

Government of South Australia

South Australian Arid Lands Natural Resources Management Board







October 2013

South Australian Arid Lands Natural Resources Management Board

Ecological condition assessment of Cooper Creek wetlands, South Australia

Henry Mancini

ECOLOGICAL CONDITION ASSESSMENT OF COOPER CREEK (SA) WETLANDS

October 2013

Henry Mancini¹

Report to the South Australian Arid Lands Natural Resources Management Board

¹ Department of Environment, Water and Natural Resources, GPO Box 1047 , Adelaide, SA agency

DISCLAIMER

The South Australian Arid Lands Natural Resources Management Board, and its employees do not warrant or make any representation regarding the use, or results of use of the information contained herein as to its correctness, accuracy, reliability, currency or otherwise. The South Australian Arid Lands Natural Resources Management Board and its employees expressly disclaim all liability or responsibility to any person using the information or advice.

This report may be cited as:

Mancini, H., 2013, Ecological condition assessments of Cooper Creek (SA) wetlands. Report to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.

Cover images:

Riparian vegetation at Minkie Waterhole, upper Cooper Creek main channel, Innamincka Regional Reserve

© 2013 South Australian Arid Lands Natural Resources Management Board

This work is copyright. Apart from any use permitted under the Copyright Act 1968 (Commonwealth), no part may be reproduced by any process without prior written permission obtained from the authors and the South Australian Arid Lands Natural Resources Management Board. Requests and enquiries concerning reproduction and rights should be directed to the General Manager, South Australian Arid Lands Natural Resources Management Board Railway Station Building, PO Box 2227, Port Augusta, SA, 5700

Table of Contents

Table of Content	S	3
List of Figures5		
List of Tables		6
Acknowledgements7		
Executive Summ	ary	9
INTRODUCTION	۱	13
Project objective	S	18
Conceptual unde	erstanding of permanent waterholes and floodplains	19
Description of Co	ooper Creek study area	23
Site Selection an	d Condition Assessment	24
Threats and Pres	ssures	27
METHODS		29
Background		29
Scope of Assess	ment	30
Summary of asse	essment criteria	30
RESULTS AND	DISCUSSION	32
Survey findings		32
Key Features and	d Management of Cooper Creek Refuges	34
Floodplain Ecolo	gy and Management	36
Results for Prioritisation 39		39
SUMMARY AND	RECOMMENDATIONS	41
Summary		41
Recommendation	ns	42
REFERENCES .		43
APPENDICES		46
APPENDIX A	Condition Assessment Scoring System	46
APPENDIX B.	Location of Survey Sites	49
APPENDIX C.	Survey Results	50

Site 1: Cullyamurra Waterhole, Cooper Creek	50
Site 2: Minkie Waterhole, Cooper Creek	56
Site 3: Scrubby Camp Waterhole – Cooper Creek	61
Site 4: Tirrawarra Waterhole, Cooper Creek	65
Site 5: Kudriemitchie Waterhole, Cooper Creek	70
Site 6: Embarka Waterhole, Cooper Creek	74
Site 7: Cuttapirie Corner Waterhole, Cooper Creek	80
Site 8: Coongie Lake inflow channel, Cooper Creek	84
Site 9: Narie Waterhole, Cooper Creek	88
Site 10: Lake Hope	106
Site 11: Lake Killalpaninna, Cooper Creek Catchment	111
Site 12: Cuttupirra Waterhole, Cooper Creek	116

List of Figures

Figure 1.	Coolabah regeneration at Coongie Lake inflow	17
Figure 2.	Conceptual diagram permanent waterhole (wet phase)	21
Figure 3.	Conceptual diagram permanent waterhole (dry phase)	22
Figure 4.	Study sites along Cooper Creek system	25
Figure 5.	Bridge construction on Cooper Creek	36
Figure 6.	Road construction across a floodplain ecosystem	37
Figure 7.	Cullyamurra waterhole aquatic species.	51
Figure 8.	Cullyamurra waterhole - Lignum.	51
Figure 9.	Cullyamurra waterhole - erosion channel	51
Figure 10.	Cullyamurra waterhole - groundcover.	51
Figure 11.	Minkie Waterhole - flooding.	51
Figure 12.	Minkie Waterhole – reduced Lignum cover	58
Figure 13.	Minkie Waterhole – firewood collection	58
Figure 14.	Minkie Waterhole – good riparian vegetation cover	60
Figure 15.	Erosion channel forming showing exposed tree root systems	63
Figure 16.	Stock damage to Lignum cover at the waterhole	68
Figure 17.	Shrub layer and riparian canopy cover generally in good condition	69
Figure 18.	Stand of Buffel Grass at the Outstation	73
Figure 19.	Regenerating Chenopodium	76
Figure 20.	Healthy mid-stratum riverine shrub layer – view east	77
Figure 21.	Healthy mid-stratum riverine shrub layer – view west	79
Figure 22.	Reduced Lignum cover	83
Figure 23.	Rabbit activity and soil disturbance	83
Figure 24.	Coongie Lake inflow	83
Figure 25.	Bare exposed areas with loss of vegetation cover.	91
Figure 26.	Reduced streambank vegetation and Lignum cover.	92
Figure 27	Exposed riverbank with loss of vegetation cover	92
Figure 28.	Good representative Lignum cover.	93

Figure 29.	Good representative canopy cover with Lignum understorey	93
Figure 30.	Lake Hope shoreline – fringing and submerged vegetation	109
Figure 31.	Woma Python at campsite	114
Figure 32.	Killalpaninna Mission site ruins and current vegetation cover.	115
Figure 33.	Open vegetation with sparse occurrence of Coolibah.	119
Figure 34.	Main vegetation consists of sedge Cyperus gymnocaulos	119

List of Tables

Table 1.	Summary of the field assessments and investment prioritisation	39
Table 2	Attribute table for Ecosystem Values	46
Table 3	Attribute table for Ecosystem Threats	47
Table 4	Attribute table for Ecosystem Pressures	47
Table 5	Key to the rapid assessment of riparian habitat condition	48

Acknowledgements

This study was part of a multi-disciplinary project funded by the Australian Government's Caring for our Country Program 2010-13 and supported by the South Australian Arid Lands Natural Resources Management Board. The input of ideas and findings of other project team members, Justin Costelloe, Jake Gillen, Gini Lee, Dale McNeil, Julian Reid, Dave Schmarr, Rupert Mathwin and Gresley Wakelin-King, to the project is greatly appreciated and acknowledged. The cooperation and support of landholders, and Parks SA staff particularly for site access and local knowledge to conduct surveys in the Cooper Creek catchment is also gratefully acknowledged.

EXECUTIVE SUMMARY

Broader Project Context

Assessing and monitoring riparian vegetation condition is a necessary and valuable investment and is an integral part of the adaptive management cycle. It provides a basis to manage and protect biodiversity assets and monitor changes in vegetation condition over time. It also assists in strategic natural resource management decision making and tracking the effectiveness of protection and restoration activities. This report is one component of a project supported by the South Australian Arid Lands (SAAL) Natural Resources Management (NRM) Board titled 'Managing the high ecological value aquatic ecosystems (HEVAE) of the Cooper Creek Catchment (SA section)' referred to as the 'Cooper Creek Project'. Funding was provided through the Australian Government Caring for Our Country Program (2008-13). The project time frame was from July 2010 to June 2013.

The 'Cooper Creek Project' adopted a broad, holistic approach. This report is one component of a multi-disciplinary process in the assessment of the Cooper Creek system in South Australia. Other investigations included geomorphological assessment and analysis, hydrological monitoring and analysis, cultural/social landscape assessments, aquatic ecology (fish monitoring) and terrestrial ecology assessments of plants, soils and birds. It is important that understanding, assessing and managing complex systems such as the Cooper Creek incorporates expert knowledge from a range of scientific disciplines with knowledge and expertise of the area. It is also important project findings are clearly communicated to the range of stakeholders involved in the region to increase awareness and understanding of these important aquatic ecosystems and to inform solutions to 'fit' the ecology and land use activity.

Cooper Creek wetlands have high conservation value. They are also highly valued for their aesthetic, cultural and recreational values. Healthy wetlands also add to the capital value of a grazing property due to the environmental services they provide for pasture and grazing requirements. Understanding and acknowledging the environmental and economic benefits of wetlands is vitally important. For this reason an understanding of their ecological function, natural processes and vulnerability is required.

This Report

The main focus of this report was to assess the ecological character and condition of high ecological value aquatic ecosystems (HEVAE) (AETG 2012), with a particular focus on refuge waterholes along the SA section of the Cooper Creek. It specifically concentrates on riparian vegetation characteristics at permanent and semi-permanent waterholes and the Lower Cooper lake systems. Together with this baseline data, assessment of current and potential threats and pressures, and appropriate management strategies are recommended. Threats include both plant (Prickly Acacia, Buffel Grass) and animal invasive species (feral

pigs, cane toads, gambusia, goldfish, rabbits and camels); water extraction and regulation of flow in upper Queensland reaches; surface and groundwater abstraction; increased nutrient loads and climate change scenarios. Pressures are primarily from increasing tourism and recreation activity, total grazing pressure, and infrastructure development for the mining and exploration resource industry.

Project objectives

- 1. Collect qualitative data on riparian structural integrity and assess the ecological and vegetation condition of a representative sample of waterbodies to create a basis for investment priority, restoration potential and importance ranking of critical refuges.
- 2. Identify threats to the system and recommend sustainable management interventions.
- 3. Assess the importance of waterholes and lakes as biological refuges that inform environmental water requirements, water affecting activities and climate change scenarios.
- 4. Communicate project findings to stakeholders so there is a clear understanding of processes and functioning and management issues.

Rationale

This project addresses a major gap in our understanding of the functioning of arid zone rivers and the role of different types of refuges in maintaining the long term biodiversity conservation of these aquatic ecosystems. The opportunity of collecting baseline data (current condition) in a significant 'boom' period provides a sound basis to monitor trend and condition into the future. The project coincided with a hydrological cycle driven by a pronounced La Niña episode of the ENSO (El Niño-Southern Oscillation) climatic cycle occurring from 2010-12. The assessments were conducted during the latter phases of this cycle with inundation and flooding a major driver of the system together with significant local rainfall events. This period of high productivity will provide valuable data to compare when the system goes into a drier phase. The assessments, therefore, record data during highly favourable conditions and must be viewed as reflecting the 'boom' conditions these arid rivers periodically encounter. Further assessments and monitoring is recommended to compare condition during expected dry or 'bust' phases.

Presently, the Cooper Creek in SA is an unregulated system and an important biodiversity corridor. It is critical periodic flow, connectivity and environmental flow requirements are maintained to ensure healthy ecosystem function. This work also contributes to addressing Water Affecting Activities (WAA), climate change adaptation reporting and Water Allocation Planning (WAP) objectives and guidelines outlined in the SAAL NRM Board Regional NRM Plan (2010). For example, a water affecting activity may include impeding flow and draining or discharging flow into natural watercourses or floodplains. The assessments also contribute to requirements for condition reporting for climate change adaptation relating to resource condition targets outlined in the Regional Plan (2010).

There are a range of knowledge gaps and a lack of data to adequately provide an understanding of the functional processes and resilience to disturbance (e.g. drought, floods, fire, climate change and habitat modification) of this river system (Butcher & Hale 2010). Arid zone rivers are hydrologically, biologically and geomorphologically different from rivers in other zones of Australia. Hydrologically they are more variable, their geomorphology is less stable, and many of their plants and animals respond to 'boom' and 'bust' conditions more opportunistically (Puckridge et al. 2001). For these reasons it is essential that sustainable management of the Cooper Creek is based on specific information relevant to this system rather than other systems where there is greater understanding of their ecological functioning and processes.

Methodology

To maintain a consistent monitoring and reporting framework across the SAAL region a standardised riparian ecological condition assessment approach was used (DEWHA 2009). This was an on-ground assessment method conducted at individual sites. The methodology has also been used to assess riparian condition at a number of other catchments in the SAAL region, e.g. Gawler Ranges; Flinders Ranges; and Neales Catchment (White & Scholz 2008; McNeil et al 2011; Scholz & Deane 2011). 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 and a sound basis for investment decision-making for on-ground management.

There are four main management units/reaches identified for the SA reaches of the Cooper Creek system that provides a distinct spatial representation of waterbodies and are used to guide an overall assessment. They align with the hydrological and fish monitoring components of the Cooper Creek Project (Costelloe 2013; Schmarr et al 2013).

Management reaches identified as four distinct management units are:

- 1. Upper Cooper Main Channel Nappa Merrie (Qld) to Northwest Branch
- 2. Northwest Branch Junction of the Main Branch to Coongie Lakes

3. Main Branch – The junction with the Northwest Branch to the junction with the northern overflow at Deparanie waterhole

4. Lower Cooper (main branch) – Northern overflow junction at Deparanie Waterhole along Main Branch to Kati Thanda-Lake Eyre North

Site locations were selected based on spatial distribution along the Cooper Creek system aligned to these management units and representative of key refuges, permanence, wetland type and hydrological connectivity. Twelve sites of varying permanence and exposure to disturbance were assessed using the condition assessment protocol. The extensive flooding and rainfall made access to some sites difficult and therefore fewer sites were able to be assessed than originally planned.

Key Findings

Key findings emphasised there was moderate impact from tourism activity and grazing pressure at some waterholes and an increase in mining activity and infrastructure development affecting floodplain environments. Generally ecological riparian condition was rated as 'good' for most sites assessed. In particular the importance of Cullyamurra Waterhole was emphasised due to its near 'reference' condition and its importance as a permanent deep refuge waterhole.

Recreation and tourist visitation at some sites had an impact on the landscape through compaction and soil erosion from vehicles and human use and through firewood collection. Feral animal grazing from rabbits was a major threat with impacts likely to increase. Vegetation responses such as extensive regeneration of Coolibah (*Eucalyptus coolabah*) seedlings and prolific seed production particularly for annual forbs and native grasses were observed due to the favorable conditions. Presently the system is not greatly impacted by any serious weed infestations, however, Buffel Grass (*Cenchrus ciliaris*) poses a serious future threat and requires investment to contain isolated populations at priority sites (e.g. Kudriemitchie Outstation and Minkie Waterhole).

Recommendations

- Increase the number of sites assessed using this protocol to improve representative sampling for each management unit to improve understanding of riparian and floodplain vegetation dynamics and current state or 'reference' conditions at a greater number of representative sites.
- 2. Develop other complimentary assessment tools such as spatial modelling and remote sensing to increase the accuracy and value of assessing vegetation condition in conjunction with on-ground assessment methods.
- 3. From the findings build solutions in partnership with land managers and industry that best 'fit' the ecology and land use enterprises, e.g. develop best practice grazing management strategies at key waterholes and trial grazing management strategies at high ecological value aquatic ecosystems (HEVAEs); develop best practice design and construction for infrastructure development at sensitive riverine and floodplain environments.
- 4. Promote best practice tourism management at key tourist sites associated with key refuge permanent waterholes where tourism and recreation activity is greatest and at culturally sensitive sites (e.g. Lake Killalpaninna).
- 5. Develop interpretive signage and information products relating to the ecological functioning, processes and cultural values of the Cooper Creek system located at key locations (e.g. Cullyamurra Waterhole, Moomba, Embarka, Killalpaninna) to create awareness of the dynamic and vulnerable nature of the entire Cooper system.
- 6. Monitor weed and feral animal infestations particularly Buffel Grass, cane toads, feral pigs and rabbits and implement appropriate control and detection strategies.

- 7. Investigate and gain a greater understanding of the recruitment triggers and success of key perennial species such as Coolibah and River Red Gum during seasonal flooding regimes and connectivity with the river channel system.
- 8. Address knowledge gaps relating to floodplain ecology and their importance in nutrient and energy cycling and connectivity with the river channel system.
- 9. Maintain naturally variable environmental flow regimes throughout the Cooper Catchment particularly at upstream catchment reaches in Queensland.
- 10. Improve understanding of climate change scenarios and the likely effects on the hydrological regimes of flooding frequency and extent and influence on key aquatic assets.
- 11. Undertake future monitoring to track changes in condition at high priority waterholes to test and assess management interventions through appropriate monitoring and evaluation processes.

INTRODUCTION

This vegetation condition assessment report was undertaken as one component of the South Australian Arid Lands (SAAL) Natural Resources Management (NRM) Board project titled 'Managing the high ecological value aquatic ecosystems (HEVAE) of the Cooper Creek Catchment (SA)'. Short title: "The Cooper Creek Project". Funding was provided through the Australian Government Caring for Our Country Program (2008-13). The timeframe for the project was from July 2010 to June 2013. There are a range of knowledge gaps and a lack of data to adequately provide an understanding of this river. Particularly there is lack of knowledge of the Lower Cooper waterbodies and wetlands system (Butcher & Hale 2010).

Cooper Creek wetlands have high conservation value. They are also highly desirable for their aesthetic, cultural and recreational values. Healthy wetlands also add to the capital value of a grazing property for the environmental services they provide for pasture and grazing requirements (Kain 2008).

It is important that understanding, assessing and managing complex systems, such as the Cooper Creek, incorporates expert knowledge from a range of scientific disciplines with knowledge and interest in the area. It is also important project findings are communicated in a clear manner to the range of stakeholders involved in the region. This will increase knowledge and understanding of ecological function and processes, improve awareness of its vulnerability, and promote protection and sustainable management.

This condition assessment report is part of a series of technical reports relating to the management and understanding of Cooper Creek aquatic ecosystems in South Australia and in particular refuge waterholes and ephemeral lake ecosystems (Costelloe 2013; Gillen & Reid; Lee 2013; Reid & Gillen 2013; Schmarr et al 2013; Wakelin 2013). In combination they will provide an overview of the ecology and cultural landscape of this important and iconic river system. These findings will contribute to improved environmental water management by addressing knowledge gaps, identifying management issues, threats and pressures, providing baseline (or current state) information and highlighting areas for further investigation and management. Project findings are used to inform land managers and assist in developing solutions that best 'fit' the ecology and the economic enterprises or management systems presently in place.

Arid zone rivers differ from rivers in other zones of Australia hydrologically, biologically and geomorphologically. Hydrologically they have higher variability, geomorphologically they are less stable, and a majority of plants and animals respond opportunistically to the 'boom' and 'bust' conditions (Puckridge et al. 2000). For these reasons it is essential that management of these rivers is based on specific local information, and not on data gathered from rivers in wetter environments.

The work presented in this report summarises the results of field surveys at 12 wetland sites. This is within a landscape scale context and relevant to regions that are relatively unmodified. Ecosystem considerations, however, are more relevant to partially modified regions, alternatively where highly modified environments exist individual species considerations are more relevant. The Cooper is relatively unmodified, therefore, a landscape scale investigation was undertaken. Qualitative surveys were conducted to establish a baseline condition reference of the aquatic ecosystems being assessed. The methodology is based on the Riverine Vegetation Indicator Protocol for river health (DEWHA 2009). Vegetation surveys and soil/carbon associations and an assessment of bird/floristics provide additional data for each study site (Gillen & Reid 2013; Reid & Gillen 2013).

The assessments were conducted and coincided with a hydrological cycle driven by a pronounced La Niña episode of the ENSO (El Niño-Southern Oscillation) climatic cycle which extended from 2010-2012. The assessments were conducted during the latter phases of this cycle with inundation and flooding a major driver of the system together with significant local rainfall events. This period of high productivity will provide valuable data to compare when the system goes into a drier phase. The assessments record data during highly favorable conditions and reflect the 'boom' conditions these arid rivers periodically encounter. Further assessments and monitoring is recommended to compare condition during expected dry or 'bust' phases. The extensive flooding and rainfall made access to some sites difficult and therefore fewer sites were able to be assessed, including Deparanie Waterhole an important lower Cooper waterhole where the northern overflow connects with the main Cooper channel.

The condition assessment protocol used in this study has been applied at a number of other catchments in the region, e.g. Gawler Ranges; Flinders Ranges; and Neales Catchment (White & Scholz 2008: McNeil et al 2011; Scholz & Deane 2011). This allows for a consistent monitoring and reporting framework across the SAAL region with a focus on the management and prioritisation of aquatic ecosystem assets and a sound basis for investment decision-making for on-ground management. This work also contributes to addressing Water Allocation Planning (WAP) and Water Affecting Activities (WAA) objectives and guidelines outlined in the SAAL NRM Board Regional NRM Plan (2010) and climate change adaptation reporting. Water affecting activities include impeding flow and draining or discharging into natural watercourses or floodplains.

Together with this baseline data, identification and assessment of current and potential threats and pressures and appropriate management strategies are recommended. These include increasing tourism pressure; invasive species (buffel grass, prickly bushes; feral pigs, cane toads, gambusia, goldfish, rabbits and camels); total grazing pressure; development through mining, exploration and resource industries; soil disturbance; climate change scenarios; and water extraction and regulation of natural flow regimes in upper Queensland reaches.

This report provides an assessment of the ecological character and condition of high ecological value aquatic ecosystems (HEVAE), with a particular focus on refuge waterholes along the SA section of the Cooper Creek. It specifically concentrates on riparian vegetation characteristics at permanent and semi-permanent waterholes, lakes and waterbodies.

