemism • Habitat diversity • Diversity of topologies • Genetic/evolutionary significance • Connectivity • Ecological connectivity and refugia • Presence of unique, extreme environments in arid zones • Many water bodies listed on asset registries (e.g. Australian National Heritage,	• Water diversion and abstraction for mining or agricultural purposes • Climate change: lower rainfall, higher evapotranspiration and decreased groundwater recharge • natural physical changes to landscape • River regulation • Land-use changes from agriculture or mining operations • Invasion and establishment by alien species • Paucity of long-term datasets • Lack of long-term ecological monitoring programmes

Ramsar, EPBC Act 1999)

- Climatic variability
- Ancient landscape
- Geology and geomorphological features of internationally importance
- Cryptic and rare native species
- Relatively 'natural', unimpacted environments
- Lack of invasive flora and fauna
- Natural hydrological variability
- Paleoclimatic significance
- Archaeological uniqueness
- Potential for discovery of new species (e.g. stygofauna)
- Anthropological significance
- Mesocosm for studying unimpacted aquatic ecosystem dynamics

- Short political cycles and rapid changes in research priorities
- Pet-trade collection and over-collection
- Creation and poor positioning of artificial water points
- Habitat fragmentation
- Conflicting community values and priorities
- Lack of political will and understanding
- Salinisation
- Poor NRM decisions
- Poor regulation on access and tourist numbers
- Damage to physical and ecological features due to impacts of high visitation
- Management strategies considering single aspects of ecosystem function, rather than taking a holistic approach
- Pollution from industrial inputs, run-off and seepage
- Effluent outfall and/or poor bush camping skills
- Erosion and loss of riparian and aquatic vegetation due to stock or feral animal access (e.g. camels, goats)
- Pressure decline in aquifers in GAB due to old or poorly constructed/maintained bores and bore drains
- Grazing pressure
- Compaction of soil
- Loss of water quality and siltation

Educational value

Attributes	Threats
• Medium with which to interact with nature and gather experiential knowledge • Opportunities for intergenerational and cross-cultural sharing of knowledge • Collegial sharing of knowledge • Opportunity to formulate and test theories/hypotheses • Increases understanding of landscape formation and ecological, geological, hydrological processes • Fosters cultural obligations to share • Maintains the diversity of Aboriginal languages • Presents research opportunities in many fields (e.g. biology, ecology, hydrology, geomorphology, anthropology, philosophy, history) • Inspires creative thinking • Fosters relationships between cultures	• Technology and the move towards non-practical, office-based learning • Loss of connection to country due to urbanisation • Habitat destruction (e.g. over-allocation of water, river regulation, industry development) • Loss of 'natural' reference systems • Poor data quality and reliance on online searching • Lack of access to water sites • Loss of older generation's knowledge, traditional stories and language • Selective education - cultural/religious/political bias • Funding cuts and short-term funding cycles • Changing political agendas • Poor communication of the intrinsic values of water, leading to lack of interest by students, teachers and public

Knowledge value

Attributes	Threats
• Power - capacity to protect and manage water (and to exploit it) • Understanding of the significance of water • Several types of knowledge associated with water: scientific, spiritual, cultural, economic, operating at many spatial and temporal scales • Form, physicality, observation, immersion, being • Communication, demonstration and dissemination • The capital of knowledge • Information, misinformation, myth information • Traditional knowledge - Aboriginal and non-Aboriginal • Historical knowledge - Aboriginal and non-Aboriginal	• Misuse and abuse of power • Restriction of information transfer, poor communication strategies • Misconstruing information • Poor interpretation of information/datasets • Access to technology/lack thereof, technological failure • Lack of data and long-term information • Ephemeral funding (boom-bust) • Lack of continuity in funding investment • Short political cycles and changing agendas • Dislocation from country

• Contemporary knowledge - Aboriginal and non-Aboriginal	• Lack of access to water places off main roads • Changes in transportation modes
Legal value	
Attributes	**Threats**
• Provides formal recognition of the concept of ownership (e.g. Native Title claims) • Provides a forum for cross-cultural engagement • Increases understanding by a wide audience of the multiple values of particular sites (e.g. Lake Eyre Native Title decision) • Wide dissemination of information on water allocation, environmental and cultural implications of management decisions	• Deliberately not adhering to legal requirements (e.g. trespassing) • Ignorance and misunderstanding of legal ramification of decisions • Cultural and socio-economic division
Ownership values	
Attributes	**Threats**
• Long-and short-term control over sites • Access and availability - permits, fees • Legal rights - Native title, private freehold lease, land trusts, conservation covenants, commons • Care/management • Responsibility - current and intergenerational stewardship • Protocols - cultural and legal • $ value of site/area - can affect decisions on ownership • Gender-specific knowledge and standpoints on ownership • Contemporary and historic connections people have with landscape • Sense of belonging/pride • Respect for jurisdiction • Legacy - transmission to younger generations • Custodianship	• Poor political decision making • Ephemeral funding • Greed • Ignorance of legal, political and cultural significance of ownership of one group versus another • Minimal communication among stakeholders • Abuse of knowledge • Multiple owners with differing agendas - 'tragedy of the commons' • Poorly developed and delivered management of land title and land use • Gate-keepers preventing access • Privacy, or conversely, information leakage • Fragmented IP

Political value

Attributes	Threats
• Leverage for votes during election campaigns • Plays a key role in environmental policy and decision making • Water management decisions affect all socio-economic groups, therefore water provides a platform for public engagement • Political water decisions can divide or unite	• No threats unless adequate supply to all users and ecosystems is guaranteed into the future

Recreational value (Tourism, Local use)

Attributes	Threats
• Fishing for food/recreation • Shade from riparian vegetation • Facilities for camping, picnics etc • Hotspots for habitat and wildlife • Opportunities to see unusual plants and animals • Unique geology and rock formations • Cultural significance of sites • Remoteness provides a sense of discovery • Remoteness promotes a sense of adventure • Photographic appeal - from landscapes to small animals/plants • Presence and movement of water - aesthetics, relaxation • Novelty value of water in arid environment • Opportunities for sport and games • Gems, minerals, fossils • Historical significance • Use of water: domestic amenity, washing • Perceived naturalness • Communing with nature	• Lack of awareness of ecological, cultural significance of area • Lack of understanding of ecological impacts associated with visitation • Impacts of high visitation (e.g. soil compaction, pollution, damage to riparian vegetation, erosion, loss of water quality) • Lack of respect for natural and cultural values • Establishment of weeds • Invasion and establishment by feral animals • Neglect • Poor bush camping skills • Over regulation and under regulation • Negative' signage • Inappropriate management or lack of management • Standardisation of management strategies across all sites and regions • Lack of access/access restrictions • Poorly constructed or sited infrastructure at camp sites • Poor regulations on fishing pressure, firewood collection, fire usage • Increased popularity and use of fragile sites • Water diversion and abstraction by industry or agriculture, and decreased discharge from key springs and creeks (e.g. Witjira-Dalhousie complex)

• Being part of an extreme environment in arid zones • Economic benefits to tourism operators and local communities • Employment opportunities in remote regions • Heightened awareness of conservation issues to wider public • Opportunities for cross-cultural and intergenerational knowledge exchange	• Lowered water quality from aforementioned water regulation actions - flow-on effects to biodiversity loss • Climate change: lower rainfall and decreased surface water levels that preclude some recreational activities (e.g. sailing on Lake Eyre) • Industry development near tourist sites • Pollution from expansion of mining and agricultural activities

4.3. Day 2: Cultural Values

The presentations on the second day of the event focussed more specifically on cultural aspects, water supply issues and recreational values of water; but many of the talks retained some ecological slant. The first session of the day - **Session 4: 'People's connections with water'** - comprised four talks. Bradley Moggridge discussed Aboriginal water values, posed some questions to the audience on cultural identity and perception and highlighted that despite approx. 2500+ generations of traditional ecological knowledge in Australia, the driest inhabited continent, Aboriginal people are still not part of the water management equation. Jenny Silcock's talk described an approach to defining the biological values of waterways in the eastern LEB through examining patterns of endemism for vascular plant, fish and mollusc species, and suggested that understanding these patterns and the biogeographical processes underlying them can contribute much setting conservation strategies. Gini Lee introduced the concept of 'deep mapping' and provided examples of how it can capture the diverse values of arid waterways in case studies of Algebuckina and Hookeys waterholes on the Neales River, and Steve Purvis gave an overview of the complexities associated with water delivery to remote Aboriginal communities in central and northern Australia, and stressed the need to build local capacity for water management.

In Session 5: 'Tourism, recreational and landholder values', Joc Schmiechen gave a detailed account of tourism activities in the LEB, discussed the conservation values of key sites (e.g. Coongie Lakes) and emphasised the requirement to better incorporate tourism and its growing impacts into natural resource management decisions. Bob Backway outlined the issues surrounding access to, and boating on Lake Eyre, and argued that boating on the Lake is a common law right - 'while Native Title gives rights to continuance and control over traditional activities it cannot override common law rights'. Lynn Brake spoke on the history of groundwater extraction across SA for pastoral needs, defined the values of groundwater from economic, ecological and cultural perspectives and reviewed the progress of GABSI in recovering artesian pressure.

Session 6: 'Integrating contemporary and traditional knowledge around water' was the final session of presentations. Bradley Moggridge presented Sue Jackson's talk (Sue was unfortunately unable to attend the event) that described some recent research into Indigenous water values focussed primarily on the tropical catchments of northern and Western Australia. The work has identified three key science challenges relating to integrating Indigenous water values into national water policy; namely, understanding resource use and flow links, acknowledgement that Indigenous management objectives may differ from conservation planners, and the need for wider recognition of Indigenous water management systems. Mick Starkey also could not attend the event; however, his presentation was to be based around the Gawler Ranges 'Rockholes Project' and a viewing of the recently released DVD that documents the substantial cultural and environmental significance of the rockholes. George Cooley gave the final presentation of the day and related some positive examples of whole-of-community partnerships in NRM programmes under the Lake Eyre Basin Intergovernmental Agreement, including the LEB Aboriginal Map and the LEB Rivers Assessment. Such partnerships were seen as crucial in communicating the continued significance of water and water places to Aboriginal people in our modern world.

