Government of South Australia
South Australian Arid Lands Natural Resources Management Board

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May 2011

South Australian Arid Lands Natural Resources Management Board

Prioritising waterholes of ecological significance in the Neales and Peake catchments

Glen Scholz and David Deane

Prioritising waterholes of ecological significance in the Neales and Peake catchments (western Lake Eyre)

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Department for Water

Report to the South Australian Arid Lands Natural Resources Management Board

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This report may be cited as:

Scholz, G. & Deane, D. (2010) Prioritising waterholes of ecological significance in the Neales and Peake Catchments (Western Lake Eyre). Report by Department of Water to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.

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ACKNOWLEDGEMENTS

This project was part of a multi-disciplinary project funded by the Australian Government's Caring for our Country Program 2009/10 and was conceived and coordinated by the South Australian Arid Lands Natural Resources Management Board. The input of the ideas and findings of other project team members to this work is acknowledged.

The provision of site access to conduct surveys by landholders in the Neales and Peake River catchments is gratefully acknowledged.

The authors would like to thank Henry Mancini from the South Australian Arid Lands Natural Resources Management Board (SAALNRMB) for supporting this project and managing its progress for the Board.

EXECUTIVE SUMMARY

This report was undertaken as a sub-component of a South Australian Arid Lands NRM Board project entitled '*Understanding and managing critical refugia in the arid lands of central northern Australia'* (the Critical Refugia project). Funding was granted through the Australian Government's Caring for Our Country 2009/10 Program. This work contributes to the SAAL Regional NRM Plan (2010) Resource Condition Target (RCT) 3: *"By 2020, the extent and condition of at least 50% of priority aquatic ecosystems is improved and other priority aquatic ecosystems are at least maintained in extent and condition"*, and RCT 8: *"By 2020 flow regimes and water quality in surface water systems are maintained or improved".*

The main project objective for this sub-component was to assess the level of impact attributable to grazing and tourism activities and report these in a standardised and consistent reporting framework. This allows for an appropriate level of comparison across the SAAL NRM Region with a clear focus on the management and prioritisation of aquatic ecosystem assets.

The work presented in this report summarises the results of field surveys of a number of waterhole and floodplain environments, intended to help place overall project findings within a landscape context. Surveys follow the aquatic ecosystem vegetation condition assessment framework developed in White and Scholz (2009) and qualitative field assessments to establish a synthetic reference condition for the aquatic ecosystem type under investigation. Target sites are then assessed against this functional reference condition using a standardised methodology based on the Riverine Vegetation Indicator Protocol for river health (Roberts and Hale, 2009).

Six sites of varying permanence and exposure to disturbance were assessed using the protocol. Four of these were low salinity sites located on the Neales River, a major tributary to Lake Eyre draining the western Basin. The Neales River sites surveyed were: North and South bank Algebuckina, The Cliff, Shepherds and Hookeys waterholes and associated floodplains. Owing to the project focus on Algebuckina as a key refuge for the region, two separate surveys were undertaken at this site, selected to reflect the contrasting disturbance levels and histories observed. The fifth site assessed was a hyper-saline, semi-permanent waterhole located on Peake Creek. This site provided context on the additional ecological consequences of high levels of salinity, and how the floodplain environment at such sites is impacted by grazing pressure.

Vegetation data for all sites was analysed using a clustering program to investigate any relationship between sites. The sites fall into three clusters, one representing the more

diverse sites where the waterholes lie within a wide low profile floodplain which are relatively frequently inundated and does not appear to have any salinity features. Another, the two Algebuckina sites and a third cluster comprising the highly saline site and the lower diversity site (The Cliff). Although no specific conclusions should be drawn from this general assessment, the site clusters may reflect specific landform characteristics, with hydrological and salinity processes having an influence, sites located near to one another are likely to share a similar flooding/drying history.

Superimposed on the main ecosystem drivers of hydrology and salinity, sites were found to have varying impact levels depending largely on grazing and tourism history. As might be expected in an arid zone ecosystem some impacts were consistent between the two disturbances, but clear differences were also apparent. Grazing was observed to impact on the vegetation structure as well as having an influence on the density of species diversity, selecting out palatable species and allowing less-palatable species to dominate. Visitation to the sites had a greater impact on the landscape through compaction and soil erosion from vehicular and traffic access, while the overstorey species *Eucalyptus coolabah* were impacted from being selectively cut for fire wood.

INTRODUCTION

This report was undertaken as a component of a South Australian Arid Lands NRM Board project entitled *'Understanding and managing critical refugia in the arid lands of central northern Australia'*. The relevant project aims were to:

1). Identify risks from exotic species and formulate appropriate management plans for Algebuckina Waterhole, a key aquatic refuge on the Neales River in the western Lake Eyre Basin; and,

2). To understand the connectivity between Great Artesian Basin spring groups and streams of the western Lake Eyre Basin.

The work presented in this report summarises the results of field surveys of a number of waterhole and floodplain environments, intended to help place overall project findings within a landscape context. Information presented will in particular assist the development of management priorities. Surveys follow the condition assessment framework approach developed in White and Scholz (2008) and incorporate the use of conceptual functional models (Scholz and Fee 2008) and qualitative field assessment to establish a synthetic reference condition for the ecotype under investigation. Target sites are then assessed against this functional reference condition using a standardised methodology based on the Riverine Vegetation Indicator Protocol for river health (Roberts and Hale, 2009).

Project objectives

The main project objective was to assess the level of impact attributable to grazing and tourism activities and report these in a standardised and consistent reporting framework. This allows for an appropriate level of comparison across the SAAL NRM Region with a clear focus on the management and prioritisation of aquatic ecosystem assets.

The project undertook five days of fieldwork and visited six waterhole and floodplain sites of ecological significance in the western Lake Eyre Basin. A qualitative ecological survey was undertaken to look at the vegetation condition and resulting impacts at each site.

Quantitative vegetation surveys will be appropriate where further management interventions are undertaken in order to demonstrate progress towards stated goals. The current work did not require this level of rigour, as monitoring aims and intervention targets are yet to be specified.

ARID ZONE RIVERINE ECOLOGY

Ecological Values

The ecology of arid zone rivers has often been described as being 'boom - bust' in nature (Costelloe et al 2004; Bunn et al 2006), with flow events creating the boom periods between which organisms need to persist. The ecological value of arid zone rivers is today well recognised (Costelloe et al 2004), and can be considered both from the perspective of purely aquatic environments as well as the influence of the river on its floodplain environment.

Arid river aquatic habitat endures brief periods of flowing water and prolonged periods of zero flow when evaporation leads to contraction of the wetted area. Waterholes of varying permanence become the key refugia for aquatic organisms during inter-flow periods, and larger, permanent sites are critically important for aquatic biota to resist extended drought phases and enable them to bounce back in the wet phase. Algebuckina is an example of such a waterhole, and is the only "permanent" aquatic refuge for western Lake Eyre Basin rivers.

The importance of overbank flooding on arid zone ecology is well known and has significance not only for the natural environment, but also the grazing industry (Capon 2003). Floodplain areas are renowned for their productivity following inundation, which leads to mass germination of grasses and forbs which dominate arid floodplain seed banks (Capon 2003). Hence floods are of great benefit to the pastoral industry through provision of high densities of good quality stock fodder.

Ecosystem drivers and natural disturbance

The ecology of large arid zone rivers has been the subject of considerable research over recent years. The ARIDFLO project (Costelloe et al 2004) established the main ecological drivers for Lake Eyre Basin riverine ecology as being salinity and hydrology. Salinity levels within arid aquatic ecosystems are largely a function of rainfall, flow duration, wet / dry sequences, geological chemistry and its influence on shallow aquifers connected to watercourses. More specifically Costello et al (2004) found that large flood events in the Neales river system around the Algebuckina waterhole can cause a rise in the saline water table in the surrounding floodplains which can then discharge into the watercourse as the flow declines. This creates a counter intuitive situation where a flow of a larger volume can result in higher waterhole salinities.

In a study conducted on Cooper Creek floodplains Capon (2003) found that salinity and water availability as modified through flooding history exerts an influence on all life history

phases of riparian and floodplain vegetation and creates specific vegetation zonation patterns.

Arid zone waterholes have been shown to rely on carbon sources generated from within the aquatic environment rather than from terrestrial sources of carbon. In a study conducted on arid zone waterholes, Bunn et al (2003) found through stable isotope analysis that the band of algae in the littoral zone of waterholes was the major source of energy for aquatic consumers. In that study, although considerable terrestrial carbon was present in the waterhole, there was no evidence of it being a significant contributor to the aquatic food web.

Conceptual diagram of arid and semi-arid riverine permanent and semi-permanent pools

The function of arid and semi-arid riverine permanent and semi-permanent pools of the Lake Eyre Basin have been identified and articulated in the ARIDFLO project (Costelloe et.al 2004). The project has identified eight 'typical' river stages that have impacts on the ecology of the Lake Eyre Basin Rivers (See Fig 1). For a full discussion on the hydro-ecological responses within waterholes refer to Costelloe et. al. 2004, following is a summary from that report.

"Regional floods are very significant hydrologically and ecologically. They are particularly important if they occur in successive flood years as they increase the spatial and temporal extent of connection. This allows biota to move over greater distance as well permitting their abundances to ramp up through increased reproduction and relative survival of offspring….

Disconnected conditions are common, the rivers are more often a series of isolated wetlands and waterholes….. During this time, regional biodiversity of aquatic-dependent biota (fish and many macroinvertebrates) is reliant on the persistence of a patchwork of waterholes of different sizes and depths….. Inter-annual seasonal variation affects many different aspects of organismal biology such as the timing, extent and success of breeding, availability of food resources, etc, and is capable of producing very different biotic responses between years even with a roughly similar sequence of seasons….

The occurrence of droughts means that the survival of the LEB fish and many macroinvertebrates is critically reliant on the persistence of relatively few drought

refuges. Populations contract under drought, which may result in localised extinctions of certain fish and macroinvertebrate species that may or may not be

replaced by dispersers (potential new colonisers) on the next big flood…. Drought reductions of aquatic habitat are greatest in the lower reaches, and so the distribution patterns and local persistence of many species and entire assemblages may be in a continuous state of flux or disequilibrium. Thus extra importance should be placed on maintaining the ecological integrity of the better- watered upstream reaches during drought."