These wetland types can be defined as areas of permanent or temporary surface water or waterlogged soil. They may be dry for decades but inundation or water-logging must be reoccurring and of sufficient duration to be useful for plants and animals to survive (Wainwright 2006). Waterholes can be classified as permanent if they have a cease to flow depth of >4m. This depth exceeds the evaporative demand estimated at approximately two metres per annum for the SAAL region and before the next flow occurs. These refuge water bodies are those that persist for at least 18-24 months without receiving inflow (Costelloe et al 2004).

This project addresses a major gap in our understanding of the functioning of arid zone rivers and the role of different types of refuges in maintaining the long term biodiversity of these systems. The opportunity of collecting baseline data in a significant wet period provides a sound basis to monitor trend and condition into the future. In particular, the importance of Cullyamurra Waterhole was emphasised due to its near reference condition and its importance as a permanent 'Ark-type' refuge waterhole (Robson et al 2008). This is the deepest permanent freshwater pool in the Lake Eyre Basin (LEB) and provides vital ecosystem services (and refuge values) to a range of biota, including freshwater mussels, Cooper Creek turtle, Cooper catfish and the full array of fish species found in this section of the LEB (Schmarr et al 2013). Loss or a decline in ecological function of these key refuge sites due to reduced flow rates could lead to species decline or loss (Silcock 2009).

The main objective of the work was to assess the condition of priority refuge Cooper Creek wetlands in South Australia. Wetland assessments have in the past referred to the 'health' of the system. These assessments predominately used macro-invertebrates and water quality assessments to infer health (Alluvium Consulting 2011). This work compliments this assessment process and is more closely associated with the term 'condition' that includes assessments of riparian fringing vegetation in terms of spatial and structural integrity; nativeness and age structure; vegetation; and habitat diversity. Threats are described in terms of weeds, feral animals, surface and groundwater abstraction, and elevated nutrient levels. Pressures relate to infrastructure development, tourism activity, soil disturbance and total grazing pressure.

Reference condition is difficult to assess due to lack of pre-disturbance data, therefore, for the purposes of this study condition is determined and defined as the best attainable 'or best on offer' condition to maintain ecological integrity taking into account the drivers of the system, i.e. catchment disturbances, such as past and present landuse, inundation, flooding and fire regimes (Stoddard et al 2006).

Ecological integrity is the preservation of ecological structure, function and composition over time and, therefore, is the preservation to the greatest extent possible of the condition that would be found if natural processes were allowed to predominate and when all of its components are maintained close to the natural condition. There are often competing objectives but through understanding how aquatic ecosystems function these can be achieved at acceptable levels. Aquatic ecosystems for the purposes of this study can be defined as being dependent on flows or periodic or sustained inundation / waterlogging for their ecological integrity (AETG 2012).

There are four core components of this:

- 1. Nativeness (i.e. the degree to which an ecosystem is dominated by native species compared to introduced species)
- 2. Pristineness (i.e. this is linked to connectivity and the ability of an ecosystem or river to connect longitudinally and laterally with adjacent floodplains and vertically with groundwater interactions)
- 3. Diversity (i.e. the number and diversity of species is maintained)
- 4. Resilience (i.e. an ecosystem is able to function despite natural fluctuations e.g. fire, flood, and drought)

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.

Riparian vegetation is a key component of the Cooper particularly perennial, long-lived structural canopy species, such as Coolibah (*Eucalyptus coolabah*) and River Red Gum (*Eucalyptus camaldulensis*). The episodic establishment of these species after the recession of large floods is an important process linked to variable and natural hydrological regimes (flooding) where seedling recruitment is pronounced. Good seasons provide opportunities for widespread recruitment through seed germination as evidenced at the Coongie Lake inflow.



Figure 1. Coolabah regeneration at Coongie Lake inflow

Understanding how these cohorts persist into long-term established stands is an area requiring further investigation. This vegetation structure provides several important ecological services by providing shelter, shade and habitat, trapping sediment, stabilizing banks, helping to control and modify hydrological processes as well as providing riparian mesic habitat in an otherwise arid landscape. It is also a primary source of carbon storage and production (Costelloe et al 2004).

The waterbodies assessed in the Cooper Creek project ranged from deep to more ephemeral waterholes to lake bodies that can persist for up to four years. They were spatially distributed and representative of the range of waterbody types characteristic of the Cooper system from the well watered upper reaches at Cullyamurra to the more ephemeral Lower Cooper lakes and wetlands at Lake Hope and Lake Killalpaninna and at Cuttupirra Waterhole. The Cooper floodplains were not directly assessed but are also critical habitats that provide nutrients and food for aquatic and terrestrial organisms including the more mobile waterbirds. Key wetland species of the Cooper system such as Cooper Creek turtle (*Emydura macquarii emmotti*), water rat (*Hydromys chrysogaster*) and freshwater mussel (*Velesunio sp.*) are more reliant on the permanent and semi-permanent refuges particularly during drought. The recent 'boom' period has provided ideal conditions for increased recruitment and dispersal into the wider Cooper system outside the permanent waterholes.

Generally, Cooper Creek riparian ecosystems were assessed to be in 'good' condition, as evidenced by findings from this study, however, an improved understanding of the ecological condition of selected high priority waterbodies is critical to balance their environmental needs against current and future demand for water resource and riparian habitat use. This baseline survey contributes to an understanding of the basic ecology of this river system over a broad spatial scale using a qualitative assessment approach. It only partly addresses the substantial knowledge gaps of the hydrology-ecology relationships of the Cooper particularly for the Lower Cooper system, and allows a qualitative prediction of the impacts that water resource use would likely have on fundamental ecosystem processes at key waterhole sites (e.g. potential extraction in upper Queensland catchment for irrigation and dams and locally for tourism, grazing, and mining activities). These studies are also useful in the management, planning and monitoring of present and future resource use activities. Therefore, it is essential that the waterholes and waterbodies of the Cooper are managed for their long-term environmental requirements and monitored for any changes in ecological integrity.

Project objectives

The main focus of this report was to assess the ecological character and condition of High Ecological Value Aquatic Ecosystems (HEVAEs), using a qualitative ecological condition assessment protocol (DEWHA 2009) with a particular focus on refuge waterholes along the SA section of the Cooper Creek. It specifically concentrates on riparian vegetation characteristics at permanent and semi-permanent waterholes (i.e. Cullyamurra and Embarka Waterhole) and the Lower Cooper lake systems (i.e. Lake Hope and Lake Killalpaninna).

Project objectives:

- 1. Collect qualitative data on riparian structural integrity and assess the ecological and vegetation condition of a representative sample of waterbodies to create a basis for investment priority, restoration potential and importance of waterbodies as critical refuges.
- 2. Identify threats to the system and recommend sustainable management interventions.
- 3. Identify the biophysical processes (e.g. riparian vegetation condition) that influence ecosystem function, sustain biodiversity and inform environmental water requirements, water affecting activities and climate change scenarios.
- 4. Communicate project findings to stakeholders so there is a clear understanding of processes and functioning and management issues.

This project addresses a major gap in our understanding of the functioning of arid zone rivers and the role of different types of refuges in maintaining the long term biodiversity of these systems. The funding body required that these aims be fulfilled by the active implementation of on-ground management actions, e.g. interpretive signage to improve understanding and protection and management interventions such as feral animal control and detection; and to provide findings to inform management strategies.

Conceptual understanding of permanent waterholes and floodplains

Conceptual diagrams provide a means of simplifying complex ecosystem processes that enable a clearer understanding of how different wetland types function (Scholz & Fee 2008). An important requirement for managing permanent refuge waterholes in arid environments is a conceptual understanding of waterhole ecology and hydrology and to map their distribution across the landscape. Identifying the key features, ecosystem processes and threats to refuge waterholes provides a basis to manage and improve our knowledge of these aquatic ecosystems.

The Cooper Creek hydrology is highly variable both spatially and temporally, and has strong seasonality and inter-annual variability. It is, therefore, necessary to describe a wet and dry phase of the permanent waterholes and associated floodplains of the system. The flow regime of the Cooper is subject to a summer-monsoonal climate and is dependent upon major flooding and seasonal flow driven by rainfall events in the upper catchment in Queensland. Floods tend to occur in clusters associated with La Niña episodes with flood pulses dictating the dynamics of floodplain-river ecosystems (Puckridge et al 2000). Successive floods enable organisms to boost recruitment, disperse more widely and gain greater refuge especially in variable dryland river environments. If annual and variable flows are maintained persistence of waterholes can be determined.

The lateral connectivity of vegetation across the floodplain from the well watered channel and permanent waterholes to the drier floodplain zone shows a typical vegetation sequence of River Red Gum and Coolibah at the riverine fringe through a band of Coolibah woodland with an understorey of Lignum. This then commonly grades to a swampy depression of Chenopodium with a more elevated fringe of Atriplex to end in a shrub land of salt tolerant plants at the margin of the floodplain. Salinity levels increase progressively in a lateral and longitudinal sequence due to salt accumulating in the soil through evaporative processes concentrating salts and at sites where there is lower water flow.

During low flow periods waterholes are disconnected and become isolated strings of waterholes. These are valuable refuges for biota and play a critical role particularly during dry periods in maintaining the biodiversity of the system (Sheldon et al 2010). There is distinct longitudinal vegetation structure along the entire system that is influenced by less reliable flooding and increased saline conditions with associated reduced species diversity.

The conceptual diagrams (Figs. 2 & 3) provide an overview of the key processes and drivers and the main features that contribute to maintenance of natural processes of permanent waterholes and floodplain interactions for the Cooper Creek system. The diagrams illustrate the boom and bust conditions that are important drivers of the system. During wet conditions and with higher temperatures and light intensity nutrients are released that drive the highly productive processes and provide for the opportunistic reproduction and productivity of plants and animals. During the dry phases there is high algal productivity that drives the aquatic ecosystem during drought and no flow periods. With these drier conditions there are associated higher evaporation losses, salinity increase and decrease in oxygen levels causing stress to the aquatic system. This natural disturbance feature emphasises the importance of long term permanent refuges to sustain populations, such as Cullyamurra Waterhole.

Waterholes associated with more ephemeral conditions will require a modified conceptual understanding. These are referred to as 'stepping stone' refuges (Robson et al 2008) and play an important role in dispersal of biota through connectivity of the system during the 'boom' or wetter phases.



Figure 2. Conceptual Diagram – permanent waterhole - wet phase (produced by J. Gillen 2013)



Figure 3. Conceptual Diagram – permanent waterhole - dry phase (produced by J. Gillen 2013)

Description of Cooper Creek study area

The study area is located in the far north-east of SA (Fig1) in the lower reaches of the Cooper Creek catchment within the Lake Eyre Basin (LEB). Cooper Creek is a very large freshwater system and is one of the major rivers of the LEB. Originating in south-west Queensland, the Cooper is influenced by occasional heavy rains that fall at unpredictable intervals in its headwaters that have a major influence on ecosystem patterns and therefore its flow is highly variable (Stafford et al 2011). On average there is an annual flow into SA and floodwaters reach Kati Thanda-Lake Eyre every 5-10 years and fills on average every 25-30 years.

Landuse is predominately pastoralism, park management, tourism, mining, gas and petroleum exploration. The major drivers that underpin an understanding of how the system functions are salinity and hydrology. The hydrological drivers include the flooding and inundation regime and wet/dry sequences. Although these are key environmental drivers of most arid areas wetland systems other drivers include soil composition, historical and current landuse, fire regime and ecosystem productivity (Kingsford 2012). The Cooper includes the important Coongie Lakes Ramsar Site (Butcher & Hale 2010) and the Parks SA Innamincka Regional Reserve (DEHAA 1998).

It is a relatively unaltered and unpolluted catchment, with at present largely unregulated, natural flows. The geological and hydrological processes within this system are complex and variable in nature characterised by extremely low gradients creating a complex range of wetland types consisting of riverine floodplains, tributaries, anastomosing and braided channels, lakes and semi-permanent and permanent waterholes all of which provide a large variety of habitats and high biodiversity. These permanent waterholes in particular support a rich ecology and species richness. The variability is characterised by extended drought periods and occasionally extensive flood regimes. The catchment in SA comprises two bioregions – the Channel Country and Simpson–Strzelecki Dunefields comprising 54,000km² or approximately 20% of the overall catchment size. The main components of the system in SA are Cooper Creek Main Channel, Northwest Branch and Coongie Lakes. During high flood levels connectivity and flow with Strzelecki Creek occurs.

The system has a high degree of productivity characterised by the flora assemblages and bird diversity. The recent 'boom' period has emphasised the high degree of seed production. In SA the main branch of Cooper Creek extends west through Innamincka and divides into two main systems. Firstly, along the North West Branch to Coongie Lakes and the Northern Overflow joining the main branch at Deparanie Waterhole, and secondly along the main channel through a series of ephemeral lakes, waterholes and floodplains to the lower Cooper terminating at Kati Thanda-Lake Eyre. Rainfall is low and highly variable with a mean annual rainfall of approximately 200mm p.a. and an annual evaporation rate exceeding the mean annual rainfall (Bureau of Meteorology).

Site Selection and Condition Assessment

Site locations were selected based on spatial distribution along the system representative of key refuges, permanence, wetland type, condition and hydrological connectivity. This study aimed to assess condition of waterbodies the length of the SA section of the Cooper including waterholes, river channel and terminating lakes.

Floodplain ecosystems were not assessed in this study as this was outside the scope of the assessment program. Floodplains are vitally important to maintain channel function and nutrient flow and it is highly recommended future assessments includes the lateral connectivity of floodplains with the main channel to understand vegetation associations and carbon and nutrient cycling.

There are four main management units or river reaches identified for the Cooper Creek system in SA that provides a distinct spatial representation of waterbodies and are used to guide an overall assessment. They also align with the hydrological and fish monitoring components of the Cooper Creek Project (Costelloe 2012; Schmarr et al 2012).

River reaches identified as the four distinct management units:

- 1. Upper Cooper Main Channel Nappa Merrie (Qld) to Northwest Branch
- 2. Northwest Branch Junction with Main Branch to Coongie Lakes

3. Main Branch – Junction with Northwest Branch to the junction with the northern overflow at Deparanie Waterhole

4. Lower Cooper (main branch) – Northern overflow junction at Deparanie Waterhole along Main Branch to Kati Thanda-Lake Eyre North



Figure 4. Study sites along Cooper Creek system

Overall 12 waterbodies were assessed using the condition assessment protocol. The project results are from the April 2012 field surveys. One site (Cuttupirra Waterhole) was assessed in November 2012. The sampling strategy of large spatial extent places the findings within a landscape context. In largely unmodified regions such as the Cooper, landscape scale considerations are the most appropriate approach to biodiversity planning to maximize effort over a wide range of ecosystems and landuse. This allowed coverage of a range of waterbodies along an extensive and complex riverine system and throughout an extended flooding period through 2010-12.

Four distinct aquatic ecosystems are identified, these align with the management units described above and are the key sites investigated:

- 1. Innamincka complex with deep, permanent waterholes, e.g. Cullyamurra Waterhole (WH) and Minkie WH;
- 2. Coongie Lakes system and North-West Branch, e.g. permanent and semi-permanent lakes and waterholes and floodplains, e.g. Scrubby Camp WH, Tirrawarra WH; Kudriemitchie WH, Coongie Lake inflow channel;
- 3. Central waterholes and Lakes, e.g. Embarka WH, Narie WH, Cuttapirie Cnr WH, Deparanie WH [not assessed due to flooding]
- 4. Lower catchment waterholes and lakes, e.g. Beach Energy Bridge (Kudnarri not assessed due to access issues), Lake Hope, Lake Killalpaninna and Cuttupirra WH.

These four ecological complexes and management units are synonymous with socialecological systems that link spatially and temporally with the cultural and social values relating to community, tourism, and cultural site management issues. The key focus sites of the study were Cullyamurra, Lake Hope and Lake Killalpaninna due respectively to their permanence, importance as sites of ecological condition and health indicators of the system, and their socio-cultural values.

The condition assessment framework measures the degree of departure of an ecosystem condition from a 'reference' ecological state or condition. This can be difficult where there is lack of data and clear knowledge gaps in our understanding of ecosystem function and processes and no data of pre-disturbance. Four types of reference condition can be used to attain a practical approach to stating any departure from a reference condition that is determined from existing knowledge (Stoddard et al 2006):

- 1. A minimally disturbed condition
- 2. Historic condition
- 3. Least disturbed condition
- 4. Best attainable condition (or 'best on offer')

Generally, the ideal reference state is the ecological state of the system immediately prior to the first anthropogenic impacts (Lee et al. 2005), which represents the minimally disturbed or historic condition and is the degree of departure of a measured ecosystem condition from a

reference ecological condition. However, it is difficult to obtain data on the condition of freshwater ecosystems prior to human influence.

For the purposes of this assessment the latter category – best attainable condition (or 'best on offer' is the most practical approach to assess condition, recommend management actions and identify the restoration potential.

Reference condition criteria 1 & 2 are normally the ideal ecological reference state immediately prior to habitat modification (e.g. grazing or introduced feral herbivores). However, apart from historical records (e.g. local knowledge, historical records and explorer accounts) it is difficult to gain an understanding of the condition of aquatic ecosystems in arid regions prior to these disturbances. Care should be given to assessing condition as a function of reference state due to factors such as drought, seasonal climatic variability and variable flooding and rain events that influence recovery and ecological responses. Therefore, this methodology uses vegetation structural integrity and condition indices, such as, spatial and structural integrity, nativeness and age structure to assess the degree that these are intact according to the ecosystems they are found in. For example, the Northwest Branch has a narrow fringing riparian vegetation zone associated with a more xeric floodplain zone and the Upper Cooper Main Channel generally has wider bands of diverse vegetation associated with higher frequency inundation events. The Lower Cooper has increasing salinity, a reduced riparian zone and lower species richness. Salinity is, therefore, a key driver of the system and influences vegetation condition.

The influence of site disturbance history especially the grazing history and the wetting/ drying cycle are difficult to determine from rapid assessment approaches. Future work needs to study a range of wetland types at a number of comparable sites during various stages of a flooding – drying cycle to assess ecological responses, recoverability and condition.

Threats and Pressures

A summary of the main threats include:

- 1. Aquatic feral species (e.g. Gambusia, and Goldfish) affecting native fish assemblages (e.g. *Gambusia*); and cane toad infestation modifying the natural biotic systems.
- Recreation and tourism activity causing impacts at waterhole sites through compaction and trampling and removal of firewood leading to loss of groundcover and soil disturbance potentially causing an increase in invasive weed species and disturbance to nesting bird habitats.
- 3. Overgrazing through total grazing pressure (including invasive herbivores) causing loss of vegetation cover, increased erosion, and destabilisation of stream bank integrity leading to a reduction in riparian plant and habitat diversity.
- 4. Water resource development (i.e. irrigation, flow diversions and dams) affecting the variable hydrological regime.

- 5. Climate change scenarios that may cause an increase in temperature leading to increased evaporation, longer drought conditions, reduced periods of inundation, higher intensity flood sequences and a decrease in waterhole permanency.
- 6. Contamination and pollution of aquatic ecosystems leading to loss of biota due to exposure to toxicants and hydrocarbons.
- 7. Unsustainable resource use such as illegal fishing or over fishing causing loss of source populations of adult breeding fish and turtles from permanent waterholes.
- 8. Potential cane toad infestation from upper reaches in Queensland moving into South Australia and impacting on native fauna populations.
- 9. Weed invasions from upper reaches in Queensland establishing permanent populations.
- 10. High nutrient concentrations causing excessive algal growth.
- 11. Infrastructure development such as bridges and roads impeding connectivity, natural flow and inundation, and movement of aquatic species.

METHODS

Background

The methodology for this study is based on the Riverine Vegetation Indicator Protocol for river health (DEWHA 2009) with assessments based on an expected 'reference' condition. The work provides a summary of baseline condition assessments at a number of permanent and semi-permanent waterhole and wetland environments. A desirable outcome in investing in environmental condition assessment is to gain a better understanding of the ability of natural aquatic ecosystems to "resist" unfavourable conditions and bounce back (resilience) when conditions are favourable. Riparian vegetation condition assessment methods are tools that quantify the 'value' of an aquatic asset for biodiversity.

The first step in prioritising assets for management and investment is to focus on the appropriate scale for an improved biodiversity outcome and to provide an assessment of the ecological, cultural and economic values associated with these assets.

The assessments and results are placed within a landscape context due to the relatively unmodified ecosystems of this arid zone river system. Information presented will in particular assist the development of management priorities. This process aims to provide the capacity to rapidly and cost-effectively assess and report on an aquatic ecosystem site. This process is also easily repeatable over time.

The rapid assessment methodology focuses on the structure and spatial integrity and extent of the vegetation community. For this project 'integrity' is defined as both the extent and condition of riparian native vegetation. Integrity of native vegetation is the extent and distribution of the vegetation associations and their condition for designated purposes, e.g. habitat, steambank stability, etc. These vegetation condition indicators are assessed and compared with a 'reference' condition to identify historic and current impacts and pressures. A reference condition compares a particular site with sites of comparable ecosystem types that are relatively unmodified or in functional condition to what still exists i.e. the 'best on offer'. This study refers to a reference condition based on a bio-physical assessment across a number of sites presenting a range of conditions. Currently there is no available data on the reference condition of these types of sites within this section of the Cooper Creek.