Workshop 2: 'Identifying knowledge gaps and canvassing new research opportunities' followed on after these talks. The principal aim of the workshop was to gather information from delegates that would directly inform the development of a research prospectus for future work on water

values in arid zones, some of which could be realised under FLOWS 2. Delegates were again divided into small discussion groups and asked to write down their answers to the following three questions:-

1. What are the key knowledge gaps that need to be filled to allow development of effective and sustainable water management strategies in arid zones of Australia?
2. In which research fields/projects should $ be invested into the future?
3. What opportunities exist for establishing collaborative projects and research linkages?

Answers to these questions were collated at the end of the session, and are presented in no specific order in Table 2 below.

Table 2. Responses by delegates on three questions regarding current knowledge gaps and future research and collaborative opportunities in relation to water and water values in arid zones of Australia.

1. ***What are the key knowledge gaps that need to be filled to allow development of effective and sustainable water management strategies in arid zones of Australia?***
• Data required on the impacts of mining activities on aquifer drawdown and loss of pressure in the GAB and other groundwater basins, and the flow-on effects to surface water quality, mound spring recharge and aquatic ecosystem function at local and landscape scales. • Lack of an effective framework for incorporating Indigenous knowledge into applied research and management - effective participation and relationship building. • Poor understanding of the requirements for tourism and water infrastructure – water in arid lands is a major drawcard for tourists. • Pressing need to develop strategies to disseminate research findings and knowledge to a broad audience, particularly outside scientific circles. – Written and verbal knowledge not getting passed on. – Lack of resources and funding to facilitate transmission of knowledge. • Intergenerational transfer of knowledge needs to be enhanced. • Requirement for long-term monitoring data and ongoing funding, particularly in north-west SA (e.g. Lake Eyre Basin Rivers Assessment (LEBRA) model) • Baseline data required on the mechanisms driving ecosystem processes and interactions in arid-zone waterbodies. E.g. mound springs, GDEs, surface water ephemeral and perennial systems. • Requirement for baseline data on:- – Hydrology and stream monitoring, especially over a long time-series, – Pre-European vegetation, – Pre-European landforms, – Water quality data for surface water resources. • The parameters immediately above can:- – Give indications of ecosystem health, – Allow measurement of sustainable groundwater yield, – Provide framework for understanding different cultural meanings of water ‘quality’.

  - Improve resolution of remote sensing maps
- Lack of spatial information on groundwater and surface water resources available to cash-poor agencies (e.g. LIDAR, QuickBird, aerial photographs).
- ANZECC guidelines not appropriate for arid lands.
- Few historical records of environmental and land-use records on cattle stations.
- Lack of documentation of oral records of landscape and climate change on country.
- No database on scattered and unpublished historical references on hydrology, ecology, climate.
- No formal protocols for sharing and integrating knowledge between Aboriginal and non-Aboriginal communities.
- Lack of spatial and temporal data at critical refugia.
- Better estimates of water consumption by pastoral and mining interests in the GAB and other groundwater basins are required.
- Robust data required on the impacts of grazing pressure by cattle, camels, goats, rabbits and native fauna on water quality, riparian vegetation and erosion at GDEs, particularly GAB springs.
- Require data on shallow groundwater resources: quantity, quality and degree of connectivity between shallow groundwater and surface waters.
- Lack of information on spatial location of water resources – particularly the case for groundwater resources and surface water resources on private/inaccessible land.
- Information required on the dynamics of shallow groundwater ecosystems in areas that are not designated for future mining exploration.
- Very few biological data from ground- and surface water systems in the APY lands and beyond the GAB.
- Recent loss of cultural knowledge (both Indigenous and non-Indigenous) brought about through changes in transport (e.g. roads not passing by historically important waterholes). Critical for effective future management of GDEs.
- Much uncertainty exists around the impact of future climate change on groundwater resources and GDEs in SA.
- More research needed on the impacts of invasive plant species on ecosystem and economic water values e.g. bamboo, date palm, *Polypogon monspeliensis*, buffel grass.
- GABSI: What are the social/economic/environmental returns on a $350 million investment by 2015?
- Need for information on relationships between aquifer pressure, bore rehabilitation works (GABSI) and GAB spring discharge.

2. *In which research fields/projects should $ be invested into the future?*

- Studies quantifying the effects of water extraction for mining purposes on aquifer drawdown, pressure loss in GAB and other groundwater basins, and the potential ecological and economic risks posed by increased salinity, reduced water quality and lower mound spring discharge associated with lower groundwater pressures.
- Improvement of programmes to achieve effective Indigenous participation and input of 'Indigenous Ecological Knowledge' into water management issues.
  - Longer funding periods to incorporate life-long information on caring for water places.
  - A multidisciplinary approach to water management is required through better engage scientists and non-scientists alike in decision-making processes.
- Creating more integrated policy to ensure sustainability of water resource use.
- Further funds invested in invasive animal research and management re: water resources:-
  - Defining nature and scope of problem and key species impacting and being impacted.
  - Risk analyses based integration of empirical data and modelling approaches.

- Investigation is required into assessing impacts of unregulated bores in central Australia on surface waters on Aboriginal lands.
- Studies using field-derived and model predictions to investigate the impacts of mining-based water extraction at key sites earmarked for future mining development.
- Implementation of research and management strategies by remote/rural/Indigenous communities.
- Collation of historical environmental (i.e. hydrology, ecology, climate-related) and land-use records on cattle stations.
- Collation and documentation of oral records of landscape and climate change on country.
- Collation of scattered and unpublished historical references on hydrology, ecology, climate in arid-zones of central Australia
- Development of a Terms Of Reference for funding allocation that prioritises engagement with Indigenous and local communities.
- Using baseline data to increase spatial resolution and accuracy of remote sensing techniques in mapping water dependant ecosystems. Particularly needed in north-western SA, where data coverage is limited.
- Integrated studies attempting to predict the effects of climatic and environmental change at priority arid-zone water sites.
    - This work could integrate remote tracking of rainfall, hydrological and climatic data (e.g. Arid Zone Water Security project) over time with ongoing on-ground ecological survey data.
    - The work would be framed at relatively small spatial scales, but would provide information relevant across the entire arid-zone.
    - Investment in instrumentation (micro-weather stations, depth/temperature loggers, water quality sensors, surveillance cameras) in addition to ongoing on-ground surveys.
- Funds needed to map the distributions of invasive plant species across the LEB.
- A holistic 'whole of catchment' approach to water research and management in SA arid-zone will aid in protecting and enhancing fragile and unique aquatic ecosystems and their cultural and environmental values.
- Jenny Davis prospectus on Arid Zone Water Security:-
    - Identifying critical refugia and conserving biodiversity - understanding the hydrological and ecological processes (connectivity, dispersal, establishment, recruitment/reproduction and behaviour) that enable arid zone biota to persist.
    - Supporting indigenous management of arid zone water -providing the training and infrastructure needed to enable indigenous groups to manage water dependent systems on their lands.
    - Managing threats - including invasive species, hydrological change (drawdown and extraction), grazing, global warming and increasing climatic variability.
    - Coordinating water sharing between all stakeholders - ensuring that the multiple values (cultural, social, economic and environmental) of arid zone water dependent ecosystems are recognised and inform policy development and planning.

- Potential PhD projects:-

- Investigation of camel, goat and rabbit impacts on arid-zone frog species.
- A collaboration with Aboriginal communities on traditional management of water and how it contributes to ecological outcomes and human health.
- Integrating hydrogeology and ecology in the mid-Finke River system, NT.
- Exploring aquatic food-web dynamics along a gradient of disturbance by invasive species.
- Ecological interactions among fishes in the Finke River

- Refugia: which places for which species? Determining patterns of connectivity for aquatic fauna, thresholds of resilience and resistance to drying and the role of land use.
- Using genetics to determine connectivity of populations across the arid zone for tracking the expansion and contraction of biota from critical refugia
- Investigate the potential to identify nursery source signatures from fish otoliths as a means for identifying the actual source of riverine colonists following periods of waterhole interconnection
- Explore relationships between fish recruitment and hydrology in arid-zone rivers.
- LEBRA could provide a strong basis for hypothesis development and as a source of data for the previous three projects.
- Measuring long-term effects of stock removal on soil and riparian vegetation at surface water points.
- Determining the most informative remote sensing methods in mapping arid-zone waters.
- Movement and colonisation by starlings in relation to hydrology in arid-zone regions of SA
- Avian diet in arid wetlands and the influence of flooding: determining functional groups: herbivores, insectivores, piscivores.
- Tracking waders in an arid landscape using satellite tags.
- Integrating deep mapping techniques in prioritising values of water places.
- Responses of riparian vegetation to rainfall and hydrological variability.
- Impacts of tourism on cultural and environmental values of water in arid zones.
- Projects under the 'Arid Zone Water Security' umbrella.