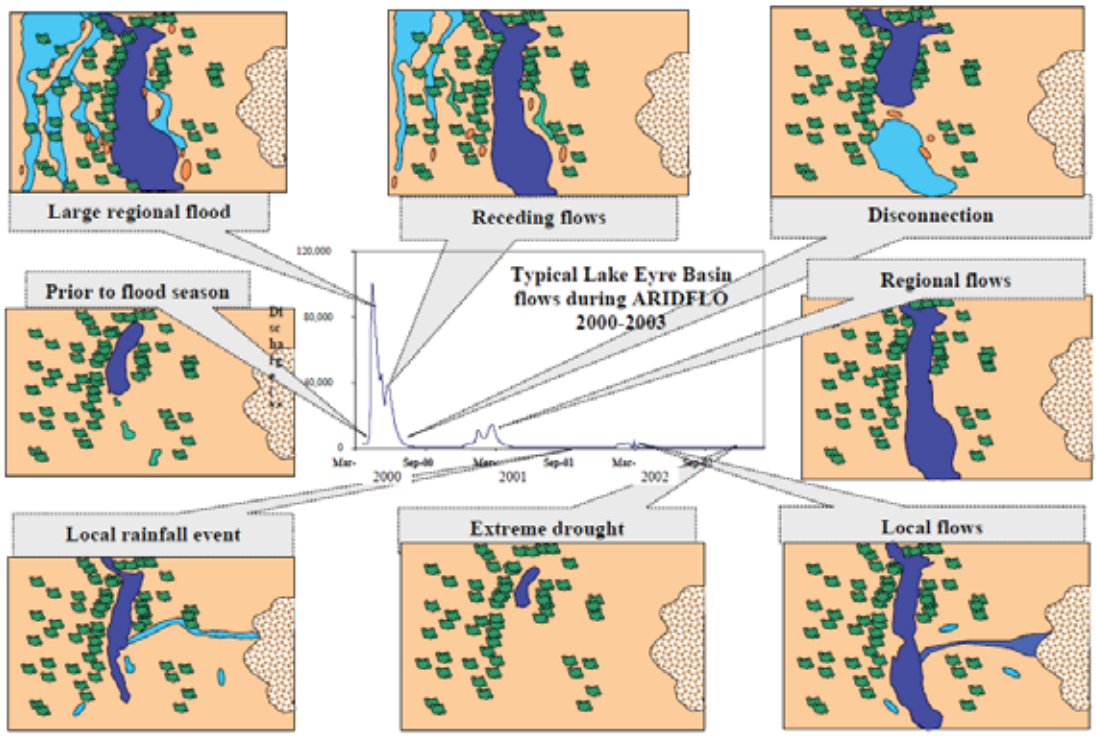


Figure 1 Conceptual model of eight stages of arid riverine function after (Costello et.al.2004)

METHODS

Prioritisation for management investment

A desirable outcome in investing in environmental condition is to maintain the natural ecosystems ability to “resist” unfavourable conditions and bounce back (resilience) when conditions are favourable. The first step in prioritising assets for investment is to focus on the appropriate scale for an improved biodiversity outcome. As discussed by DEH 2007 (unpublished) the most relevant considerations for biodiversity planning are:

1. In unmodified regions, landscape scale considerations are the most relevant.
2. In partially modified regions, ecosystem scales are more relevant.
3. In heavily modified regions, individual species considerations are more relevant.

In relation to the waterholes of the Western Lake Eyre Basin the biodiversity management considerations focus on (1) the landscape and (2) the ecosystem scale.

The assessment methods used in this project focussed on four attributes: ecosystem function (its setting and value within the landscape); condition (naturalness); the threatening processes and; recoverability potential.

Within this context, prioritisation for investment should be weighted towards sites that have the greatest contribution as an aquatic ecosystem refuge within the catchment as well as those that have the greatest recoverability potential in relation to management investment and intervention. Sites that are significantly ecologically impaired may have a lower priority for investment due to a low recovery potential and those that are ecologically intact may also have a lower priority for investment due to their relative security under current environmental conditions and management regimes.

The methods used for assessment in this study can be found in the Appendices, with a more detailed description of methods available in White and Scholz, (2009).

RESULTS AND DISCUSSION

Survey findings

The rapid assessment methodology applied in this study has a strong focus on the structure and spatial extent of the vegetation community. These features along with some other indicators of condition are then compared with a reference condition to identify areas where degradation has, or is, occurring. The reference condition may take the form of an actual reference site or sites, or can be an inferred reference condition based on a bio-physical assessment across a number of sites presenting a range of conditions, this study employed the latter approach, as there is no available data on the reference condition of these types of sites.

An exhaustive taxonomic study was not an objective of these surveys with a focus on the main perennial / biennial floodplain species. 38 species were recorded in observational surveys conducted at each of the sites. Three species were ubiquitous, being found at every site: Dillon bush (*Nitraria billardierei*); coolibah (*Eucalyptus coolabah*); and lignum (*Meulenbeckia florulenta*). In contrast, 17 species were only found at a single site.

Maximum site level diversity of 22 species was observed at both Shepherds and Hookeys waterholes. These sites are geographically close to one another, both located on the Neales River floodplain within a few kilometres of Oodnadatta township. The water level at these sites was only 1-2 metres below the floodplain. The minimum diversity observed was 7 species, found at both The Cliff and Peake Creek sites. The Peake Creek waterhole was hyper saline.

Vegetation data for all sites was analysed using a clustering program to investigate any relationship between sites (Fig 2). The sites fall into three clusters, one representing the more diverse sites where the waterholes lie within a wide low profile floodplain which are relatively frequently inundated and does not appear to have any salinity features. Another, two Algebuckina sites and a third cluster comprising the highly saline site and the lower diversity site (The Cliff). With the exception of the Peake – Cliff cluster, these also reflect geographical proximity. Although no specific conclusions should be drawn from this general assessment, the site clusters may reflect specific landform characteristics, with hydrological and salinity processes having an influence. Sites located near to one another are likely to share a similar flooding/drying history.

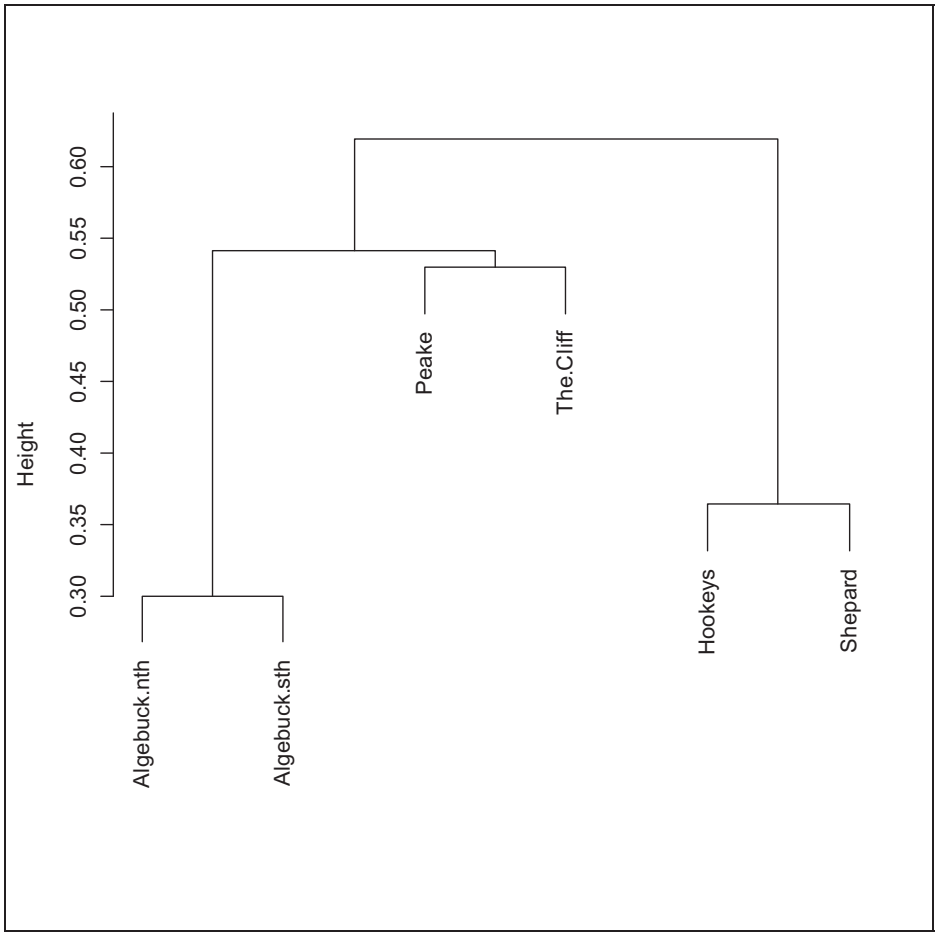


Figure 2 Hierarchical clustering (UPGMA) of vegetation binary data for all sites.

Ecological Implications

This study has found a clear indication of the influence of grazing as a source of disturbance on vegetation structure, age class and density. Grazed sites featured little or no regeneration of tree and shrub species as well as impacts on the structure of vegetation with the mid and lower stratum most heavily impacted.

The study identified a number of sites where *E. coolabah* seedlings and juveniles were grazed off and sub adults and adults were cut for firewood use. In an arid zone waterhole ecosystem where impacts may take decades if not hundreds of years to recover, the loss of regeneration of important structural species such as coolibah will not be fully felt until the surviving adults die off. Over the longer term still other habitat values provided by canopy species such as wood hollows and submerged woody debris will be lost.

Little information is known about the life cycle of coolibah. The most comprehensive review of coolibah can be found in Roberts and Marston (in prep) the following discussion is sourced from this document.

The lifespan of coolibah is generally assumed to be a few hundred years old, although no trees have been reliably dated.

Coolibahs are described as occurring on floodplains that are infrequently flooded. Wilson et.al (2009) found that on the Lower Gwydir floodplain the flooding frequency for coolibah woodlands is around 1:10 to 1:20 years. Coolibahs are generally believed to be dependent on significant floods for large-scale regeneration. Kerle (2005) found that in New South Wales, there have been only six major regeneration events in 105 years: pre-1890, 1890, 1955 to 56, 1974 to 76 and 1983 to 4.

Studies in the Lake Eyre Basin have shown that coolibah has low transpiration rates and are not solely dependent on surface water flooding for survival, instead they are able to access highly saline soil and groundwater at chloride concentrations of 20,000 mg L (Costelloe et al. 2008). On the floodplain of the Diamantina River, coolibahs have been recorded growing and using groundwater at salinities greater than 30,000 mg L (Payne et al 2006).