Prioritisation for investment is targeted at sites that have the highest value 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 heavily impacted may have a low priority for investment due to their reduced recovery potential. Sites that are ecologically intact may also have a lower priority for investment due to current environmental conditions, landuse and management systems, e.g. Cullyamurra Waterhole. The ecological importance ranking is the key assessment component and provides a guide for long-term asset management and protection.

Scope of Assessment

Within the study area (Fig. 4) fifteen sites were identified for investigation and assessment, however, due to flooding and access issues some sites were omitted. Twelve sites were assessed using the assessment protocol outlined below. The assessments provide baseline (or current state) data to inform objective findings for management considerations. The sites were assessed between 14th to 30th April 2012 and one site in November 2011.

Assessments were conducted along one bank of each waterhole / waterbody to determine the current condition and extent of riparian habitat. Traverses of approximately one kilometre along the waterbody riparian zone were undertaken to collate data using the rapid appraisal process. Field survey scoring and assessment criteria are detailed in the assessment sheets (see Appendix A).

Summary of assessment criteria

There are 4 main components to the condition assessment protocol:

- Site Description and Environmental Setting
- Ecological Values, Threats and Pressures
- Riparian Condition Assessment
- Riparian Habitat Summary

The assessment protocol uses a qualitative 'score card' approach in reporting condition. An assessment of riparian condition, ecosystem values, threats and pressures and recovery potential and investment priority was completed for each waterbody. Attribute tables are populated with colour coded 'ranking scores'.

1. Site Description and Environmental Setting:

This outlines details of site location features (i.e. type of waterbody; use zone; size/area, conceptual understanding, recent rainfall and inundation events, depth of waterbody, elevation, and vegetation association); a comprehensive plant list is also included.

2. Ecological Values, Threats and Pressures:

An assessment of the ecosystem values, threats and pressures for each waterbody is provided consisting of 15 attributes. These provide a comprehensive summary of key influences and features that provide a baseline summary and can be easily re-assessed to monitor changes over time.

Ecosystem Values:

riparian plant diversity; riparian habitat diversity, hydrological value, salinity, cultural site importance, uniqueness, key aquatic refuge.

Ecosystem Threats:

weeds, exotic animals, surface and groundwater abstraction, nutrients.

Ecosystem Pressures:

infrastructure development, tourism and recreation activity, soil disturbance (e.g. compaction, erosion) and total grazing pressure.

3. Riparian Condition Assessment:

This assessment considered five indicators of site condition for native vegetation cover and quality:

<u>Spatial integrity:</u> Ranks integrity of riparian vegetation associations within riparian areas. This includes:

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

<u>Nativeness</u>: Ranks riparian vegetation based on the proportion of 'nativeness' relating to non-native and high threat species and the abundance of non-native and high threat species in different strata.

<u>Structural integrity:</u> Ranks number of strata represented in riparian vegetation based on a reference community.

<u>Age structure:</u> Ranks age structure of riparian vegetation for each strata present (juveniles, sub-adults, and adults). Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

<u>Debris:</u> Ranks amount of debris within riparian vegetation based on a reference community. Abundance of fallen logs. Presence (or abundance) of standing dead trees and cover of litter.

4. Riparian Habitat Summary:

For each site Condition Ranking; Ecological Importance Ranking; Connectivity Value; Investment Priority; Restoration Potential, and Management Priorities are provided.

Condition: Riparian habitat condition rated either good, moderate, or degraded	
Ecological Importance: Value of waterbody as a critical refuge rated high, moderate, low	
Connectivity Value: Value of riparian habitat to facilitate species movement, rated high, moderate, low	
Investment Priority: Investment according to condition, importance ranking and current management – rated high, moderate, low	
Restoration Potential: Riparian recovery potential rated high, moderate, low	
Management priorities: Management interventions rated high, moderate, low	

RESULTS AND DISCUSSION

Survey findings

The findings of this study are based on observations and attribute data to provide an objective assessment of vegetation and riparian condition. These attributes are assessed visually and will primarily reflect total grazing pressure, presence of introduced weed species, visitor impacts and development. It was clear from the condition assessment surveys that grazing pressure is a prime determinant of riparian condition around waterholes along the Cooper with some localised recreational impacts and resource industry infrastructure development contributing to current condition.

Generally the vegetation of the Cooper Creek was in good condition due to three years of La Niña cycle with extensive local rainfall and prolonged inundation events from a number of hydrological pulses maintaining wet conditions. An objective of these surveys was to focus on the main perennial / biennial riverine vegetation and assess riparian plant and habitat diversity. The Cooper Creek riverine system has high floristic richness and productivity. There were a high number of genera represented in plant surveys emphasising the 'boom' conditions with over 148 species recorded for all sites). The majority of these were perennial species (58%). Two species were found at all sites: Ruby saltbush (*Enchylaena tomentosa*) and Coolibah (*Eucalyptus coolabah*). There were 16 introduced or naturalised species observed during field assessments (Gillen & Reid 2013).

Groundcover is an effective visual indicator of waterhole condition as it influences water quality, sedimentation and bank erosion. It is important to note that bare areas do not infer grazing pressure as there will be a shear zone or bare area adjacent to the watercourse at some locations with only a few groundcover species present. Naturally bare areas are also common due to natural salinity gradients and during dry periods at sites with deep cracking clays or at small channels back from the main channel or waterhole.

All management reaches were assessed as being in good condition due to the favourable conditions over the last 2-3 years and reflect the effectiveness of current management practices. Vegetation changes associated with historical grazing has had an influence across the sites, however, it is difficult to make objective judgments regarding the current condition of riparian vegetation due to lack of data describing conditions prior to existing land use.

The most discernible and widespread impact was 'moderate' riparian and streambank damage by stock at some sites. Also there was low to moderate impact at high visitor use sites. Historic wood cutting for firewood is evident at most sites and more recent activity was only observed at high visitor use areas mainly at Lake Killalpaninna.

The riverine vegetation associated with the Cooper channel and waterhole margins is characterised and dominated by two important structural canopy species i.e. River Red Gum (Eucalyptus camaldulensis) and Coolibah (Eucalyptus coolabah) with a decreasing canopy cover gradient following the creek's westerly path to Kati Thanda-Lake Eyre. There was a dense understorey of ephemeral and perennial forbs, perennial and annual grasses were well represented. The associated floodplains are more sparsely vegetated, with *E. coolabah* the dominant species. Surveys emphasised groundcover is dominated by *Enchylaena* tomentosa and *Einadia nutans*, the mid-stratum understorey by *Acacia salicina*, *A.* stenophylla and *Muehlenbeckia florulenta* (Lignum). In the upper reaches of the system where there is more regular freshwater inflow the upper stratum comprises *E.* camaldulensis, *E. coolabah* and *Bauhinia gilva*. There is a shift in vegetation structure and plant species composition with associated reduction in structural diversity and floristic richness downstream from Cullyamurra along the North West and Main Branches to the Lower Cooper due to less frequent flow and an associated higher salinity gradient (Gillen & Reid 2013).

Lignum typically occurs on cracking or heavy clay soils of floodplains or wetlands prone to periodic inundation, as well as forming a fringe beside major and minor drainage lines. On account of its wide distribution, local dominance, distinctive character, and importance as habitat and providing streambank stability, Lignum is considered one of the most significant floodplain shrubs in arid river systems.

At Narie and Tirrawarra Waterholes, Lignum and ground litter cover was reduced due to past and more recent cattle activity. Soils were heavily impacted to a fine powdery consistency and are potentially open to erosion and increased soil loss.

The majority of the waterbodies sampled were fresh with salinities generally <500mg/l. The Lower Cooper had salinities of >500mg/l due to intermittent flood pulses concentrating salts during flow events. The waterbodies were sampled at near to cease to flow depths at higher water levels, therefore, waterholes did not show high salinities and were relatively fresh due to being flushed by recent flows. As the water levels recede and there are no flood pulses through the system salinities increase. This is due to very low water levels not flushing salts through the system and higher evaporation rates increasing salt levels (Costelloe et al 2004).

The influence of grazing as a source of disturbance on vegetation structure, age class and density was evident at sites where there was recent stock access and rabbit activity. 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, i.e. Tirrawarra, Narie and Cuttapirie Corner waterholes where Coolibah seedlings and juveniles were grazed and sub adults and adults were trampled and cut for firewood use. During this recruitment phase and prolonged wet period it is important cohorts of Coolibah are protected from trampling and grazing to allow for viable germination to occur. In an arid zone riparian ecosystem impacts may take many years to recover. The loss of important structural species such as Coolibah from these regeneration events will not be fully realised until the surviving adults die off. Also other

habitat values provided by canopy species such as wood hollows and submerged woody debris will be lost.

Rabbit activity was evident throughout the study sites with most notable activity at Coongie Lake National Park, Kudriemitchie and Tirrawarra Waterholes and at the lower Cooper site at Cuttapirie Waterhole. At present Buffel Grass (*Cenchrus ciliaris*) poses a potential major weed threat in the Cooper Creek region. The species was observed at Kudriemitchie and at Minkie Waterholes. This is a highly invasive coloniser species that forms dense monocultures. It threatens refuges, displaces native vegetation and changes fire regimes (Biosecurity SA 2012).

Maximum site level plant diversity (species richness) of 49 species was observed at Cullyamurra, Scrubby Camp and Minkie waterholes (Gillen & Reid 2013). These sites are in the better watered reaches of the catchment with regular water flows and lower salinity recordings. They are geographically close to one another, and located within the Innamincka Regional Reserve on the Cooper Creek floodplain within a few kilometres of Innamincka township. The minimum plant diversity observed was 27 species found at Narie and 28 species at Lake Killalpaninna sites. These sites had relatively higher historic disturbance from human and grazing activity.

At Cuttapirie Corner Waterhole the presence of disturbance species such as *Sclerolaena intricata* and *S. bicornis* indicates past impact from grazing pressure. At Narie Waterhole dense stands of *Verbine officinalis* and the native *Senecio lanibracteus* were observed indicating increased impact and disturbance. These are generally unpalatable species that dominant at the expense of palatable species. There was lower structural integrity and species diversity at these sites.

Overall the sites visited were in good condition reflecting the recent 'boom' conditions but also reflect the management systems currently in place.

Key Features and Management of Cooper Creek Refuges

The Cooper Creek is characterised by the highly variable and unpredictable nature of the hydrological regimes of flooding and inundation. This is influenced by periodic rain events in the upper catchment in Queensland. The Cooper is a dryland river that experiences episodic large floods and extended low or no flow periods. More permanent waterholes are found to persist during dry periods in wide and deeper sections of river channel and usually provide refuge during prolonged dry conditions for a range of aquatic species (Knighton & Nanson 1994).

The refuge waterholes assessed in this project in the upper Cooper main channel are characterised by their larger, deeper and greater microhabitat complexity. This complexity equates with greater hydrological persistence that supports the relatively larger number of aquatic species in refuge waterholes. Permanent refuge waterholes are significant and important habitats and are defined to be those that persist for at least 18-24 months in the event that they do not receive inflow during a flood season. To retain water for two years, such waterholes need cease to flow depths (CTFD) of greater than four metres depending on their location so that they are capable of withstanding large annual losses due to evapotranspiration (1.3 - 3.0m/year). Long term refuges also require annual inundation events so that the absence of inflow for an entire flood season is a rare occurrence (Costelloe et al 2004).

During dry periods refuge habitats become reduced and disconnected as pools dry up. Some may be hundreds of kilometres apart in large dry-land rivers such as the Cooper. These are significant ecological sites that during dry periods are further subjected to intense pressures from water extraction and stock access. These influences have the potential to reduce the habitat quality and their capacity to support aquatic biota populations and provide resilience mechanisms for their survival.

Cullyamurra Waterhole is a permanent waterhole that has long term persistence and does not lose its ability to support aquatic biota. It is the key permanent waterhole in the Cooper catchment that supports and consists of a representative assemblage of aquatic species for that catchment. It is classified as an 'Ark-type' refuge. These refuges provide habitat conditions where species are able to avoid the impacts of climatic disturbances, such as drought, and are able to recolonise at the landscape / catchment scale. (Robson et al 2008).

Sedimentation through lack of major hydrologic flushing processes can further reduce the capacity of the channel to hold water so that persistent pools are reduced in number and temporal quality. Further to this, development of artificial barriers (culverts, flood mitigation barriers, crossings etc) have the potential to reduce connectivity between refuge areas and other parts of the system (e.g. floodplains). This loss of connectivity can reduce the potential for recolonisation from refuges to the remainder of the system and may greatly reduce the capacity for natural recovery causing potential extinctions or a decline in species diversity through reducing long-term viability of populations.

The persistence of a refuge waterhole is the length of time it contains water in the absence of flow and, therefore, determines the maximum survival time of aquatic biota that reside in it, e.g. fish, aquatic macrophytes, turtles and some macro-invertebrates. For example, Tirrawarra Waterhole has a cease to flow depth of four metres which means it has approximately a two year permanency without inflow. It is therefore important to understand the factors which affect waterhole persistence for each management unit. The benefits to understanding persistence of waterbodies provides valuable information to identify key permanent waterbodies that can be identified and targeted for conservation or predict changes in persistence under different flow regimes or climate change scenarios, for example, flow regulation in the upper Cooper Creek catchment in Queensland.

There are several management strategies for arid zone wetlands and refuge sites. Some sites may require temporarily or permanently removing grazing and conducting weed and feral animal control programs. To maintain land condition where grazing occurs matching
stocking rates to carrying capacity to maintain vegetation and groundcover is an important consideration. Spelling pastures to allow plants to regenerate and seed prior to grazing and identify management actions through objective assessment of condition to determine any impacts occurring can be a practical option. To assist with assessing riparian condition where historic grazing has occurred it is necessary to understand the complexity of plant responses to disturbance. Decreaser species decline under persistent grazing while increaser species become more dominant, e.g. *Sclerolaena* spp. In wetlands blue rod (*Stemodia florulenta*) is a wetland increaser species. When increaser species become more dominant it is often a sign of declining land condition.

Where tourism and recreation activities are impacting information describing the importance of the refuge can be used to modify behaviour.

Floodplain Ecology and Management

Floodplains play an important role in landscape function, including cycling of carbon, water and nutrients, water purification, regulation of flows, provision of habitats and productive grazing value and so are important components of rivers. Their connectivity ensures there is beneficial exchange of nutrients and sediments that maintains the health of the whole system.

Floodplains in the Cooper Creek are potentially under pressure from a range of sources including grazing by livestock and feral animals, incision from road construction, infestation from non-native plants and water extraction for irrigation and dams in upper Queensland reaches altering natural flow and inundation regimes. These factors can significantly modify the hydraulic character of a floodplain by modifying the infiltration rate during the next flood thus altering soil water regimes (Roberts et al 2000).



Figure 5. Bridge construction can cause changes in flow rates and creek morphology



Figure 6. Road construction across a floodplain ecosystem can decrease inundation and flow rates causing changes in floodplain ecosystem processes

Floodplain wetlands are usually large and diverse and are usually well vegetated providing important economic returns for grazing enterprises. This study did not include floodplains in the condition assessments, mainly due to no defined condition assessment framework existing for arid floodplain ecosystems and the complex and variable nature of these environments.

The vegetation of floodplains has value as habitat providing refuge and breeding opportunities for large waterbird populations that are dependent on flooding cycles. Therefore, the hydrology-vegetation interactions are important considerations and maintaining flow levels and inundation sequences are critical to their function.

There is a general lack of information on floodplain hydrology, geomorphology and vegetation making management and condition assessments a difficult task. Floodplains are sediment deposition environments formed over long periods from sediments transported by rivers in flood. They, therefore, are important for nutrient storage that replenish the adjacent riverine channel system and riparian environments. They are able to provide nutrients and carbon during lateral flow connectivity sequences and are generally low energy environments due to their low relief (Roberts et al 2000).

The range of plants on floodplains includes species that are adapted to dry, semi-terrestrial conditions during dry periods or respond to wetter aquatic conditions. On wet-dry floodplains,

such as the Cooper Creek in SA, the changes that result from flooding and flood recession provide a brief growing opportunity. Short-lived and dormant herbs and forbs grow quickly.

The vegetation-hydrology relationships are an important function of the viability and health of a floodplain. The duration of inundation or the time that surface water is present is important for vegetation growth as it determines the potential growing period including flowering and seed set and defines the period when soil water is recharged by infiltration. Duration of flood intervals and seasonal flooding are also important for floodplain processes and vegetation responses.

An increase or decrease in flood frequency or flood duration may affect soils and vegetation. Changes to flooding-drying cycles such as prolonged soil water logging or complete drying can provide an opportunity for invasive plants tolerant of wetter or drier conditions to germinate and establish and can cause decline of perennial species reliant on irregular wet/dry sequences. Vegetation cover changes may occur to a more terrestrial woody plant structure and other opportunistic species may dominate at the expense of palatable species important for viable grazing operations.

Due to the flat topography of floodplains, small changes in ground level have a large impact on water movement and flood inundation patterns. Examples of this are levee construction to modify and control flood patterns and road grading and construction. These modifications to the floodplain affect relationships between inundated areas and flood volume as well as movement of juvenile fish and plant propagules and the transfer of organic material (carbon) and dissolved nutrients. Further research and understanding of these processes is required.

Some species persist in the seed bank and only germinate, grow and reproduce in response to flooding whereas other long-lived species, including *Eucalyptus coolabah* require specific inundation patterns for germination and establishment of seedlings (Roberts & Marston 2000). Floods also provide the mechanism for connectivity between rivers, wetlands and floodplains, which otherwise remain isolated under dry conditions.

Management of floodplains has high priority and must be viewed as an important component of overall riverine condition assessments. Any activities and development adjacent to floodplain ecosystems must ensure an understanding of the flooding cycles, inundation events and wet-dry sequences so there is not a detrimental modification of the hydrologyvegetation relationships.

Floodplains are key drivers of ecological function and health, they are biologically rich and play an important role in ecosystem processes. Obstruction of local drainage through reducing natural water volume transfer will adversely affect local ecology but may have less impact on a landscape function scale. Therefore it is important ecological assessments are made when infrastructure proposals are being planned at these floodplain sites to determine long term ecological effects. In some cases floodplains may have to be 'sacrifice areas' due to their lower ecological priority ranking.

Results for Prioritisation

A summary of the 12 wetland sites visited for this project in April 2012 are listed in Table 1.

Table 1.Summary of the field assessments and investment prioritisation

Note: Cuttupirra Waterhole assessed in November 2011

Wetland Site	Catchment section / Management Unit	Investment Priority	Restoration Potential	Key Aquatic Refuge ECOLOGICAL PRIORITY	Condition	Connectivity Value
Cullyamurra Waterhole	Upper Cooper Creek main channel	HIGH	HIGH	HIGH - Permanent upper refuge	GOOD	HIGH
Minkie Waterhole	Upper Cooper Creek main channel	HIGH	HIGH	HIGH - Permanent upper refuge	GOOD	HIGH
Scrubby Camp Waterhole	Northwest Branch Cooper Creek	HIGH	HIGH	HIGH - Permanent upper refuge	GOOD	HIGH
Tirrawarra Waterhole	Northwest Branch Cooper Creek	HIGH	HIGH	HIGH - Permanent Northwest Branch refuge	MODERATE	HIGH
Kudriemitchie Waterhole	Northwest Branch Cooper Creek	HIGH	HIGH	MODERATE- Permanent Northwest Branch refuge	MODERATE	MODERATE
Embarka Waterhole	Main Branch Cooper Creek	HIGH	HIGH	HIGH - Permanent Main Branch refuge -	GOOD	HIGH
Cuttapirie Corner Waterhole	Main Branch Cooper Creek	MODERATE	MODERATE	MODERATE - Semi-permanent refuge	MODERATE	MODERATE
Coongie Lake inflow	Northwest Branch Cooper Creek	HIGH	HIGH	MODERATE	MODERATE	MODERATE
Narie Waterhole	Main Branch Cooper Creek	MODERATE	MODERATE	MODERATE- HIGH - Semi- permanent refuge	MODERATE	MODERATE
Lake Hope shoreline	Lower Cooper Creek	MODERATE	MODERATE	MODERATE- HIGH - Non- permanent Lower Cooper lake	MODERATE	MODERATE
L. Killalpaninna	Lower Cooper Creek	HIGH	MODERATE	MODERATE- HIGH - Non- permanent Lower Cooper lake	MODERATE	MODERATE
Cuttupirra Waterhole	Lower Cooper Creek	LOW	LOW	MODERATE - Ephemeral Lower Cooper waterhole	MODERATE	MODERATE

The highest ranking for investment priority is related to the potential for successful recoverability / restoration and therefore "value for money" in resource investment. It also relates to the ecological priority ranking and the potential threats and pressures and management regimes currently in place for that site. Cullyamurra has the highest investment and ecological priority ranking. Due mainly to current management structures in place. There is potential for increased impact from visitation, therefore, investment priority is elevated. Cuttupirra Waterhole has a low investment priority, low restoration potential and moderate ecological priority due to being an ephemeral non-permanent waterhole in a remote location.

The ranking for restoration potential is based on current management regimes, potential and existing threats and location, e.g. whether adjacent to intact habitat, isolation from public access, total grazing pressure and presence of invasive species.

Key aquatic refuge and ecological importance ranking is based on its current condition ranking, role as an aquatic refuge and representativeness as a key refuge site in the system.