3. *What opportunities exist for establishing collaborative projects and research linkages?*

- Foster multidisciplinary partnerships e.g. local communities – mining industry representatives – pastoralists – research scientists and managers from tertiary institutions (e.g. Monash University, University of Adelaide, Flinders University, Charles Darwin University, The University of Melbourne, The University of Queensland) State/Federal government agencies and NGOs (e.g. NRMs, SARDI, CSIRO, Geoscience Australia, Ninti One Limited) – tourism operators – naturalists – historians.
- Establishment of a CRC focussed on desert ecology that could enable collaboration and project development among these bodies and stakeholders to occur.
- Development of an integrated research programme to track physical, hydrological, climatic and ecological changes and patterns of connectivity over time at key ephemeral and permanent water sites (e.g. Arid Zone Water Security). The programme could be managed by local custodians with data and results disseminated on the interne
- Potential funding bodies and collaborators include:-
  - CSIRO
  - Caring for our Country (CFOC)
  - DEWNR
  - National Climate Change Adaptation Facility
  - BHP community fund
  - Bush Heritage Australia
  - ARC Linkage and Discovery grants
  - National Water Commission
  - National Research Consortium
  - BHP
  - Santos
  - Native Vegetation Fund – SEB offsets
  - Australian Water Commission

- SAALNRMB
- Alinytjara Wilurara NRM
- NRETAS
- Water Planning (NT)
- Department of Sustainability, Environment, Water, Population and Communities (SEWPaC)
- Non-governmental organisations (e.g. Ninti One Limited)
- Goyder Institute for Water Research
- SARDI
- DEC (WA)
- DERM (QLD)
- Flinders University
- The University of Adelaide
- Monash University
- The University of NSW
- Griffith University
- The University of Queensland
- The University of Melbourne
- Charles Darwin University
- Private donors

Information gathered in this session and from chapter 3 was used to develop a research prospectus, comprising a series of projects that aim to address the identified knowledge gaps around water and water values in arid zones of Australia. This prospectus forms the crux of chapter 5.

5. Future research directions and opportunities

Based upon the feedback received during the workshop sessions (Table 2), written contributions received from delegates who attended the Forum and Workshop, and following discussions at the June 19 2012 meeting of the Goyder Institute for Water Research FLOWS team, several ideas for future projects were developed. These are detailed below. Some of these projects link closely with the anticipated direction of FLOWS 2. However, our aim here was to create a library of projects that reflect what the delegates viewed as critical to the future protection of water values across arid zones of Australia, but which may not necessarily be aligned with the FLOWS initiative. The projects are listed in no particular order of importance, although we feel that Project 2 is a particularly high priority for FLOWS 2.

Project 1: Scoping and coordination study

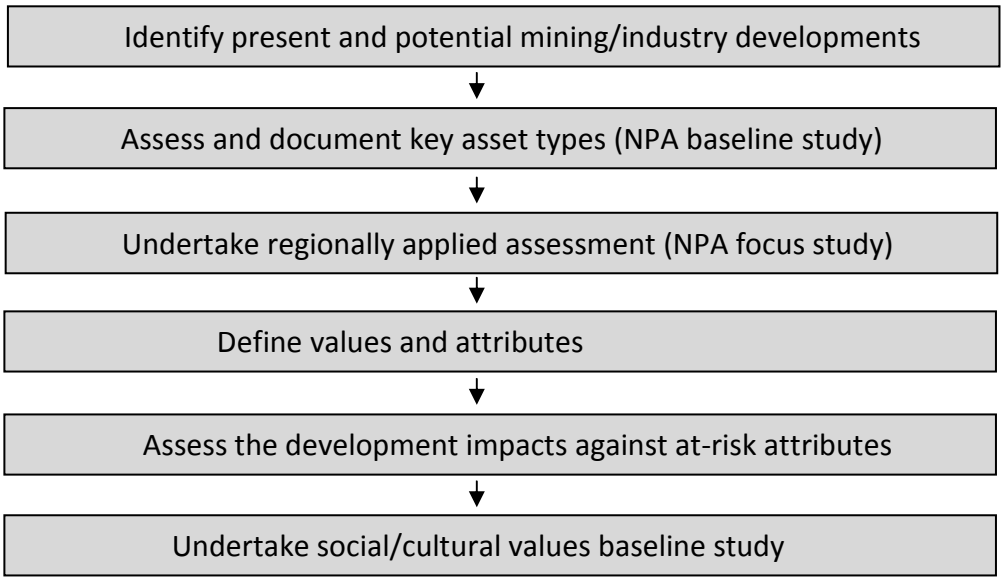
This study will establish the framework and define activities for the suite of projects funded through FLOWS 2. It is envisaged that this study would build strategically on the outcomes of FLOWS 1, Task 7.

Project 2: Assessment and prioritisation of 'High Development Risk' sites

This project could leverage off LEBRA and the 'baseline' and 'focus' studies carried out as part of the National Partnership Agreement on Coal Seam Gas and Large Coal Mining (NPA). Specifically, the project will respond to the requirements for:-

- Data on the impacts of mining activities on aquifer drawdown and pressure loss in the GAB and other groundwater basins.
- Knowledge of the flow-on effects of aquifer drawdown to surface water quality, mound spring recharge, subsurface and surface GDE biota and ecosystem functioning.
- Better estimates of water consumption by pastoral and mining interests in the GAB and other groundwater basins.
- Information on spatial location of water resources – particularly the case for groundwater resources and surface water resources on private/inaccessible land.
- Data on the impacts of invasive plant species (e.g. bamboo, date palm, *Polypogon monspeliensis*, buffel grass) on ecosystem and economic water values.
- Baseline data to increase spatial resolution and accuracy of remote sensing techniques in mapping water dependent ecosystems. Particularly needed in north-western SA, where data coverage is limited.
- Studies using field-derived and model predictions to investigate the impacts of mining-based water extraction at key sites earmarked for future mining development.

The project methodology will be developed around the following steps:-



Project 3: Indigenous ecological knowledge (IEK) and cultural values of water in South Australia

A clear message arising from the workshop sessions was the need to achieve effective Indigenous participation and input of 'Indigenous ecological knowledge' into water management issues. This is particularly pertinent today, due to the recent loss of cultural knowledge (both Indigenous and non-Indigenous) brought about through changes in transport pathways through arid regions (e.g. roads not passing by historically important waterholes).

Moreover, it was widely agreed that a multidisciplinary approach to water management is required to better engage scientists and non-scientists alike in decision-making processes. However, significant barriers remain in the sharing of water knowledge and in cross-cultural understanding of water's significance to Aboriginal and non-Aboriginal communities in South Australia.

By using methods first applied in other states and climatic zones (e.g. TRaCK in northern NT – see Jackson 2006, Ens et al. 2012, Jackson et al. in press and papers therein), and potentially linking in with aspects of Projects 2 and 4 and 6 (see below) this project aims to collate and document Indigenous records of water values in arid zones of South Australia, and engage remote/rural and Indigenous communities in developing and implementing water research and management plans.

Project 4: Participatory and collaborative water planning in arid zones

This project idea was contributed by Sue Jackson (CSIRO) and aims to take the research into the institutional arena, moving beyond simple identification and description of values by asking: how should water planning incorporate the diversity and potential contestation over values in arid zones of SA? It would explore ways in which water management can give expression to such diverse value types as documented in Table 1, and engage community groups and individuals in finding ways to ameliorate threats and protect water values. A similar approach has been outlined

in recent papers by Jackson et al. (in press) and Tan et al. (in press a, b) that describe and evaluate tools for increasing collaboration and reducing conflict between communities and water planners in Australia, and highlight the social, political and legal challenges to developing collaborative water planning processes.

Project 5: Remote water: cultural values, landscape services and pest impacts

Quantitative data are needed on the impacts of grazing pressure by cattle, camels, goats, rabbits and other introduced and native terrestrial fauna on water quality, riparian vegetation and erosion at GDEs, particularly GAB springs in South Australia. Furthermore, very few biological data exist from ground- and surface water systems in the APY lands, the Maralinga Tjarutja Lands, and Yalata and there remain major gaps in our understanding of the ecological consequences to water values of invasion by alien species in this region.

This project aims to tackle these issues and assess threats to water assets in remote arid landscapes of South Australia, by defining the nature and scope of the problem and the key species impacting and being impacted. Risk analyses are proposed based on integration of empirical data (e.g. remote camera technology at key sites) and modelling approaches (e.g. generalised additive models – GAMs, McLeod and Pople 2010), following the protocols established for feral camels in the Northern Territory (see Brim-Box et al. 2010).

Project 6: Arid Zone Water Security

Understanding how aquatic ecosystems function and hence, how best to manage and protect values associated with them, requires multidisciplinary studies that aim to predict the effects of multiple environmental and anthropogenic stressors on species, ecosystems and landscapes.

The 'Arid Zone Water Security' proposal takes such multi-faceted approach by:-

- *Identifying critical refugia and conserving biodiversity* - understanding the hydrological and ecological processes (connectivity, dispersal, establishment, recruitment/reproduction and behaviour) that enable arid zone biota to persist.
- *Supporting indigenous management of arid zone water* - providing the training and infrastructure needed to enable indigenous groups to manage water dependent systems on their lands.
- *Managing threats* - including invasive species, hydrological change (drawdown and extraction), grazing, global warming and increasing climatic variability.
- *Coordinating water sharing between all stakeholders* - ensuring that the multiple values (cultural, social, economic and environmental) of arid zone water dependent ecosystems are recognised and inform policy development and planning.

Dr Jenny Davis (Monash University) developed the ideas behind this proposal and would be the principal investigator on this project. The project would also link strongly with NCCARF.

The following five project ideas were contributed by Gresley-Wakelin King (Wakelin Associates Pty Ltd). Seven doctoral-length projects, and one shorter project are proposed. The projects concern water-transmitting landforms, their formative and current geomorphic processes, and questions of their post-European status in the arid zone of SA.

Project 8: Gullying and Valley-Floor Incision in the Neales River Catchment (three subprojects; adapted from Wakelin-King 2011).

It is possible that some of the gullying and valley-floor incision has occurred in geomorphically vulnerable areas. If either 1) the erosion existed already or 2) relatively mild land use merely hastened an inevitable change, this is likely to make a difference to management priorities. This is a difficult question to resolve and further investigation is recommended. Also, some gullying is not in geomorphically vulnerable areas. Are we recognising it, and how did it arise? The follow three subprojects attempt to address this question.

Subproject 1: A small-scale project investigating archival aerial photography will provide valuable information about the inception and speed of development of gully networks, and is strongly recommended. Target areas include the Wirri badlands, Hann and Ockenden Creeks, and the lower Neales.