Restoration potential for management

The understanding of ecological cycles in the arid zone has been advanced over recent years, but additional study is required to determine the recovery potential at sites. Owing to ecological lag times because of the aridity, the consequent low productivity will mean improvements will need to be observed over relatively long periods of time to demonstrate recovery.

A key factor for recoverability will be the presence of viable propagules, including seed banks. Seed bank composition has been found to be the dominant influence on species abundances during experimental conditions, with inundation frequencies then providing a filter that determined which plants were able to establish (Webb et al 2006).

In addition the influence of site disturbance history – especially the grazing history and the wetting/ drying cycle - on observed character are difficult to determine from rapid assessment approaches. Future work needs to directly study a number of sites of different character across a flooding – drying cycle to examine and characterise the ecological responses in order to be able to make accurate assessments about recoverability or even current condition.

Results for Prioritisation

A summary of the six waterholes visited and prioritised for this project are listed in Table 1.

Table 1. Summary of the field assessment and investment prioritisation sheets from the 6 waterholes visited in November 2010

Waterhole	*Catchment*	*Investment Priority*	*Restoration Potential*	*Key Aquatic Refuge*
Algebuckina South Bank	*Neales Creek*	*HIGH*	*MODERATE-LOW*	*HIGH*
Hookeys	*Neales Creek*	*HIGH*	*MODERATE -HIGH*	*MODERATE*
Algebuckina North Bank	*Neales Creek*	*MODERATE*	*MODERATE*	*HIGH*
The Cliff	*Neales Creek*	*MODERATE- LOW*	*HIGH*	*MODERATE*
Shepherds	*Neales Creek*	*LOW*	*INTACT*	*MODERATE*
Peake Bridge	*Peake creek*	*LOW*	*MODERATE*	*MODERATE - LOW*

At the top of the list for high investment priority were Algebuckina south bank and Hookeys, this was because both sites are significant aquatic refugia, have high visitation and due to the potential for further impact, management investment is required . Algebuckina north bank had similar values but was a lower priority as the visitation impact was much lower. Algebuckina is particularly significant as the only recognised permanent waterhole in the Neales and Peake catchments.

The Cliff waterhole is a site of low visitation and was of moderate to low priority for investment. The riparian zone has been impacted by stock grazing and activity however, this site would recover rapidly. Fencing the site could also be a problem due to flood activity on a low profile floodplain.

Shepherds waterhole was classified as intact and considered as low investment priority as the current management activities (part of the town common) has low tourist and low grazing impact and is in excellent condition. It is recommended that current management actions are maintained to ensure the waterhole and ecosystem remains in good condition.

Finally, the Peake Bridge waterhole was considered of low priority primarily due to the low aquatic ecosystem values of the water-hole and surrounding vegetation.

Once a full inventory of the waterholes is completed, some waterholes are likely to group together, whilst others will individually be classed as important assets.

Conclusions & Recommendations

This project has built on the use of the rapid assessment method developed for ecological assessment of springs in the Flinders Ranges and found that it works well with minimal modification. The main value in such a system is to allow rapid acquisition of baseline level data across the full range of environmental assets of interest. As further sites are visited in the region more knowledge on waterhole condition and functional processes will be developed.

Within the natural patterns of vegetation zonation driven by plant life history traits, flooding and salinity, the effects of grazing and human activity are superimposed. Depending on the intensity of the disturbance these have a fundamental influence on the vegetation species composition, structure and density within the functional categories.

Grazing was observed to impact on the vegetation structure as well as having an influence on the density of species diversity, selecting out palatable species and allowing less-palatable species to dominate. Visitation to the sites had a greater impact on the landscape through compaction and soil erosion from vehicular and traffic access, while the overstorey species *Eucalyptus coolabah* were impacted from being selectively cut for fire wood.

The recommendations for the management of arid zone waterholes and associated floodplains for the Western Lake Eyre Basin region include:

1. Aim towards completing a full inventory of waterhole type and condition in the South Australian Lake Eyre Basin using the rapid assessment method outlined in this report;
2. Integrate the geomorphological, hydrological and fish data to improve understanding of sites visited as part of this project
3. Gain an understanding of the riparian and floodplain vegetation reference condition at fresh and saline waterholes across wetting and drying cycles.
4. Gather additional information on topographical and environmental parameters to assist in interpretation of vegetation patterns.

APPENDICES

APPENDIX A. Scoring System for assessment

This assessment employed a qualitative decision support system based on that presented in Roberts et al 2009. This provides a means of undertaking a consistent assessment methodology across ecotypes, allowing for comparison between the different environments. The system consists of environmental attributes within three broad categories, each of which is assigned a score based on general criteria. The three attribute categories are ecosystem values, ecosystem threats and vegetation condition and descriptions of the attribute decision system is presented below.

Table 2. Scoring criteria for Ecosystem Values and Threats attributes

ECOSYSTEM VALUES							ECOSYSTEM THREATS				
1	2	3	4	5	6	7	8	9	10	11	12
Riparian Plant Diversity	Riparian Habitat Diversity	Hydrological Value	Salinity (see Appendix A)	Designated Cultural Site	Uniqueness	Key Aquatic Refuge	High Threat Weeds	Exotic Animals	Groundwater abstraction	Spring (surface water) abstraction	Nutrients
Reference condition TBD	Reference condition TBD	Permanent	TDS <500 mg/L	National Park, Aboriginal or European heritage site	Only 'type' in sub-catchment	High value (Site in catchment and ecosystem values)	Absent	Absent	Absent	Absent	TBD
More than one species present for each strata	All strata present and >3 geomorphic features		TDS 500-3,000 mg/L								TBD
At least 1 species present for each strata	All strata present and ≤3 geomorphic features	Seasonal	TDS 3,000-20,000 mg/L	Infrastructure at site i.e. pump	Same 'type' in sub-catchment	Moderate value					TBD
No species within a strata	One strata missing and <3 geomorphic features		TDS 20,000-50,000 mg/L								TBD
Two or more strata's missing	Two or more strata's missing and/or one geomorphic feature	Episodic	>50,000 mg/L	Stock watering point	Same 'type' in stream reach	Low value	Present	Present	Present	Present	TBD

The scoring system is presented in this Appendix to provide a deeper understanding of the differences between the sites that have resulted in the assigned scores. The system is under continual development as it is applied across different regions of the state.

Vegetation condition attribute description

13. Spatial Integrity: .

Width of riparian vegetation (as defined by inundation dependent species).
Longitudinal continuity continuous cover of dominant stratum along the channel.
Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

14. Nativeness:

Percentage of non-native and high impact species.
Abundance of non-native and high impact species in different strata. (perennials).

15. Structural Integrity:

Number of strata and/or life forms.
Cover for each stratum.

16. Age Structure:

Cover of canopy species.
Presence (or abundance) of different age stages.
Presence (or abundance) of large old trees.

17. Debris:

Abundance of fallen logs.
Presence (or abundance) of standing dead trees.
Percentage cover of litter.

Table 3. Scoring system for vegetation condition

	LARGELY UNMODIFIED	SLIGHTLY MODIFIED	MODERATELY MODIFIED	SUBSTANTIALLY MODIFIED	SEVERELY MODIFIED
13. SPATIAL INTEGRITY	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
14. NATIVENESS (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
15. STRUCTURAL INTEGRITY	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (eg. grassland shrubland, forest pasture)
16. AGE STRUCTURE	Dominant strata with reference level of cover and at least three age classes present (juvenile, sub-adults and adults)	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
17. DEBRIS	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (eg. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

Table 4. Key to the ecosystem values listed above

ECOSYSTEM VALUES							*THREATS*				
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1 sp. for each strata (aquatic)	*≥3 geomorphic features*	*Permanent*	*<340 µS/cm*	*National Park, Aboriginal or European heritage*	*Only 'type' in catchment / rock outcrop*	*HCVAE / Ramsar / equiv. Threatened (or equiv.) sp. present*	*Absent*			*Low*	
1 sp. for each strata (non-aquatic)			*340 - 2,040 µS/cm*			*Refuge feature during droughts / permanent*					
1 strata	*2*	*Seasonal*	*2,040*	*Infrastructure*	*>1 type in*	*Refuge*					

missing	*geomorphic features*		*- 13,600 µS/cm*	*at site eg. pump*	*catchment / rock outcrop*	*feature during droughts / semi-permanent*		
2 strata's missing			*13,600 - 34,000 µS/cm*			*Aquatic fauna present*		
3 strata's missing	*1 geomorphic features*	*Episodic*	*> 34,000 µS/cm*	*Stock watering point*	*>1 type in stream reach*	*Aquatic fauna not observed or absent*	*Present*	*High*

KEY 1: Vegetation Condition Sub-Indices Attributes (for each indicator refer to appropriate row in Table 4 for assessment criteria).

Spatial Integrity: *Width of riparian vegetation (as defined by inundation dependent species). Longitudinal continuity continuous cover of dominant stratum along the channel. Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).*

Nativeness: *Percentage of non-native and high impact species. Abundance of non-native and high impact species in different strata. (This project will focus on perennials due to the arid system, annual cover is determined by rainfall which can coincide with site visits).*

Structural Integrity: *Number of strata and/or life forms. Cover for each stratum.*

