Assessment of risks to groundwater dependent ecosystems in the Far North Prescribed Wells Area

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Foreword

The Department for Environment and Water (DEW) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, Landscape SA Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

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Acknowledgements

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Summary

The Far North Prescribed Wells Area (FN PWA) covers a large area in the northeast corner of South Australia (Figure 1). Underground water, from the Great Artesian Basin (GAB) and other aquifers, supports the pastoral, mining, petroleum and tourist industries in the region. It is also critical to the health of groundwater dependent ecosystems (GDEs).

The FN PWA was prescribed under the Water Resources Act 1997 in 2003 in order to achieve responsible use of underground water, eliminate wasteful practices, ensure ecosystem health and clarify the rights and responsibilities of underground water users. The current water allocation plan (WAP) (SAAL NRMB, 2009), adopted in 2009, describes the prescribed resource and its dependencies and establishes water allocation criteria. Consistent with the *Natural Resources Management Act 2004, t*he 2009 Far North Prescribed Wells Area (PWA) WAP aims to maintain, and where appropriate improve, the condition of GDEs in the areas they are currently found. Similarly, the Lake Eyre Basin intergovernmental agreement sets out objectives for the LEB, which include protecting and maintaining ecological integrity and natural function of in-stream and floodplain ecosystems.

GDEs dependent on GAB springs are protected by the 2009 WAP through a 5km buffer zone in which no water will be allocated for any new wells. In 2017 the SAAL NRM Board conducted an internal review of the 2009 WAP. This review identified that the 2009 WAP only provides protection for GDEs dependent on the Great Artesian Basin (GAB). It was identified that there is a need to address risks to GDEs dependent on unconfined shallow aquifers. This report identifies those shallow unconfined aquifer GDEs that are at risk from the development of the prescribed resource. The approach used adopts South Australia's risk management framework for water planning and management (DEWNR, 2012), which is based on the AS/NZS ISO 31000:2009 international standard.

Most sources of risk to GDEs dependent on shallow unconfined aquifers are either controlled (e.g. Mining Act 1971, Petroleum and Geothermal Energy Act 2000, Planning, Development and Infrastructure Act 2016), or determined to be not applicable for the FN PWA. It was identified that take of water from pastoral wells is the primary source of risk to ecosystems dependent on shallow unconfined aquifers to be addressed by the WAP. The pathway of risk assessed is described by the following statement:

> *There is the potential that take of water from pastoral wells could cause a change in water availability, quality or regime, which results in groundwater dependent ecosystems being impacted.*

This report identifies GDEs and describes an assessment of risks to these and an approach to managing the risks.

The purpose of the current assessment is to:

- Identify ecosystems dependent on shallow unconfined aquifers (GDEs)
- Assess the level of risk to these GDEs caused by take from future pastoral wells
- Inform options for risk treatment including the assignment of buffer zones around GDEs determined to be at risk

The source of risk investigated was take from pastoral bores at a rate of up to 10 ML per year. The risk assessment identified six classes of GDEs characterized by shallow aquifers, which could be at risk from this type of development. One of the asset types (isolated local aquifers – asset type 5) was determined to be at medium risk, while the remaining asset types are at low risk from pastoral bores. Further analysis indicates that the risks to ecosystems dependent on isolated local aquifers can be mitigated by applying a buffer distance of 100m in locations of isolated local aquifer ecosystem types provides for adequate control of the risk over 10 years and a slight exceedance of the 0.5m drawdown threshold (i.e. 0.55m) over 30 years.

On the basis of this assessment, it is proposed that treatment of identified risks could by applied on a case by case basis as follows:

1. For applications outside of identified GDEs, no further verification of the level of risk is required

2. For applications near GDEs determined to be at low risk (asset types 1, 2, 3, 4, and 6), no further verification of the level risk is required

3. For applications within buffer zones of GDEs determined to be at elevated risk (i.e. corresponding to asset type 5, isolated local aquifers), further site specific information related to the level of risk is required to support the application.

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1 Context

1.1 Far North Prescribed Wells Area water allocation plan

The Far North Prescribed Wells Area (FN PWA) covers a large area in the northeast corner of South Australia (Figure 1). Underground water, from the Great Artesian Basin (GAB) and other aquifers, supports the pastoral, mining, petroleum and tourist industries in the region. It also supports groundwater dependent ecosystems (GDEs), which are those ecosystems that require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements to maintain their communities of plants and animals, ecological processes and ecosystem services.

The FN PWA was prescribed under the Water Resources Act 1997 in 2003 in order to achieve responsible use of underground water, eliminate wasteful practices, ensure ecosystem health and clarify the rights and responsibilities of underground water users. The current water allocation plan (WAP) (SAAL NRMB, 2009), adopted in 2009, describes the prescribed resource and its dependencies and establishes water allocation criteria. It aims to maintain, and where appropriate improve, the condition of GDEs in which they are currently found,

In 2017, the SAAL NRM Board conducted an internal review of the 2009 WAP. This review identified that the 2009 WAP only provides protection for GDEs dependent on the Great Artesian Basin (GAB). It was determined that there is a need to address risks to GDEs dependent on unconfined shallow aquifers. This report proposes a risk management approach for these types of GDEs.

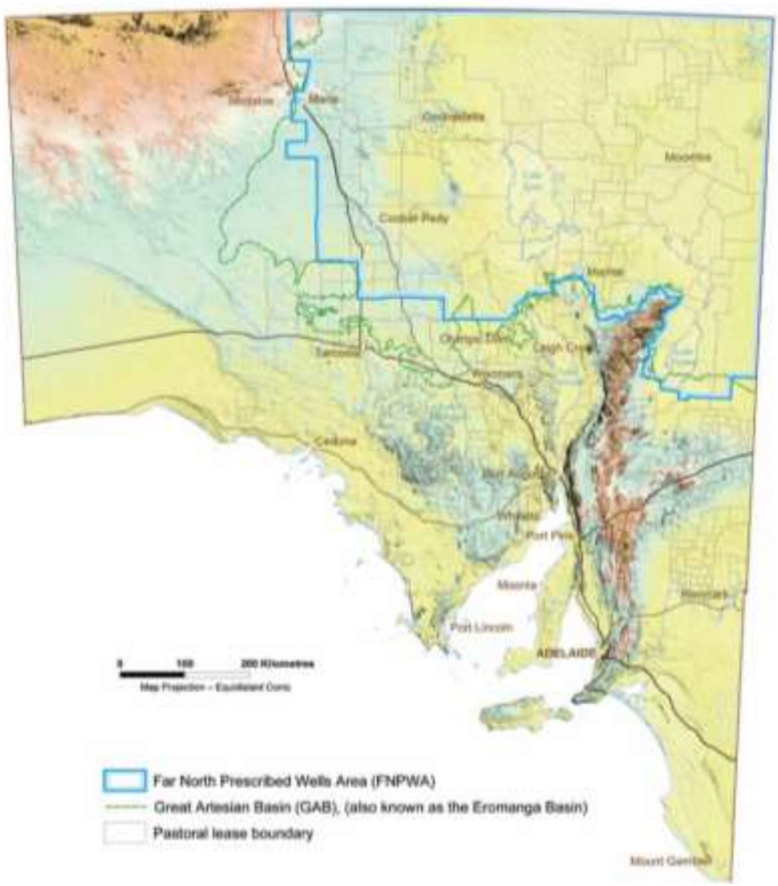


Figure 1. Location of Far North PWA (after SAAL 2009)

1.2 GDEs in the Far North PWA

The Far North PWA is located entirely in the Lake Eyre Basin (LEB), which is a large, unregulated dryland river system having highly variable flows (Puckridge et al. 1998). Despite being arid, the PWA hosts an abundance of surface and groundwater dependent ecosystems. These are associated with permanent springs fed by the Great Artesian Basin (GAB), and numerous riverine waterholes and riparian and floodplain woodlands (Keppel et al, 2017). Health assessments have determined that LEB rivers are in near natural condition (LEBSAP 2008).

The PWA includes wetlands of national and international importance that support waterbird populations (Reid et al, 2010) and a number of nationally threatened and endemic species (Morton et al. 1995).

The ecology of the LEB is driven by rainfall and resulting flow regimes and cycles from 'boom' periods following large floods to 'bust' periods with very little or no flow (Bunn et al. 2006). These cycles are unpredictable and tend to occur over decadal rather than annual timeframes. Groundwater underpins overall ecosystem resilience in the Far North PWA by maintaining refuges for flora and fauna during dry periods and by supporting ecological connectivity. Ecosystem dependency on groundwater may vary temporally (over time) and spatially (depending on its location in the landscape).

Data and knowledge related to shallow aquifers and the dependence of ecosystems on these aquifers is limited. Investigations on GDEs in the FN PWA since the 2009 WAP include DEWNR's *Coal Seam Gas and Coal Mining Water Knowledge Program* (e.g. Miles and Miles (2015), Miles and Costelloe (2015), White et al (2014)). Following on from this work, Keppel et al (2017) undertook initial investigations of the characteristics of shallow groundwater and the level of groundwater dependence of ecosystems for the western rivers region of the LEB.

Hobbs et al (2018) implemented a methodology for estimating groundwater dependence of terrestrial vegetation in the arid zone based on remote sensing data from Landsat TM. Analysis of this data in the context of climatic information shows that certain locations in the arid zone retain elevated "greenness" during periods of extended drought. It is assumed that vegetation in these locations is sustained by underground water, which could include shallow unconfined groundwater or large subsurface soil moisture stores.

These reports informed the risk assessment approach for GDEs documented in this technical note.