Subproject 2: It is also strongly recommended that a doctoral-level investigation of the Peake-Neales confluence and Lower Neales be undertaken to investigate the origin and management responses to the arroyos and badlands. This can possibly be jointly funded between land management sector, and hydrocarbon exploration (the Lower Neales is likely to be a modern analogue of a type of sequence stratigraphic scenario).

Subproject 3: There is a strong possibility that the small channel to the west of Algebuckina Crossing is not natural at all, but is a channel developed after early-settlement road development. This represents a serious threat to the long-term viability of Algebuckina Waterhole. A doctoral-level investigation of the geomorphology , in combination with historical & pastoral records of land use there (focussing on travel paths), is strongly recommended.

Project 9: Documenting Valley-floor Incision in the South Australia Arid Lands (non-LEB)

Valley floor incision is about water utilisation, and retaining water in the ecosystem. So much of the literature on valley-floor incision depends on inference, or secondary evidence - SAAL has landforms both original, compromised, and in transition (which I've seen in projects over the last 5 years). This project would document landforms in good condition vs. altered condition, and the processes under which they operate (when in good condition, and during the process of change). Outputs will be immensely relevant to land management in a preventative sense, as well as rehabilitation practices.

Project 10: Lake Hope and the "Long Lakes" Geomorphology

A doctoral-level investigation of the origin and Cainozoic history of the non-Coongie lakes would provide new information and be relevant to sustainable land and fishery management. It is likely also to expand the understanding of fish/biota radiation patterns.

Project 11: Vegetation and Landforms of a Rare Reference Area

One of the hardest questions to tease apart in range assessment and research is what a place was originally like, because so much of the damage happened so soon after settlement. "Reference areas" are hard to find, and once found, it remains to be demonstrated that they really are in good condition - which is very difficult without baseline data. Two complementary projects are proposed for Kanowna, Western Australia - one on plants, one on geomorphology. Kanowna has not previously been grazed by stock, but the new roads are opening up that region. This is a rare opportunity to gather baseline information of the vegetation, landforms and grazing impacts before extensive grazing takes place. Results from this study could have direct implications for grazing pressure assessments in the arid zone of SA.

Project 12: Cosmogenic Dating of Regolith-stripping Hillslope Processes in the Curnamona-Broken Hill areas

An assumption is widespread amongst land managers that stripping of soil from hill-crests and slopes occurred only in post-European times, leaving rocky skeletal soils and changing the fluvial processes in the downslope valleys. These areas fare poorly in range assessments, are considered to be degraded, and are possibly even good targets for rehabilitation works. However, this assumption overlooks potential geological causes for soils in some of these locations. Cosmogenic dating of exposed bedrock will address this question, adding information to the picture of pre-European Australia. A key outcome will be better targeting of rehabilitation efforts. The dating part of the project would be funded and supported by ANSTI (who are trawling for this kind of applied work) and the dating supervisor has done work on the SA gibber and dunefields. Postgraduate and field support would still need to be found.

6. Conclusions

Task 7 of the FLOWS 1 initiative has attempted to capture current knowledge on the values of water in arid zones of SA. This report hopes to provide a resource to guide water science and management objectives throughout the region, in addition to facilitating opportunities for collaboration and dissemination of knowledge outside the traditional science and management boundaries. It is clear from the literature review that considerable research investment has been apportioned to understanding the role and meaning of water in the arid landscape. Achieving a definition of water's *value* that is acceptable to all appears extremely complex, and particularly so in light of water's current scarcity in these regions and the multiple threats facing communities, industry and ecosystem processes under projections of a drier climate.

With a large portion of SA's arid zone considered highly prospective for future mining exploration, there is a pressing need to identify, prioritise and incorporate the values associated with water in these regions into risk assessments. Although several of the projects outlined in chapter 5 could contribute substantially in this regard, it must be noted that they represent only a very small subset of the work required in this field. Below, we draw on the outcomes of Task 7 and make some further general recommendations for future approaches to assessing water values.

Firstly, we recommend that the approach adopted in Task 7, which aimed to identify water values on a state-wide level, be downscaled to focus on individual mining and/or industry developments at specific sites and/or regions. This will have multiple benefits including: This will have multiple benefits including: reduced complexity and increased accuracy in defining water values and determining attributes; better understanding of the cumulative and/or interactive nature of threats and solutions to these threats; greater opportunities for engagement with all stakeholders; and more tangible outcomes.

Secondly, a cross-jurisdictional approach to water science and management that draws on skills from multiple disciplines needs to be instilled at the outset and in the design phase of new projects.

Finally, we recommend strong investment in the continued engagement and inclusion of scientists, managers, community members, industry bodies, tourism operators, and tourists in decision-making processes. Fostering relationships among user groups, and creating conduits for knowledge exchange through forums held both on and off country may be productive in building cross-cultural understanding of value systems - understanding that directly underpins the success of management strategies aimed at preserving water's value in arid zones.

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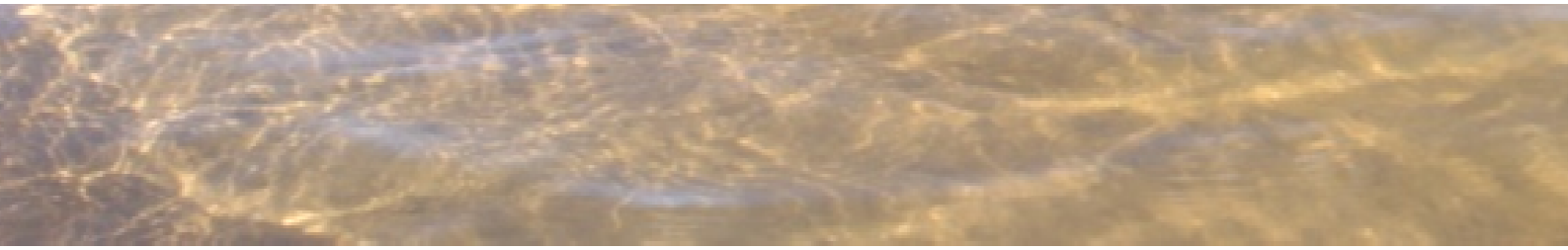
Appendix 1: Forum and Workshop programme, abstracts and participants



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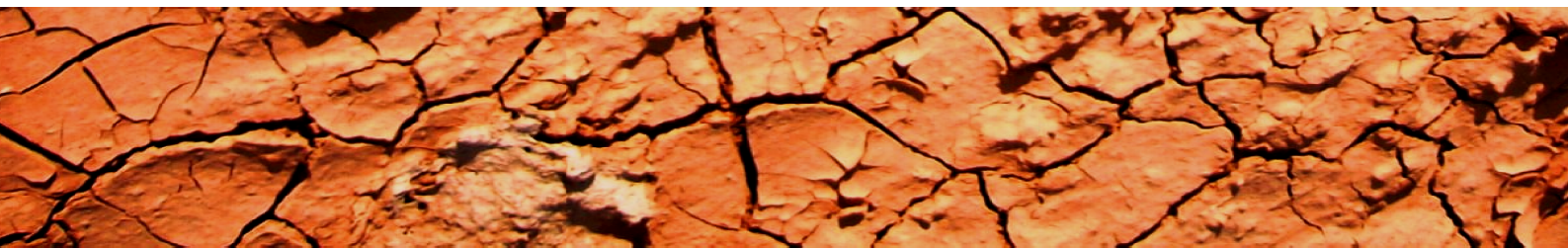

Thursday 10 May – Environmental values of water

8:45 – 9:20: Meet and Registration		
9:20 – 9:40: Introduction to the Forum and Welcome to Country		
Session 1: Hydrology and geomorphology: water's role in shaping the landscape		
9:40 – 10:00	Justin Costelloe (The University of Melbourne)	Using the rivers of the Lake Eyre Basin to provide hydrological context for surface water values in outback South Australia
10:00 – 10:20	Tanya Doody (CSIRO)	Water dependent ecosystems in South Australia
10:20 – 10:40	Gresley Wakelin-King (Wakelin Associates Pty Ltd)	Geomorphologic features in central Australia
10:40 – 11:00	Travis Gotch (SAALNRMB)	Classifying GAB spring values
Morning tea		
Session 2: Ecological values associated with water		
11:30 – 11:50	Dale McNeil (SARDI, DEWNR)	Fish ecology in central Australia
11:50 – 12:10	Jenny Davis (Monash University)	Refugia, connectivity, dispersal: identifying important sites and the processes supporting arid zone freshwater biodiversity under a changing climate
12:10 – 12:30	Chris Purnell (Birdlife Australia)	Waterbird migration to arid ephemeral waters in flood years
12:30 – 12:50	Angus Duguid (NRETAS)	Assessing ecological values of an outback river: good Finking batman
Lunch		
Session 3: Managing water values and assessing threats		
13:50 – 14:10	Andy Bubb (Ninti One Limited)	Big Problems – Big Solutions: feral camels and their impact on water
14:10 – 14:30	Jayne Brim-Box (NRETAS)	Assessing camel impacts on remote central Australia waterbodies
14:30 – 14:50	Pat Hodgens (NRETAS)	Monitoring wetlands with camera traps: What goes on when we're not there?
14:50 – 15:10	Veronica Dobson	Protecting the springs of Urlampe-arenye Ranges at Ltyentye Apurte in the Australian Outback
Afternoon tea		
15:30 – 17:00: Workshop session		
18:00 – 22:00: Dinner and drinks (Adelaide Sailing Club)		