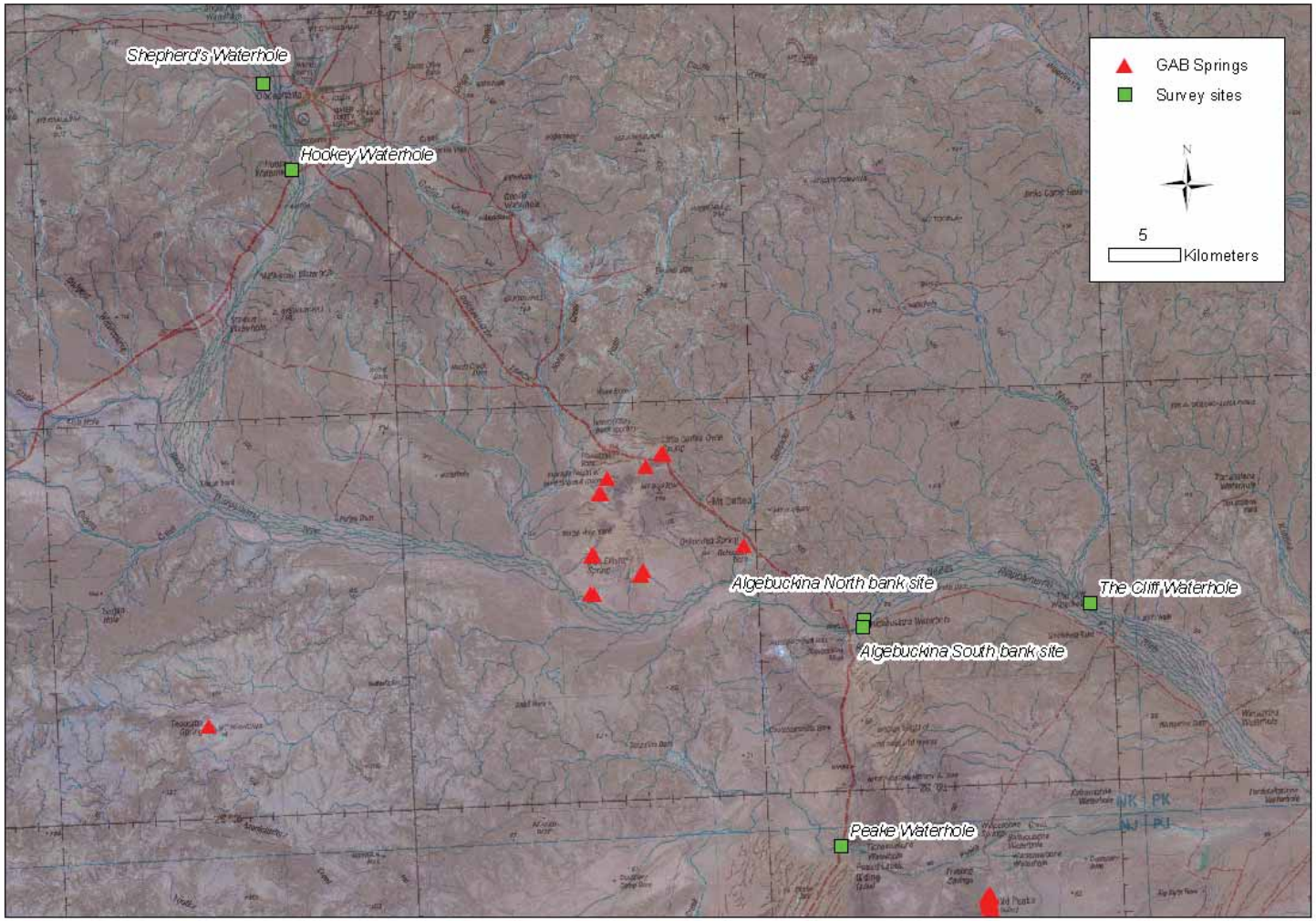
Age Structure: *Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.*

Debris: *Abundance of fallen logs. Presence (or abundance) of standing dead trees. Percentage cover of litter.*

Table 5. Key to the ecosystem 'values' listed in box above.

	Largely Unmodified	*Slightly Modified*	*Moderately Modified*	*Substantially Modified*	*Severely Modified*
Spatial Integrity	No or little evidence of broad scale loss of native vegetation	Width reduced by up to 1/3 and/or some breaks in continuity	About 50% of the native vegetation remains, either in strips or patches	Only small patches of well-separated native vegetation remains	Little or no remaining native vegetation
Nativeness (perennials)	Vegetation predominately native, few weeds and no 'high threat' species.	Exotic species present but not dominating any strata, 'high threat' species rare	One or more strata dominated by exotic species, 'high threat' species present	Most strata dominated by exotic species, 'high threat' species abundant	Few native species remaining, cover dominated by exotic species
Structural Integrity	Number of strata and cover within each strata is similar to reference	Cover within one stratum 50% lower or higher than reference	One stratum missing or extra cover within remaining stratum 50% lower or higher than reference	More than one stratum completely altered from reference (lost or <10% remaining)	Structure completely altered from reference (eg. grassland, shrub land, forest pasture)
Age Structure	Dominant strata with reference level of cover and at least three age classes present	Reduced cover (75-50%) of dominant strata, and/or only two age classes present	Reduced cover (75-50%) of dominant strata, and only one age class present	Reduced cover (<50%) of dominant strata, and only one age class present	Dominant strata mostly absent
Debris	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (eg. firewood collection, trampling of leaf litter by stock)	Quantities and/or cover 50% higher or lower than reference	Very small quantities of debris present	Debris mostly absent or completely dominating the sites, with little or no living vegetation

APPENDIX B. Location of survey sites



APPENDIX C. Survey Results

Site 1: Algebuckina Waterhole, Neales River – North Bank

Site information

Site: Algebuckina Waterhole (north bank), Neales River lower Neales River catchment.
Easting / Northing:
Date: 16 November 2009
Description of feature assessed

- *Feature type:* Surface flow driven waterhole feature.
- *Size / Area:* at time of visit, the waterhole extended from the Oodnadatta Track for at least two kilometres downstream. Shallow and isolated pools were found as far upstream as the bridge.
- *Conceptual understanding:* In stream permanent pool
- *Recent rainfall / inundation events:*
- *Depth:* At time of visit, depth was around 0.5 m below cease to flow. Maximum observed depth was >3 m (typical depth range 0.5 – 1.0 m), but deeper pools may exist.
- *Elevation:* ~ 60 m
- *Vegetation association:* Eucalyptus (*E. Coolabah)* / Lignum *(Muelenbeckia florulenta) open woodland*

Species list of perennials from a rapid survey (annual weeds species have been included):

Strata	***Species***
Aquatic	*None expected for this wetland type within this location*
Understorey (grasses and forbs)	*Chloris truncata*; *Cyperus alterniflora*; *Cyperus* spp.; *Erogrostis* spp.; samphire spp*; Sclerostegia medullosa*.
Shrubs (low-shrubs and tall-shrubs)	*Acacia salicina; Acacia spp; Enchylaena tomentosa; Eremophila spp.; Muehlenbeckia florulenta; Nitraria billardierei; Santalum lanceolatum*
Trees	*Eucalyptus coolabah*

Figure 3. Algebuckina waterhole

Ecosystem Values and Threats

Table 6. Algebuckina North - ecosystem values and threats

	Indicator	Value	Description	Confidence
1	Riparian plant diversity	MODERATELY HIGH	14 species observed including species of known riparian plants	QUALITATIVE
2	Riparian habitat diversity	MODERATELY HIGH	> 3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (bedrock, sand, silt)	HIGH
3	Hydrological Value	PERMANENT	Waterhole considered to be permanent	HIGH
4	Salinity	SUB-SALINE	During site visit (16/11/2009): 766 EC. able to support majority freshwater flora and fauna	HIGH
5	Designated Cultural Site	HIGH	High Aboriginal and European significance	HIGH
6	Uniqueness	HIGH	Only permanent refuge pool on the Neales and Peake catchment	HIGH
7	Key Aquatic Refuge	MODERATELY HIGH	Size, permanence, proximity to Lake Eyre and key biota (native fish) make this site a critical refuge.	HIGH
8	High threat weeds	ABSENT	No weeds observed	QUALITATIVE
9	Exotic animals	PRESENT	Very low numbers observed mean virtually no impact	QUALITATIVE
10	Groundwater abstraction	ABSENT		MODERATE
11	Spring abstraction	ABSENT	.	HIGH
12	Nutrients	ABSENT		

Refer Appendix A for interpretation of scoring system

Site Condition

Table 7. Algebuckina North vegetation condition

Indicator	*Value*	*Description*	*Confidence*
Spatial Integrity	*LARGELY UNMODIFIED*	*Both width and longitudinal continuity of lignum and coolibah was intact.*	*Observation*
Nativeness	*LARGELY UNMODIFIED*	*No perennial weeds were recorded at the site.*	*Observation*
Structural Integrity	*LARGELY UNMODIFIED*	*Possibly some slight reduction in sub-shrubs and grasses.*	Observation
Age Structure	*LARGELY UNMODIFIED*	*Good regeneration of overstorey species, but possibly some reduction in chenopod regeneration.*	*Observation*
Debris	*LARGELY UNMODIFIED*	*Some evidence of wood cutting, but minimal intensity and extent*	*Observation*

Refer Appendix A for interpretation of scoring system

Restoration Potential and Investment Priority

General comments: the north bank of the Algebuckina waterhole is accessible via a narrow track but access is restricted, especially for larger vehicles and caravans owing to a relatively dense vegetation cover. Some clearings have been created allowing for camping and other recreational activities. Evidence of woodcutting was observed, but was isolated and apparently had little to no impact on vegetation structure.

Grazing pressures appear to be minimal on this side of the waterhole and although one rabbit buckheap and some fresh diggings were observed, no animals were sighted and impacts appear to be limited.

Overall the riparian condition was good, with all strata present and multiple species present within each. There was some suggestion of a reduced lower stratum cover of sub-shrubs and grasses but this is difficult to confirm without time series data at the site over flooding and drying cycles. No weed impacts were observed. A range of age classes was observed in overstorey species including new recruits, sub-adults and a range of adult ages. Chenopod regeneration may be reduced as sub-adult shrubs were absent on the floodplain. This is difficult to confirm without additional understanding of floodplain vegetation trajectories in response to elapsed time since last inundation and the extent and duration of flooding history.

Owing to the steep bank profiles streamside vegetation was dominated by lignum (*M. florulenta*) and coolibah (*E. coolabah*). Channel morphology and hydrology dictates that there is limited opportunity for extensive sedge zones to occur adjacent to the stream. Some patches of mixed sedge (*Cyperus* spp.) were present near to the Oodnadatta Track in a shallow backwater channel where water levels maintained

saturated conditions at the observed levels. There are a number of stock access points to the waterhole where vegetation is absent, but riparian cover is mostly continuous on the north bank throughout the area surveyed.

Management recommendations:

The waterhole on this bank appears to be in quite good condition, and it appears little would be achieved by additional management interventions as the south bank appears to sustain the main impacts. There is a small camping area close to the road crossing and access further along the waterhole is prevented by a fenceline. If interventions were undertaken on the south bank steps should be considered to prevent camping impact levels from increasing on the north bank. From a management perspective improved understanding of return periods for overbank flooding would be helpful in ascertaining vegetation condition during rapid assessment surveys such as the current work. Improved understanding of reference condition would also be a valuable asset.

Restoration Potential: Moderate

This site is within the floodplain zone and is subjected to relatively frequent inundation. This site is already in good condition.

Investment Priority: Moderate

Given that this site is already in good condition, not much more improvement would be expected at the site from further intervention. However ongoing monitoring will be required to ensure access and impact at this site is not increasing.