Condition ranking is primarily a measure of vegetation in terms of structural and spatial integrity.

Other sites with high investment priority and ranked highly for their ecological importance are Minkie Waterhole, Tirrawarra Waterhole and Embarka Waterhole. These are significant permanent aquatic refuge sites that have potential impact from visitation levels increasing and potential feral animal and weed invasions.

Scrubby Camp and Tirrawarra have slightly lower investment rated at Moderate-High investment priority. This is due to lower visitation rates, present management structure (ParksSA) and status as not being the only representative sample as the only waterhole of this type in the catchment (SA section)

SUMMARY AND RECOMMENDATIONS

Summary

This study has provided current knowledge of the Cooper Creek system and is positioned to provide practical applications for natural resource management outcomes. Key findings were that impacts from grazing and tourism activity is an area requiring attention and more is needed to ensure floodplains and the river channel are protected from the expanding mining, exploration and petroleum industry sector.

The key management principles for managing refuge waterholes and aquatic ecosystems are:

- Maintenance of riparian structural vegetation and lateral connection with floodplain ecosystems
- Management of refuges within a catchment / landscape scale context
- Visitor management
- Feral animal and weed management and control
- Prioritisation and importance ranking of aquatic refuges
- Monitoring of the function of refuges after disturbance
- Maintain flow regimes at natural levels and cycles
- Refuges that are adaptive to landscape and climate change

There are several management strategies for arid zone wetlands and refuge sites. This may include temporarily or permanently removing grazing. To maintain land condition where grazing occurs matching stocking rates to carrying capacity to maintain vegetation and groundcover can be considered. Also spelling pastures to allow plants to regenerate and seed prior to grazing is a feasible management approach at priority sites (Kain 2008).

To manage tourism impacts signage and information detailing the importance of refuges using a whole of catchment approach will improve awareness and understanding and use of these resources. A visitor management protocol where condition is assessed at high use areas is a process of monitoring and controlling impacts at key sites.

Informed and careful planning for infrastructure development and consideration of channel and floodplain dynamics will also protect system function and enable natural processes to be maintained and unimpeded.

The next phase of the Cooper Creek project is to work with industry and community in the region to protect and manage resources sustainably. The following recommendations are a guide to achieve this.

Recommendations

- Increase the number of sites assessed using this protocol to improve representative sampling for each management unit to improve understanding of riparian and floodplain vegetation dynamics and current state or 'reference' conditions at a greater number of representative sites.
- 2. Develop other complimentary assessment tools such as spatial modelling and remote sensing to increase the accuracy and value of assessing vegetation condition in conjunction with on-ground assessment methods.
- 3. From the findings build solutions in partnership with land managers and industry that best 'fit' the ecology and land use enterprises, e.g. develop best practice grazing management strategies at key waterholes and trial grazing management strategies at high ecological value aquatic ecosystems (HEVAEs); develop best practice design and construction for infrastructure development at sensitive riverine and floodplain environments.
- 4. Promote best practice tourism management at key tourist sites associated with key refuge permanent waterholes where tourism and recreation activity is greatest and at culturally sensitive sites (e.g. Lake Killalpaninna).
- 5. Develop interpretive signage and information products relating to the ecological functioning, processes and cultural values of the Cooper Creek system located at key locations (e.g. Cullyamurra Waterhole, Moomba, Embarka, Killalpaninna) to create awareness of the dynamic and vulnerable nature of the entire Cooper system.
- 6. Monitor weed and feral animal infestations particularly Buffel Grass, cane toads, feral pigs and rabbits and implement appropriate control and detection strategies.
- 7. Investigate and gain a greater understanding of the recruitment triggers and success of key perennial species such as Coolibah and River Red Gum during seasonal flooding regimes and connectivity with the river channel system.
- 8. Address knowledge gaps relating to floodplain ecology and their importance in nutrient and energy cycling and connectivity with the river channel system.
- 9. Maintain naturally variable environmental flow regimes throughout the Cooper Catchment particularly at upstream catchment reaches in Queensland.
- 10. Improve understanding of climate change scenarios and the likely effects on the hydrological regimes of flooding frequency and extent and influence on key aquatic assets.
- 11. Undertake future monitoring to track changes in condition at high priority waterholes to test and assess management interventions through appropriate monitoring and evaluation processes.

REFERENCES

Alluvium Consulting (2011) *Framework for the assessment of river and wetland health: findings from the trials and options for uptake*, Waterlines report, National Water Commission, Canberra.

Aquatic Ecosystems Task Group (AETG) (2012) Aquatic Ecosystems Toolkit. Module 3: Guidelines for identifying High Ecological Value Aquatic Ecosystems (HEVAE). Australian Government Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Badman, F.J. (1989) The birds of middle and lower Cooper Creek in SA. Nature Conservation Society of SA, Adelaide.

Biosecurity SA (2012) SA Buffel Grass Strategic Plan: A plan to reduce the weed threat of buffel grass in SA, Government of SA.

Butcher, R., & Hale, J. (2010) *Ecological Character Description for Coongie Lakes Ramsar site*. Report to the Department of the Environment, Water, Heritage and the Arts, Canberra.

Carini, G., Hughes, J.M., & Bunn, S.E. (2006) *The role of waterholes as 'refugia' in sustaining genetic diversity and variation of two freshwater species in dryland river systems (Western Queensland, Australia).* Freshwater Biology 51, 1434-1446.

Costelloe, J.F., Hudson, P.J., Pritchard, J.C., Puckridge, J.T., & Reid, J.R.W., (2004) *ARIDFLO Scientific Report: Environmental Flow Requirements of Arid Zone Rivers with Particular Reference to the Lake Eyre Drainage Basin.* School of Earth and Environmental Sciences, University of Adelaide, Adelaide. Final Report to South Australian Department of Water, Land and Biodiversity Conservation and Commonwealth Department of Environment and Heritage.

Costelloe, J.F. (2013) Hydrological assessment and analysis of the Cooper Creek catchment, South Australia. Report to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.

Cunningham, G.M., Mulham, W.E., Milthorpe, P.L., & Leigh, J.H. (1992) Plants of western New South Wales. Inkata Press, North Ryde.

DEWHA (2009) Indicator protocol: riverine (riparian) vegetation. Department of the Environment, Water, Heritage and the Arts. Australia.

Department for Environment, Heritage and Aboriginal Affairs (1998) A Review of Innamincka Regional Reserve 1988-1998. Department for Environment, Heritage and Aboriginal Affairs, Government of South Australia.

Gillen, J.S. (2010) An ecological study of the landscape, perennial plants and soils of the Cooper Creek floodplain, South Australia. PHD Thesis, Australian National University, Canberra.

Gillen, J.S. & Reid, J.R.W. (2013) Vegetation and soil assessment and riparian bird assemblages of selected waterholes of the main and northwest channels of Cooper Creek,

South Australia. Report to the South Australian Arid Lands Natural Resources Management Board.

Hamilton, S.K., Bunn., S.E., Thoms, M.C., & Marshall, J.C. (2005) *Persistence of aquatic refugia between flow pulses in a dryland river system (Cooper Creek, Australia).* Limnology and Oceanography 50, (3), 743-754.

Kain, A. (2008) *Pastoral management options for central Australian wetlands*, Greening Australia, NT.

Kingsford, R.T. & Biggs, H.C. (2012) Strategic adaptive management guidelines for effective conservation of freshwater ecosystems in and around protected areas of the world. IUCN WCPA Freshwater Taskforce, Australian wetlands and Rivers Centre, Sydney.

Knighton, A. & Nanson, G.C. (2001) *An event based approach to the hydrology of arid zone rivers in the Channel Country of Australia.* Journal of Hydrology 254, 102-123.

Lee, G.A. (2013) Cultural landscape assessment and analysis of the Cooper Creek catchment, South Australia. Report to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.

McNeil, D., Schmarr, D., & Rosenberger, A. (2011) Climatic variability, fish and the role of refuge waterholes in the Neales River catchment: Lake Eyre Basin, SA. Report by South Australian Research and Development Institute (Aquatic Sciences) to the South Australian Arid Lands NRM Board, Port Augusta.

Morton, S.R., Stafford Smith, D.M., Dickman, C.R., Dunkerley, D.L. Friedel, M.H., McAllister, R.R.J., Reid, J.R.W., Roshier, D.A., Smith, M.A., Walsh, F.J., Wardle, G.M., Watson, I.W., & Westoby, M. (2011) *A fresh framework for the ecology of arid Australia.* Journal of Arid Environments 75, 313-329.

Puckridge, J.T., Walker, K.F. & Costelloe, J.F. (2000) *Hydrological persistence and the ecology of dryland rivers.* Regulated Rivers Research and Management 16, 385-402.

Reid, J.R.W. & Gillen, J.S. (2013) Riparian bird assemblages of Cooper Creek, south Australia April-May 2012. Report by the ANU to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.

Roberts, J., Young, B. & Marston, F. (2000) *Estimating the water requirements for plants of floodplain wetlands: a guide.* Land and Water Resources Research & Development Corporation, Canberra.

Robson, B.J., Chester, E.T., Mitchell, B.D. & Matthews, T.G. (2008) *Identification and management of refuges for aquatic organisms*, Waterlines report, National Water Commission, Canberra.

Schallenberg, M., Kelly, D., Clapcott, J., Death, R., MacNeil, C., Young, R., Sorrell, B., & Scarsbrook, M. (2011) Approaches to assessing ecological integrity of NZ freshwaters. Department for Conversation, wellington, NZ.

Schmarr, D.W., Mathwin, R., Cheshire, D.L., & McNeil, D.G. (2013) Aquatic ecology assessment and analysis of the Cooper Creek catchment: Lake Eyre Basin, South Australia. Report by South Australian Research and Development Institute (Aquatic Sciences) to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.

Scholz, G. & Deane, D. (2011) 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.

Scholz, G. & Fee, B. (2008) A Framework for the Identification of Wetland Condition Indicators: A National Trial – South Australia Report DEP19, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Adelaide.

Sheldon, F., Bunn, S.E., Hughes, J.M., Arthington, A.H., Balcombe, S.R., Fellows, C.S. (2010) *Ecological roles and threats to aquatic refugia in arid landscapes: dryland river waterholes.* Marine and Freshwater Research 61, 885-895.

Silcock, J. (2009) Identification of permanent refuge waterbodies in the Cooper Creek and Georgina-Diamantina River catchments for Queensland and South Australia. Final Report to South Australian Arid Lands Natural Resources Management Board.

South Australian Arid Lands Natural Resources Management Board (2010) Regional Natural Resources Management Plan. SA Arid Lands NRM Board, Government of South Australia, Port Augusta.

Stoddard, J.L., Larsen, D.P., Hawkins, C.P., Johnson, R.K., Norris, R.H. (2006) Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16, 1267-1276.

Wainwright, P., Tunn, Y., Gibson, D. & Cameron, J. (2006) *Wetland mapping, Channel Country bioregion, South Australia*. Dept. For Environment and Heritage, Adelaide.

Wakelin-King, G. A. (2013) Geomorphological assessment and analysis of the Cooper Creek catchment (SA section). Report to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.

White, M., & Scholz, G. (2008). Prioritising springs of ecological significance in the Flinders Ranges. DWLBC report 2009/16, Government of South Australia through Department of Water, Land and Biodiversity Conservation.

APPENDICES

APPENDIX A. Condition Assessment Scoring System

The prioritisation for investment of Cooper Creek waterbodies requires evaluating which ecosystems have the greatest contribution and value as an aquatic ecosystem refuge within the catchment and those that have the greatest recoverability potential in relation to management investment and intervention. This assessment is based on a qualitative decision support protocol adapted from DEWHA 2009. This provides a consistent, rapid assessment methodology and enables a comparison between the different wetland typologies. Refer to section on 'Methods' for a summary of assessment criteria.

ECOSYSTEM VALUES						
1	2	3	4	5	6	7
Riparian Plant Diversity	Riparian Habitat Diversity	Hydrological Value	Salinity	Cultural Site	Uniqueness	Key Aquatic Refuge
Reference condition >2 species for each strata- all strata present HIGH VALUE	Reference condition – all strata present – high diversity HIGH VALUE	Permanent HGH VALUE	< 800 EC Fresh	National Park, Aboriginal or European heritage site HIGH VALUE	Only 'type' in catchment HIGH VALUE	High value site in catchment – permanent HIGH VALUE
More than one species present for each strata - all strata present MODERATE to HIGH VALUE	All strata present and >3 geomorphic features MODERATE to HIGH VALUE	Semi-Permanent MODERATE to HIGH VALUE	800 - 2500 EC Sub-saline	Moderate cultural importance MODERATE to HIGH VALUE	Same 'type' in catchment MODERATE to HIGH VALUE	High value refuge during drought - permanent MODERATE to HIGH VALUE
At least 1 species present for each strata – 1 strata missing MODERATE VALUE	All strata present with 3 geomorphic features MODERATE VALUE	Seasonal MODERATE VALUE	2,500 – 10,000EC Saline	Infrastructure at site i.e. pump MODERATE VALUE	Same 'type' in catchment MODERATE VALUE	Semi-permanent waterbody MODERATE VALUE
2 strata missing MODERATE to LOW VALUE	One strata missing and <3 geomorphic features MODERATE to LOW VALUE	Ephemeral MODERATE to LOW VALUE	10,000 – 34,000 EC Saline – Saline - Hyper- saline	Mixed land use recreation and some stock grazing MODERATE to LOW VALUE	Same 'type' in catchment MODERATE to LOW VALUE	Semi-permanent pool MODERATE to LOW VALUE
3 or more strata missing LOW VALUE	Two or more strata missing and/or one geomorphic feature	Episodic LOW VALUE	> 34,000 EC Hyper-saline	Stock watering point LOW VALUE	Same 'type' in stream reach LOW VALUE	Ephemeral waterbody LOW VALUE

Table 2 Attribute table for Ecosystem Values

ECOSYSTEM THREATS							
8 9 10 11							
Weeds	Exotic Animals	Surface & Ground water abstraction	Nutrients				
Absent	Absent	Absent	Absent				
No WONS weeds present – <3 perennial weeds present	Present – low level activity evident	Present – Iow level	Low level				
No WONS weeds present – 4-5 perennial weeds present	Present – some activity evident	Present – moderate level	Moderate level				
No WONS weeds present – >5 perennial weeds present	Present - moderate level	Present moderate – high level	Moderate to high level				
WONS weeds present	Present – high level	Present – high level	High level				

Table 3 Attribute table for Ecosystem Threats

Table 4 Attribute table for Ecosystem Pressures

ECOSYSTEM PRESSURES					
12 13 14 15					
Infrastructure development (e.g. roads, bridges, flow diversions)	Tourism & Recreation Activity	Soil disturbance (e.g. trampling, erosion)	Grazing		
Absent	Absent	Absent	Absent		
Low level	Present – low level activity evident – controlled management	Present – Iow level	Low level		
Low – moderate level	Present – some activity evident – no on-site management	Present – moderate level	Low – moderate level		
Moderate – high level	Present - moderate level	Present moderate – high level	Moderate – high level		
Present – high level	Present – high level – high impact	Present – high level	High level		

	· · · · · · · · · · · · · · · · · · ·	· · · · ·			,
	LARGELY UNMODIFIED	SLIGHTLY MODIFIED	MODERATELY MODIFIED	SUBSTANTIALLY MODIFIED	SEVERELY MODIFIED
16. SPATIAL INTEGRITY	No or little evidence of broadscale 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
17. 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
18. 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, woodland)
19. 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
20. DEBRIS	Quantities and cover similar to reference	Some evidence of unnatural loss of debris (e.g. 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 5 Key to the rapid assessment of riparian habitat condition (DEWHA 2009).

KEY 1: Riparian Habitat Condition Attributes (for each indicator refer to appropriate column in Table 5 for assessment criteria)

Spatial Integrity:

Ranks integrity of riparian vegetation associations within riparian areas. This includes:

Lateral connectivity - the width of riparian vegetation (as defined by inundation dependent species); Longitudinal continuity - continuous cover of dominant stratum along the channel; and

Connectedness of the riverine vegetation to other areas of native vegetation (riparian or terrestrial).

Nativeness:

Ranks riparian vegetation based on the proportion of 'nativeness' relating to non-native and high threat species and the abundance of non-native and high threat species in different strata.

Structural Integrity:

Ranks number of strata represented in riparian vegetation based on a reference community.

Age Structure:

Ranks age structure of riparian vegetation for each of the strata present (juveniles, sub-adults, and adults) Cover of canopy species. Presence (or abundance) of different age stages. Presence (or abundance) of large old trees.

Debris:

Ranks amount of debris within riparian vegetation based on a reference community. Abundance of fallen logs. Presence (or abundance) of standing dead trees and cover of litter.

APPENDIX B. Location of Survey Sites

- 1. Cullyamurra Waterhole
- 2. Minkie Waterhole
- 3. Scrubby Camp Waterhole
- 4. Tirrawarra Waterhole
- 5. Kudriemitchie Waterhole
- 6. Embarka Waterhole
- 7. Cuttapirie Corner Waterhole
- 8. Coongie Lake Inflow Channel (channel feeding directly into Lake Coongie)
- 9. Narie Waterhole
- 10. Lake Hope
- 11. Lake Killalpaninna
- 12. Cuttupirra Waterhole

APPENDIX C. Survey Results

Site 1: Cullyamurra Waterhole, Cooper Creek

Site information

Site: Cullyamurra Waterhole (south bank), Innamincka Regional Reserve

Management reach: Upper Cooper Main Channel – Nappa Merrie (Qld) to NW Branch

Easting / Northing: -27.42720 140.53044

Date: 14th April 2012

Description of feature assessed:

- Feature type: Surface flow driven permanent waterhole
- Use zone: Mixed use zone Pastoral (Innamincka Station) / Innamincka Regional Reserve (Parks SA) camping/tourism/recreation area
- Size / Area: The waterhole extends for approx. 8km from Burke's Grave site upstream to the Innamincka choke / approx. 70m at its widest
- **Conceptual understanding:** In stream permanent waterhole ('Ark-type' refuge)
- **Recent rainfall / inundation events:** 135mm at Innamincka Station during March 2012 / Large flood and rainfall events 2010-12 / Average annual rainfall ~ 190mm.
- **Depth:** At time of visit, maximum observed depth was 26m at cease to flow depth (CTFD) typical depth range 4.5 5.0m / channel was flowing
- Elevation: ~ 51 m
- Vegetation association: River Red Gum RRG (*Eucalyptus camaldulensis*) Coolibah (E. coolabah) riparian Woodland

Strata	Species
Aquatic/ semi-aquatic	Velvet Knotweed (Persicaria attenuata ssp attenuata)
Understorey (grasses and forbs)	Asperula gemella; Boerhavia dominii; Chenopodium auricomum; Eragrostis dielsii var. dielsii; Eragrostis setifolia; Eulalia aurea; Goodenia glauca; Haloragis aspera; Lavatera plebeia; Mukia maderaspatana; Nicotiana velutina; Portulaca intraterranea; Pseudoraphis spinescens; Pterocaulon sphacelatum; Tetragonia tetragonioides; Solanum esuriale; Sporobolus mitchellii; Teucrium racemosum; Tribulus eichlerianus Introduced spp.: Cynodon dactylon; Salsola kali; Solanum nigrum; Sonchus oleraceus; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Acacia salicina; Muehlenbeckia florulenta; Einadia nutans ssp. eremaea; Enchylaena tomentosa var. glabra; Eremophila bignoniiflora; Sclerolaena bicornis; Sclerolaena muricata var. muricata
Small Trees	-
Trees	Bauhinia gilva; Eucalyptus camaldulensis var. obtusa; Eucalyptus coolabah

Plant list of key perennial and annual species from J. Gillen 2012 vegetation survey



Figure 7. Cullyamurra Waterhole - Persicaria attenuata ssp. attenuata aquatic species present.



Figure 8. *E. camaldulensis* with recent flood level evident, good *Muehlenbeckia florulenta* (Lignum) cover.