Friday 11 May – Cultural values of water

9:00 – 9:20: Coffee		
Session 4: People's connections with water		
9:20 – 9:40	Brad Moggridge (CSIRO)	National perspectives on the cultural significance of water
9:40 – 10:00	Jenny Silcock (University of Queensland)	Four desert waters: setting arid zone wetland conservation priorities through understanding patterns of endemism
10:00 – 10:20	Gini Lee (The University of Melbourne)	Mapping Critical Refugia: landscape approaches to arid lands waterholes
10:20 – 10:40	Steve Purvis (Centre for Appropriate Technology)	Community water requirements in remote regions
Morning tea		
Session 5: Tourism, recreational and landholder values		
11:10 – 11:30	Joc Schmiechen (LEBCAC)	Lake Eyre Basin Tourism – Much about water
11:30 – 11:50	Bob Backway (Lake Eyre Yacht Club)	Tourism and recreational values of Lake Eyre and other waterways in FNSA - In a multicultural society the public estate needs to be shared
11:50 – 12:10	Lynn Brake (University of South Australia)	Landholder interests in water in South Australia
Lunch		
Session 6: Integrating contemporary and traditional knowledge around water		
13:00 – 13:30	Sue Jackson (CSIRO)	Addressing Indigenous interests in water research
13:30 – 13:50	Mick Starkey (SAALNRMB)	Protecting rock-holes in the Gawler Ranges
13 50 – 14:10	George Cooley (LEBCAC)	Water mapping project: overlaying Aboriginal knowledge
Afternoon tea		
14:40 – 16:30: Workshop session		
17:00: End of Forum and Workshop		

Abstracts for presentations (in order of speaking)

Using the rivers of the Lake Eyre Basin to provide hydrological context for surface water values in outback South Australia

Justin Costelloe

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There are remarkably few long-term flow records for streams and rivers in outback South Australia. The two longest records are from the Diamantina River at Birdsville and Cooper Creek near Innamincka. However, these large rivers differ substantially from other streams and rivers in northern South Australia in terms of their catchment area, source of runoff and timing of flow. An eleven year dataset from the Neales River in the western Lake Eyre Basin is compared against the Cooper and Diamantina gauging station records to identify the flow regime features that are more typical of smaller streams of the South Australian outback. The water regimes of critical fluvial aquatic refugia are also examined, both in the context of their relationship with the river's flow regime and their connectivity with local unconfined groundwater aquifers.

Lake Eyre Basin Geomorphology: Landscape, Water, Ecology, People

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Geomorphology is the geology of landscapes, covering their evolution and development, and their present-day processes. Geomorphology uses information on rock and sediment types, tectonic setting, climates and paleoclimates, river and hillslope behaviour, and biophysical interactions. In the Lake Eyre Basin (LEB), the underlying geology is a direct and continuing influence on the rivers. In the LEB's resource-limited landscape, the geological forces that distribute water and nutrients govern ecosystems and productivity. Good geomorphological information is crucial for good land management, yet drylands rivers are under-investigated. Drylands rivers are qualitatively different from "normal" (perennial) rivers, and Australian drylands rivers are unlike those from overseas. Further, Australia's rivers are very different from each other. Good local information is key.

Who benefits from local geomorphology information? Why should a LEB landholder let me on their place? Beneficiaries range from landholders to the international science community to urban Australians. Geomorphology investigations can produce information that is specifically relevant to management actions and priorities, and the design and implementation of rehabilitation and on-ground works. In the LEB, geomorphology research since the mid-'80s has contributed immensely to international understanding of certain geological questions. Cooper Creek especially has a huge international profile as a result. While this doesn't seem to be of direct relevance to LEB inhabitants, it touches on the wider question that all people, everywhere, benefit from science done out of sight of the eventual recipients. There's no vehicle driven in Australia that doesn't owe something to a 19th-century geologist wandering around Utah. Finally, urban Australians look to the LEB for tourism, adventure, and national identity, and derive indirect benefits from a well-

managed landscape. There are overlapping rights, responsibilities and expectations from all stakeholders. While the experiences of the local stakeholders are the most involved and intense, outback viability depends on engagement with the wider Australian community as well.

Valuing River Ecosystems in the Lake Eyre Basin: Native Fish as an icon, indicator and informant

Dale McNeil

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Understanding aquatic ecosystems in South Australia's outback catchments is a complex task, but is essential for Natural Resource Managers to identify and protect the processes that maintain viable river ecosystems and native biota. Studying the ecology of native fish provides information that enhances the management of a wide range of ecological values, and promotes the need to protect outback water values through the intrinsic iconicity of the outback's freshwater fishes.

As icons for recreational and commercial fisherman, tourist, aboriginal communities and conservation, as well as their role as indicators of ecological health, the outback's native fish are an invaluable resource in the fight to protect the values of outback waterways. This presentation touches on some of the key values around fish in the outback and outlines some of the recent work that is helping to inform the management of river health in the Lake Eyre Basin.

Refugia, connectivity, dispersal: **identifying important sites and the processes supporting arid zone freshwater biodiversity under a changing climate**

Jenny Davis

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This project, which is funded by the National Climate Change Adaptation and Research Grants Program, focuses on the locally-fed springs and relictual streams, mound springs, riverine waterholes and rockholes of the Lake Eyre Basin, the Western Plateau and the Indian Ocean Drainage Divisions. These waterbodies, which are supported by groundwater, surface water or a combination of both, represent 'islands' within extremely dry terrestrial landscapes. These sites are experiencing some of the most rapid warming observed on the Australian continent. Annual maximum temperatures recorded at the Alice Springs meteorological station have increased by 2°C since 1900 while annual rainfall is highly variable and episodic. Our objective is to identify important refugia and to understand how connectivity and dispersal support the persistence of aquatic biota across the arid zone. To do this we are combining landscape genetics and phylogeographic analyses with a knowledge of ecological and evolutionary processes to identify the critical processes supporting outback waterbodies. This will help identify the scales at which climate adaptation management can be best applied. Our first task has been to review existing studies to combine an understanding of past climatic, geological and geomorphological processes with what is known of the phylogenies and phylogeographies of extant freshwater fishes and aquatic invertebrates. This is a collaborative project which combines the expertise of researchers based in state agencies responsible for arid zone environmental management: Dale McNeil (SARDI), Jayne Brim-Box (NRETAS), Adrian Pinder (DECWA) and Satish Choy (DERM QLD), with that

of researchers based at tertiary institutions: Jenny Davis, Paul Sunnucks and Ross Thompson (Monash University), Jane Hughes and Fran Sheldon (Griffith University) and Brian Timms (UNSW).

Assessing ecological values of an outback river - good Finking batman

Angus Duguid

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The Finke River is the largest of those rivers that once reached Lake Eyre but now dissipate in the sands of the Simpson Desert. The high biological diversity of the Finke has been recognised by scientists since the Horn Scientific Expedition of 1894. For example, it has nine species of fish whereas the other rivers have one species or none. Three of the fish species are endemic, reflecting the isolation of the Finke from those rivers that relatively frequently flow to Lake Eyre. This diversity is related to the relative abundance of permanent waterholes. The Finke catchment is notable for many springs and the role of groundwater in the ecology of the river. Some parts of the river system have been relatively well studied by scientists; particularly the permanent waterholes of the West MacDonnell Ranges, which have long been regarded as important for their natural values. In contrast, there is little scientific documentation of natural values in other parts of the Finke catchment. Even the permanent waterholes of the West MacDonnell Ranges have only recently been surveyed systematically for fish, through the Lake Eyre Basin Rivers Assessment. The Finke River has a long history of Aboriginal occupation and was the pathway for early exploration of central Australia by Europeans. More recent history includes identifying places of particularly high conservation significance, starting in 1993 with "A Directory of Important Wetlands in Australia". The most recent approach is the framework for High Ecological Value Aquatic Ecosystems (HEVAE), and the sometimes enigmatic list for funding under the Caring for Our Country program. This paper examines issues around identifying and ranking biologically significant places through the example of the Finke River and especially the drought refuge waterholes of the mid-section or mid-Finke.

Big Problems – Big Solutions: feral camels and their impact on water

Andy Bubb[1], Jayne Brim-Box[2], Glenn Edwards[2], Pat Hodgens[2] and Glenis McBurnie[2]

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Feral camels can destroy water places. Their ability to move across inland Australia, ignoring borders, fences and management lines is unmatched in Australia by any other large grazing animal. The Australian Feral Camel Management Project (AFCMP) uses a cross-jurisdictional management strategy to address the problems caused by feral camels, and one of the goals of the project is to reduce camel impacts on biodiversity hotspots, including water places, across Western Australia, South Australia, Queensland and the Northern Territory. The AFCMP brings together 19 partner organisations that represent Aboriginal Land Councils, State and Territory

Governments and the pastoral industry, with the aim of lowering feral camel densities and the subsequent damage they cause. This presentation will outline the complexities of a large cross-jurisdictional project and highlight that strong collaborations can provide tangible Natural Resource Management outcomes on a national scale.

Assessing camel impacts on remote central Australia waterbodies

Jayne Brim-Box[1], Glenn Edwards[1], Pat Hodgens[1], Glenis McBurnie[1] and Andy Bubb[2]

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Camels pose a significant threat to central Australian waterbodies, and these threats include trampling, fouling, muddying, destabilising, drinking, grazing and browsing. Camels can also access waterholes that were previously inaccessible to most feral or domestic stock. As part of the Australian Feral Camel Management Project we are currently monitoring camel impacts at 60 waterbodies in designated key asset areas across three bioregions, reaching from the APY lands in South Australia, to the Southern Tanami Desert in the Northern Territory. Monitoring efforts are focused on four target areas: aquatic macroinvertebrates, water quality, terrestrial animal use of waterbodies, and riparian and site condition. Results thus far suggest that by using this multi-faceted approach we can adequately and quantitatively measure camel damage to inland waterbodies. This information will prove invaluable for the long-term management of these resources as feral camel densities are reduced.

Monitoring wetlands with camera traps: What goes on when we're not there?

Pat Hodgens[1], Jayne Brim-Box[1], Glenn Edwards[1], Glenis McBurnie[1] and Andy Bubb[2]

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Central Australian wetlands are often biological hotspots of high endemism. Many waterbodies are heavily used by feral camels, especially waterbodies on remote Aboriginal land trusts. We sought to determine if and how feral camels impacted on native animals at these remote waterbodies, as few studies have looked at the ecosystem services these waterbodies provide to terrestrial animals.