Figure 4. Floodplain ecosystem *E. coolabah* (adult background, seedling foreground), *Acacia salicina, Eremophila* sp

Figure 5. *Cyperus alterniflora*. dominated backwater

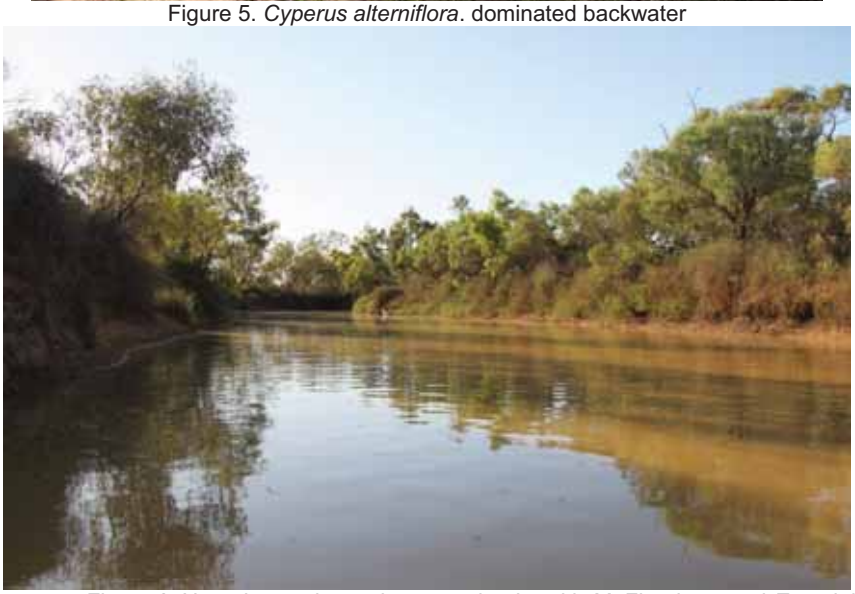


Figure 6. Near the road crossing steep banks with *M. Florulenta* and *E.coolabah*

SITE 2: Algebuckina Waterhole, Neales River – South bank

Site Information

Site: Algebuckina Waterhole (south bank), Neales River
Easting / Northing:
Date: 19 November 2009
Description of feature assessed

- *Feature type:* Surface flow driven waterhole feature.
- *Size / Area:* at time of visit, the waterhole extended from the Oodnadatta Track for at least two kilometres downstream. Shallow and isolated pools were found as far upstream as the bridge.
- *Conceptual understanding:* In stream permanent pool
- *Recent rainfall / inundation events:*
- *Depth:* At time of visit, depth was around 0.5 m below cease to flow. Maximum observed depth was >3 m
- *Elevation:* 60 m
- *Vegetation association:* Eucalyptus (*E. Coolabah) /* Lignum *(Muehlenbeckia florulenta)* open woodland

Species list of perennials from a rapid survey (annual weeds species have been included):

Strata	***Species***
Aquatic	*None expected for this wetland type within this location*
Understorey (grasses and forbs)	*Chloris truncata*; *Cyperus alterniflora*; *Cyperus* spp.; *Erogrostis* spp.; samphire spp*; Sclerostegia medullosa*.
Shrubs (low-shrubs and tall-shrubs)	*Acacia salicina; Acacia spp; Enchylaena tomentosa; Eremophila spp.; Muehlenbeckia florulenta; Nitraria billardierei; Santalum lanceolatum*
Trees	*Eucalyptus coolabah*

Figure 7. Looking at north bank Algebuckina waterhole

Ecosystem values and threats

Table 8. Algebuckina south bank ecosystem values and threats

	Indicator	Value	Description	Confidence
1	Riparian plant diversity	MODERATELY HIGH	14 species observed including 14 species of known riparian plants	QUALITATIVE
2	Riparian habitat diversity	MODERATELY HIGH	> 3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (bedrock, sand, silt)	HIGH
3	Hydrological Value	PERMANENT	Waterhole considered to be permanent	HIGH
4	Salinity	SUB-SALINE	During site visit (16/11/2009): 766 EC. able to support majority freshwater flora and fauna	HIGH
5	Designated Cultural Site	HIGH	High Aboriginal and European significance	HIGH
6	Uniqueness	HIGH	Only permanent refuge pool on the Neales and Peake catchment	HIGH
7	Key Aquatic Refuge	MODERATELY HIGH	Size, permanence, proximity to Lake Eyre and key biota (native fish) make this site a critical refuge.	HIGH
8	High threat weeds	ABSENT	No weeds observed	QUALITATIVE
9	Exotic animals	PRESENT	Very low numbers observed mean virtually no impact	QUALITATIVE
10	Groundwater abstraction	ABSENT		MODERATE
11	Spring abstraction	ABSENT	.	HIGH
12	Nutrients	ABSENT		

Refer Appendix A for interpretation of scoring system

Site Condition

Table 9. Algebuckina south bank vegetation condition

Indicator	*Value*	*Description*	*Confidence*
Spatial Integrity	*LARGELY UNMODIFIED*	*Both width and longitudinal continuity of lignum and coolibah was intact.*	*Observation*
Nativeness	*LARGELY UNMODIFIED*	*No perennial weeds were recorded at the site.*	*Observation*
Structural Integrity	*LARGELY UNMODIFIED*	*Possibly some reduction in sub-shrubs and grasses.*	Observation
Age Structure	*LARGELY UNMODIFIED*	*Good regeneration of overstorey species, but possibly some reduction in chenopod regeneration.*	*Observation*
Debris	*SLIGHTLY MODIFIED*	*Significant evidence of wood cutting at camping sites and along the river bank*	*Observation*

Refer Appendix A for interpretation of scoring system

Restoration Potential and Investment Priority

General comments: the south bank of the Algebuckina waterhole is widely accessible via a well defined side road from the Oodnadatta Track. Site surveyed was to the east of the track; access also occurs to the western side near to the old railway bridge, however the waterhole in this reach is not permanent and so the site was not assessed.

Land use at the surveyed site has historically been a combination of grazing and tourism, but grazing was recently removed and the main pressure now comes from camping and recreation.

The riparian edge along the length of the waterhole features a fine soil substrate sourced from the bed of the pool which has been mobilised and deposited over the waterhole bank through high flow events. This feature is narrow at the upstream end fanning out wider at the downstream end; this geomorphic process is discussed in detail in Wakelin-King (2010). An example of this feature can be seen clearly in Figure 8 at “The Cliff” waterhole. The soil substrate does not promote dense establishment of vegetation as it contains fine clay particles which compact and seal easily when wet. Careful consideration needs to be taken when assessing the condition of this zone as the bare appearance can give the impression that the site has had significant grazing impact; however the lower density of vegetation is a natural feature. The combination of fine clays, soil salinity, inundation level, erosion and grazing all contribute to the varying condition of this zone. It was noted that the

vegetation density and structure is much sparser on the south bank than the north (Fig. 9), with rabbit buckheaps and some fresh diggings observed.

Considerable damage has occurred to the riparian zone along this south bank, apparently largely through vehicle access. Natural hummocking does occur in this zone due to trapping of flood mobilised sediment with vegetation growing on the upstream side and sand deposited on the downstream end (see Fig. 9). However the lack of a clearly defined single access road had led to multiple tracks being created facilitating wind erosion and resulting in the loss of vegetation and “erosional” hummocking of some of the remaining vegetation (see Fig. 11). In addition major woodcutting impacts were observed along, in particular, the streamside zones where most camping activity also occurs.

Figure 8.Fine clay sediments deposited over bank on the riparian zone of the water hole at “The Cliff

Figure 9. South bank sparse vegetation density, showing natural flow aligned hummocking

Figure 10. North bank moderate vegetation density

Management recommendations: The floodplain in general and particularly the streamside zone would benefit from some management intervention at this site. Controls over the access of vehicles could be implemented to limit the damage to the substrate. In addition, installation of signage prohibiting firewood cutting and possibly some provision of firewood as occurs at Coward Springs camp ground may help reduce impacts from timber cutting.

Figure 11. Vehicle impact on vegetation

Figure 12. Soil erosion from vehicle access tracks

Restoration Potential: Low - Moderate

The restoration potential may be limited as the soil substrate contains fine clay particles which compact and seal easily when wet and does not promote establishment of vegetation (fig 11). In many sites considerable loss of topsoil has also occurred (fig 11, 12), and may lead to limited re-vegetation success. Revegetation would be a slow process.

Investment Priority: High

Due to high visitation and potential for further impact further management investment is required.

SITE 3: The Cliff Waterhole, Neales River

Site Information

Site: The Cliff, Neales River
Easting / Northing:
Date: 17 November 2009
Description of feature assessed

- *Feature type:* Waterhole within branch of anastomising channel situated along the edge of stony plains in wide floodplain environment
- *Size / Area:* Waterhole was approximately one kilometre in length, typical width was around 15 metres and depth was less than 2 metres.
- *Conceptual understanding:* In stream semi-permanent pool
- *Recent rainfall / inundation events:*
- *Depth:* This pool is considered to be semi-permanent, a result of its shallow depth. At the time of survey, water levels were around 0.3 metres below the cease to flow height, and maximum water depth was below 2 metres. This pool is unlikely to last for longer than about 12 months without rainfall or flow inputs.
- *Elevation:*
- *Vegetation association:* Eucalyptus (*E. Coolabah) / Lignum (Muehlenbeckia florulenta) open woodland*

Species list of perennials from a rapid survey (annual weeds species have been included):

Strata	***Species***
Aquatic	*None expected for this wetland type within this location*
Understorey (grasses and forbs)	samphire spp*; (Sclerostegia medullosa. Halosarcia indica*)
Shrubs (low-shrubs and tall-shrubs)	*Acacia salicina Enchylaena tomentosa; Muehlenbeckia florulenta; Myoporum montanum; Nitraria billardierei; Santalum lanceolatum*
Trees	*Eucalyptus coolabah*