1.3 Purpose and scope of risk assessment

GDEs dependent on GAB springs are protected by the 2009 WAP through a 5km buffer zone in which no water will be allocated for any new wells. However, the 2009 WAP provides no protection for other GDEs in the FNPWA, such as those dependent on shallow unconfined aquifers. It is proposed that a revised WAP provide for "risk based" protection of GDEs outside the buffer zones of GAB springs.

Under such an approach, a suitable buffer zone is defined for those assets determined to be at elevated risk from groundwater extraction. Proponents intending to develop resources within buffer zones must demonstrate that there will be no detrimental effect to GDEs prior to being granted a license to take underground water. This requirement does not apply to the remaining GDEs outside these buffer zones that have been determined to be at low risk.

A prerequisite for such an approach is a risk assessment to identify those GDEs which are at elevated risk from the types of groundwater extraction expected in the PWA. Therefore, the purpose of the current assessment is to:

- Identify ecosystems dependent on shallow unconfined aquifers (GDEs)
- Assess the level of risk to these GDEs caused by take of water
- Inform options for risk treatment including the assignment of buffer zones around GDEs determined to be at risk

1.4 Approach to risk assessment

South Australia has adopted a risk management framework for water planning and management (DEWNR, 2012), which is based on the AS/NZS ISO 31000:2009 international standard. Accordingly, risk is defined as *the effect of uncertainty on objectives*. The risk management process is summarized as three steps (Figure 2), which are:

1. *Establishing context*, which involves determining the purpose, scope, principles, scales and criteria to be taken into account when managing risk
2. *Assessing risks,* involving
    a. *Risk identification,* whereby risks are identified, recognized and described
    b. *Risk analysis,* which involves comprehending the risk and determining likelihood and consequence, and
    c. *Risk evaluation,* to determine the tolerability of the risk and the need for treatment.
3. *Risk treatment,* involving actions in response to the risk assessment (e.g. reducing risk, avoidance, transfer to another party, retain and accept)

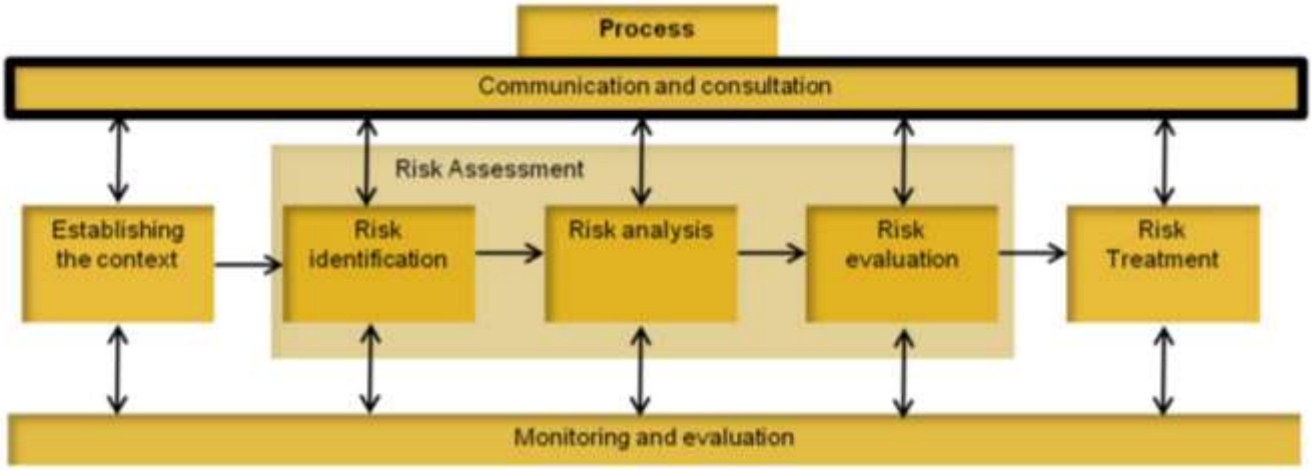


Figure 2. AS/NZS ISO 31000:2009 risk management process (after DEWNR 2012)

Due to the large size of the FNPWA (approximately 315,000 km2) and the limited information available on specific GDEs, the risk assessment firstly identified distinct classes of assets (i.e. types of GDEs dependent on shallow unconfined aquifers) and then assessed the risks to each of these asset types in turn. The level of risk for each asset type was then generalized for the spatial extent of the PWA using GIS analysis. The output of the assessment is a map of GDEs in the FNPWA indexed by risk.

Similar to previous large-scale risk assessment to inform water planning, such as DEW (2019a), DEW (2019b) and DEWNR (2018), the risk assessment method used an expert elicitation approach for defining criteria and assessing risk. This process was facilitated by DEW Science, Information and Technology branch and involved participation of relevant DEW hydrogeology, ecology and policy expertise.

2 Risk identification

2.1 Pathway of risk

Previous water planning risk assessments, such as (DEW, 2019b), adopted a simple three-step model for describing water resource risks:

There is the potential that [RISK SOURCE] leads to [EVENT] which results in [CONSEQUENCE]' where:

- A risk source is an element which alone, or in combination, has the intrinsic potential to give rise to risk
- An event is an occurrence or change of a particular set of circumstances
- A consequence is the outcome of an event affecting objectives

For this context, events are defined as changes in water quantity or availability, water quality or water regime. The task of risk identification therefore involves determination of the sources of risk that could cause events and the types of consequences that could eventuate.

Potential sources of risk associated with extraction of groundwater may arise from a range of development including mining and petroleum developments, town water supply, industrial use, irrigated agricultural, intensive farming and pastoral use. Most of these sources of risk are already controlled through existing legislation and policy (e.g. *Mining Act 1971*, *Petroleum and Geothermal Energy Act 2000*, *Planning, Development and Infrastructure Act 2016*), or determined to be not applicable for the FN PWA. However, take of water from pastoral wells was determined to be a potential source of risk to aquatic ecosystems that is not controlled by existing means such as the WAP. Therefore pastoral wells are the focus of this risk assessment.

Consistent with the purpose of this risk assessment, "consequence" is defined as degradation of the health of GDEs.

Based on the identified source of risk, event and consequences, the full pathway of risk to be assessed is summarized in the following risk statement:

> *There is the potential that take of water from pastoral wells could cause a change in water availability, quality or regime, which results in the health of groundwater dependent ecosystems being degraded.*

Participants in the risk identification process further refined the descriptions of the risk source, event and consequence (Table 1). Note that the risk assessment only considers consequences caused by changes in water resource condition and not by other factors such as the direct impacts of stock near watering points.

Table 1. Elements of risk pathway.

Element of risk pathway	***Circumstance***	***Scope***
Source of risk	Take of underground water	Take from unconfined, or non-GAB aquifers. Volume and pattern of take consistent with future pastoral wells complying with requirements of the WAP – i.e. a properly maintained, closed system. Assumed upper limit of take: 10 ML per year.
Event	Change in water availability, water level and/or water quality	Unconfined, shallow non-GAB aquifers.
Consequence	Impact to groundwater dependent ecosystems	May include terrestrial and aquatic ecosystems that are wholly or partially dependent on underground water. Includes direct and indirect impacts. Does not include direct impacts from stock (e.g. near watering points).

2.2 Consequence criteria

2.2.1 Context

Consequence criteria must reflect the values the community places on water resources as expressed in existing plans, policy and legislation.

Consistent with the *Natural Resources Management Act 2004,* the 2009 Far North Prescribed Wells Area (PWA) WAP aims to maintain, and where appropriate improve, the condition of GDEs in which they are currently found. Similarly, the Lake Eyre Basin intergovernmental agreement sets out objectives for the LEB, which include protecting and maintaining ecological integrity and natural function of in-stream and floodplain ecosystems.

The Far North PWA includes the Coongie Lakes Ramsar listed wetlands of international importance. Consistent with Australian Ramsar Management Principles (*Environment Protection and Biodiversity Conservation Regulations 2000*), a key objective for these wetlands is to enhance ecological character.

For the purposes of defining consequence criteria, the following general principles are applied:

- GDEs are defined as ecosystems that rely on groundwater for some or all of their water requirements.
- GDEs include ecosystems which draw on groundwater indirectly or which are only partially dependent on groundwater.
- Ecological resistance relates to the capacity of an ecosystem to respond to a perturbation or disturbance by resisting that disturbance.
- Ecological resilience relates to the capacity of an ecosystem to respond to a perturbation or disturbance by recovering rapidly after the disturbance.

2.2.2 Levels of consequence severity

Consistent with the risk frameworks established by DEWNR (2012), this assessment defines five levels of consequence severity from insignificant through to catastrophic (Table 2). All consequences that have a greater than "insignificant" impact are considered as unacceptable should they occur. Note that this is different from the acceptability or tolerability of risk, which must also take into account likelihood (i.e. likelihood less than certain).

Criteria for consequence severity (Table 2) are based on the ecology and species components of GDEs. It was determined that these criteria are aligned with the community's objectives for GDEs in the Far North PWA as expressed by the existing 2009 WAP (SAAL NRMB, 2009).

As a general principle, consequence severity is proportional to:

- Scale of the impact (i.e. local or regional scale)
- Likelihood of recovery

Minor and moderate consequences (Table 2) describe outcomes at a local scale and which are recoverable within a reasonable timeframe. Major and catastrophic consequences describe regional scale outcomes and are either irreversible or reversible only over protracted timeframes.

Local scale relates to impacts in the vicinity of a well and associated impact on underground water. Local scale impacts may be severe at that site, but have no importance beyond that scale – e.g. degradation of habitat in a way that does not impact ecosystem resilience at a larger scale or affect threatened species.