Working with both Traditional Owners and Indigenous ranger groups, camera traps were installed at over 20 remote waterbodies across central Australia, with particular focus on the Katiti-Petermann and South Tanami Aboriginal land trusts. From the over 500,000 images captured to date, 58 bird species, 15 mammal species and 6 reptile species have been documented using these waterholes. Not surprisingly, waterholes were most heavily used during drought, and it appeared that some species of native wildlife were outcompeted by camels for access to water. Data obtained in this project will be used to determine if faunal recovery occurs as camel densities are

reduced. In addition, camera traps have proved to be a valuable outreach tool, in that they provide Traditional Owners and rangers with visual documentation of the significant degradation that camels can inflict on their water places.

Protecting the springs of Urlampe-arenye Ranges at Ltyentye Apurte in the Australian Outback

Veronica Perurrle Dobson[1], Jayne Brim-Box[2] and Meg Mooney[3]

[1]*23 Barclay Cres, Alice Springs, Northern Territory.*
[2]*Wildlife Use, Department of Natural Resources, Environment, the Arts and Sport, Alice Springs, Northern Territory.*
[3]*Landcare, Tangentyere Council, Alice Springs, Northern Territory.*

I will talk about rehabilitating, maintaining and protecting Mparntwenge (Hayes Springs) and Ilkerteye (Salt Springs). These springs are located at Ltyentye Apurte (Santa Teresa) and are ancestral water sources for the local Eastern Arrernte people. Ltyentye Apurte (Santa Teresa) is a small community about 80 kilometres south-east of Alice Springs. At the Springs, considerable damage had occurred over many years due to feral animals and cattle. A group of traditional owners got together and talked about how to get support to fix up the Springs and teach the younger generations to care for them and maintain them properly for the future. We knew that the only way this project would work was to involve as many community members as possible, and with the help of various organizations, we started working at the Springs. Tangentyere's Land and Learning program set up an education program about the springs for the secondary class from Santa Teresa School. The students learn on country in a '2-way approach' - traditional Arrernte way and also Western scientific way. Resources have been developed in Arrernte and English to continue the teaching. The project started off small but with a strong focus on improving life and hopes for the future for young people.

Four desert waters: setting arid zone wetland conservation priorities through understanding patterns of endemism

Rod Fensham[1,2], **Jenny Silcock[2]**, Adam Kereszy[3] and Winston Ponder[4]

[1]*Queensland Herbarium, Environmental Protection Agency, Mt. Coot-tha Road, Toowong, Queensland.*
[2]*The Ecology Centre, School of Biological Sciences, University of Queensland, St Lucia, Queensland.*
[3]*Australian Rivers Institute, Griffith University, Queensland; Bush Heritage Australia, Melbourne, Victoria.*
[4]*Australian Museum, 6 College Street, Sydney, NSW.*
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The sharp contrast between permanent water and the surrounding environment engenders assumptions about their biological importance. We identified and mapped permanent natural wetlands across the Eastern Lake Eyre Basin and classified them into four types: riverine waterholes, rockholes, discharge springs and outcrop springs. Waterholes are the most widespread and numerous source of lasting water, while springs and rockholes are confined to relatively discrete clusters. The characteristics of each wetland type are summarised, and their biological values compared by examining various scales of endemism for vascular plant, fish and

mollusc species. Discharge springs contain an exceptional concentration of endemic species across all three lifeforms at a range of scales. Waterholes are critical drought refugia for native fish species that also utilise a vast network of ephemeral streams during and after floods. Rockholes and outcrop springs do not contain any known specialised endemics, although the latter have disjunct populations of some plants and fish. The existing knowledge of antiquity, connectivity and habitat differentiation of the wetland types is compiled and their role in determining biological endemism is discussed. Exotic fish are a major conservation issue, the recovery of the discharge springs should be paramount, and the intact network of permanent waterholes should be preserved. A focus on endemism, combined with an understanding of the biogeographical processes underlying the observed patterns provides an effective and systematic approach to setting priorities for regional biodiversity conservation.

Mapping Critical Refugia: landscape approaches to arid lands waterholes

Gini Lee

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How can we recognize and record the diverse qualities of arid waterways and waterholes? Our cultural landscape approach aligned to deep mapping methods documents the process underway in the Neales River and Cooper Creek Catchments of South Australia. As a critical refugia Algebuckina Waterhole is a potent site for deep mapping as a place where critical cultural and ecological conditions coincide. The need to gain shared values is informed by mapping the range of conditions for its present and future existence influenced by engagement across all communities and ultimately, through negotiated management.

Tourism Dynamics in the Lake Eyre Basin – Much about Water

Joc Schmiechen

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The Lake Eyre Basin covers 1.2 million square kilometres and is amongst the world's last unregulated wild river systems terminating in Lake Eyre, one of the largest salt lakes in the world. The Basin contains some of the most outstanding and visited heritage assets in Australia. Within its catchments are contained a diverse range of classic Outback landscapes. These include Desert Uplands, Mitchell Grass Downs, Mulga Woodlands, Brigalow Scrub, Gibber Plains, Dunefields, Wetlands, Braided Channels, Billabongs, Arid Mountain Ranges and the ephemeral desert river systems. The most important areas are the sites of permanent water. This is where plants, animal life and human activity have focused.

Just as these precious waters have been the focal point for intense Aboriginal occupation over thousands of years and more recently an integral part of both pastoral and mining activities, they are now the major attraction for an ever-increasing tourism flow. Major centres such as Alice Springs and Longreach have now become as dependent on the growing tourism traffic to enhance their economic viability as much as servicing the traditional regional enterprises. In Longreach, the

permanent waterhole of the Thomson River that provided the lifeline for the town's establishment today is an important tourism focus for tourism businesses such as the river cruises as well as a desirable location for camping and recreation by locals and visitors alike. The creation of major heritage centres such as the Stockman's Hall of Fame and the Qantas Founders Museum have been important contributors to attracting and retaining visitors to the town.

This trend has been mirrored by other smaller settlements in the catchment such as Barcaldine and Blackhall each with heritage centres of their own. The sealed Matilda Highway connecting these centres is a major tourism flow route for traffic from the east heading towards the Northern Territory and the Kimberley in Western Australia as well as funnelling in the destinational visitors. Other connecting roads from the major coastal centres are progressively being sealed providing ever-increasing options for a wide variety of self drive traffic. National Parks such as at Idalia on the Bullo River headwaters, Welford on the Barcoo and Lochern on the Thomson also form an important part in the tourism fabric of the upper Cooper catchment.

Tourism Queensland in association with the Outback Queensland Tourism Association has embarked on an extensive marketing campaign to attract more visitors and broaden the appeal to a greater range of visitors. Many of the local Shire Councils have seized on developing tourism as an opportunity to revitalise the economic fortunes of their regions. This mid west sector of the Queensland Outback has well-developed infrastructure to cater for the growing visitor numbers and is developing a growing presence in the market place. Similar developments have occurred in Central Australia and the Flinders Ranges in South Australia with both areas declared and promoted as National Landscapes. Tourism has become an integral part of the local economy and delivers greater returns than the traditional pastoral enterprises. For the most it is embraced at the local level and is seen as vital to future economic sustainability.

The Cooper Catchment is a prime example of how tourism now permeates throughout the system. From the headwaters near Hughenden numerous creeks, streams and minor rivers of the Thomson catchment from the north and the Barcoo in the east join near Windorah to become Cooper Creek. From here the flow is characterised by an enormous area of braided channels – part of the Channel Country. Here too the tourist flow is on the increase with regular traffic from the east and from the north focusing on Birdsville and Innamincka. Windorah has become a natural hub and stopover point for this drive traffic. This is reflected in the increasing facilities in the town to meet the visitor demand.

South from Windorah the myriad of braided channels progressively flow together as the relief changes. In a major directional change the Cooper turns west and is concentrated through the Innamincka choke. As the Cooper flows westerly across the Queensland border into South Australia it entails its most significant natural and cultural assets. The Coongie Lakes north west of Innamincka is a wetland region of exceptional ecological value. It is internationally recognised under the Ramsar Convention as a habitat for large numbers of migratory and nomadic birds. It also has a diverse aquatic fauna including the desert rainbow fish, shrimp, numerous frog species and the Cooper tortoise. The wetlands, floodplains and deep waterholes have been recognised by Federal and State governments for their conservation values and included on the Register of the National Estate.

Because of the strong association with both Aboriginal and European history a one kilometre strip either side of the Cooper totalling 120 square kilometres has been proclaimed as a South Australian State Heritage Area. The Innamincka Regional Reserve, administered by the South

Australian Parks and Wildlife was declared to protect and manage these unique features. Just across the Queensland border Nappa Merrie waterhole has equal significance and incorporates the DIG Tree site of the ill-fated Burk and Wills expedition final depot. The exceptional natural environment, Aboriginal and European history have made this area of the Cooper catchment one of the Outback tourism hot spots worthy of recognition as an area of National Significance.

Over 40,000 visitors per year now inundate Innamincka a small desert township of around 18 residents. Nearby the DIG tree site on the Nappa Merrie waterhole has approximately 10,000 visitors annually. Two of the most recognised Outback tracks in the Birdsville and Strzelecki both lead into this section of the Cooper bringing an ever-growing volume of visitors seeking the essence of the Outback experience. Both tracks have now been upgraded to well formed unsealed roads making it ever easier for the urban adventurers. The proliferation of four wheel drive vehicles, increased marketing of such Outback locations through magazines, television, promotional campaigns such as 'Year of the Outback 2002' and the burgeoning four wheel drive accessories and camping industries all are major contributors in the increasing visitation. The recent extensive rains and continuing flow of the major river systems and filling of Lake Eyre have further led to a boom in tourism visitation fuelled by extensive media coverage.