Figure 13. “The Cliff” waterhole

Ecosystem Values and Threats

Table 10. The Cliff waterhole ecosystem values and threats

	Indicator	Value	Description	Confidence
1	Riparian plant diversity	MODERATELY HIGH	No aquatic species mid-stratum significantly grazed. Only seven plant species recorded, with several in small numbers	QUALITATIVE
2	Riparian habitat diversity	MODERATELY HIGH	> 3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (bedrock, sand, silt)	HIGH
3	Hydrological Value	SEMI-PERMANENT	Waterhole considered to be semi-permanent	HIGH
4	Salinity	FRESH	381 EC at time of survey	HIGH
5	Designated Cultural Site	MODERATE-LOW	Stock water only use, aboriginal significance unknown	LOW
6	Uniqueness	MODERATE	Typical of waterholes of region and riparian zone in poor condition	MODERATE
7	Key Aquatic Refuge	Moderate	Good fish diversity, but only semi-permanent	HIGH
8	High threat weeds	ABSENT	No weeds observed	QUALITATIVE
9	Exotic animals	PRESENT	Open to stock grazing	QUALITATIVE
10	Groundwater abstraction	ABSENT		MODERATE
11	Spring abstraction	ABSENT	.	HIGH
12	Nutrients	UNKNOWN	Likely to be low with some input from cattle waste	QUALITATIVE

Refer Appendix A for interpretation of scoring system

Site Condition

Table 11. The Cliff waterhole vegetation condition

Indicator	*Value*	*Description*	*Confidence*
Spatial Integrity	*MODERATLEY MODIFIED*	*Many mid-stratum species only exist in narrow strips*	*Observation*
Nativeness	*LARGELY UNMODIFIED*	*No exotic species observed*	*Observation*
Structural Integrity	*SLIGHTLY MODIFIED*	*Loss of mid-stratum*	Observation
Age Structure	*SLIGHTLY MODIFIED*	*Only two age classes present in overstorey, reduced cover of mid-stratum*	*Observation*
Debris	*SLIGHTLY MODIFIED*	*Some likely loss of vegetative matter build up, but woody debris still appears at natural levels*	*Observation*

Refer Appendix A for interpretation of scoring system

Restoration Potential and Investment Priority

General comments: This pool is considered to be semi-permanent, a result of its shallower depth. At the time of survey, water levels were around 0.3 metres below the cease to flow height, and maximum water depth was below 2 metres. This pool is unlikely to last for longer than about 12 months without rainfall or flow inputs. The presence of a small, but steep gibber range adjacent to the waterhole suggests local runoff inputs would also be received during rainfall events, potentially supplementing inflows to the pool.

While fringing riparian lignum covered around 80% of the bank and a sparse coolibah overstorey was present in places, grazing is having a considerable impact on vegetation structure and spatial distribution particularly on the side facing the gibber range. Palatable stock species and regenerating coolibah were only observed within stands of lignum, an indication that this is providing protection from grazing. Grazing impacts were observed on 100% of mid-stratum species with Dillon bush (*Nitraria billardierei*) the only commonly observed shrub species. Species commonly found in association with Dillon bush, such as *Enchylaena tomentosa*, were observed but only within the lignum stands. *Santalum lanceolatum* was a common tall shrub species present in the near stream zone, but this too was being impacted by grazing, with upper most leaves being broken off at around 1.5 metres height resulting in a dwarfing effect.

While riparian plant diversity and structure were heavily impacted, aquatic biodiversity at the site is known to be good, with a diverse and numerous native fish

fauna (D. McNeil, pers comm). Exotic animal impacts are largely unknown with the exception of some evidence of rabbits observed within stands of lignum.

Management recommendations: this site would benefit from reduced stock grazing and activity, which would result in an increase in diversity and extent of in particular mid-stratum species. The absence of regeneration of *E. coolabah* is likely to impact the site in future, as no adults are recruiting within the population to replace natural losses. This will increasingly impact on the ecological values at the site due to the loss of habitat and shade species.

If fencing were to occur on the range side, quantitative monitoring of the regeneration at the site should be capable of readily demonstrating environmental improvements. Key aspects of vegetation to focus on in monitoring would be the distribution of the mid-stratum species, and also on the regeneration of canopy species currently being grazed such as *E. coolabah*.

Figure 14. The Cliffs Waterhole *E.coolabah* and *M. florulenta* association

Figure 15. Stock access to waterhole grazing on *Santalum lanceolatum. E. Coolabah* seedling growing within protection of Lignum (*Muehlenbeckia florulenta*).

Figure 16. Grazing line on riparian zone

Figure 17. *Grazing impact on Santalum lanceolatum*

Restoration Potential: High

The riparian zone has been impacted by stock grazing and activity. There is a good distribution of species along the riparian zone and signs of establishing juvenile plants in protected sites. This site would recover rapidly.

Investment Priority: Moderate - Low

This site would improve although site is of low visitation. Fencing the site could also be a problem due to flood activity on a low profile floodplain.

SITE 4 – Shepherds Waterhole, Neales Creek

Site Information

Site: Shepherds Waterhole, Neales River (adjacent to Oodnadatta)
Easting / Northing:
Date: 19 November 2009
Description of feature assessed

- *Feature type:* Waterhole within branch of anastomosing channel situated in wide floodplain environment
- *Size / Area:* Waterhole was approximately 500 metres in length, typical width was around 5-8 metres
- *Conceptual understanding:* In stream semi-permanent waterhole
- *Recent rainfall / inundation events:*
- *Depth:* less than 1.2 metres
- *Elevation:*
- *Vegetation association:* Eucalyptus (*E. Coolabah) / Lignum (Muehlenbeckia florulenta) open woodland*

Species list of perennials from a rapid survey (annual weeds species have been included):

Strata	***Species***
Aquatic	None expected for this wetland type within this location
Understorey (grasses and forbs)	*Alternanthera denticulata; Chenopodium auricomum; Cyperus alterniflora*; *Cyperus exaltatus.; Enneapogon* spp; *Eragrostis setifolia; Eulalia aurea; Malvastrum americanum; Panicum decompositum; Rhagodia nutans;* samphire spp*; Sclerostegia medullosa. Sclerolaena bicornis.*
Shrubs (low-shrubs and tall-shrubs)	*Acacia spp.1(Acacia salicina); Acacia spp; Enchylaena tomentosa; Eremophila spp.; Nitraria billardierei; Maireana aphylla; Muehlenbeckia florulenta; Myoporum montanum*
Trees	*Eucalyptus coolabah*

Figure 18. Southern end of Shepherds Waterhole and riparian zone

Ecosystem Values and Threats

Table 12. Shepherd's waterhole ecosystem values and threats

	Indicator	Value	Description	Confidence
1	Riparian plant diversity	LARGELY UNMODIFIED	*High vegetation diversity in all strata; 22 species recorded, equal highest number of species found.*	MODERATE
2	Riparian habitat diversity	LARGELY UNMODIFIED	*High density and diversity of vegetation. Levels of vegetation cover clearly exceeded that of any site surveyed. > 3 habitat classes: deep pools, overhanging vegetation; flood runners; anastomosing channels*	HIGH
3	Hydrological Value	SEMI-PERMANENT	*Shallow depth means likely to dry following no-flow periods exceeding 1-2 years*	HIGH
4	Salinity	FRESH	*227 EC*	HIGH
5	Designated Cultural Site	MODERATE-HIGH	Of European significance as Oodnadatta town common and water supply dam. Aboriginal significance unknown.	MODERATE
6	Uniqueness	MODERATE	*Other similar waterholes are found in the Neales River system within a short distance both up and downstream*	MODERATE
7	Key Aquatic Refuge	MODERATE	*Similar waterholes are present in system, however floodplain vegetation diversity and habitat condition is optimal*	HIGH
8	High threat weeds	ABSENT	*None observed*	QUALITATIVE
9	Exotic animals	PRESENT	*Very Low grazing level. Horse dung observed but low population level*	QUALITATIVE
10	Groundwater abstraction	ABSENT	*None known*	MODERATE
11	Spring abstraction	ABSENT	*None known*	HIGH
12	Nutrients	UNKNOWN	*Due to low stock and native animal impact presumed low*	QUALITATIVE

Refer Appendix A for interpretation of scoring system

Site Condition

Table 13. Shepherd's waterhole vegetation condition

Indicator	*Value*	*Description*	*Confidence*
Spatial Integrity	LARGELY UNMODIFIED	*No evidence of vegetation removal or loss*	*Observation*
Nativeness	LARGELY UNMODIFIED	*No exotic species observed*	*Observation*
Structural Integrity	LARGELY UNMODIFIED	*All structural layers present*	Observation
Age Structure	LARGELY UNMODIFIED	*Adults, juveniles and seedlings of all structural layers were present*	*Observation*
Debris	LARGELY UNMODIFIED	*High levels of natural debris present*	*Observation*

Refer Appendix A for interpretation of scoring system

Restoration Potential and Investment Priority

General comments: This pool is considered to be semi-permanent, a result of its shallow depth. At the time of survey, water levels were around half a metre below the cease to flow height, and maximum water depth was below 1.2 metres. Even at full supply level, the waterhole currently would not have depths exceeding 2 metres. There was considerable build up of fine anoxic silty sediments rich in organic matter, suggesting that it has been some time since a flow large enough to totally flush the waterhole has occurred, a flushing flow could lead to scouring of the substrate that might increase pool depth. An indicative average depth at the time of survey would be of the order of 0.5m.

This waterhole and floodplain complex was considered to be the most intact and closest to reference condition of all the sites visited. Vegetation structure, density and diversity were noticeably higher than at any other site. This complexity clearly provided highly favourable habitat for both woodland and water-dependent bird species, and over 20 species were informally noted during the site visit, the most diversity observed at any site.

The waterhole itself, while shallow, did have some features not observed at any other site visited. Most notable was the overhanging streamside vegetation, which completely shaded the pool for much of its length. The advantages of overhanging vegetation include not only regulating water temperature fluctuations, but this also increases the input of terrestrial carbon to the aquatic environment. This would potentially result in higher levels of productivity relative to other pools in this study, although assessment of this was beyond the scope of investigations.

Management recommendations: This site provides the most optimal example of floodplain vegetation in good condition of all sites observed and would provide a good reference site for monitoring vegetation change or trajectory in the region. Maintain current management.

Figure 19. Riparian zone and floodplain showing *E. coolabah* regeneration and healthy shrub (E.) and understory layer

Restoration Potential: Intact

This waterhole lies within a wide low profile floodplain, is relatively frequently inundated and does not appear to have any salinity features. Its restoration potential is naturally high and due to the low grazing impact, this site remains in excellent condition.

Investment Priority: Low

No management intervention is needed at this site, although it does represent a flood-plain ecosystem in excellent natural condition and the site should continue to be managed to maintain these values.