Ecosystem Values, Threats and Pressures

	Indicator	Value	Description	Confidence			
Eco	Ecosystem Values						
1	Riparian plant diversity	HIGH	High species diversity in all strata n=49. Mix of emergent, perennial and annual forbs; shrubs and trees.	QUALITATIVE SURVEY			
2	Riparian habitat diversity	HIGH	All strata present. >3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (bedrock, sand, silt). High number of in- stream snags.	QUALITATIVE SURVEY			
3	Hydrological Value	PERMANENT	Permanency confirmed through hydrological / historical records, and species presence (Cooper Creek Turtle <i>Emydura macquarii emmotti</i> , Water Rat <i>Hydromys chrysogaster</i> and freshwater mussel <i>Velesunio</i> sp.). CTFD <26m.	QUANTITATIVE HYDROLOGICAL MONITORING			
4	Salinity	FRESH	During site visit (14/04/2012): 152 EC. Relatively low able to support majority freshwater flora and fauna.	EcTester SALINITY METER			
5	Cultural Site (Aboriginal & European)	HIGH	High Aboriginal significance (designated traditional use zone and evidence of past occupation (rock engraving site); European significance (early explorers); Regional Reserve (camping / recreation).	QUALITATIVE SURVEY			
6	Uniqueness	HIGH	Permanent 'Ark-type' refuge waterhole – large size and depth 26-28m – deepest and most permanent waterhole in the LEB.	QUALITATIVE SURVEY			
7	Key Aquatic Refuge	HIGH	Size, permanence, and key biota (native fish, turtles, water rat) make this site a critical 'Ark-type' refuge. Mod-high abundance of native fish species (n=10) at time of visit. Will contain all species in drier periods.	QUANTITATIVE FISH SURVEY (2010-2012)			
Eco	system Threats						
8	Weeds	PRESENT	No significant (WONS) weeds observed; a variety of introduced and naturalised species present (n=5). 3 perennial species.	QUALITATIVE SURVEY			
9	Exotic animals	PRESENT	Some feral pig activity - low number observed (n=1) with little to no observable impact. Introduced fish present (gambusia and goldfish).	QUALITATIVE SURVEY			
10	Surface & Groundwater Abstraction	PRESENT	Low level stock watering infrastructure present – solar pump setup.	QUALITATIVE SURVEY			
11	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth. Toilet drops and high visitor numbers could contribute to elevated nutrient levels.	QUALITATIVE SURVEY			
Eco	system Pressures	 ;					
12	Infrastructure development (e.g.tracks, bridges, flow diversions)	LOW LEVEL	Vehicle and walking tracks are generally well managed with a number of drop toilets located along the camping zone.	QUALITATIVE SURVEY			

Cullyamurra Waterhole - ecosystem values, threats and pressures

13	Tourism & Recreation Activity	PRESENT	High visitor use area – extended camping and day visitors. Controlled management. Historic wood cutting for firewood evident – none recently.	QUALITATIVE SURVEY
14	Soil disturbance (e.g. trampling, erosion)	PRESENT	Some disturbance observed at the streambank area where foot access down steep embankments has created erosion points – there are also erosion channels forming from the vehicle access track.	QUALITATIVE SURVEY
15	Grazing Pressure	ABSENT	Stock exclusion zone – no recent grazing activity. Little evidence of feral animal activity.	QUALITATIVE SURVEY

Refer Appendix A for interpretation of scoring system

Site Condition

Cullyamurra Waterhole - riparian habitat condition

Indicator	Value	Description	Confidence
16. Spatial Integrity	LARGELY UNMODIFIED	Both width and longitudinal continuity of Lignum, RRG and Coolibah was intact. Good connectivity of riparian habitat with floodplain vegetation zone.	Observation
17. Nativeness	LARGELY UNMODIFIED	Vegetation is predominately native with no significant or WONS weeds recorded. A number of perennial introduced species are present (n=3).	Observation
18. Structural Integrity	LARGELY UNMODIFIED	All structural layers present apart from camping zones where there is a reduction of the understorey layer.	Observation
19. Age Structure	LARGELY UNMODIFIED	Regeneration of overstorey species evident. 3 age classes present (adults, sub-adults & juveniles).	Observation
20. Debris	LARGELY UNMODIFIED	Good organic matter cover apart from designated camping 'sacrifice' zones. Evidence of historic wood cutting for firewood, but no recent activity. Firewood collection has reduced debris at camping sites. There are generally high levels of natural debris present.	Observation

Refer Appendix A for interpretation of scoring system

Summary

The waterhole is generally in good condition. The site is within the Innamincka Regional Reserve and has direct management through Parks SA and is within the Cullyamurra Waterhole Conservation Exclosure (DEHAA 1998). The assessment was conducted on the south bank of the waterhole from the start of the camping zone to the end of the access track. From there a walking trail continues east for 2.5km to the Cullyamurra Choke. The 'choke' is at the upstream end of the waterhole and is an important geomorphological feature characterised by constricted creek morphology and no floodplain. The camping area is accessible via defined park tracks. Access to camping is restricted beyond the designated camping zones. Clearings have been created allowing for camping and other recreational activities. There is evidence of historic woodcutting, with no recent activity observed. Toilet blocks are provided that supports reduced impact camping.

Feral grazing pressure is minimal on this side of the waterhole. There is some evidence of stock access in the adjacent floodplain but this is minimal. There was no recent rabbit

activity evident. The presence of *Sclerolaena bicornis* (Goathead burr), *Portulaca intraterranea* (Large pigweed), *Nicotiana velutina* (Velvet tobacco), *Tribulus eichlerianus* (Bull-head) and *Salsola kali* (Buck bush) is an indicator of disturbance probably from previous grazing pressure.

There were no major weed infestations. With the recent flood levels there is prolific herbaceous cover with cosmopolitan plants well represented e.g. *Tetragonia tetragonioides* (Native spinach). All strata are present with multiple species present within each stratum. A range of age classes was observed in overstorey species including new recruits, sub-adults and adult ages, particularly for River Red Gum (*Eucalyptus camaldulensis*) at the eastern section of the survey site. There is good Lignum (*Muehlenbeckia florulenta*) cover along the waterhole with established stands of *Melaleuca trichostachya* (River paperbark). This species is found along banks of permanent watercourses with low salinity in River Red Gum communities which regularly flood.

Through cessation of grazing, since the Cullyamurra Waterhole Conservation Exclosure was established in 1997, the waterhole has recovered from drought and intensive land use. There is high plant diversity and variability along the transect. The riparian zone to streambank edge is dominated by River Red Gum and Coolibah. The main introduced species are *Solanum nigrum* (Black-berry nightshade), *Cynodon dactylon* (Couch grass) and *Verbena officinalis* (Common verbane).

Dense stands of *Persicaria attenuata ssp attenuata*, (Velvet knotweed), a semi-aquatic plant of freshwater environments with a high waterlogging tolerance was observed growing at the bank-full margin of the waterhole. *Persicaria* helps in stabilising banks and beds of waterways and provides habitat for birds and other animals when they grow in dense stands.

The main impact is from recreational activity. Camping sites are well maintained and concentrated in the recreational use / camping zone. Riparian cover is mostly continuous with high levels of leaf litter apart from these camping areas where vehicle and foot access occurs. There is a number of erosion gullies formed from the track edge towards the waterhole. Recent inundation and rain events have exacerbated this problem at some points. Without intervention this could increase erosion and sediment transfer into the channel.

Access by visitors and campers to the water's edge was more pronounced at the camping zone. The use of a 'sacrifice' camping zone requires long term monitoring and visitor management, e.g. restricting numbers during peak periods and after any rain events that may cause soil disturbance and erosion. It is recommended interpretive signage is further developed to inform visitors of the ecological importance of the waterhole as a key refuge site. Monitoring of present campsites is required to guard against extensive stream bank degradation and possible further erosion points forming. This site is a key area for the potential incursion of cane toads and should be a priority site for monitoring as part of an early detection system.

Survey of visitor numbers, monitoring recreational fishing activities and monitoring of any encroachment of introduced plants is a priority. Feral animal control and monitoring (e.g. feral pigs, rabbits and cane toads) is an ongoing management issue. Monitoring of any contamination from toilet areas and potential leakage into the groundwater and into the waterhole is recommended to ensure water quality is not affected. Other indirect impacts from visitor use include pollution of water through litter and motor vehicle oils, increased runoff velocity through soil compaction (risk of erosion) and spread of weeds.

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS
Condition	Good	Near intact with good vegetation cover and habitat diversity – some visitor pressure at designated sites
Ecological Importance	High	Permanent waterhole classed as an 'Ark-type' refuge
Connectivity Value	High	Permanent refuge - high value for species dispersal
Investment Priority	High	High importance – maintain current visitor management and pest species control strategies
Restoration Potential	High	Current management and condition verifies this
Management priorities	High	Monitoring and on-going visitor management requirements, weed and feral animal control



Figure. 9. Erosion channel forming at designated campground area



Figure.10. Prolific groundcover vegetation growth

Site 2: Minkie Waterhole, Cooper Creek

Site information

Site: Minkie Waterhole (south bank), Innamincka Regional Reserve

Management reach: Upper Cooper Main Channel – Nappa Merrie (Qld) to NW Branch

Easting / Northing: -27.4720 140.3844

Date: 17th April 2012

Description of feature assessed:

- Feature type: Surface flow driven permanent waterhole
- **Use zone:** Mixed use zone Pastoral (Innamincka Station) and Innamincka Regional Reserve camping/tourism/recreation area (Parks SA)
- Size / Area: The waterhole extends for approx 1.5km / approx. 100m wide
- Conceptual understanding: In stream permanent waterhole
- **Recent rainfall / inundation events:** 135mm at Innamincka Station during March 2012 / Large flood and rainfall events 2010-12 / Average annual rainfall ~ 190mm.
- **Depth:** At time of visit, maximum observed depth was 6.85m at cease to flow depth typical depth range 4m / channel was flowing
- Elevation: ~ 51m
- Vegetation association: River Red Gum RRG (*Eucalyptus camaldulensis*) Coolibah (E. coolabah) riparian Woodland

Strata	Species
Aquatic/ semi-aquatic	Velvet Knotweed (Persicaria attenuata ssp. attenuata)
Understorey (grasses and forbs)	Asperula gemella; Boerhavia dominii; Enneapogon avenaceus; Eragrostis dielsii var. dielsii; Eragrostis setifolia; Haloragis aspera; Lavatera plebeia; Mukia maderaspatana; Nicotiana velutina; Pseudoraphis spinescens; Pterocaulon sphacelatum; Setaria jubiflora; Solanum esuriale; Sporobolus mitchellii; Stemodia florulenta; Tetragonia tetragonioides; Teucrium racemosum; Tribulus eichlerianus Introduced spp.: Cucumis melo; Salsola kali; Solanum nigrum; Sonchus oleraceus; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Acacia salicina; Einadia nutans ssp. eremaea; Enchylaena tomentosa var. glabra; Muehlenbeckia florulenta; Sclerolaena muricata var muricata
Small Trees	Atalaya hemiglauca
Trees	Bauhinia gilva; Eucalyptus camaldulensis var. obtusa; Eucalyptus coolabah

Plant list of key perennial and annual species from J. Gillen 2012 vegetation survey

Ecosystem Values, Threats and Pressures

	Indicator	Value	Description	Confidence			
Ecos	Ecosystem Values						
1	Riparian plant diversity	HIGH	High species diversity in all strata n=50. Mix of emergent, perennial and annual forbs; shrubs and trees.	QUALITATIVE SURVEY			
2	Riparian habitat diversity	HIGH	>3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (sand, silt). High number of in-stream snags.	QUALITATIVE SURVEY			
3	Hydrological Value	PERMANENT	Waterhole considered to be permanent with a CTFD of 6.5m. Presence of native fish and Cooper Creek turtle.	QUANTITATIVE HYDROLOGICA L MONITORING			
4	Salinity	FRESH	During site visit (17/04/2012): 162 EC. Able to support majority freshwater flora and fauna.	Ec Tester SALINITY METER			
5	Cultural Site (Aboriginal & European)	MODERATE	Designated camping site – Parks SA managed. Old stockyards nearby.	QUALITATIVE SURVEY			
6	Uniqueness	MODERATE	Similar permanent refuge waterholes are found in this section of the Cooper.	QUALITATIVE SURVEY			
7	Key Aquatic Refuge	HIGH	Size, permanence, and key biota (native fish, turtles) make this site a critical refuge. Mod-high abundance of native fish species (n=10).	QUANTITATIVE FISH SURVEY (2010-12)			
Ecos	system Threats						
8	Weeds	PRESENT	No significant (WONS) weeds observed – a variety of introduced and naturalised species present (n=5).	QUALITATIVE SURVEY			
9	Exotic animals	PRESENT	Introduced fish present (goldfish and gambusia). No rabbits observed – probably with low numbers in the vicinity - little to no impact.	QUALITATIVE SURVEY			
10	Surface & Ground Water Abstraction	ABSENT	None observed.	QUALITATIVE SURVEY			
11	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth. Toilet drops and high visitor numbers could contribute to elevated nutrient levels.	QUALITATIVE SURVEY			
Ecos	Ecosystem Pressures						
12	Infrastructure development (e.g. tracks, bridges, flow diversions)	LOW	Toilet facilities present, car park and campgrounds.	QUALITATIVE SURVEY			
13	Tourism & Recreation Activity	PRESENT	High visitor use area – day visitors and camping – toilet facilities present. Controlled management.	QUALITATIVE SURVEY			

Minkie Waterhole - ecosystem values, threats and pressures

14	Soil disturbance (e.g. trampling, erosion)	PRESENT	Minor erosion gullies forming at car park area.	QUALITATIVE SURVEY
15	Grazing Pressure	ABSENT	No present grazing observed – historical grazing old stockyards nearby. High level of disturbance indicator species present <i>Tribulus eichlerianus</i> (Bull-head).	QUALITATIVE SURVEY

Refer Appendix A for interpretation of scoring system



Figure 11. Minkie Waterhole – Large River Red Gum at high flood levels 2012.



Figure 12. Minkie Waterhole – reduced Lignum cover

Site Condition

Indicator	Value	Description	Confidence
16. Spatial Integrity	LARGELY UNMODIFIED	Good width and longitudinal continuity of canopy and understorey species.	Observation
17. Nativeness	LARGELY UNMODIFIED	No significant perennial weeds present apart from a range of introduced forbs (n=5).	Observation
18. Structural Integrity	LARGELY UNMODIFIED	All structural layers present with a slight reduction in the Lignum layer.	Observation
19. Age Structure	LARGELY UNMODIFIED	Regeneration of overstorey species observed particularly Coolibah.	Observation
20. Debris	LARGELY UNMODIFIED	Good leaf litter cover and high levels of natural debris present including submerged snags. Some evidence of previous wood cutting.	Observation

Minkie Waterhole vegetation condition

Refer Appendix A for interpretation of scoring system

Summary

Minkie Waterhole is located 9km south west of Innamincka. The survey zone on the south bank is adjacent to camping and vehicle access points. The site is a popular camping and day visitor location. Access to camping is restricted beyond the designated camping zones. At the time of visit the camping area was submerged due to the recent flooding events. Evidence of historic woodcutting was observed, but was isolated and has minimal impact on current vegetation structure. The floodplain zone had high level of Coolibah regeneration. The riparian vegetation was supported by a thick mulch layer of leaf litter and debris. There was no evidence of recent grazing.

Overall the riparian condition was good, with all strata present and multiple species present within each stratum. No significant 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. An old stockyard is located near to the waterhole which may account for the reduced Lignum cover at this site, exposed banks from past grazing activity and high density of *Tribulus eichlerianus* (Bull-head). The site has responded well to reduced grazing pressure and the recent inundation and rain events. This waterhole is considered permanent as it receives flow in most years and due to its relatively deep profile (>4m). Large River Red Gums are found at the waterhole with a high number of submerged snags observed.

The waterhole on this bank is in relatively good condition with minimal requirement for additional management interventions. It is recommended signage to inform visitors of the ecological importance of the waterhole and as a key refuge site is provided. Erosion control where gullying is forming will need attention at the car park and where foot traffic leads to the waterhole. Ongoing monitoring will be required to ensure access and impact at this site is not increasing. Given that this site is managed under Parks SA and is in good condition, not much more improvement would be expected at the site from further intervention. However survey of visitor numbers, recreational fishing activities, monitoring of any encroachment of

introduced weeds (Buffel Grass was observed as an outlier near to the waterhole) and feral animal control, particularly for rabbits is a priority. Monitoring of potential contamination from toilet drops and potential leakage to groundwater and into the channel is recommended to ensure water quality is not affected.

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS	
Condition	Good	Good vegetation cover and habitat diversity	
Ecological Importance	High	Permanent aquatic refuge	
Connectivity Value	High	Permanent refuge - high value for species dispersal	
Investment Priority	High	Important refuge site – maintain current visitor management and pest species control strategies	
Restoration Potential	High	Current management and condition verifies this	
Management priorities	High	On-going visitor management requirements; weed and feral animal control	



Figure 13. Minkie Waterhole - firewood collection showing damage to old Coolibah tree



Figure 14. Minkie Waterhole – good riparian vegetation cover

Site 3: Scrubby Camp Waterhole, Cooper Creek

Site information

Site: Scrubby Camp Waterhole (north bank), Innamincka Regional Reserve

Management reach: Northwest Branch - Junction of Main Branch to Coongie Lakes

Easting / Northing: -27.39637 140.23036

Date: 18th April 2012

Description of feature assessed:

- Feature type: Surface flow driven permanent waterhole
- **Use zone:** Mixed use zone Pastoral (Innamincka Station) and Innamincka Regional Reserve camping/tourism/recreation area (Parks SA)
- Size / Area: The waterhole extends for approx. 500m / approx. 30m wide
- Conceptual understanding: In-stream permanent waterhole
- Recent rainfall / inundation events: 174mm at Tirrawarra Moomba during March 2012 / Large flood and rainfall events throughout 2010-12 / Average annual rainfall 186mm
- **Depth:** At time of visit, cease to flow depth 5.4m / channel was flowing
- Elevation: ~ 42m
- **Vegetation association:** River Red Gum RRG (*Eucalyptus camaldulensis*) Coolibah (*E. coolabah*) *Acacia salicina* riparian Woodland

Strata	Species
Aquatic/ semi-aquatic	None observed
Understorey (grasses and forbs)	Boerhavia dominii; Lavatera plebeia; Portulaca intraterranea; Setaria dielsii; Setaria jubiflora; Solanum chenopodinum; Solanum esuriale; Tetragonia tetragonioides; Teucrium racemosum; Tribulus eichlerianus
	Solanum nigrum; Sonchus oleraceus; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Acacia salicina; Chenopodium auricomum; Einadia nutans spp. eremaea; Einadia nutans ssp. nutans; Enchylaena tomentosa var. glabra; Eremophila bignoniiflora; Grevillea striata; Muehlenbeckia florulenta
Small Trees	Atalaya hemiglauca; Capparis mitchellii; Owenia acidula; Pittosporum angustifolium; Santalum lanceolatum
Trees	Bauhinia gilva; Eucalyptus camaldulensis var. obtuse; Eucalyptus coolabah; Grevillea striata

Plant list of key perennial and annual species from J. Gillen 2012 vegetation survey

Ecosystem Values, Threats and Pressures

	Indicator	Value	Description	Confidence			
Ecos	Ecosystem Values						
1	Riparian plant diversity	HIGH	Relatively high number of species present (n=39). Perennial species of all structural classes (n=25). High level of upper-mid canopy species presence (n=10).	QUALITATIVE SURVEY			
2	Riparian habitat diversity	HIGH	>3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (sand, silt). High number of in-stream snags.	QUALITATIVE SURVEY			
3	Hydrological Value	PERMANENT	Permanency confirmed through hydrological assessment and species presence (Cooper Creek turtle). Waterhole considered to be permanent.	QUANTITATIVE HYDROLOGICA LMONITORING			
4	Salinity	FRESH	During site visit (18/04/2012): 188 EC. Relatively low able to support majority freshwater flora and fauna.	EcTester SALINITY METER			
5	Cultural Site (Aboriginal & European)	MODERATE	Tourism and recreational camping in Regional Reserve; Aboriginal significance unknown. 3 generations of stockyards nearby.	QUALITATIVE SURVEY			
6	Uniqueness	MODERATE	Other similar waterholes are found on the North West Branch.	QUALITATIVE SURVEY			
7	Key Aquatic Refuge	MODERATE	Permanence and key biota (native fish, turtles) make this site an important aquatic refuge site.	QUANTITATIVE FISH SURVEY			
Ecos	Ecosystem Threats						
8	Weeds	PRESENT	No significant (WONS) weeds observed – a variety of introduced and naturalised species present (n=6) with 3 perennial species.	QUALITATIVE SURVEY			
9	Exotic animals	PRESENT	Some rabbit activity observed with grazing impact evident.	QUALITATIVE SURVEY			
10	Surface & Groundwater Abstraction	ABSENT	None observed. QUALITATIV SURVEY				
11	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). QUALITATI High level of algal growth. Minimal grazing . SURVEY				
Ecos	system Pressures						
12	Infrastructure development (e.g.tracks, bridges, flow diversions)	PRESENT – LOW LEVEL	Track leading into campsite - no major infrastructure at waterhole except for nearby stockyards.	QUALITATIVE SURVEY			
13	Tourism & Recreation Activity	PRESENT	Camping use area although no recent activity due to closure of Coongie road – some previous woodcutting SURVEY SURVEY				
14	Soil disturbance (e.g. trampling,	PRESENT	Moderate to high level of soil disturbance. Major	QUALITATIVE			

Scrubby Camp Waterhole - ecosystem values, threats and pressures

	erosion)		erosion channels forming from the access track.	SURVEY
15	Grazing Pressure	LOW LEVEL	Some evidence of rabbit grazing on juvenile plants – no recent stock grazing.	QUALITATIVE SURVEY

Refer Appendix A for interpretation of scoring system



Figure 15. Erosion channel forming showing exposed tree root systems

Site Condition

Indicator	Value	Description	Confidence
16. Spatial Integrity	LARGELY UNMODIFIED	Both width and longitudinal continuity of Lignum and Coolibah was intact.	Observation
17. Nativeness	LARGELY UNMODIFIED	No perennial weeds were recorded at the site. High level of disturbance species evident due to historic grazing activity.	Observation
18. Structural Integrity	SLIGHTLY MODIFIED	Some reduction in sub-shrubs and grasses and Lignum cover.	Observation
19. Age Structure	SLIGHTLY MODIFIED	Plant recruitment – regeneration of overstorey species evident. No recent recruitment of Coolibah or Beefwood.	Observation
20. Debris	SLIGHTLY MODIFIED	Good leaf litter cover apart from camping zone. Some evidence of historic wood cutting, but no recent evidence.	Observation

Scrubby Camp Waterhole vegetation condition

Refer Appendix A for interpretation of scoring system

Summary

Scrubby Camp waterhole is located 37km West of Innamincka on the Coongie road. The assessment was conducted on the north bank of the waterhole. This is a well known camping site there is no signage or toilet facilities at the site. There is evidence of historic woodcutting, with no recent activity observed.