Regional scale impacts have importance beyond the local scale. These may include impacts to, or loss of:

- endemic or threatened species
- migratory bird species
- factors affecting larger scale ecosystem resilience such as critical refuges or ecological connectivity

Table 2. Consequence criteria - risk to GDEs

Level	Criteria
Catastrophic	Irreversible damage causing permanent widespread decline in ecosystem health and/or habitat quality. Irreversible loss of species or ecological communities having state, national or international importance
Major	Severe impact to ecosystem health and habitat quality over a large area. Substantial impact or decline of species and/or ecological communities having state, national or international importance. Recovery is protracted, uncertain and requires extensive policy and management intervention and resources.
Moderate	Severe temporary impacts to ecosystem health and habitat quality over a limited area. Observed impacts to species and/or ecological communities having state, national or international importance. Recovery is feasible with dedicated management intervention and resources.
Minor	Temporary impacts to ecosystem health and habitat quality affecting local area.

	Minor temporary impacts to species and/or ecological communities. Recovery is likely with minimal management intervention.
Insignificant	Nil or negligible damage or impacts to ecosystem health, habitat quality or species and/or ecological communities

2.3 Likelihood criteria

For the present assessment, likelihood is defined as the probability that a given consequence will be the worst observed over some future timeframe. Consistent with the context of this assessment, it was determined that risk be assessed over a 30 year period. This period was determined to be an appropriate timeframe for analyzing risk because it is consistent with the typical lifetime of bore infrastructure and the arid ephemeral nature of LEB hydrology and ecosystems.

Criteria for categories of likelihood (**Error! Reference source not found.**) provide descriptions of probability to facilitate meaningful communication and evaluation of risk using a risk matrix (Figure 8). As an example, a likelihood rating of “possible” indicates that there is a 25% to 50% probability that a given consequence will be the worst observed in 30 years.

Table 3. Likelihood criteria (after DEW, 2018)

Category	Description	Likelihood
Rarely	Only occurs in exceptional circumstances	0-5% chance
Unlikely	Unusual but not exceptional	5-25% chance
Possible	Less than even chance but not unusual	25-50% chance
Likely	Greater than even chance but not certain	50-90% chance
Almost certain	Expected in all circumstances	90-100% chance

2.4 Asset types

The risk assessment team identified a set of six asset types (Table 4) to be representative of the types of GDEs potentially at risk from take of water from shallow unconfined aquifers. The following criteria informed identification of these asset types:

- Presence of shallow unconfined aquifers that have the potential to fully or partially support aquatic or terrestrial ecosystems, either directly or indirectly
- Any degradation or loss of GDEs is consistent with agreed consequence criteria (Table 2)
- The asset is the subject of international agreements (i.e. Ramsar)
- Assets are likely to provide important drought refuges for terrestrial or aquatic species.

Case studies were identified for each of the asset types to assist with the risk analysis process.

Table 4. GDE asset types and case studies

Id	Asset type	Case study	Notes
1	Channel Floodplain	Kallakoopah Creek	Ephemeral water course with no permanent water. Restricted floodplain, with GDEs Aquifers supporting GDEs may have relatively small volumes of water Potential for pastoral well development.
2	Permanent waterhole	Algebuckina waterhole	Regionally important aquatic ecosystem. Drought refuge for fish and birds.
3	Semi-permanent waterhole and associated floodplains	Hookey's waterhole	Considers the broader floodplains in the vicinity likely to support significant GDEs Supports aquatic and terrestrial ecosystems Relatively low salinity water. Potential for pastoral well development.
4	Freshwater Lake	Coongie Lakes	Nationally and internationally important wetland supporting migratory birds. Ramsar site subject to an international agreement.
5	Isolated riverine local aquifers	Small valleys (e.g. in vicinity of Hookey's waterhole)	Many small aquifer systems with potentially high quality water. Supports vegetation. Local channel ponding, but no permanent waterholes. Small aquifers could be sensitive to take.
6	Terminal lake	Lake Hope	Terminal lake Supports aquatic and terrestrial ecosystems during larger flood events Frequently dry lakes, fresh water after floods becoming more saline as lake dries out. Aguifers more likely to be saline

3 Risk analysis

3.1 Method

The purpose of risk analysis is to comprehend the nature of risk and to determine likelihood and consequence. Similar to previous water planning risk assessments, such as DEW, 2019b, this assessment adopted an expert elicitation approach.

3.1.1 Expert elicitation method

Analysis of each of the six asset types (Table 4) was undertaken through a series of expert workshops. Participants at these workshops included scientific and policy officers from within DEW.

The risk analysis workshops followed a standardized agenda (Table 5) designed to promote discussion among participants in order to identify and comprehend the factors affecting risk. Care was taken to ensure that the risk analysis process had regard for the scope of the risk management context, the risk pathway and consequence criteria that had been identified and documented through the first two steps of the risk management process.

Table 5. Risk analysis process

No	Item	Description
Recap context and criteria		
1	Context, risk pathway and criteria	Presentation – i) risk management context and purpose ii) risk pathway iii) consequence criteria
Repeat steps 2 to 5 for each asset type		
2	Asset type	Presentation and discussion on the asset type being analysed and case studies.
3	Risk factors	Identify and discuss factors affecting risk including those relating to i) source of risk, ii) water resource, and iii) potential for consequences affecting GDEs.
4	Risk controls	Analysis of the effectiveness and implementation of existing controls for risk
5	Likelihood and consequence	Group discussion on the level of risk. Judgement on likelihood and consequence based on identified factors and criteria.

3.1.2 Risk factors and controls

A key element of risk analysis was identification and documentation of key factors affecting risk. For this purpose, risk factors are defined as any attribute, characteristic, exposure or vulnerability that affects the level of risk, which are relevant to the pathway of risk being analysed. Factors may include evidence such as data, observations, outputs of models and expert judgement. Participants in the analysis must weigh the factors according their knowledge, the evidence presented and the agreed criteria when making judgements regarding likelihood and consequence.

The risk factors presented in the results are a synthesis of the discussion during the workshop process. They are grouped according to the element of the risk pathway that they relate to (i.e. source of risk, event or consequence).

Equally important for risk analysis is an understanding of the effectiveness and level of implementation for existing controls. In the water planning and management context, controls include government policies, plans or programs for managing risk.

3.1.3 Likelihood and consequence

Determination of likelihood and consequence considered the factors and controls relevant for the asset type and the agreed criteria for likelihood and consequence (section 2). The key question addressed when making a judgement about likelihood and consequence (i.e. step 5 in Table 5) was:

> *What is the likelihood that a consequence will be the worst outcome observed over a 30 year timeframe?*

To allow participants to express uncertainty regarding future outcomes, the analysis determined the distribution of likelihoods against all five consequence severity levels, where the total likelihood sums to 100% (i.e. a probability distribution). This approach was explained to participants in the following way:

> *The consequence criteria outline all potential outcomes that could occur over a future time period. One of these five outcomes is certain to be observed. However, we may be uncertain as to which of these outcomes will occur.*

The risk analysis was facilitated as a robust process where participants were encouraged to question assumptions and the relevance of evidence. Where there was the potential for disagreement regarding the level of risk, participants were invited to vote on the probability distribution of consequences.

3.2 Results

Each of the groundwater dependent ecosystem types was workshopped using a case study as a representative example from the FNPWA region.

The results represent the output from risk analysis workshops, which are presented in a format that is consistent with the workshop agenda (Table 5). The results include a description of the case study, the risk factors related to the source of risk and the event, risk factors related to consequences and finally a table presenting the likelihood for each of the consequence levels.

3.2.1 Asset type 1 – Channel floodplain

Case study: Kallakoopah Creek

Kallakoopah creek is an anabranch of the Warburton Creek. It follows a northerly path through the Simpson Desert dunefields to the Kati Thanda/Lake Eyre intake area. It is an ephemeral river with a restricted floodplain set within terraces and cliffs (Wakelin King, 2017). There are multiple channels and ephemeral waterholes.

The hydrology of Kallakoopah Creek is described in Costelloe (2017). Its waters can be very saline. Satellite data indicates this creek flooded six times in the 23 years from 1991 to 2013 (Osti, 2014).

Figure 3. Asset type 1 – Channel floodplain (Kallakoopah Creek). Photo by G. Scholz

Identified risk factors: Source of risk and events:

- This asset type is characterised by many localised shallow aquifers
- Aquifers such as these are composed of alluvial sediments deposited by the watercourse in question and are therefore likely to be long, narrow and more frequently connected.
- Aquifers typically have high transmissivity. Drawdown associated with pumping from such aquifers is expected to stabilise after a short period of time if pumping rates remain similar. It is expected that a cone of depression resulting from pumping will be relatively shallow.
- Recharge events are expected to occur 1 in 7 years. Osti (2014) determined from satellite observations that there were six floods in the 23 years from 1991 to 2013.
- Wells are unlikely to be situated in flood prone areas.
- Assuming maximum annual use, recharge frequency, aquifer porosity and depth, it is inferred that extraction could potentially exhaust an aquifer having an area of 5ha, which could, in turn, cause impacts to surface vegetation.
- Given a maximum annual use of 10ML, it is inferred that there could be as much as 70 to 100ML of take between significant recharge events.