Tourism throughout the Basin has surpassed pastoralism as the major land use, yet it is hardly recognised, nor regulated like more traditional land uses such as pastoralism, mining and conservation. This is placing considerable pressures on both the natural and human resources. For some in the settlements such as Innamincka, Birdsville, Marree and Coober Pedy, tourism is seen as a vital economic opportunity and to be encouraged. For others such as some pastoralists and the oil and gas industry it is seen as a potential interference with their core business. Unlike the more developed tourism precincts like Central Australia, mid-west Queensland and the Flinders Ranges, tourism in what could be described as the 'Heart of the Basin' with the hub of Lake Eyre is not seen as beneficial by many of the locals. Managing this new wave of land users creates many challenges, especially for the vastly under-resourced National Parks Services.

What was once a trickle of hardy visitors seeking challenge and adventure in the remote Outback has now turned into a major flood. Unlike the earlier users who were often more aware of the protocols of remote area travel and better versed in the skills of bush camping their modern counterparts seem to be less able, or willing to taking a more caring approach. In many cases the very qualities that are being sought, to '...experience a feeling of being in a 'wilderness' surrounded by a vast, natural landscape' are being compromised by both sides. The local reaction is to erect fences to keep the new invaders out effectively removing the sense of uninterrupted space or tourism entrepreneurs building inappropriate structures that have no sense of place. The tourists unknowingly love the prime locations to death by sheer weight of numbers, especially as access is increasingly restricted denying other desirable locations or their poor outdoor practices and lack of environmental ethics create major damage to the natural and cultural values of what are generally very fragile areas.

There is little doubt that the desire to visit and experience the Outback especially the classic locations around Lake Eyre and bounded by the iconic Oodnadatta, Birdsville and Strzelecki Tracks will continue unabated. Despite the misgivings of some of the small populations of pastoralists and mining interests that have been the prime land users of these areas this trend cannot be stopped but needs to be sensitively managed. It needs to be recognised as a major land use following Aboriginal occupation, pastoralism, and mining. Unlike the last two it has little legislative structure or clear protocols for the users now seeking to utilise the heritage assets of the catchment.

In some cases it offers different economic opportunities for local entrepreneurs, an opportunity to diversify and possibilities for Aboriginal people to gain value and return from engaging with tourism. It also presents a major challenge for local communities, protected areas managers, tourism industry, recreational user organizations and a range of State and Federal government agencies to take on a more coordinated and holistic approach. This is essential to ensuring a truly sustainable approach to both accommodating the needs of the visitors and preserving the heritage values of the catchment environment. In all cases water remains the key point of interest and as such, tourism use and impacts should be seriously considered for future natural resource management approaches and the Lake Eyre Basin Ministerial Forum.

Tourism and recreational values of Lake Eyre and other waterways in FNSA - In a multicultural society the public estate needs to be shared

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This paper will scope the waterways of FNSA from a tourism and boating perspective, explore the cultural reasons that drive visitors to the area and discuss growing problems with access for tourists wishing to visit, camp or boat within a part of the public estate subject to cultural conflict.

1.1 *Scoping the Lake*

Most people don't comprehend the size of Lake Eyre. When the lake is full it covers almost 10,000 square kilometres but the "average" flood provides between 500 and 2000 square kilometres of navigable water in a season. Historically, every two years part of Lake Eyre is navigable, more often Lake Eyre South. For the past 4 years Lake Eyre has had navigable areas each season as we are currently in the wet part of the climate cycle. For a size comparison Port Phillip Bay, an almost enclosed waterway, is 1900 square km. Thus Lake Eyre, Australia's inland sea, is huge even if only partially full. Boating opportunities can extend to week long trips.

1.2 *Scoping the rivers*

In 1886 the explorer P E Warburton, visiting in a wet year, reported that there were over 500 miles (800KM) of navigable rivers in FNSA. The actual distance is much greater than this given that the Warburton River/Kallakoopah Creek loop is 584km, The Cooper from the Birdsville Punt to Lake Eyre is about 180km and the Birdsville Punt to Lake Hope about 100km. Upstream from Lake Hope and around Innamincka on The Cooper has not yet been measured but would exceed 200km. The Diamantina River up and down stream from Birdsville is at least 100km. Strzelecki Creek provided a 3 week boating window of opportunity around Easter in 2010 of about 200km. The total length exceeding 1300km, approximately half the length of the Murray River, does not include all the possibilities. The frequency of flood varies greatly with the Diamantina and Warburton rivers navigable every few years, Kallakoopah Creek every 10 years and The Cooper floods 2 out of 20 years. Flood pulses are narrow with rivers can be navigable for over 6 months.
Many of these waterways are comparable to the Murray River when in flood. Boating trips on rivers typically take from 7-20 days.

1.3 *Other waterways in the Far North*

A number of waterways are not accessible in flood years due to closed roads. Some of these hold water for three years after a flood. These dry year alternatives, such as Coongie and other Cooper Lakes provide an extension of the window for an outback boating experience.

1.4 *Data is available*

I have compiled two resources for studying past floods in FNSA. The first is "Satview" an easy to use image viewing and animation program based on Landsat imagery obtained from the Geoscience site on the Internet. Unfortunately Landsat satellite images will soon be unavailable as the last one alive is experiencing imaging difficulties. Twice daily MODIS images are available via the Lake Eyre Yacht Club web site's "Lake Status Page". The second is a spreadsheet of floods of Lake Eyre and contributing waterways dating from 1979 when Landsat imagery commenced and extended back to 1974 using data compiled by the SA Geographical Society. A copy of this data will be made available to the conference or email me for copies.

2.0 *Tourism in the Far North and the attraction of outback waterways.*

"You do not learn to love and respect a place until you've spent a sunset and dawn there."

2.1 *Types of tourists and tourism*

The Lake Eyre Yacht Club is funded by tourism industry sponsorship and tourist purchases of Club merchandise. In exchange tourists are provided with advice and encouragement on how to get the best value out of their visit. This advice is given from the point of view of a tourist because that's how we discovered the area. A lot of effort is put in to extending the tourists time in the area thus increasing significantly the income of the tourist/service businesses in the towns neighbouring Lake Eyre. Lake Eyre and Marree are on the Central Australian tourist route. Approximately 70% of tourists who pass through have visited the Lake Eyre Yacht Club's web site during their trip planning stage.

Short duration interstate flights
Tourists sourced mainly from office workers in capital cities who have a weekend at Lake Eyre. Tour normally incorporates a flight over Lake Eyre and indigenous tour.

Bus tours (from comprehensive to budget)
Vary from lunch in Marree with no guidance to a comprehensive tour of the town, a visit to the Lake (wet and dry parts) and a flight over the Lake and tributaries with an ecological talk.

Fast flying school holiday tourists
Often stay only one night and do flight next morning then move on. We have been successful in suggesting another day be spent in area sightseeing. This doubles the tourist income for the town.

Club driven – Variety Bashes, Motorcycle Clubs
Clubs often email us at the planning stage. By providing accurate and interesting information we have been successful in them spending the night at Marree rather than "just passing through". Again this doubles the town's income.

Event driven – Birdsville Races, LEYC Regattas
Most tourists who are on their way to the Birdsville races spend a day or two sightseeing in the area. The LEYC Regatta, being after the Marree Camel Cup keeps tourists occupied in the area for over a week.

(*Mostly Grey) Nomads*
It is becoming easier to persuade "Nomads" to spend a week in Marree and take day trips in 3-4 directions. Now that the south road is almost all sealed an increasing number of non off-road caravans are brought up to Marree.

Backpackers
The number of backpackers passing through the area is inversely proportional to the Australian dollar. Backpackers do not contribute much value to tourism but do provide most of the itinerant employment for tourist business. It is becoming more common for those in the categories above who have their own transport to be carrying a canoe or small boat to take advantage of the boating opportunities offered in FNSA.

Tourists main aims when visiting are:-

1. A flight over Lake Eyre
2. Get their feet wet in Lake Eyre or walk out onto the salt crust while marvelling at its size
3. Camp on the edge of the Lake and view a sunset/sunrise
4. View bird life
5. Boat in the area
6. Fish in the area

Aims 2 - 6 are becoming increasingly harder to realize and are discussed in section 5.

2.2 *Tourism in FNSA is subject to certain natural restraints*

The summers are too hot and can be dangerous to inexperienced and ill equipped persons. The "flood" is difficult to plan for and the window of opportunity often narrow. With the typical short term planning of this current era capitalizing on a flood is difficult and risky. Most employees now have to roster leave months in advance when no certainty can be given about the size of the flood. These restraints inhibit large scale tourist development which from my point of view is a good thing given that most large scale tourism in this country is overdone, over invested in, and eventually a failure due to the "been there - done that" factor. For tourism to be successful in FNSA it must be based on the individual who wants to experience the romance of the Australian outback. These people enjoy the vast open spaces and the isolation of the desert. The lack of "city type" comforts is part of the attraction to the area for those who want to escape from the rat race.

3.0 *Environmental impact*
The natural restraints mentioned above reduce the environmental impact of visitors to the area. This particularly applies to those areas accessed by boat with typical periods of two, ten or twenty years between boating opportunities. We generally find that those planning a boating adventure in the area are very environmentally aware and automatically follow "tread lightly" and "carry in – carry out" policies. Compared with other stakeholders in the LEB tourists and boating enthusiasts consume or pollute waterways the least. Compared to other areas we visit in this country most

FNSA tourist destinations are devoid of rubbish. One pastoralist whose property we regularly camp on commented that he has significantly more trouble with visiting locals lack of care of the environment than tourists.

4.0 *Lake Eyre a special place for all Australians*
From our observations the cultural significance of Lake Eyre to non indigenous Australians is greatly underestimated by tourism interests and Governments alike. Many of our visitors have a deep emotional attraction to the lake; however defining the cause of this attraction to Lake Eyre is difficult.