Overall the riparian condition was rated good. All strata are present with multiple species present within each stratum. A range of age classes was observed in overstorey species including new recruits, sub-adults and adult ages. There is good recovery at the site from recent rain and flood inundation with good levels of regeneration of all strata particularly native grasses, groundcovers and the mid-stratum shrub layer. This will ensure good seed production for the next regeneration cycle. There are three generations of stock yards indicating long-term grazing pressure at the site.

The mid-stratum small tree / shrub layer is well represented. Disturbance species such as *Malvastrum americanum* (Malvastrum), *Portulaca intraterranea* (Large Pigweed); and *Tribulus eichlerianus* (Bull-head) are widespread. There is a lower density of Lignum on this side of the waterhole compared to dense stands on the southern bank margins likely due to historic grazing pressure, however, evidence of regeneration is occurring. Grazing pressure is low with only minor evidence of recent grazing. Recent rabbit activity was observed, however, not at levels noted at other sites, e.g. Tirrawarra and Kudriemitchie.

Riparian cover is mostly continuous with high levels of leaf litter apart from camping areas where vehicle and foot access occurs. Major gullying is occurring leading from the access track exposing the root systems of a mature stand (to 8m) of *Grevillea striata* (Beefwood). Recent inundation and rain events have exacerbated the problem. There is no regeneration of this species.

Ongoing monitoring will be required to ensure impact at this site is not increasing. Survey of visitor numbers, recreational fishing activities and monitoring of any encroachment of introduced weeds is a priority. Feral animal control is an ongoing management issue that requires funding support.

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS		
Condition	Good	Good vegetation cover and habitat diversity – some soil disturbance issues		
Ecological Importance	High	Permanent refuge waterhole		
Connectivity Value	High	Permanent refuge - high value for species dispersal		
Investment Priority	High	Important refuge site – maintain current visitor management and pest species control strategies		
Restoration Potential	High	Current management and condition verifies this		
Management priorities	High	Visitor management; erosion control; control of invasive weeds and animals		

Site 4: Tirrawarra Waterhole, Cooper Creek

Site information

Site: Tirrawarra Waterhole (north bank), Innamincka Regional Reserve

Management reach: Northwest Branch - Junction of Main Branch to Coongie Lakes

Easting / Northing: -27.26710 140.09740

Date: 20th April 2012

Description of feature assessed:

- Feature type: Surface flow driven permanent waterhole
- **Use zone:** Mixed use zone Pastoral (Innamincka Station) and Innamincka Regional Reserve camping/tourism/recreation area (Parks SA)
- Size / Area: The waterhole extends for approx. 1km / Approx. 40m wide
- Conceptual understanding: In stream permanent waterhole
- Recent rainfall / inundation events: 174mm at Tirrawarra Moomba during March 2012 / Large flood and rainfall events throughout 2010-12 / Average annual rainfall 186mm
- Depth: At time of visit, cease to flow depth 4m / waterhole was disconnected
- Elevation: ~ 51 m
- **Vegetation association:** River Red Gum RRG (Eucalyptus camaldulensis) Coolibah (E. coolabah) riparian Woodland

Plant list of key	perennial and	annual spe	ecies from J.	Gillen 2	012 vegetation	survev
i lanc not of hoy	pororinar ana	unnau opt			orz vogotation	ourvoy

Strata	Species
Aquatic/ semi-aquatic	Echinochloa inundata (Marsh millet)
Understorey (grasses and forbs)	Asperula gemella; Atriplex muelleri; Epaltes cunninghamii; Erogrostis setifolia; Haloragis aspera; Lavatera plebeia; Mentha australis; Pterocaulon sphacelatum; Setaria jubiflora; Teucrium racemosum
	Introduced spp.: Brassica tournefortii; Malvastrum americanum; Solanum nigrum; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Acacia salicina; Acacia stenophylla; Chenopodium auricomum; Einadia nutans ssp. nutens; Einadia nutans ssp. eremaea; Enchylaena tomentosa var. glabra; Eremophila bignoniiflora; Muehlenbeckia florulenta; Sclerolaena bicornis; Sclerolaena muricata var muricata; Senecio lanibracteus
Small Trees	Atalaya hemiglauca; Pittosporum angustifolium; Santalum lanceolatum;
Trees	Bauhinia gilva; Eucalyptus camaldulensis var. obtusa; Eucalyptus coolabah

Ecosystem Values, Threats and Pressures

	Indicator	Value	Description	Confidence			
Eco	Ecosystem Values						
1	Riparian plant diversity	HIGH	High number of species present (n=39). Perennial species (n=26).	QUALITATIVE SURVEY			
2	Riparian habitat diversity	HIGH	>3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (bedrock, sand, silt). High number of in-stream snags.	QUALITATIVE SURVEY			
3	Hydrological Value	PERMANENT	Waterhole considered to be permanent confirmed through hydrological records and species presence (i.e. Cooper Creek turtle).	QUALITATIVE SURVEY			
4	Salinity	FRESH	During site visit (20/4/12): 153 EC. Able to support majority freshwater flora and fauna	EcTester SALINITY METER			
5	Cultural Site Aboriginal & European)	MODERATE TO HIGH	Stock yards adjacent to waterhole.	QUALITATIVE SURVEY			
6	Uniqueness	HIGH	Important example of a permanent refuge waterhole on North-west Branch – persistence, size and depth (at 4m CTFD).	QUALITATIVE SURVEY			
7	Key Aquatic Refuge	MODERATE TO HIGH	Size, permanence, and key biota (native fish, turtles) make this site a critical refuge. Moderate-high native fish species present (n=10).	QUANTITATIVE FISH SURVEY			
Ecos	system Threats						
8	Weeds	PRESENT	No significant (WONS) weeds observed; a variety of introduced and naturalised species present (n=4). 3 perennial weed species.	QUALITATIVE SURVEY			
9	Exotic animals	PRESENT	Rabbits and feral pig activity in vicinity. Introduced fish present (Gambusia and goldfish).	QUALITATIVE SURVEY			
10	Surface & Groundwater Abstraction	PRESENT	Low level – windmill present at site.	QUALITATIVE SURVEY			
11	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth. Minimal grazing .	QUALITATIVE SURVEY			
Ecos	Ecosystem Pressures						
12	Infrastructure development (e.g. tracks, bridges, flow diversions)	LOW LEVEL	Old windmill pump infrastructure present on south bank.				
13	Tourism & Recreation	LOW LEVEL	Low level tourist / visitor activity at the site – due to Coongie Road closures over previous 2 years.	QUALITATIVE SURVEY			

Tirrawarra Waterhole - ecosystem values, threats and pressures

	Activity			
14	Soil disturbance (e.g. trampling, erosion)	MODERATE to HIGH	High degree of soil trampling and pugging causing loss of soil surface structure where stock have access to the waterhole.	QUALITATIVE SURVEY
15	Grazing Pressure	MODERATE TO HIGH	Evidence of heavy stock grazing impacts with loss of Lignum at streambank edge.	QUALITATIVE SURVEY

Refer Appendix A for interpretation of scoring system

Site Condition

Tirrawarra Waterho	le vegetation	condition
--------------------	---------------	-----------

Indicator	Value	Description	Confidence
16. Spatial Integrity	SLIGHTLY MODIFIED	Some loss of mid-stratum layer especially Lignum stands.	Observation
17. Nativeness	SLIGHTLY MODIFIED	Few introduced species present.	Observation
18. Structural Integrity	SLIGHTLY MODIFIED	Possibly some slight reduction in sub-shrubs and grasses.	Observation
19. Age Structure	SLIGHTLY MODIFIED	All age classes represented with some recruitment of overstorey species evident.	Observation
20. Debris	MODERATELY MODIFIED	Good leaf litter layer except where heavy trampling and stock grazing occurs.	Observation

Refer Appendix A for interpretation of scoring system

Summary

The assessment was conducted on the north bank of Tirrawarra Waterhole. The site is approximately 70km north-west of Innamincka. There is evidence of historic woodcutting, with no recent activity observed. There are no designated camping areas at the site. The riparian vegetation was heavily impacted at the main camping area. All strata are present with some species loss within lower strata layers. There were generally low levels of regeneration with minimal Coolibah recruitment. Stream bank vegetation dominated by Lignum was heavily impacted at stock access points indicating high grazing pressure at the waterhole. There was evidence of browsing on the mid-shrub layer. The presence of *Sclerolaena* spp. is evidence of historical grazing pressure. Feral animals were present mainly recent rabbit activity and evidence of feral pig activity nearer to Tirrawarra Swamp.

Overall the riparian condition was rated moderate at the main camp site zone with all strata present and multiple species present within each stratum. There was evidence of regenerating River Red Gum, Coolibah and Queensland Beantree and a reduced lower stratum cover of sub-shrubs and grasses.. The range of introduced species did not include serious WONS species or Buffel grass. The main perennial weed was *Solanum nigrum* (Blackberry nightshade).

Riparian canopy cover is dominated by Coolibah and was mostly continuous on this side of the waterhole and throughout the area surveyed. The waterhole on this bank is heavily impacted

from grazing. There was evidence of recent extensive grazing and stock activity and with a number of stock access points to the waterhole where vegetation is impacted with loss of Lignum cover. This has the potential to cause bank instability and erosion points forming. Restricting stock access is an effective management initiative at appropriate times to spell the paddock and to allow regeneration to occur. Rabbit control will also need to be addressed.

This site is within the Innamincka Regional Reserve and is a managed site that is subjected to relatively frequent inundation. As this is a permanent waterhole and acts as a critical refuge site, it is an important site for restoration and management intervention. Ongoing monitoring will be required to ensure access and impact at this site is not increasing.

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS
Condition	Moderate	Good vegetation cover and habitat diversity – some loss of Lignum cover
Ecological Importance	High	Permanent aquatic refuge
Connectivity Value	High	Permanent refuge - high value for species dispersal
Investment Priority	High	Important refuge site
Restoration Potential	High	Current management and condition verifies this
Management priorities	High	Grazing management; invasive weeds; feral pig control



Figure 16. Stock damage to Lignum cover at the waterhole



Figure 17. Shrub layer and riparian canopy cover generally in good condition

Site 5: Kudriemitchie Waterhole, Cooper Creek

Site information

Site: Kudriemitchie Waterhole (north bank), Innamincka Regional Reserve

Management reach: Northwest Branch - Junction of Main Branch to Coongie Lakes

Easting / Northing: -27.21713 140.12282

Date: 21st April 2012

Description of feature assessed:

- Feature type: Surface flow driven permanent waterhole
- **Use zone:** Mixed use zone Pastoral (Innamincka Station) and Innamincka Regional Reserve camping/tourism/recreation area (Parks SA)
- Size / Area: The waterhole extends for approx. 400m / approx. 55m wide
- Conceptual understanding: In stream permanent pool
- Recent rainfall / inundation events: 140mm at Moomba during March 2012 / Large flood and rainfall events throughout 2010-12 / Average annual rainfall 186mm
- Depth: At time of visit, cease to flow depth 5m channel was flowing
- Elevation: ~ 35 m
- Vegetation association: Coolibah (*Eucalyptus coolabah*) River Red Gum RRG (*E. camaldulensis*) Acacia salicina riparian Woodland

Strata	Species
Aquatic/ semi-aquatic	None observed
Understorey (grasses and forbs)	Asperula gemella; Boerhavia dominii; Epaltes cunninghamii; Erogrostis dielsii var. dielsii; Erogrostis setifolia; Haloragis aspera; Lavatera plebeia; Nicotiana velutina; Pseudoraphis spinescens; Setaria jubiflora; Solanum esuriale; Tetragonia tetragonioides; Sporobolus mitchellii; Stemodia florulenta; Teucrium racemosum; Tribulus eichlerianus Introduced spp.: Cenchrus ciliaris; Cucumis melo; Solanum nigrum; Sonchus
	oleraceus; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Acacia salicina; Acacia stenophylla; Chenopodium auricomum; Einadia nutans ssp. eremaea; Eremophila bignoniiflora; Muehlenbeckia florulenta; Sclerolaena bicornis; Senecio lanibracteus;
Small Trees	-
Trees	Bauhinia gilva; Eucalyptus camaldulensis var. obtusa; Eucalyptus coolabah

Plant list of key perennial and annual species from J. Gillen 2012 vegetation survey

Ecosystem Values, Threats and Pressures

	Indicator	Value	Description	Confidence
Ecosystem Values				
1	Riparian plant diversity	HIGH	Moderate number of native species richness with a total of 42 species observed. Perennial species (n=5).	QUALITATIVE SURVEY
2	Riparian habitat diversity	HIGH	>3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (bedrock, sand, silt). Moderate number of in- stream snags.	QUALITATIVE SURVEY
3	Hydrological Value	NEAR PERMANENT	Waterhole considered to be close to permanent with a CTFD of 5m.	QUANTITATIVE HYDROLOGICAL MONITORING
4	Salinity	LOW	During site visit (20/04/2012): 158 EC. Able to support majority freshwater flora and fauna.	QUALITATIVE SURVEY
5	Cultural Site (Aboriginal & European)	HIGH	European significance – location of Outstation building linked to historical pastoral activity. Nearby old stock yards.	QUALITATIVE SURVEY
6	Uniqueness	MODERATE - HIGH	Near permanent refuge waterhole –other similar waterholes are found in this section of the Cooper (North-west Branch).	QUALITATIVE SURVEY
7	Key Aquatic Refuge	MODERATE - HIGH	Size, permanence, and key biota (endemic native fish, turtles, water rat) make this site an important refuge.	QUANTITATIVE FISH SURVEY
Eco	system Threats			
8	Weeds	PRESENT	No significant (WONS) weeds observed. A variety of introduced and naturalised species present (n=5). 3 perennial weed species present. There is a major stand of Buffel Grass at the Outstation.	QUALITATIVE SURVEY
9	Exotic animals	PRESENT	Rabbit activity observed. Gambusia and goldfish present.	QUALITATIVE SURVEY
10	Surface & Groundwater Abstraction	ABSENT	None observed.	QUALITATIVE SURVEY
11	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth. Minimal grazing .	QUALITATIVE SURVEY
Ecosystem Pressures				
12	Infrastructure development (e.g.tracks, bridges, flow diversions)	LOW LEVEL	Outstation building located at the site – no significant development near to the site. Access track well maintained.	QUALITATIVE SURVEY

Kudriemitchie Waterhole - ecosystem values, threats and pressures
13	Tourism & Recreation Activity	LOW LEVEL	Moderate to high visitor access due to historic Outstation Building. Site is well maintained for visitors.	QUALITATIVE SURVEY
14	Soil disturbance (e.g. trampling, erosion)	PRESENT LOW LEVEL	Soil disturbance through rabbit activity destabilising sand/silt substrate.	QUALITATIVE SURVEY
15	Grazing Pressure	LOW LEVEL	Historic stock grazing and recent feral animal grazing.	QUALITATIVE SURVEY

Site Condition

Indicator	Value	Description	Confidence
16. Spatial Integrity	SLIGHTLY MODIFIED	Both width and longitudinal continuity of Lignum and Coolibah was impacted.	Observation
17. Nativeness MODERATELY MODIFIED		Perennial weed (Buffel grass) was observed at the site.	Observation
18. Structural Integrity	SLIGHTLY MODIFIED	Possibly some slight reduction in sub-shrubs and grasses.	Observation
19. Age Structure SLIGHTLY MODIFIED		Plant recruitment – regeneration of overstorey species – only one age class evident of Coolibah.	Observation
20. Debris	SLIGHTLY MODIFIED	Due to rabbit grazing there are bare patches with reduced litter cover.	Observation

Refer Appendix A for interpretation of scoring system

Summary

The assessment was conducted on the north bank of Kudriemitchie Waterhole at the historical, heritage listed, pastoral Outstation site. The site is 85km north-west of Innamincka along the Coongie Track. Access to camping is restricted to the campground adjacent the Outstation. The Outstation building is maintained by volunteers. A nearby stock yard represents past intensive grazing activity at the site. Historic grazing activity has caused modification to natural cover of surrounding landscapes with unpalatable disturbance species *Sclerolaena bicornis* (Goatshead Burr), *Pycnosorus eremaeus* (Golden Billybuttons) and *Tribulus eichlerianus* (Bullhead) indicating past grazing activity. Riparian canopy vegetation consists of a narrow strip consisting of River Red Gum, Queensland Beantree and Coolibah. The shrub layer is patchy and consists of a reduced cover of Lignum. There is little evidence of Coolibah regeneration.

Feral grazing pressure and activity was high with recent rabbit activity evident. The Outstation has a large and expanding stand of Buffel Grass (*Cenchrus ciliaris*) that requires control. This is classed as a permanent waterhole and therefore has high hydrological and habitat value. Restoration potential and investment priority is rated high due to the structural diversity present and historical importance of the site.

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS
Condition	Moderate	Vegetation cover and habitat diversity has been modified
Ecological Importance	Moderate	Near permanent refuge
Connectivity Value	Moderate	Permanent refuge - high value for species dispersal
Investment Priority	High	Important refuge site – maintain current visitor management and implement pest species control strategies
Restoration Potential	High	Current management and condition verifies this
Management priorities	High	Visitor management; invasive weeds; rabbit control



Figure 18. Stand of Buffel Grass at the Outstation

Site 6: Embarka Waterhole, Cooper Creek

Site information

Site: Embarka Waterhole (south bank) - Gidgealpa Station

Management reach: Main Branch – Junction with NW Branch to junction with northern overflow at Deparanie Waterhole

Easting / Northing: -27.4071 140.11848

Date: 22nd April 2012

Description of feature assessed:

- Feature type: Surface flow driven permanent waterhole
- Use zone: Hydrocarbon industry / Pastoral grazing
- Size / Area: The waterhole extends for approx. 1km / approx. 40m wide
- Conceptual understanding: In channel permanent waterhole
- Recent rainfall / inundation events: 174mm at Tirrawarra Moomba during March 2012 / Large flood and rainfall events throughout 2010-12 / Average annual rainfall 186mm
- **Depth:** At time of visit, cease to flow depth was 3.8m / the waterhole was disconnected
- **Elevation:** ~ 42.5m
- Vegetation association: Coolibah (*Eucalyptus coolabah*) riparian Woodland

Strata	Species
Aquatic/ semi-aquatic	None observed
Understorey (grasses and forbs)	Boerhavia dominii; Epaltes cunninghamii; Eragrostis dielsii var. dielsii; Eragrostis setifolia; Goodenia glauca; Haloragis aspera; Lavatera plebeia; Mentha australis; Minuria denticulata; Nicotiana velutina; Setaria jubiflora; Sida ammophila; Solanum esuriale; Tetragonia tetragonioides; Teucrium racemosum; Tribulus eichlerianus Introduced spp.: Citrullus lanatus; Cucumis melo; Heliotropium supinum; Salsola kali: Solanum pigrum: Sonchus oleraceus: Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Acacia stenophylla; Chenopodium auricomum; Einadia nutans ssp. eremaea; Einadia nutans ssp. nutans; Enchylaena tomentosa var. glabra; Eremophila bignoniiflora; Muehlenbeckia florulenta; Sclerolaena bicornis; Sclerolaena muricata var muricata;
Small Trees	Santalum lanceolatum
Trees	Bauhinia gilva; Eucalyptus coolabah

Plant list of key perennial and annual species from J. Gillen 2012 vegetation survey

	Indicator	Value	Description	Confidence
Eco	system Values			
1	Riparian plant diversity	HIGH	High number of species present with a total of 51 species observed. Perennial species (n=5).	QUALITATIVE SURVEY
2	Riparian habitat diversity	MODERATE	All strata present and >3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (bedrock, sand, silt). Moderate number of in-stream snags.	QUALITATIVE SURVEY
3	Hydrological Value	PERMANENT	Waterhole considered to be permanent.	QUANTITATIVE HYDROLOGY MONITORING
4	Salinity	LOW	During site visit (22/04/2012): 158 EC. Relatively low able to support majority freshwater flora and fauna.	EcTester SALINITY METER
5	Cultural Site (Aboriginal & European)	MODERATE to HIGH VALUE	Waterhole is adjacent to Gidgealpa Homestead has amenity value with a designated camping site.	QUALITATIVE SURVEY
6	Uniqueness	MODERATE to HIGH VALUE	Permanent refuge waterhole. This waterhole is a good representative example in this section of the Cooper .	QUALITATIVE SURVEY
7	Key Aquatic Refuge	HIGH VALUE	Permanent refuge waterhole with high refuge value. Size, permanence, and key biota (Cooper turtle, water rat present) make this site a critical refuge.	QUANTITATIVE FISH SURVEY
Eco	system Threats			
8	Weeds PRESENT No significant (WONS) weeds observed; a vintroduced 'cosmopolitan' species present (riperennial species.		No significant (WONS) weeds observed; a variety of introduced 'cosmopolitan' species present (n=7). 2 perennial species.	QUALITATIVE SURVEY
9	Exotic animals	PRESENT	Some rRabbit activity observed – low level . Goldfish present.	QUALITATIVE SURVEY
10	Surface & Groundwater Abstraction	PRESENT	Water extraction for homestead and stock watering – minimal.	QUALITATIVE SURVEY
11	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth. Moderate grazing .	QUALITATIVE SURVEY
Eco	system Pressures	·		
12	Infrastructure development (e.g.tracks, bridges, flow diversions)	LOW LEVEL	Waterhole is adjacent the homestead with associated infrastructure.	QUALITATIVE SURVEY

Embarka Waterhole - ecosystem values, threats and pressures

13	Tourism & Recreation Activity	PRESENT LOW LEVEL	Controlled management of visitors – directed to designated camping area.	QUALITATIVE SURVEY
14	Soil disturbance (e.g. trampling, erosion)	PRESENT	Minimal soil disturbance observed.	QUALITATIVE SURVEY
15	Grazing Pressure	LOW – MODERATE LEVEL	Site is moderately grazed and in response to vegetation and palatable species occurrence.	QUALITATIVE SURVEY



Figure 19. Regenerating Chenopodium



Figure 20. Healthy mid-stratum riverine shrub layer - view east

Site Condition

Indicator	Value	Description	Confidence
16. Spatial Integrity	LARGELY UNMODIFIED	Both width and longitudinal continuity of lignum and Coolibah was intact.	Observation
17. Nativeness	LARGELY UNMODIFIED	No perennial weeds were recorded at the site. A number of introduced species were observed (n=7).	Observation
18. Structural Integrity LARGELY UNMODIFIED		Possibly some slight reduction in sub-shrubs and grasses through grazing activity.	Observation
19. Age Structure	LARGELY UNMODIFIED	Plant recruitment – regeneration of overstorey species evident.	Observation
20. Debris	LARGELY UNMODIFIED	Good leaf litter cover. No extensive loss of wood or evidence of extensive historical wood cutting.	Observation

Embarka Waterhole vegetation condition

Refer Appendix A for interpretation of scoring system

Summary

Embarka Waterhole is one of the deepest and largest of the downstream waterholes on the Main Branch. It receives flow most years and retains water for at least 2 years without inflow. It is classed as a high value aquatic refuge due to its depth, permanency, uniqueness and location in the system. The site is grazed by stock with some evidence of rabbit activity in the hind dunes although this is at low levels.