Identified risk factors: Consequences

- Kallakoopah Creek is mostly dry with infrequent flood events. Therefore the GDEs of concern are related to riparian vegetation such as redgums and coolabah. Risk to aquatic ecosystems is not a consideration for this asset type.
- Recharge events are important for maintaining groundwater dependent vegetation.
- Vegetation around watercourses accesses water from the unsaturated zone. However it was determined that dropping the water level or exhausting a small aquifer increases the likelihood of detrimental effects to vegetation.
- The unconfined aquifer provides deep-rooted vegetation with water independent from other sources. It is assumed that the maximum depth that vegetation can exploit groundwater is over 30 metres (Colloff 2014).
- Risk to vegetation dependent on groundwater is correlated with the depth to the water table. A deeper water table leads to greater sensitivity of dependent vegetation to changes in water level.
- In the pastoral zone, 5 ha clearance of vegetation is classified as a “level 2” clearance according to risk management criteria from the Native Vegetation regulations 2017. The ecological consequences of clearance depends on multiple factors.
- These types of ecosystems are more resistant to hydrological drying processes.

Summary of factors for asset type

- Participants in the analysis were not aware of cases where terrestrial vegetation was lost due to taking of water from shallow unconfined aquifers associated with this asset type. Known occurrences of such a pathway of impact are generally associated with mine dewatering.
- It was determined that any consequences to GDEs that may arise from pastoral well development would, at worst, affect small areas of vegetation. In this event, it is unlikely that there will be ecosystem impacts having a regional consequence (i.e. as defined by the consequence criteria) because any impacts will be unlikely to affect connectivity across this type of floodplain ecosystem.
- Any impacts, should they occur, will likely impact an insignificant proportion of the total area of the asset.

Likelihood of consequences – asset type 1

Consequence	**Likelihood**
Insignificant	Likely
Minor	Possible
Moderate	Unlikely
Major	Very unlikely
Catastrophic	Very unlikely

3.2.2 Asset type 2 – Permanent waterhole

Case study: Algebuckina waterhole

Algebuckina waterhole is a large, permanent waterhole in the Neales catchment. It is situated in an ephemeral river system flowing towards Lake Eyre through tablelands and gibber and gypsum plains. It is a critical refuge for aquatic organisms for the catchment as it is typically the only remaining habitat for isolated populations in times of severe drought (Lee, 2011). Excessive use of water, either directly or indirectly through groundwater extraction, could reduce the value of these types of waterholes as refuges. This, in turn, could cause regional scale ecological impacts.

Figure 4. Asset type 2 - permanent waterhole (Algebuckina waterhole). Photo by G. Scholz.

Risk factors: Source of risk and events:

- Algebuckina is considered a permanent waterhole. It is not known to have dried completely, although it has nearly dried once over the last decade.
- Groundwater interactions do occur. Floods cause salinity in the waterhole through additional saline groundwater inflow (Costelloe, 2011).
- The volume of water in the waterhole is large as it is 2km long and up to 50m wide. The volume of water in local aquifers is also likely to be large.
- The return frequency of flows leading to recharge of aquifers is in the order of 7 years.

- There is opportunity for pastoral-well development, although the presence of permanent surface water reduces the likelihood of such a development.

Risk factors: Consequences

- Permanent waterholes are regionally important refuges for fish and birds in times of drought. Algebuckina is the most important refuge in this landscape due to its persistence, size, habitat variability and connection potential (Costelloe, 2011).
- Consequences to aquatic ecosystems arising from the loss of this type of refuge are potentially severe. Impacts to ecological resilience could have regional significance.
- The species of fish found in Algebuckina are commonly occurring. However, populations are likely to be genetically unique in arid catchments.

Summary of factors for asset type

- Permanent waterholes are regionally important refuges for fish and birds in times of drought due to their persistence, size, habitat variability and connection potential.
- It was determined that the likelihood of significant consequence is very low because the local aquifers are large and therefore unlikely to be impacted by take from pastoral wells.
- Ecosystems associated with permanent waterhole environments are more heavily dependent on the frequency of surface water inflow than on groundwater.

Likelihood of consequences – asset type 2

Consequence	Likelihood
Insignificant	Likely
Minor	Unlikely
Moderate	Unlikely
Major	Very unlikely
Catastrophic	Very unlikely

3.2.3 Asset type 3 – Large non-permanent waterhole. Unrestricted floodplain.

Case study: Hookey's waterhole

Hookey's waterhole is a large non-permanent waterhole in the Neales catchment. This analysis considers aquifers associated with this type of surface feature, including the braided river channels having a large floodplain. It does not consider risks to GDEs in small valleys that drain into this asset type (addressed by risk id 5).

As an aquatic habitat, Hookey's waterhole is classified as a so-called "disco" refuge (McNeil et al, 2015). These refuge types are important for breeding and rebuilding populations of fish following drought. They dry completely during prolonged dry periods.

Figure 5. Asset type 3 – Large non-permanent waterhole (Hookey's waterhole). Photo by G. Scholz.

Risk factors: Source of risk and events:

- This asset type includes semi-permanent surface water (e.g. Hookey’s waterhole).
- These types of moderately deep waterholes (including Angle Pole, Shepherds and Hookeys) can have relatively long persistence times due to their depths and high frequencies of inflow (Costelloe 2011).
- Aquifers are considered “semi regional” since they are characterised by higher volumes than typical for those considered by risk id 1.
- Aquifers are likely to be fine-grained with lower transmissivity relative to those of risk id 1.
- Alluvial sediments deposited within this watercourse system may be relatively isolated from deeper more regional groundwater systems (Drexel and Preiss, 1995)
- The fine-grained sediments deposited in these types of waterholes following floods tends to seal the bottoms of these types of waterholes.
- The above two factors mean that leakage from these types of waterholes tends to be limited. Evaporation is the primary cause of water losses.
- Elevated areas within these floodplains mean that it is possible to situate wells with low risk of flood damage.

Risk factors: Consequences

- There are many perennial vegetation species on the floodplain

- It was determined that while aquatic ecosystems (i.e. semi-permanent surface water) are important ecologically (i.e. as a "disco" refugia), they are very unlikely to be affected by take from nearby aquifers by pastoral wells

Summary of factors for asset type

- It was determined that size of the aquifer and likely recharge frequency means that terrestrial vegetation is unlikely to be affected by take from pastoral wells
- Any impacts to GDEs will most likely have local significance only and not regional significance (i.e. in accordance with the consequence criteria).

Likelihood of consequences – asset type 3

Consequence	Likelihood
Insignificant	Likely
Minor	Unlikely
Moderate	Unlikely
Major	Unlikely
Catastrophic	Very unlikely

3.2.4 Asset type 4 – Freshwater Lake

Case study: Coongie Lakes

The Coongie Lakes Ramsar site is located in the north east corner of South Australia near the town of Innamincka. It includes the Cooper Creek system from the South Australia border with Queensland. The site covers a wide diversity of wetlands, which are representative of the Channel Country. These include permanent waterholes, near permanent lakes, intermittently filled flood outs and channels, fresh and saline wetlands and interdunal wetlands and swamps.

The Coongie Lakes site supports a number of nationally and internationally listed species of conservation significance. It supports a diversity and abundance of waterbirds all year round, with peaks in abundance following extensive inundation. Groundwater flow and surface and groundwater interactions contribute to the ecological character of the site (Butcher and Hale, 2011).

Risk factors: Source of risk and events:

- There is some inflow or connection of water almost every year, with larger floods leading to filling approximately 1 in 10 years (Costelloe, 2013).
- Shallow unconfined groundwater occurs under Coongie Lakes wetlands, and is generally highly saline (Costelloe, 2013).
- Groundwater under the more frequently inundated lakes is fresh (Costelloe et al., 2009).
- Flood events can lead to rising saline groundwater, which in turn lead to impacts to riparian and floodplain vegetation (Costelloe, 2013).

Figure 6. Asset type 4 - Freshwater lake (Coongie Lakes). Photo by G. Scholz

Risk factors: Consequences

- These assets are important habitat for wetland birds and large breeding events.
- It was determined that the risk pathway (i.e. take from pastoral wells affecting the quantity and quality of groundwater) is unlikely to have a significant impact on GDEs (aquatic or terrestrial) due to the high volume of water in this system.

Summary of factors for asset type

- It is assumed that aquifers have a large volume, and that take by pastoral wells is unlikely to significant affect groundwater level or quality.
- This asset type is dependent on large scale flood events rather than groundwater, which means they are relatively insensitive to groundwater impacts.

Likelihood of consequences – asset type 4

Consequence	Likelihood
Insignificant	Almost certain
Minor	Very unlikely
Moderate	Very unlikely
Major	Very unlikely
Catastrophic	Very unlikely

3.2.5 Asset type 5 – Isolated local aquifers

Case study: Smaller drainage lines of the Neales River

These asset types are small, localised aquifers recharged from local draining systems. They may include waterholes and alluvial sediments that dry out within months of being filled. They show up as small, isolated patches on maps of "greenness" based on remote sensing data obtained during prolonged drought (Hobbs et al, 2018).

Figure 7. Asset type 5 – Isolated local aquifers. Photo by G. Scholz.

Risk factors: Source of risk and events:

- Aquifers are typically small and are recharged with medium frequency through local rainfall (i.e. within 1 in 5 years).
- Water in these aquifers is likely to have low salinity and therefore is suitable for pastoral use.
- These assets are distributed everywhere where there is runoff into small channels
- These alluvial sediment aquifers are typically perched and isolated from regional aquifers. They may provide localised recharge to regional systems. Shallow alluvial aquifers may be connected to deeper aquifer systems.
- Some, but not all, aquifers are gravel based which means that they support pumping rates suitable for stock.