Figure 20. Shepherds Waterhole a dense riparian zone with a large diversity of plant species

Figure 21. Diverse riparian zone featuring a healthy range of shrub age classes

Figure 22. Floodplain featuring regenerating *E. coolabah* regeneration and healthy perennial grass cover

Site 5: Hookeys Waterhole, Neales River

Site Information

Site: Hookeys Waterhole, Neales River
Easting / Northing:
Date: 19 November 2009
Description of feature assessed

- *Feature type:* Waterhole within branch of anastomising channel situated in broad floodplain environment
- *Size / Area:* waterhole was approximately one kilometre in length, typical width was around 10-12 metres
- *Conceptual understanding:* Semi-permanent waterhole
- *Recent rainfall / inundation events:*
- *Depth:* The depth exceeded 2 metres (maximum depth not recorded).
- *Elevation:*
- *Vegetation association:* Eucalyptus (*E.camaldulensis / E. Coolabah) / Lignum (Muehlenbeckia florulenta) open woodland*

Species list of perennials from a rapid survey (annual weeds species have been included):

Strata	***Species***
Aquatic	None expected for this wetland type within this location:
Understorey (grasses and forbs)	*Bamboo spp.; Cyperus alterniflora*; *Cyperus exaltatus.;* Enneapogon spp; *Eragrostis spp; Eulalia aurea; Malvastrum americanum; Sclerolaena bicornis; Sclerolaena intricata; Zygophyllum spp.*
Shrubs (low-shrubs and tall-shrubs)	*Acacia stenophylla; Acacia tetragonaphylla Acacia spp(Acacia salicina); Enchylaena tomentosa; Eremophila macdonnellii; Eremophila spp; Muehlenbeckia florulenta; Myoporum montanum; Nitraria billardierei Santalum lanceolatum;*
Trees	*Eucalyptus camaldulensis; Eucalyptus coolabah*

Figure 23. Hookeys Waterhole *E.coolabah* overstorey and large diversity of plant species

Ecosystem Values and Threats

Table 14. Hookey waterhole ecosystem values and threats

	Indicator	Value	Description	Confidence
1	Riparian plant diversity	LARGELY UNMODIFIED	*High vegetation diversity in all strata; 22 species recorded, equal highest number of species found.*	HIGH
2	Riparian habitat diversity	HIGH	*> 3 habitat classes: deep pools, overhanging vegetation; flood runners; instream snags*	HIGH
3	Hydrological Value	SEMI-PERMANENT	*Semi-permanent*	HIGH
4	Salinity	FRESH	*222 EC*	HIGH
5	Designated Cultural Site	HIGH	*Designated aboriginal heritage site.*	HIGH
6	Uniqueness	MODERATE - HIGH	*Considered to be close to the southern most extent of E.camaldulensis in the catchment, indicating freshwater and low salinity at the site*	LOW
7	Key Aquatic Refuge	MODERATE	*Semi-permanent freshwater waterhole, in drought periods is known not to support full diversity of fish species.*	MODERATE
8	High threat weeds	PRESENT	*Bamboo observed on west bank and mallow weed also present (although not high threat).*	HIGH
9	Exotic animals	PRESENT	*Stock grazing (cattle) on west bank, east bank under conservation agreement as Aboriginal Heritage Site. Horse grazing present.*	MODERATE
10	Groundwater abstraction	ABSENT		MODERATE
11	Spring abstraction	ABSENT		HIGH
12	Nutrients	UNKNOWN	*Due to low stock and native animal impact presumed low*	

Refer Appendix A for interpretation of scoring system

Site Condition

Table 15. Hookey waterhole vegetation condition

Indicator	*Value*	*Description*	*Confidence*
Spatial Integrity	LARGELY UNMODIFIED	*Some localised degradation of floodplain zone indicated at southern end of waterhole outside the designated cultural site.*	*Observation*
Nativeness	LARGELY UNMODIFIED	*Bamboo and mallow weed present*	*Observation*
Structural Integrity	LARGELY UNMODIFIED	*Some localised loss of shrub layer at southern end of waterhole outside the designated cultural site.*	Observation
Age Structure	SLIGHTLY MODIFIED	*Redgum and coolibah were spatially restricted, and redgum was absent from streamside zone.*	*Observation*
Debris	SLIGHTLY MODIFIED	*Some woodcutting and firewood collection. In stream debris was good.*	*Observation*

Refer Appendix A for interpretation of scoring system

Restoration Potential and Investment Priority

General comments: Stock grazing (cattle) on west bank, east bank under conservation agreement as Aboriginal Heritage Site.

Maximum water depth was not assessed at this site, but as this pool is considered to be permanent it was likely to exceed 2.5 metres. At the time of survey water level was around 0.5 metres below the cease to flow line.

One of the furthest downstream locations of *E.camaldulensis* suggests that there is a shallow freshwater aquifer lens enabling this species to persist at the site. *E.camaldulensis* has a much lower salinity tolerance than E. coolibah which dominates the riparian vegetation along the Neales and Peake Creeks.

This site featured good riparian vegetation, with some modification of floodplain vegetation structure as a result of grazing. The streamside zone was notable for the presence of river red gums, which in association with coolibah created a good canopy cover in places shading much of the waterhole. There was some suggestion that visitor and stock access may have impacted the lignum cover, which was sparse and restricted to one end of the waterhole.

Management recommendations: There is also significant localised impact at the site from visitor access close to the road with soil compaction, bank erosion and firewood cutting. The Aboriginal heritage site further along the water hole is fenced off and the ecosystem is in good condition.

Restoration Potential: Moderate - High

The site of greatest impact is the localised visitation site close to the road (see below). Due to the close proximity of the well vegetated Aboriginal heritage site and the landform features resulting in frequent inundation, the site would respond well to rehabilitation.

Investment Priority: High

Removal of the bamboo stand is highly recommended whilst this remains a small isolated patch. Some structures and signage to reduce visitation impact at sites would be beneficial.

Figure 24. Hookeys waterhole, historical chinese vegetable garden, Jerry Ah Chee Photo: Courtesy of Oodnadatta museum

Figure 25. Floodplain vegetation

Figure 26. Bamboo growing on stream bank

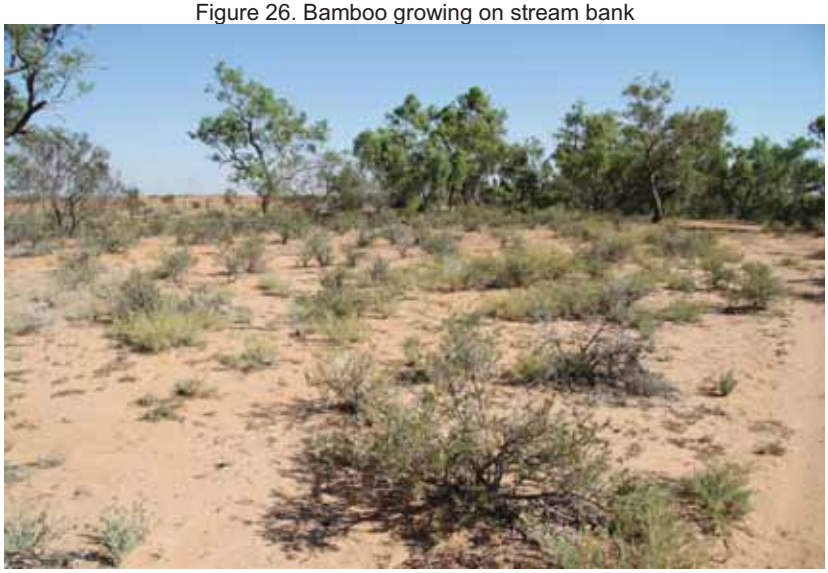


Figure 27. *Eremophilla macdonnellii* grove

Figure 28. *Eremophilla macdonnellii* flowering

Figure 29. Cutting of trees for firewood

Figure 30. Stream bank erosion around camping activity site

Site 6: Peake Bridge, Peake Creek

Site Information

Site: Railway crossing waterhole, Peake Creek
Easting / Northing:
Date: 20 November 2009
Description of feature assessed

- *Feature type:* Waterhole within channel between two ridges creating a flow constriction
- *Size / Area:* Waterhole was approximately 200 metres in length, typical width was around 8-10 metres.
- *Conceptual understanding:* Semi-permanent waterhole
- *Recent rainfall / inundation events:*
- *Depth:* Maximum depth thought to be less than 2 metres
- *Elevation:*
- *Vegetation association:* Eucalyptus (*E. Coolabah) / Lignum (Muehlenbeckia florulenta) / Oldman saltbush (Atriplex nummularia) open woodland*

Species list of perennials from a rapid survey

Strata	***Species***
Aquatic	*None expected for this wetland type within this location*
Understorey (grasses and forbs)	*Erogrostis setifolia;* samphire spp*; (Sclerostegia medullosa)*. (*Halosarcia indica)*;
Shrubs (low-shrubs and tall-shrubs)	*Acacia spp; Atriplex nummularia; Enchylaena tomentosa; Muehlenbeckia florulenta; Nitraria billardierei; Sclerolaena bicornis*
Trees	*Eucalyptus coolabah*

Figure 31. Peake creak saline waterhole looking downstream from the railway crossing

Ecosystem Values and Threats

Table 16. Peake waterhole ecosystem values and threats

	Indicator	Value	Description	Confidence
1	Riparian plant diversity	LOW IMPACT	*10 species observed, likely to be close to reference, some possible grazing impact Some possible grazing related changes to vegetation diversity on south bank*	MODERATE
2	Riparian habitat diversity	LOW - MODERATE	*1 habitat class: deep pool. No overhanging vegetation; flood runners or instream snags*	HIGH
3	Hydrological Value	SEMI-PERMANENT	*Shallow pool unlikely to last more than 6 – 12 months without flow unless site has groundwater input*	HIGH
4	Salinity	*HYPERSALINE*	*177,000 EC*	HIGH
5	Designated Cultural Site	LOW	*Unknown cultural significance, thought to be unlikely owing to salinity and semi-permanence*	MODERATE
6	Uniqueness	MODERATE-LOW	*A number of saline pools are known in this system*	MODERATE
7	Key Aquatic Refuge	MODERATE-LOW	*Salinity extremely limiting to biota, and only semi-permanent – however native fish were observed*	MODERATE
8	High threat weeds	ABSENT	*None observed*	QUALITATIVE
9	Exotic animals	PRESENT	*Area has stock access but currently no signs of stock*	QUALITATIVE
10	Groundwater abstraction	ABSENT	*None observed*	MODERATE
11	Spring abstraction	ABSENT	*None observed*	HIGH
12	Nutrients	UNKNOWN	*Due to low stock and native animal impact presumed low*	

Refer Appendix A for interpretation of scoring system

Site Condition

Table 17. Peake waterhole vegetation condition

Indicator	*Value*	*Description*	*Confidence*
Spatial Integrity	LARGELY UNMODIFIED	*Large floodplain dominated by coolibah, Atriplex and Dillon bush.*	*Observation*
Nativeness	LARGELY UNMODIFIED	*No high threat weed species observed*	*Observation*
Structural Integrity	SLIGHTLY MODIFIED	*Some loss of sub-shrubs and possibly grasses from grazing or lack of recent floods*	Observation
Age Structure	LARGELY UNMODIFIED	*Regeneration observed for coolibah and Old man saltbush. Three age classes present.*	*Observation*
Debris	LARGELY UNMODIFIED	*No obvious difference from natural conditions, no evidence of woodcutting*	*Observation*

Refer Appendix A for interpretation of scoring system

Restoration Potential and Investment Priority

General comments: This pool is semi-permanent, a result of its shallow depth. At time of survey water level was around 1.5 metres below cease-to-flow. It is also hyper-saline with salinities exceeding 170,000 EC. The waterhole is located in the mid channel, and the channel itself is well below the elevation of the floodplain. No overhanging vegetation was observed in the channel, which exhibited some surface salinisation, and fringing vegetation was limited to samphire species.