The site is approximately 55km west of Innamincka. The assessment was conducted on the south bank. There is a small camping area close to the homestead and waterhole that provides amenity value. Firewood collection is controlled by managers.

The site consists of main-channel vegetation association of Coolibah (*Eucalyptus coolabah*), River Cooba (*Acacia stenophylla*) and River Emu Bush (*Eremophila bignoniiflora*), with Queensland Bluebush (*Chenopodium auricomum*) dominant on the floodplain.

The recent inundation events were sufficient to exclude cattle for long enough to allow the bluebush to establish. It is resilient to heavy grazing although once preferred green pick is exhausted cattle will heavily graze this species during drier times. It is preferred to protect plants from heavy grazing at their juvenile stage as this can lead to decline in density and vigour. This bluebush swamp zone has high value for pastoralism and is resilient to heavy grazing with regular inundation.

Overall the riparian condition was rated as 'good' with fairly high vegetation diversity present. With the recent flood levels there is prolific regeneration of Queensland Bluebush cover as the dominant shrub layer in floodplain areas. No major weed impacts were observed. All strata are present with multiple species present within each stratum. A range of age classes was observed in overstorey species including new recruits, sub-adults and adult ages, for Coolibah although this was at a low level. There were established intact stands of Lignum indicating good stock grazing management on this side of the waterhole.

This site is well managed and is subjected to relatively frequent inundation. Given that this site is managed close to the homestead and is in good condition, not much more improvement would be expected at the site from further investment or intervention. Recreational fishing activities and monitoring of any encroachment of introduced weeds is a priority. Feral animal control is an ongoing management issue that requires attention. It is recommended signage to inform visitors of the ecological importance of the waterhole as a key refuge site is developed.

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS	
Condition	Good	Good vegetation cover and habitat diversity on this side of the waterhole	
Ecological Importance	High	Permanent aquatic refuge	
Connectivity Value	High	Permanent refuge - high value for species dispersal	
Investment Priority	High	Important refuge site – maintain current visitor management and pest species control strategies	
Restoration Potential	High	Current management and condition verifies this	
Management priorities	High	Management of invasive weeds and animals; grazing management	



Figure 21. Healthy mid-stratum riverine shrub layer - view west

Site 7: Cuttapirie Corner Waterhole, Cooper Creek

Site information

Site: Cuttapirie Corner Waterhole (North Bank), Innamincka Regional Reserve

Management reach: Main Branch – Junction with North West Branch to junction with northern overflow at Deparanie Waterhole

Easting / Northing: -27.36710 139.53740

Date: 23rd April 2012

Description of feature assessed:

- Feature type: Surface flow driven semi-permanent waterhole
- Use zone: Mixed use zone Pastoral (Innamincka Station) and Innamincka Regional Reserve camping/tourism/recreation area (Parks SA)
- Size / Area:
- **Conceptual understanding:** In stream semi-permanent pool
- Recent rainfall / inundation events: 174mm at Tirrawarra Moomba during March 2012 / Large flood and rainfall events throughout 2010-12 / Average annual rainfall 186mm
- **Depth:** At time of visit cease to flow depth (CTFD) was <5m / channel was flowing
- Elevation: ~ 31 m
- Vegetation association: Coolibah (*Eucalyptus coolabah*) riparian Woodland

Strata	Species
Aquatic/ semi-aquatic	None observed
Understorey (grasses and forbs)	Boerhavia dominii; Lavatera plebeia; Nicotiana velutina; Portulaca intraterranea; Tetragonia tetragonioides; Tribulus eichlerianus Introduced spp.: Cucumis melo; Solanum nigrum; Sonchus oleraceus; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Acacia salicina; Acacia stenophylla; Chenopodium auricomum; Einadia nutans ssp. eremaea; Enchylaena tomentosa var. glabra; Eremophila bignoniiflora; Muehlenbeckia florulenta; Sclerolaena bicornis; Sclerolaena intricata; Senecio lanibracteus
Small Trees	Santalum lanceolatum
Trees	Bauhinia gilva; Eucalyptus coolabah

Plant list of key perennial and annual species from J. Gillen 2012 vegetation survey

	Indicator	Value	Description	Confidence			
Eco	Ecosystem Values						
1	Riparian plant diversity	MODERATE -	Low number of native species present.	QUALITATIVE SURVEY			
2	Riparian habitat diversity	MODERATE	>3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (bedrock, sand, silt). Moderate number of in-stream snags.	QUALITATIVE SURVEY			
3	Hydrological Value	SEMI- PERMANENT	Waterhole considered to be semi-permanent.	QUANTITATIVE HYDROLOGICA L MONITORING			
4	Salinity	FRESH	During site visit (14/04/2012): 185 EC. Relatively low able to support majority freshwater flora and fauna.	EcTester SALINITY METER			
5	Cultural Site (Aboriginal & European)	MODERATE	No known cultural significance at this site. Evidence of Aboriginal artefacts. Old stockyards nearby.	QUALITATIVE SURVEY			
6	Uniqueness	MODERATE	There are other waterholes of similar typology in the catchment reach.	QUALITATIVE SURVEY			
7	Key Aquatic Refuge	MODERATE	This waterhole is frequently dry and has moderate value as an aquatic refuge. Presence of turtles and range of native fish makes this an important 'stepping stone' refuge.	QUANTITATIVE FISH SURVEY			
Eco	system Threats						
8	Weeds	PRESENT	No significant (WONS) weeds observed; a variety of introduced and naturalised species present (n=4). 2 perennial weed species.	QUALITATIVE SURVEY			
9	Exotic animals	PRESENT	Recent rabbit activity observed. Gambusia and goldfish present.	QUALITATIVE SURVEY			
10	Surface & Groundwater Abstraction	ABSENT	None observed.	QUALITATIVE SURVEY			
11	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth. Minimal grazing.	QUALITATIVE SURVEY			
Eco	system Pressures	;					
12	Infrastructure development (e.g. tracks, bridges, flow diversions)	LOW LEVEL	Walkers Crossing bridge located upstream of waterhole.	QUALITATIVE SURVEY			
13	Tourism & Recreation Activity	PRESENT	No evidence of recent tourism or visitor access to the site. Some historic wood collection evident.	QUALITATIVE SURVEY			

Cuttapirie Corner Waterhole - ecosystem values, threats and pressures

14	Soil disturbance (e.g. trampling, erosion)	PRESENT – MODERATE LEVEL	No recent soil trampling evident. Some bare compacted areas from previous intensive stock grazing.	QUALITATIVE SURVEY
15	Grazing Pressure	PRESENT – LOW LEVEL	Minimal current grazing pressure at the site.	QUALITATIVE SURVEY

Site Condition

Cuttapirie Corner Waterhole vegetation condition

Indicator	Value	Description	Confidence
16.Spatial Integrity	SLIGHTLY MODIFIED	Both width and longitudinal continuity of Lignum and Coolibah has been modified.	Observation
17. Nativeness	SLIGHTLY MODIFIED	2 perennial weeds were recorded at the site. Overall 4 weed species recorded.	Observation
18. Structural Integrity	SLIGHTLY MODIFIED	Possibly some slight reduction in sub-shrubs and grasses.	Observation
19. Age Structure	SLIGHTLY MODIFIED	Plant recruitment reduced minimal regeneration of overstorey species evident.	Observation
20. Debris	SLIGHTLY MODIFIED	Moderate leaf litter cover and debris present.	Observation

Refer Appendix A for interpretation of scoring system

Summary

The assessment was conducted on the north bank of Cuttapirie Corner Waterhole. This is approximately 95km west of Innamincka. There is reduced species diversity and a noticeable increase in cover of introduced and unpalatable native species emphasised by the presence of disturbance species such as *Sclerolaena* spp. This is evidence of historical impacts from grazing. Rabbit activity was evident and causing soil disturbance near to the waterhole.

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS
Condition	Moderate	Past grazing pressure has modified riparian condition
Ecological Importance	Moderate	Not highly rated as a critical refuge due to semi- permanent status
Connectivity Value	Moderate	Near permanent refuge – moderate value for species dispersal
Investment Priority	Moderate	Moderate investment priority
Restoration Potential	Moderate	Current management and condition verifies this
Management priorities	Moderate	Weed and feral animal control; grazing management



Figure 22. Reduced Lignum cover



Figure 23 Rabbit activity and soil disturbance

Site 8: Coongie Lake inflow channel, Cooper Creek

Site information

Site: Coongie Lake inflow, Cooper Creek

Management reach: Northwest Branch – Junction of Main Branch to Coongie Lakes

Easting / Northing: -27.10823140.09740

Date: 19th April 2012

Description of feature assessed:

- Feature type: channel of main branch along Cooper Creek
- Use zone: Mixed use zone Pastoral (Innamincka Station) and Innamincka Regional Reserve – camping/tourism/recreation area / Indigenous protected zone (Parks SA)
- Size / Area: the channel extends for 250m / approx. 55m wide
- **Conceptual understanding:** semi-permanent in-flow channel to terminal lake (Coongie Lake)
- Recent rainfall / inundation events: 174mm at Tirrawarra Moomba during March 2012 / Large flood and rainfall events throughout 2010-12 / Average annual rainfall 186mm
- Depth: At time of visit CTFD was 3.5m / channel was disconnected
- Elevation: ~ 35m
- Vegetation association: River Red Gum RRG (*Eucalyptus camaldulensis*) Coolibah (*E. coolabah*) riparian Woodland

Strata	Species
Aquatic/ semi-aquatic	None observed
Understorey (grasses and forbs)	 Atriplex velutinella; Crinum flaccidum; Cyperus gymnocaulos; Erogrostis dielsii var. dielsii; Mukia maderaspatana; Nicotiana velutina; Portulaca intraterranea; Pterocaulon sphacelatum; Sida ammophila; Stemodia florulenta; Tecticornia indica ssp. leiostachya; Tribulus eichlerianus; Introduced spp.: Conyza sumatrensis; Cucumis melo; Salsola kali; Solanum nigrum; Sonchus oleraceus; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Acacia salicina; Acacia stenophylla; Atriplex nummularia; Einadia nutans ssp. eremaea; Enchylaena tomentosa var. glabra; Eremophila bignoniiflora; Muehlenbeckia florulenta; Sclerolaena intricata; Senecio lanibracteus
Small Trees	Santalum lanceolatum
Trees	Bauhinia gilva; Eucalyptus camaldulensis var. obtusa; Eucalyptus coolabah

Plant list of key perennial and annual species from J. Gillen 2012 vegetation survey



Figure 24. Coongie Lake inflow

	Indicator	Value	Description			
Eco	Ecosystem Values					
1	Riparian plant diversity	MODERATE - HIGH	Moderate to high species diversity - 34 species observed.	QUALITATIVE SURVEY		
2	Riparian habitat diversity	HIGH	>3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (bedrock, sand, silt). High number of in-stream snags.			
3	Hydrological Value	SEASONAL	Non-permanent waterbody – connecting channel to Coongie Lake.	QUANTITATIVE HYDROLOGICL MONITORING		
4	Salinity	FRESH	During site visit (14/04/2012): 158 EC. Relatively low able to support majority freshwater flora and fauna.			
5	Cultural Site (Aboriginal & European)	HIGH	High Aboriginal significance (designated traditional use zone and evidence of past occupation – artefacts and midden sites).			
6	Uniqueness	MODERATE to HIGH VALUE	Other similar reaches along Cooper.	QUALITATIVE SURVEY		

Coongie Inflow Channel - ecosystem values, threats and pressures

7	Key Aquatic Refuge	MODERATE	Short term refuge value due to its episodic inundation and shallow depth.	QUANTITATIVE FISH MONITORING
Eco	system Threats			
8	Weeds	PRESENT	No significant (WONS) weeds observed; a variety of introduced and naturalised species present (n=5).	QUALITATIVE SURVEY
9	Exotic animals	PRESENT	Rabbit activity is causing some loss of regenerating species. Gambusia and goldfish present.	QUALITATIVE SURVEY
10	Surface & Groundwater Abstraction	PRESENT	Old windmill and pump present	QUALITATIVE SURVEY
11	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth.	QUALITATIVE SURVEY
Eco	system Pressures	i		
12	Infrastructure development (e.g.tracks, bridges, flow diversions)	LOW LEVEL	Toilet drops and shelters are provided. Old windmill located at the site and nearby stockyards.	QUALITATIVE SURVEY
13	Tourism & Recreation Activity	PRESENT LOW LEVEL	Some visitor access occurs on this side of the channel – the Coongie Lakes side has high visitor numbers with controlled management.	QUALITATIVE SURVEY
14	Soil disturbance (e.g. trampling, erosion)	PRESENT LOW LEVEL	Minimal soil disturbance apart from where rabbits have established in sandy swale areas.	QUALITATIVE SURVEY
15	Grazing Pressure	ABSENT	No current grazing – within Coongie Lakes National Park.	QUALITATIVE SURVEY

Site Condition

Coongie Lake Inflow Channel vegetation condition

Indicator	Value	Description	Confidence
16. Spatial Integrity	LARGELY UNMODIFIED	Both width and longitudinal continuity of Lignum and Coolibah was intact.	Observation
17. Nativeness	LARGELY UNMODIFIED	2 perennial weeds were recorded at the site. Overall 5 weed species recorded.	Observation
18. Structural Integrity	LARGELY UNMODIFIED	Possibly some slight reduction in sub-shrubs and grasses.	Observation
19. Age Structure	LARGELY UNMODIFIED	Plant recruitment – extensive regeneration of overstorey Eucalyptus species evident.	Observation
20. Debris	SLIGHTLY MODIFIED	Good leaf litter cover apart from designated camping zones.	Observation

Refer Appendix A for interpretation of scoring system

Summary

This site is approximately 95km north-west of Innamincka. Coongie inflow is a connecting channel to Coongie Lake. It has moderate ecological importance as it receives intermittent flow and has a shallow depth with low persistence as a waterbody. The site was rated in good condition as there was little evidence of any changes in ecosystem structure and function. Survey of visitor numbers, monitoring recreational fishing activities and monitoring of any encroachment of introduced plants is a priority. Feral animal control and monitoring, particularly for rabbits is an ongoing management issue. Monitoring of potential contamination from toilet drops and potential leakage to groundwater and into the channel is recommended to ensure water quality is not affected.

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS
Condition	Moderate	Good vegetation cover and habitat diversity – some visitor pressure at designated sites
Ecological Importance	Moderate	Low refuge status due to shallow depth and non- permanency status
Connectivity Value	Moderate	High value for species dispersal into Coongie Lake
Investment Priority	High	Maintain current visitor management and pest species control strategies
Restoration Potential	High	Current management and condition verifies this
Management priorities	High	Visitor management; invasive weeds and animals (rabbits, feral pigs)

Site 9: Narie Waterhole, Cooper Creek

Site information

Site: Narie Waterhole, Cooper Creek

Management reach: Main Branch – Junction with NW Branch to junction with northern overflow at Deparanie Waterhole

Easting / Northing: -27.27220 140.04392

Date: 27th April 2012

Description of feature assessed:

- Feature type: Surface flow driven semi-permanent waterhole
- Use zone: Mixed use zone Pastoral (Innamincka Station) and Innamincka Regional Reserve (Parks SA)
- Size / Area: The waterhole extends for approx. 250m / approx. 35m wide
- **Conceptual understanding:** In stream semi-permanent waterhole
- **Recent rainfall / inundation events:** Large flood and rainfall events throughout 2010-12 / Average annual rainfall 186mm
- Depth: At time of visit, cease to flow depth 4m / waterhole was disconnected
- Elevation: ~ 32m
- Vegetation association: Coolibah (*Eucalyptus coolabah*) Queensland Bean tree (*Bauhinia gilva*) riparian Woodland

Plant list of key perennial and annual species from J. Gillen 2012 vegetation survey

Strata	Species
Aquatic/ semi-aquatic	None observed
Understorey (grasses and forbs)	Boerhavia dominii; Haloragis aspera; Lavatera plebeia; Nicotiana velutina; Rutidosis helichrysoides var. Helichrysoides; Solanum esuriale Introduced spp.: Cucumis melo; Malvastrum americanum; Solanum nigrum; Sonchus oleraceus; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Acacia salicina; Acacia stenophylla; Einadia nutans ssp. eremaea; Enchylaena tomentosa var. glabra; Eremophila bignoniiflora; Muehlenbeckia florulenta; Senecio lanibracteus; Senna artemisioides ssp. sturtii
Small Trees	Atalaya hemiglauca; Santalum lanceolatum
Trees	Bauhinia gilva; Eucalyptus coolabah

	Indicator	Value	Description	Confidence		
Eco	Ecosystem Values					
1	Riparian plant diversity	MODERATE TO HIGH	Moderate species diversity n=27.	QUALITATIVE SURVEY		
2	Riparian habitat diversity	MODERATE TO HIGH	3 habitat classes: deep pools, overhanging vegetation; flood runners; range of substrates (bedrock, sand, silt). High number of snags 9in- stream)	QUALITATIVE SURVEY		
3	Hydrological Value	SEMI- PERMANENT	Moderate depth – likely to dry after extended dry period of 3-4yrs.	QUANTITATIVE HYDROLOGICA L MONITORING		
4	Salinity	FRESH	During site visit (27/04/2012): 165 EC. Relatively low able to support most freshwater flora and fauna.	EcTester SALINITY METER		
5	Cultural Site (Aboriginal & European)	LOW- MODERATE	Some stone fragments evident however due to past landuse most evidence removed. Stock yards present.	QUALITATIVE SURVEY		
6	Uniqueness	MODERATE	Other similar waterholes are found along this section of the Cooper.	QUALITATIVE SURVEY		
7	Key Aquatic Refuge	MODERATE TO HIGH	Presence of Cooper Creek catfish. Size, permanence, and key biota (endemic native fish, turtles) make this site a critical refuge.	QUANTITATIVE FISH SURVEY		
Eco	system Threats					
8	Weeds	PRESENT	No WONS weeds observed; variety of introduced & naturalised species present (n=5). 3 perennial weeds present.	QUALITATIVE SURVEY		
9	Exotic animals	PRESENT MODERATE LEVEL	High numbers of rabbit present – activity and active warrens. Gambusia and goldfish present.	QUALITATIVE SURVEY		
10	Surface & Groundwater Abstraction	ABSENT	None observed.	QUALITATIVE SURVEY		
11	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth.	QUALITATIVE		
Eco	system Pressures	;				
12	Infrastructure development (e.g.tracks, bridges, flow diversions)	LOW	Minimal infrastructure at the site	QUALITATIVE SURVEY		
13	Tourism & Recreation Activity	LOW	Minimal access to this site	QUALITATIVE SURVEY		

Narie Waterhole - ecosystem values, threats and pressures

14	Soil disturbance (e.g. trampling, erosion)	LOW	Some evidence of soil compaction	QUALITATIVE SURVEY
15	Grazing Pressure	MODERATE TO HIGH	Historic and current stock grazing.	QUALITATIVE SURVEY

Site Condition

Narie Waterhole vegetation condition

Indicator	Value	Description	Confidence
16. Spatial Integrity	SLIGHTLY MODIFIED	Both width and longitudinal continuity of Lignum and Coolibah was intact.	Observation
17. Nativeness	SLIGHTLY MODIFIED	3 perennial weeds were recorded at the site.	Observation
18. Structural Integrity	SLIGHTLY MODIFIED	Some reduction in sub-shrubs and grasses.	Observation
19. Age Structure	SLIGHTLY MODIFIED	Plant recruitment – regeneration of overstorey species evident.	Observation
20. Debris	SLIGHTLY MODIFIED	Good leaf litter cover apart from designated camping 'sacrifice' zones. Some evidence of historic wood cutting, but no recent evidence.	Observation

Refer Appendix A for interpretation of scoring system

Summary

The assessment was conducted on the south bank of Narie Waterhole. This site is located approximately 75km north-west of Innamincka. Riparian vegetation has recovered however there is low species richness. There are extensive compacted patches at the outer riparian edge. Disturbance indicator species such as Goats Head Burr (Sclerolaena bicornis) is present. Moderate levels of debris and leaf litter present away from heavy use areas. Stockyards are located nearby. Shrub layer has low species diversity mainly dominated by introduced and naturalised species and species indicating prior disturbance. There is a reduction in *Chenopodium* in the floodplain and reduced Lignum cover at the stream bank edge. There is a lack of Coolibah regeneration although there is evidence of Bauhinia and Eremophila regeneration. Some sections of banks are exposed and heavily impacted. Rabbit activity is evident in sandy areas with evidence of grazing on native grasses. Narie Waterhole has ideal morphology to support Lignum however this species is heavily denuded and emphasises overgrazing with minimal regeneration evident. There are numerous tracks leading to the waterhole. There is evidence of pig activity but not recent. There is a lack of recruitment of perennial shrubs and trees associated with the riparian fringe e.g. Coolibah, Atalaya hemiglauca, Santalum lanceolatum, Acacia salicina and A. stenophylla.