- Destocking during dry times may reduce demand for water at these times. It is assumed that areas away from water and vegetation will likely be destocked first.
- Some, but not all, of these assets will be characterised by temporary waterholes which may hold water for 3 months or more after filling
- Taking groundwater could reduce the likelihood of temporary waterholes filling from local rainfall

Risk factors: Consequences

- The environmental values at risk are primarily associated with riparian vegetation that is dependent on groundwater. These assets have less value as aquatic ecosystems since waterholes generally dry out within months of filling.
- The terrestrial GDEs associated with this asset type are refuges for vertebrates including threatened and endangered species such as native rodents.
- The importance of these drought refuges is correlated with isolation, with increasing isolation leading to greater ecological importance and thus potential consequence.
- Vegetation can exploit moisture in the unsaturated zone. However, it was determined that reducing groundwater level or exhausting the aquifer will likely lead to detrimental effects to vegetation.
- The conservation value of vegetation is generally assumed to be low, although it may be correlated with isolation.
- It is difficult to determine the extent of past losses arising from this risk pathway. Groundwater effects on habitat can be masked by the direct impacts of grazing pressure.
- Loss of assets could impact threatened vertebrates, particularly where the asset is isolated.
- The potential consequence of change or loss of vegetation is affected by landscape context including the density of these GDEs and impacts on ecological connectivity.

Summary of factors for asset type

- Examples of this asset type can have good quality water that may be targeted for pastoral use. The aquifers may have small volumes and therefore the water level may be sensitive to take.
- These types of GDEs are infrequently connected and potentially provide habitat for species having high ecological value such as threatened vertebrates. It was concluded that here is potential for development of pastoral wells to cause more significant ecological consequences for these asset types.

Likelihood of consequences – asset type 5

Consequence	**Likelihood**
Insignificant	Possible
Minor	Likely
Moderate	Possible
Major	Possible
Catastrophic	Very unlikely

3.2.6 Asset type 6 – Terminal lake

Case study: Lake Hope

Lake Hope is a terminal lake that receives water periodically (7 to 10 years) due to flooding of Cooper Creek. It can retain water for up to four years when full (Kingsford et al. 1999, Costelloe 2013). It is host to an opportunistic commercial fishery.

Risk factors: Source of risk and events:

- The groundwater is likely to be saline and of limited pastoral value. Therefore the potential for development was determined to be low.
- The aquifer is assumed to be large and insensitive to typical pastoral use

Risk factors: Consequences

- This asset supports large waterbird breeding events during "boom" times following large flows similar to asset type 4 (freshwater lake).
- This asset is not an important refuge for fish as it typically dries up between filling events (Costello, 2013).
- There is significant fringing vegetation
- It was determined that any impacts from groundwater development will have local significance only

Summary of factors for asset type

- Although examples of this asset type potentially contain large volumes of water, the quality of the water is likely to be low and therefore not targeted for pastoral use.
- Ecological values are greatest for this asset when receiving freshwater from regional flooding events. Take of groundwater is unlikely to impact ecosystem values at these times.

Likelihood of consequences – asset type 6

Consequence	**Likelihood**
Insignificant	Almost certain
Minor	Unlikely
Moderate	Very unlikely
Major	Very unlikely
Catastrophic	Very unlikely

4 Risk evaluation

4.1 Introduction

The purpose of risk evaluation is to compare the results of the risk analysis with risk criteria to determine acceptability or tolerability of risk. Risks were evaluated for each of the six groundwater dependent ecosystem types identified (section 2.3) based on the likelihood of consequences determined through the analysis (section 3.2).

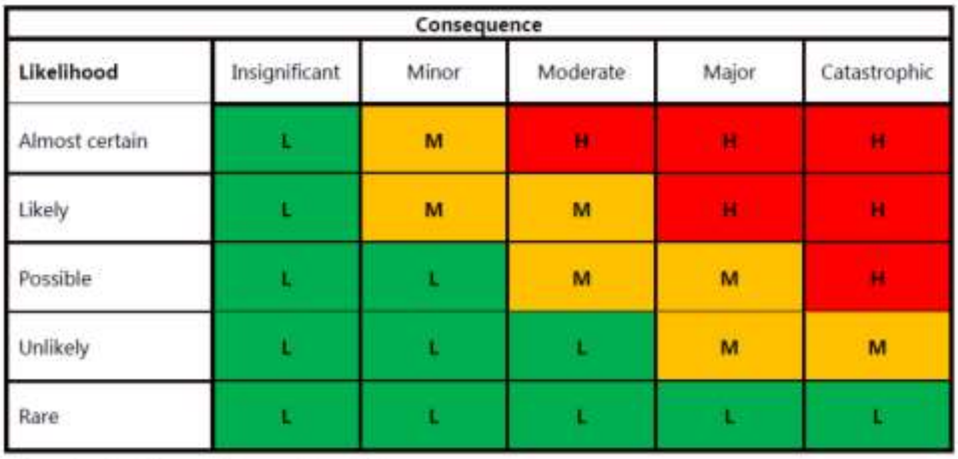
4.2 Criteria for level of risk

The level of risk is correlated with likelihood and consequence. Criteria for risk tolerability is expressed as a risk matrix (Figure 8). For this risk assessment, risk criteria are based on DEWNR (2012) as adapted by DEW (2018). Risk is evaluated into 3 levels – low, medium and high.

A feature of these criteria is that they represent the target condition with respect to likelihood and consequence. Thus:

- Rare likelihood = low risk, because this is the desired likelihood for all consequences having minor or worse severity
- Insignificant consequence = low risk, because this is the desired outcome

The risk matrix represents these conditions by setting the column representing "insignificant" and the row representing "rare" to low risk.



	Consequence				
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	L	M	H	H	H
Likely	L	M	M	H	H
Possible	L	L	M	M	H
Unlikely	L	L	L	M	M
Rare	L	L	L	L	L

Where L = low; M = medium; and H = high

Figure 8. Risk evaluation criteria - 3 levels of risk according to likelihood and consequence

Criteria for risk tolerability takes into account the risk management context, since the level of risk indicates the need for treatment to modify risk:

- Low risk means that risk is acceptable and no further action is required apart from monitoring the risk
- Medium risk is conditionally tolerable depending on the practicality and benefits of risk treatment
- High risk means that risk is intolerable requiring treatment to modify the risk level

Typically the decision to treat medium risk depends on consideration of the costs versus benefits of treatment. One common principle is that medium risk is tolerated providing it is as low as reasonably practicable (ALARP), which means that the benefits of treatment are greatly outweighed by the costs.

4.3 Method

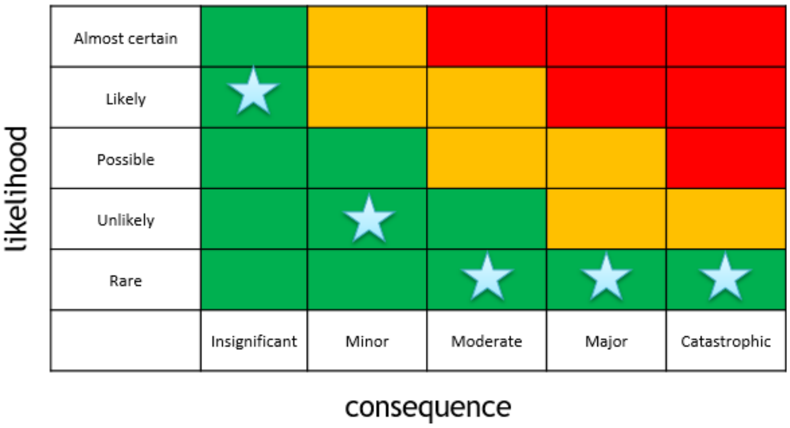
Evaluation of the tolerability of risk from the probability distribution of consequences involved the following steps:

1. Determine cumulative likelihood for each consequence. Cumulative likelihood is the sum of likelihoods having equal or more severe consequence than the current consequence level. It represents the likelihood of consequences at least as severe as the current consequence.
2. Compare each of the cumulative likelihoods for minor or worse consequences with the risk matrix and record the outcome. This will return four risk ratings.
3. Record the risk rating as the highest risk from step 2.

Figure 9 and Figure 10 demonstrate how this process has been applied for a low and medium level risk respectively. Figure 9 evaluates risks for asset type 1 (channel floodplains). Stars denote cumulative likelihood for each of the consequences. In this case it is likely that there will be insignificant consequence to GDEs arising from take from a pastoral. Consequences of at least “minor” are unlikely, while moderate, major and catastrophic consequences are determined to be rare. The risk matrix indicates low risk in all cases meaning that the overall level of risk is low.

Figure 10 evaluates risk for asset type 5 (isolated local aquifers). In this case, consequences of minor or worse are likely; moderate or worse is possible, and major or worse is unlikely. The matrix indicates medium risk against each of these combinations of likelihood and consequence. Therefore, the overall level of risk is determined to be medium.

The same process was applied to asset types 2, 3, 4 and 6.



Almost certain	🟩	🟨	🟥	🟥	🟥
Likely	🟩 ★	🟨	🟨	🟥	🟥
Possible	🟩	🟩	🟨	🟨	🟥
Unlikely	🟩	🟩 ★	🟩	🟨	🟨
Rare	🟩	🟩	🟩 ★	🟩 ★	🟩 ★
	Insignificant	Minor	Moderate	Major	Catastrophic

Figure 9. Risk evaluation. Asset type 1: channel floodplain. Low risk.