The floodplain on the left bank (facing downstream) and right banks had different soil types, with the left bank containing sandy red soils and the right bank silty loams. Grazing intensity appears to be greater on the left bank as many of the species found on the right bank, particularly regenerating Oldman saltbush (*Atriplex nummularia*) were absent from the left bank. However this could also be due to differences in bank elevation and soil type indicative of potential flood inundation on the right bank, but without further information this assessment is only theoretical.

Management recommendations: Although this site shows indications of historical grazing impact further investigation is required to determine whether soil types and landform are unfavourable for establishing greater density of vegetation. The pool water salinity is such that stock would not drink from the pool with the vegetation within the channel reflecting the high salinity. No aquatic species were observed. The waterhole ecosystem is disconnected from the floodplain and its associated vegetation. The site was of interest as a saline site for comparison freshwater waterhole systems.

Restoration Potential: **Moderate**

The right bank has a higher restoration potential as shown by the current significant re-establishment of Oldman saltbush. The left bank soil types and landform may be unfavourable for establishing greater density of vegetation as shown by the sparse density of shrub layer vegetation. Further information is required to assess whether historical grazing has had a significant impact at this site.

Investment Priority: Low

This is due to the low aquatic ecosystem values of the water-hole and surrounding vegetation.

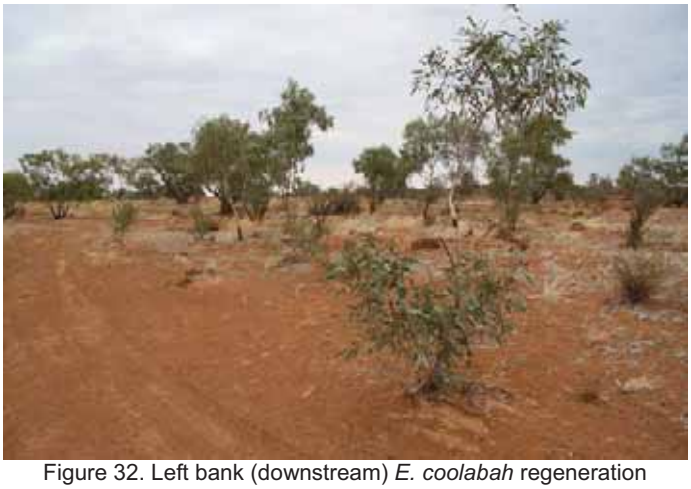


Figure 32. Left bank (downstream) *E. coolabah* regeneration

Figure 33. Landscape showing sparse mid story vegetation with some shrub regeneration in mid and foreground

Figure 34. Right bank (downstream) showing Oldman saltbush (*A. nummularia*) regeneration

Figure 35. Right bank (downstream) showing Oldman saltbush (*A. nummularia*) regeneration

APPENDIX D. Aquatic ecosystems – salinity thresholds

Table 18. Aquatic Ecosystems Salinity Thresholds.

Group	*Taxa*	*Threshold (mg/L)/(ppm)*	*Threshold EC (□S/cm)**	*Effect*	*Reference*
Plants - Aquatic	*Algae*	*>10,000*	*>16,700*	*Majority of algae not tolerant*	*1*
	Aquatic Plants	*1,000–4,000*	*1,700-6,700*	*From significant impact on germination to upper tolerance limit (non halophytes)*	*1*
	Most submerged macrophytes	*1,000–2,000*	*1,700-3,300*	*Sublethal effects, lethal for some*	*2,3*
	Submerged stonewarts (Chara sp)	*1,000–3,000*	*1,700-5,000*	*Disappear from wetlands*	*2*
	Submerged stonewarts (Nitella sp)	*1,000–5,000*	*1,700-8,300*	*Disappear from wetlands*	*2*
	Dominant macrophytes	*4,000*	*6,700*	*Disappear from wetlands*	*2*
	Microbial mat dominated system (see References below)	*>100,000*	*>166,700*	*Threshold between macrophyte or phytoplankton dominated and microbial mat dominated system*	*3*
Plants – Riparian	*Trees (Eucalypt, Melaleuca, Casuarina)*	*>2,000*	*>3,300*	*Adverse effects*	*2,3*
Animals – no exoskeleton	*Small multicellular organisms (hydra, leeches, flatworms)* *Macroinvertebrates without impermeable exoskeletons*	*Not tolerant to elevation in salinity levels*		*Lethal above limited range*	*2*
Macro-invertebrates	*Significant changes in community structure*	*<1,000* *<3,000* *>10,000*	*<1,700* *<5,000* *>16,700*	*Little ecological stress* *Most freshwater tolerant sp.* *Change less rapid above this level*	*1,2,3*
	Emergence	*2,000*	*3,300*	*Significantly reduced emergence for most taxa*	*2*
Frogs	*Frogs* *(6 common sp, South-Eastern Australia)*	*<1,800*	*<3,000*	*Salinities less than this should not limit tadpole presence*	*4*
		>3,300	*>6,000*	*Precludes larvae*	*4*
Fish	*Juvenile fish pre-hardened eggs*	*2,000-4,500*	*3,300-7,500*	*Adverse effects*	*2*
	Juvenile fish growth rate, survivorship	*3,000-5,000*	*5,000-8,300*	*Optimal between these figures*	*2*
	Adult fish	*8,800-10,000*	*14,700-16,700*	*Most are tolerant to this level*	*2,3*
Birds	*Water bird broods (see notes below)*	*15,300*	*25,500*	*Majority found below this level*	*2*

*EC @25C to mg/L conversion 0.6, rounded to 100 EC.
Editor: Glen Scholz DWLBC South Australia, revised 2008

References and notes:

(1) Neilsen DL, Brock MA, Rees GN, Baldwin DS (2003) Effects of increasing salinity on freshwater ecosystems in Australia. Australian Journal of Botany, 51, 655-665.

(2) Kimberly RJ, Cant J, Ryan T (2003) Responses of freshwater biota to rising salinity levels and implications for saline water management: a review. Australian Journal of Botany, 51, 703 – 713.

"Pulsed release of saline water into freshwater systems should be avoided as it is likely to cause higher mortality and loss of biodiversity in a system than does a slow build up to the same level."

" …flushes of freshwater to saline systems at inappropriate times may have a negative impact on biodiversity…"

"Waterbirds are directly dependent upon macrophytes (for food, nesting and cover) and invertebrates (for food). However these taxonomic groups are likely to be adversely affected at salinity levels well below those causing direct affects on waterbirds (Stolley et al.)"

(3) Davis J, McGuire M, Halse S, Hamilton D, Horowitz P, McComb A, Froend R, Lyons M, Sim L (2003) What happens when you add salt: Predicting impacts of secondary salinisation on shallow aquatic ecosystems by using an alternative-states model. Australian Journal of Botany 51, 715-724, in Hart BT, Lake PS, Webb JA, Grace MR (2003) Ecological risk to aquatic systems from salinity increases. Australian Journal of Botany, 51, 689 – 702.

Three alternative were states identified in shallow wetlands influenced by increasing salinity:

Freshwater emergent macrophyte – dominated wetlands to;

Submerged macrophyte or phytoplankton – dominated wetlands to;

Microbial mat dominated systems.

(4) Michael J. Smith, Sabine Schreiber, Michele Kohout, Keely Ough, Joanne Potts, Ruth Lennie, Derek Turnbull, Changhao Jin, and Tim Clancy (2007). Associations between anuran tadpoles and salinity in a landscape mosaic of wetlands impacted by secondary salinisation. Freshwater Biology, Volume 52, Number 1, January 2007 , pp. 75-84(10).

Table 19. Categories of Lake ecosystem salinity (Reference 5, 6 & 7)

Category	*TDS (mg/L)*
Fresh	*<500*
Subsaline	*500 - 3000*
Hyposaline	*3,000-20,000*
Mesosaline	*20,000 – 50,000*
Hypersaline	*>50,000*

References and notes (Table A.2):

(5) Hammer, U. T., 1986. Saline Lake Ecosystems of the World. Dr W. Junk Publishers, Dordrecht, 616 pp.

(6) Williams W.D. (1998) Salinity as a determinant of the structure of biological communities in salt lakes. Hydrobiologica 381: 191-201

(7) Timms, B. V., 1993. Saline lakes of the Paroo, inland New South Wales, Australia. Hydrobiologia 267: 269–289.

An extract from discussion with Lana Hedon QLD EPA 2008)

While many authors point to the temporal variability and arbitrary nature of any saline-fresh threshold, it is pretty clear there is a meaningful ecological transition between 1,000-4,000 mg/l and there is virtually unanimous support for 3,000 mg/l as the saline/fresh threshold (Williams 1981, Timms 1993, 1997, Timms & Boulton 2001, Hammer 1986 quoted by Timms 1993, Pinder *et al*. 2005, Halse et al. 1998).

Above 3,000 mg/l there is still a clear relationship between salinity level and types of halophyte fauna assemblages. Timms (1993) after Hammer (1986) suggested breaking saline wetlands into three categories: hypo-saline 3,000-20,000 mg/l, meso-saline 20,000-50,000 mg/l, hyper-saline > 50,000 mg/l). These cut-offs are supported by many studies although sometimes cut-off is 15,000 rather than 20,000 and sometimes 60,000 rather than 50,000 (e.g. Hales et al 1998).

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