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS
Condition	Moderate	Vegetation cover and habitat diversity reduced – some visitor pressure at designated sites
Ecological Importance	Moderate	Classed as a semi-permanent aquatic refuge
Connectivity Value	Moderate	Near permanent refuge - has value for species dispersal
Investment Priority	Moderate	Important refuge site – maintain management and implement pest control strategies
Restoration Potential	Moderate	Current management and condition verifies this
Management priorities	Moderate	Grazing management; invasive weeds and animals



Figure 25. Bare exposed areas with loss of vegetation cover.



Figure 26. Reduced streambank vegetation and Lignum cover.



Figure 27. Exposed riverbank with loss of vegetation cover



Figure 28. Good representative Lignum cover.



Figure 29. Good representative canopy cover with Lignum understorey

Site 10: Lake Hope

Site information

Site: Lake Hope, Cooper Creek Catchment

Management reach: Lower Cooper (main branch) – northern overflow junction at Deparanie Waterhole along Main Branch to Lake Eyre North

Easting / Northing: -28.22855 139.14853

Date: 30TH April 2012

Description of feature assessed:

- Feature type: Non-permanent Terminal Lake (off channel)
- Use zone: Mixed use zone Pastoral (Mulka Station) / Lake Hope Fishery / gas/petroleum/mining and exploration.
- Size / Area: The lake extends for approx. 8km long and 4km wide
- Conceptual understanding: Terminal Lake
- Recent rainfall / inundation events: / Large flood and rainfall events 2010-12 / Average annual rainfall 130mm
- **Depth:** At time of visit, maximum observed depth was 7m at cease to flow depth / minor inflow
- Elevation: ~ 8m
- Vegetation association: Eucalyptus (*E. coolabah*) / *Acacia ligulata* Open Woodland

Plant list of key	perennial and a	annual species	from J. Gillen	2012 vegetation	survev
1 10111 1131 01 1109	perenniai ana a	armual species	nom o. Omen	2012 Vegetation	Survey

Strata	Species
Aquatic/ semi-aquatic	Water milfoil (Myriophyllum sp.)
Understorey (grasses and forbs)	Boerhavia coccinea; Cullen discolor; Cyperus gymnocaulos; Enneapogon avenaceus; Epaltes australis; Euphorbia drummondii; Haloragis aspera; Nicotiana velutina; Phyllanthus lacunellus; Portulaca intraterranea; Ptilotus atriplicifolius; Senecio gregorii; Sida ammophila; Sporobolus mitchellii; Stemodia florulenta; Triraphis mollis; Zygochloa paradoxa Introduced spp.: Brassica tournefortii; Salsola kali; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Cynanchum floribundum; Enchylaena tomentosa var. glabra; Sclerolaena diacantha; Sclerolaena intricate; Solanum oligacanthum;
Small Trees	-
Trees	Eucalyptus coolabah

	Indicator	Value	Description	Confidence		
Eco	Ecosystem Values					
1	Riparian plant diversity	MODERATE	33 species observed. Plant diversity moderate.	QUALITATIVE SURVEY		
2	Riparian habitat diversity	LOW TO MODERATE	<3 habitat classes: deep pools, overhanging vegetation; dune floodplain swales. High number of snags.	QUALITATIVE SURVEY		
3	Hydrological Value	SEMI- PERMANENT	Ephemeral lake body degree of permanency confirmed through hydrological monitoring records – persistence approx. 3yrs at CTFD.	QUANTITATIVE HYDROLOGICA L MONITORING		
4	Salinity	LOW	During site visit (30/04/2012): EC. Relatively low able to support majority freshwater flora and fauna.	EcTester SALINITY METER		
5	Cultural Site (Aboriginal & European)	MODERATE TO HIGH	High Aboriginal and European significance (early explorers, fishery).	QUALITATIVE SURVEY		
6	Uniqueness	MODERATE to HIGH VALUE	Terminal Lake and important ecological indicator of Cooper Creek system function receiving substantial inflow every 10years.	QUALITATIVE SURVEY		
7	Key Aquatic Refuge	MODERATE VALUE	Semi-permanent waterbody with persistence of 3-4yrs.	QUANTITATIVE FISH SURVEY		
Eco	system Threats					
8	Weeds	PRESENT	No significant (WONS) weeds observed; a variety of introduced and naturalised species present (n= 3). One perennial species.	QUALITATIVE SURVEY		
9	Exotic animals	PRESENT	Evidence of camel and rabbit activity. Gambusia present.	QUALITATIVE SURVEY		
10	Surface & Groundwater abstraction	ABSENT	None observed.	QUALITATIVE SURVEY		
12	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth.	QUALITATIVE SURVEY		
Eco	Ecosystem Pressures					
12	Infrastructure development (e.g.tracks, bridges, flow diversions)	LOW LEVEL	Commercial fishing operation located on shoreline – minimal impact.	QUALITATIVE SURVEY		
13	Tourism & Recreation Activity	ABSENT	No activity at this site	QUALITATIVE SURVEY		

Lake Hope shoreline - ecosystem values, threats and pressures

14	Soil disturbance (e.g. trampling, erosion)	LOW LEVEL	Minimal soil disturbance apart from rabbit warrens.	QUALITATIVE SURVEY
15	Grazing Pressure	PRESENT	Stocking rates are generally low to reflect landscape and vegetation condition.	QUALITATIVE SURVEY



Figure 30. Lake Hope shoreline – fringing and submerged vegetation

Site Condition

Lake Hope shoreline vegetation condition

Indicator	Value	Description	Confidence
16. Spatial Integrity	SLIGHTLY MODIFIED	Native vegetation cover reduced.	Observation
17. Nativeness	SLIGHTLY MODIFIED	Some weed species present.	Observation
18. Structural Integrity	SLIGHTLY MODIFIED	All structural layers present although reduced.	Observation
19. Age Structure	MODERATELY MODIFIED	Reduction in recruitment of shrub layer evident.	Observation
20. Debris	SLIGHTLY MODIFIED	Leaf litter and debris reduced due to stock and rabbit activity.	Observation

Refer Appendix A for interpretation of scoring system

Summary

Lake Hope is located 55km east of the Birdsville Track. It is 12km long and varies between two and five km in width. It supports a commercial fishery which is activated depending on flow volumes further upstream in the catchment in SA. This occurs every 10 years. The site has very sparse riparian fringe vegetation consisting of mature Coolibah and sand dune species. Species diversity is relatively low. Management of the Lake and its importance as an indicator of the health of the Cooper system warrants management investment to determine fish assemblage and catch per unit effort. Lake Hope persists for about 4 years after it is filled with the first 3 years remaining fresh. It becomes brackish as it dries up with salinities remaining relatively low. It is the most important waterbird habitat in management Units 3 and 4 - Main Branch – junction with the Northwest Branch to the junction with the northern overflow at Deparanie waterhole and the Lower Cooper (main branch).

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS
Condition	Moderate	Relatively good condition
Ecological Importance	Moderate	Lower Cooper Lake - short term refuge value – ecologically important terminal lake – health indicator
Connectivity Value	Moderate	Terminal lake
Investment Priority	Moderate	Important for fish migration through system
Restoration Potential	Moderate	Current management and condition verifies this
Management priorities	Moderate	Grazing management; invasive weeds and animals

Site 11: Lake Killalpaninna, Cooper Creek Catchment

Site information

Site: Lake Killalpaninna, Cooper Creek Catchment

Management reach: Lower Cooper (main branch) – northern overflow junction at Deparanie Waterhole along Main Branch to Lake Eyre North

Easting / Northing: -28.35 138.33

Date: 29th April 2012

Description of feature assessed:

- **Feature type:** Ephemeral Terminal Lake (off channel)
- Use zone: Mixed use zone Pastoral (Etadunna Station) / Tourist (Mission Site)
- Size / Area: The lake extends for approx 8km / approx. 200m wide
- Conceptual understanding: Terminal Lake
- Recent rainfall / inundation events: Large flood and rainfall events 2010-12 / Average annual rainfall 160mm
- **Depth:** At time of visit the Lake was disconnected with a maximum observed depth greater than 8.5m at cease to flow depth
- Elevation: ~ 6m
- Vegetation association: Acacia salicina tall shrubland emergent Coolibah (Eucalyptus coolabah)

Strata	Species
Aquatic/ semi-aquatic	Water milfoil (Myriophyllum sp.)
Understorey (grasses and forbs)	Aristida holathera var holathera; Cyperus gymnocaulos; Erogrostis dielsii var. dielsii; Sporobolus mitchellii; Stemodia florulenta; Epaltes australis; Euphorbia drummondii; Nicotiana velutina; Phyllanthus lacunellus; Sauropus trachyspermus; Sida ammophila; Teucrium racemosum; Zygochloa paradoxa Introduced spp.: Heliotropium curassivicum; Salsola kali; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Acacia salicina; Atriplex nummularia; Cynanchum floribundum; Enchylaena tomentosa var. glabra; Eremophila spp.; Einadia nutans ssp. eremaea; Solanum oligacanthum
Small Trees	-
Trees	Eucalyptus coolabah

Plant list of key perennial and annual species from J. Gillen 2012 vegetation survey

	Indicator	Value	Description	Confidence		
Eco	Ecosystem Values					
1	Riparian plant diversity	MODERATE TO HIGH	28 species observed. Highest % site cover was <i>Acacia salicina</i> – mid strata layer.	QUALITATIVE SURVEY		
2	Riparian habitat diversity	MODERATE TO LOW	2 habitat classes: overhanging vegetation; range of substrates (sand, silt). Moderate number of snags present.	QUALITATIVE SURVEY		
3	Hydrological Value	SEMI - PERMANENT	Moderate value in terms of hydrological connectivity.	QUANTITATIVE HYDROLOGICA L MONITORING		
4	Salinity	SUB-SALINE	During site visit (29/04/2012): 2400EC.	EcTester SALINITY METER		
5	Cultural Site (Aboriginal & European)	HIGH	High Aboriginal & European significance – Bethesda Lutheran Mission site est. 1880s.	QUALITATIVE SURVEY		
6	Uniqueness	MODERATE to HIGH	Other waterbodies in system similar to this site.	QUALITATIVE SURVEY		
7	Key Aquatic Refuge	MODERATE VALUE	Semi-permanent waterbody.	QUANTITATIVE FISH SURVEY		
Eco	system Threats					
8	Weeds	PRESENT	No significant (WONS) weeds observed; a variety of introduced and naturalised species present (n=3). One perennial weed.	QUALITATIVE SURVEY		
9	Exotic animals	PRESENT	Minimal rabbit activity observed. Gambusia present.	QUALITATIVE SURVEY		
10	Surface & Groundwater Abstraction	ABSENT	None observed.	QUALITATIVE SURVEY		
11	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth.	QUALITATIVE SURVEY		
Eco	Ecosystem Pressures					
12	Infrastructure development (e.g.tracks, bridges, flow diversions)	LOW LEVEL	Tracks leading into the site generally well maintained.	QUALITATIVE SURVEY		
13	Tourism & Recreation Activity	PRESENT	Moderate numbers of visitors to the site – controlled management via locked gate.	QUALITATIVE SURVEY		

Lake Killalpaninna - ecosystem values, threats and pressures

14	Soil disturbance (e.g. trampling, erosion)	LOW LEVEL	Grazing and visitor access has caused some low level soil disturbance.	QUALITATIVE SURVEY
15	Grazing Pressure	LOW LEVEL	Site is lightly grazed – Mission site fenced no stock access.	QUALITATIVE SURVEY

Site Condition

Lake Killalpaninna vegetation condition

Indicator	Value	Description	Confidence
16. Spatial Integrity	MODERATELY MODIFIED	Native vegetation cover reduced.	Observation
17. Nativeness	SLIGHTLY MODIFIED	Some weed species present.	Observation
18. Structural Integrity	MODERATELY MODIFIED	All structural layers present although reduced.	Observation
19. Age Structure	MODERATELY MODIFIED	Reduction in recruitment of shrub layer evident.	Observation
20. Debris	MODERATEY MODIFIED	Leaf litter and debris reduced due to stock and rabbit activity.	Observation

Refer Appendix A for interpretation of scoring system



Figure 31. Woma Python at campsite



Figure 32. Killalpaninna Mission site ruins and current vegetation cover.

Summary

The site is located approximately 15km west of the Birdsville Track. It has high cultural significance both from an Aboriginal (Dieri Community) and European perspective due to it being a Lutheran Mission site. The site has had historic intensive landuse and occupation reflecting the modified habitat. Current management is maintaining the site. This is one of several large freshwater lakes in the area (including Lake Hope and Lake Kopperamanna) Lake Killalpaninna retains water for a little over 2 years after flood. The lake becomes brackish as it dries up however salinities remain quite low (Badman 1989).

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS
Condition	Moderate	
Ecological Importance	Moderate	Lower Cooper lake non-permanent
Connectivity Value	Moderate	
Investment Priority	High	Visitor management and pest species control strategies
Restoration Potential	Moderate	Current management and condition verifies this
Management priorities	High	Visitor and cultural site management; grazing management; invasive weeds and animals

Site 12: Cuttupirra Waterhole, Cooper Creek

Site information

Site: Cuttupirra Waterhole, Cooper Creek

Management reach: Lower Cooper (main branch) – northern overflow junction at Deparanie Waterhole along Main Branch to Lake Eyre North

Easting / Northing: -28.33109 138.04420

Date: 10th November 2012

Description of feature assessed:

- Feature type: Surface flow driven non-permanent waterhole
- **Use zone:** Pastoralism (Etadunna Station)
- Size / Area: 500m long / 50m wide
- Conceptual understanding: In stream ephemeral pool
- Recent rainfall / inundation events: Flooding events 2010-12
- **Depth:** At time of visit, cease to flow depth 1.6m / minor inflow
- Elevation: ~ 0 m (approx. 30km from Lake Eyre)
- Vegetation association: Coolibah (*Eucalyptus coolabah*) Open Woodland / sedge understorey

Plant	list	of	kev	perennial	and	annual	species.
i iuiii	not	0.	n o y	pororinia	ana	annaan	0000000

Strata	Species
Aquatic/ semi-aquatic	Water milfoil (<i>Myriophyllum</i> sp.)
Understorey (grasses and forbs)	Cyperus gymnocaulos; Erogrostis sp.; Sporobolus mitchellii; Stemodia florulenta; Euphorbia drummondii; Nicotiana velutina; Senecio sp.; Zygochloa paradoxa Introduced spp.: Heliotropium curassivicum; Salsola kali; Verbena officinalis
Shrubs (low-shrubs and tall-shrubs)	Atriplex nummularia; Cynanchum floribundum; Enchylaena tomentosa var. glabra
Small Trees	
Trees	Eucalyptus coolabah

	Indicator	Value	Description	Confidence		
Eco	Ecosystem Values					
1	Riparian plant diversity	MODERATE - HIGH	Low number of species present. Diversity reflects higher salinity and drier conditions.	QUALITATIVE SURVEY		
2	Riparian habitat diversity	MODERATE - LOW	All strata present with 2 geomorphic features present: flood runners, range of substrates (sand, silt, gravels). Low number of in-stream snags.			
3	Hydrological Value	EPHEMERAL	Non-permanent ephemeral pool with low hydrological QUANTIT, value – short term value as a refuge. HYDROLO			
4	Salinity	SALINE	During site visit 7200 EC. EcTester SALINITY METER			
5	Cultural Site (Aboriginal & European)	MODERATE - LOW	No known Aboriginal or European significance. MODER Mainly stock grazing and remote access.			
6	Uniqueness	MODERATE - LOW	One of several 'stepping stone' refuges along this MODERAT section of the Cooper.			
7	Key Aquatic Refuge	MODERATE	Low habitat value, non-permanent waterhole. Moderately important as an end of system 'stepping stone' refuge.	QUANTITATIVE FISH SURVEY		
Ecos	system Threats					
8	Weeds	PRESENT	No significant (WONS) weeds observed; a variety of introduced and naturalised species present 3 perennial introduced species.			
9	Exotic animals	PRESENT MODERATE LEVEL	High number of active rabbit warrens observed. Grazing of low shrubs and juvenile seedlings. Gambusia present.	QUALITATIVE SURVEY		
10	Surface & Groundwater Abstraction	ABSENT	None observed. QUALITATIVE SURVEY			
12	Nutrients	MODERATE TO HIGH	Elevated nutrient levels (e.g. N & K –source unknown). High level of algal growth.			
Ecosystem Pressures						
13	Infrastructure development (e.g.tracks, bridges, flow diversions)	ABSENT	No development – basic infrastructure associated with grazing activities.	QUALITATIVE SURVEY		

Cuttupirra Waterhole - ecosystem values, threats and pressures

14	Tourism & Recreation Activity	ABSENT	Remote location – very little tourism activity expected at this site.	QUALITATIVE SURVEY
15	Soil disturbance (e.g. trampling, erosion)	PRESENT LOW LEVEL	Minimal soil disturbance apart from rabbit warrens causing some soil disturbance.	QUALITATIVE SURVEY
16	Grazing Pressure	PRESENT	Low level grazing.	QUALITATIVE SURVEY



Figure 33. Open vegetation with sparse occurrence of Coolibah.



Figure 34. Main vegetation consists of sedge Cyperus gymnocaulos

Site Condition

Indicator	Value	Description	Confidence
16. Spatial Integrity	SLIGHTLY MODIFIED	Native vegetation cover reduced.	Observation
17. Nativeness	SLIGHTLY MODIFIED	Some weed species present.	Observation
18. Structural Integrity SLIGHTLY MODIFIED		All structural layers present although reduced.	Observation
19. Age Structure MODERATELY MODIFIED		Reduction in recruitment of shrub layer evident due to high numbers of rabbits present.	Observation
20. Debris MODERATELY MODIFIED		Leaf litter and debris reduced due to stock and rabbit Observation activity.	

Cuttupirra Waterhole vegetation condition

Refer Appendix A for interpretation of scoring system

Summary

Cuttupirra Waterhole is located 65km west of the Birdsville Track and approximately 30km east of Kati Thanda-Lake Eyre North. Groundcover was sparse reflecting the hypersaline conditions of the lower reaches of the Cooper. At Cuttupirra habitat is reduced with only a sparse covering of plants including *Zygochloa paradoxa* (Sandhill canegrass), *Cyperus gymnocaulos* (Spiny flatsedge) and scattered Coolibahs. A distinguishing feature of this section of the Cooper is that waterholes are saline except immediately after a flood. The sand dunes support large numbers of rabbits with active warrens causing dune destabilisation. Downstream from Cuttupirra there are no trees, no floodplain and no large waterholes. The creek bed is below sea level with a corresponding reduced bird habitat (Badman 1989).

RIPARIAN HABITAT SUMMARY	RANKING	COMMENTS
Condition	Moderate	Slightly modified riparian habitat
Ecological Importance	Moderate	Ephemeral short term waterhole with minimal refuge status except immediately after flooding
Connectivity Value	Moderate	Ephemeral short term refuge – moderate value for species dispersal into Lake Eyre
Investment Priority	Low	Minimal refuge status and remote access makes this site a low investment priority
Restoration Potential	Low	Current condition indicates the site would respond to management interventions
Management priorities	Moderate	Invasive animals (rabbits); weeds; grazing management.