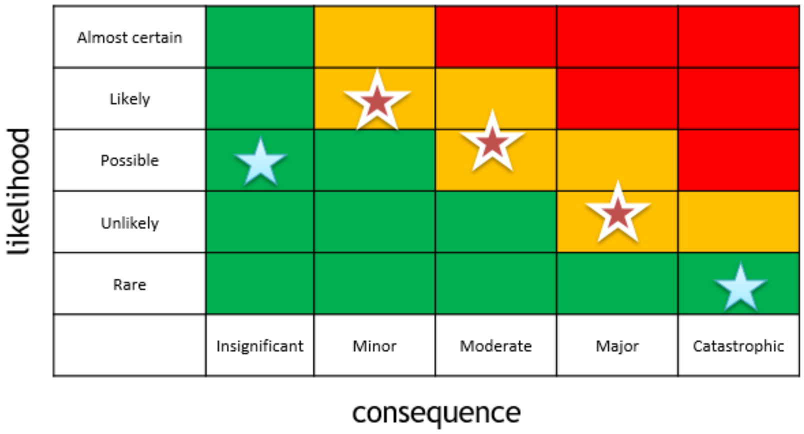


Figure 10. Risk evaluation. Asset type 5: isolated local aquifers. Medium risk.

4.4 Risk evaluation results – profile of risks to GDEs

A total of six asset types were assessed for risks to GDEs caused by take from shallow unconfined aquifers by pastoral wells. The results of the risk evaluation (Table 6) show that asset type 5 (isolated local aquifers) was evaluated as a medium level risk, while the remaining asset types (1, 2, 3, 4 and 6) were evaluated as low risks.

Table 6. Risk register. Risk level by asset type.

Id	Asset type	Case study	Risk
1	Channel floodplain	Kallakoopah Creek	Low
2	Permanent waterhole	Algebuckina waterhole	Low
3	Semi-permanent waterhole	Hookey's waterhole	Low
4	Freshwater Lake	Coongie Lakes	Low
5	Isolated local aquifers	Small valleys	Medium
6	Terminal lake	Lake Hope	Low

Likelihood and consequence for each of the asset types is presented in the results section (section 3.2).

5 Risk treatment

5.1 Approach to risk treatment

The risk assessment determined that there is medium risk to GDEs caused by pastoral well development for asset type 5 (isolated local aquifers), and low risk for all other asset types.

Consistent with the concept of a "risk-based" approach to protecting ecosystems dependent on shallow groundwater (see context in section 1.3) it was determined that an appropriate treatment for these risks to GDEs includes:

- Mapping GDEs likely to be dependent on isolated local aquifers
- Establishing a buffer zone around "at risk" GDEs for which additional controls on development apply.

5.2 Mapping GDEs dependent on isolated local aquifers

Potential GDEs were identified by analysis of time series of Landsat data as described by Hobbs et al (2018). This approach compares measures of green vegetation cover for time periods corresponding with normal rainfall and severe drought (i.e. the Millennium drought). Areas supporting higher transpiration rates than surrounding dryland landscapes during drought are inferred to have received additional water supplies from sub-surface flows. These sources could be shallow unconfined groundwater or subsurface soil moisture stores.

Analysis of Landsat data according to this method identifies GDEs potentially corresponding to all six of the asset types addressed by this assessment. Therefore further analysis was required to distinguish asset type 5 (i.e. GDEs dependent on isolated local aquifers) from the other asset types. It was determined that occurrence of GDEs in an area having low overall density of GDEs is indicative of this asset type, since higher density indicates larger assets or the presence of GDEs associated with rivers and floodplains. The threshold for low density was set at equal or less than 50ha of GDE per 5 km radius, as this was found to be effective for distinguishing small isolated systems from larger features in the landscape.

A map of GDEs classified according to density (Figure 11) shows all potential GDEs identified from Landsat data using the method established by Hobbs et al (2018) in yellow and blue. Yellow corresponds to buffers around GDEs classified as asset type 5 (i.e. according to the density analysis) and blue corresponds to all other asset types. This map shows that the density classification differentiates isolated GDEs from those associated with river channels, floodplains, wetlands and lakes. A zoomed map (Figure 12) displays the pattern of classification results with greater detail.

Note that buffers displayed in Figure 11 and Figure 12 were set to 200m for the purposes of display. This distance does not necessarily represent the buffer to be used for the purposes of treating risks to GDEs.