4.1 *Why Lake Eyre?*
1. Its ephemeral nature with a 10-15 and a 30-35 year cycle gives the impression that to see the Lake with water in it is rare "once in a lifetime" event. The inferred infrequency of water in Lake Eyre places it higher on the cultural destination scale than our other national and much disputed cultural treasure – Uluru/Ayers Rock.
2. The sheer beauty of the Lake when viewed from the air is frequently covered in print and TV media almost to the point of hysteria. It has become an annual event in February-March when items of interest must be thin on the ground.
3. The alien landscape. FNSA is as opposite in climate and ecosystem to the visitors eastern states home cities that you can get. Hence the terms "Outback" and "Never never"
4. The repetition of myths concerning Lake Eyre. "How do the birds know about the Lake filling"?
5. The introduction at Primary School age to the Lake via the Australian plastic template. This template contains nation building icons from Federation to post WW2 period.
6. The study in Australian history of explorers such as Sturt who carried a whaleboat into the desert in search of the inland sea. Eyre who found the Lake and Stuart who followed the indigenous trade route past Lake Eyre South to Central Australia.
The deep set attraction of Australians to Lake Eyre makes an interesting study when you watch an Australian try to enthuse an international visitor as to the beauty of a seemingly dead salt lake. It's an Australian "thing" unique to our culture.

4.2 *Post European settlement cultural heritage*
Both Madigan in 1939 and Elliot Price in 1950 (as the first to boat on the Lake) made radio broadcasts that received national coverage. Writers such as Farwell and Idriess captured the character of the outback post WW2. More recently in the 1970-80's Bonython, Serventy, Dulhunty and Ellis continued to build on this culture with stories of adventure and adversity. Holding a yachting regatta in FNSA attracts world wide coverage in mainstream media.

4.3 *The bucket list*
We find it surprising how many visitors have Lake Eyre, and more recently the Yacht Club, on their bucket list. Numerous cancer sufferers and other terminally ill or just simply old aged, people have been provided with information on how to enjoy their life's last wishes.

5.0 *The battle for access*

5.1 *We are a multicultural society – no one culture can own the public estate*
Lake Eyre is significant to Australians as a whole regardless of their culture. It is part of the public estate and therefore can be visited by all. It must be shared.

5.2 *A National Park is a public place in which all Australians have a right to recreate.*

"A national park is a reserve of natural or semi-natural land, declared or owned by a government, set aside for human recreation and enjoyment, animal and environmental protection and restricted from most development."

A NATIONAL PARK IS NOT A HUMAN EXCLUSION ZONE!

An increasing problem irritating tourists is gaining access to Lake Eyre National Park. Recently we have seen the closing of access tracks that have been in use for over 50 years. Also the frequent closure of Public Access Roads (PARs) due to lack of maintenance, restrictions on camping despite these camping areas not being within the Park, fences (with more planned), access to the Lake only by walking through mud and unfriendly signage. We are aware of the political nature of these changes. The appeasing of a particularly powerful indigenous group who have the ability to disrupt the expansion of South Australia's largest Uranium mine. All cultures have rights to a National Park and the people we represent have a legal right to recreate in this park. The making of decisions and the barring of access without due consideration of all stakeholders amounts to gross mis-management by DENR and the South Australian Government. Attempting to force one particular cultural group to pay a third party (another cultural group) in order to gain access to the public estate is immoral and illegal.

6.0 *The law and how it affects tourism and boating*

6.1 *The right to access the public estate*

With the exception of a handful of small townships FNSA comprises Crown Land and reserves which are part of the public estate. The Pastoral Act which covers Crown Land in FNSA not subject to mining leases incorporates common law rights of access. These are being ignored. Increasingly visitors are faced with threatening signs informing them that they will be prosecuted as trespassers for walking to a point of interest. The Pastoral Act also incorporates provision for the creation of Public Access Roads (PARs) to points of interest. The creation of PARs appears to have stalled following disputes about who will maintain these roads. It is ridiculous to expect a leaseholder to maintain a road they don't need and DENR do not have the funds to maintain roads leading to but outside National Parks. Road maintenance is the responsibility of the Department of Transport and political pressure needs to be applied to force the issue. A number of tracks that were not made into PARs because they had been used by the public for years are being closed. For example the track off the Oodnadatta Track to the camping and boat launching area of Lake Eyre South. Access to historical tracks such as the Inside Track and the original Strzelecki Track is becoming more difficult due to lack of maintenance and leaseholder interests. Visitors are becoming increasingly frustrated by attempts to prevent them from accessing a point of interest to the point of ignoring signs and creating numerous off road tracks when previously one track satisfied the need. Common sense should prevail for the sake of the visitors and the environment.

6.2 *The right to boat on navigable waterways*

6.2.1 *A navigable waterway is a public highway*

This is embodied in a legal principle called the Public Trust Doctrine that certain resources are preserved for public use and that the government is required to maintain them for the public's reasonable use. This principal has its origins in Roman law, is contained in the Magna Carta and has been discussed in South Australian courts. It is a common law right. To boat on Lake Eyre is like driving on the Wilpena – Blinman Road through the Flinders Ranges National Park.

6.2.2 *Native Title and Common Law Rights*
While Native Title gives rights to continuance and control over traditional activities it cannot override common law rights. Federal Courts have already made decisions that native title rights and interests that are contrary to well established principles of common law can not be recognized if to do so would 'fracture a skeletal principle' of the Australian legal system.

6.2.3 *What is navigable, the Harbors and Navigation Act and boating safety*
A court would probably accept the argument that if you can float a boat on a waterway it is navigable. In South Australia though we do not need to consider such a question as there exists the "Harbors and Navigation Act 1993". Schedule 1 of this act defines the boating safety requirements for Lake Eyre and other FNSA waterways as "Smooth waters". The Department of Transport who administer this act is responsible for boating and boating safety on Lake Eyre.

7.0 *The solution*
As the managing authority, the South Australian government needs to accept its obligation to all cultures in regards to access to the public estate and manage it accordingly. Any lasting solution must consider the common law rights of stakeholders as well as native title.

Let's be partners: protecting and celebrating the waters and river systems of the Lake Eyre Basin

George Cooley[1] and Michelle Rodrigo[2]

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With a lifetime spent almost entirely in South Australia's outback town of Coober Pedy as a community leader and passionate environmentalist, George Cooley provides a window into the people and places of the arid outback and the enduring and intimate connection of Aboriginal people to water and land. George is an advocate for whole-of-community partnerships in NRM and for the respectful sharing of knowledge about the natural and cultural environment. He presents some positive examples of programs and projects under the Lake Eyre Basin Intergovernmental Agreement, including the LEB Aboriginal Map and the LEB Rivers Assessment, which seek to honour and celebrate the long-standing presence of Aboriginal people in the arid outback, and communicate the enduring significance of water and water places to Aboriginal people in our modern world.

List of participants that attended and/or contributed to the Forum and Workshop

Allen McIlwee (DEWNR)
Andrew Johnston (SANTOS)
Andrew Willson (DEWNR)
Andy Bubb (Ninti One Limited)
Angus Duguid (NRETAS)
Angus Emmott (LEBCAC)
April Langerak (AWNRMB)
Arron Strawbridge (SARDI)
Bob Backway (Lake Eyre Yacht Club)
Brad Moggridge (CSIRO)
Brooke Madill (The University of Melbourne)
Bruce Hammond (Indigenous Land Managers)
Chris Bice (SARDI)
Chris Purnell (Birdlife Australia)
Christina Son (DEWNR)
Dale McNeil (SARDI, DEWNR)
Dave Dolman (LEBCAC)
David Alexander (LEBCAC)
David Leek (SAALNRMB)
David Schmarr (SARDI)
David Short (SARDI)
Dean Ah Chee (DEWNR)
Dick Kimber
Gary Overton (Commercial fisherman, Lake Hope)
Gavin Begg (SARDI)
George Cooley (First People's Water Engagement Council, LEBCAC)
Gini Lee (The University of Melbourne)
Glenis McBurnie (NRETAS)
Gresley Wakelin-King (Wakelin-Associates Pty Ltd)
Henry Mancini (SAALNRMB)
Hugh Pringle (NRETAS)
Ian Magraith (SARDI)
Jayne Brim Box (NRETAS)
Jed Macdonald (SARDI)
Jenny Davis (Monash University)
Jenny Silcock (The University of Queensland)
Joc Schmiechen (Tourism representative, LEBCAC)
Josh Fredburg (SARDI)
Judith Harrison (LEBCAC)
Justin Costelloe (The University of Melbourne)
Kate Frahn (SARDI)
Keith Bellchambers (Australian Wildlife Conservancy)
Kelly Marsland (DEWNR)
Kelly Wiltshire (Flinders University)
Kristin Weidenbach (Author)
Leigh Thwaites (SARDI)

Luciana Bucater (SARDI)
Lynn Brake (University of South Australia)
Marcus Barber (CSIRO)
Mat Gilfedder (CSIRO)
Matt Turner (The Wilderness Society)
Matt Ward (DEWNR)
Michael Ellul (CFOC coordinator)
Michelle Rodrigo (Northern Territory Government)
Mick Starkey (South Australian Native Title Services)
Murray Tyler (BHP)
Neil Power (DEWNR)
Neva Collings (Orange Door Consulting)
Pat Hodgens (NRETAS)
Perri Carter (SAALNRMB)
Phillipa Wilson (SARDI)
Qifeng Ye (SARDI)
Rene Kulitja
Robert Brandle (DEWNR)
Rod Ward (SARDI)
Rupert Mathwin (SARDI)
Scott Gorringe (LEBCAC)
Sharon Oldfield (LEBCAC)
Steve Golley (Toyota Land Cruisers Club of South Australia)
Steve Morton (CSIRO)
Steve Purvis (Centre for Appropriate Technologies)
Sue Jackson (CSIRO)
Tanya Doody (CSIRO)
Tim Munday (CSIRO)
Tracey Guest (Central Land Council)
Travis Gotch (SAALNRMB)
Trevor Whitelaw (SANTOS)
Veronica Dobson
Vol Norris (LEB Ministerial Forum)

Government of South Australia
Department of Environment, Water and Natural Resources

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