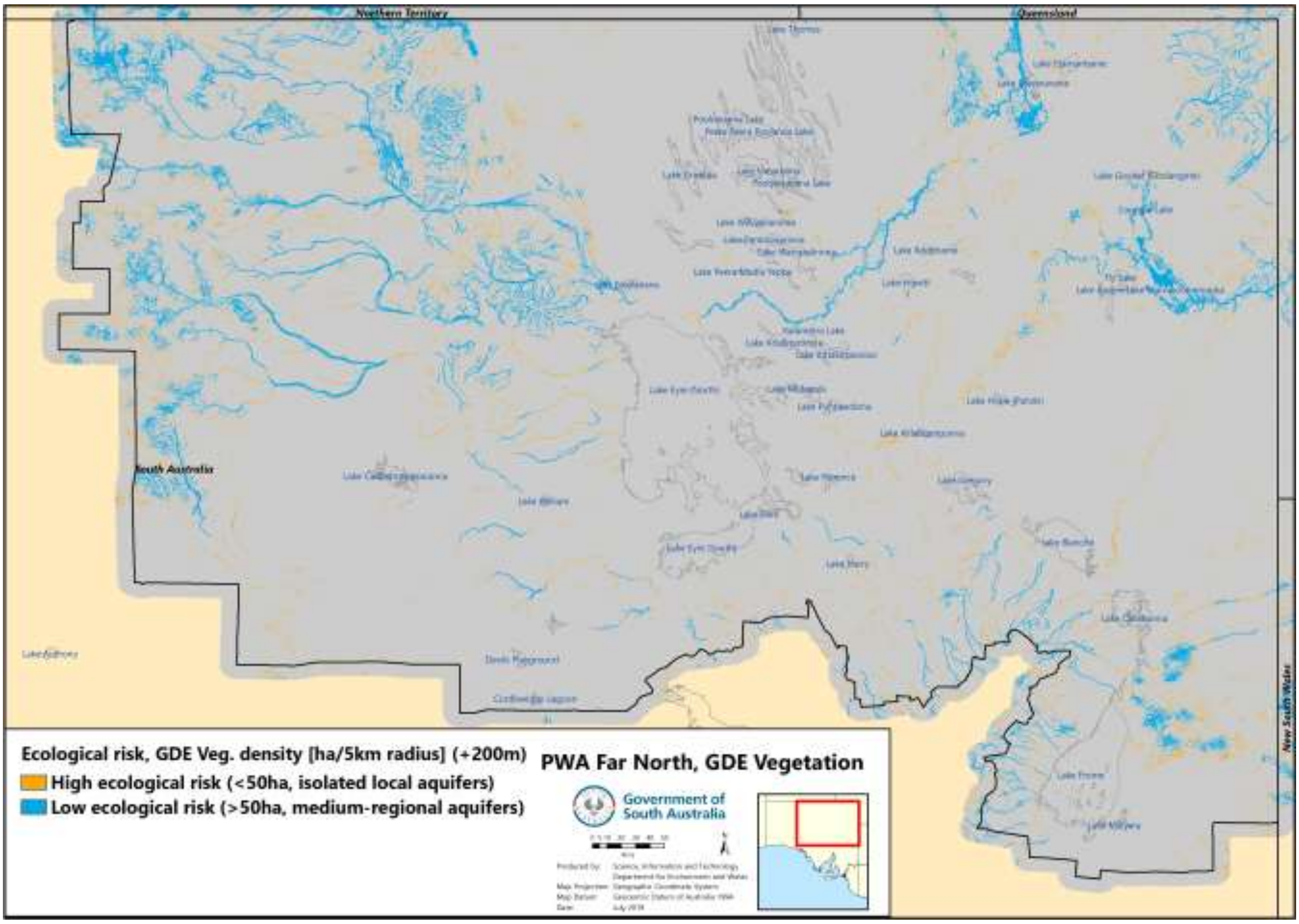


Figure 11. Classification of low and elevated risk GDEs

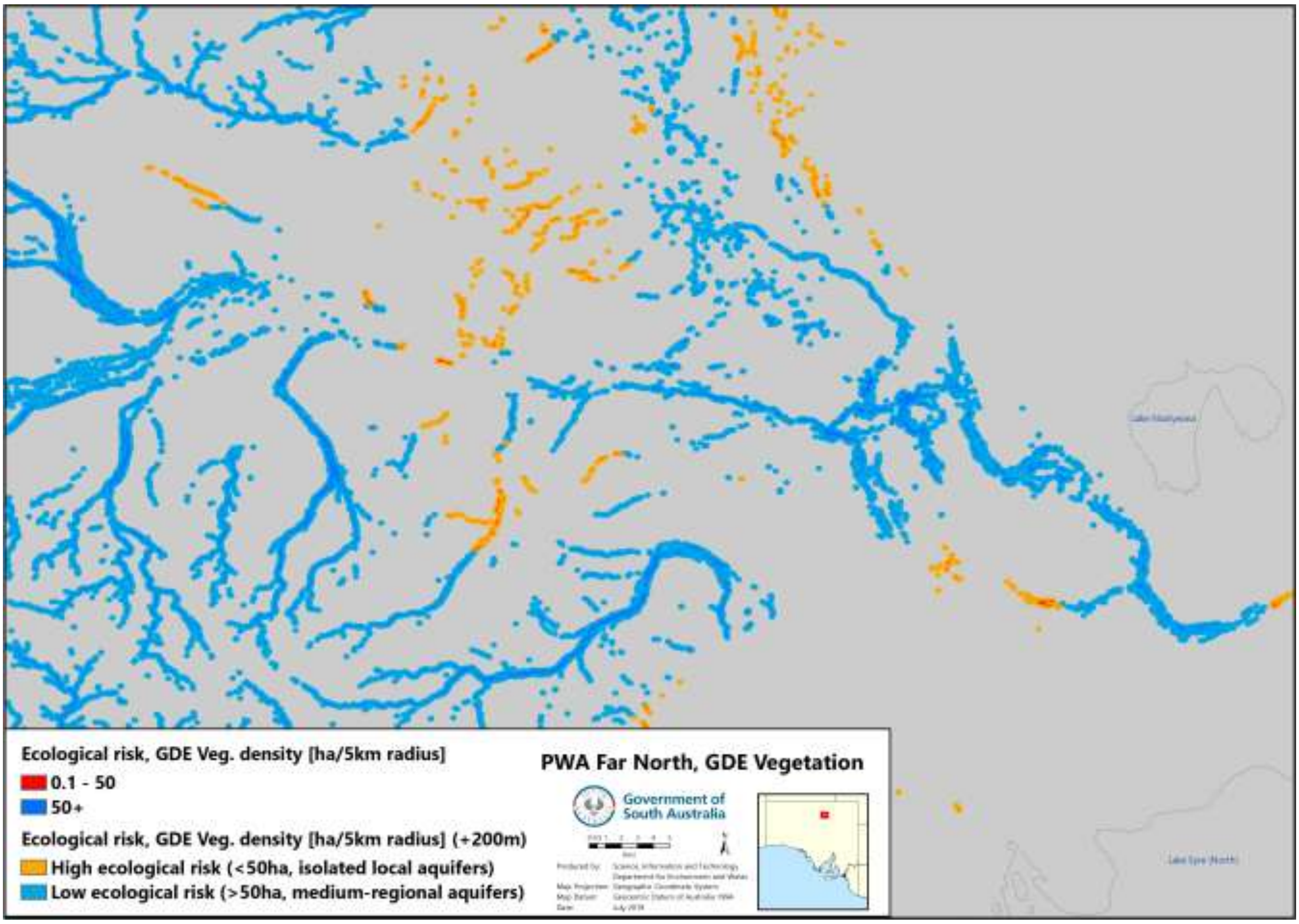


Figure 12. Classification of low and elevated risk GDEs - zoomed.

5.3 Determination of buffer distance as a treatment for risk

Determination of buffer distances to be applied for asset type 5 (isolated local aquifers) considers the following factors:

- Aquifer properties relating to transmissivity
- Root depth of terrestrial vegetation
- Assumptions regarding the drawdown of groundwater caused by pumping from a well
- Assumed maximum pumping rate

Pumping water from a well causes a cone of depression in an unconfined aquifer. Therefore, the analysis aimed to determine the minimum distance between a pastoral well and a GDE to ensure that the cone of depression from taking water will not drop the groundwater level more than 0.5m beneath GDEs, which is the level of drawdown assumed to cause negative impacts on terrestrial vegetation.

The response of groundwater level to take from wells depends on hydrogeological attributes of the Far North PWA (Table 7). The vast area of the PWA means there is significant heterogeneity in these attributes. The geology is characterized by four depositional sequences. The oldest (bottom) layer is the Precambrian crystalline basement rock, followed by Paleozoic strata, which incorporates the Arckaringa, Cooper, Warburton, Simpson and Pedirka Basins. Above these are the Mesozoic era formations, including the Great Artesian Basin. The most recent sediments, formed during the Cenozoic era, include the Hamilton Basin in the far north-west, and the Lake Eyre Basin, which covers the remainder of the PWA (DEW, 2011).

Table 7. Stratigraphy, hydrostratigraphy and geology of the Lake Eyre Basin in SA (DEW 2011, Drexel and Preiss 1995)

Age			Basin		Formation	Hydrogeology	Maximum thickness (m)
Cainozoic	Quaternary		Lake Eyre Basin	Simpson and Tirari Deserts	Simpson Sand	Unconfined aquifers	50
					Katipiri Formation		5
					Kutjitara Formation		10
					Tirari Formation		12
				Strzelecki Desert, Lake Frome, Lake Callabonna	Coonarbine Formation		50
					Eurinilla Formation		10
					Katipiri Formation equivalent		45
					Coomb Spring Formation		8
					Millyera Formation		10
					Willawortina Formation		150
	Tertiary	Oligocene			Namba Formation	Unconfined and confined aquifer; aquitard in many places	20-210
					Etadunna Formation	Unconfined and confined aquifer; aquitard in places	80
		Eocene			Eyre Formation	Unconfined, confined and artesian aquifer	140

Since the risk management context relates to risks from development of shallow unconfined aquifers, calculations regarding buffer distances consider the properties of the Tertiary and Quaternary unconfined aquifers of the Lake Eyre Basin. Consistent with the source of risk (section 2.1) it is assumed that the maximum rate of taking water from a pastoral well will be 10ML per year, and that the average life of a well is 30 years.

The Theis radial flow equation (figure) determines the drawdown of groundwater in a radius caused by pumping water out of a shallow unconfined aquifer (Freeze and Cherry, 1979).

Equation 1 Theis well drawdown

$$u = \frac{r^2 S}{4Tt}$$

$$s = \frac{Q}{4\pi T} \cdot w(u)$$

r = distance from the well (m)

S = aquifer storage

t = pumping period (days)

s = drawdown (m)

Q = discharge rate (m^3/day)

T = transmissivity (m^2/day)

W(u) = well function of Theis

Appropriate values for thickness, transmissivity and storage coefficient were determined from the literature (Table 8).

Table 8. Attributes of Lake Eyre Basin unconfined Quaternary aquifers

Component	Parameters
Thickness	<60 m (DEW 2011)
Transmissivity	35.7 m^2/day (Morris, 1981)
Storage Coefficient	0.01 (Stapleton, 1973)

The calculation determined drawdown (m) of the unconfined aquifer at a range of distances from a groundwater extracting well (Table 9) and considered 1, 10 and 30 year pumping periods. The results indicate that a buffer distance of 100m provides for adequate control of the risk over 10 years and a slight exceedance of the 0.5m drawdown threshold (i.e. 0.55m) over 30 years.

Table 9. Drawdown at distance from pastoral well

Radius Distance from well	Pumping period (year(s))	drawdown (m)
20 m	1	0.54
	10	0.68
	30	0.75
50 m	1	0.43
	10	0.57
	30	0.64
100 m	1	0.35
	10	0.49
	30	0.55
250 m	1	0.23
	10	0.38
	30	0.44

6 Discussion and Conclusions

6.1 Reliability of the risk assessment

Uncertainties affecting this risk assessment may be related to the following:

- Representation of the types of GDEs (asset types) that could be at risk from take from pastoral wells
- The accuracy of the risk analysis process, including modelling the impact of the source of risk on aquifers, and determination of the ecological consequences of these impacts.
- Mapping of GDEs through analysis of Landsat imagery
- Classification of the GDEs by spatial analysis

Uncertainties affecting the proposed approach to risk treatment may be related to the following:

- Determination of drawdown impacts
- Determination of appropriate buffer zones for "at risk" GDEs

This range of uncertainties is expected given the high-level nature of the assessment, the very large area involved and the knowledge and data gaps. It was determined that the reliability of the assessment is fit for purpose, since:

- This is intended as an initial risk assessment to identify those GDEs where additional risk assessment may be required prior to granting a license to take water.
- The proposed risk management approach represents an increased level of protection for GDEs dependent on shallow unconfined aquifers.

6.2 Conclusion and recommendations

The risk assessment determined that take from pastoral wells places GDEs associated with isolated local aquifers (asset type 5) at elevated risk. Key factors affecting risk for this asset type include:

- Aquifers associated with this asset type potentially contain good quality water which could be targeted for development
- Aquifers may have small volumes meaning that they could be sensitive to take by pastoral wells (e.g. through impacts to groundwater level or exhaustion of the aquifer)
- The health of terrestrial ecosystems could be impacted by changes to groundwater level or quality caused by take of water
- The isolated nature of these ecosystems means that they are important as refuges for threatened species, such as native rodents, during dry periods
- Losses of threatened species is consistent with a more severe consequence according to the risk criteria.

Analysis of Landsat data, combined with additional GIS processing, was used to identify GDEs and to classify those associated with isolated local aquifers (Figure 11). A buffer distance, based on reasonable assumptions regarding the hydrogeology of the FN PWA, is proposed for managing risks to isolated local aquifers.

On the basis of this assessment, it is proposed that treatment of identified risks could by applied on a case by case basis as follows:

1. For applications outside of identified GDEs, no further verification of the level of risk is required

2. For applications near GDEs determined to be at low risk (asset types 1, 2, 3,4, and 6), no further verification of the level risk is required

3. For applications within buffer zones of GDEs determined to be at elevated risk (i.e. corresponding to asset type 5), further site specific information related to the level of risk is required to support the application.

7 References

Bunn, S. E., Thoms, M. C., Hamilton, S. K., Capon, S. J. 2006. Flow variability in dryland rivers: boom, bust and the bits in between. River Research and Applications 22, 179-186.

Butcher, R, and Hale, J. 2011. Ecological Character Description for Coongie Lakes Ramsar site. Report to the Department of Sustainability, Environment, Water, Population and Communities, Canberra.

Colloff, M. J. 2014. Flooded Forest and Desert Creek. Ecology and History of the River Red Gum. CSIRO Publishing, Collingwood Victoria.

Costelloe, J. F., Ivine, E. C., Western, A. W., Herczeg, A. L., 2009. Groundwater recharge and discharge dynamics in an arid zone, ephemeral lake system, Australia. Limnology and Oceanography 54, 86-100.

Costelloe, J. F. 2011. Hydrological assessment and analysis of the Neales Catchment. Report by the University of Melbourne to the South Australian Arid Lands NRM Board, Port Augusta.

Costelloe, J. F. 2013. Hydrological assessment and analysis of the Cooper Creek Catchment, South Australia. Report by the University of Melbourne to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.

Costelloe, J. F. 2017. Hydrological assessment and analysis of the Diamantina River catchment, South Australia. Report by the University of Melbourne to the South Australian Arid Lands Natural Resources Management Board, Port Augusta.

Department for Environment and Water (DEW) 2019a, Eastern Mount Lofty Ranges Water Resource Plan Area Risk Assessment. DEW Technical report 2018-10, Government of South Australia, Department for Environment and Water, Adelaide.

Department for Environment and Water (DEW) 2019b, South Australian River Murray Water Resource Plan Area Risk Assessment. DEW Technical report 2018/05, Government of South Australia, Department for Environment and Water, Adelaide.

Department of Environment, Water and Natural Resources (DEWNR) 2012, Risk Management Framework for Water Planning and Management, DEWNR, Government of South Australia, Adelaide.

Department of Environment, Water and Natural Resources (DEWNR) 2018, South Australian Murray Region Risk Assessment, DEWNR Technical report 2017/20, Government of South Australia. Department of Environment, Water and Natural Resources, Adelaide.

Drexel, J.F., Preiss, W.V. (Eds) 1995. The geology of South Australia. Vol. 2, The Phanerozoic. South Australian Department of Mines and Energy, Adelaide.

Environment Protection and Biodiversity Conservation Regulations 2000, Environment Protection and Biodiversity Conservation Act (Australia) 1999

Hobbs TJ, Wenham D, Herrmann T, Brandle R, Maconochie J, Baird G, Schutz A, Howell S, Spencer J, Owen J, Fitzgerald L, Bowen Z, Wood H. 2018. Environmental values in the Cooper-Eromanga Basin, DEW Technical report 2018/04, Government of South Australia, Department for Environment and Water & Department for Energy and Mining, Adelaide, South Australia.

Joint Technical Committee OB-007 2013, Risk Management Guidelines – Companion to AS/NZS ISO 31000:2009, SA/SNZ HB 436:2013, Standards Australia Limited/Standards New Zealand.

Keppel M, Miles C, Harding C, Turner D, Costelloe J, Clarke K and Lewis M, 2017. An examination of ecosystem dependence on shallow groundwater systems in the Western Rivers region, Lake Eyre Basin, South Australia – Volume 1: Report, DEWNR Technical report 2017/04, Government of South Australia, Department of Environment, Water and Natural Resources, Adelaide.

Kingsford, R T, Curtin, A. L., Porter, J. 1999. Water flows on Cooper Creek in arid Australia determine 'boom' and 'bust' periods for waterbirds. Biological Conservation, 88: 231-248.

Miles, C and Costelloe, J F. 2015. Lake Eyre Basin (South Australia): mapping and conceptual models of shallow groundwater dependent ecosystems, DEWNR Technical note 2015/22, Government of South Australia, through the Department of Environment, Water and Natural Resources, Adelaide.

Miles, C and Miles, M W. 2015. South Australian Lake Eyre Basin aquatic ecosystem mapping and classification, DEWNR Technical report 2015/43, Government of South Australia, through Department of Environment, Water and Natural Resources, Adelaide.

Lake Eyre Basin Scientific Advisory Panel (LEBSAP) 2008. State of the Basin 2008: Rivers Assessment, Lake Eyre Basin Scientific Advisory Panel, Commonwealth of Australia, Canberra.

Lee, G. 2011. Cultural landscape assessment and analysis of the Neales Catchment and Algebuckina Waterhole. A report by the Queensland University of Technology to the South Australian Arid Lands Natural Resources Management Board. Port Augusta.

McNeil, D. G., Cheshire D. L. M., Schmarr, D. W. and Mathwin, R. 2015, A conceptual review of aquatic ecosystem function and fish dynamics in the Lake Eyre Basin, central Australia. Goyder Institute for Water Research Technical Report Series No. 15/36, Adelaide, South Australia.

Morton, S. R., Doherty, M. D., Barker R. D. 1995. Natural heritage values of the Lake Eyre Basin in South Australia: World Heritage Assessment. Consultancy report prepared for the World Heritage Unit, Department of the Environmetn, Sport and Territories. CSIRO Division of Wildlife and Ecology, Canberra.

Osti A, 2014, Hydrological modelling of the Diamantina-Warburton River System, DEWNR Technical note 2014/15, Government of South Australia, through the Department of Environment, Water and Natural Resources, Adelaide.

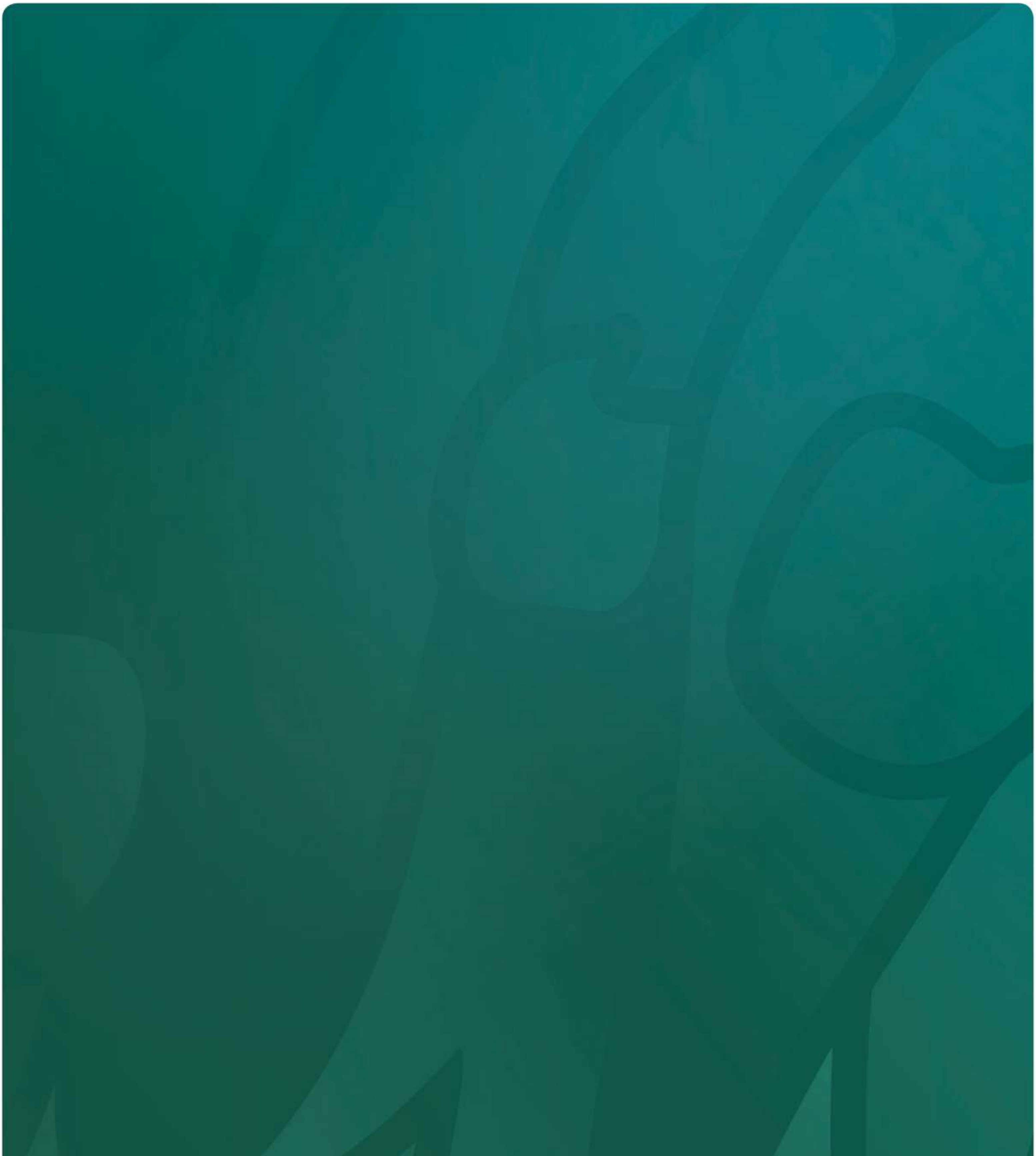
Puckridge JT, Sheldon F, Walker KF and Boulton AJ, 1998, Flow variability and the ecology of large rivers, Marine and Freshwater Research, 49: 55-72

Reid J. R. W., Kingsford R. T., Jaensch, R. P. 2010, Waterbird surveys in the Channel Country floodplain wetlands, autumn 2009. Australian National University, University of New South Wales and Wetlands International – Oceania, Report to the Department of Environment, Water, Heritage and the Arts, Canberra.

South Australian Arid Lands Natural Resources Management Board (SAAL NRMB) 2009. Water allocation plan for the Far North Prescribed Wells Area. Government of South Australia, South Australian Arid Lands Natural Resources Management Board, Port Augusta.

Wakelin-King, G. A., 2017. Geomorphology of the Diamantina River Catchment (SA). Report by Wakelin Associates to the South Australian Arid Lands Natural Resources Management Board, Pt Augusta.

White, D, Clarke, K, Lewis, M. 2014. Mapping groundwater dependent wetland and riparian vegetation with remote sensing. School of Biological Sciences. The University of Adelaide.



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